LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (CRAFTH00550029) on TOWN HIGHWAY 55, crossing the BLACK RIVER, CRAFTSBURY, VERMONT

U.S. Geological Survey
Open-File Report 96-386

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

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Pembroke, New Hampshire

1996

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (CRAFTH00550029) ON TOWN HIGHWAY 55, CROSSING THE BLACK RIVER, CRAFTSBURY, VERMONT

By **Erick M. Boehmler and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CRAFTH00550029 on town highway 55 crossing the Black River, Craftsbury, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province of north-central Vermont in the town of Craftsbury. The 24.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have woody vegetation coverage except for the upstream left bank and the downstream right bank, which have more brush cover than trees.

In the study area, the Black River has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 41 ft and an average channel depth of 5.5 ft. The predominant channel bed material is sand and gravel (D_{50} is 44.7 mm or 0.147 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 7, 1995, indicated that the reach was stable.

The town highway 55 crossing of the Black River is a 32-ft-long, one-lane bridge consisting of one 28-foot span steel stringer superstructure with a timber deck (Vermont Agency of Transportation, written communication, August 4, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 10 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was evident at mid-channel immediately downstream of the bridge during the Level I assessment. The only scour protection measure at the site was type-1 stone fill (less than 12 inches diameter) on the upstream right bank and road approach embankment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.9 to 1.4 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 12.1 to 15.5 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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 CRAFTH00550029 ***Stream*** Black River

County Orleans ***Road*** TH 55 ***District*** 09

Description of Bridge

Bridge length 32 ***ft*** ***Bridge width*** 15.1 ***ft*** ***Max span length*** 28 ***ft***

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

Abutment type Vertical ***Embankment type*** Steeply sloping

Stone fill on abutment? No ***Date of inspection*** 6/7/95

Description of stone fill Type-1 on the upstream right bank and upstream right road approach.

Abutments and wingwalls are concrete. The concrete is very weathered with spalls and pockets where the concrete has fallen away.

Brief description of piers/abutments

Y

Is bridge skewed to flood flow according to Y ***survey?*** ***Angle*** 40

There is a severe channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/7/95	0	0
Level II	6/7/95	--	--

Potential for debris Low due to stable banks in vicinity of this site. Debris potential further upstream may be higher but was not considered in this study.

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

None as of 6/7/95.

Description of the Geomorphic Setting

General topography The channel is probably incised in a 70 foot-wide valley, with no flood plain and steep valley walls on each side.

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

Date of inspection 6/7/95

DS left: Steep channel bank to a flat, sand and gravel, industry parking area.

DS right: Steep channel bank to valley wall.

US left: Steep road approach embankment to a flat, sand and gravel parking area.

US right: Moderately sloped bank to valley wall.

Description of the Channel

Average top width 41 *ft* ***Average depth*** 5.5 *ft*

Predominant bed material Sand / Gravel ***Bank material*** Cobble / Boulder

Sinuous but stable

with non-alluvial channel boundaries and no flood plain.

6/7/95

Vegetative co Trees and brush

DS left: Trees, shrubs, and brush

DS right: Trees and shrubs

US left: Trees and shrubs

US right: Y

Do banks appear stable? -

date of observation.

None on 6/7/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 24.7 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description Black River at Coventry, VT

USGS gage number 04296000

Gage drainage area 122 ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 1,830 ***ft***^{3}***/s*** ***Q500*** 2,160 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [Q=Qg(24.6/122)exp 0.5] with the gage, where Qg is the 100- and 500-year discharge at the gage. The 100- and 500- year discharges from the gaged records were 4,080 and 4,800 respectively.

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" in a chisled square at the DS end of the left abutment (elev. 496.98 ft, arbitrary datum). RM2 is a chiseled "X" on top of boulder (bedrock) about 10 feet US of the US end of the right abutment (elev. 492.60 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
APPRO	44	2	Modelled Approach section (Templated from APTEM)
APTEM	54	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 0.070, and overbank "n" values were 0.080.

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 0.010 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986a & b).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0125 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

While the channel approach to the bridge opening is skewed at an angle near 40 degrees, the flow was considered to align with the abutment walls through the bridge. Therefore, the opening-skew-to-roadway of 10 degrees was applied for each discharge modeled.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.6 *ft*
Average low steel elevation 497.1 *ft*

100-year discharge 1,830 *ft³/s*
Water-surface elevation in bridge opening 494.1 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 165 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 14.1 *ft/s*

Water-surface elevation at Approach section with bridge 496.4 *ft*
Water-surface elevation at Approach section without bridge 495.7 *ft*
Amount of backwater caused by bridge 0.7 *ft*

500-year discharge 2,160 *ft³/s*
Water-surface elevation in bridge opening 497.1 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 240 *ft²*
Average velocity in bridge opening 9.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.0 *ft/s*

Water-surface elevation at Approach section with bridge 498.9 *ft*
Water-surface elevation at Approach section without bridge 496.5 *ft*
Amount of backwater caused by bridge 2.4 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

The 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Therefore, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 100-year discharge. The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F. For contraction scour computations using the Laursen's equation, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The computed armoring depths suggest that contraction scour depths are not limited by streambed armoring.

Abutment scour at each abutment for each discharge modelled was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). The Froehlich equation gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). 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	1.4	0.9	--
Depth to armoring	11.1	2.7	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	13.9	15.5	--
Right abutment	12.1	14.6	--
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	1.5	--
Right abutment	2.4	1.5	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

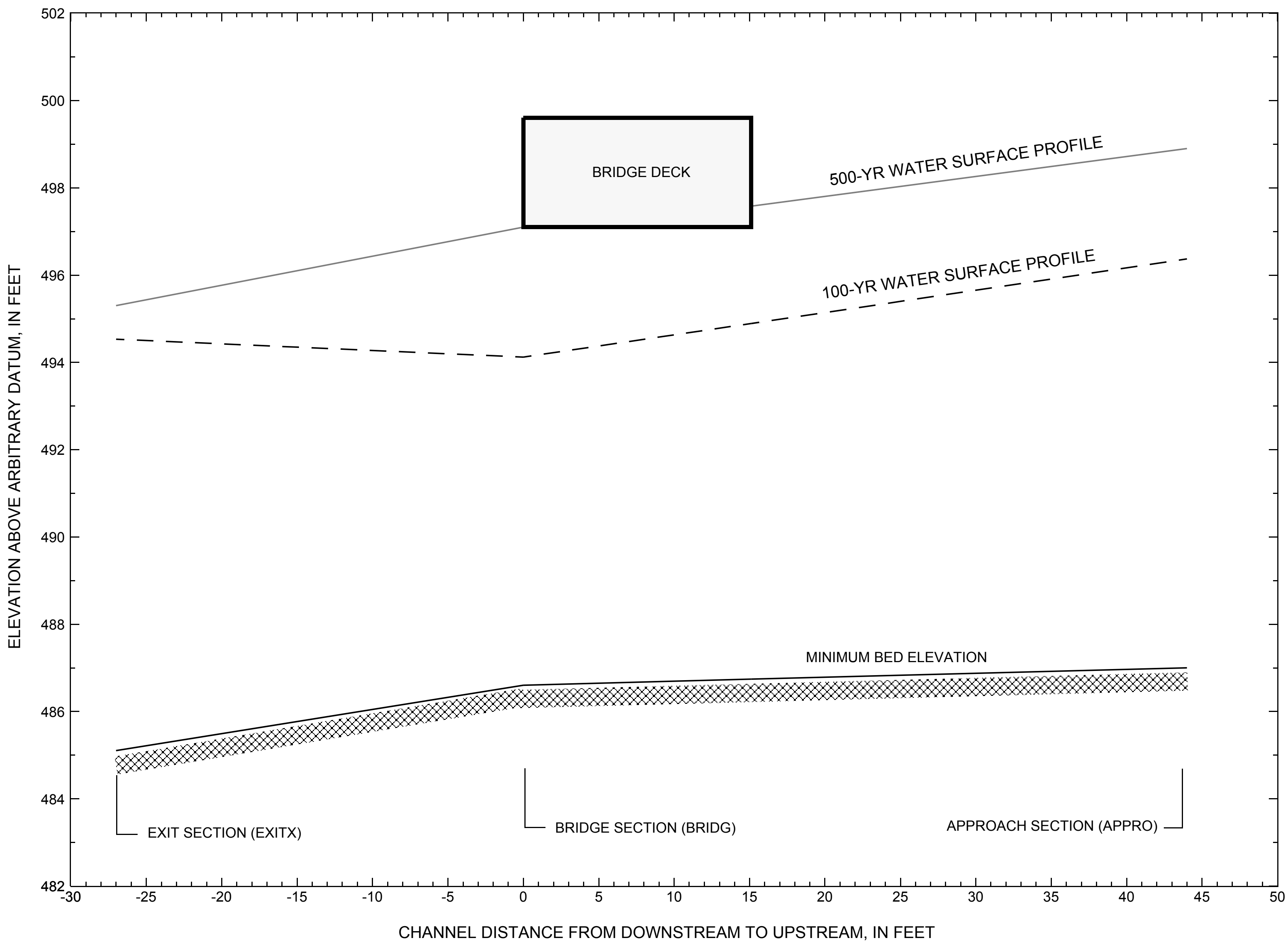

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CRAFTH00550029 on town highway 55, crossing the Black River, Craftsbury, Vermont.

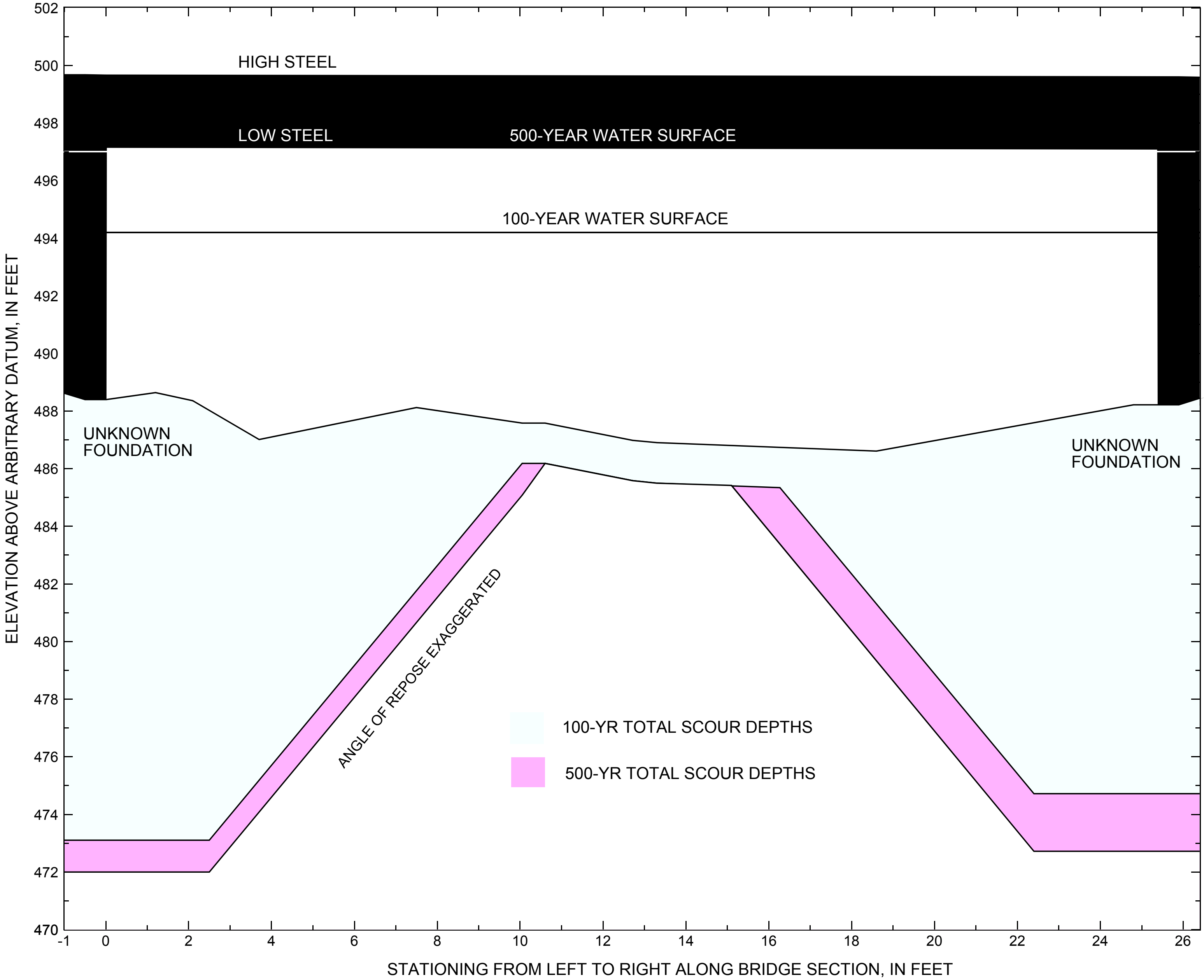

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CRAFTH00550029 on town highway 55, crossing the Black River, Craftsbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CRAFTH00550029 on Town Highway 55, crossing the Black River, Craftsbury, 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 1,830 cubic-feet per second											
Left abutment	0.0	--	497.1	--	488.4	1.4	13.9	--	15.3	473.1	--
Right abutment	25.4	--	497.1	--	488.2	1.4	12.1	--	13.5	474.7	--

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 CRAFTH00550029 on Town Highway 55, crossing the Black River, Craftsbury, 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 2,160 cubic-feet per second											
Left abutment	0.0	--	497.1	--	488.4	0.9	15.5	--	16.4	472.0	--
Right abutment	25.4	--	497.1	--	488.2	0.9	14.6	--	15.5	472.7	--

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, 1986b, Craftsbury, Vermont 7.5 Minute Series quadrangle map, provisional edition: U.S. Geological Survey Topographic Maps, Aerial photography, 1980, Contour interval, 6 meters, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File craf029.wsp
T2        Hydraulic analysis for structure CRAFTH00550029   Date: 29-FEB-96
T3        Town Highway 55 Bridge Crossing the Black River, Craftsbury, VT    EMB
Q           1830.0   2160.0
SK          0.0100   0.0100
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -27           0.
GR          -12.4, 498.75     -7.0, 493.67      0.0, 488.15      5.7, 486.67
GR           11.6, 485.13     22.3, 485.74     23.7, 488.31     25.7, 493.46
GR           31.6, 494.23     38.0, 498.79
*
N           0.060        0.080
SA                   25.7
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.11      10.0
GR            0.0, 497.10     -0.1, 488.45      1.2, 488.64      2.1, 488.36
GR            3.7, 487.01      7.5, 488.12     13.3, 486.90     18.6, 486.61
GR           24.8, 488.22     25.4, 497.13      0.0, 497.10
*
*         Removed:  3.7, 487.01  2.1, 487.62  These points reflect channel
*                  irregularities that are not present through the bridge
*                  but only at the location of the section
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      21.9 * *     23.4      7.5
N           0.050
*
XT   APTEM     54
GR          -21.8, 499.21    -16.2, 493.44     -7.9, 488.35      4.0, 487.22
GR           10.7, 487.14     19.9, 487.32     27.5, 488.44     33.3, 491.75
GR           52.9, 494.52     64.9, 502.85
*
*           GR data above was horizontally shifted by -7.9 feet to align
*           more closely centered with stationing of bridge section GR data
*
AS   APPRO     44  *  *  *  0.0125
GT
N           0.070        0.080
SA                   41.2
*
HP 1 BRIDG   494.12 1 494.12
HP 2 BRIDG   494.12 * * 1830
HP 1 APPRO   496.37 1 496.37
HP 2 APPRO   496.37 * * 1830
*
HP 1 BRIDG   497.13 1 497.13
HP 2 BRIDG   497.13 * * 2160
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
  T1        U.S. Geological Survey WSPRO Input File craf029.wsp
  T2        Hydraulic analysis for structure CRAFTH00550029   Date: 29-FEB-96
  T3        Town Highway 55 Bridge Crossing the Black River, Craftsbury, VT    EMB

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      165     13267     25     37                         2410
   494.12           165     13267     25     37  1.00      0     25     2410

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.12    -0.1    25.2   164.9   13267.    1830.  11.10

 X STA.        -0.1        2.8        4.2        5.5        6.7        8.0
  A(I)            16.0        9.7        8.3        7.9        7.7
  V(I)            5.72       9.44      11.03      11.53      11.85

 X STA.         8.0        9.2       10.3       11.4       12.4       13.3
  A(I)             7.4        7.2        6.9        6.8        6.6
  V(I)           12.40      12.78      13.22      13.47      13.93

 X STA.        13.3       14.2       15.1       16.1       17.0       17.9
  A(I)             6.5        6.5        6.7        6.7        6.8
  V(I)           14.08      13.98      13.72      13.74      13.38

 X STA.        17.9       18.9       19.9       21.0       22.5       25.2
  A(I)             7.0        7.4        7.9        9.4       15.5
  V(I)           13.02      12.38      11.54       9.72       5.92

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      44.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      438     33538     60     64                         6694
             2       36      1165     15     15                          316
   496.37           474     34703     75     79  1.06    -18     56     6556

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      44.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.37   -19.2    55.7   473.6   34703.    1830.   3.86

 X STA.       -19.2       -9.4       -6.2       -3.5       -1.0        1.3
  A(I)            39.1       25.9       22.7       22.0       20.7
  V(I)            2.34       3.53       4.03       4.16       4.43

 X STA.         1.3        3.6        5.7        7.8        9.9       11.9
  A(I)            20.4       19.7       19.5       19.3       19.3
  V(I)            4.49       4.65       4.70       4.74       4.73

 X STA.        11.9       14.0       16.1       18.2       20.3       22.6
  A(I)            19.3       19.2       19.3       19.9       20.1
  V(I)            4.75       4.77       4.73       4.60       4.56

 X STA.        22.6       25.0       27.7       31.5       38.3       55.7
  A(I)            21.1       21.7       26.2       31.4       46.8
  V(I)            4.33       4.21       3.49       2.91       1.96
1
```

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      240     16500      0     68                            0
   497.13           240     16500      0     68  1.00      0     25        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.13    -0.1    25.4   239.6   16500.    2160.   9.02

 X STA.        -0.1        2.5        3.9        5.2        6.4        7.6
  A(I)             21.5       13.8       11.8       11.3       11.1
  V(I)             5.03       7.81       9.14       9.53       9.69

 X STA.         7.6        8.8       10.0       11.1       12.1       13.1
  A(I)             10.8       10.6       10.5       10.1       10.0
  V(I)             9.96      10.22      10.26      10.70      10.80

 X STA.        13.1       14.1       15.1       16.0       17.0       18.0
  A(I)              9.9       10.0        9.8       10.0       10.3
  V(I)            10.88      10.81      11.01      10.78      10.52

 X STA.        18.0       19.0       20.1       21.3       22.7       25.4
  A(I)             10.5       10.8       12.0       13.2       21.5
  V(I)            10.27      10.03       9.03       8.21       5.02

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      44.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      591     53401     63     68                        10297
             2       76      3509     18     20                          888
   498.86           668     56910     81     87  1.07    -21     59    10514

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      44.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.86   -21.6    59.3   667.6   56910.    2160.   3.24

 X STA.       -21.6      -10.6       -6.8       -3.8       -1.0        1.6
  A(I)             55.9       38.4       32.3       31.2       29.2
  V(I)             1.93       2.81       3.35       3.47       3.70

 X STA.         1.6        4.0        6.4        8.7       10.9       13.2
  A(I)             28.1       28.1       27.2       27.0       26.9
  V(I)             3.84       3.84       3.96       4.00       4.01

 X STA.        13.2       15.5       17.8       20.1       22.5       25.0
  A(I)             26.9       26.8       27.0       27.4       28.2
  V(I)             4.01       4.03       4.00       3.94       3.84

 X STA.        25.0       27.8       31.5       36.6       43.1       59.3
  A(I)             29.2       34.6       37.2       41.3       64.8
  V(I)             3.70       3.12       2.91       2.62       1.67
1
  EX
```

WSPRO OUTPUT FILE (continued)

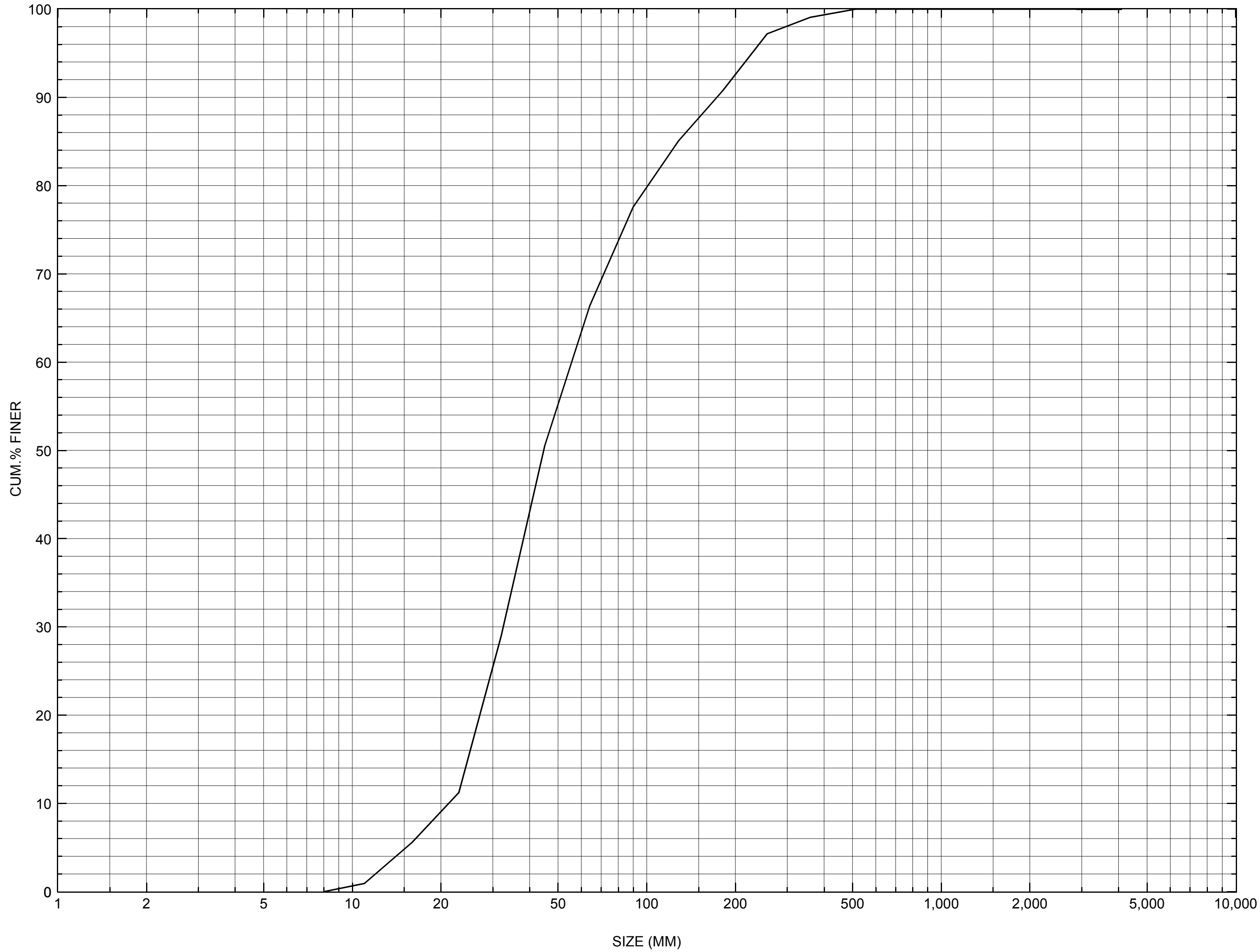
```
+++ BEGINNING PROFILE CALCULATIONS --   2

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

EXITX:XS   ******     -7      236  0.96 *****  495.49  491.80    1830  494.53
       -26 ******     32    18295  1.03 ***** *******    0.57    7.74

FULLV:FV       27     -7      251  0.86  0.25  495.74 *******    1830  494.88
         0     27     33    19781  1.04  0.00    0.01    0.53    7.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.49

APPRO:AS       44    -17      423  0.31  0.25  495.99 *******    1830  495.68
        44     44     55    29459  1.06  0.00    0.00    0.33    4.33
         <<<<<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       27      0      165  1.92  0.37  496.03  493.00    1830  494.12
         0     27     25    13254  1.00  0.17    0.00    0.76   11.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.11 ****** ****** ******

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

APPRO:AS       22    -18      474  0.25  0.17  496.62  491.66    1830  496.37
        44     24     56    34740  1.06  0.42    0.01    0.28    3.86

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.654  0.378   21570.    -2.    23.   496.31

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD     LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.     -8.    32.   1830.   18295.     236.    7.74  494.53
   FULLV:FV       0.     -8.    33.   1830.   19781.     251.    7.30  494.88
   BRIDG:BR       0.      0.    25.   1830.   13254.     165.   11.11  494.12
   APPRO:AS      44.    -19.    56.   1830.   34740.     474.    3.86  496.37

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    23.   21570.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.80     0.57  485.13  498.79************  0.96  495.49  494.53
   FULLV:FV  ********     0.53  485.13  498.79  0.25  0.00  0.86  495.74  494.88
   BRIDG:BR    493.00     0.76  486.61  497.13  0.37  0.17  1.92  496.03  494.12
   APPRO:AS    491.66     0.28  487.02  502.73  0.17  0.42  0.25  496.62  496.37
```

WSPRO OUTPUT FILE (continued)

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

EXITX:XS   ******     -8      268  1.06 *****  496.35  492.44    2160  495.30
       -26 ******     33    21599  1.05 ***** *******    0.57    8.07

FULLV:FV       27     -8      283  0.95  0.25  496.61 *******    2160  495.66
         0     27     34    23256  1.05  0.00    0.01    0.54    7.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.55

APPRO:AS       44    -18      485  0.33  0.25  496.85 *******    2160  496.53
        44     44     56    35959  1.06  0.00    0.00    0.32    4.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.75     497.16     497.33     497.11

 ===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       27      0      240  1.23 *****  498.36  493.60    2130  497.13
         0 ******     25    16500  1.00 ***** *******    0.51    8.89

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.435 ******  497.11 ****** ****** ******

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

APPRO:AS       22    -21      668  0.17  0.12  499.04  492.19    2160  498.86
        44     24     59    56956  1.07  0.45   -0.01    0.21    3.23

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.83

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.    -9.    33.   2160.   21599.     268.    8.07  495.30
   FULLV:FV       0.    -9.    34.   2160.   23256.     283.    7.63  495.66
   BRIDG:BR       0.     0.    25.   2130.   16500.     240.    8.89  497.13
   APPRO:AS      44.   -22.    59.   2160.   56956.     668.    3.23  498.86

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.44    0.57  485.13  498.79************  1.06  496.35  495.30
   FULLV:FV  ********    0.54  485.13  498.79  0.25  0.00  0.95  496.61  495.66
   BRIDG:BR    493.60    0.51  486.61  497.13************  1.23  498.36  497.13
   APPRO:AS    492.19    0.21  487.02  502.73  0.12  0.45  0.17  499.04  498.86
  ER
1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect at the approach cross-section for structure CRAFTH00550029, in Craftsbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CRAFTH00550029

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 04 / 94

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 16300

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

Waterway *(I - 6)* BLACK RIVER

Road Name *(I - 7):* -

Route Number TH055

Vicinity *(I - 9)* 0.03 MI TO JCT W CL2 TH4

Topographic Map Craftsbury

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44382

Longitude *(i - 17; nnnnn.n)* 72222

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100600291006

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

Maximum span length *(I - 48; nnnn)* 0028

Year built *(I - 27; YYYY)* 1925

Structure length *(I - 49; nnnnnn)* 000032

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

Deck Width *(I - 52; nn.n)* 151

Year of ADT *(I - 30; YY)* 91

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

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

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

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

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*) -

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

Vertical clearance from streambed (*nnn.n ft*) 010.5

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

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

Comments:

Structural inspection of 07/22/93 indicated the ambient water surface velocity was 2 ft/s. The structure is a steel stringer type bridge with a timber deck. Deep spalling was noted along the bottom right abutment and random spalling on wingwalls. Footings of the abutments and wingwalls were indicated as boulders and/or bedrock. The report also indicates the protection at this site is the bedrock or native boulder material in good condition on the banks and abutments. There is a sharp channel bend into the bridge and a small silt point bar along the left abutment. Roadway embankment erosion is noted as minor and there is no channel scour.

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: STONES, BOULDERS AND SAND

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)* : LIGHT Debris *(Heavy, Moderate, Light)*: MOD-HEAV

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} (*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)* 24.7 mi^2 Lake and pond area .79 mi^2
Watershed storage *(ST)* 3.2 %
Bridge site elevation 900 ft Headwater elevation 1988 ft
Main channel length 10.25 mi
10% channel length elevation 965 ft 85% channel length elevation 1535 ft
Main channel slope *(S)* 74 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:

-

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:

-

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 cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 02/12/96
Computerized by: CG Date: 02/12/96
Reviewd by: EMB Date: 04/15/96

Structure Number CRAFTH00550029

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. Degnan Date *(MM/DD/YY)* 06 / 07 / 1995

2. Highway District Number 09 Mile marker 0

County Orleans (019) Town Craftsbury (16300)

Waterway *(I - 6)* Black River Road Name -

Route Number TH 055 Hydrologic Unit Code: 01110000

3. Descriptive comments:

This is a wooden bridge going to a town highway garage. The frame consists of 4 steel I-beams supporting a wooden deck. It is 0.03 Mi to the junction with CL 2 TH 4.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 5 RBDS 5 Overall 6

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 2 UB 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 32 *(feet)* Span length 28 *(feet)* Bridge width 15.1 *(feet)*

Road approach to bridge:

8. LB 1 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 0.0:1 US right 0.0:1

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

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

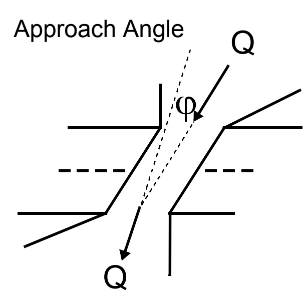
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

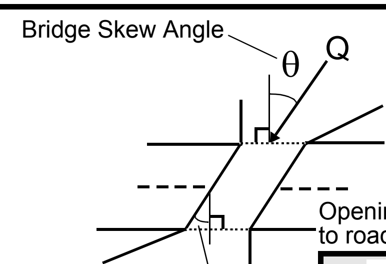
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 45 16. Bridge skew: 40





Opening skew to roadway
α= 10.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 3
Range? 15 feet DS *(US, UB, DS)* to 40 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. Level II Bridge Type: **1a**

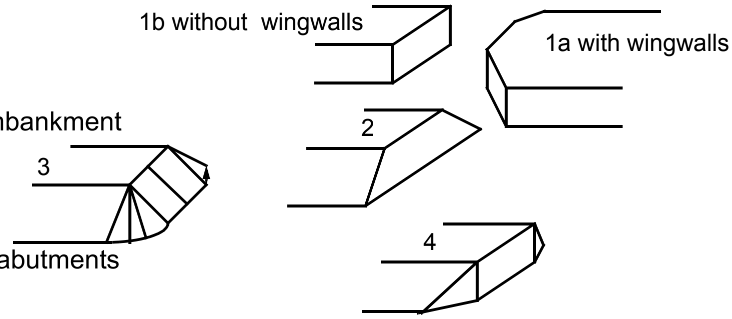
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The upstream banks are forested, but beyond in the overbank area there are a few barns and parking lots. This is probably much higher than high water, but the parking lot on the left bank is about low steel level.
7. measured bridge length = 31 feet, measured span length = 26 feet, measured bridge width = 15 feet
The span length is measured from abutment to abutment. The width is from curb to curb.
11-17. The right bank doesn't appear to have artificial protection on much of its impact zone except upstream, but bedrock extends from 10 feet upstream to as far as you can see downstream. This bedrock provides excellent natural protection.

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
36.0	**5.0**			**3.5**	**2**	**3**	**35**	**54**	**1**	**2**

23. Bank width **30.0** 24. Channel width **30.0** 25. Thalweg depth **49.5** 29. Bed Material **543**

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

Two minor inflows occur at 15 feet and 35 feet upstream on the right bank. They have a steep gradient and only the 35 feet upstream inflow in currently flowing.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **20** 35. Mid-bar width: **2**

36. Point bar extent: **0** feet **US** *(US, UB)* to **40** feet **US** *(US, UB, DS)* positioned **0** %LB to **5** %RB

37. Material: **34**

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

The point bar is very narrow.

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? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **35'**

47. Scour dimensions: Length **10'** Width **10'** Depth : **1'** Position **90** %LB to **100** %RB

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

This could be related to the minor inflow which enters here.

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
35.5		**1.0**		**2**	**7**	**7**	**1**

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

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

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

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

523

Abutments are poured over large boulders. The left bank abutment has been refaced and currently has no footing. The bottom of the old face upstream wingwall has been damaged; large chunks are missing. The right abutment has a footing and hasn't been refaced. Most of the footing on the upstream side has fallen into the channel.

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

70. Debris and Ice Comments:

1

Ice scars are seen on the right side on the abutment face and on trees about 4.5 feet above present water level.

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	2	1	0	-	90.0
RABUT	1	45	90			0	2	25.0

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.):

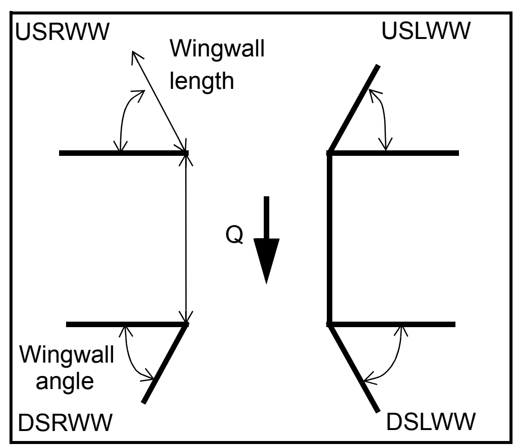
1'
2
1

The right abutment footing is eroded and undermined in some places.
The left abutments has no footing, but is scoured out on the upstream end where no rock is under it. It's at the present water level though and is only one inch in depth.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						25.0	
USRWW:	Y		1		1	1.5	
DSLWW:	0		0		Y	18.5	
DSRWW:	1		1		0	19.0	

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	0	1	Y	0	-	-	-	-
Condition	Y	0	1	0	-	-	-	-
Extent	1	0	1	0	0	0	0	0

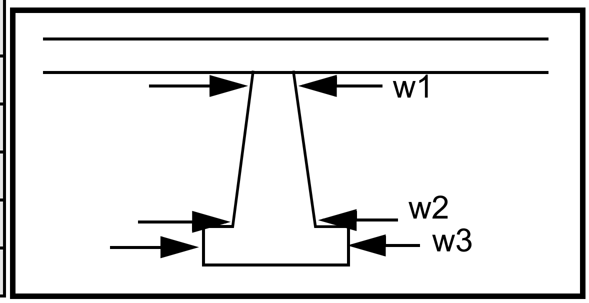
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
0
-
-
0
-
-
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	11.0	25.0
Pier 2	5.5			5.0	14.5	55.0
Pier 3		-	-	16.5	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	betw	der	been	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	wing	een	it sits	erod	**1**- Solid pier, **2**- column, **3**- bent
88. Material	walls	the	on.	ed,	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	have	upst	The	but	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	no	ream	upst	it is	Y- yes; N- no
91. Attack ∠ (BF)	foot-	right	ream	pres-	
92. Pushed	ings.	wing	left	ently	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	Ther	wall	wing	abov	
95. Cross-members	e is a	and	wall	e	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	one	the	con-	wate	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	inch	large	crete	r	
98. Exposure depth	gap	boul-	has	level.	

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

The downstream wingwall are eroded slightly. The cement face has cleaved off near the bottom of the wing-wall.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -____

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length 1_____ Width 53_____ Depth: 5_____ Positioned 0____ %LB to 0____ %RB

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

52
0
0
-

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

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

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

Confluence comments (eg. confluence name):

nstream left wingwall is gravel; the bouldrs are about 20 feet downstream near the cross section.

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

-

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: CRAFTH00550029 Town: CRAFTSBURY
Road Number: TH 55 County: ORLEANS
Stream: BLACK RIVER

Initials EMB Date: 3/20/96 Checked: Date:

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	1830	2160	0
Main Channel Area, ft2	438	591	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	36	76	0
Top width main channel, ft	60.4	62.8	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	14.5	18.1	0
D50 of channel, ft	0.147	0.147	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	7.3	9.4	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	2.5	4.2	ERR
Total conveyance, approach	34386	55238	0
Conveyance, main channel	33250	51927	0
Conveyance, LOB	0	0	0
Conveyance, ROB	1137	3311	0
Percent discrepancy, conveyance	-0.00291	0	ERR
Qm, discharge, MC, cfs	1769.543	2030.528	ERR
Ql, discharge, LOB, cfs	0	0	ERR
Qr, discharge, ROB, cfs	60.51038	129.4717	ERR
Vm, mean velocity MC, ft/s	4.0	3.4	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.7	1.7	ERR
Vc-m, crit. velocity, MC, ft/s	8.2	8.6	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	438	591	0
Main channel width, ft	60.4	62.8	0
y1, main channel depth, ft	7.251656	9.410828	ERR

Bridge Section

(Q) total discharge, cfs	1830	2160	0
(Q) discharge thru bridge, cfs	1830	2143	
Main channel conveyance	13267	16500	
Total conveyance	13267	16500	
Q2, bridge MC discharge,cfs	1830	2143	ERR
Main channel area, ft2	165	240	0
Main channel width (skewed), ft	24.7	24.9	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.7	24.9	0
y_bridge (avg. depth at br.), ft	6.676113	9.62249	ERR
Dm, median (1.25*D50), ft	0.18375	0.18375	0
y2, depth in contraction,ft	8.043872	9.14615	ERR
ys, scour depth (y2-ybridge), ft	1.37	-0.48	N/A
ys, scour depth (y2-y1), ft	0.79	-0.26	N/A
ys, scour depth (y2-yfullv), ft		1.05	

ARMORING

D90	0.568	0.568	
D95	0.746	0.746	
Critical grain size,Dc, ft	0.503669	0.283872	ERR
Decimal-percent coarser than Dc	0.12	0.237	
Depth to armoring,ft	11.08071	2.741699	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	0	2160	0
Vc, critical velocity, ft/s	0	8.6	0
Vc, critical velocity, m/s	0	2.621152	0
Main channel width (skewed), ft	0	25.1	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	25.1	0
qbr, unit discharge, ft^2/s	ERR	86.05578	ERR
qbr, unit discharge, m^2/s	N/A	7.994063	N/A
Area of full opening, ft^2	0	239.6	0
Hb, depth of full opening, ft	ERR	9.545817	ERR
Hb, depth of full opening, m	N/A	2.909423	N/A
Fr, Froude number MC	1	0.51	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
Elevation of Low Steel, ft	0	497.11	0
Elevation of Bed, ft	N/A	487.5642	N/A
Elevation of approach WS, ft	0	498.86	0
HF, bridge to approach, ft	0	0.12	0
Elevation of WS immediately US, ft	0	498.74	0
ya, depth immediately US, ft	N/A	11.17582	N/A
ya, depth immediately US, m	N/A	3.472908	N/A
Mean elev. of deck, ft	0	499.63	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.961508	ERR
Ys, depth of scour (chang), ft	N/A	0.86126	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1830	2160	0	1870	2160	0
a', abut.length blocking flow, ft	19.2	21.5	0	30.8	34.2	0
Ae, area of blocked flow ft2	117.8	167.9	0	127	206.1	0
Qe, discharge blocked abut.,cfs	401.8	469.4	0	369.8	536.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.410866	2.795712	ERR	2.911811	2.601164	ERR
ya, depth of f/p flow, ft	6.14	7.81	ERR	4.12	6.03	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	0	100	100	0
K2	0.984805	0.984805	0	1.013791	1.013791	0
Fr, froude number f/p flow	0.24	0.18	ERR	0.25	0.19	ERR
ys, scour depth, ft	13.88	15.49	N/A	12.11	14.65	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	19.2	21.5	0	30.8	34.2	0
y1 (depth f/p flow, ft)	6.14	7.81	ERR	4.12	6.03	ERR
a'/y1	3.13	2.75	ERR	7.47	5.68	ERR
Skew correction (p. 49, fig. 16)	0.96	0.96	0.96	1.02	1.02	1.02
Froude no. f/p flow	0.24	0.18	N/A	0.25	0.19	N/A
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	Qother			
Fr, Froude Number	0.76	0.51		0.76	0.51	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.7	9.6		6.8	9.6	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	2.39	1.54	0.00	2.43	1.54	0
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR