LEVEL II SCOUR ANALYSIS FOR BRIDGE 6 (RICHTH00030006) on TOWN HIGHWAY 3, crossing an UNNAMED TRIBUTARY TO THE MISSISQUOI RIVER, RICHFORD, VERMONT

U.S. Geological Survey
Open-File Report 96-635

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

LEVEL II SCOUR ANALYSIS FOR BRIDGE 6 (RICHTH00030006) on TOWN HIGHWAY 3, crossing an UNNAMED TRIBUTARY TO THE MISSISQUOI RIVER,

RICHFORD, VERMONT

BY ROBERT H. FLYNN AND DONALD L. SONG

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Pembroke, New Hampshire

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 6 (RICHTH00030006) ON TOWN HIGHWAY 3, CROSSING AN UNNAMED TRIBUTARY TO THE MISSISQUOI RIVER, RICHFORD, VERMONT

By **Robert H. Flynn and Donald L. Song**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RICHTH00030006 on Town Highway 3 crossing an unnamed tributary to the Missisquoi River, Richford, 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 Green Mountain section of the New England physiographic province of northern Vermont. The 4.5-mi^2 drainage area is in a predominantly rural basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge.

In the study area, the unnamed tributary to the Missisquoi River is a sinuous channel with a slope of approximately 0.008 ft/ft, an average channel top width of 39 ft and an average channel depth of 2 ft. The channel slope was obtained from a topographic map (USGS, 1986). The predominant channel bed material is gravel with a median grain size (D_{50}) of 26.2 mm (0.0861 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 28, 1995, indicated that the reach was stable.

The Town Highway 3 crossing of an unnamed tributary to the Missisquoi River is a 26-ft-long, two-lane bridge consisting of one 24-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 9, 1995). 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 0.0 degrees.

The only scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) along the upstream right wingwall and at the upstream end of the right abutment. 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 1.7 to 1.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Scour at the left abutment ranged from 7.6 to 12.6 ft with the worst case occurring at the 100-year event. Scour at the right abutment ranged from 1.6 to 5.6 ft with the worst case occurring at the 500-year event. 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.

Richford, VT. Quadrangle, 1:24,000, 1986

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 RICHTH00030006 ***Stream*** Unnamed trib. to Missisquoi Riv.

County Franklin ***Road*** TH3 ***District*** 8

Description of Bridge

Bridge length 26 ***ft*** ***Bridge width*** 23.4 ***ft*** ***Max span length*** 24 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 06/28/95

Description of stone fill Type-2, around the upstream end of the right abutment and upstream right wingwall in good condition.

Brief description of piers/abutments Abutments and wingwalls are concrete.The footing of both abutments are exposed. The right abutment has a subfooting.

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

There is a mild channel bend in the upstream and downstream 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	06/28/95	0	0
Level II	06/28/95	0	0

Potential for debris Low. There is no debris accumulation although there is a slight constriction of the channel due to the bridge.

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

Description of the Geomorphic Setting

General topography The channel is located within a low relief valley setting with an irregular flood plain.

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

Date of inspection 06/28/95

DS left: Moderately sloping channel bank to a wide terrace

DS right: Low sloping channel bank to flood plain

US left: Low sloping channel bank to flood plain

US right: Moderately sloping channel bank to a wide terrace

Description of the Channel

Average top width 39 *ft* ***Average depth*** 2 *ft*

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

Meandering but stable with alluvial channel boundaries and an irregular flood plain.

06/28/95

Vegetative co Pasture

DS left: Pasture

DS right: Pasture

US left: Pasture.

US right:

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

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 785 ***ft³/s*** ***Q500*** 1080 ***ft³/s***

The 100- and 500-year discharges are based on the median of discharge frequency curves which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the right end of the downstream bridge rail (elev. 501.73 ft, arbitrary survey datum). RM2 is a chiseled "X "on top of the upstream end of the upstream left wingwall (elev. 495.19 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	45	2	Modelled Approach section (Templated from APTEM)
APTEM	37	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 0.033 to 0.037, and overbank "n" values ranged from 0.037 to 0.043.

This unnamed tributary drains into the Missisquoi River approximately 600 feet downstream of the bridge. The close proximity of the confluence may affect the hydraulics at this bridge site, especially if the flow peaks are simultaneous. However an analysis of potential backwater from the Missisquoi River is outside of the scope of this study and 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 0.0082 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 (0.0082 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 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. Analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile passes through critical depth within the bridge opening for the 100-year discharge. Thus, the assumption of critical depth is a satisfactory solution for the 100-year discharge.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.2 *ft*
Average low steel elevation 495.3 *ft*

100-year discharge 785 *ft³/s*
Water-surface elevation in bridge opening 492.5 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 73.8 *ft²*
Average velocity in bridge opening 10.6 *ft/s*
Maximum WSPRO tube velocity at bridge 12.9 *ft/s*

Water-surface elevation at Approach section with bridge 494.7
Water-surface elevation at Approach section without bridge 492.8
Amount of backwater caused by bridge 1.9 *ft*

500-year discharge 1080 *ft³/s*
Water-surface elevation in bridge opening 495.6 *ft*
Road overtopping? N *Discharge over road* -
Area of flow in bridge opening 132.4 *ft²*
Average velocity in bridge opening 8.2 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 493.5
Amount of backwater caused by bridge 3.4

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 -
Water-surface elevation at Approach section without bridge -
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.

Contraction scour for the 100-year discharge was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 500-year discharge resulted in unsubmerged pressure 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). Contraction scour for the 500-year event was computed by the Chang pressure flow scour equation (Richardson and others, 1995, p. 145-146). The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F.

Abutment scour at the left abutment for the 100-year discharge 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 overopping.

Scour at the right abutment for the 100- and 500-year discharges and the left abutment for the 500-year discharge was 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	1.7	1.8	--
Depth to armoring	52.4	4.4	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	12.6	7.6	--
Left abutment	1.6	5.6	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.5	1.2	--
Left abutment	1.5	1.2	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

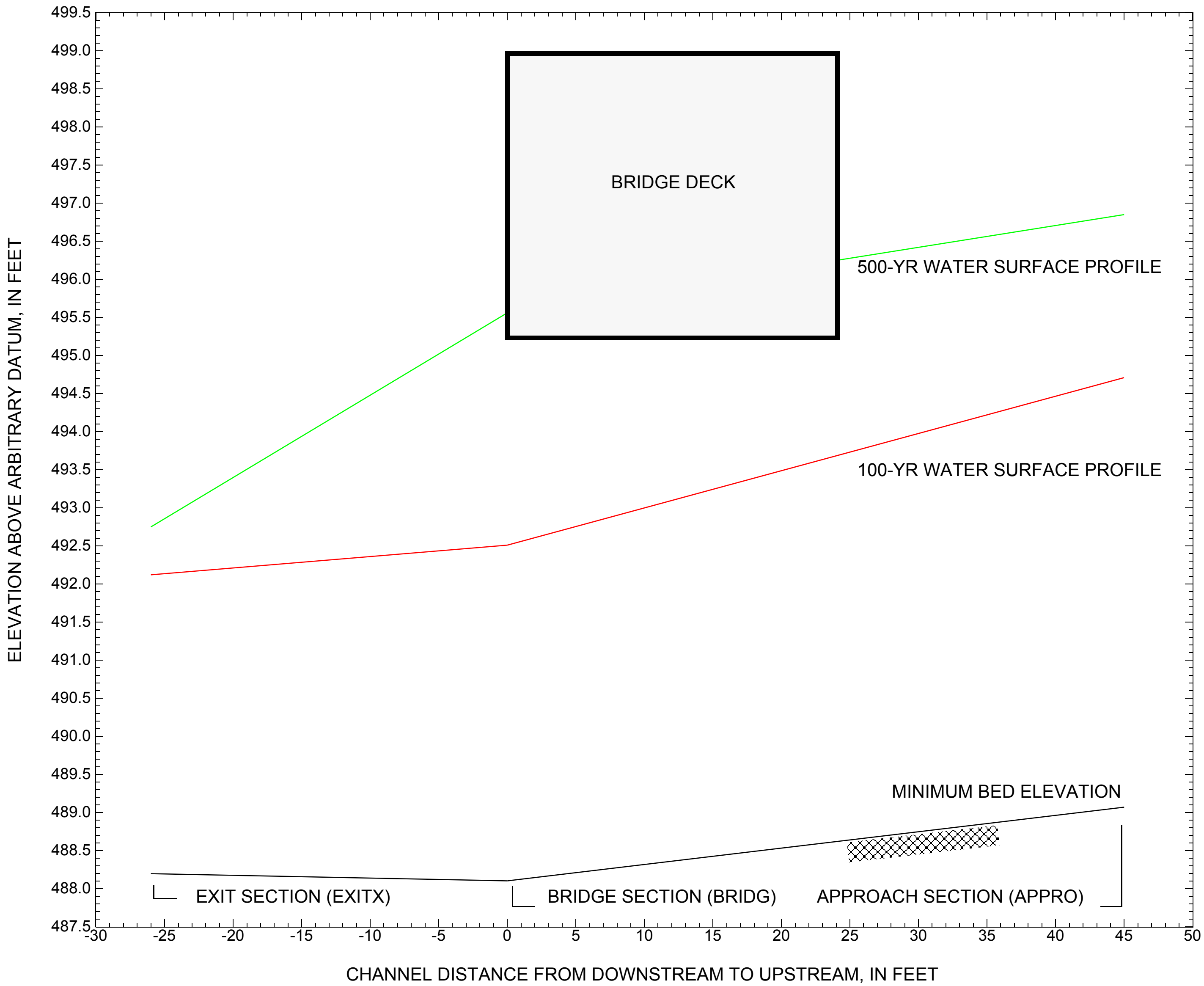

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RICHTH00030006 on Town Highway 34, crossing an unnamed tributary to the Missisquoi River, Richford, Vermont.

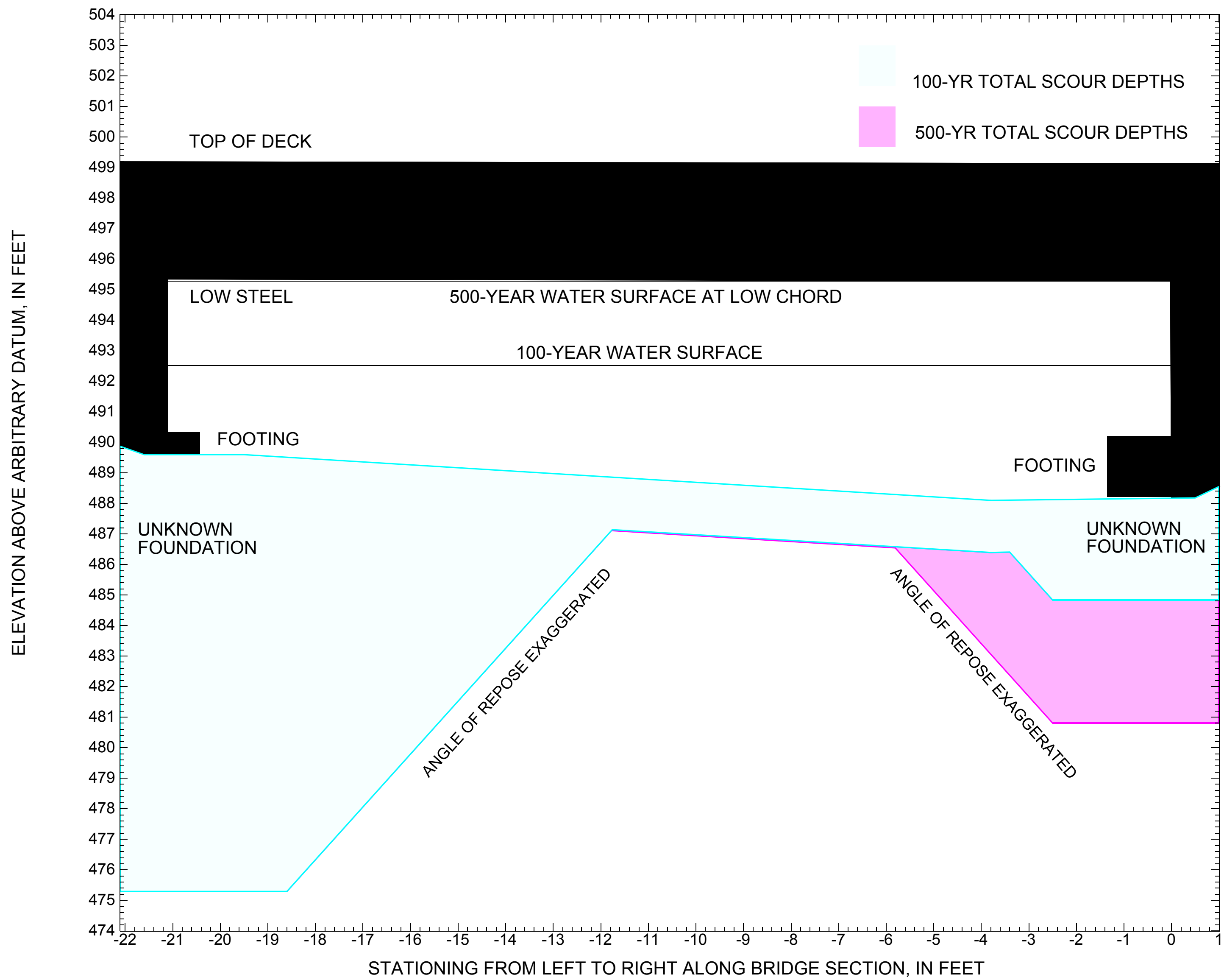

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RICHTH00030006 on Town Highway 34, crossing an unnamed tributary to the Missisquoi River, Richford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RICHTH00030006 on Town Highway 34, crossing an unnamed tributary to the Missisquoi River, Richford, 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 785 cubic-feet per second											
Left abutment	-21.1	--	495.1	--	489.6	1.7	12.6	--	14.3	475.3	--
Right abutment	0.0	--	495.6	--	488.2	1.7	1.6	--	3.3	484.9	--

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 RICHTH00030006 on Town Highway 34, crossing an unnamed tributary to the Missisquoi River, Richford, 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 1,080 cubic-feet per second											
Left abutment	-21.1	--	495.1	--	489.6	1.8	7.6	--	9.4	480.2	--
Right abutment	0.0	--	495.6	--	488.2	1.8	5.6	--	7.4	480.8	--

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

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U.S. Geological Survey, 1986, Richford, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File rich006.wsp
T2        Hydraulic analysis for structure richth00030006   Date: 12-SEP-96
T3
Q            785.0    1080.0
SK          0.0082   0.0082
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -26           0.
GR         -130.6, 501.37    -34.1, 499.35    -30.2, 496.72    -12.4, 490.70
GR           -8.8, 488.84      0.0, 488.20      3.5, 488.28      8.0, 488.85
GR           15.0, 490.00     48.6, 492.41    121.8, 492.97    201.8, 494.47
GR          227.0, 497.85    254.1, 499.29    277.1, 502.12
*
N           0.042        0.037        0.037
SA                  -34.1         15.0
*
*
XS   FULLV      0  * * *   0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0    495.30       0.0
GR          -21.1, 495.05    -20.5, 490.25    -19.8, 490.06    -19.5, 489.60
GR           -9.5, 488.63     -3.8, 488.10     -1.5, 488.18     -1.5, 488.83
GR           -1.4, 490.29      0.0, 490.29      0.0, 495.56    -21.1, 495.05
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      32.8 * *     59.4      6.5
N           0.033
*
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     12      23.4     1
GR         -421.7, 504.14   -278.7, 502.11   -123.9, 499.93    -22.0, 499.23
GR            0.0, 499.11     69.9, 498.61    144.9, 498.74    277.8, 502.61
*
*
*           EXPECTED SRD =   45 AT ONE BR. LENGTH BUT COMPUTED SRD =   37
*
XT   APTEM     37           0.
GR         -300.0, 500.89   -197.2, 495.63   -126.5, 496.07    -89.6, 494.91
GR          -54.6, 490.65    -21.3, 489.55    -16.6, 489.07    -12.6, 489.33
GR           -5.2, 491.75      0.0, 493.41     34.6, 494.24    112.1, 494.46
GR          178.6, 497.09    217.4, 498.82    228.3, 500.96    272.7, 505.18
*
AS   APPRO     45 * * * 0.0082
GT
N           0.038        0.035        0.043
SA                 -54.6         0.0
*
HP 1 BRIDG    492.51 1 492.51
HP 2 BRIDG    492.51 * * 785
HP 1 APPRO    494.71 1 494.71
HP 2 APPRO    494.71 * * 785
*
HP 1 BRIDG    495.56 1 495.56
HP 2 BRIDG    495.56 * * 1080
```

APPENDIX B:

WSPRO OUTPUT FILE

```
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File rich006.wsp
         Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

            *** RUN DATE & TIME: 09-20-96  08:40

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

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      74.    6457.    21.    27.                         789.
    492.51           74.    6457.    21.    27.  1.00   -21.     0.    789.
1
   HP 2 BRIDG    492.51 * * 785

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        492.51   -20.8     0.0    73.8    6457.     785.  10.64

 X STA.       -20.8      -18.4      -17.0      -15.9      -14.8      -13.8
   A(I)            6.2        4.1        3.8        3.5        3.4
   V(I)           6.35       9.65      10.36      11.31      11.49

 X STA.       -13.8      -12.9      -12.0      -11.1      -10.3       -9.5
   A(I)            3.3        3.2        3.1        3.1        3.1
   V(I)          11.80      12.12      12.46      12.58      12.71

 X STA.        -9.5       -8.7       -7.9       -7.2       -6.4       -5.7
   A(I)            3.0        3.1        3.1        3.0        3.2
   V(I)          12.92      12.69      12.76      12.88      12.34

 X STA.        -5.7       -4.9       -4.2       -3.3       -2.4        0.0
   A(I)            3.2        3.3        3.6        4.2        7.2
   V(I)          12.32      11.77      10.96       9.24       5.47



     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      66.    4056.    33.    33.                         526.
              2     239.   27051.    55.    55.                        2843.
              3      52.    1037.   117.   117.                         195.
    494.71          356.   32144.   204.   205.  1.38   -87.   117.   2272.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

          WSEL     LEW     REW    AREA        K        Q    VEL
        494.71   -87.4   116.8   356.4   32144.     785.   2.20

 X STA.       -87.4      -64.1      -57.3      -52.8      -49.3      -45.8
   A(I)           33.1       22.1       17.5       14.6       14.5
   V(I)           1.19       1.77       2.24       2.68       2.71

 X STA.       -45.8      -42.6      -39.4      -36.4      -33.5      -30.6
   A(I)           14.2       14.1       13.7       13.4       13.7
   V(I)           2.76       2.78       2.86       2.93       2.87

 X STA.       -30.6      -27.9      -25.2      -22.6      -20.0      -17.6
   A(I)           13.1       13.4       12.8       13.1       13.0
   V(I)           2.99       2.93       3.06       3.00       3.01

 X STA.       -17.6      -15.3      -12.8       -9.7       -4.7      116.8
   A(I)           12.9       13.6       14.7       18.0       60.9
   V(I)           3.04       2.90       2.67       2.18       0.64
```

```
        U.S. Geological Survey WSPRO Input File rich006.wsp
        Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

           *** RUN DATE & TIME: 09-20-96  08:40
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     132.  10856.     0.    54.                           0.
   495.56          132.  10856.     0.    54.  1.00   -21.     0.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.56   -21.1     0.0   132.4   10856.    1080.   8.16

X STA.       -21.1      -18.7      -17.4      -16.2      -15.1      -14.1
  A(I)            11.0        7.4        6.7        6.5        6.0
  V(I)            4.89       7.27       8.06       8.37       8.95

X STA.       -14.1      -13.2      -12.2      -11.3      -10.5       -9.6
  A(I)             6.0        5.8        5.8        5.7        5.7
  V(I)            8.95       9.32       9.26       9.39       9.54

X STA.        -9.6       -8.8       -8.0       -7.2       -6.4       -5.5
  A(I)             5.5        5.6        5.6        5.6        5.7
  V(I)            9.75       9.61       9.70       9.62       9.39

X STA.        -5.5       -4.8       -3.9       -3.1       -2.1        0.0
  A(I)             5.7        6.0        6.4        7.4       12.1
  V(I)            9.41       9.02       8.45       7.33       4.47
```

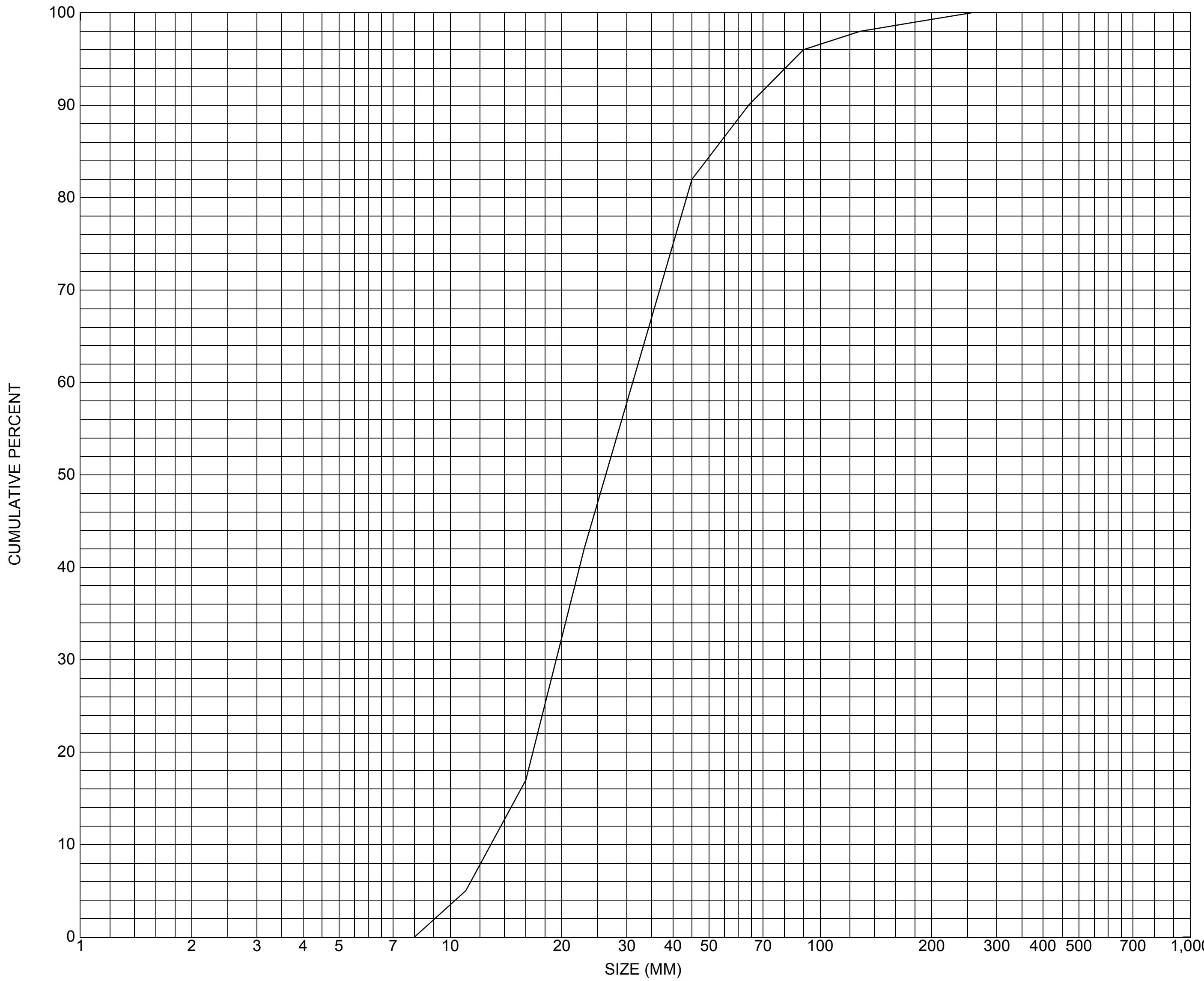
```
        U.S. Geological Survey WSPRO Input File rich006.wsp
        Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

           *** RUN DATE & TIME: 09-20-96  08:40
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     267.  14403.   165.   165.                        1926.
             2     356.  52482.    55.    55.                        5161.
             3     359.  20436.   171.   171.                        2957.
   496.85          982.  87321.   391.   392.  1.81  -220.   171.   6574.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.85  -219.8   170.9   982.5   87321.    1080.   1.10

X STA.      -219.8      -93.5      -67.9      -57.2      -51.2      -46.4
  A(I)           119.7       76.6       55.3       36.7       30.3
  V(I)            0.45       0.71       0.98       1.47       1.78

X STA.       -46.4      -41.9      -37.4      -33.2      -29.2      -25.1
  A(I)            29.1       29.6       28.7       27.9       28.5
  V(I)            1.86       1.83       1.88       1.93       1.90

X STA.       -25.1      -21.3      -17.5      -14.0       -9.9       -3.7
  A(I)            27.5       27.6       27.2       29.5       34.4
  V(I)            1.96       1.95       1.98       1.83       1.57

X STA.        -3.7       13.0       37.4       65.8       97.4      170.9
  A(I)            56.4       67.7       70.9       76.1      102.8
  V(I)            0.96       0.80       0.76       0.71       0.53
```

```
        U.S. Geological Survey WSPRO Input File rich006.wsp
        Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

           *** RUN DATE & TIME: 09-20-96  08:40

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

EXITX:XS   ******   -17.     123.  0.73 *****  492.85  491.84    785.  492.12
      -26. ******    45.    8662.  1.16 ***** *******    0.86    6.39

FULLV:FV      26.   -18.     147.  0.55  0.18  493.03 *******    785.  492.48
        0.    26.    58.   10542.  1.22  0.00    0.00    0.75    5.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      45.   -72.     156.  0.42  0.22  493.26 *******    785.  492.83
       45.    45.    -2.   11775.  1.07  0.00    0.00    0.62    5.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =      785.     492.51

            <<<<<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      26.   -21.      74.  1.76 *****  494.27  492.51    785.  492.51
        0.    26.     0.    6445.  1.00 ***** *******    1.00   10.65

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  495.30 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      12.   -87.     356.  0.10  0.06  494.81  492.08    785.  494.71
       45.    19.   117.   32122.  1.38  0.49    0.00    0.35    2.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.703  0.623   12104.   -40.   -20.   494.70

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

        U.S. Geological Survey WSPRO Input File rich006.wsp
        Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

           *** RUN DATE & TIME: 09-20-96  08:40
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -26.   -17.    45.    785.     8662.     123.    6.39  492.12
   FULLV:FV       0.   -18.    58.    785.    10542.     147.    5.35  492.48
   BRIDG:BR       0.   -21.     0.    785.     6445.      74.   10.65  492.51
   RDWAY:RG      12.**************      0.******************    1.00********
   APPRO:AS      45.   -87.   117.    785.    32122.     356.    2.20  494.71

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -40.   -20.   12104.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     491.84    0.86  488.20  502.12************  0.73  492.85  492.12
   FULLV:FV   ********    0.75  488.20  502.12  0.18  0.00  0.55  493.03  492.48
   BRIDG:BR     492.51    1.00  488.10  495.56************  1.76  494.27  492.51
   RDWAY:RG   ****************  498.61  504.14**********************************
   APPRO:AS     492.08    0.35  489.14  505.25  0.06  0.49  0.10  494.81  494.71
```

```
1         U.S. Geological Survey WSPRO Input File rich006.wsp
         Hydraulic analysis for structure richth00030006   Date: 12-SEP-96

            *** RUN DATE & TIME: 09-20-96  08:40

  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -18.     172.  0.86 ***** 493.61  492.39   1080.  492.75
      -26. ******    93.   11919.  1.39 ***** *******    1.06    6.29

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.44

 FULLV:FV      26.   -20.     250.  0.43  0.15  493.74 *******   1080.  493.31
         0.    26.   140.   17127.  1.50  0.00   -0.01    0.74    4.31
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  APPRO:AS      45.   -77.     203.  0.48  0.18  493.95 *******   1080.  493.47
        45.    45.     0.   17048.  1.09  0.02    0.00    0.60    5.33
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   493.34     495.94     495.99     495.30

  ===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      26.   -21.     132.  1.00 *****  496.56  493.28   1061.  495.56
         0. ******     0.   10856.  1.00 ***** *******    0.56    8.01

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.461 ******  495.30 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS      12.  -220.     984.  0.03  0.02  496.89  492.55   1080.  496.85
        45.    19.   171.   87486.  1.81  0.49   -0.02    0.16    1.10

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ******   496.85
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -26.   -18.    93.   1080.   11919.     172.    6.29  492.75
    FULLV:FV       0.   -20.   140.   1080.   17127.     250.    4.31  493.31
    BRIDG:BR       0.   -21.     0.   1061.   10856.     132.    8.01  495.56
    RDWAY:RG      12.**************       0.*****************    1.00********
    APPRO:AS      45.  -220.   171.   1080.   87486.     984.    1.10  496.85

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
    EXITX:XS    492.39    1.06  488.20  502.12************  0.86  493.61  492.75
    FULLV:FV  ********    0.74  488.20  502.12  0.15  0.00  0.43  493.74  493.31
    BRIDG:BR    493.28    0.56  488.10  495.56************  1.00  496.56  495.56
    RDWAY:RG ****************  498.61  504.14************  0.00  500.28********
    APPRO:AS    492.55    0.16  489.14  505.25  0.02  0.49  0.03  496.89  496.85
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect in the channel approach of structure RICHTH00030006, in Richford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RICHTH00030006

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 09 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 59125

Mile marker *(I - 11; nnn.nnn)* 000680

Waterway *(I - 6)* UNNAMED BROOK

Road Name *(I - 7):* -

Route Number TH003

Vicinity *(I - 9)* 1.2 MI W JCT. VT.105

Topographic Map Richford

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44597

Longitude *(i - 17; nnnnn.n)* 72410

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20030200060611

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

Maximum span length *(I - 48; nnnn)* 0024

Year built *(I - 27; YYYY)* 1900

Structure length *(I - 49; nnnnnn)* 000026

Average daily traffic, ADT *(I - 29; nnnnnn)* 001025

Deck Width *(I - 52; nn.n)* 234

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

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

Structure type *(I - 43; nnn)* 104

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*) 5.0

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

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

Comments:

The structural inspection report of 5/12/94 indicates the structure is a single span concrete T-beam type bridge. The left abutment wall has a full height vertical crack visible and areas of moderate to heavy concrete scaling. The upstream and downstream left wingwalls also show heavy to moderate concrete scaling. The footing of the left abutment is partially exposed and heavily scaled with some scour noted at the upstream end but no undermining. The right abutment wall has some light scaling noted and the upstream and downstream right wingwalls have moderate to heavy concrete scaling. The exposed footing appears to have a newer concrete facing and is in good condition. Apparently, **(Continued, page 31)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

Comments:
there was an undermining problem at one time, and the facing on the footing was constructed as a result, the report indicated. The channel makes a sharp turn into the structure, with flow attacking the right abutment. Point bars located along the left abutment are noted and visible in photographs. There is some riprap protection noted along the right abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **4.50** mi^2 Lake and pond area **0.03** mi^2
Watershed storage *(ST)* **0.7** %
Bridge site elevation **433** ft Headwater elevation **1542** ft
Main channel length **4.26** mi
10% channel length elevation **440** ft 85% channel length elevation **935** ft
Main channel slope *(S)* **154.93** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

If 2: Pile Type: - (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: -

If 3: Footing bottom elevation: -

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low 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: RB Date: 3/6/96
Computerized by: RB Date: 3/6/96
Reviewd by: RF Date: 10/7/96

Structure Number RICHTH00030006

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* D. SONG Date *(MM/DD/YY)* 6 / 28 / 1995
2. Highway District Number 8 Mile marker 000680
County 011 Town (59125) RICHFORD
Waterway *(I - 6)* UNNAMED BROOK Road Name -
Route Number TH003 Hydrologic Unit Code: 02010007
3. Descriptive comments:
1.2 miles to the junction with VT 105. Farmland.

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 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 26 *(feet)* Span length 24 *(feet)* Bridge width 23.4 *(feet)*

Road approach to bridge:

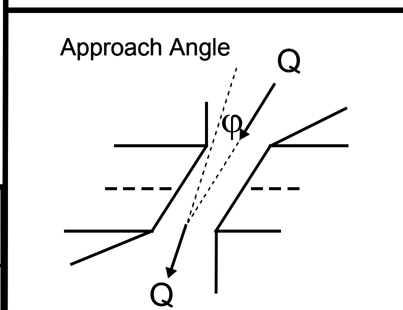
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 1.1:1 US right 2.3:1

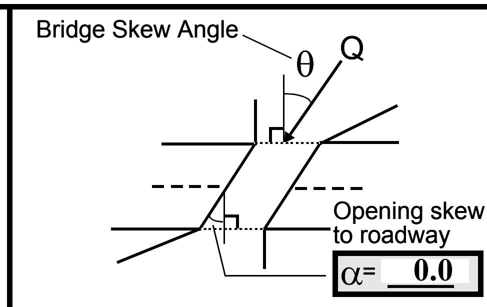
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	1	3	0	-
RBDS	1	1	0	-
LBDS	1	1	0	-

*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: 20 16. Bridge skew: 40



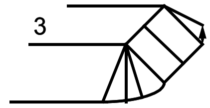


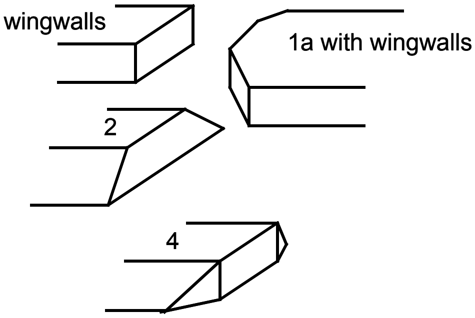
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 5 feet US *(US, UB, DS)* to 10 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 40 feet DS *(US, UB, DS)* to 80 feet DS

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

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

7. Values are from VT AOT files.

18. Bridge is a combination of 1a and 4, but sloping wingwalls end at the low chord.

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
17.0	**1.0**			**2.5**	**1**	**1**	**32**	**32**	**0**	**0**

23. Bank width **0.0** 24. Channel width **15.0** 25. Thalweg depth **49.5** 29. Bed Material **3**

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

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

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

The left bank US is a path for cows that continues under the bridge. There is some erosion because of lack of vegetation.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR

49. Are there major confluences? N (Y or if N type ctrl-n mc) 50. How many? -

51. Confluence 1: Distance - 52. Enters on - (LB or RB) 53. Type - (*1- perennial; 2- ephemeral)*

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB ___ (*1- natural bank; 2- abutment; 3- artificial levee)*

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
9.5		0.5		2	7	7	-

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

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

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

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

3

Ambient channel runs along the impact zone at the right abutment.

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

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

No debris accumulation, slight bridge constriction of channel.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0**	**0.5**	**90.0**
RABUT	**1**	**40**	**90**			**2**	**2**	**21.0**

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

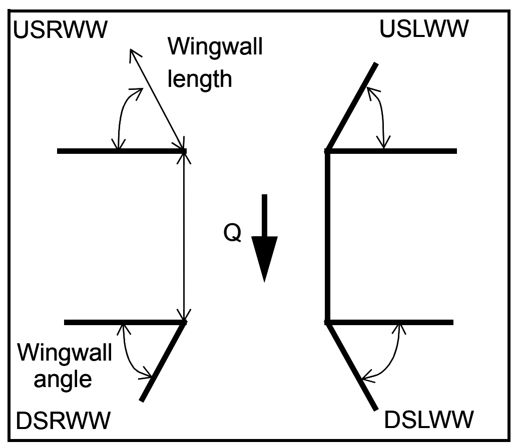
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0.5
2
1
Historical records note a previous undermining problem of the right abutment which was remedied by a new footing.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**21.0**	
USRWW:	**Y**		**1**		**0**	**0.5**	
DSLWW:	**0**		**0**		**Y**	**24.5**	
DSRWW:	**1**		**0**		**0**	**24.0**	

*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**	**0**	**Y**	**0.5**	**-**	**1**	**-**	**1**
Condition	**Y**	**0**	**1**	**2**	**-**	**1**	**-**	**2**
Extent	**1**	**0**	**2**	**0**	**2**	**0**	**2**	**0**

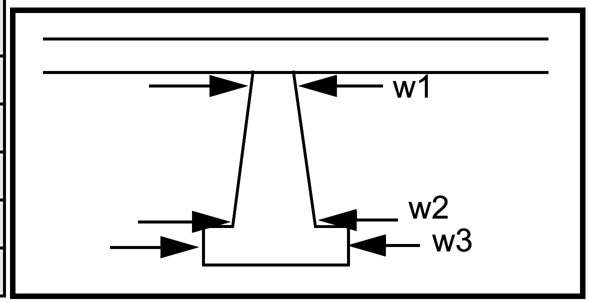
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length; **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? _-____ *(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				30.0	15.0	90.0
Pier 2			7.5	10.5	60.0	55.0
Pier 3	7.5	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	N	-	-	-	
98. Exposure depth	-	-	-	-	

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
-	-			-	-	NO	PIE	RS		

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.):

1
1
32
32
0
0
3
0
0
-
-
Bed material ranges from sand to gravel. The cow path continues from US and crosses the stream DS at the bridge onto the right bank. There is a little vegetation and some erosion on the right bank immediately DS of

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

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

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

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **0** feet **10** *(US, UB, DS)* to **0** feet **US** *(US, UB, DS)*

Bank damage: **10** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
50
2,3

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

Scour dimensions: Length **grav** Width **el** Depth: **bar** Positioned **alo** %LB to **ng** %RB

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

the left abutment.

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

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

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

Confluence comments (eg. confluence name):

NO CUT BANKS

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

N
-
-
-
-
-
-
NO CHANNEL SCOUR

N

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: RICHTH00030006 Town: RICHFORD
Road Number: TH003 County: 11
Stream: UNNAMED BROOK TO MISSISQUOI RIVER

Initials RF Date: 11/12/96 Checked: SAO

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	785	1080	0
Main Channel Area, ft2	239	356	0
Left overbank area, ft2	66	267	0
Right overbank area, ft2	52	359	0
Top width main channel, ft	55	55	0
Top width L overbank, ft	33	165	0
Top width R overbank, ft	117	171	0
D50 of channel, ft	0.0861	0.0861	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	4.3	6.5	ERR
y1, average depth, LOB, ft	2.0	1.6	ERR
y1, average depth, ROB, ft	0.4	2.1	ERR
Total conveyance, approach	32144	87321	0
Conveyance, main channel	27051	52482	0
Conveyance, LOB	4056	14403	0
Conveyance, ROB	1037	20436	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	660.6	649.1	ERR
Ql, discharge, LOB, cfs	99.1	178.1	ERR
Qr, discharge, ROB, cfs	25.3	252.8	ERR
Vm, mean velocity MC, ft/s	2.8	1.8	ERR
Vl, mean velocity, LOB, ft/s	1.5	0.7	ERR
Vr, mean velocity, ROB, ft/s	0.5	0.7	ERR
Vc-m, crit. velocity, MC, ft/s	6.3	6.8	N/A
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	N/A
Left Overbank	-	-	N/A
Right Overbank	-	-	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	239	356	0
Main channel width, ft	55	55	0
y1, main channel depth, ft	4.35	6.47	ERR
Bridge Section			
(Q) total discharge, cfs	785	1080	0
(Q) discharge thru bridge, cfs	785	1080	
Main channel conveyance	6457	10856	
Total conveyance	6457	10856	
Q2, bridge MC discharge,cfs	785	1080	ERR
Main channel area, ft2	74	132	0
Main channel width (skewed), ft	20.8	21.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.8	21.1	0
y_bridge (avg. depth at br.), ft	3.55	6.26	ERR
Dm, median (1.25*D50), ft	0.107625	0.107625	0
y2, depth in contraction,ft	5.26	6.83	ERR
ys, scour depth (y2-ybridge), ft	1.71	0.57	N/A
ys, scour depth (y2-yfullv), ft	N/A	2.56	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)

(Richarson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q, total, cfs	785	1080	0
Q, thru bridge, cfs	785	1080	0
Total Conveyance, bridge	6457	10856	0
Main channel(MC) conveyance, bridge	6457	10856	0
Q, thru bridge MC, cfs	785	1080	ERR
Vc, critical velocity, ft/s	6.32	6.76	N/A
Vc, critical velocity, m/s	1.93	2.06	N/A
Main channel width (skewed), ft	20.8	21.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.8	21.1	0.0
qbr, unit discharge, ft^2/s	37.7	51.2	ERR
qbr, unit discharge, m^2/s	3.5	4.8	N/A
Area of full opening, ft^2	73.8	132.0	0.0
Hb, depth of full opening, ft	3.55	6.26	ERR
Hb, depth of full opening, m	1.08	1.91	N/A
Fr, Froude number, bridge MC	1	0.56	0

Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
Elevation of Low Steel, ft	0	495.3	0
Elevation of Bed, ft	-3.55	489.04	N/A
Elevation of Approach, ft	0	496.85	0
Friction loss, approach, ft	0	0.02	0
Elevation of WS immediately US, ft	0.00	496.83	0.00
ya, depth immediately US, ft	3.55	7.79	N/A
ya, depth immediately US, m	1.08	2.37	N/A
Mean elevation of deck, ft	0	499.1695	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.95	ERR
Ys, depth of scour, ft	N/A	1.75	N/A

ARMORING

D90	0.21	0.21	0
D95	0.279	0.279	0
Critical grain size,Dc, ft	0.4019	0.1943	ERR
Decimal-percent coarser than Dc	0.0225	0.1176	
Depth to armoring,ft	52.38	4.37	ERR

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	785	1080	0	785	1080	0
a', abut.length blocking flow, ft	66.6	198.7	0	116.8	170.9	0
Ae, area of blocked flow ft2	219.27	491.35	0	58.54	361.4	0
Qe, discharge blocked abut.,cfs	537.42	596.84	0	37.73	258.04	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.45	1.21	ERR	0.64	0.71	ERR
ya, depth of f/p flow, ft	3.29	2.47	ERR	0.50	2.11	ERR
--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	
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.238	0.136	ERR	0.160	0.087	ERR
ys, scour depth, ft	12.60	11.47	ERR	3.69	7.96	ERR

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)	66.6	198.7	0	116.8	170.9	0
y1 (depth f/p flow, ft)	3.29	2.47	ERR	0.50	2.11	ERR
a'/y1	20.23	80.35	ERR	233.04	80.82	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.24	0.14	N/A	0.16	0.09	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	9.31	ERR	1.99	6.86	ERR
vertical w/ ww's	ERR	7.64	ERR	1.63	5.62	ERR

spill-through	ERR	5.12	ERR	1.10	3.77	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	1	0.56	0	1	0.56	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	3.55	6.26	0.00	3.55	6.26	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.21	0.00	ERR	1.21	0.00
Fr>0.8 (vertical abut.)	1.48	ERR	ERR	1.48	ERR	ERR
Fr<=0.8 (spillthrough abut.)	ERR	1.06	0.00	ERR	1.06	0.00
Fr>0.8 (spillthrough abut.)	1.31	ERR	ERR	1.31	ERR	ERR