LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (CRAFTH00220025) on TOWN HIGHWAY 22, crossing the WILD BRANCH LAMOILLE RIVER, CRAFTSBURY, VERMONT

U.S. Geological Survey
Open-File Report 96-312

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
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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

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INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CRAFTH00220025 on town highway 22 crossing the Wild Branch Lamoille 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). A Level I study is included in Appendix E of this report. A Level I study 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 can be found in Appendix D.

The site is in the New England Upland physiographic province of north-central Vermont in the town of Bridgewater. The 9.52-mi^2 drainage area is in a predominantly rural basin with some pasture on the valley bottom. In the vicinity of the study site, the banks have less than 25% woody vegetation coverage.

In the study area, the Wild Branch Lamoille River has a meandering channel in a low relief valley setting with wide flood plains and a slope of approximately 0.0044 ft/ft, an average channel top width of 35 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel (D_{50} is 38.6 mm or 0.127 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 9, 1994, indicated that the reach was laterally unstable.

The town highway 22 crossing of the Wild Branch Lamoille River is a 31-ft-long, two-lane bridge consisting of one 29-foot span concrete slab superstructure (Vermont Agency of Transportation, written commun., August 4, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening and the opening-skew-to-roadway is 20 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the left bank side of the channel upstream during the Level I assessment. There are tall, steep stone fill embankments (artificial levees) that make up both banks between 50 feet upstream and the upstream face of the bridge, which straighten and constrict the channel. Type-2 stone fill (less than 36 inches diameter) is reported on the banks upstream, the upstream wingwalls, the abutments, 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 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 0.0 to 2.5 ft. The worst-case contraction scour occurred at the incipient overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 4.7 to 8.6 ft. The worst-case abutment scour also occurred at the incipient overtopping 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). Many factors, including historical performance during flood events, the geomorphic assessment, scour protection, and the results of the hydraulic analyses, must be considered to properly assess the validity of abutment scour results. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein, based on the consideration of additional contributing factors and experienced engineering judgement.

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 CRAFTH00220025 **_Stream_** Wild Branch Lamoille River

County Orleans **_Road_** TH 22 **_District_** 09

Description of Bridge

Bridge length 31 **_ft_** **_Bridge width_** 25.3 **_ft_** **_Max span length_** 29 **_ft_**

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

Abutment type Vertical **_Embankment type_** Sloping

Stone fill on abutment? Yes **_Date of inspection_** 11/09/94

Description of stone fill Type-2, on the upstream banks, the upstream wingwalls, the abutments, the downstream left wingwall, and the downstream left bank.

Abutments and wingwalls are concrete.

Y 20

Is bridge skewed to flood flow according to Y **_survey?_** **_Angle_**

There is a mild channel bend in the upstream reach. A scour hole has developed along the left bank side of the channel.

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	11/09/94	0	0
Level II	11/09/94	--	--

Potential for debris High. There are some piles of tree debris along the right side of the channel upstream. The channel is laterally unstable with bank failure.

Describe any features near or at the bridge that may affect flow (include observation date) On 11/09/94, tall, steep embankments were noted lining the channel upstream, which will impede overbank flow returning to the main channel during floods.

Description of the Geomorphic Setting

General topography

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

Date of inspection

DS left:

DS right:

US left:

US right:

Description of the Channel

Average top width ft *Average depth* ft

Predominant bed material *Bank material*

Vegetative co

DS left:

DS right:

US left:

US right:

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

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 9.52 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
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? No

-

USGS gage description -

USGS gage number -

Gage drainage area ***mi²***

Is there a lake/ - No.

Calculated Discharges

Q100 2000 ***ft³/s*** ***Q500*** 2400 ***ft³/s***

The 100-year discharge is based on flood frequency estimates from the VTAOT database (Written communication, VTAOT, May 4, 1995) and several empirical relationships (Potter, 1957a&b; Johnson and Tasker, 1974; Benson, 1962; Talbot, 1887). The 500-year discharge is based on the extrapolated flood frequency curve from each empirical method applied for the 100-year discharge.

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 Add 987 feet to the USGS survey to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a brass VT Survey Mark on top of the US end of the left abutment (elev. 100.11 ft, arbitrary datum). RM2 is a chiseled square on top of the DS end of the right abutment (elev. 100.27 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-44	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	55	2	Modelled Approach section (Templated from APTEM)
APTEM	71	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 analysis 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, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.040, and overbank "n" values ranged from 0.035 to 0.055.

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 0.0044 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.003 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.

For the incipient roadway-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. Analyzing both the supercritical and subcritical profile, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge section is a satifactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 100.4 *ft*
Average low steel elevation 98.8 *ft*

100-year discharge 2,000 *ft³/s*
Water-surface elevation in bridge opening 98.8 *ft*
Road overtopping? Y *Discharge over road* 591 *ft³/s*
Area of flow in bridge opening 209 *ft²*
Average velocity in bridge opening 6.6 *ft/s*
Maximum WSPRO tube velocity at bridge 9.1 *ft/s*

Water-surface elevation at Approach section with bridge 99.6 *ft*
Water-surface elevation at Approach section without bridge 96.1 *ft*
Amount of backwater caused by bridge 3.5 *ft*

500-year discharge 2,400 *ft³/s*
Water-surface elevation in bridge opening 98.8 *ft*
Road overtopping? Y *Discharge over road* 847 *ft³/s*
Area of flow in bridge opening 209 *ft²*
Average velocity in bridge opening 7.3 *ft/s*
Maximum WSPRO tube velocity at bridge 10.2 *ft/s*

Water-surface elevation at Approach section with bridge 99.8 *ft*
Water-surface elevation at Approach section without bridge 98.2 *ft*
Amount of backwater caused by bridge 1.6 *ft*

Incipient overtopping discharge 1714 *ft³/s*
Water-surface elevation in bridge opening 95.8 *ft*
Area of flow in bridge opening 133 *ft²*
Average velocity in bridge opening 12.9 *ft/s*
Maximum WSPRO tube velocity at bridge 16.3 *ft/s*

Water-surface elevation at Approach section with bridge 98.3 *ft*
Water-surface elevation at Approach section without bridge 95.5 *ft*
Amount of backwater caused by bridge 2.8 *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. Because the computed total scour depths for the 500-year discharge were less than those for the 100-year discharge, only the 100-year total scour depths at the bridge are presented in figure 8.

The 100-year and 500-year discharges 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). Therfore, contraction scour for the 100-year and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The results of Laursen's clear-water contraction scour for these two events were also computed and can be found in appendix F. Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the incipient road-overflow discharge. 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. In this case, the incipient road-overflow model resulted in the worst-case contraction scour and total scour with depths of 2.5 ft. and 11.1 feet respectively.

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

Scour for both abutments at the 100- and 500-year discharges were computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	2.5
Depth to armoring	0.4	0.9	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	5.7	5.2	8.6
Right abutment	6.0	4.7	6.6
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	0.9	1.1	2.1
Right abutment	0.9	1.1	2.1
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

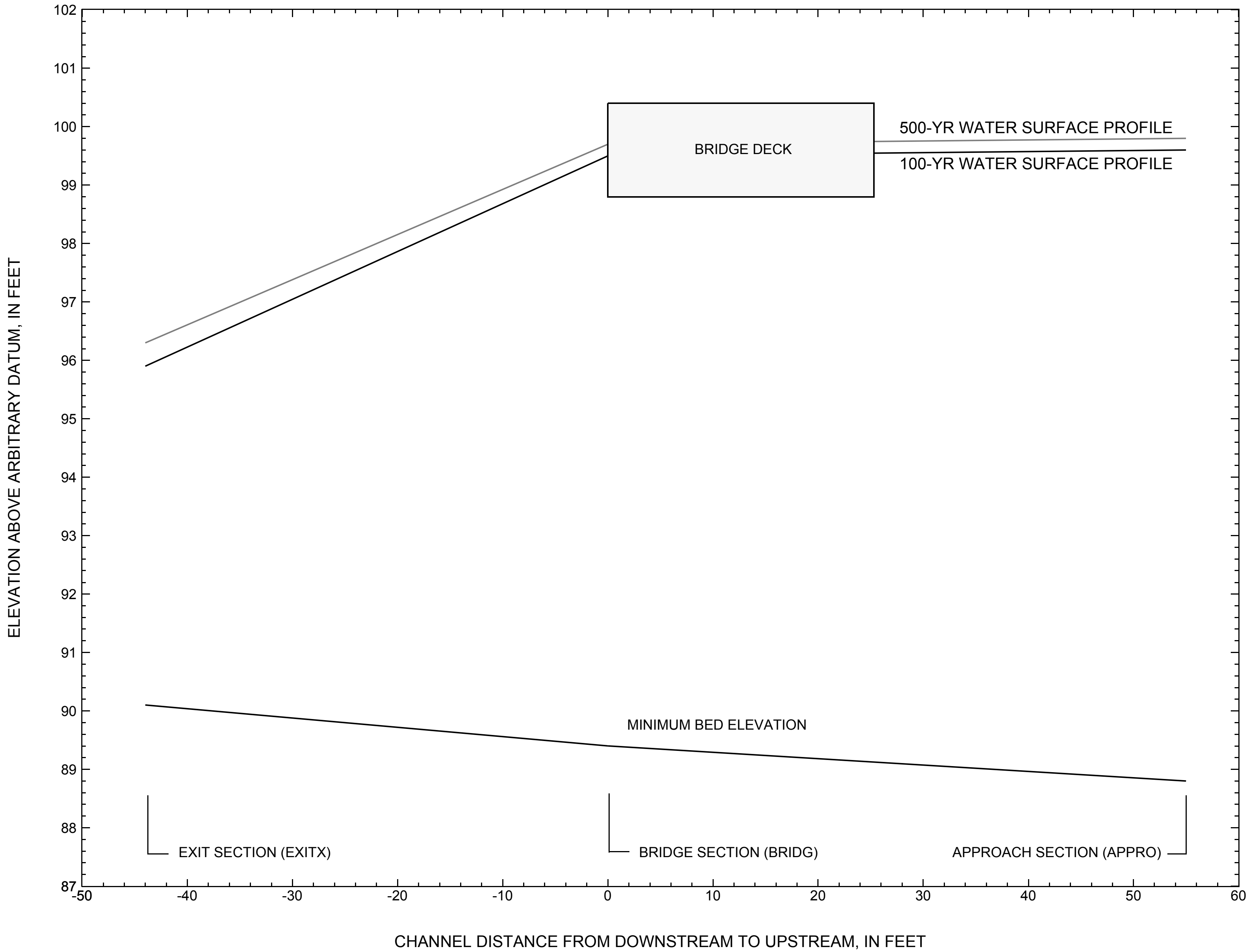

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CRAFTH00220025 on town highway 22, crossing the Wild Branch Lamoille River, Craftsbury, Vermont.

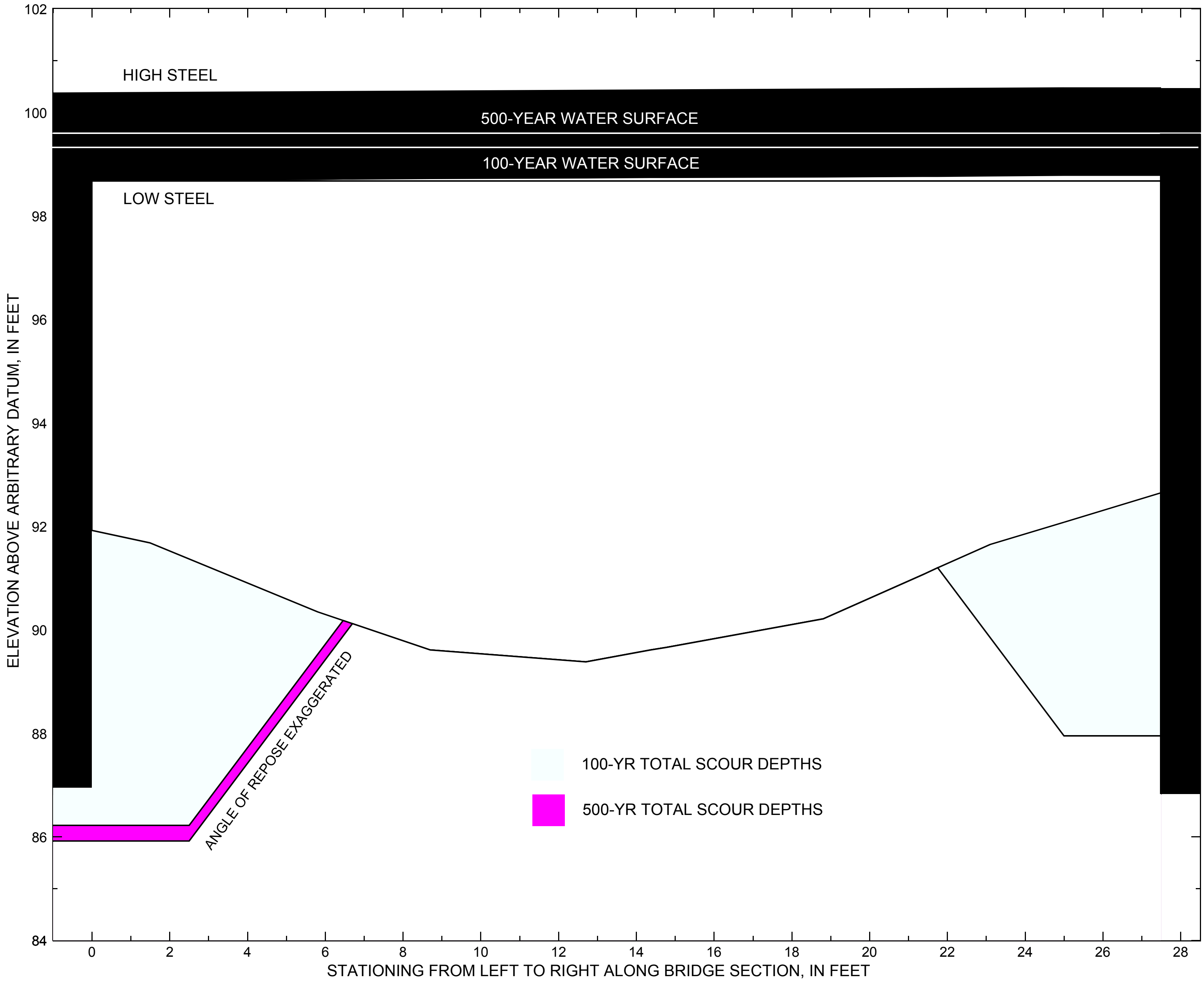

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CRAFTH00220025 on town highway 22, crossing the Wild Branch Lamoille River, Craftsbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CRAFTH00220025 on Town Highway 22, crossing Wild Branch Lamoille 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 2,000 cubic-feet per second											
Left abutment	0.0	1085.	98.6	87.	91.9	0.0	5.7	--	5.7	86.2	-1
Right abutment	27.5	1086.	98.9	87.	92.6	0.0	5.2	--	5.2	87.4	0

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CRAFTH00220025 on Town Highway 22, crossing Wild Branch Lamoille 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 2,400 cubic-feet per second											
Left abutment	0.0	1085.	98.6	87.	91.9	0.0	6.0	--	6.0	85.9	-1
Right abutment	27.5	1086.	98.9	87.	92.6	0.0	4.7	--	4.7	87.9	1

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1          U.S. Geological Survey WSPRO Input File craf025.wsp
T2          Hydraulic analysis for structure CRAFTH00220025   Date: 12-FEB-96
                                                                            MB
```

```
*
HP 1 BRIDG    98.75 1  98.75
HP 2 BRIDG    98.75 * * 1372
HP 2 RDWAY    99.47 * *  591
HP 1 APPRO    99.58 1  99.58
HP 2 APPRO    99.58 * * 2000
*
*
HP 1 BRIDG    98.75 1  98.75
HP 2 BRIDG    98.75 * * 1537
HP 2 RDWAY    99.70 * *  847
HP 1 APPRO    99.84 1  99.84
HP 2 APPRO    99.84 * * 2400
*
HP 1 BRIDG    95.77 1  95.77
HP 2 BRIDG    95.77 * * 1714
HP 1 APPRO    98.31 1  98.31
HP 2 APPRO    98.31 * * 1714
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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

  WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW     REW      OCR
```

```
V(I)            4.71       4.61       4.27       3.47       2.16
```

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

 WSEL  SA#     AREA          K    TOPW   WETP  ALPH     LEW     REW       OCR
```

WSPRO OUTPUT FILE (continued)

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      133     14165     26     34                         1711
    95.77           133     14165     26     34  1.00      0     28     1711

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

         WSEL     LEW     REW    AREA        K        Q    VEL
        95.77     0.0    27.5   132.9   14165.    1714.  12.89

X STA.         0.0        3.0        4.7        6.1        7.3        8.4
  A(I)             11.9        7.7        6.9        6.2        5.9
  V(I)             7.23      11.06      12.44      13.72      14.45

X STA.         8.4        9.3       10.3       11.2       12.1       13.0
  A(I)              5.6        5.5        5.5        5.3        5.3
  V(I)            15.25      15.65      15.68      16.29      16.18

X STA.        13.0       13.9       14.8       15.8       16.8       17.9
  A(I)              5.4        5.4        5.5        5.7        5.8
  V(I)            15.92      15.74      15.59      15.16      14.74

X STA.        17.9       19.0       20.4       21.9       24.0       27.5
  A(I)              6.1        6.6        6.9        8.1       11.6
  V(I)            14.00      13.04      12.43      10.54       7.36

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      154      6042    173    173                          822
             2      250     27932     43     48                         3421
    98.31           404     33974    216    221  1.49   -189     32     2571

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
        98.31  -190.0    31.9   403.8   33974.    1714.   4.24

X STA.      -190.0     -149.6     -110.1      -67.5       -2.1        1.0
  A(I)             40.0       40.1       41.2       51.8       19.6
  V(I)             2.14       2.14       2.08       1.66       4.37

X STA.         1.0        3.0        4.5        6.0        7.3        8.5
  A(I)             15.5       13.5       13.0       12.2       12.0
  V(I)             5.52       6.32       6.61       7.05       7.14

X STA.         8.5        9.8       11.1       12.4       13.7       15.1
  A(I)             11.8       11.6       12.0       12.2       12.2
  V(I)             7.28       7.38       7.15       7.05       7.02

X STA.        15.1       16.6       18.2       20.0       22.6       31.9
  A(I)             12.8       13.4       15.0       17.3       26.7
  V(I)             6.70       6.39       5.73       4.95       3.21
  EX
+++ BEGINNING PROFILE CALCULATIONS --   3

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

EXITX:XS   ******    -48      355  0.63 *****   96.57   95.23    2000   95.94
       -43 ******     76    30143  1.28 ***** *******    0.67    5.63

FULLV:FV       44    -49      369  0.58  0.18   96.76 *******    2000   96.18
         0     44     77    31774  1.27  0.00    0.01    0.63    5.42
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    95.68     111.98    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    95.68     111.98      96.06

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                  WSBEG,WSEND,CRWS =    96.06     111.98      96.06
```

WSPRO OUTPUT FILE (continued)

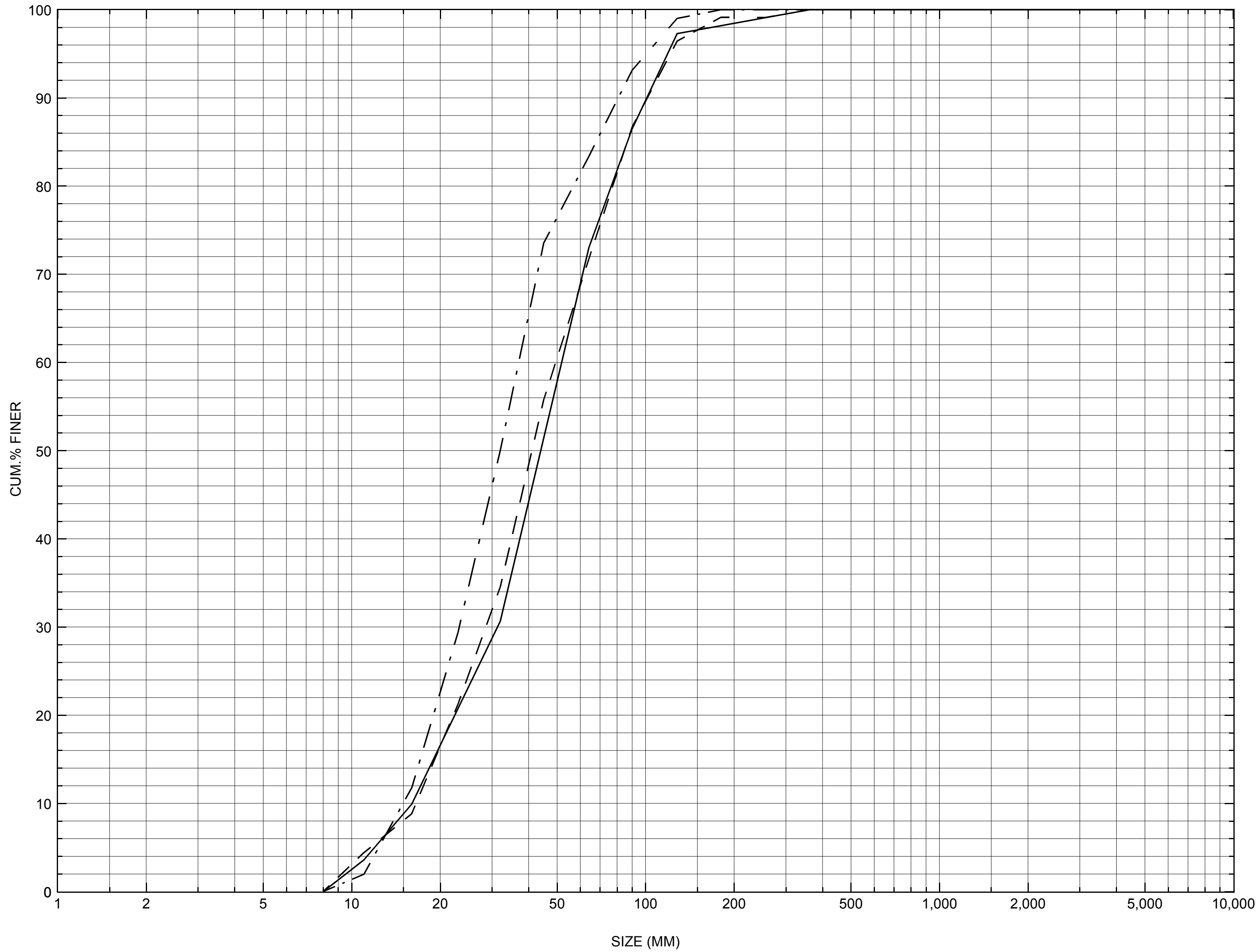
```
APPRO:AS       55     -5      163  2.34 *****   98.40   96.06    2000   96.06
        55     55     28    15880  1.00 ***** *******    1.00   12.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =    99.66       0.00      96.33      98.24

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   100.87         1.      1999.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===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       44      0      209  0.67 *****   99.42   95.06    1372   98.75
         0 ******     28    22627  1.00 ***** *******    0.42    6.55

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.374  0.000   98.75 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    30.  0.03  0.16   99.71   -0.02    591.   99.47

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    591.   172.  -205.   -32.   1.2   0.9   4.6   3.9   1.1   2.9
   RT:      0.   238.    13.   251.   1.0   0.9   5.4   6.2   1.5   2.9

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

APPRO:AS       17   -195      696  0.16  0.03   99.74   96.06    2000   99.58
        55     18     58    64758  1.28  0.00   -0.02    0.35    2.87

       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     -44.   -49.    76.   2000.   30143.     355.    5.63   95.94
   FULLV:FV       0.   -50.    77.   2000.   31774.     369.    5.42   96.18
   BRIDG:BR       0.     0.    28.   1372.   22627.     209.    6.55   98.75
   RDWAY:RG      15.*******   591.    591.*********       0.    2.00   99.47
   APPRO:AS      55.  -196.    58.   2000.   64758.     696.    2.87   99.58

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     95.23    0.67   90.07  103.59************  0.63   96.57   95.94
   FULLV:FV  ********    0.63   90.20  103.72  0.18  0.00  0.58   96.76   96.18
   BRIDG:BR     95.06    0.42   89.38   98.86************  0.67   99.42   98.75
   RDWAY:RG  ****************   98.24  112.03  0.03******  0.16   99.71   99.47
   APPRO:AS     96.06    0.35   88.76  111.98  0.03  0.00  0.16   99.74   99.58

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

EXITX:XS   ******    -52      412  0.68 *****   97.02   95.57    2400   96.34
       -43 ******    209    36147  1.29 ***** *******    0.93    5.82

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85      96.59      95.70
```

```
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    95.84     103.72    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    95.84     103.72      95.70

FULLV:FV       44    -53      448  0.61  0.18   97.21   95.70    2400   96.61
         0     44    211    38678  1.36  0.00    0.01    0.84    5.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    96.11     111.98    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    96.11     111.98      98.19

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =     98.19     111.98      98.19

APPRO:AS       55   -188      378  0.93 *****   99.12   98.19    2400   98.19
        55     55     32    32023  1.48 ***** *******    1.02    6.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   100.83       0.00      97.07      98.24

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   100.98         0.      2400.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===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       44      0      209  0.84 *****   99.59   95.42    1537   98.75
         0 ******     28    22627  1.00 ***** *******    0.47    7.34

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.408  0.000    98.75 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    30.  0.03  0.19  100.00   -0.01    847.   99.70

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    847.   183.  -206.   -23.   1.5   1.1   5.2   4.4   1.3   3.0
   RT:      0.   238.    13.   251.   1.1   0.9   5.5   6.3   1.5   2.9


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

APPRO:AS       17   -196      763  0.19  0.06  100.03   98.19    2400   99.84
        55     25     71    72925  1.26  0.00   -0.01    0.37    3.14

       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     -44.   -53.   209.   2400.   36147.     412.    5.82   96.34
   FULLV:FV       0.   -54.   211.   2400.   38678.     448.    5.35   96.61
   BRIDG:BR       0.     0.    28.   1537.   22627.     209.    7.34   98.75
   RDWAY:RG      15.*******   847.    847.*********       0.    2.00   99.70
   APPRO:AS      55.  -197.    71.   2400.   72925.     763.    3.14   99.84

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

```
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     95.57    0.93   90.07  103.59************  0.68   97.02   96.34
   FULLV:FV     95.70    0.84   90.20  103.72  0.18  0.00  0.61   97.21   96.61
   BRIDG:BR     95.42    0.47   89.38   98.86************  0.84   99.59   98.75
   RDWAY:RG  ****************   98.24  112.03  0.03******  0.19  100.00   99.70
   APPRO:AS     98.19    0.37   88.76  111.98  0.06  0.00  0.19  100.03   99.84

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

EXITX:XS   ******    -46      316  0.59 *****   96.21   94.97    1714   95.62
       -43 ******     75    25819  1.30 ***** *******    0.68    5.43

FULLV:FV       44    -47      329  0.54  0.18   96.41 *******    1714   95.86
         0     44     75    27289  1.29  0.00    0.01    0.64    5.21
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.01      95.44      95.47

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =    95.36     111.98    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    95.36     111.98      95.47

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.49

APPRO:AS       55     -4      143  2.23  0.44   97.70   95.47    1714   95.47
        55     55     27    13403  1.00  0.84    0.01    1.00   11.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1714.      95.77

            <<<<<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       44      0      133  2.58 *****   98.35   95.77    1714   95.77
         0     44     28    14172  1.00 ***** *******    1.00   12.89

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   98.75 ****** ****** ******

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


APPRO:AS       17    -10      250  0.73  0.13   99.04   95.47    1714   98.31
        55     18     32    27911  1.00  0.55    0.01    0.50    6.85

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.149  0.000   30159.    -2.    25.    98.24

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -44.   -47.    75.   1714.   25819.     316.    5.43   95.62
   FULLV:FV       0.   -48.    75.   1714.   27289.     329.    5.21   95.86
   BRIDG:BR       0.     0.    28.   1714.   14172.     133.   12.89   95.77
   APPRO:AS      55.   -11.    32.   1714.   27911.     250.    6.85   98.31

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    25.   30159.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     94.97    0.68   90.07  103.59************  0.59   96.21   95.62
   FULLV:FV  ********    0.64   90.20  103.72  0.18  0.00  0.54   96.41   95.86
   BRIDG:BR     95.77    1.00   89.38   98.86************  2.58   98.35   95.77
   APPRO:AS     95.47    0.50   88.76  111.98  0.13  0.55  0.73   99.04   98.31
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure CRAFTH00220025, in Craftsbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CRAFTH00220025

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)* Wild Branch Lamoille River

Road Name *(I - 7):* -

Route Number TH022

Vicinity *(I - 9)* 0.1 MI TO JCT W CL3 TH21

Topographic Map Albany

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44401

Longitude *(i - 17; nnnnn.n)* 72258

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100600251006

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1989

Structure length *(I - 49; nnnnnn)* 000031

Average daily traffic, ADT *(I - 29; nnnnnn)* 000260

Deck Width *(I - 52; nn.n)* 253

Year of ADT *(I - 30; YY)* 94

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 20

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

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

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

Structure type *(I - 43; nnn)* 101

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*) 008.0

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

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

Comments:

Structural inspection report of 7/20/93 indicates a concrete slab type bridge. Abutments and wingwalls in like new condition. The footings are not exposed. No channel scour. Minor road embankment erosion on downstream right bank side. The channel proceeds straight through bridge. Good riprap coverage and no point bars were reported.

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: **Boulders, riprap, coarse gravel**

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **1050** Q_{25} -

Q_{50} - Q_{100} **2150** 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)*: **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: **Remains of old bridge structure in place upstream.**
Fish habitat stones (4 boulder cluster) in a diamond formation placed about 4 feet downstream of the bridge. Two thirds of the long dimension of each boulder is submerged into the streambed according to the plans.

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*)	-	**1084.8**	-	-	**1086.7**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -
-

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft*^{2}): -

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **9.52** mi^2 Lake and pond area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1082.7** ft Headwater elevation **2519.7** ft
Main channel length **5.65** mi
10% channel length elevation **1102.4** ft 85% channel length elevation **1870.1** ft
Main channel slope *(S)* **181.17** 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? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **05** / **1989**

Project Number **BRZ 1449(17)** Minimum channel bed elevation: **1076.0**

Low superstructure elevation: USLAB **1085.26** DSLAB **1085.16** USRAB **1085.47** DSRAB **1085.43**

Benchmark location description:

BM#1 a VTAOT bronze disk on the top of the wall where the upstream left bank wingwall and the abutment meet at an angle, elevation 1087.29. BM#2 on the face of the same wingwall 2 feet down from the top of the wall and 1 foot over from the abutment corner is a bridge marker in the shape of Vermont.

Reference Point (*MSL, Arbitrary, Other*): **Other** Datum (*NAD27, NAD83, Other*): **NGVD29**

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

If 1: Footing Thickness **2** Footing bottom elevation: **1074.0**

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:

Hydraulic data available on page 1 of bridge plans; drainage area=9.4 square miles, Q10=1050 CFS high water elevation=1084.8, Q100=2150 CFS high water elevation=1086.7. The 1989 construction is replacement of an older bridge.

Cross-sectional Data

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

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

Comments: **Upstream bridge face cross section.**

Station	**1.5**	**12**	**29.5**								
Feature	**LCL**	**TD**	**LCR**								
Low cord elevation	**1086.0**		**1085.5**								
Bed elevation	**1078.4**	**1077.5**	**1082.5**								
Low cord to bed length											

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

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

Comments: **Downstream bridge face cross section.**

Station	**1.5**	**13**	**29.5**								
Feature	**LCL**		**LCR**								
Low cord elevation	**1086.0**		**1086.0**								
Bed elevation	**1078.4**	**1078.1**	**1078.4**								
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: **DLS** Date: **2/9/95**

Computerized by: **MI** Date: **2/9/95**

Reviewd by: **EMB** Date: **3/22/96**

Structure Number **CRAFTH00220025**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **11** / **09** / 19**94**

2. Highway District Number **09** Mile marker **-**

County **ORLEANS (019)** Town **CRAFTSBURY (16300)**

Waterway *(I - 6)* **Wild Branch Lamoille River** Road Name **-**

Route Number **TH022** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

This structure is a concrete slab type bridge located about 0.1 mile from the intersection of TH22 with TH21.

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 **31.0** *(feet)* Span length **29.0** *(feet)* Bridge width **25.3** *(feet)*

Road approach to bridge:

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

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

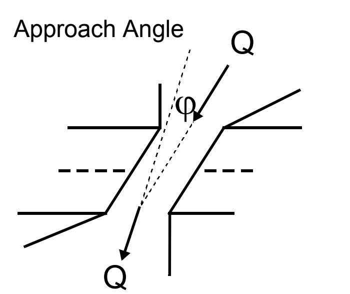
10. Embankment slope (*run / rise in feet / foot*):
US left **-:1** US right **-:1**

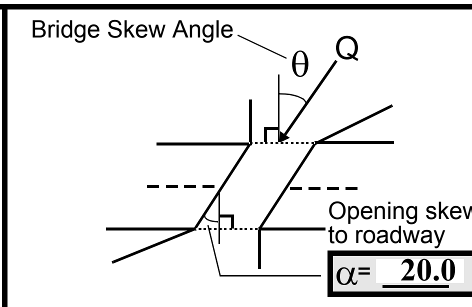
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*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: **20**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **80** feet **US** *(US, UB, DS)* to **100** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **50** feet **DS** *(US, UB, DS)* to **100** feet **DS**

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

18. Level II Bridge Type: **1A/4**

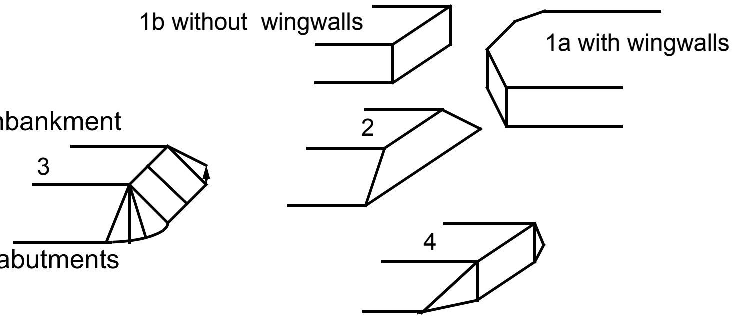
1a- Vertical abutments with wingwalls

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.)

Measurements of the bridge dimensions are 31.0 feet for the bridge length, 29.0 feet for the span length, and 25.0 feet for the roadway width. The bridge type is 1a for a water level up to about 7 feet deep above which the bridge type is 4. The surface coverage is pasture invariably. Roadway overflow is likely first over the left road approach to the bridge where the roadway width is about 26.0 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
45.1	5.0			4.5	1	1	1	1	0	0

23. Bank width **40.0** 24. Channel width **35.0** 25. Thalweg depth **29.0** 29. Bed Material **3**

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.):

The bank protection indicated extends 50 feet upstream from the upstream face of the bridge on both banks. The stone fill here protects the upstream banks where there was once another structure crossing the river apparently. The predominant bank material is composed of silt and clay over sand and gravel. The bed material is gravel mainly with some sand and cobbles embedded in the sand and gravel.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **260** 35. Mid-bar width: **100**

36. Point bar extent: **190** feet **US** (US, UB) to **400** feet **US** (US, UB, DS) positioned **0** %LB to **90** %RB

37. Material: **3**

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

The point bar is very large with an extensive cut bank equal and opposite this bar on the right bank. The point bar is composed of mainly gravel.

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

41. Mid-bank distance: **300** 42. Cut bank extent: **500** feet **US** (US, UB) to **200** feet **US** (US, UB, DS)

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

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

There is extensive erosion of the bank which has resulted in fallen trees and slumping bank material. The cut bank extends along the edge of the road embankment approaching the right side of the bridge. An additional, much smaller cut bank has developed on the left bank from about 50 to 100 feet upstream that shows some slip failure of the bank material.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **55**

47. Scour dimensions: Length **100** Width **10** Depth : **1.5** Position **5** %LB to **60** %RB

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

The channel is constricted and straightened by fill material and riprap protection on the fill placed on both banks upstream which may have caused the scouring of the bed here. The protection is extensive along both banks and prevents lateral movement of the channel as is evident further upstream.

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
21.5		3.0		2	7	7	-

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

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

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

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

3

The predominant bed material is gravel with sand and some cobbles embedded in the sand and gravel.

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

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

70. Debris and Ice Comments:

1

Debris production is likely due to active bank cutting evident on the right bank upstream with trees falling in the channel. The bridge span is about 80% of the channel width upstream and debris and ice is likely to flow through the bridge without accumulating and blocking flow.

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	-	-	90.0
RABUT	1	0	90			2	0	27.5

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

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

-

-

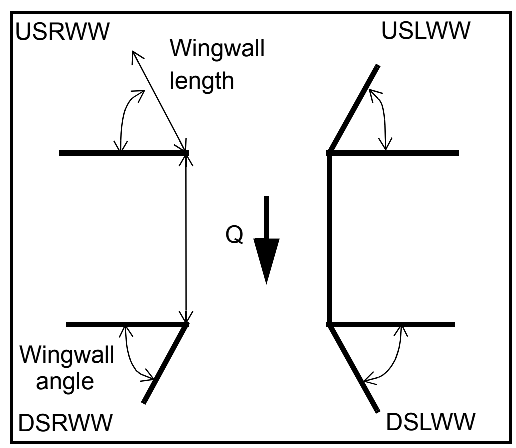
1

Both abutment walls are protected and the deepest part of the flow through the bridge is near mid-span.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						24.0	
USRWW:	Y		1		0	2.5	
DSLWW:	-		-		Y	30.5	
DSRWW:	1		0		-	31.0	

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

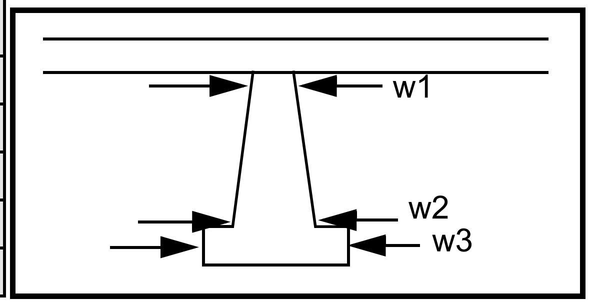
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
2
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				**50.0**	**10.0**	**20.0**
Pier 2				**14.5**	**20.0**	**15.0**
Pier 3			**-**	**50.0**	**10.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**ied**	**rial.**	**-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**entir**	**by**		**-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**e**	**the**		**-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**base**	**rip-**		**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**s of**	**rap**		**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**pro-**		**-**	
92. Pushed	**upst**	**tec-**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**ream**	**tion**		**-**	
95. Cross-members	**wing**	**over**		**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**walls**	**back**		**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**are**	**fill**		**-**	
98. Exposure depth	**bur-**	**mate**	**N**	**-**	

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 (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? N *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

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

PIERS

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

Point bar extent: ______ feet **1** *(US, UB, DS)* to **1** feet **1** *(US, UB, DS)* positioned **1** %LB to **1** %RB

Material: **2**

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

3
2
0
1

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

Cut bank extent: **bank** feet **pro** *(US, UB, DS)* to **tec-** feet **tio** *(US, UB, DS)*

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

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

extends 30 feet downstream from the downstream face of the bridge. The bank material is silt and clay predominantly overlying sand and gravel. The bed material is composed primarily of gravel with sand and cobbles embedded in the sand and gravel.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

Confluence 1: Distance **NO** Enters on **DR** *(LB or RB)* Type **OP** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

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: CRAFTH00220025 Town: Craftsbury
Road Number: TH 22 County: Orleans
Stream: Wild Branch Lamoille River

Initials EMB Date: 03/08/96 Checked: SAO Date: 3/12/96

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	2000	2400	1714
Main Channel Area, ft2	307	318	250
Left overbank area, ft2	383	431	0
Right overbank area, ft2	7	15	0
Top width main channel, ft	44.7	44.7	43.1
Top width L overbank, ft	184.3	185.5	0
Top width R overbank, ft	25.5	38	0
D50 of channel, ft	0.127	0.127	0.127
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.9	7.1	5.8
y1, average depth, LOB, ft	2.1	2.3	ERR
y1, average depth, ROB, ft	0.3	0.4	ERR
Total conveyance, approach	64850	73075	27932
Conveyance, main channel	38209	40654	27932
Conveyance, LOB	26566	32203	0
Conveyance, ROB	75	218	0
Percent discrepancy, conveyance	0	0	0
Qm, discharge, MC, cfs	1178.381	1335.198	1714
Ql, discharge, LOB, cfs	819.3061	1057.642	0
Qr, discharge, ROB, cfs	2.31303	7.159767	0
Vm, mean velocity MC, ft/s	3.8	4.2	6.9
Vl, mean velocity, LOB, ft/s	2.1	2.5	ERR
Vr, mean velocity, ROB, ft/s	0.3	0.5	ERR
Vc-m, crit. velocity, MC, ft/s	7.8	7.8	7.6
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	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	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	307	318	250
Main channel width, ft	44.7	44.7	43.1
y1, main channel depth, ft	6.868009	7.114094	5.800464

Bridge Section			
(Q) total discharge, cfs	2000	2400	1714
(Q) discharge thru bridge, cfs	1372	1537	1714
Main channel conveyance	22627	22627	14165
Total conveyance	22627	22627	14165
Q2, bridge MC discharge,cfs	1372	1537	1714
Main channel area, ft2	209	209	133
Main channel width (skewed), ft	25.8	25.8	25.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.8	25.8	25.8
y_bridge (avg. depth at br.), ft	8.112403	8.112403	5.151163
Dm, median (1.25*D50), ft	0.15875	0.15875	0.15875
y2, depth in contraction,ft	6.311992	6.957297	7.638622
ys, scour depth (y2-ybridge), ft	-1.80	-1.16	2.49
ys, scour depth (y2-y1), ft	-0.56	-0.16	1.84
ys, scour depth (y2-yfullv), ft	0.77	0.99	N/A

ARMORING			
D90	0.311	0.311	0.311
D95	0.38	0.38	0.38
Critical grain size,Dc, ft	0.130518	0.163799	0.595253
Decimal-percent coarser than Dc	0.481	0.355	N/A
Depth to armoring,ft	0.42	0.89	N/A

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	1372	1537	0
Vc, critical velocity, ft/s	7.8	7.8	0
Vc, critical velocity, m/s	2.377324	2.377324	0
Main channel width (skewed), ft	25.8	25.8	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	25.8	25.8	0
qbr, unit discharge, ft^2/s	53.17829	59.57364	ERR
qbr, unit discharge, m^2/s	4.939943	5.534032	N/A
Area of full opening, ft^2	209.3	209.3	0
Hb, depth of full opening, ft	8.112403	8.112403	ERR
Hb, depth of full opening, m	2.47254	2.47254	N/A
Fr, Froude number MC	0.42	0.47	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	98.75	98.75	0
Elevation of Bed, ft	90.6376	90.6376	N/A
Elevation of approach WS, ft	99.58	99.84	0
HF, bridge to approach, ft	0.03	0.06	0
Elevation of WS immediately US, ft	99.55	99.78	0
ya, depth immediately US, ft	8.912403	9.142403	N/A
ya, depth immediately US, m	2.769547	2.84102	N/A
Mean elev. of deck, ft	100.42	100.42	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.977146	0.970925	ERR
Ys, depth of scour (chang), ft	-1.13522	-0.24604	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	2000	2400	1714	2000	2400	1714
a', abut.length blocking flow, ft	195.9	197.1	11.2	32.8	45.3	6.1
Ae, area of blocked flow ft2	279.6	291	32.3	42.3	52.9	16
Qe, discharge blocked abut.,cfs	--	--	128.6	91.1	112.3	60.8
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	2.14	2.46	3.981424	2.153664	2.122873	3.8
ya, depth of f/p flow, ft	1.43	1.48	2.88	1.29	1.17	2.62
--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	110	110	110	70	70	70
K2	1.02643	1.02643	1.02643	0.967857	0.967857	0.967857
Fr, froude number f/p flow	0.26	0.28	0.41	0.33	0.35	0.41
ys, scour depth, ft	11.26	12.05	8.64	6.08	6.48	6.59

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)	195.9	197.1	11.2	32.8	45.3	6.1
y1 (depth f/p flow, ft)	1.43	1.48	2.88	1.29	1.17	2.62
a'/y1	137.26	133.50	3.88	25.43	38.79	2.33
Skew Correction (pg. 49, fig. 16)	1.044	1.044	1.044	0.9667	0.9667	0.9667
Froude no. f/p flow	0.26	0.28	0.41	0.33	0.35	0.41
Ys w/ corr. factor K1/0.55:						
vertical	6.90	7.34	ERR	6.32	5.79	ERR
vertical w/ ww's	5.66	6.02	ERR	5.18	4.74	ERR
spill-through	3.80	4.04	ERR	3.47	3.18	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	0.42	0.47	1	0.42	0.47	1
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.1	8.1	5.1	8.1	8.1	5.1
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.88	1.11	ERR	0.88	1.11	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.13	ERR	ERR	2.13