LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (SUTTTH00450004) on TOWN HIGHWAY 45, crossing CALENDER BROOK, SUTTON, VERMONT

Open-File Report 98-528

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 4 (SUTTTH00450004) on TOWN HIGHWAY 45, crossing CALENDER BROOK, SUTTON, VERMONT

By MICHELLE M. SERRA AND LAURA MEDALIE

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Pembroke, New Hampshire

1998

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CONTENTS

Conversion Factors, Abbreviations, and Vertical Datum iv
Introduction and Summary of Results 1
Level II summary 7
Description of Bridge 7
Description of the Geomorphic Setting 8
Description of the Channel 8
Hydrology 9
Calculated Discharges 9
Description of the Water-Surface Profile Model (WSPRO) Analysis 10
Cross-Sections Used in WSPRO Analysis 10
Data and Assumptions Used in WSPRO Model 11
Bridge Hydraulics Summary 12
Scour Analysis Summary 13
Special Conditions or Assumptions Made in Scour Analysis 13
Scour Results 14
Riprap Sizing 14
Selected References 18

Appendices:
A. WSPRO input file 19
B. WSPRO output file 21
C. Bed-material particle-size distribution 26
D. Historical data form 28
E. Level I data form 34
F. Scour computations 44

FIGURES

1. Map showing location of study area on USGS 1:24,000 scale map 3
2. Map showing location of study area on Vermont Agency of Transportation town highway map 4
3. Structure SUTTTH00450004 viewed from upstream (August 3, 1995) 5
4. Downstream channel viewed from structure SUTTTH00450004 (August 3, 1995). 5
5. Upstream channel viewed from structure SUTTTH00450004 (August 3, 1995). 6
6. Structure SUTTTH00450004 viewed from downstream (August 3, 1995). 6
7. Water-surface profiles for the 100- and 500-year discharges at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont. 15
8. Scour elevations for the 100- and 500-year discharges at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont. 16

TABLES

1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont 17
2. Remaining footing/pile depth at abutments for the 500-year discharge at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont 17

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 4 (SUTTTH00450004) ON TOWN HIGHWAY 45, CROSSING CALENDER BROOK, SUTTON, VERMONT

By **Michelle M. Serra and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SUTTTH00450004 on Town Highway 45 crossing Calender Brook, Sutton, 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 White Mountain section of the New England physiographic province in northeastern Vermont. The 15.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge on the left overbank while the immediate bank is covered by trees. Downstream of the bridge is forested as is the upstream right bank.

In the study area, Calender Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 47 ft and an average bank height of 4 ft. The channel bed material ranges from sand to boulders with a median grain size (D_{50}) of 93.8 mm (0.308 ft). The geomorphic assessment at the time of the Level I and Level II site visits on August 2 and 3, 1995, indicated that the reach was stable.

The Town Highway 45 crossing of Calender Brook is a 44-ft-long, one-lane bridge consisting of one 41-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March, 28, 1995). The opening length of the structure parallel to the bridge face is 40 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 55 degrees to the opening while the opening-skew-to-roadway is 25 degrees.

A scour hole 3.3 ft deeper than the mean thalweg depth was observed in the center of the channel on the upstream side of the bridge during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream right wingwall. There is a concrete slab, presumably a former wingwall, located in front of the upstream left wingwall that is protecting the wingwall from scour. Both the left and right abutments have exposed footings. There is no undermining reported in the structural inspection on 10/31/1994. However, the inspection indicated a vertical settling crack was observed in the left abutment wall. 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 0.6 to 1.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.1 to 15.3 ft. The worst-case abutment scour also 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. 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.

Lyndonville, and Sutton VT. Quadrangles, 1:24,000, 1986

NORTH

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

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

LEVEL II SUMMARY

Structure Number SUTTTH0450004 ***Stream*** Calender Brook

County Caledonia ***Road*** TH45 ***District*** 7

Description of Bridge

Bridge length 44 ***ft*** ***Bridge width*** 20.4 ***ft*** ***Max span length*** 41 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Nearly vertical

Stone fill on abutment? No ***Date of inspection*** 8/2/95

Description of stone fill Type-2 stonefill protects the upstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. Both of the abutments have exposed footings. The upstream left and downstream right wingwalls also have exposed footings.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 55

There is a severe channel bend in the upstream reach as well as a moderate bend in the downstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/2/95	0	0
Level II	8/2/95	0	0

Potential for debris Debris potential for the bridge is low.

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

None as of 8/2/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with little to no flood plains and steep to moderately sloped valley sides.

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

Date of inspection 8/2/95

DS left: Steep channel bank to an irregular overbank

DS right: Steep channel bank

US left: Steep channel bank to a mildly sloped overbank

US right: Steep channel bank

Description of the Channel

Average top width 47 ***ft***

Average depth 4 ***ft***

Predominant bed material Gravel / Cobbles

Bank material Sand/Boulders

Perennial but flashy, sinuous and stable with non-alluvial channel boundaries and narrow point bars.

8/2/95

Vegetative co Forest

DS left: Forest

DS right: Trees on the immediate bank with grass lawn and a house on the overbank.

US left: Forest.

US right:

Do banks appear stable? Yes

If not, describe location and type of instability and date of observation.

The banks appear stable, but there are some cut-banks on both banks downstream of the bridge. The right bank cut-bank is within one bridge length, the left bank cut-bank is located further downstream.

None as of 8/2/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 15.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None as of 8/2/95

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 2,360 ***ft³/s*** ***Q500*** 3,500 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(15.1/20.5)exp 0.7] with flood frequency estimates available from the VTAOT database (written communication, March 1995) for bridge 14 crossing Calender Brook in Burke. These area adjusted values were within a range defined by flood frequency curves derived 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 Subtract 399.4 ft from USGS arbitrary survey datum to obtain VTAOT plans' datum to nearest foot.

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on the corner of the upstream left wingwall and the left abutment (elev. 498.31 ft, arbitrary survey datum). RM2 is a chiseled "X" on the corner of the upstream right wingwall and the right abutment (elev. 498.41 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	-43	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	63	2	Modelled Approach section (Templated from APTEM)
APTEM	73	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.050, and overbank "n" values ranged from 0.040 to 0.055.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0190 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0120 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.1 ***ft***
Average low steel elevation 496.1 ***ft***

100-year discharge 2,360 ***ft^3/s***
Water-surface elevation in bridge opening 490.9 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 189 ***ft^2***
Average velocity in bridge opening 12.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 493.3
Water-surface elevation at Approach section without bridge 492.6
Amount of backwater caused by bridge 0.7 ***ft***

500-year discharge 3,500 ***ft^3/s***
Water-surface elevation in bridge opening 492.3 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 239 ***ft^2***
Average velocity in bridge opening 14.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.2 ***/s***

Water-surface elevation at Approach section with bridge 495.5
Water-surface elevation at Approach section without bridge 494.0
Amount of backwater caused by bridge 1.5 ***ft***

Incipient overtopping discharge - ***ft^3/s***
Water-surface elevation in bridge opening - ***ft***
Area of flow in bridge opening - ***ft^2***
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 100- and 500-year scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100- 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	0.6	1.6	--
Depth to armoring	22.7	37.1	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	7.1 8.9	-- 11.4	15.3
Left abutment	--	--	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.2	2.8
Pier 3			

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:	--	2.2	2.8
Left abutment	--	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

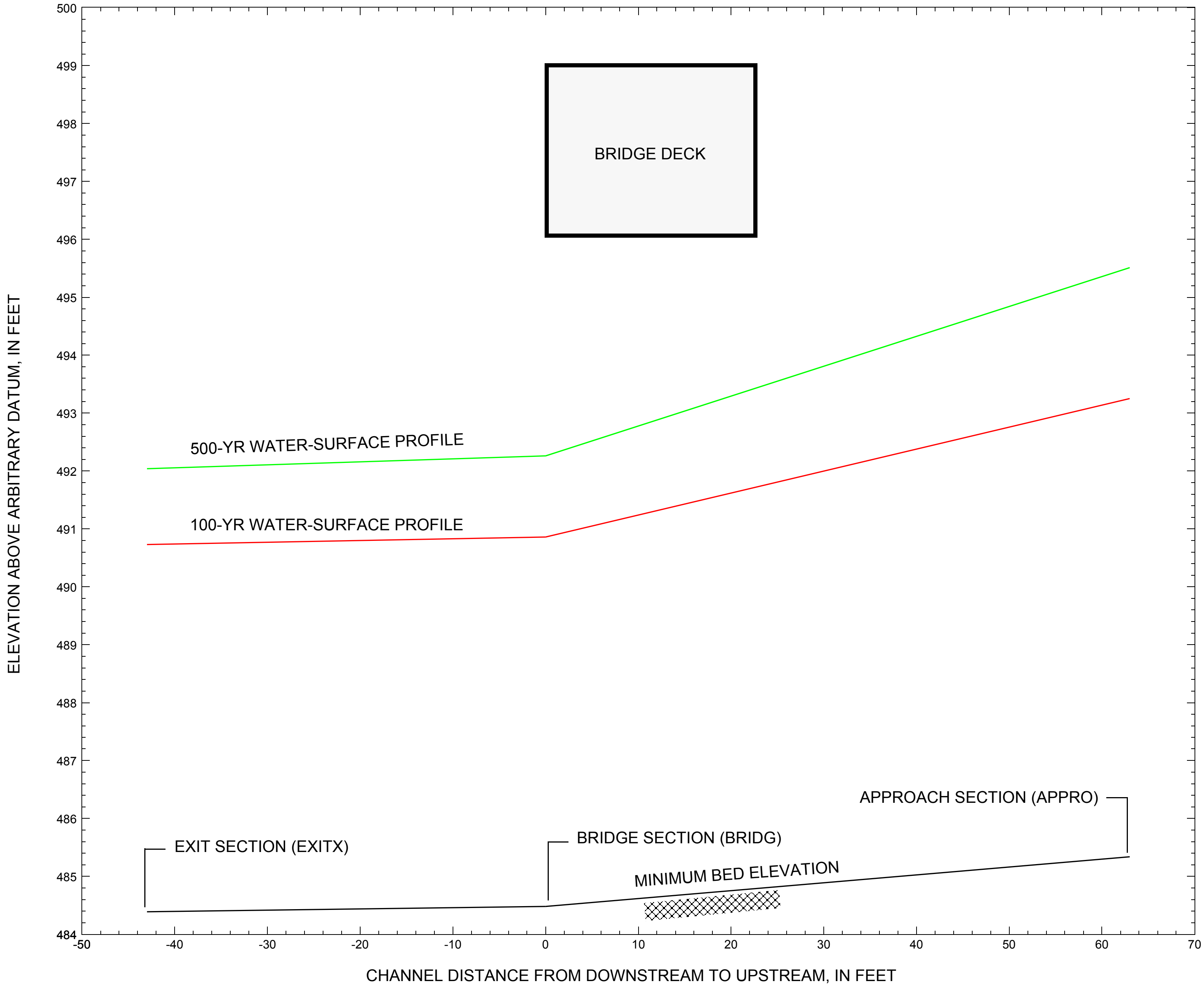

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont.

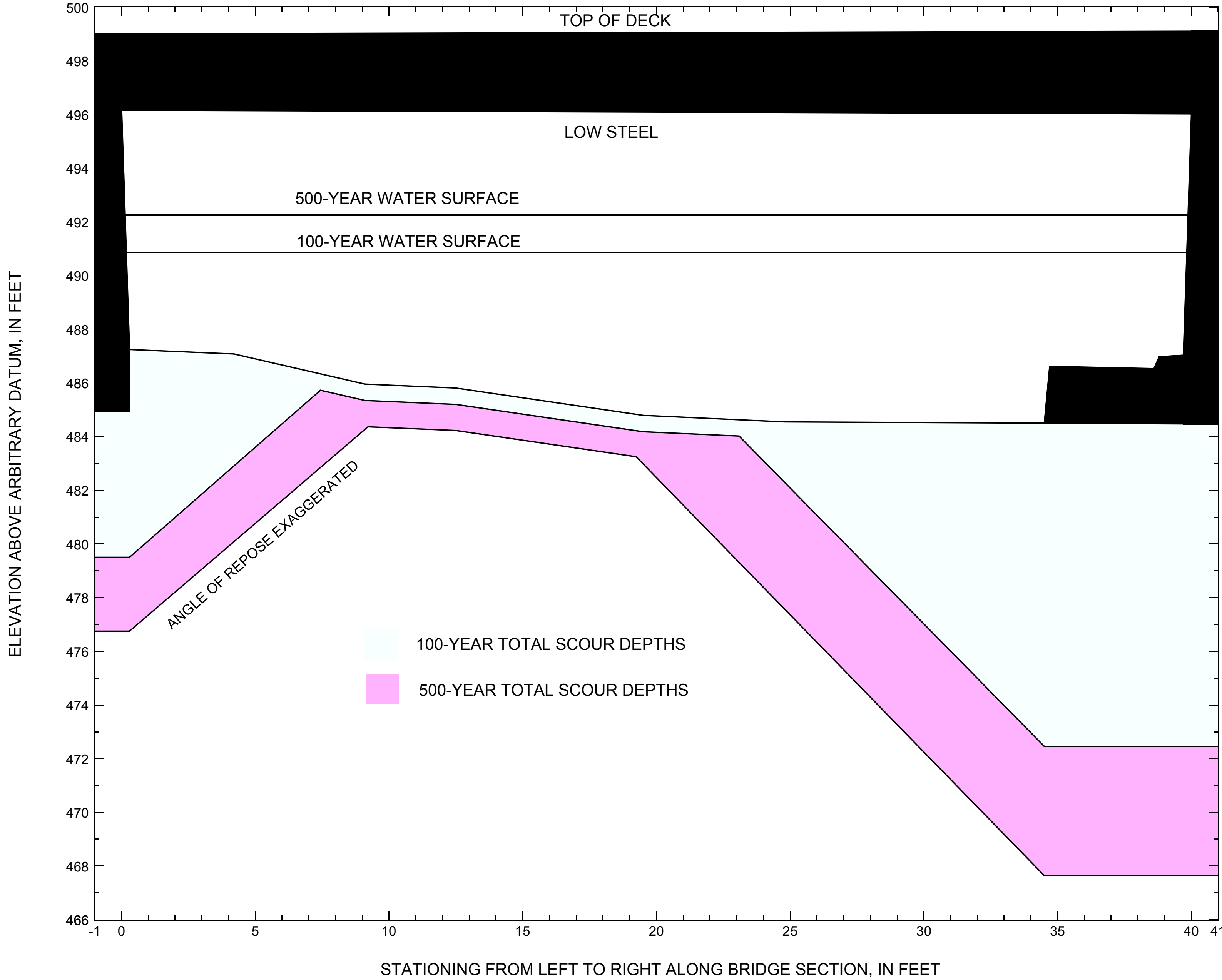

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont.

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

Description	Station[1]	VTAOT top of abutment elevation (feet)	Surveyed top of abutment 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 2,360 cubic-feet per second											
Left abutment	0.0	98.9	498.3	485	487.3	0.6	7.1	--	7.7	479.6	-5
Right abutment	40.0	98.9	498.4	485	484.5	0.6	11.4	--	12.0	472.5	-13

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 SUTTTH00450004 on Town Highway 45, crossing Calender Brook, Sutton, Vermont.

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

Description	Station[1]	VTAOT top of abutment elevation (feet)	Surveyed top of abutment 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 3,500 cubic-feet per second											
Left abutment	0.0	98.9	498.3	485	487.3	1.6	8.9	--	10.5	476.8	-8
Right abutment	40.0	98.9	498.4	485	484.5	1.6	15.3	--	16.9	467.6	-17

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

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File sutt004.wsp
T2        Hydraulic analysis for structure suttth00450004   Date: 07-AUG-97
T3        hydraulic analysis of bridge 4 in sutton over calender brook
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          2360.0   3500.0
SK         0.0190   0.0190
*
XS   EXITX    -43           0.
GR         -261.4, 507.03    -62.5, 494.56    -37.3, 494.46     -6.1, 492.60
GR            0.0, 489.05      5.4, 485.90     15.7, 485.91     20.3, 485.74
GR           23.4, 485.48     29.1, 484.95     33.6, 484.39     37.3, 484.73
GR           37.7, 485.73     41.5, 486.10     42.4, 487.32     47.1, 489.94
GR           56.3, 496.46     66.8, 497.10    126.3, 501.08    140.5, 506.77
GR          164.4, 511.92
*
N          0.055        0.050
SA                 -6.1
*
XS   FULLV      0  * * *   0.0040
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    496.10      25.0
GR            0.0, 496.16      0.3, 487.25      4.2, 487.08      9.1, 485.96
GR           12.5, 485.81     19.5, 484.79     24.8, 484.55     29.5, 484.55
GR           34.5, 484.48     34.7, 486.62     38.6, 486.54     38.8, 486.98
GR           39.7, 487.04     40.0, 496.03      0.0, 496.16
*
*        BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      30.0 * *     14.6       18
N          0.040
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     13      20.4     1
GR         -260.0, 504.04   -255.5, 512.08   -233.9, 509.19   -228.1, 507.36
GR         -220.3, 507.14   -196.5, 501.71   -133.6, 500.64    -92.2, 499.98
GR            0.0, 499.01     40.2, 499.11     66.0, 499.66    104.9, 501.79
GR          148.9, 505.65
*
*          EXPECTED SRD =   63 AT ONE BR. LENGTH BUT COMPUTED SRD =   73
*
XT   APTEM     73           0.
GR         -231.1, 512.34   -216.2, 510.17   -208.9, 504.86   -159.3, 502.57
GR         -139.8, 498.22    -93.8, 498.55    -75.8, 499.57    -48.0, 498.93
GR          -38.1, 498.76    -31.7, 500.62    -22.9, 500.25    -19.6, 498.93
GR          -10.3, 498.34      0.0, 491.85      5.1, 487.45      7.6, 486.87
GR            8.9, 486.10     19.2, 485.46     25.9, 486.17     32.1, 486.72
GR           38.2, 487.24     41.0, 489.64     49.6, 490.15     55.5, 495.71
GR           67.7, 497.03    102.5, 523.45
*
AS   APPRO     63  * * *  0.0120
GT
N          0.040        0.050
SA               -10.3
*
HP 1 BRIDG  490.86 1 490.86
HP 2 BRIDG  490.86 * * 2360
HP 1 APPRO  493.25 1 493.25
HP 2 APPRO  493.25 * * 2360
*
HP 1 BRIDG  492.26 1 492.26
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File sutt004.wsp
       Hydraulic analysis for structure suttth00450004   Date: 07-AUG-97
       hydraulic analysis of bridge 4 in sutton over calender brook
          *** RUN DATE & TIME: 01-06-98  10:11
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      189     18106     36     46                          2454
  490.86           189     18106     36     46  1.00      0     40      2454

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      490.86     0.2    39.8   188.7   18106.    2360.  12.51

X STA.         0.2        4.9        7.8       10.0       12.0       13.9
  A(I)            15.6       11.1        9.7        9.3        8.7
  V(I)            7.56      10.60      12.17      12.75      13.54

X STA.        13.9       15.7       17.3       18.8       20.2       21.6
  A(I)             8.5        8.3        8.1        7.7        7.8
  V(I)           13.81      14.15      14.55      15.27      15.07

X STA.        21.6       23.0       24.4       25.7       27.1       28.5
  A(I)             7.6        7.7        7.9        7.8        8.0
  V(I)           15.43      15.28      14.98      15.09      14.80

X STA.        28.5       30.0       31.5       33.1       35.6       39.8
  A(I)             8.4        8.6        9.2       12.6       15.9
  V(I)           14.10      13.75      12.76       9.36       7.42


   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            2      305     26878     55     60                          4063
  493.25           305     26878     55     60  1.00     -1     53      4063

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.25    -2.4    53.0   305.2   26878.    2360.   7.73

X STA.        -2.4        5.9        8.5       10.5       12.3       14.1
  A(I)            25.8       16.4       14.8       13.5       13.3
  V(I)            4.57       7.21       7.99       8.73       8.87

X STA.        14.1       15.7       17.4       18.9       20.5       22.1
  A(I)            12.8       12.6       12.3       12.6       12.3
  V(I)            9.25       9.39       9.61       9.38       9.59

X STA.        22.1       23.8       25.6       27.4       29.4       31.4
  A(I)            12.7       12.8       13.3       13.4       14.1
  V(I)            9.28       9.22       8.86       8.82       8.39

X STA.        31.4       33.6       35.9       38.6       43.6       53.0
  A(I)            14.2       15.2       16.3       21.1       25.9
  V(I)            8.32       7.74       7.24       5.60       4.56
```

```
        U.S. Geological Survey WSPRO Input File sutt004.wsp
        Hydraulic analysis for structure suttth00450004   Date: 07-AUG-97
        hydraulic analysis of bridge 4 in sutton over calender brook
           *** RUN DATE & TIME: 01-06-98  10:11
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      239     25813     36     48                         3495
   492.26           239     25813     36     48  1.00      0     40     3495

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       492.26     0.1    39.9   239.1   25813.    3500.  14.64

X STA.         0.1        4.7        7.4        9.6       11.6       13.4
  A(I)            20.6       13.8       12.1       11.6       10.9
  V(I)            8.49      12.68      14.51      15.10      16.10

X STA.        13.4       15.2       16.8       18.3       19.8       21.2
  A(I)            10.6       10.3       10.0        9.9        9.8
  V(I)           16.51      16.92      17.58      17.60      17.89

X STA.        21.2       22.6       24.0       25.5       26.9       28.3
  A(I)             9.6        9.7        9.9        9.8       10.3
  V(I)           18.17      18.02      17.68      17.80      17.04

X STA.        28.3       29.8       31.4       33.1       35.7       39.9
  A(I)            10.3       11.1       11.7       16.2       20.9
  V(I)           17.00      15.75      14.99      10.80       8.38

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      437     45228     61     68                         6620
   495.51           437     45228     61     68  1.00     -5     55     6620

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA         K        Q    VEL
       495.51    -6.0    55.4   437.2   45228.    3500.   8.01

X STA.        -6.0        4.8        7.7       10.0       12.0       14.0
  A(I)            39.0       24.6       21.8       19.6       19.2
  V(I)            4.48       7.12       8.03       8.94       9.10

X STA.        14.0       15.9       17.7       19.4       21.2       23.0
  A(I)            18.4       18.1       17.6       17.9       17.6
  V(I)            9.51       9.67       9.92       9.76       9.94

X STA.        23.0       24.8       26.7       28.7       30.8       33.0
  A(I)            18.0       18.2       18.4       19.0       19.6
  V(I)            9.72       9.62       9.50       9.21       8.92

X STA.        33.0       35.3       37.8       41.3       45.9       55.4
  A(I)            20.2       21.3       25.3       26.7       36.6
  V(I)            8.65       8.22       6.91       6.56       4.79
```

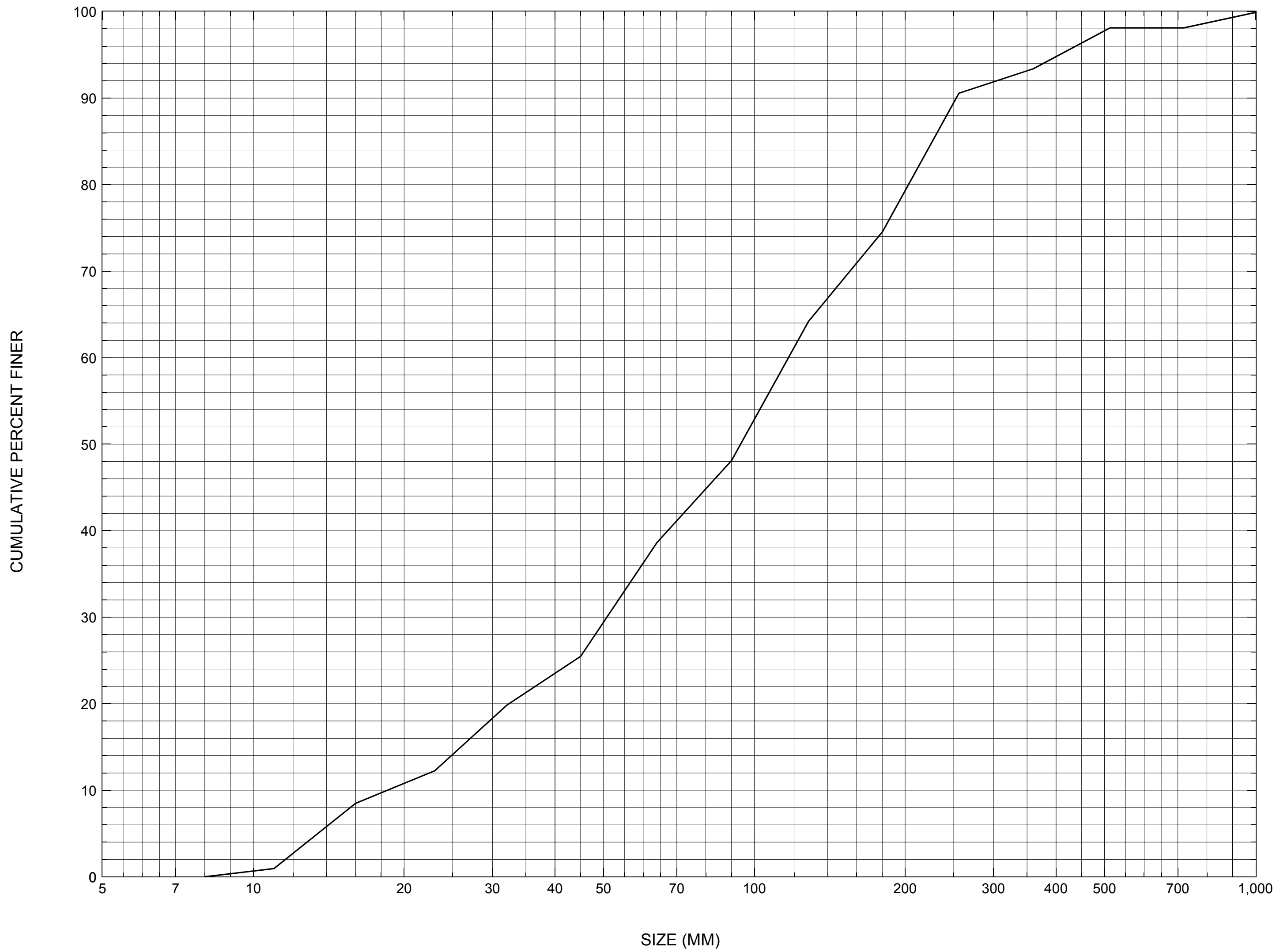
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File sutt004.wsp
        Hydraulic analysis for structure suttth00450004   Date: 07-AUG-97
        hydraulic analysis of bridge 4 in sutton over calender brook
           *** RUN DATE & TIME: 01-06-98  10:11

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

EXITX:XS   ******     -2      224  1.72 *****  492.46  490.35    2360  490.73
       -42 ******     48    17110  1.00 ***** *******    0.89   10.52

FULLV:FV       43     -4      277  1.13  0.60  493.04 *******    2360  491.91
         0     43     50    23303  1.00  0.00   -0.02    0.66    8.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       63      0      268  1.21  0.68  493.77 *******    2360  492.57
        63     63     52    22190  1.00  0.04    0.02    0.70    8.81
         <<<<<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       43      0      189  2.43  0.77  493.29  490.73    2360  490.86
         0     43     40    18113  1.00  0.06   -0.01    0.96   12.50

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.10 ****** ****** ******

    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       33     -1      305  0.93  0.39  494.18  491.38    2360  493.25
        63     34     53    26903  1.00  0.51    0.01    0.58    7.73

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.259  0.005   26651.     1.    40.   492.92

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -43.    -3.    48.   2360.   17110.     224.   10.52  490.73
   FULLV:FV       0.    -5.    50.   2360.   23303.     277.    8.51  491.91
   BRIDG:BR       0.     0.    40.   2360.   18113.     189.   12.50  490.86
   RDWAY:RG      13.**************       0.******************     1.00********
   APPRO:AS      63.    -2.    53.   2360.   26903.     305.    7.73  493.25

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    40.   26651.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    490.35    0.89  484.39  511.92************  1.72  492.46  490.73
   FULLV:FV  ********    0.66  484.56  512.09  0.60  0.00  1.13  493.04  491.91
   BRIDG:BR    490.73    0.96  484.48  496.16  0.77  0.06  2.43  493.29  490.86
   RDWAY:RG  ****************  499.01  512.08**********************************
   APPRO:AS    491.38    0.58  485.34  523.33  0.39  0.51  0.93  494.18  493.25
```

```
        U.S. Geological Survey WSPRO Input File sutt004.wsp
        Hydraulic analysis for structure suttth00450004   Date: 07-AUG-97
        hydraulic analysis of bridge 4 in sutton over calender brook
           *** RUN DATE & TIME: 01-06-98  10:11

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

EXITX:XS   ******     -4      294  2.20 *****  494.25  491.67    3500  492.04
       -42 ******     50    25374  1.00 ***** *******    0.91   11.91

FULLV:FV       43    -15      363  1.47  0.60  494.84 *******    3500  493.37
         0     43     52    34361  1.01  0.00   -0.01    0.74    9.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       63     -3      349  1.56  0.69  495.59 *******    3500  494.03
        63     63     54    32718  1.00  0.05    0.02    0.72   10.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3500.     492.26

            <<<<<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       43      0      239  3.33 *****  495.59  492.26    3500  492.26
         0     43     40    25828  1.00 ***** *******    1.00   14.63

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.10 ****** ****** ******

    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       33     -5      437  1.00  0.36  496.51  492.69    3500  495.51
        63     35     55    45210  1.00  0.55    0.01    0.53    8.01

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.307  0.029   43851.     2.    41.   495.25

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -43.    -5.    50.   3500.   25374.     294.   11.91  492.04
   FULLV:FV       0.   -16.    52.   3500.   34361.     363.    9.65  493.37
   BRIDG:BR       0.     0.    40.   3500.   25828.     239.   14.63  492.26
   RDWAY:RG      13.**************      0.*****************     1.00********
   APPRO:AS      63.    -6.    55.   3500.   45210.     437.    8.01  495.51

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    41.   43851.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL     WSEL
   EXITX:XS    491.67    0.91  484.39  511.92************  2.20  494.25  492.04
   FULLV:FV  ********    0.74  484.56  512.09  0.60  0.00  1.47  494.84  493.37
   BRIDG:BR    492.26    1.00  484.48  496.16************  3.33  495.59  492.26
   RDWAY:RG  ****************  499.01  512.08**********************************
   APPRO:AS    492.69    0.53  485.34  523.33  0.36  0.55  1.00  496.51  495.51
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SUTTTH00450004, in Sutton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SUTTTH00450004

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 28 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 71575

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

Waterway *(I - 6)* CALENDAR BROOK

Road Name *(I - 7):* -

Route Number TH045

Vicinity *(I - 9)* 0.1 MI JCT TH 45 + TH 1

Topographic Map Lyndonville

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44371

Longitude *(i - 17; nnnnn.n)* 72010

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031400040314

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

Maximum span length *(I - 48; nnnn)* 0041

Year built *(I - 27; YYYY)* 1926

Structure length *(I - 49; nnnnnn)* 000044

Average daily traffic, ADT *(I - 29; nnnnnn)* 000150

Deck Width *(I - 52; nn.n)* 204

Year of ADT *(I - 30; YY)* 92

Channel & Protection *(I - 61; n)* 5

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

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

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.4

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

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

Comments:

The structural inspection report of 10/31/94 indicates the structure is a concrete T-beam type bridge. The abutment walls and wingwalls are concrete. The right abutment footing is exposed and the concrete is spalled, with areas of section loss. The abutment and its wingwall faces have a few fine cracks and small leaks reported overall. The abutment has been patched, but the patchwork is starting to break out again. The left abutment has alligator cracks and leaks at both ends reported. There also is a vertical settling crack in the face. Boulder fill is reported along the banks up- and downstream of the bridge. The banks also are reported as showing signs of erosion from previous flooding. **(Continued, page 31)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Stones and boulders.

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:

The report indicates the channel has scoured down 2 to 3 feet in front of the upstream end of the left abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **15.11** mi^2 Lake/pond/swamp area **0.03** mi^2

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

Bridge site elevation **958** ft Headwater elevation **2544** ft

Main channel length **6.77** mi

10% channel length elevation **1043** ft 85% channel length elevation **1673** ft

Main channel slope *(S)* **93.06** 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)*: **04** / **1926**

Project Number **-** Minimum channel bed elevation: **-**

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

Benchmark location description:

There is no benchmark information shown on the plans. The plans show a few points with elevations: 1) the point on the top streamward edge of the concrete where the right abutment and upstream right wingwall meet, elevation 98.92, and 2) the point at the same location but where the upstream left wingwall and left abutment meet, elevation 98.92.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **85.5**

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

If 3: Footing bottom elevation: ____

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

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

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

With the current structural problems, the elevation on the right upstream corner of the abutment may be more reliable. The left abutment is reported as having settled.

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: EW Date: 03/22/96
Computerized by: EW Date: 03/22/96
Reviewd by: MS Date: 01/07/98

Structure Number SUTTTH00450004

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 08 / 02 / 1995

2. Highway District Number 07 Mile marker 000000

County CALEDONIA (005) Town SUTTON (71575)

Waterway *(I - 6)* CALENDAR BROOK Road Name -

Route Number TH045 Hydrologic Unit Code: 01080102

3. Descriptive comments:

This bridge is located 0.1 miles from the junction of Town Highway 45 and Town Highway 1.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 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 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 44 *(feet)* Span length 41 *(feet)* Bridge width 20.4 *(feet)*

Road approach to bridge:

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

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

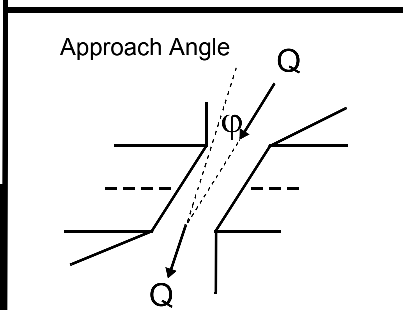
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

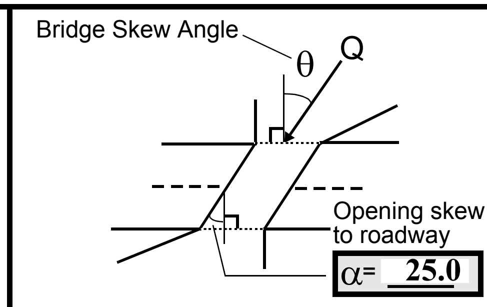
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	2	1	3	2
RBDS	2	1	2	1
LBDS	0	-	0	-

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 55





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 60 feet US *(US, UB, DS)* to 10 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 15 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**

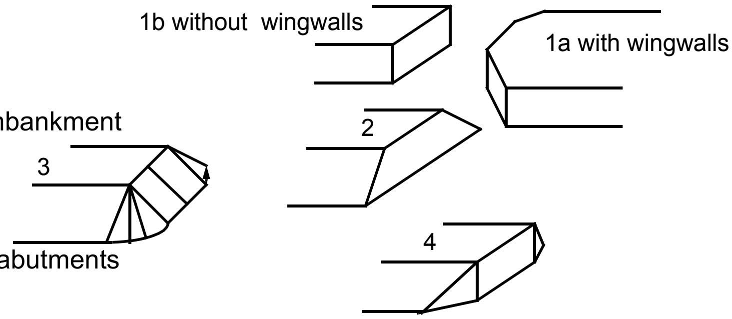
1a- Vertical abutments with wingwalls

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.)

#7: These values are from VTAOT; the measured values are: bridge length = 45 feet, bridge span = 41 feet, and bridge width = 20 feet.
#11: On the upstream right bank, the road approach protection is also the right bank of the tributary stream described in #49. The upstream left bank has road approach stone fill type-2 protection (few boulders) just above the wingwall subfooting; additionally, some asphalt exists to protect the road approach.
#17: The left bank impact zone ends at the upstream end of the left abutment. The right bank impact zone starts at the upstream confluence and ends at the downstream end of the right abutment.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
36.5	**4.5**			**2.5**	**2**	**3**	**2345**	**4325**	**1**	**1**

23. Bank width **40.0** 24. Channel width **40.0** 25. Thalweg depth **41.0** 29. Bed Material **4325**

30 .Bank protection type: LB **3** RB **0** 31. Bank protection condition: LB **1** RB **-**

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

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

The left bank protection consists of stone fill which extends from 60 feet US to 20 feet US (US end of the USLWW). There is also poured asphalt up to 80 feet upstream.
#26: Percent vegetation cover on the left bank increases from category 3 to 4 (76% to 100%) at 100 feet US from the bridge.

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

36. Point bar extent: 20 feet US (US, UB) to 60 feet US (US, UB, DS) positioned 85 %LB to 100 %RB

37. Material: 342

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

This is an unvegetated point 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? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 5US

47. Scour dimensions: Length 44 Width 22 Depth : 3.3 Position 10 %LB to 90 %RB

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

Average thalweg is one foot.

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

51. Confluence 1: Distance 15 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):

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
33.0		1.5		2	7	7	-

58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 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.):

3452

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

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

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

70. Debris and Ice Comments:

1

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**	**2**	**-**	**1**	**90.0**
RABUT	**1**	**70**	**90**			**0**	**2**	**36.0**

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

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

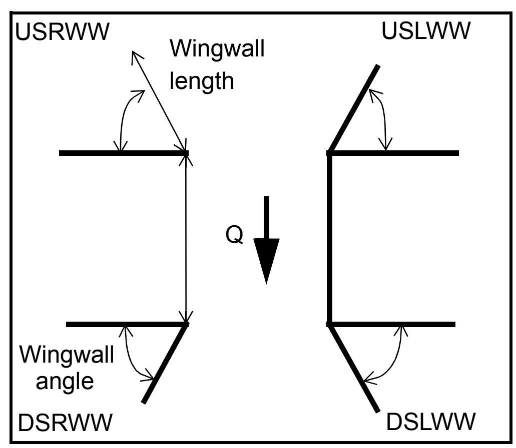
-
2
1

#76: The exposure depth at the right abutment is at a maximum at the downstream end; at the upstream end much of the footing has been washed away (exposure depth is 0.5 feet). The left abutment footing is only exposed from the upstream end to about 10 feet along the abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**36.0**	
USRWW:	**Y**		**1**		**2**	**1.5**	
DSLWW:	**-**		**1.5**		**Y**	**25.5**	
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**	**-**	**4***	**1**	**-**	**-**
Condition	**Y**	**-**	**1**	**1.7**	**1**	**2**	**-**	**-**
Extent	**1**	**-**	**2**	**5***	**2**	**0**	**0**	**-**

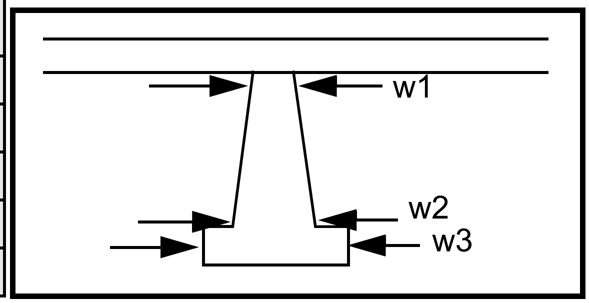
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length; **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? **#80** *(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	0.0			23.5	25.0	14.0
Pier 2				115.0	14.5	40.0
Pier 3		-	-	11.0	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	: The	the	has a	nel	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	upst	right	pre-	and	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	ream	abut	vious	lies	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	right	ment	wing	almo	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	wing	.	wall	st	*Y- yes; N- no*
91. Attack ∠ (BF)	wall	#82:	that	hori-	
92. Pushed	is at	The	has	zon-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	a 90	upst	falle	tal in	
95. Cross-members	degr	ream	n	the	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	ee	left	into	strea	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	angl	wing	the	m	
98. Exposure depth	e to	wall	chan	bed.	

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

Only the downstream end of upstream left wingwall (at the corner of the left abutment) has exposed footing. The downstream left wingwall extends out along same face as the left abutment. It is protected effectively by a side bar.

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: **3**

Scour dimensions: Length **4** Width **4523** Depth: **235** Positioned **2** %LB to **2** %RB

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

435
0
3
-

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

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

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

Confluence comments (eg. confluence name):

the left bank increases to category 4 (76% to 100%) 90 feet downstream from the bridge. Right bank protection extends from the end of the downstream right wingwall to 20 feet downstream.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

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

N

109. G. Plan View Sketch

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: SUTTTH00450004 Town: Sutton
Road Number: TH45 County: Caledonia
Stream:

Initials MS Date: 09/30/97 Checked:EB

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	2360	3500	0
Main Channel Area, ft2	305	437	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	55	61	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.308	0.308	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.5	7.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	26878	45228	0
Conveyance, main channel	26878	45228	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	2360.0	3500.0	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	7.7	8.0	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	10.1	10.5	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?

	100 yr	500 yr	other Q
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	2360	3500	0
(Q) discharge thru bridge, cfs	2360	3500	0
Main channel conveyance	18106	25813	0
Total conveyance	18106	25813	0
Q2, bridge MC discharge,cfs	2360	3500	ERR
Main channel area, ft2	189	239	0
Main channel width (normal), ft	35.9	36.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.9	36.1	0
y_bridge (avg. depth at br.), ft	5.26	6.62	ERR
Dm, median (1.25*D50), ft	0.385	0.385	0
y2, depth in contraction,ft	5.88	8.20	ERR
ys, scour depth (y2-ybridge), ft	0.61	1.58	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	2360	3500	N/A
Main channel area (DS), ft2	189	239	0
Main channel width (normal), ft	35.9	36.1	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	35.9	36.1	0.0
D90, ft	0.8295	0.8295	0.0000
D95, ft	1.3314	1.3314	0.0000
Dc, critical grain size, ft	0.8309	1.0314	ERR
Pc, Decimal percent coarser than Dc	0.099	0.077	0.000
Depth to armoring, ft	22.69	37.09	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	2360	3500	0	2360	3500	0
a', abut.length blocking flow, ft	4.5	8	0	15	17.3	0
Ae, area of blocked flow ft2	13.99	28.89	0	50.62	86.43	0
Qe, discharge blocked abut.,cfs	63.98	129.63	0	262.22	510	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.57	4.49	ERR	5.18	5.90	ERR
ya, depth of f/p flow, ft	3.11	3.61	ERR	3.37	5.00	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	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.457	0.416	ERR	0.497	0.465	ERR
ys, scour depth, ft	7.14	8.92	N/A	11.41	15.26	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)	4.5	8	0	15	17.3	0
y1 (depth f/p flow, ft)	3.11	3.61	ERR	3.37	5.00	ERR
a'/y1	1.45	2.22	ERR	4.44	3.46	ERR
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.06	1.06	1.06
Froude no. f/p flow	0.46	0.42	N/A	0.50	0.47	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	0.96	1	0	0.96	1	0
y, depth of flow in bridge, ft	5.26	6.62	0.00	5.26	6.62	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.)	2.17	2.77	ERR	2.17	2.77	ERR