LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (FFIETH00470046) on TOWN HIGHWAY 47, crossing BLACK CREEK, FAIRFIELD, VERMONT

Open-File Report 98-424

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By EMILY C. WILD AND ROBERT H. FLYNN

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U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 46 (FFIETH00470046) ON TOWN HIGHWAY 47, CROSSING BLACK CREEK, FAIRFIELD, VERMONT

By **Emily C. Wild 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 FFIETH00470046 on Town Highway 47 crossing Black Creek, Fairfield, 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, gathered from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in northwestern Vermont. The 37.8 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 have dense woody vegetation.

In the study area, Black Creek has a meandering channel with a slope of approximately 0.0005 ft/ft, an average channel top width of 51 ft and an average bank height of 6 ft. The channel bed material ranges from sand to bedrock with a median grain size (D_{50}) of 0.189 mm (0.00062 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 12, 1995, indicated that the reach was stable.

The Town Highway 47 crossing of Black Creek is a 35-ft-long, one-lane bridge consisting of one 31-ft steel-stringer span (Vermont Agency of Transportation, written communication, March 8, 1995). The opening length of the structure parallel to the bridge face is 28.0 ft. The bridge is supported by vertical, laid-up stone abutments with wingwalls. The channel is skewed approximately zero degrees to the opening and the opening-skew-to-roadway is zero degrees.

A scour hole 6.0 ft deeper than the mean thalweg depth was observed just downstream of the bridge during the Level I assessment. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the left abutment. Type-2 stone fill (less than 36 inches diameter) extended along the upstream left and right banks, the upstream left and right wingwalls, the downstream left wingwall, and the downstream left bank. 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 1.4 to 8.2 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 5.8 to 15.6 ft. At the left abutment, the worst-case abutment scour occurred at the 100-year discharge, and at the right abutment the worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results.” Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 FFIETH00470046 ***Stream*** Black Creek

County Franklin ***Road*** TH 47 ***District*** 8

Description of Bridge

Bridge length 35 ***ft*** ***Bridge width*** 14.0 ***ft*** ***Max span length*** 31 ***ft***

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

Abutment type Vertical, laid-up stone ***Embankment type*** Sloping

Stone fill on abutment? Yes, LABUT ***Date of inspection*** 7/12/95

Description of stone fill Type-1, along the left abutment. Type-2, along the upstream left and right wingwalls and the downstream left wingwall.

Abutments and wingwalls are laid-up stone.

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

No --

There are moderate channel bends in the upstream and downstream reaches.

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*
	7/12/95	0	0
Level I	7/12/95	0	0
Level II			

Potential for debris Moderate. There is some debris in the channel upstream of the bridge.

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

There is a railroad bridge with pilings located upstream of this bridge, as observed on 7/12/95. Bedrock was exposed in the channel upstream near the bridge.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with narrow flood plains.

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

Date of inspection 7/12/95

DS left: Steep channel bank with a moderately sloped overbank

DS right: Steep channel bank with a narrow flood plain

US left: Steep channel bank with a moderately sloped overbank

US right: Steep channel bank with a narrow flood plain

Description of the Channel

Average top width 51 ft ***Average depth*** 6 ft

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

Perennial and meandering with semi-alluvial channel boundaries and narrow point bars.

7/12/95

Vegetative co Pasture with some trees along the immediate bank

DS left: Pasture with some trees along the immediate bank

DS right: Pasture with some trees along the immediate bank

US left: Pasture with some trees along the immediate bank

US right: Yes

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

None were observed on 7/12/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 37.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,480 ***ft³/s*** ***Q500*** 4,990 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(37.8/46.7)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 9 in Fairfield. Bridge number 9 crosses Black Creek downstream of this site and has a drainage area of 46.7 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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 upstream end of the right abutment (elev. 498.80 ft, arbitrary survey datum). RM2 is a chiseled X on top of a concrete block at the upstream end of the left abutment (elev. 498.36 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	-28	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	7	1	Road Grade section
APPRO	42	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 0.050 to 0.055, and overbank "n" values were 0.035.

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 0.0005 ft/ft, which was estimated from surveyed points.

The surveyed approach section (APPRO) was modelled 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 500.5 ***ft***
Average low steel elevation 499.1 ***ft***

100-year discharge 3,480 ***ft³/s***
Water-surface elevation in bridge opening 499.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 2,530 ***ft³/s***
Area of flow in bridge opening 283 ***ft²***
Average velocity in bridge opening 3.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 4.3 ***ft/s***

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 500.4
Amount of backwater caused by bridge 0.2 ***ft***

500-year discharge 4,990 ***ft³/s***
Water-surface elevation in bridge opening 499.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 4,170 ***ft³/s***
Area of flow in bridge opening 283 ***ft²***
Average velocity in bridge opening 2.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 3.7 ***ft/s***

Water-surface elevation at Approach section with bridge 501.6
Water-surface elevation at Approach section without bridge 501.4
Amount of backwater caused by bridge 0.2 ***ft***

Incipient overtopping discharge 730 ***ft³/s***
Water-surface elevation in bridge opening 496.6 ***ft***
Area of flow in bridge opening 216 ***ft²***
Average velocity in bridge opening 3.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 4.6 ***ft/s***

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 496.8
Amount of backwater caused by bridge 0.1 ***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 for the 100-year discharge are shown graphically in figure 8. Total scour depths at the 500-year discharge were less than those for the 100-year discharge and therefore do not appear in figure 8.

Contraction scour for the incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is usually best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). However, in this case the Chang equation (Richardson and Davis, 1995, p. 145-146) was not used. The Chang equation for pressure scour was derived solely with data for clear-water scour, and under live-bed conditions, "may yield overly conservative results" (Richardson and Davis, 1995, p. 147-148). Therefore, contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17).

For comparison, contraction scour for the discharges resulting in orifice flow also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Also, contraction scour was computed for the incipient roadway-overtopping discharge by use of the Laursen live-bed contraction scour equation, as the mean velocity in the main channel was close to the critical velocity. Results from these computations are presented in appendix F.

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

The length to depth ratio of the embankment blocking flow exceeded 25 for the right abutment at each modeled discharge. Although the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used for this analysis. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and Davis, 1995). The HIRE equation results were assumed not to apply for the narrow, upland valley at this site.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	4.9	1.4	-
Clear-water scour	-	-	8.2
Depth to armoring	N/A N/	A N/	A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	14.6	14.2	12.5
Right abutment	13.9	15.6	5.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	0.2	0.2	0.3
Right abutment	0.2	0.2	0.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

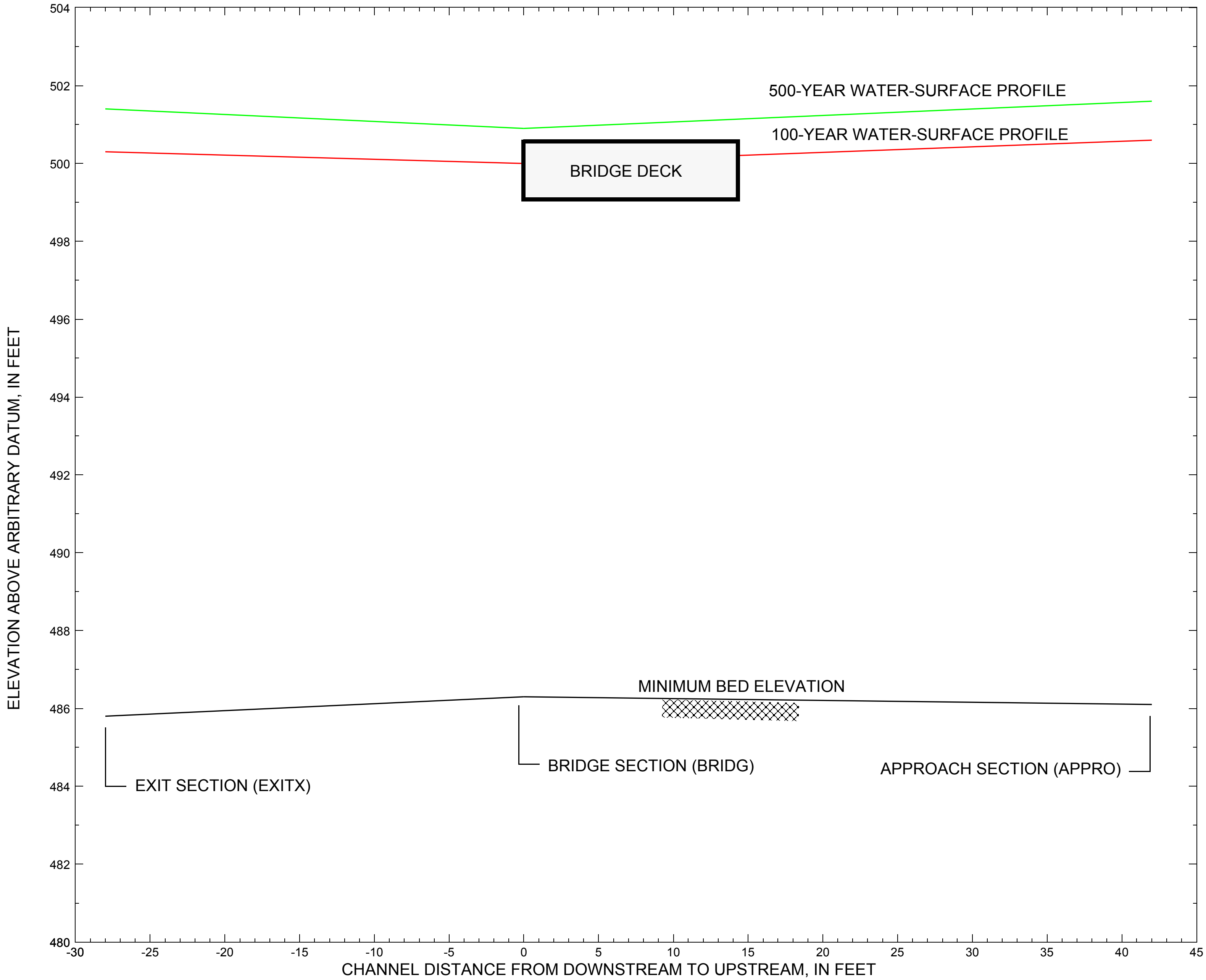

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure FFIETH00470046 on Town Highway 47, crossing Black Creek, Fairfield, Vermont.

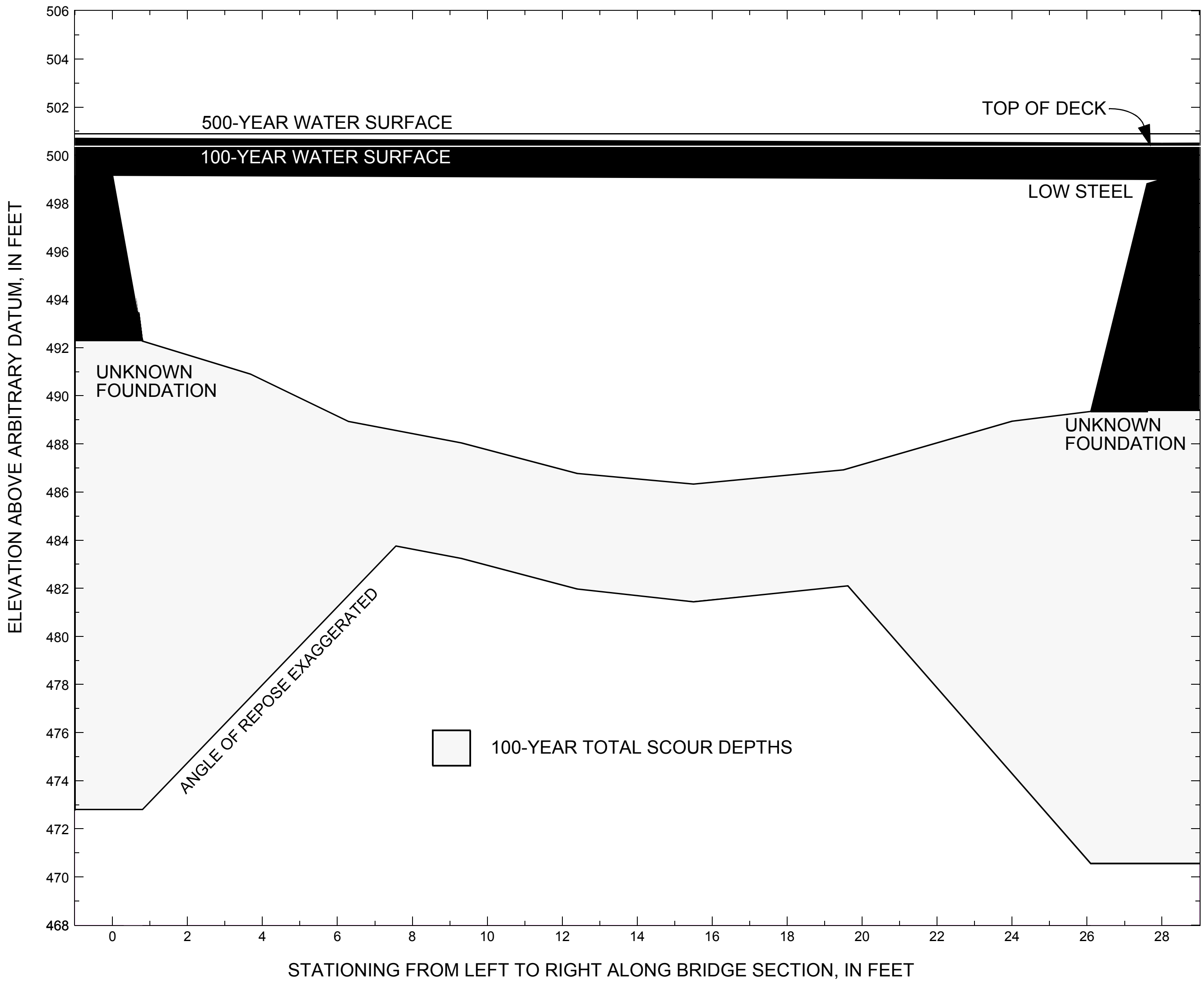

Figure 8. Scour elevations for the 100- and 500-year discharges at structure FFIETH00470046 on Town Highway 47, crossing Black Creek, Fairfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure FFIETH00470046 on Town Highway 47, crossing Black Creek, Fairfield, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,480 cubic-feet per second											
Left abutment	0.0	--	499.2	--	492.3	4.9	14.6	--	19.5	472.8	--
Right abutment	28.0	--	499.0	--	489.4	4.9	13.9	--	18.8	470.6	--

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 FFIETH00470046 on Town Highway 47, crossing Black Creek, Fairfield, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 4,990 cubic-feet per second											
Left abutment	0.0	--	499.2	--	492.3	1.4	14.2	--	15.6	476.7	--
Right abutment	28.0	--	499.0	--	489.4	1.4	15.6	--	17.0	472.4	--

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

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U.S. Geological Survey, 1986, Bakersfield, 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

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T1        U.S. Geological Survey WSPRO Input File ffie046.wsp
T2        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
T3        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
*
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           3480.0   4990.0
SK          0.0005   0.0005
*
XS   EXITX     -28 * * * 0.0005
GR         -187.3, 496.05    -87.3, 496.05    -17.3, 500.14     -2.0, 492.75
GR            5.0, 488.95      6.9, 487.33     11.0, 485.78     16.3, 485.88
GR           19.7, 486.51     24.2, 487.04     28.0, 487.91     30.9, 488.91
GR           40.7, 494.91     46.9, 497.32     65.8, 496.09    109.6, 496.90
GR          156.3, 497.96    245.0, 501.93    258.3, 507.49
*
*           Exit section surveyed upstream of scour hole.
*
N           0.035        0.055        0.035
SA                 -17.3         46.9
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    499.08       0.0
GR            0.0, 499.17      0.3, 498.41      0.8, 492.27      3.7, 490.89
GR            6.3, 488.93      9.3, 488.04     12.4, 486.77     15.5, 486.33
GR           19.5, 486.92     24.0, 488.94     26.1, 489.35     27.6, 498.81
GR           28.0, 499.00      0.0, 499.17
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      18.5 * *     21.2     11.1
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      7      14.0     2
GR         -127.3, 503.34    -67.5, 500.08    -31.9, 499.34     -2.2, 500.59
GR            0.0, 500.69     27.4, 500.49     29.5, 500.52     31.1, 500.28
GR           86.9, 496.91    113.5, 497.16    166.6, 497.70    268.0, 500.16
GR          290.7, 509.46
*           -2.5, 504.03      29.7, 503.89
*
AS   APPRO     42           0.
GR         -127.3, 503.34    -35.1, 499.70    -28.9, 496.03
GR          -20.9, 489.72    -18.5, 488.90    -15.7, 488.87     -5.0, 489.75
GR            5.8, 490.41      9.5, 488.89     10.5, 488.07     19.1, 486.08
GR           20.1, 486.97     22.7, 488.93     29.8, 493.61     48.7, 495.25
GR          116.2, 495.61    270.4, 498.61    312.9, 509.56
*
N           0.035        0.055        0.035
SA                 5.8          29.8
*
HP 1 BRIDG 499.17 1 499.17
HP 2 BRIDG 499.17 * * 958
HP 2 RDWAY 500.03 * * 2527
HP 1 APPRO 500.59 1 500.59
HP 2 APPRO 500.59 * * 3480
*
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```
T1        U.S. Geological Survey WSPRO Input File ffie046.wsp
T2        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
T3        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
*
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           730.0
SK          0.0005
*
XS   EXITX      -28 * * * 0.0005
GR          -17.3, 500.14     -2.0, 492.75
GR            5.0, 488.95      6.9, 487.33     11.0, 485.78     16.3, 485.88
GR           19.7, 486.51     24.2, 487.04     28.0, 487.91     30.9, 488.91
GR           40.7, 494.91     46.9, 497.32
*
*           Exit section surveyed upstream of scour hole.
*
N           0.035        0.055        0.035
SA                 -17.3         46.9
*
XS   FULLV       0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    499.08       0.0
GR            0.0, 499.17      0.3, 498.41      0.8, 492.27      3.7, 490.89
GR            6.3, 488.93      9.3, 488.04     12.4, 486.77     15.5, 486.33
GR           19.5, 486.92     24.0, 488.94     26.1, 489.35     27.6, 498.81
GR           28.0, 499.00      0.0, 499.17
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD            1      18.5 * *     21.2     11.1
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY       7      14.0     2
GR         -127.3, 503.34    -67.5, 500.08    -31.9, 499.34     -2.2, 500.59
GR            0.0, 500.69     27.4, 500.49     29.5, 500.52     31.1, 500.28
GR           86.9, 496.91    113.5, 497.16    166.6, 497.70    268.0, 500.16
GR          290.7, 509.46
*
AS   APPRO      42           0.
GR         -127.3, 503.34    -35.1, 499.70    -28.9, 496.03
GR          -20.9, 489.72    -18.5, 488.90    -15.7, 488.87     -5.0, 489.75
GR            5.8, 490.41      9.5, 488.89     10.5, 488.07     19.1, 486.08
GR           20.1, 486.97     22.7, 488.93     29.8, 493.61     48.7, 495.25
GR          116.2, 495.61    270.4, 498.61    312.9, 509.56
*
N           0.035        0.055        0.035
SA                 5.8          29.8
*
HP 1 BRIDG 496.63 1 496.63
HP 2 BRIDG 496.63 * * 730
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File ffie046.wsp
       Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
       Bridge #46 over Black Creek in Fairfield, Vt.   RHF
          *** RUN DATE & TIME: 06-22-98  10:14
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      283.  20959.     0.    72.                           0.
  499.17           283.  20959.     0.    72.  1.00     0.    28.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.17     0.0    28.0   282.9   20959.     958.   3.39

X STA.        0.0        5.1        6.5        7.6        8.7        9.8
  A(I)            36.7       13.3       11.7       12.1       11.4
  V(I)            1.30       3.61       4.09       3.96       4.20

X STA.        9.8       10.8       11.8       12.7       13.6       14.5
  A(I)            11.8       11.2       11.5       11.1       11.2
  V(I)            4.06       4.26       4.17       4.31       4.27

X STA.       14.5       15.4       16.2       17.1       18.0       18.9
  A(I)            11.2       11.2       11.2       11.0       11.1
  V(I)            4.28       4.27       4.26       4.34       4.31

X STA.       18.9       19.9       20.8       21.9       23.0       28.0
  A(I)            11.2       11.4       11.7       11.8       38.9
  V(I)            4.27       4.22       4.08       4.06       1.23

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.03   -65.1   262.6   427.3   26764.    2527.   5.91

X STA.      -65.1       64.6       74.1       80.9       86.7       91.9
  A(I)            43.1       19.6       17.3       17.0       16.1
  V(I)            2.93       6.46       7.29       7.45       7.87

X STA.       91.9       97.3      103.0      108.8      114.8      119.9
  A(I)            16.7       16.9       17.1       17.5       14.2
  V(I)            7.58       7.49       7.39       7.22       8.88

X STA.      119.9      124.5      130.5      136.6      142.9      149.7
  A(I)            12.9       16.3       16.4       16.4       17.1
  V(I)            9.80       7.77       7.71       7.70       7.38

X STA.      149.7      156.7      163.9      171.9      181.2      262.6
  A(I)            17.4       17.3       18.2       19.5       80.4
  V(I)            7.26       7.30       6.96       6.47       1.57

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      383.  52138.    63.    67.                        5334.
            2      282.  36289.    24.    27.                        5483.
            3     1009. 109276.   248.   249.                       11541.
  500.59          1674. 197703.   336.   343.  1.03   -58.   278.  20859.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.59   -57.6   278.1  1673.6  197703.    3480.   2.08

X STA.      -57.6      -13.0       -9.0       -4.7       -0.2        4.5
  A(I)           179.3       45.6       47.4       47.9       48.8
  V(I)            0.97       3.81       3.67       3.63       3.56

X STA.        4.5       10.8       16.0       21.1       30.4       41.2
  A(I)            69.7       69.0       71.4       89.4       69.9
  V(I)            2.49       2.52       2.44       1.95       2.49

X STA.       41.2       54.1       68.8       83.7       99.1      114.9
  A(I)            71.4       77.2       77.6       78.6       79.7
  V(I)            2.44       2.25       2.24       2.21       2.18

X STA.      114.9      131.9      150.8      173.5      204.1      278.1
  A(I)            82.3       84.6       92.9      108.9      181.8
  V(I)            2.11       2.06       1.87       1.60       0.96
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ffie046.wsp
        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
           *** RUN DATE & TIME: 06-22-98  10:14
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     283.  20959.     0.    72.                           0.
   499.17          283.  20959.     0.    72.  1.00     0.    28.       0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.17     0.0    28.0   282.9   20959.     822.   2.91

X STA.         0.0        5.1        6.5        7.6        8.7        9.8
  A(I)            36.7       13.3       11.7       12.1       11.4
  V(I)            1.12       3.10       3.51       3.40       3.60

X STA.         9.8       10.8       11.8       12.7       13.6       14.5
  A(I)            11.8       11.2       11.5       11.1       11.2
  V(I)            3.48       3.65       3.58       3.70       3.66

X STA.        14.5       15.4       16.2       17.1       18.0       18.9
  A(I)            11.2       11.2       11.2       11.0       11.1
  V(I)            3.67       3.66       3.66       3.73       3.70

X STA.        18.9       19.9       20.8       21.9       23.0       28.0
  A(I)            11.2       11.4       11.7       11.8       38.9
  V(I)            3.67       3.62       3.50       3.48       1.06

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.87   -82.0   269.7   692.5   51736.    4167.   6.02

X STA.       -82.0      -21.3       61.2       72.4       80.8       87.8
  A(I)            60.9       67.8       30.9       28.0       26.5
  V(I)            3.42       3.07       6.75       7.44       7.86

X STA.        87.8       94.4      101.4      108.5      115.7      122.4
  A(I)            25.9       27.0       26.7       27.1       24.2
  V(I)            8.03       7.73       7.80       7.68       8.59

X STA.       122.4      128.6      136.2      143.9      151.9      160.5
  A(I)            22.4       26.6       26.6       26.7       28.3
  V(I)            9.28       7.84       7.82       7.80       7.36

X STA.       160.5      169.3      179.1      190.8      205.8      269.7
  A(I)            28.0       29.1       32.1       36.0       91.6
  V(I)            7.44       7.16       6.50       5.79       2.27

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     457.  56774.    88.    92.                        5901.
             2     305.  41475.    24.    27.                        6183.
             3    1254. 155397.   252.   253.                       15873.
   501.57         2017. 253646.   364.   371.  1.00   -82.   282.  26875.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.57   -82.5   281.9  2016.6  253646.    4990.   2.47

X STA.       -82.5      -11.4       -6.8       -1.8        3.3        9.9
  A(I)           256.0       55.6       59.2       58.4       76.9
  V(I)            0.97       4.49       4.21       4.27       3.24

X STA.         9.9       16.0       22.0       32.6       44.3       57.5
  A(I)            86.3       88.3      103.4       84.4       84.5
  V(I)            2.89       2.83       2.41       2.96       2.95

X STA.        57.5       70.9       85.2      100.1      114.9      131.0
  A(I)            83.4       87.8       91.1       88.9       93.6
  V(I)            2.99       2.84       2.74       2.81       2.66

X STA.       131.0      148.4      168.3      191.3      220.5      281.9
  A(I)            95.7      102.3      108.5      123.4      188.8
  V(I)            2.61       2.44       2.30       2.02       1.32
```

```
        U.S. Geological Survey WSPRO Input File ffie046.wsp
        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
           *** RUN DATE & TIME: 06-22-98  11:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     216.   20211.    27.    39.                       3485.
   496.63          216.   20211.    27.    39.  1.00     0.    27.   3485.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.63     0.4    27.3   216.3   20211.     730.   3.38

 X STA.        0.4         6.2        7.3        8.4        9.4       10.4
  A(I)            31.8        9.1        8.6        8.7        8.7
  V(I)            1.15       4.02       4.23       4.19       4.21

 X STA.       10.4        11.3       12.2       13.0       13.8       14.6
  A(I)             8.4        8.5        8.1        8.1        8.2
  V(I)            4.33       4.29       4.48       4.48       4.43

 X STA.       14.6        15.5       16.2       17.1       17.9       18.7
  A(I)             8.3        8.1        8.2        8.1        7.9
  V(I)            4.37       4.50       4.43       4.52       4.60

 X STA.       18.7        19.5       20.4       21.3       22.3       27.3
  A(I)             8.2        8.3        8.6        8.6       33.6
  V(I)            4.47       4.39       4.27       4.26       1.09

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     228.   31625.    36.    39.                       3249.
             2     193.   19317.    24.    27.                       3109.
             3     187.    9142.   152.   152.                       1178.
   496.89          608.   60084.   212.   218.  1.40   -30.   182.   4929.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.89   -30.4   182.0   608.3   60084.     730.   1.20

 X STA.      -30.4       -18.8      -16.5      -14.3      -12.0       -9.6
  A(I)            48.9       17.9       17.4       18.1       18.3
  V(I)            0.75       2.04       2.10       2.02       1.99

 X STA.       -9.6        -7.0       -4.4       -1.7        1.2        4.2
  A(I)            19.2       18.9       19.3       19.3       20.1
  V(I)            1.90       1.93       1.89       1.89       1.82

 X STA.        4.2         8.0       11.6       14.3       16.8       19.1
  A(I)            25.7       29.5       26.1       24.6       23.9
  V(I)            1.42       1.24       1.40       1.48       1.53

 X STA.       19.1        22.2       30.3       44.0       79.2      182.0
  A(I)            29.5       46.1       36.2       56.1       93.1
  V(I)            1.24       0.79       1.01       0.65       0.39
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ffie046.wsp
        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
           *** RUN DATE & TIME: 06-22-98  10:14

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

EXITX:XS   ******  -187.    1598.  0.08 *****  500.40  494.65   3480.  500.32
      -28. ******   209.  155591.  1.04 ***** *******    0.20    2.18

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   500.34     496.05     507.49

FULLV:FV      28.  -187.    1605.  0.08  0.01  500.41 *******   3480.  500.34
        0.    28.   209.  156568.  1.04  0.00    0.00    0.19    2.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.   -52.    1595.  0.08  0.02  500.43 *******   3480.  500.35
       42.    42.   277.  186332.  1.06  0.00    0.00    0.18    2.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   500.34     499.08

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                 QRD,QRDMAX,RATIO =    2527.      2414.    1.05

            <<<<<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      28.     0.     283.  0.18 *****  499.35  491.77    958.  499.17
        0. ******    28.   20959.  1.00 ***** *******    0.19    3.39

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.08 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG       7.    28.  0.01  0.07  500.65    0.00   2527.  500.03

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    132.    49.   -65.   -16.   0.7   0.3   4.2   7.8   1.0   2.8
   RT:   2395.   227.    35.   262.   3.1   1.8   6.5   5.9   2.4   2.8

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

APPRO:AS      24.   -58.    1673.  0.07  0.04  500.66  494.71   3480.  500.59
       42.    37.   278.  197628.  1.03  0.00    0.00    0.17    2.08

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

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.  -187.   209.   3480.  155591.    1598.    2.18  500.32
   FULLV:FV       0.  -187.   209.   3480.  156568.    1605.    2.17  500.34
   BRIDG:BR       0.     0.    28.    958.   20959.     283.    3.39  499.17
   RDWAY:RG       7.*******   132.   2527.*****************    2.00  500.03
   APPRO:AS      42.   -58.   278.   3480.  197628.    1673.    2.08  500.59

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.65    0.20  485.78  507.49************  0.08  500.40  500.32
   FULLV:FV  ********    0.19  485.78  507.49  0.01  0.00  0.08  500.41  500.34
   BRIDG:BR    491.77    0.19  486.33  499.17************  0.18  499.35  499.17
   RDWAY:RG  ****************  496.91  509.46  0.01******  0.07  500.65  500.03
   APPRO:AS    494.71    0.17  486.08  509.56  0.04  0.00  0.07  500.66  500.59
```

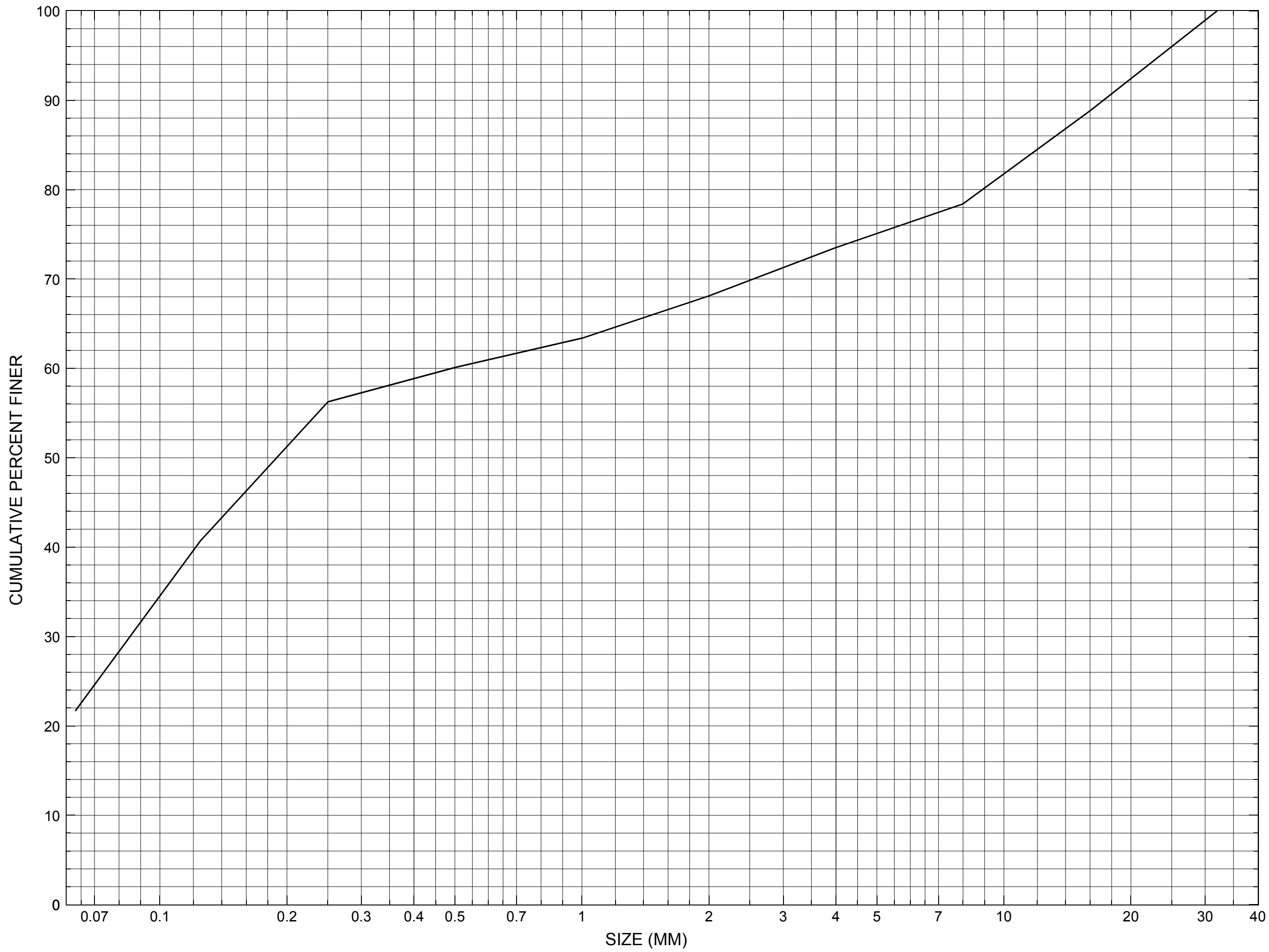
```
        U.S. Geological Survey WSPRO Input File ffie046.wsp
        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
           *** RUN DATE & TIME: 06-22-98  10:14

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

EXITX:XS   ******  -187.    2032.  0.10 *****  501.48  497.56   4990.  501.38
      -28. ******   233.  223010.  1.03 ***** *******    0.20    2.46

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                          WSEL,YLT,YRT =   501.40     496.05     507.49

FULLV:FV      28.  -187.    2040.  0.10  0.01  501.50 *******   4990.  501.40
        0.    28.   233.  224227.  1.03  0.00    0.00    0.20    2.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -79.    1962.  0.10  0.02  501.52 *******   4990.  501.42
       42.    42.   281.  244118.  1.00  0.00    0.00    0.19    2.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   501.40     499.08

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    4167.      3800.    1.10

            <<<<<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      28.     0.     283.  0.13 *****  499.30  491.37    822.  499.17
        0. ******    28.   20959.  1.00 ***** *******    0.16    2.91

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    6.  0.800  0.000  499.08 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.    28.  0.01  0.10  501.66    0.00   4167.  500.87

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    551.    96.   -82.    14.   1.5   0.8   5.4   7.1   1.6   2.8
   RT:   3615.   255.    14.   270.   4.0   2.4   6.6   5.9   3.2   2.5

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

APPRO:AS      24.    -83.    2018.  0.10  0.06  501.67  496.87   4990.  501.57
       42.    40.   282.  253874.  1.00  0.00    0.00    0.19    2.47

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.  -187.   233.   4990.  223010.    2032.    2.46  501.38
   FULLV:FV       0.  -187.   233.   4990.  224227.    2040.    2.45  501.40
   BRIDG:BR       0.     0.    28.    822.   20959.     283.    2.91  499.17
   RDWAY:RG       7.*******   551.   4167.******************    2.00  500.87
   APPRO:AS      42.   -83.   282.   4990.  253874.    2018.    2.47  501.57

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    497.56    0.20  485.78  507.49************  0.10  501.48  501.38
   FULLV:FV  ********    0.20  485.78  507.49  0.01  0.00  0.10  501.50  501.40
   BRIDG:BR    491.37    0.16  486.33  499.17************  0.13  499.30  499.17
   RDWAY:RG  ****************  496.91  509.46  0.01******  0.10  501.66  500.87
   APPRO:AS    496.87    0.19  486.08  509.56  0.06  0.00  0.10  501.67  501.57
  ER
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ffie046.wsp
        Hydraulic analysis for structure FFIETH00470046   Date: 10-OCT-97
        Bridge #46 over Black Creek in Fairfield, Vt.   RHF
           *** RUN DATE & TIME: 06-22-98  11:12

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

 EXITX:XS   ******   -10.     365.  0.06 *****  496.79  489.82    730.  496.73
      -28. ******    45.   32637.  1.00 ***** *******    0.14    2.00

 FULLV:FV      28.   -10.     366.  0.06  0.01  496.81 *******    730.  496.75
        0.    28.    45.   32741.  1.00  0.00    0.00    0.14    2.00
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.77

 APPRO:AS      42.   -30.     586.  0.03  0.01  496.82 *******    730.  496.78
       42.    42.   177.   57832.  1.40  0.00    0.00    0.15    1.25
          <<<<<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      28.     0.     216.  0.25  0.02  496.88  491.09    730.  496.63
        0.    28.    27.   20194.  1.43  0.06    0.00    0.25    3.38

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  0.835 ******  499.08 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       7.        <<<<<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      24.   -30.     607.  0.03  0.01  496.92  490.94    730.  496.89
       42.    32.   182.   59990.  1.40  0.02    0.01    0.15    1.20

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.870  0.541   27478.   -10.    16.   496.88

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -28.   -10.    45.    730.   32637.     365.    2.00  496.73
    FULLV:FV       0.   -10.    45.    730.   32741.     366.    2.00  496.75
    BRIDG:BR       0.     0.    27.    730.   20194.     216.    3.38  496.63
    RDWAY:RG       7.**************      0.*****************     2.00********
    APPRO:AS      42.   -30.   182.    730.   59990.     607.    1.20  496.89

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS     -10.    16.   27478.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    489.82    0.14  485.78  500.14************  0.06  496.79  496.73
    FULLV:FV  ********    0.14  485.78  500.14  0.01  0.00  0.06  496.81  496.75
    BRIDG:BR    491.09    0.25  486.33  499.17  0.02  0.06  0.25  496.88  496.63
    RDWAY:RG  ****************  496.91  509.46**********************************
    APPRO:AS    490.94    0.15  486.08  509.56  0.01  0.02  0.03  496.92  496.89
   ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a sediment sample from the channel approach of structure FFIETH00470046, in Fairfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number FFIETH00470046

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. MEDALIE

Date *(MM/DD/YY)* 03 / 08 / 95

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 25225

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

Waterway *(I - 6)* BLACK CREEK

Road Name *(I - 7)*: -

Route Number TH047

Vicinity *(I - 9)* 0.05 MI TO VT W VT36

Topographic Map Bakersfield

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44476

Longitude *(i - 17; nnnnn.n)* 72523

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10060500460605

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

Maximum span length *(I - 48; nnnn)* 0031

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

Structure length *(I - 49; nnnnnn)* 000035

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 140

Year of ADT *(I - 30; YY)* 93

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

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

Waterway adequacy *(I - 71; n)* 6

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 24.8

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

Vertical clearance from streambed (*nnn.n ft*) 11

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

Waterway of full opening (*nnn.n ft*^{2}) 272.8

Comments:

The structural inspection report of 8/22/94 indicates the structure is a steel stringer-type bridge with sections of partially concrete-filled steel-grid decking. Abutments and wingwalls are laid-up stone with metal backwalls and a concrete cap on the left abutment. Small voids are reported on the abutment walls overall, with several broken stones on the face of the right abutment. The downstream right wingwall bulges out and appears somewhat unstable. Some stones of the left abutment face shifted forward before the concrete cap was installed. Some stones are cracked, with some small sections slipping out. Small voids are still present on both ends. A few stones and boulders are present in front of the left **(Continued, page 34)**

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*): - Frequency: -

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

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

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

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

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

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

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

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

Comments:

abutment, with a few random boulders showing on the banks. There are some signs of bank erosion from past flooding. Bedrock reportedly outcrops in the channel upstream. Several inches of settlement have occurred at the left abutment, according to the inspection report. No footings are evident. Report comments indicated that the channel is approximately 3.5 ft deep near mid-span. Minor point bars and debris are reported. Not much stone fill is noted.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **37.80** mi^2 Lake/pond/swamp area **0.18** mi^2

Watershed storage *(ST)* **0.5** %

Bridge site elevation **374** ft Headwater elevation **1440** ft

Main channel length **16.25** mi

10% channel length elevation **394** ft 85% channel length elevation **710** ft

Main channel slope *(S)* **25.93** 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? N *If no, type ctrl-n xs*

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

Comments: -
NO CROSS SECTION INFORMATION
-

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

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

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

Comments: **NO CROSS SECTION INFORMATION**
-

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: 3/11/96

Computerized by: RB Date: 3/11/96

Reviewd by: EW Date: 7/1/98

Structure Number FFIETH00470046

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 7 / 12 / 1995

2. Highway District Number 8 Mile marker 000

County FRANKLIN (011) Town FAIRFIELD (25225)

Waterway *(I - 6)* BLACK CREEK Road Name -

Route Number TH047 Hydrologic Unit Code: 02010007

3. Descriptive comments:

The bridge is located 0.05 miles to junction with VT 36.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 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 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 35 *(feet)* Span length 31 *(feet)* Bridge width 14 *(feet)*

Road approach to bridge:

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

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

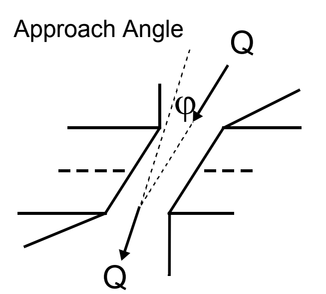
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

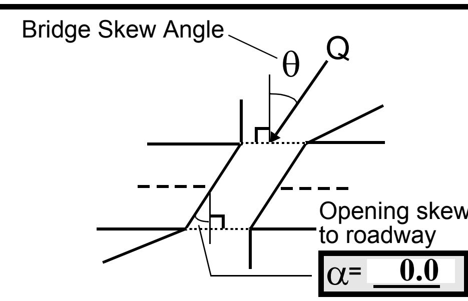
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*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? LB *(LB, RB)* Severity 2
Range? 30 feet US *(US, UB, DS)* to 70 feet US

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

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

18. Bridge Type: **1a**

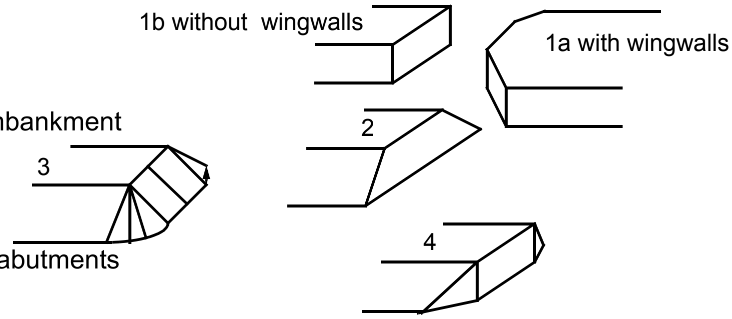
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. The bridge dimensions are from the VTAOT files. Measured span length is 26.5 feet, bridge width is 14 feet, and bridge length is 34 feet.

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
39.0	**6.5**			**6.5**	**2**	**2**	**321**	**321**	**2**	**1**

23. Bank width **35.0** 24. Channel width **35.0** 25. Thalweg depth **59.0** 29. Bed Material **326**

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.):

A railroad bridge is located 120 feet from the US face.
27. The bank material consists of gravel and sand with overlying silt from the overbanks.
29. The bed material consists of gravel and sand with bedrock outcrops along the channel.
30. The left bank protection extends 25 feet along the bank. The right bank protection extends 35 feet along the 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? Y (Y or if N type ctrl-n cb) 40. Where? LB (LB or RB)

41. Mid-bank distance: 70 42. Cut bank extent: 30 feet US (US, UB) to 100 feet US (US, UB, DS)

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

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

The cut bank begins 30 feet from the bridge and extends beyond the railroad bridge US.

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
41.0		3.0		2	7	7	-

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

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

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

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

345

Bed material consists of gravel, cobbles, and some boulders.

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

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

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

70. Debris and Ice Comments:

2

There is debris accumulation US of the bridge along the banks with some debris caught in the old railroad piers. The bridge opening is 60% of the US bank width with boulders further constricting the channel.

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

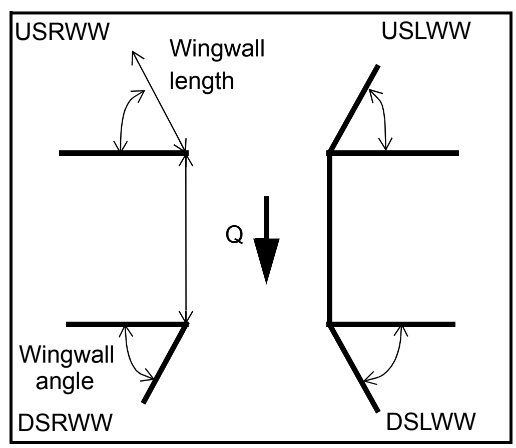
0
0
2

The abutments are laid-up stone, within which some of the smaller stones have eroded away, leaving gaps in the channel restraint.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						28.0	
USRWW:	Y		2		0	2.5	
DSLWW:	-		-		Y	13.5	
DSRWW:	2		0		-	15.5	

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



82. **Bank / Bridge Protection**:

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

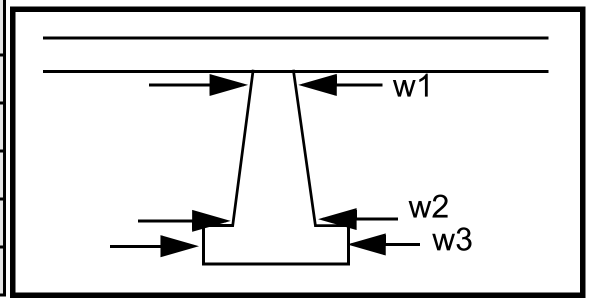
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
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				25.0	10.0	15.0
Pier 2				14.0	10.0	15.5
Pier 3			-	15.0	11.5	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e DS	foot	s	ht.	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	right	more	appe		**1**- Solid pier, **2**- column, **3**- bent
88. Material	wing	than	ar to		**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	wall	at	bulg		**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	bulg	the	e out		Y- yes; N- no
91. Attack ∠ (BF)	es	base.	more		
92. Pushed	out	The	than		LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	at	US	1		
95. Cross-members	the	right	foot		**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	top,	wing	at		**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	abou	wall	mid-	N	
98. Exposure depth	t 1	stone	heig	-	

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

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

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

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

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

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

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

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

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

Point bar extent: NO _____ feet PI _____ *(US, UB, DS)* to ERS _____ feet _____ *(US, UB, DS)* positioned _____ %LB to _____ %RB

Material: _____

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

Is a cut-bank present? _____ *(Y or if N type ctrl-n cb)* Where? 2 _____ *(LB or RB)* Mid-bank distance: 2 _____

Cut bank extent: 124 _____ feet 124 _____ *(US, UB, DS)* to 1 _____ feet 2 _____ *(US, UB, DS)*

Bank damage: 421 _____ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

2
0
1
-

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

Scour dimensions: Length bank _____ Width pro- _____ Depth: tec- _____ Positioned tion _____ %LB to exte _____ %RB

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

nds 15 feet along the bank. There are some scattered boulders on the right bank at the downstream end of the scour hole.

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

N

-

-

-

-

109. G. Plan View Sketch

- -

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: FFIETH00470046 Town: FAIRFIELD
Road Number: TH 47 County: FRANKLIN
Stream: BLACK CREEK

Initials ECW Date: 6/22/98 Checked: EMB

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3480	4990	730
Main Channel Area, ft2	282	305	193
Left overbank area, ft2	383	457	228
Right overbank area, ft2	1009	1254	187
Top width main channel, ft	24	24	24
Top width L overbank, ft	63	88	36
Top width R overbank, ft	248	252	152
D50 of channel, ft	0.00062	0.00062	0.00062
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.8	12.7	8.0
y1, average depth, LOB, ft	6.1	5.2	6.3
y1, average depth, ROB, ft	4.1	5.0	1.2
Total conveyance, approach	197703	253646	60084
Conveyance, main channel	36289	41475	19317
Conveyance, LOB	52138	56774	31625
Conveyance, ROB	109276	155397	9142
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	638.8	815.9	234.7
Ql, discharge, LOB, cfs	917.7	1116.9	384.2
Qr, discharge, ROB, cfs	1923.5	3057.1	111.1
Vm, mean velocity MC, ft/s	2.3	2.7	1.2
Vl, mean velocity, LOB, ft/s	2.4	2.4	1.7
Vr, mean velocity, ROB, ft/s	1.9	2.4	0.6
Vc-m, crit. velocity, MC, ft/s	1.4	1.5	1.4
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	0
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 Davis, 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	3480	4990	730	3480	4990	730
Total conveyance	197703	253646	60084	20959	20959	20211
Main channel conveyance	36289	41475	19317	20959	20959	20211
Main channel discharge	639	816	235	958	822	730
Area - main channel, ft2	282	305	193	283	283	216
(W1) channel width, ft	24	24	24	28	28	26.9
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	24	24	24	28	28	26.9
D50, ft	0.00062	0.00062	0.00062			
w, fall velocity, ft/s (p. 32)	0.107155	0.107155	0.107155			
y, ave. depth flow, ft	11.75	12.71	8.04	10.11	10.11	8.03
S1, slope EGL	0.000476	0.000476	0.00024			
P, wetted perimeter, MC, ft	27	27	27			
R, hydraulic Radius, ft	10.444	11.296	7.148			
V*, shear velocity, ft/s	0.400	0.416	0.235			
V*/w	3.735	3.884	2.193			
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	14.95	11.50	19.66			
ys, scour depth, ft (y2-y_bridge)	4.85	1.39	11.63			

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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3480	4990	730
(Q) discharge thru bridge, cfs	958	822	730
Main channel conveyance	20959	20959	20211
Total conveyance	20959	20959	20211
Q2, bridge MC discharge,cfs	958	822	730
Main channel area, ft2	283	283	216
Main channel width (normal), ft	28.0	28.0	26.9
Cum. width of piers in MC, ft	0.0	0.0	0.0

W, adjusted width, ft	28	28	26.9
y_bridge (avg. depth at br.), ft	10.11	10.11	8.03
Dm, median (1.25*D50), ft	0.000775	0.000775	0.000775
y2, depth in contraction,ft	19.79	17.35	16.22
ys, scour depth (y2-ybridge), ft	9.68	7.25	8.19

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 Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	3480	4990	730
Q, thru bridge MC, cfs	958	822	730
Vc, critical velocity, ft/s	1.44	1.46	1.35
Va, velocity MC approach, ft/s	2.27	2.68	1.22
Main channel width (normal), ft	28.0	28.0	26.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.0	28.0	26.9
qbr, unit discharge, ft2/s	34.2	29.4	27.1
Area of full opening, ft2	283.0	283.0	216.0
Hb, depth of full opening, ft	10.11	10.11	8.03
Fr, Froude number, bridge MC	0.19	0.16	0
Cf, Fr correction factor (<=1.0)	0.73	0.68	0.00
**Area at downstream face, ft2	0	0	0
**Hb, depth at downstream face, ft	0.00	0.00	0.00
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	499.08	499.08	499.08
Elevation of Bed, ft	488.97	488.97	491.05
Elevation of Approach, ft	500.59	501.57	0
Friction loss, approach, ft	0.04	0.06	0
Elevation of WS immediately US, ft	500.55	501.51	0.00
ya, depth immediately US, ft	11.58	12.54	-491.05
Mean elevation of deck, ft	500.5	500.5	500.5
w, depth of overflow, ft (>=0)	0.05	1.01	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.97	ERR
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	23.28	20.34	N/A
Ys, scour w/Umbrell equation, ft	6.61	8.82	N/A

Armoring

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

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

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	958	822	730
Main channel area (DS), ft2	283	283	216
Main channel width (normal), ft	28.0	28	26.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	28.0	28.0	26.9
D90, ft	0.0564	0.0564	0.0564
D95, ft	0.0770	0.0770	0.0770
Dc, critical grain size, ft	0.0196	0.0144	0.0207
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 Davis, 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	3480	4990	730	3480	4990	730
a', abut.length blocking flow, ft	57.6	82.5	30.8	250.1	253.9	154.7
Ae, area of blocked flow ft2	310.62	360.06	191.98	631.51	686.29	202.47
Qe, discharge blocked abut.,cfs	--	--	318.43	--	--	123.02
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.18	2.14	1.66	1.91	2.43	0.61
ya, depth of f/p flow, ft	5.39	4.36	6.23	2.53	2.70	1.31
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.163	0.173	0.117	0.166	0.191	0.094
ys, scour depth, ft	14.58	14.22	12.47	13.86	15.63	5.78

HIRE equation (a'/ya > 25)

ys = 4*Fr^0.33*y1*K/0.55

(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	57.6	82.5	30.8	250.1	253.9	154.7
y1 (depth f/p flow, ft)	5.39	4.36	6.23	2.53	2.70	1.31
a'/y1	10.68	18.90	4.94	99.05	93.93	118.20
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.16	0.17	0.12	0.17	0.19	0.09
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	10.15	11.38	4.36
vertical w/ ww's	ERR	ERR	ERR	8.33	9.33	3.57
spill-through	ERR	ERR	ERR	5.58	6.26	2.40

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.19	0.16	0.25	0.19	0.16	0.25
y, depth of flow in bridge, ft	10.11	10.11	8.03	10.11	10.11	8.03
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.23	0.16	0.31	0.23	0.16	0.31
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR