LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (SHERTH00470032) on TOWN HIGHWAY 47, crossing ROARING BROOK, SHERBURNE, VERMONT

Open-File Report 98-258

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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LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (SHERTH00470032) on TOWN HIGHWAY 47, crossing ROARING BROOK, SHERBURNE, VERMONT

By MICHAEL A. IVANOFF AND TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

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CONTENTS

FIGURES

TABLES

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (SHERTH00470032) ON TOWN HIGHWAY 47, CROSSING ROARING BROOK, SHERBURNE, VERMONT

By **Michael A. Ivanoff and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHERTH00470032 on Town Highway 47 crossing Roaring Brook, Sherburne, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, 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 central Vermont. The 5.55-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of cut grass and a few houses upstream of the bridge with trees on the immediate banks. Downstream of the bridge is forested.

In the study area, Roaring Brook has an incised, straight channel with a slope of approximately 0.04 ft/ft, an average channel top width of 46 ft and an average bank height of 10 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 105 mm (0.343 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 2, 1995, indicated that the reach was stable.

The Town Highway 47 crossing of Roaring Brook is a 34-ft-long, two-lane bridge consisting of one 31-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 29.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The right abutment footing was exposed from 2 ft to 4 ft and the left abutment footing was exposed 2 ft as observed during the Level I assessment. The scour protection counter measures at the site included type-3 stone fill (less than 48 inches diameter) along the upstream left and right wingwalls and upstream left and right banks and type-2 stone fill (less than 36 inches diameter) along the upstream left and right banks. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. 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 0.3 to 0.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.8 to 7.8 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Pico Peak, VT. Quadrangle, 1:24,000, 1961
Photorevised 1980

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 SHERTH00470032 ***Stream*** Roaring Brook

County Rutland ***Road*** TH 47 ***District*** 3

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 26.0 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 10/2/95

Description of stone fill Type-3, along the upstream left and right wingwalls.

Abutments and wingwalls are concrete. The right abutment footing is exposed from 2 ft to 4 ft and the left abutment footing is exposed 2 ft.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 10

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	10/2/95	0	0
Level II	10/2/95	0	0

Potential for debris Low. Some debris has accumulated upstream.

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

In front of the downstream left wingwall, the side bar has covered with concrete as of 10/2/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a flat to slightly irregular narrow flood plain.

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

Date of inspection 10/2/95

DS left: Steep channel bank to a narrow flood plain

DS right: Steep channel bank to a narrow flood plain

US left: Steep channel bank to a moderately sloped overbank

US right: Steep channel bank to a narrow flood plain

Description of the Channel

Average top width 46 ***ft*** ***Average depth*** 10 ***ft***

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

Straight, perennial but flashy stream with non-alluvial channel boundaries and narrow side bars.

Vegetative co 10/2/95

DS left: Trees and brush

DS right: Trees and brush

US left: Short grass with a few trees

US right: Short grass with a few trees

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

None observed as of 10/2/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.55 ***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***: There are a couple of houses on the downstream left and right banks.

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 1,520 ***ft³/s*** ***Q500*** 2,370 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.55/3.0)exp 0.67] with flood frequency estimates for bridge number 26 in Sherburne available from the VTAOT database (written communication, May 1995). Bridge number 26, crossing Falls Brook has a similar drainage area (3.0 square miles) as Roaring Brook. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the US end of the right abutment (elev. 498.04 ft, arbitrary survey datum). RM2 is a chiseled X on top of the DS end of the DS left wingwall (elev. 499.11 ft, arbitrary survey datum). RM3 is a nail in a utility pole 4 ft up from the base at the US corner of the intersection of TH 47 and TH 1 (elev. 507.90 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	-36	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	56	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.070.

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 0.0379 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The approach section (APPRO) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100-year and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.0 ***ft***
Average low steel elevation 496.5 ***ft***

100-year discharge 1,520 ***ft³/s***
Water-surface elevation in bridge opening 491.7 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 128 ***ft²***
Average velocity in bridge opening 11.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.6 ***ft/s***

Water-surface elevation at Approach section with bridge 494.6
Water-surface elevation at Approach section without bridge 493.6
Amount of backwater caused by bridge 1.0 ***ft***

500-year discharge 2,370 ***ft³/s***
Water-surface elevation in bridge opening 493.2 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 173 ***ft²***
Average velocity in bridge opening 13.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.2 ***ft/s***

Water-surface elevation at Approach section with bridge 496.5
Water-surface elevation at Approach section without bridge 495.2
Amount of backwater caused by bridge 1.3 ***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 analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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	0.3	0.9	--
Depth to armoring	15.9	23.4	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.1	7.8	--
Right abutment	4.8	7.0	--
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	1.8	2.4	--
Right abutment	1.8	2.4	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

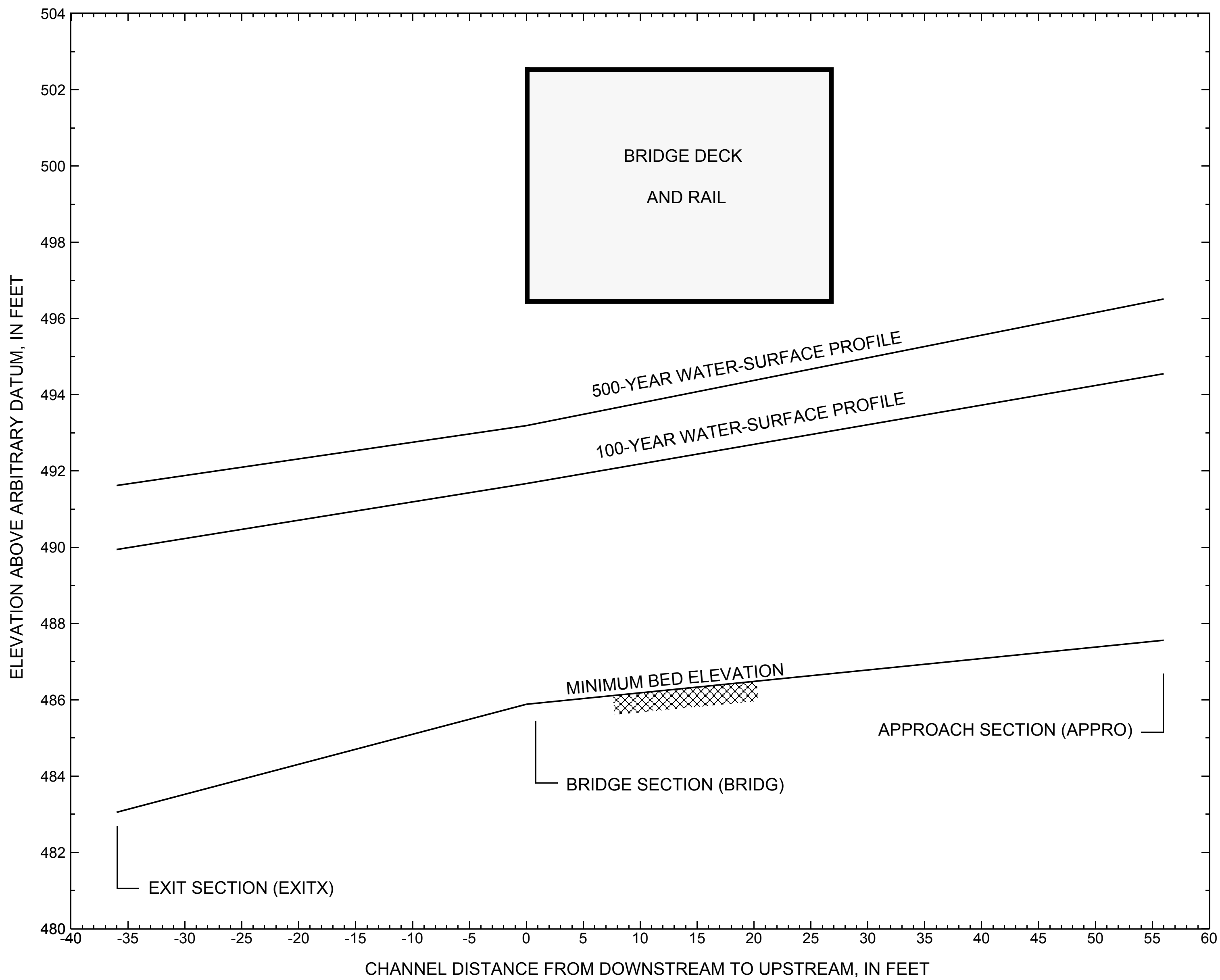

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SHERTH00470032 on Town Highway 47, crossing Roaring Brook, Sherburne, Vermont.

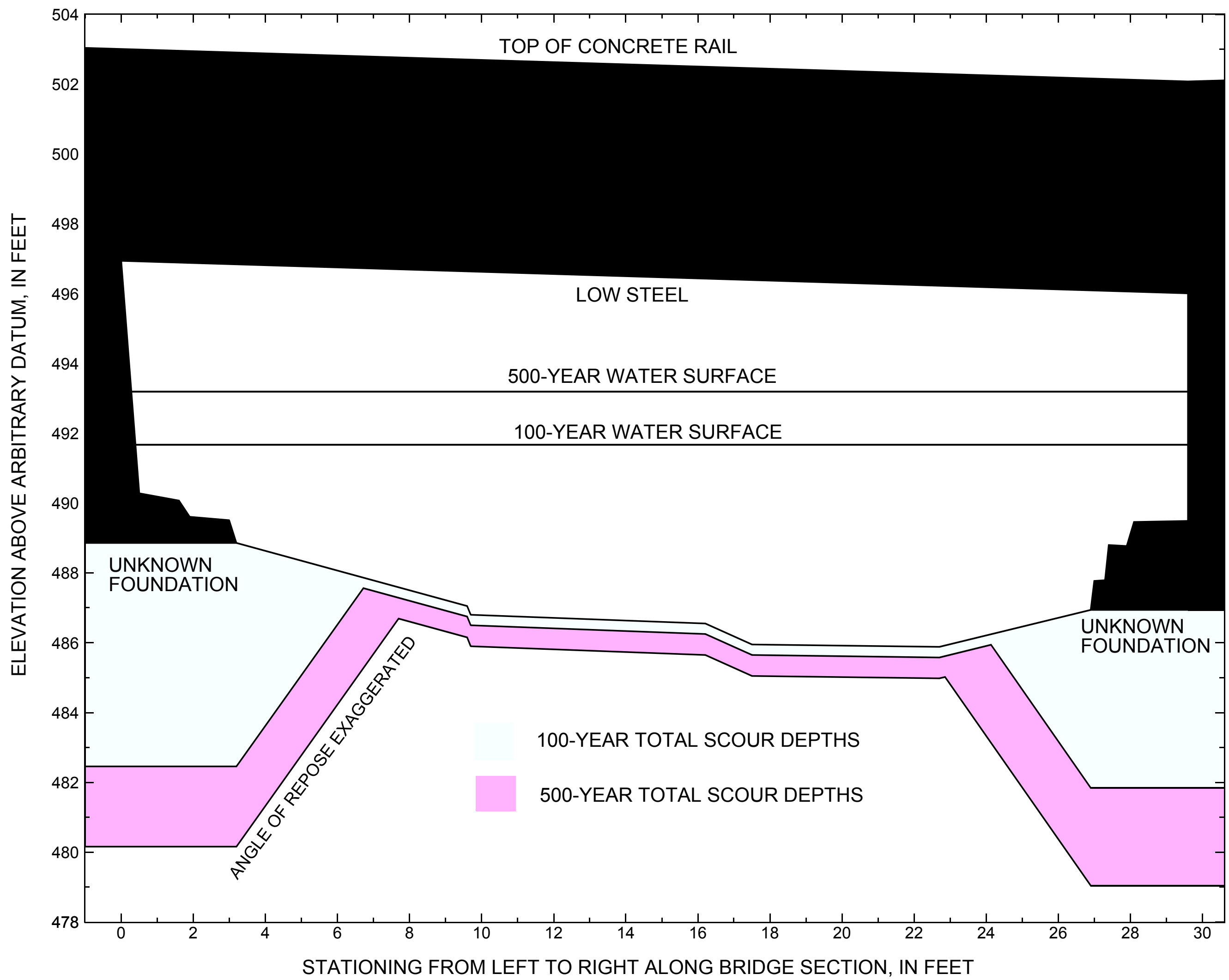

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SHERTH00470032 on Town Highway 47, crossing Roaring Brook, Sherburne, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHERTH00470032 on Town Highway 47, crossing Roaring Brook, Sherburne, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 1,520 cubic-feet per second											
Left abutment	0.0	--	496.9	--	488.9	0.3	6.1	--	6.4	482.5	--
Right abutment	29.6	--	496.0	--	486.9	0.3	4.8	--	5.1	481.8	--

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 SHERTH00470032 on Town Highway 47, crossing Roaring Brook, Sherburne, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 2,370 cubic-feet per second											
Left abutment	0.0	--	496.9	--	488.9	0.9	7.8	--	8.7	480.2	--
Right abutment	29.6	--	496.0	--	486.9	0.9	7.0	--	7.9	479.0	--

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, 1961, Pico Peak, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File sher032.wsp
T2        Hydraulic analysis for structure SHERTH00470032   Date: 26-NOV-97
T3        Bridge 32 on River Road over Roaring Brook in Sherburne, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1520.0   2370.0
SK          0.0379   0.0379
*
XS   EXITX    -36
GR         -116.9, 507.51    -68.8, 502.34    -55.7, 499.83    -15.9, 499.53
GR            0.0, 498.11     14.7, 485.33     20.6, 484.22     24.4, 483.05
GR           27.5, 483.38     31.8, 483.56     32.1, 484.23     36.4, 486.36
GR           46.3, 497.32     52.2, 498.28     84.5, 498.78
N           0.070
*
XS   FULLV      0  * * *   0.0410
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.48       0.0
GR            0.0, 496.94      0.5, 490.28      1.6, 490.07      1.9, 489.61
GR            3.0, 489.51      3.2, 488.86      9.6, 487.05      9.7, 486.80
GR           16.2, 486.55     17.5, 485.95     22.7, 485.88     26.9, 486.94
GR           26.9, 486.96     27.0, 487.77     27.3, 487.79     27.4, 488.80
GR           27.9, 488.77     28.1, 489.46     29.6, 489.49     29.6, 496.01
GR            0.0, 496.94
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      33.7 * *     45.6      6.8
N           0.055
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      26.0     1
GR         -118.8, 506.96    -91.1, 503.37    -67.9, 502.51    -16.5, 501.13
GR            0.0, 500.39      0.9, 503.01     34.3, 502.08     34.3, 499.61
GR           58.8, 498.88
*     150.5, 495.24
*
AS   APPRO     56
GR          -75.5, 508.06    -63.4, 504.76    -50.7, 502.85    -17.4, 500.41
GR          -11.1, 496.60      0.0, 490.33      4.2, 488.71      4.3, 487.67
GR            8.8, 487.56     11.7, 487.57     13.6, 488.23     17.1, 488.14
GR           20.6, 489.11     23.6, 490.36     32.3, 498.46     48.0, 499.34
GR           71.8, 499.20    127.8, 499.21
N           0.065
*
HP 1 BRIDG   491.67 1 491.67
HP 2 BRIDG   491.67 * * 1520
HP 1 APPRO   494.55 1 494.55
HP 2 APPRO   494.55 * * 1520
*
HP 1 BRIDG   493.19 1 493.19
HP 2 BRIDG   493.19 * * 2370
HP 1 APPRO   496.51 1 496.51
HP 2 APPRO   496.51 * * 2370
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File sher032.wsp
Hydraulic analysis for structure SHERTH00470032   Date: 26-NOV-97
Bridge 32 on River Road over Roaring Brook in Sherburne, VT  by MAI
   *** RUN DATE & TIME: 04-13-98  16:08

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     128.    8040.    29.    36.                         1521.
   491.67          128.    8040.    29.    36.  1.00     0.    30.   1521.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.67     0.4    29.6   128.0    8040.    1520.  11.87

X STA.         0.4         6.6         8.1         9.4        10.6        11.7
  A(I)            16.1         6.1         5.8         5.6         5.3
  V(I)            4.71       12.51       13.00       13.56       14.33

X STA.        11.7        12.7        13.8        14.8        15.8        16.9
  A(I)             5.2         5.2         5.3         5.2         5.4
  V(I)           14.52       14.69       14.46       14.52       14.16

X STA.        16.9        17.8        18.7        19.5        20.4        21.3
  A(I)             5.2         5.0         5.1         5.0         5.0
  V(I)           14.48       15.11       14.96       15.33       15.26

X STA.        21.3        22.1        23.0        23.9        24.8        29.6
  A(I)             4.9         5.0         5.1         5.0        17.6
  V(I)           15.60       15.27       14.95       15.15        4.33


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     169.   10064.    36.    40.                         2081.
   494.55          169.   10064.    36.    40.  1.00    -7.    28.   2081.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.55    -7.5    28.1   168.5   10064.    1520.   9.02

X STA.        -7.5         1.8         3.2         4.8         5.7         6.7
  A(I)            23.8         7.7         9.6         6.3         6.5
  V(I)            3.20        9.85        7.94       12.11       11.76

X STA.         6.7         7.6         8.5         9.4        10.3        11.3
  A(I)             6.4         6.5         6.4         6.5         6.5
  V(I)           11.88       11.78       11.94       11.66       11.67

X STA.        11.3        12.3        13.3        14.4        15.4        16.5
  A(I)             6.8         6.9         6.7         6.8         6.8
  V(I)           11.17       11.00       11.28       11.14       11.22

X STA.        16.5        17.6        18.7        19.9        21.3        28.1
  A(I)             6.7         6.9         7.0         7.4        20.3
  V(I)           11.29       10.99       10.80       10.27        3.74
```

```
      U.S. Geological Survey WSPRO Input File sher032.wsp
      Hydraulic analysis for structure SHERTH00470032   Date: 26-NOV-97
      Bridge 32 on River Road over Roaring Brook in Sherburne, VT  by MAI
         *** RUN DATE & TIME: 04-13-98  16:08


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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     173.   12524.    29.    39.                        2375.
 493.19          173.   12524.    29.    39.  1.00     0.    30.   2375.


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

       WSEL     LEW     REW    AREA        K        Q    VEL
     493.19     0.3    29.6   172.5   12524.    2370.  13.74

X STA.        0.3        5.9        7.4        8.7        9.9       11.0
  A(I)            21.9        8.0        7.4        7.7        7.1
  V(I)            5.40      14.80      16.10      15.48      16.78

X STA.       11.0       12.1       13.1       14.2       15.3       16.3
  A(I)             6.8        6.9        7.0        7.0        7.0
  V(I)           17.37      17.18      16.94      17.03      16.92

X STA.       16.3       17.4       18.3       19.2       20.1       21.0
  A(I)             7.3        6.7        6.7        6.7        6.6
  V(I)           16.33      17.73      17.59      17.60      17.98

X STA.       21.0       21.9       22.8       23.8       24.7       29.6
  A(I)             6.6        6.5        6.7        6.6       25.5
  V(I)           18.02      18.20      17.77      17.98       4.65


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     244.   16751.    41.    47.                        3365.
 496.51          244.   16751.    41.    47.  1.00   -11.    30.   3365.


  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.51   -10.9    30.2   243.7   16751.    2370.   9.73

X STA.      -10.9        0.4        2.0        3.4        5.0        6.0
  A(I)            36.0       10.9       10.3       12.9        8.9
  V(I)            3.29      10.88      11.49       9.21      13.26

X STA.        6.0        7.0        8.0        9.1       10.1       11.1
  A(I)             9.1        9.2        9.0        9.3        9.3
  V(I)           13.03      12.93      13.10      12.79      12.79

X STA.       11.1       12.2       13.4       14.5       15.7       16.8
  A(I)             9.7        9.9        9.8        9.5        9.5
  V(I)           12.26      11.97      12.15      12.50      12.52

X STA.       16.8       18.0       19.2       20.5       22.0       30.2
  A(I)             9.8        9.5       10.0       10.6       30.6
  V(I)           12.12      12.44      11.80      11.19       3.87
```

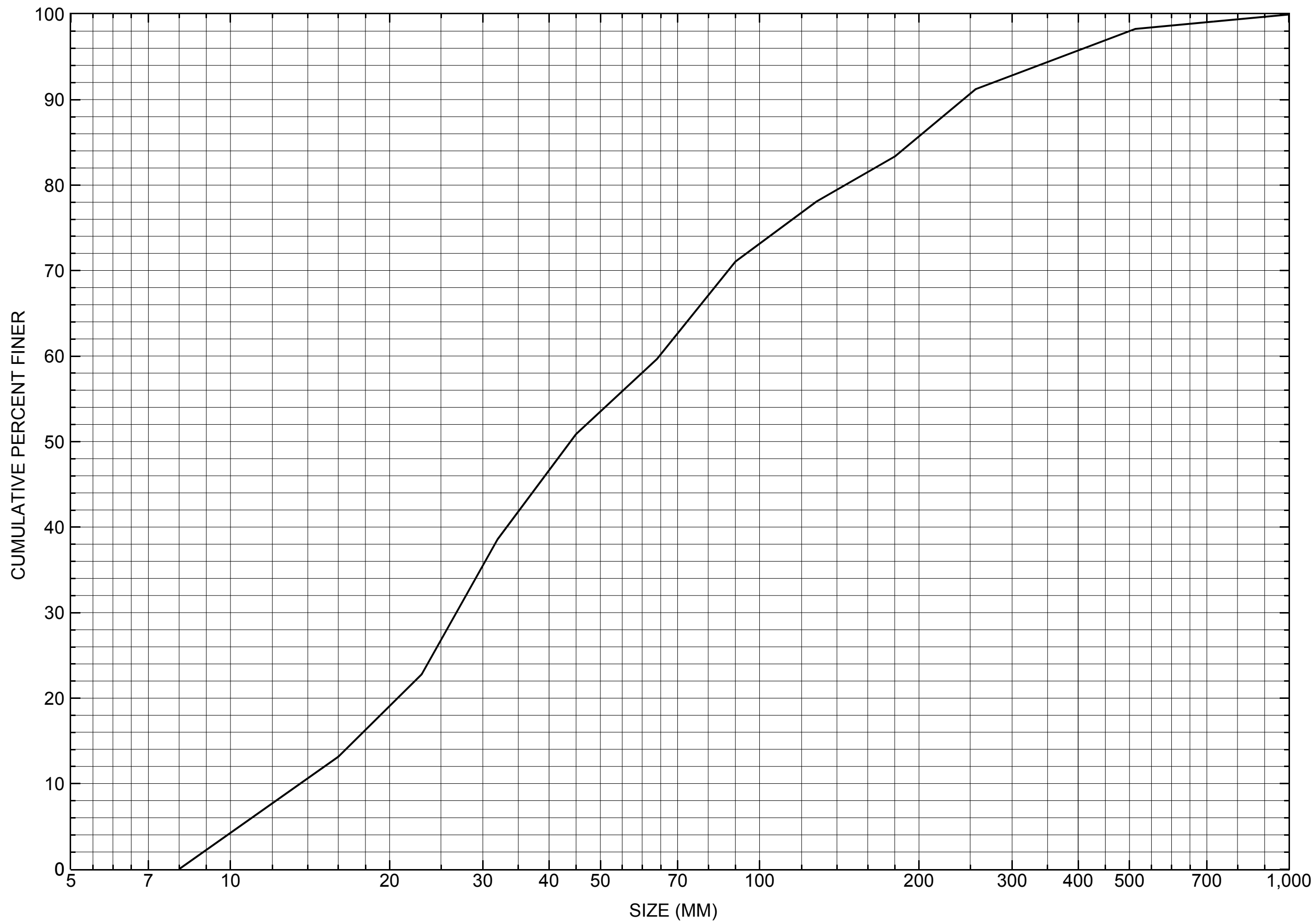
```
        U.S. Geological Survey WSPRO Input File sher032.wsp
        Hydraulic analysis for structure SHERTH00470032   Date: 26-NOV-97
        Bridge 32 on River Road over Roaring Brook in Sherburne, VT  by MAI
           *** RUN DATE & TIME: 04-13-98  16:08

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

EXITX:XS   ******     9.     143.  1.76 *****  491.70  489.45   1520.  489.94
      -36. ******    40.    7805.  1.00 ***** *******    0.86   10.63

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.89     491.32     490.93

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   489.44     508.99    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   489.44     508.99     490.93

FULLV:FV      36.    10.     140.  1.84  1.41  493.15  490.93   1520.  491.31
        0.    36.    40.    7563.  1.00  0.04    0.00    0.89   10.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.98     493.57     493.50

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   490.81     508.06    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   490.81     508.06     493.50

APPRO:AS      56.    -6.     135.  1.96  2.31  495.54  493.50   1520.  493.58
       56.    56.    27.    7407.  1.00  0.06    0.02    0.98   11.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    1520.     491.67

            <<<<<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      36.     0.     128.  2.19 *****  493.86  491.67   1520.  491.67
        0.    36.    30.    8038.  1.00 ***** *******    1.00   11.87

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.48 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      13.        <<<<<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      22.    -7.     168.  1.27  0.74  495.81  493.50   1520.  494.55
       56.    26.    28.   10059.  1.00  1.21   -0.02    0.73    9.02

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.111  0.000   10703.    -5.    24.   493.87

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -36.     9.    40.   1520.    7805.     143.   10.63  489.94
   FULLV:FV       0.    10.    40.   1520.    7563.     140.   10.87  491.31
   BRIDG:BR       0.     0.    30.   1520.    8038.     128.   11.87  491.67
   RDWAY:RG      13.***************      0.*****************    1.00********
   APPRO:AS      56.    -7.    28.   1520.   10059.     168.    9.02  494.55

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    24.   10703.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
   EXITX:XS     489.45    0.86  483.05  507.51************  1.76  491.70  489.94
   FULLV:FV     490.93    0.89  484.53  508.99  1.41  0.04  1.84  493.15  491.31
   BRIDG:BR     491.67    1.00  485.88  496.94************  2.19  493.86  491.67
   RDWAY:RG  ***************  498.88  506.96**********************************
   APPRO:AS     493.50    0.73  487.56  508.06  0.74  1.21  1.27  495.81  494.55
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File sher032.wsp
        Hydraulic analysis for structure SHERTH00470032   Date: 26-NOV-97
        Bridge 32 on River Road over Roaring Brook in Sherburne, VT  by MAI
           *** RUN DATE & TIME: 04-13-98  16:08

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

EXITX:XS   ******     7.     196.  2.26 *****  493.88  491.08   2370.  491.62
      -36. ******    41.   12164.  1.00 ***** *******    0.88   12.06

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.90     492.98     492.56

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.12     508.99    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.12     508.99     492.56

FULLV:FV      36.     8.     192.  2.36  1.41  495.33  492.56   2370.  492.97
        0.    36.    41.   11824.  1.00  0.05    0.00    0.90   12.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.96     495.19     495.03

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.47     508.06    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.47     508.06     495.03

APPRO:AS      56.    -9.     192.  2.38  2.21  497.56  495.03   2370.  495.18
       56.    56.    29.   12018.  1.00  0.01    0.01    0.96   12.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =   2370.     493.19

            <<<<<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      36.     0.     173.  2.94 *****  496.12  493.19   2370.  493.19
        0.    36.    30.   12523.  1.00 ***** *******    1.00   13.74

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.48 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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      22.   -11.     244.  1.47  0.66  497.98  495.03   2370.  496.51
       56.    24.    30.   16766.  1.00  1.21    0.01    0.70    9.72

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.216  0.000   17880.    -5.    24.   495.91

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -36.     7.    41.   2370.   12164.     196.   12.06  491.62
   FULLV:FV       0.     8.    41.   2370.   11824.     192.   12.31  492.97
   BRIDG:BR       0.     0.    30.   2370.   12523.     173.   13.74  493.19
   RDWAY:RG      13.**************      0.******************     1.00********
   APPRO:AS      56.   -11.    30.   2370.   16766.     244.    9.72  496.51

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    24.   17880.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     491.08    0.88  483.05  507.51************  2.26  493.88  491.62
   FULLV:FV     492.56    0.90  484.53  508.99  1.41  0.05  2.36  495.33  492.97
   BRIDG:BR     493.19    1.00  485.88  496.94************  2.94  496.12  493.19
   RDWAY:RG  ****************  498.88  506.96********************************
   APPRO:AS     495.03    0.70  487.56  508.06  0.66  1.21  1.47  497.98  496.51
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHERTH00470032, in Sherburne, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHERTH00470032

General Location Descriptive

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

Date (MM/DD/YY) 03 / 22 / 95

Highway District Number (I - 2; nn) 03

County (FIPS county code; I - 3; nnn) 021

Town (FIPS place code; I - 4; nnnnn) 64825

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

Waterway (I - 6) Roaring Brook

Road Name (I - 7): River Road

Route Number TH047

Vicinity (I - 9) 0.02 miles to the jct with TH1

Topographic Map Pico.Peak

Hydrologic Unit Code: 01080106

Latitude (I - 16; nnnn.n) 43395

Longitude (i - 17; nnnnn.n) 72464

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10112100321121

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0031

Year built (I - 27; YYYY) 1925

Structure length (I - 49; nnnnnn) 000034

Average daily traffic, ADT (I - 29; nnnnnn) 000060

Deck Width (I - 52; nn.n) 260

Year of ADT (I - 30; YY) 93

Channel & Protection (I - 61; n) 5

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

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 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) 010.0

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

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

Comments:

The structural inspection report of 7/5/93 indicates the structure is a concrete T-beam type bridge with an asphalt roadway surface. The abutment walls and wingwalls are concrete. The exposed footings of both abutments are reported as having been patched recently. There is some stone and boulder fill noted in front of the each abutment and wingwall, and along the channel banks. The report further indicates the stone fill noted on the right abutment has been partially eroded away from the wall. While the footings are exposed, undermining and settling are reported as not apparent.

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:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 5.55 mi^2

Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1220 ft

Headwater elevation 4235 ft

Main channel length 5.51 mi

10% channel length elevation 1460 ft

85% channel length elevation 2700 ft

Main channel slope *(S)* 300.07 ft / mi

Watershed Precipitation Data

Average site precipitation - in

Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 02/16/96
Computerized by: CG Date: 02/16/96
Reviewd by: MAI Date: 04/18/98

Structure Number SHERTH00470032

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 10 / 02 / 1995
2. Highway District Number 03 Mile marker -
County Rutland (021) Town Sherburne (64825)
Waterway *(I - 6)* Roaring brook Road Name River Road
Route Number TH047 Hydrologic Unit Code: 01080106
3. Descriptive comments:

This site is located 0.02 miles from the junction with Town Highway 1 and 100 ft downstream from US 4.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 6 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 2 UB 1 DS 2 *(**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 34 *(feet)* Span length 31 *(feet)* Bridge width 26 *(feet)*

Road approach to bridge:

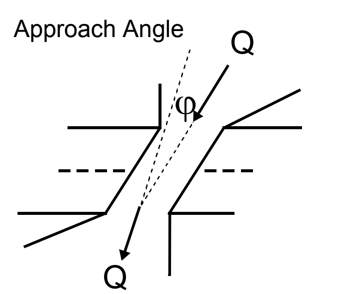
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

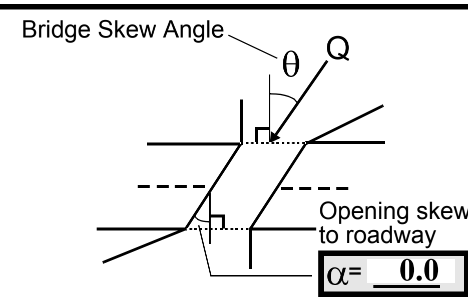
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	0

*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: 10 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 0 feet US *(US, UB, DS)* to 40 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 5 feet US *(US, UB, DS)* to 10 feet DS

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

18. Bridge Type: **1a**

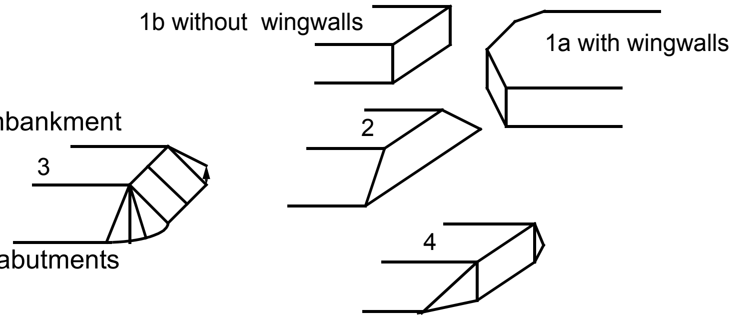
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

Measured bridge length = 34.2 ft; measured span length = 31.5 ft; measured width = 25.9 ft.
Both the left bank downstream and the right bank upstream have asphalt drainage channels for runoff.
"1925" is cast in the concrete railing on the upstream right bank.
There are guardrails at all four corners.
The U.S. route 4 bridge is 100 ft upstream.
The channel is fairly straight.
There are wood structures on both downstream banks with forest immediately beyond. Upstream (DS of U.S. route 4 bridge) there is a tree-lined bank with mowed grass beyond. Upstream of the Route 4 bridge is forest. The upstream right overbank decreases in elevation from the top of bank following U.S. route 4 to the valley floor.

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
30.5	**8.0**			**8.0**	**1**	**1**	**54**	**54**	**1**	**1**

23. Bank width **25.0** 24. Channel width **40.0** 25. Thalweg depth **43.5** 29. Bed Material **435**

30 .Bank protection type: LB **32** RB **32** 31. Bank protection condition: LB **1** RB **1**

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

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

The protection consists of boulders mostly along the left bank. This is a vertical V-shaped channel.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **10** 35. Mid-bar width: **12**

36. Point bar extent: **15** feet **US** *(US, UB)* to **18** feet **UB** *(US, UB, DS)* positioned **0** %LB to **50** %RB

37. Material: **4**

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

This is a side bar.

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
There is localized scour in the pools between riffles.

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
19.5		1.5		2	-	-	2

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **2**

*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.):

43
Erosion is evident along both abutments.
There is localized scour at the bridge, but it is not greater than in the upstream pools.
There is evidence of channel erosion under the bridge.

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

67. Debris Potential **US**___ *(**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:

2

-

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**	**-**	**2**	**90.0**
RABUT	**1**	**10**	**90**			**2**	**2**	**29.5**

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.):

-

4*

1

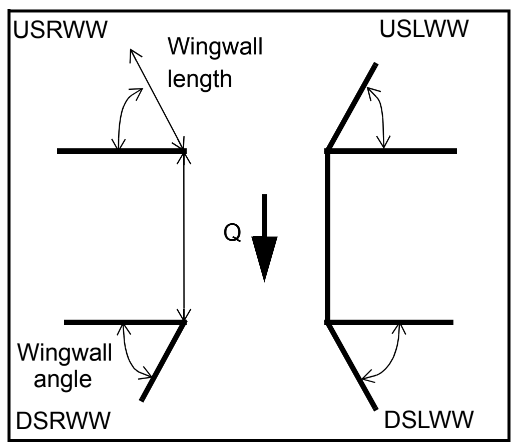
74. The left abutment footing is exposed (was undermined but has been repaired- form set and undermining filled in on the upstream and downstream ends). It is penetrable by 0.5 ft just upstream of the center of the abutment.

***A head-cut is occurring under the bridge. The footing exposure on the downstream right bank is 4 ft whereas the footing exposure on the upstream right bank is 2 ft.**

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**29.5**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**-**		**-**		**Y**	**26.5**	
DSRWW:	**1**		**0**		**-**	**27.0**	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**1**	**2**	**-**	**-**
Condition	**Y**	**-**	**1**	**4**	**1**	**1**	**-**	**-**
Extent	**1**	**-**	**3**	**3**	**3**	**0**	**0**	**-**

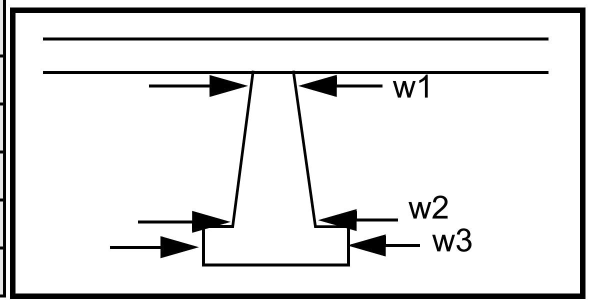
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
0
-
-

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				45.0	10.0	45.0
Pier 2	9.5	9.0	9.5	90.0	90.0	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is a	down-	bank.	erod-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	built	strea	The	ing	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	up/	m	bank	and	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	laid	left	at	mass	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	up	wing	the	wasti	*Y- yes; N- no*
91. Attack ∠ (BF)	stone	wall	end	ng	
92. Pushed	wall	that	of	has	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	at	con-	the	occu	
95. Cross-members	the	tinu-	right	rred.	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	end	ing	abut	80.	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	of	up	ment	Ther	
98. Exposure depth	the	the	is	e	

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

was undermining beneath the downstream right wingwall with 1 ft penetration with a range pole.
The side bar in front of the downstream left wingwall is covered with paved concrete.

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 - Thalweg depth - Bed Material -

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

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

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

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

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

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

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

Point bar extent: __-__ 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: __4__

Scour dimensions: Length __4__ Width __45__ Depth: __45__ Positioned __1__ %LB to __1__ %RB

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

453
-
-
-

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

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

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

Confluence comments (eg. confluence name):

protected to some extent due to large boulders in the bank.
There is localized scour occurring in pools downstream of the bridge.

F. Geomorphic Channel Assessment

107. Stage of reach evolution __Thi__

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)*:

s is a vertical V-shaped channel.

109. G. Plan View Sketch

N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	SHERTH00470032	Town:	Sherburne
Road Number:	TH 47 River Road	County:	Rutland
Stream:	Roaring Brook		

Initials MAI   Date: 12/5/97   Checked: RLB

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	1520	2370	0
Main Channel Area, ft2	169	244	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	36	41	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3434	0.3434	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.7	6.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	10064	16751	0
Conveyance, main channel	10064	16751	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1520.0	2370.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	9.0	9.7	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.2	10.6	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
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1520	2370	0
(Q) discharge thru bridge, cfs	1520	2370	0
Main channel conveyance	8040	12524	0
Total conveyance	8040	12524	0
Q2, bridge MC discharge,cfs	1520	2370	ERR
Main channel area, ft2	128	173	0
Main channel width (normal), ft	29.2	29.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.2	29.3	0
y_bridge (avg. depth at br.), ft	4.38	5.90	ERR
Dm, median (1.25*D50), ft	0.42925	0.42925	0
y2, depth in contraction,ft	4.66	6.81	ERR
ys, scour depth (y2-ybridge), ft	**0.28**	**0.90**	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	1520	2370	N/A
Main channel area (DS), ft2	128	173	0
Main channel width (normal), ft	29.2	29.3	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.2	29.3	0.0
D90, ft	1.3694	1.3694	0.0000
D95, ft	1.6563	1.6563	0.0000
Dc, critical grain size, ft	1.0578	1.2044	ERR
Pc, Decimal percent coarser than Dc	0.166	0.134	0.000
Depth to armoring, ft	**15.94**	**23.35**	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	1520	2370	0	1520	2370	0

a', abut.length blocking flow, ft	5.5	8.9	0	0.9	2.9	0
Ae, area of blocked flow ft2	14.08	28.35	0	2.69	10.82	0
Qe, discharge blocked abut.,cfs	44.95	93.33	0	10.06	41.91	0

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	3.19	3.29	ERR	3.74	3.87	ERR
ya, depth of f/p flow, ft	2.56	3.19	ERR	2.99	3.73	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	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	0.352	0.325	ERR	0.381	0.353	ERR
ys, scour depth, ft	**6.06**	**7.83**	N/A	**4.83**	**7.04**	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)	5.5	8.9	0	0.9	2.9	0
y1 (depth f/p flow, ft)	2.56	3.19	ERR	2.99	3.73	ERR
a'/y1	2.15	2.79	ERR	0.30	0.78	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.35	0.33	N/A	0.38	0.35	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	4.32	5.84	0.00	4.32	5.84	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.)	**1.81**	**2.44**	ERR	**1.81**	**2.44**	ERR