LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (TROYTH00120008) on TOWN HIGHWAY 12, crossing the MISSISQUOI RIVER, TROY, VERMONT

U.S. Geological Survey
Open-File Report 98-016

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

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

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By ERICK M. BOEHMLER

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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 8 (TROYTH00120008) ON TOWN HIGHWAY 12, CROSSING THE MISSISQUOI RIVER, TROY, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure TROYTH00120008 on Town Highway 12 crossing the Missisquoi River, Troy, 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 in north-central Vermont. The 131-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest except for the left overbank downstream, which is pasture.

In the study area, the Missisquoi River has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 154 ft and an average bank height of 5 ft. The predominant channel bed materials are gravel and cobbles with a median grain size (D_{50}) of 75.6 mm (0.248 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 14, 1995, indicated that the reach was laterally unstable. The lateral instability is evident primarily in the significantly wider channel at bends with wide point bars.

The Town Highway 12 crossing of the Missisquoi River is a 95-ft-long, one-lane bridge consisting of one 91-foot wooden-truss span (Vermont Agency of Transportation, written communication, March 7, 1995). The opening length of the structure parallel to the bridge face is 84.5 ft. The bridge is supported by vertical, concrete abutments with concrete wingwalls on the left abutment only. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 5.5 feet deeper than the mean thalweg depth was observed along the edge of a bedrock outcrop at the right abutment during the Level I assessment. The scour protection measures at the site were type-1 stone fill (less than 12 inches diameter) on the downstream right bank and type-2 stone fill (less than 36 inches diameter on the upstream right bank and upstream end of the left abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). 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 0.8 to 1.9 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 19.4 to 25.9 feet. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The right abutment, however, appears to be founded on bedrock.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number TROYTH00120008 ***Stream*** Missisquoi River

County Orleans ***Road*** TH 12 ***District*** 9

Description of Bridge

Bridge length 95 ***ft*** ***Bridge width*** 11.6 ***ft*** ***Max span length*** 91 ***ft***

Alignment of bridge to road (on curve or straight) Straight, left and curved, right

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

Stone fill on abutment? Yes ***Date of inspection*** 6/14/95

Description of stone fill Type-2, at the upstream end of the right abutment. The left abutment was not protected. Type-2 stone fill also was present on the right bank upstream and type-1 stone fill on the downstream right bank.

Brief description of piers/abutments Abutments and wingwalls are concrete. Only the left abutment has wingwalls.

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

There is a severe channel bend in the upstream reach. The scour hole has developed in the location where the flow impacts the bedrock outcrop on the right bank.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	6/14/95	0	0
Level II	6/14/95	0	0

Potential for debris Moderate. There is significant vegetation cover on the banks but the channel is stable. Residents indicate ice blocks accumulate on point bar US.

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

None evident on 6/14/95.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting with flat to slightly irregular flood plains and moderately sloping to steep valley walls.

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

Date of inspection 6/14/95

DS left: Moderately sloping channel bank to a narrow flood plain.

DS right: Steep channel bank and valley wall.

US left: Moderately sloping channel bank to a narrow flood plain.

US right: Moderately sloping channel bank and valley wall.

Description of the Channel

Average top width 154 ft ***Average depth*** 5 ft

Predominant bed material Gravel / Cobbles ***Bank material*** Sand to Boulders

Perennial and sinuous with wide bends and point bars, and semi-alluvial channel boundaries.

6/14/95

Vegetative co Grass and brush with a few trees

DS left: Trees, brush, and grass.

DS right: Trees, brush, and grass.

US left: Trees and brush

US right:

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

There is a point bar upstream noted on 6/14/95 that directs flow at most stages toward the right bank and horizontally occupies 80% of the channel. Residents indicated that ice accumulates on the point bar and contributes to right bank erosion during spring runoff.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 131 ***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? Yes

USGS gage description Missisquoi River near North Troy, VT

USGS gage number 04293000

Gage drainage area 131 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 8,460 ***ft³/s*** ***Q500*** 9,900 ***ft³/s***

The 100- and 500-year discharges are based on a Log-Pearson type III analysis of the peak discharge records from 1931 through 1993 at the gage approximately 1 mile downstream of this site. A provisional peak discharge of 9000 cubic feet per second occurred on July 15, 1997, and was not considered in the peak discharge analysis.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the upstream end of the left abutment (elev. 510.02 feet, arbitrary survey datum). RM2 is a chiseled "X" on top of the downstream end of the right abutment (elev. 512.28 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-97	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	104	5	Approach section

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modeling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.045, and overbank "n" values were 0.045.

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 0.00307 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

Because the upstream channel bed slope is significantly greater than the slope of the overbank areas, the surveyed approach section (SRD at 127 ft) was moved by correcting only the channel points along the approach channel slope of 0.0369 ft/ft to establish the modelled approach section (APPRO, SRD at 104 ft). The modelled approach section was one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 514.6 *ft*
Average low steel elevation 511.9 *ft*

100-year discharge 8,460 *ft³/s*
Water-surface elevation in bridge opening 503.8 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 691 *ft²*
Average velocity in bridge opening 12.3 *ft/s*
Maximum WSPRO tube velocity at bridge 15.7 *ft/s*

Water-surface elevation at Approach section with bridge 507.7
Water-surface elevation at Approach section without bridge 505.7
Amount of backwater caused by bridge 2.0 *ft*

500-year discharge 9,900 *ft³/s*
Water-surface elevation in bridge opening 504.0 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 706 *ft²*
Average velocity in bridge opening 14.0 *ft/s*
Maximum WSPRO tube velocity at bridge 17.7 */s*

Water-surface elevation at Approach section with bridge 508.8
Water-surface elevation at Approach section without bridge 506.2
Amount of backwater caused by bridge 2.6 *ft*

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

Water-surface elevation at Approach section with bridge --
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 Davis, 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 the scour depths are presented graphically in figure 8.

Contraction scour for each modeled discharge was computed by use of Laursen's clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20).

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

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.8	1.9	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	19.4	20.8	--
Right abutment	24.9	25.9	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	3.4	3.5	--
Right abutment	3.4	3.5	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

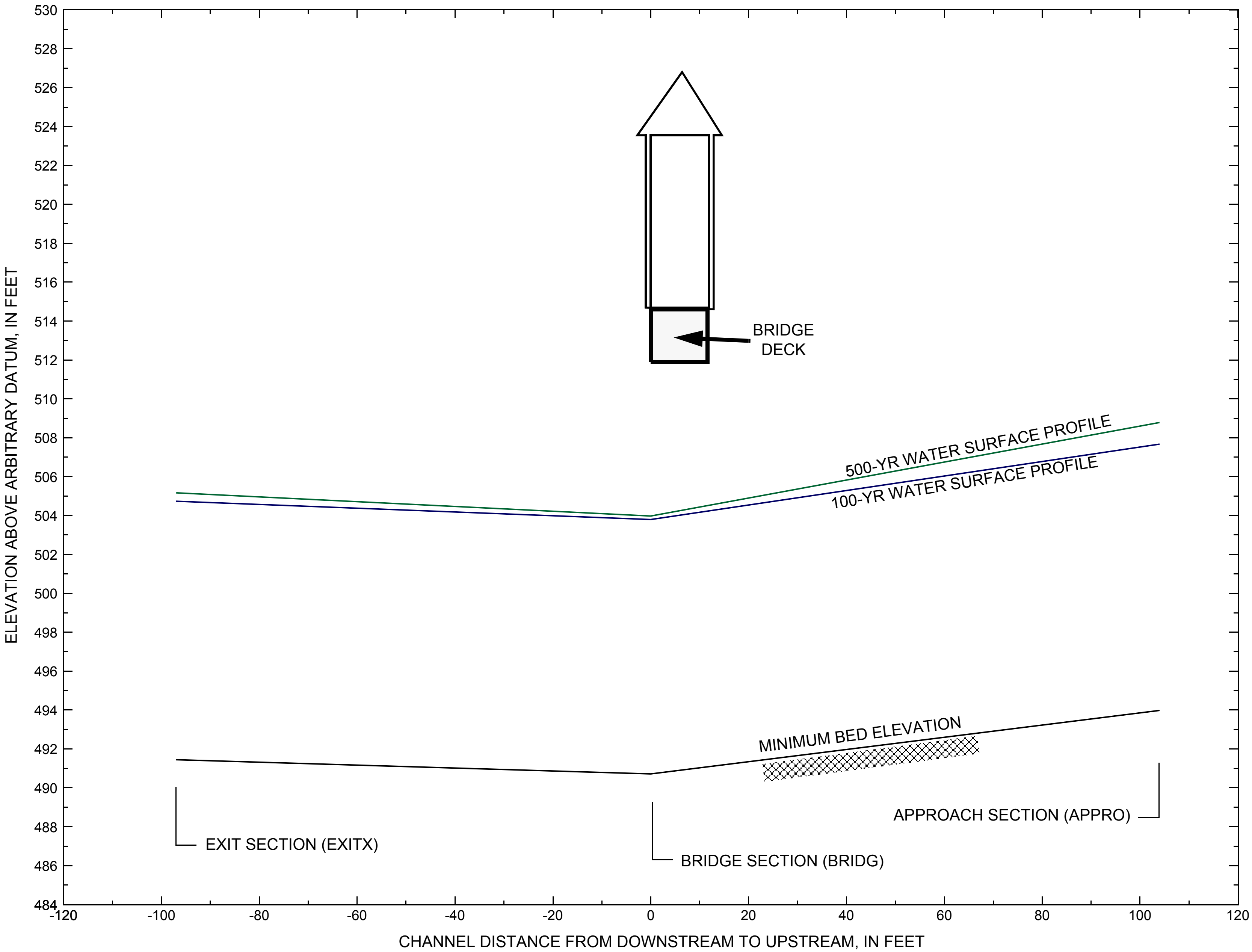

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure TROYTH00120008 on Town Highway 12, crossing the Missisquoi River, Troy, Vermont.

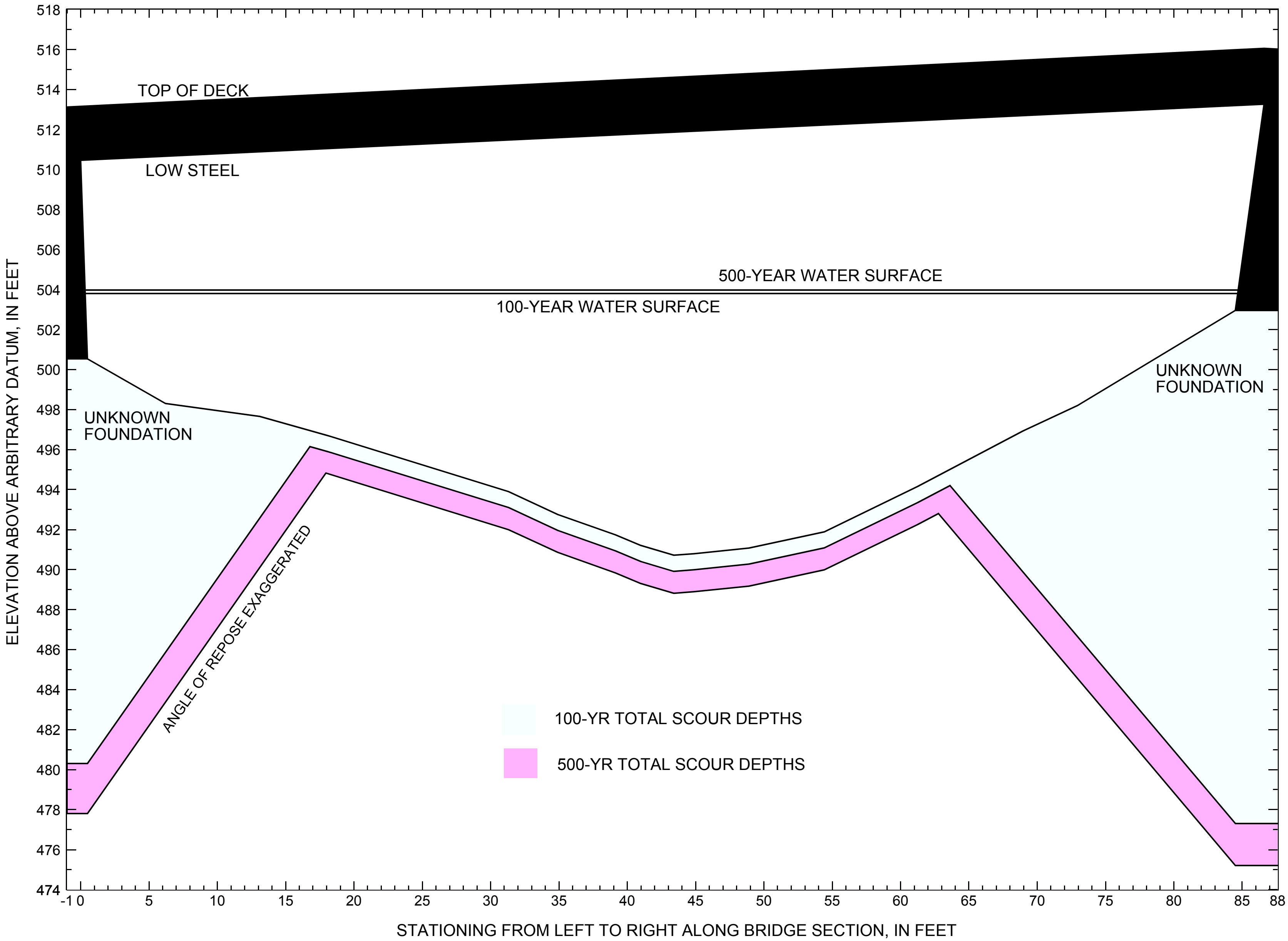

Figure 8. Scour elevations for the 100- and 500-year discharges at structure TROYTH00120008 on Town Highway 12, crossing the Missisquoi River, Troy, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure TROYTH00120008 on Town Highway 12, crossing the Missisquoi River, Troy, 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-year discharge is 8,460 cubic-feet per second											
Left abutment	0.0	--	510.5	--	500.5	0.8	19.4	--	20.2	480.3	--
Right abutment	86.6	--	513.3	--	503.0	0.8	24.9	--	25.7	477.3	--

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 TROYTH00120008 on Town Highway 12, crossing the Missisquoi River, Troy, 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-year discharge is 9,900 cubic-feet per second											
Left abutment	0.0	--	510.5	--	500.5	1.9	20.8	--	22.7	477.8	--
Right abutment	86.6	--	513.3	--	503.0	1.9	25.9	--	27.8	475.2	--

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

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Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

U.S. Geological Survey, 1986, North Troy, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1981; Contour interval, 6 meters; scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File troy008.wsp
T2        Hydraulic analysis for structure TROYTH00120008   Date: 11-APR-97
T3        Town Highway 12 crossing the Missisquoi River, Troy, VT            EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           8460.0   9900.0
SK          0.00307  0.00307
*
XS   EXITX   -97
GR         -550.0, 510.00   -550.0, 503.06   -292.1, 503.06   -149.3, 504.19
GR          -23.4, 504.12    -10.7, 505.02     -0.8, 499.16      0.0, 498.24
GR            6.9, 496.94     27.6, 497.59     36.3, 497.74     44.2, 497.05
GR           51.5, 495.77     71.9, 491.44     80.6, 493.14     84.7, 495.98
GR           97.5, 498.33     98.1, 504.05    112.5, 510.96
*
N           0.045        0.040
SA                 -10.7
*
XS   FULLV       0  * * *   0.0000
*
*             SRD     LSEL
BR   BRIDG     0    511.86
GR            0.0, 510.46      0.0, 500.53      6.2, 498.30     13.1, 497.65
GR           18.4, 496.63     22.5, 495.77     31.3, 493.90     34.9, 492.76
GR           39.1, 491.74     41.0, 491.20     43.4, 490.71     43.5, 490.91
GR           44.9, 490.79     48.9, 491.07     54.4, 491.88     61.3, 494.17
GR           69.0, 496.95     73.0, 498.22     84.5, 502.95     84.5, 510.26
GR           86.6, 510.26     86.6, 513.26      0.0, 510.46
*
*        BRTYPE  BRWDTH        WWANGL    WWWID
CD          1      21.6 * *     25.4      3.6
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY       9      11.6      2
GR         -550.0, 510.00   -550.0, 509.26   -273.6, 509.26   -203.7, 509.03
GR         -123.6, 508.95   -103.7, 508.91    -68.2, 509.46    -29.5, 511.51
GR            0.0, 513.15     91.4, 516.05    124.2, 516.93    145.1, 517.29
GR          165.5, 520.20    177.3, 525.34
*
AS   APPRO    104
GR         -550.0, 510.00   -550.0, 502.93   -287.7, 502.93   -227.4, 502.72
GR         -189.1, 504.27   -119.1, 505.38   -110.5, 504.33    -93.8, 503.24
GR          -80.0, 502.03    -77.0, 502.48    -64.4, 503.67    -58.7, 499.46
GR          -58.1, 498.39    -45.3, 497.92    -36.3, 497.94    -24.5, 498.22
GR          -17.3, 498.34    -13.9, 499.26     -6.3, 499.58      0.0, 500.55
GR           28.2, 497.82     48.3, 497.14     53.9, 495.89     62.0, 497.04
GR           75.6, 496.02     90.5, 495.36    104.6, 493.98    112.0, 495.50
GR          128.3, 497.52    129.0, 498.09    134.9, 502.17    146.2, 503.86
GR          161.2, 513.39    175.4, 518.44    186.7, 519.68
*
N           0.045        0.045
SA                 -64.4
*           Notice: the points right of sta. 0.0 and left of sta. 129.0
*                   inclusive were lowered by the slope 0.0369 over 23 feet
*                   The section was placed at srd 104 feet upstream from 127
```

```
*                    feet upstream. Only the deepest section of the main
*                    channel lowered by the slope indicated. The elevation of
*                    the remaining section points fall at a slope closer to zero
*                    between this section and the bridge.
*



HP 1 BRIDG 503.79 1 503.79
HP 2 BRIDG 503.79 * * 8460
HP 1 APPRO 507.67 1 507.67
HP 2 APPRO 507.67 * * 8460
*
HP 1 BRIDG 503.97 1 503.97
HP 2 BRIDG 503.97 * * 9900
HP 1 APPRO 508.78 1 508.78
HP 2 APPRO 508.78 * * 9900
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File troy008.wsp
        Hydraulic analysis for structure TROYTH00120008   Date: 11-APR-97
        Town Highway 12 crossing the Missisquoi River, Troy, VT            EMB
           *** RUN DATE & TIME: 05-16-97  09:15

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      691     98631     85     92                        11205
   503.79           691     98631     85     92  1.00      0     85    11205

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.79     0.0    84.5   690.7   98631.    8460.  12.25

X STA.         0.0       11.1       17.9       22.9       27.0       30.6
  A(I)            55.4       43.6       37.5       35.3       33.2
  V(I)            7.63       9.70      11.29      11.97      12.73

X STA.        30.6       33.6       36.3       38.8       41.1       43.2
  A(I)            31.2       29.8       29.0       28.1       27.5
  V(I)           13.56      14.19      14.59      15.08      15.38

X STA.        43.2       45.3       47.4       49.6       51.8       54.2
  A(I)            27.1       27.0       27.9       27.6       29.1
  V(I)           15.60      15.68      15.15      15.34      14.52

X STA.        54.2       56.9       60.1       63.8       69.3       84.5
  A(I)            30.7       33.3       35.5       42.5       59.3
  V(I)           13.76      12.71      11.92       9.96       7.13

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     104.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     2127    187283    486    491                        25264
             2     2075    304510    217    222                        36436
   507.67          4202    491793    702    713  1.19   -549    152    53485

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     104.

         WSEL     LEW     REW    AREA        K        Q    VEL
       507.67  -550.0   152.2  4201.9  491793.    8460.   2.01

X STA.      -550.0     -491.9     -436.4     -380.9     -324.3     -269.4
  A(I)           275.5      262.9      263.1      268.4      261.0
  V(I)            1.54       1.61       1.61       1.58       1.62

X STA.      -269.4     -214.5      -98.2      -53.4      -36.0      -18.6
  A(I)           265.1      369.0      246.6      168.5      165.8
  V(I)            1.60       1.15       1.72       2.51       2.55

X STA.       -18.6        4.9       25.7       41.7       55.9       69.7
  A(I)           188.9      178.3      160.3      155.1      151.5
  V(I)            2.24       2.37       2.64       2.73       2.79

X STA.        69.7       82.3       94.2      105.4      118.2      152.2
  A(I)           146.6      145.6      147.1      158.2      224.5
  V(I)            2.88       2.90       2.88       2.67       1.88
```

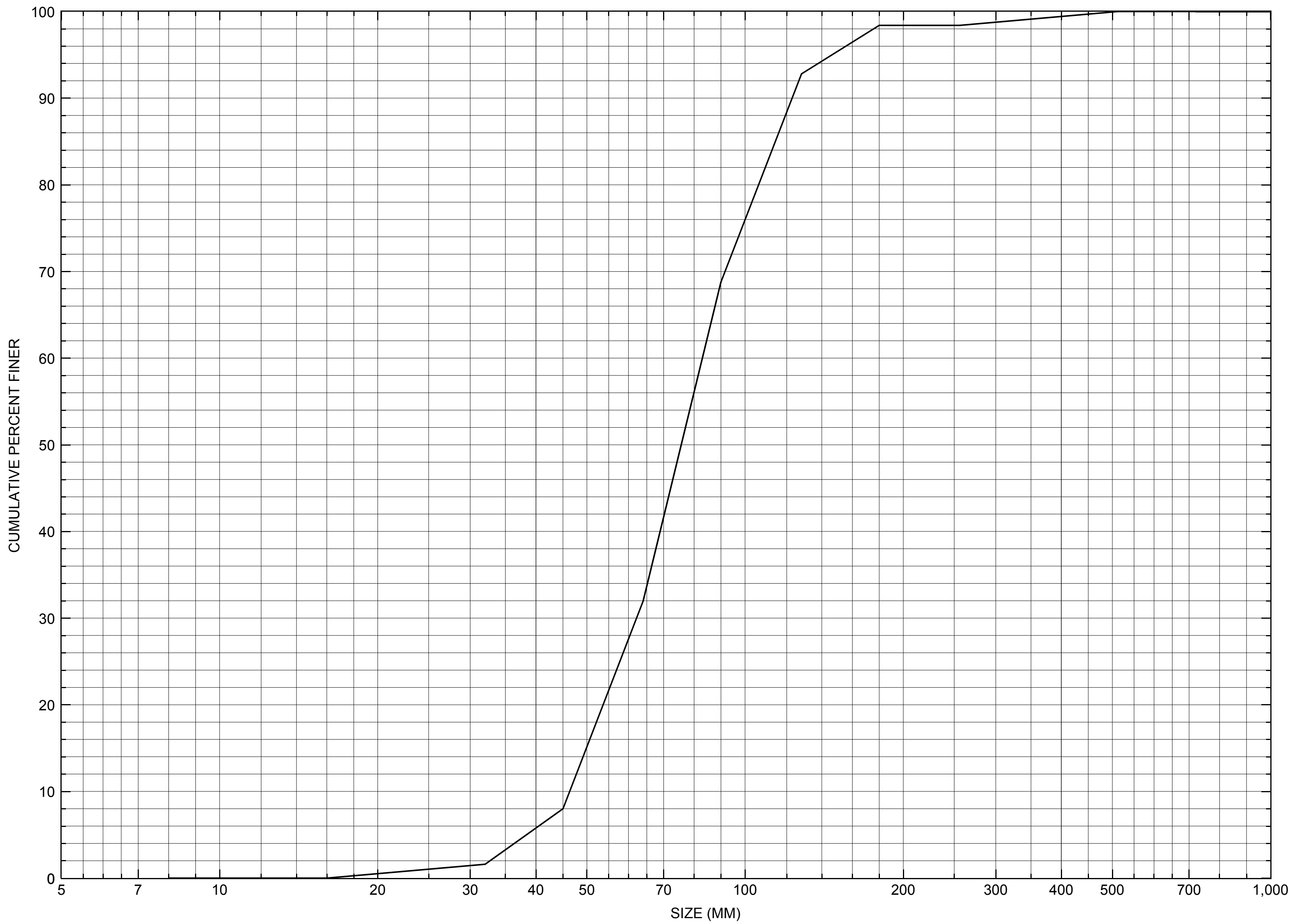
```
        U.S. Geological Survey WSPRO Input File troy008.wsp
        Hydraulic analysis for structure TROYTH00120008   Date: 11-APR-97
        Town Highway 12 crossing the Missisquoi River, Troy, VT            EMB
           *** RUN DATE & TIME: 05-16-97  09:15

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      706    102011     85     92                        11577
   503.97           706    102011     85     92  1.00      0     85    11577

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.97     0.0    84.5   705.9  102011.    9900.  14.03

X STA.         0.0       11.1       17.6       22.7       26.9       30.5
  A(I)            57.4       43.0       39.3       36.1       33.9
  V(I)            8.63      11.52      12.60      13.70      14.59

X STA.        30.5       33.5       36.3       38.8       41.0       43.2
  A(I)            31.8       30.4       29.5       28.6       28.0
  V(I)           15.57      16.30      16.76      17.34      17.69

X STA.        43.2       45.3       47.5       49.7       51.9       54.3
  A(I)            28.2       28.0       28.0       28.9       29.4
  V(I)           17.58      17.67      17.68      17.15      16.86

X STA.        54.3       57.0       60.2       64.2       69.5       84.5
  A(I)            31.5       34.1       37.2       41.7       61.0
  V(I)           15.71      14.51      13.30      11.87       8.11

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     104.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     2666    272470    486    492                        35452
             2     2316    363568    218    224                        42804
   508.78          4982    636038    704    716  1.14   -549    154    70482

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     104.

         WSEL     LEW     REW    AREA        K        Q    VEL
       508.78  -550.0   153.9  4982.3  636038.    9900.   1.99

X STA.      -550.0     -495.5     -445.0     -393.6     -344.4     -293.4
  A(I)           318.5      295.5      300.8      287.8      298.2
  V(I)            1.55       1.68       1.65       1.72       1.66

X STA.      -293.4     -242.7     -185.6      -91.9      -52.1      -33.7
  A(I)           300.3      310.7      389.1      275.1      198.7
  V(I)            1.65       1.59       1.27       1.80       2.49

X STA.       -33.7      -14.7       10.6       30.8       47.7       62.7
  A(I)           200.7      226.5      206.3      191.0      184.5
  V(I)            2.47       2.19       2.40       2.59       2.68

X STA.        62.7       77.5       91.2      103.8      118.0      153.9
  A(I)           182.4      179.6      178.0      193.5      265.2
  V(I)            2.71       2.76       2.78       2.56       1.87
```

```
       U.S. Geological Survey WSPRO Input File troy008.wsp
       Hydraulic analysis for structure TROYTH00120008   Date: 11-APR-97
       Town Highway 12 crossing the Missisquoi River, Troy, VT            EMB
          *** RUN DATE & TIME: 05-16-97  09:15

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

EXITX:XS   ******   -549     1556  0.82 *****  505.55  502.11    8460  504.73
       -96 ******    100   152546  1.79 ***** *******    0.83    5.44

FULLV:FV       97   -549     1880  0.56  0.25  505.79 *******    8460  505.23
         0     97    101   183704  1.78  0.00   -0.01    0.62    4.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.54

APPRO:AS      104   -549     2844  0.18  0.14  505.91 *******    8460  505.73
       104    104    149   282756  1.33  0.00   -0.02    0.30    2.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       97      0      691  3.62  0.46  507.41  502.35    8460  503.79
         0     97     85    98634  1.55  1.39    0.00    0.94   12.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.803 ******  511.86 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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       82   -549     4199  0.08  0.18  507.74  501.36    8460  507.67
       104    121    152   491301  1.19  0.16    0.01    0.16    2.01

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.879  0.763  116165.   -18.    67.   507.64

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -97.  -550.   100.   8460.  152546.    1556.    5.44  504.73
   FULLV:FV       0.  -550.   101.   8460.  183704.    1880.    4.50  505.23
   BRIDG:BR       0.     0.    85.   8460.   98634.     691.   12.25  503.79
   RDWAY:RG       9.**************      0.*****************     2.00********
   APPRO:AS     104.  -550.   152.   8460.  491301.    4199.    2.01  507.67

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -18.    67.  116165.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    502.11    0.83  491.44  510.96************  0.82   505.55  504.73
   FULLV:FV   ********   0.62  491.44  510.96  0.25  0.00  0.56   505.79  505.23
   BRIDG:BR    502.35    0.94  490.71  513.26  0.46  1.39  3.62   507.41  503.79
   RDWAY:RG  ***************  508.91  525.34**********************************
   APPRO:AS    501.36    0.16  493.98  519.68  0.18  0.16  0.08   507.74  507.67
```

```
        U.S. Geological Survey WSPRO Input File troy008.wsp
        Hydraulic analysis for structure TROYTH00120008   Date: 11-APR-97
        Town Highway 12 crossing the Missisquoi River, Troy, VT            EMB
           *** RUN DATE & TIME: 05-16-97  09:15

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

EXITX:XS   ******   -549     1831  0.81 *****  505.97  504.12    9900  505.16
       -96 ******    100   178565  1.78 ***** *******    0.76    5.41

FULLV:FV       97   -549     2156  0.56  0.25  506.22 *******    9900  505.66
         0     97    101   214239  1.71  0.00    0.00    0.58    4.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.51

APPRO:AS      104   -549     3140  0.20  0.15  506.36 *******    9900  506.16
       104    104    150   323484  1.29  0.00   -0.01    0.30    3.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       97      0      706  4.50  0.52  508.46  503.17    9900  503.97
         0     97     85   101960  1.47  1.97    0.00    1.04   14.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.825 ******  511.86 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.         <<<<<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       82   -549     4985  0.07  0.19  508.85  501.80    9900  508.78
       104    124    154   636605  1.14  0.20    0.01    0.14    1.99

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.879  0.785  136913.   -27.    58.   508.76

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -97.  -550.   100.   9900.  178565.    1831.    5.41  505.16
   FULLV:FV       0.  -550.   101.   9900.  214239.    2156.    4.59  505.66
   BRIDG:BR       0.     0.    85.   9900.  101960.     706.   14.03  503.97
   RDWAY:RG       9.**************      0.*****************     2.00********
   APPRO:AS     104.  -550.   154.   9900.  636605.    4985.    1.99  508.78

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -27.    58.  136913.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    504.12    0.76  491.44  510.96************  0.81  505.97  505.16
   FULLV:FV  ********    0.58  491.44  510.96  0.25  0.00  0.56  506.22  505.66
   BRIDG:BR    503.17    1.04  490.71  513.26  0.52  1.97  4.50  508.46  503.97
   RDWAY:RG  ****************  508.91  525.34**********************************
   APPRO:AS    501.80    0.14  493.98  519.68  0.19  0.20  0.07  508.85  508.78
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TROYTH00120008, in Troy, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number TROYTH00120008

General Location Descriptive

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

Date (MM/DD/YY) 03 / 07 / 95

Highway District Number (I - 2; nn) 09

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

Town (FIPS place code; I - 4; nnnnn) 73525

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

Waterway (I - 6) MISSISQUOI RIVER

Road Name (I - 7): -

Route Number TH012

Vicinity (I - 9) 0.06 MI TO JCT W C3 TH22

Topographic Map North.Troy

Hydrologic Unit Code: 02010007

Latitude (I - 16; nnnn.n) 44573

Longitude (i - 17; nnnnn.n) 72236

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10101700081017

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0091

Year built (I - 27; YYYY) 1910

Structure length (I - 49; nnnnnn) 000095

Average daily traffic, ADT (I - 29; nnnnnn) 000040

Deck Width (I - 52; nn.n) 116

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) 8

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 710

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) 16.0

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

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

Comments:

The structural inspection report of 6/29/93 indicates the structure is a lattice, timber thru-truss covered bridge. Both abutments are concrete, but may be concrete faced "laid up" stone. The right abutment has a hairline vertical crack below the roadway centerline. The concrete of each abutment is indicated on the inspection to be poured to ledge (bedrock). The left abutment is undermined at the downstream end according to the report. The undermined penetration was found to be up to 16 inches under the wall. There are no significant cracks in the left abutment concrete. The waterway makes a sharp bend just upstream of the bridge. The stream bank along the outside of the bend is composed **(Continued, page 32)**

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: sand & gravel & stones with some small boulders and bedrock

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} (*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:

of bedrock. The streambed is composed of silts and sand along the left abutment becoming more rocky toward the right. Scour and bank erosion were noted as not evident. There is a small silt and sand point bar extending along the left abutment. Riprap is noted as needed on the left abutment where “erosion” has occurred. Settlement is noted as not apparent.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **130.56** mi^2 Lake and pond area **0.35** mi^2

Watershed storage *(ST)* **0.2** %

Bridge site elevation **748** ft   Headwater elevation **3858** ft

Main channel length **22.00** mi

10% channel length elevation **689** ft   85% channel length elevation **1190** ft

Main channel slope *(S)* **30.36** 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)*: **02** / **1978**

Project Number **TH 3730** Minimum channel bed elevation: **N/A**

Low superstructure elevation: USLAB **N/A** DSLAB **N/A** USRAB **N/A** DSRAB **N/A**

Benchmark location description:

-

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

Foundation Type: **3** (*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: **N/A**

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

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

Briefly describe material at foundation bottom elevation or around piles:

The right abutment is noted as poured to bedrock on the structural inspection of 6/29/93. The left abutment is set in regolith.

Comments:

The plans available had no benchmark information and no elevations. The plans mainly covered the lattice part of the superstructure, which was reconstructed. No hydrologic information was provided.

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: **4/11/96**

Computerized by: **RB** Date: **4/11/96**

Reviewd by: **EMB** Date: **6/2/97**

Structure Number **TROYTH00120008**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **6** / **14** / 19**95**

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

County **ORLEANS (019)** Town **TROY (73525)**

Waterway *(I - 6)* **MISSISQUOI RIVER** Road Name **-**

Route Number **TH 12** Hydrologic Unit Code: **02010007**

3. Descriptive comments:

This bridge is a covered bridge located about 0.06 miles from the intersection of TH12 with TH22.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **4** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **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 **95** *(feet)* Span length **91** *(feet)* Bridge width **11.6** *(feet)*

Road approach to bridge:

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

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

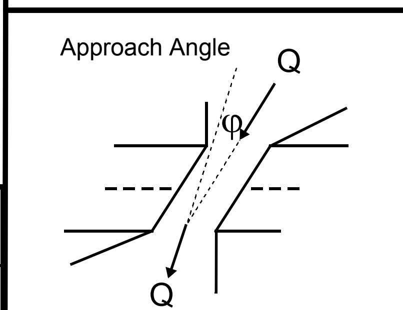
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

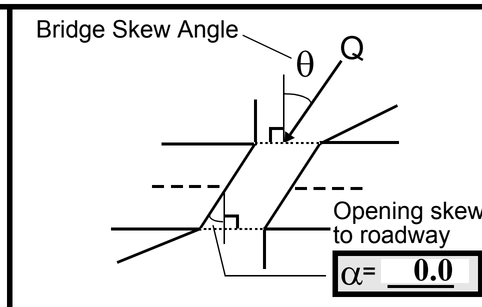
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	3	2
RBDS	0	-	2	1
LBDS	0	-	2	1

*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: **80** 16. Bridge skew: **10**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **35** feet **US** *(US, UB, DS)* to **135** feet **US**

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

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

18. Bridge Type: **1a**

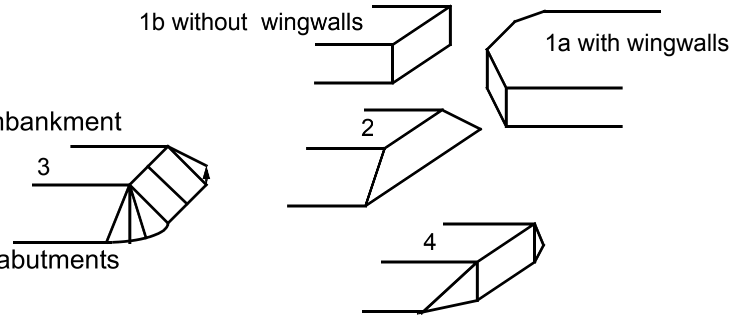
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The bridge dimension values are from the VTAOT files. A bridge width of 12.9 feet, a bridge length of 92.5 feet, and span length of 91.5 feet were measured in the field.
The right abutment has no wingwalls and thus the opening is type 1b. The left abutment is a type 1a opening up to about 2 feet below the low chord elevation at which point the opening is type 4.
The right bank US is mainly forested, then it flattens off to the road approach (TH22) and pasture. On the left bank US, the road approach forms the high bank which is mostly grass covered and then forest 30 feet from the waters edge. The DS left bank is virtually all pasture except for a couple of trees. The right bank DS is forest with a house and pasture on the high bank.
The channel impacts the US right bank where the road approach is located and makes a 90 degree bend to pass through the bridge. This is the main location where road wash runs down the embankment into the channel via. gullies. A similar but smaller gully is on the DS right road embankment. There are larger gullies that take water off the roadway and flow into the channel away from the bridge about 30 feet DS on the DS right bank and 10 feet DS on the DS left bank.

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
110.0	**4.0**			**5.0**	**3**	**3**	**243**	**564**	**1**	**2**

23. Bank width **35.0**   24. Channel width **15.0**   25. Thalweg depth **199.5**   29. Bed Material **324**

30 .Bank protection type: LB **0** RB **2**   31. Bank protection condition: LB **-** RB **1**

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

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

There is some bedrock at the surface on the right bank US. The rock is weathered and eroding at the road approach section mainly 5 feet to 35 feet US where road wash flows down the embankment. At high flow, the channel impacts this area too. There is almost no vegetation growing on this area of the embankment. A small channel is forming on the left side of the point bar on the left bank upstream.
The stone fill on the right bank extends from the US end of the right abutment to 45 feet US.
There are some bedrock outcrops on the streambed US but the majority of the bed material is fine to coarse gravel and medium to coarse sand with some cobbles.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **153** 35. Mid-bar width: **116**

36. Point bar extent: **300** feet **US** (US, UB) to **25** feet **US** (US, UB, DS) positioned **0** %LB to **80** %RB

37. Material: **324**

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

The bar is composed mostly of sand deposited on top of medium to coarse gravel and cobbles. The point bar is 80% covered with grasses and other vegetation.

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: **145** 42. Cut bank extent: **156** feet **US** (US, UB) to **135** feet **US** (US, UB, DS)

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

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

Some cutting of material is occurring where the main channel begins to proceed around the bend but ends where the bedrock outcrop begins 135 feet US to the US bridge face.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **220** Width **40** Depth : **5.5** Position **40** %LB to **80** %RB

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

Scour is deepest along the edge of the bedrock on the right bank side of the channel. There is a section of the channel bed that is bedrock from 10 to 20 feet out into the channel along the right bank side that forms a shelf where depths are only 1 to 1.5 feet. The depth drops to between 4 and 5 feet at the edge of the bedrock. The average channel depth elsewhere is around 2.5 feet.

49. Are there major confluences? **Y** (Y or if N type ctrl-n mc) 50. How many? **1**

51. Confluence 1: Distance **300** 52. Enters on **RB** (LB or RB) 53. Type **1** (**1**- perennial; **2**- ephemeral)

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

54. Confluence comments (eg. confluence name):

Jay branch of the Missisquoi River.

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
160.0		**3.5**		**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.):

326

Bedrock is visible at the surface under 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 2____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

2

Local residents indicated that ice accumulates on the point bar US. Then during the spring runoff the ice pounds against the right bank just US of the bridge and on the right abutment.

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	0	1	0	0	90.0
RABUT	1	-	90			2	0	86.5

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.):

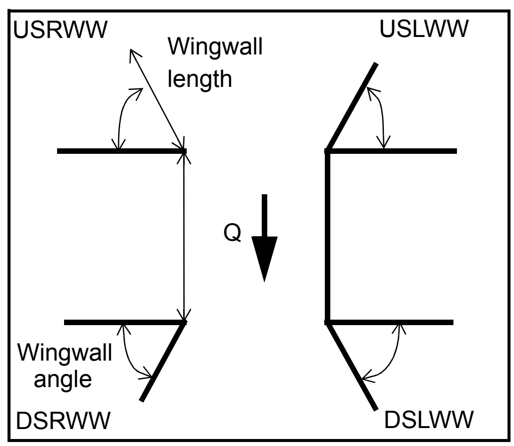
0
0
1

The right abutment is visibly set in bedrock at the surface. The left abutment has some sediment accumulation along the wall. Minor undermining of the left abutment wall is visible for the downstream-most 4 feet of the abutment and for 4 to 5 feet along the DS left wingwall from the end of the abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						86.5	
USRWW:	Y		1		0	7.5	
DSLWW:	-		-		N	15.5	
DSRWW:	-		-		-	19.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	1	N	-	-	-	-	2
Condition	Y	0	-	-	-	-	-	4
Extent	1	0	-	0	-	0	2	-

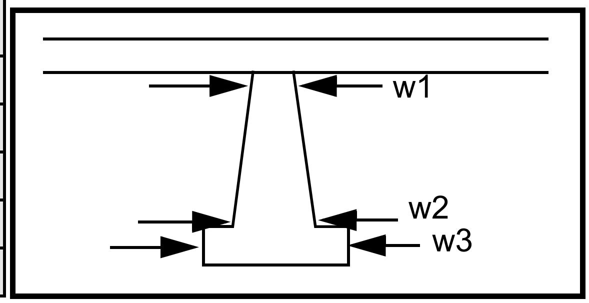
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
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	11.5	-
Pier 2			-	65.0	11.0	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is	the DS	rial is	where	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	some	left	no	some	1- Solid pier, 2- column, 3- bent
88. Material	stone	wing	lon-	mino	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	fill	wall.	ger	r	1- Round; 2- Square; 3- Pointed
90. Inclined?	pro-	It	cov-	unde	Y- yes; N- no
91. Attack ∠ (BF)	tect-	has	ering	rmin	
92. Pushed	ing	slum	the	ing is	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	the	ped	bot-	evi-	
95. Cross-members	entir	such	tom	dent.	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	e	that	of	Ther	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	lengt	the	the	e is	
98. Exposure depth	h of	mate	wall,	some	

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

class 2 stone fill at the US end of the right abutment from 2 to 5 feet under the bridge which is in contact with the bedrock outcrop. The bedrock outcrop drops below the ground elevation at the DS end of the right abutment and is in contact with type-1 stone fill, which protects the DS end of the right abutment and the DS right bank. Along the US left wingwall there are some bigger boulders that were deposited and embedded in the bank material that protect the wingwall. However, the boulder protection coverage is sparse.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

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

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: **1**

Scour dimensions: Length **4** Width **234** Depth: **643** Positioned **1** %LB to **0** %RB

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

342
0
1
-

Are there major confluences? **1** (Y or if N type ctrl-n mc) How many? **Bed-**

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

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

Confluence comments (eg. confluence name):

DS right bank with some deposited cobble and coarse gravel in places at its toe where the bedrock outcrop is set back from the channel. The right bank is protected from about 5 feet under the bridge to 25 feet DS where

F. Geomorphic Channel Assessment

107. Stage of reach evolution **the**

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)*:

bedrock outcrop appears again at the surface along the right edge of the water.

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: TROYTH00120008   Town: Troy
Road Number: TH 12   County: Orleans
Stream: Missisquoi River

Initials EMB   Date: 5/15/97   Checked: LKS   5/30/97

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	8460	9900	N/A
Main Channel Area, ft2	2075	2316	0
Left overbank area, ft2	2127	2666	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	217	218	0
Top width L overbank, ft	486	486	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.248	0.248	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.6	10.6	ERR
y1, average depth, LOB, ft	4.4	5.5	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	491793	636038	0
Conveyance, main channel	304510	363568	0
Conveyance, LOB	187283	272470	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	5238.3	5659.0	ERR
Ql, discharge, LOB, cfs	3221.7	4241.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	2.5	2.4	ERR
Vl, mean velocity, LOB, ft/s	1.5	1.6	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.3	10.4	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	N/A

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	8460	9900	N/A
Main channel area (DS), ft2	690.7	705.9	0
Main channel width (normal), ft	84.5	84.5	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	84.5	84.5	0.0
D90, ft	0.4030	0.4030	0.0000
D95, ft	0.4801	0.4801	0.0000
Dc, critical grain size, ft	0.4982	0.6480	ERR
Pc, Decimal percent coarser than Dc	0.044	0.016	0.000
Depth to armoring, ft	N/A	N/A	ERR

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	8460	9900	N/A
(Q) discharge thru bridge, cfs	8460	9900	0
Main channel conveyance	98631	102011	0
Total conveyance	98631	102011	0
Q2, bridge MC discharge,cfs	8460	9900	ERR
Main channel area, ft2	691	706	0
Main channel width (normal), ft	84.5	84.5	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	84.5	84.5	0
y_bridge (avg. depth at br.), ft	8.17	8.35	ERR
Dm, median (1.25*D50), ft	0.31	0.31	0
y2, depth in contraction,ft	8.97	10.26	ERR
ys, scour depth (y2-ybridge), ft	0.79	1.91	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	8460	9900	N/A	8460	9900	N/A
a', abut.length blocking flow, ft	119.1	119.1	0	67.7	69.4	0
Ae, area of blocked flow ft2	796.72	919.05	0	648.5	724.5	0
Qe, discharge blocked abut.,cfs	--	--	0	1613.8	1727.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.69	1.73	ERR	2.49	2.38	ERR
ya, depth of f/p flow, ft	6.69	7.72	ERR	9.58	10.44	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--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	0.135	0.125	ERR	0.142	0.130	ERR
ys, scour depth, ft	19.35	20.82	N/A	24.88	25.86	N/A

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

a'(abut length blocked, ft)	119.1	119.1	0	67.7	69.4	0
y1 (depth f/p flow, ft)	6.69	7.72	ERR	9.58	10.44	ERR
a'/y1	17.80	15.43	ERR	7.07	6.65	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.14	0.13	N/A	0.14	0.13	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.94	1	0	0.94	1	0
y, depth of flow in bridge, ft	8.17	8.35	0.00	8.17	8.35	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	3.36	3.49	ERR	3.36	3.49	ERR