LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (BRATTH00120007) on TOWN HIGHWAY 12, crossing HALLADAY BROOK, BRATTLEBORO, VERMONT

Open-File Report 98-074

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

U.S. Department of the Interior

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By RONDA L. BURNS and ERICK M. BOEHMLER

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Pembroke, New Hampshire

1998

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 7 (BRATTH00120007) ON TOWN HIGHWAY 12, CROSSING HALLADAY BROOK, BRATTLEBORO, VERMONT

By **Ronda L. Burns and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRATTH00120007 on Town Highway 12 crossing Halladay Brook, Brattleboro, 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 (Federal Highway Administration, 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 New England Upland section of the New England physiographic province in southeastern Vermont. The 5.53-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture while the immediate banks upstream have some trees and shrubs.

In the study area, Halladay Brook has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 29 ft and an average bank height of 5 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 66.6 mm (0.219 ft). There is also a bedrock outcrop in the channel upstream. The geomorphic assessment at the time of the Level I and Level II site visit on August 14, 1996, indicated that the reach was stable.

The Town Highway 12 crossing of Halladay Brook is a 28-ft-long, two-lane bridge consisting of one 25-foot concrete slab span (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 21.9 ft. The bridge is supported by vertical, laid-up stone abutments with laid-up stone wingwalls, except for the downstream right wingwall which is concrete. The channel is skewed approximately 55 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the right abutment and downstream right wingwall during the Level I assessment. The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the downstream right wingwall, type-2 stone fill (less than 36 inches diameter) along the upstream right bank, and a type-5 laid-up stone retaining wall on the upstream left bank. 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. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 1.1 to 3.4 ft. The worst-case contraction scour occurred at the 100-year discharge. The left abutment scour ranged from 1.7 to 2.8 ft. The worst-case left abutment scour occurred at the 500-year discharge. The right abutment scour ranged from 4.6 to 4.8 ft. The worst-case right 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.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number BRATTH00120007 ***Stream*** Halladay Brook

County Windham ***Road*** TH 12 ***District*** 2

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 20.2 ***ft*** ***Max span length*** 25 ***ft***

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

Abutment type Vertical, laid-up stone ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 8/14/96

Description of stone fill Type-1, at the downstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are laid-up stone except for the downstream right wingwall which is concrete. There is a one foot deep scour hole in front of the right abutment and downstream right wingwall.

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

There is a moderate channel bend through the bridge. The scour hole has developed in the location where the flow impacts the right abutment and downstream right wingwall.

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	8/14/96	0	0
Level II	8/14/96	0	0

Potential for debris Low.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 8/14/96.

Description of the Geomorphic Setting

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

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

Date of inspection 8/14/96

DS left: Moderately sloped overbank

DS right: Narrow flood plain

US left: Mildly sloped overbank

US right: Narrow flood plain

Description of the Channel

Average top width 29 ***ft*** ***Average depth*** 5 ***ft***

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

Straight and stable with semi-alluvial channel boundaries.

8/14/96

Vegetative co

Grass and brush with lawn on the overbank

DS left: Shrubs and brush with lawn on the overbank

DS right: Grass and brush with a few trees and lawn on the overbank

US left: Trees and brush with lawn and a gravel road on the overbank

US right:

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

The assessment of 8/14/96 noted bedrock on the right side of the upstream channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.53 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

-

Calculated Discharges

Q100 1,580 ***ft***^{3}***/s*** ***Q500*** 2,250 ***ft***^{3}***/s***

The 100- and 500-year discharges are the median values from a range defined by flood frequency curves developed by several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream right wingwall near the end of the right abutment (elev. 498.86 ft, arbitrary survey datum). RM2 is a chiseled X on top of the concrete bridge deck at the center of the upstream bridge face (elev. 500.84 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	Section Reference Distance (SRD) in feet	[2]Cross-section development	Comments
EXITX	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	19	1	Road Grade section
APPRO	53	2	Modelled Approach section (Templated from APTEM)
APTEM	64	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 0.035 to 0.055, and overbank "n" values ranged from 0.035 to 0.060.

For the incipient road-overtopping discharge, 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 0.0136 ft/ft which was estimated from surveyed thalweg points downstream of the bridge. For the 100-year and 500-year discharges, critical depth at the exit section (EXITX) was assumed as the starting water surface. Normal depth was computed below critical depth approximately 0.24 ft by use of the slope-conveyance method.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0045 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 provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.9 ***ft***
Average low steel elevation 497.5 ***ft***

100-year discharge 1,580 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 413 ***^{3}/s***
Area of flow in bridge opening 89 ***ft^2***
Average velocity in bridge opening 13.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.4 ***ft/s***

Water-surface elevation at Approach section with bridge 501.8
Water-surface elevation at Approach section without bridge 498.9
Amount of backwater caused by bridge 2.9 ***t***

500-year discharge 2,250 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 1079 ***/s***
Area of flow in bridge opening 89 ***ft^2***
Average velocity in bridge opening 13.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.5 ***/s***

Water-surface elevation at Approach section with bridge 502.4
Water-surface elevation at Approach section without bridge 501.7
Amount of backwater caused by bridge 0.7 ***t***

Incipient overtopping discharge 870 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Area of flow in bridge opening 89 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.7 ***ft/s***

Water-surface elevation at Approach section with bridge 500.8
Water-surface elevation at Approach section without bridge 497.0
Amount of backwater caused by bridge 3.8 ***t***

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.

At this site, the 100-year and 500-year discharges resulted in submerged orifice flow and the incipient road-overtopping discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). Results of this scour analysis are shown in tables 1 and 2 and figure 8. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and is presented in appendix F. Furthermore, for the incipient road-overtopping discharge, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution are provided in appendix F.

Abutment scour at the left abutment 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 at the right abutment was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	3.4	3.3	1.1
Depth to armoring	N/A	N/A	16.1
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	2.6	2.8	1.7
Right abutment	4.6	4.8	4.7
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.5	2.5	2.0
Right abutment	2.5	2.5	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

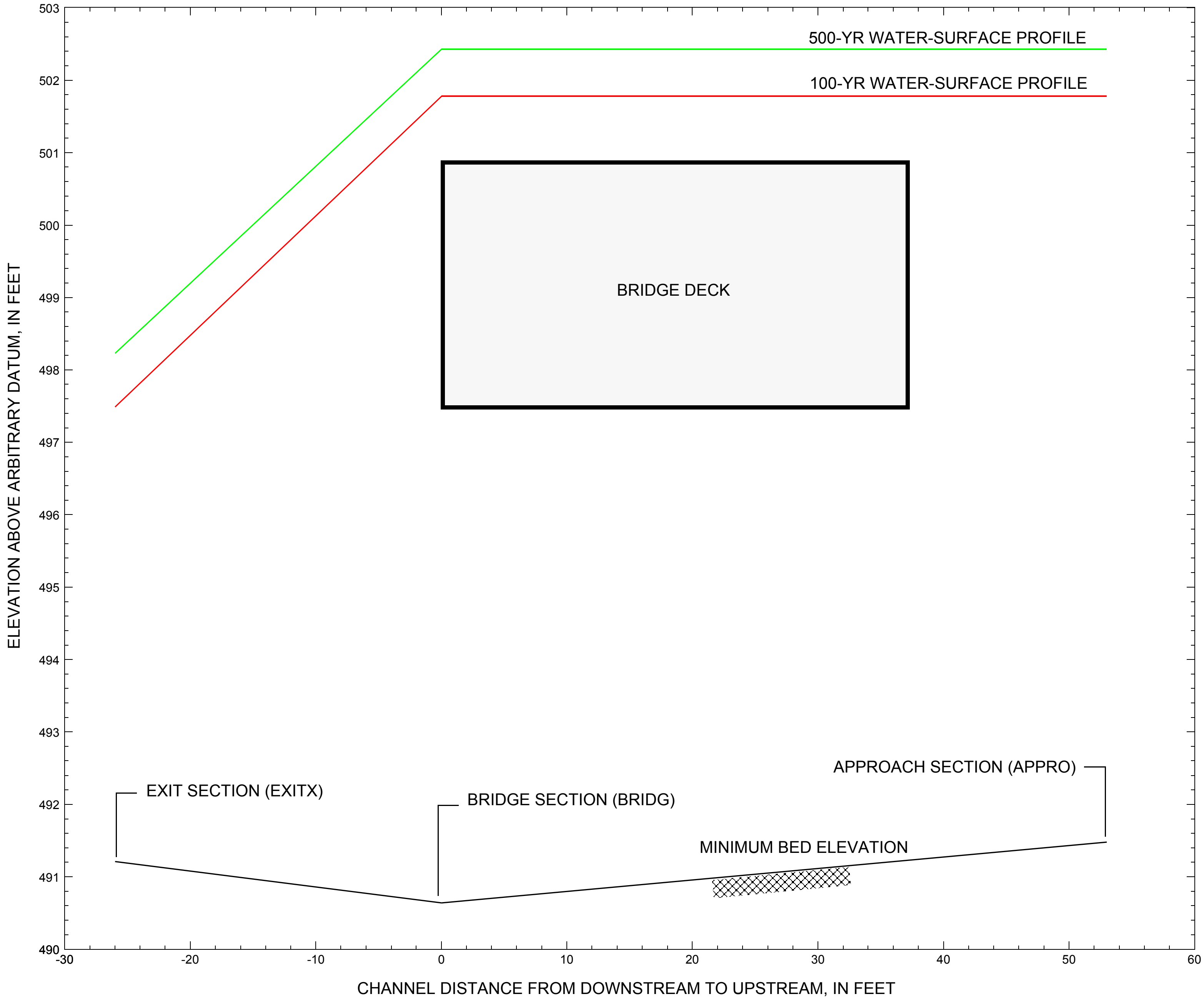

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRATTH00120007 on Town Highway 12, crossing Halladay Brook, Brattleboro, Vermont.

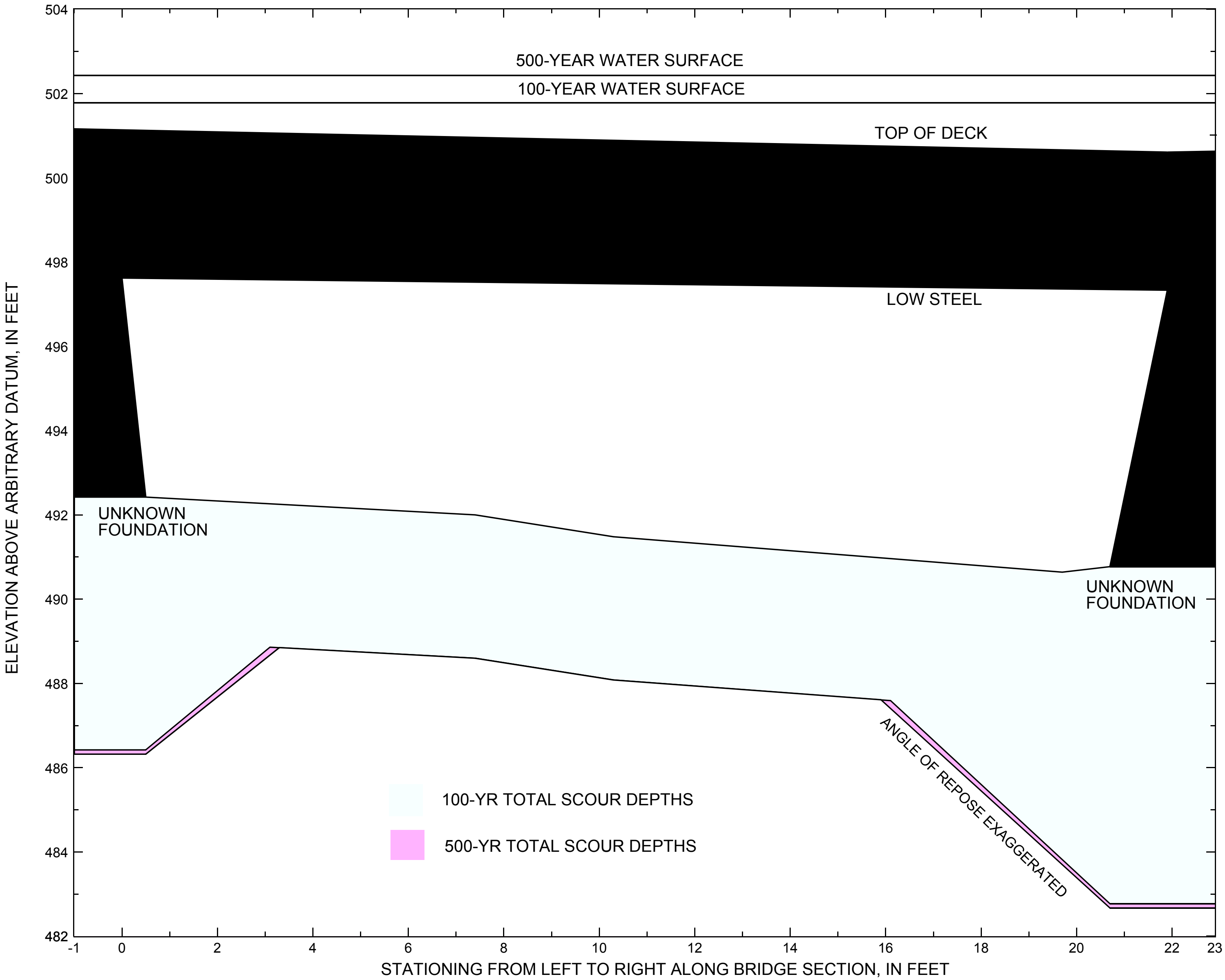

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRATTH00120007 on Town Highway 12, crossing Halladay Brook, Brattleboro, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRATTH00120007 on Town Highway 12, crossing Halladay Brook, Brattleboro, 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-yr. discharge is 1,580 cubic-feet per second											
Left abutment	0.0	--	497.6	--	492.4	3.4	2.6	--	6.0	486.4	--
Right abutment	21.9	--	497.3	--	490.8	3.4	4.6	--	8.0	482.8	--

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 BRATTH00120007 on Town Highway 12, crossing Halladay Brook, Brattleboro, 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-yr. discharge is 2,250 cubic-feet per second											
Left abutment	0.0	--	497.6	--	492.4	3.3	2.8	--	6.1	486.3	--
Right abutment	21.9	--	497.3	--	490.8	3.3	4.8	--	8.1	482.7	--

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, 1984, Newfane, Vermont-New Hampshire 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brat007.wsp
T2        Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
T3        TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1580.0   2250.0   870.0
SK          0.0136   0.0136  0.0136
*
XS   EXITX    -26           0.
GR         -217.7, 509.95   -203.4, 502.75   -130.4, 498.88     -9.7, 495.76
GR            0.0, 492.28      2.8, 491.95      3.2, 491.41      5.2, 491.21
GR            7.1, 491.29     10.3, 491.27     12.6, 491.94     17.7, 492.63
GR           23.8, 497.11     26.7, 498.84     32.0, 499.29     68.4, 498.74
GR           75.4, 502.70    179.3, 501.88    245.8, 508.12
*
N           0.035        0.045        0.050
SA                  -9.7         26.7
*
XS   FULLV      0  * * *   0.0020
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    497.47      45.0
GR            0.0, 497.62      0.5, 492.42      7.4, 492.00     10.3, 491.48
GR           15.0, 491.10     19.7, 490.64     20.7, 490.77     21.2, 492.00
GR           21.9, 497.33      0.0, 497.62
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      48.4  * *    80.5     29.6
N           0.035
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     19      20.2     1
GR         -297.9, 510.71   -263.1, 506.48   -213.6, 504.56   -149.9, 502.76
GR          -16.1, 501.75      0.0, 501.14     23.3, 500.61     63.1, 500.79
GR           85.8, 504.15    144.6, 502.98    255.6, 508.32
*
XT   APTEM     64           0.
GR         -297.9, 510.71   -263.1, 506.48   -213.6, 504.56   -149.9, 502.76
GR          -16.1, 501.75     -3.6, 500.57     -0.2, 499.29      0.0, 498.33
GR            0.0, 492.29      0.3, 491.93      2.0, 491.53      4.6, 491.79
GR            7.7, 491.97      9.5, 492.26     15.5, 493.73     22.9, 500.05
GR           63.1, 500.79     85.8, 504.15    144.6, 502.98    255.6, 508.32
*
AS   APPRO     53  * * *  0.0045
GT
N           0.035        0.055        0.060
SA                  -3.6         22.9
*
HP 1 BRIDG  497.62 1 497.62
HP 2 BRIDG  497.62 * * 1185
HP 2 RDWAY  501.78 * * 413
HP 1 APPRO  501.78 1 501.78
HP 2 APPRO  501.78 * * 1580
*
HP 1 BRIDG  497.62 1 497.62
HP 2 BRIDG  497.62 * * 1194
HP 2 RDWAY  502.43 * * 1079
HP 1 APPRO  502.43 1 502.43
HP 2 APPRO  502.43 * * 2250
*
HP 1 BRIDG  497.62 1 497.62
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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      U.S. Geological Survey WSPRO Input File brat007.wsp
      Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
      TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
         *** RUN DATE & TIME: 01-07-98  13:58

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1      89.    6292.     0.    42.                    4891410.
 497.62           89.    6292.     0.    42.  1.00     0.    22.4891410.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.62     0.0    21.9    89.2    6292.    1185.  13.29

X STA.         0.0         3.3         4.3         5.3         6.3         7.3
 A(I)             11.2         3.8         3.8         3.9         3.8
 V(I)             5.29       15.70       15.56       15.12       15.44

X STA.         7.3         8.2         9.2        10.1        10.9        11.8
 A(I)              3.8         3.8         3.8         3.7         3.7
 V(I)            15.78       15.68       15.76       16.16       16.00

X STA.        11.8        12.6        13.5        14.3        15.1        15.9
 A(I)              3.7         3.7         3.7         3.6         3.6
 V(I)            16.09       15.94       16.17       16.45       16.67

X STA.        15.9        16.7        17.5        18.2        19.0        21.9
 A(I)              3.6         3.6         3.5         3.4        11.7
 V(I)            16.56       16.57       16.90       17.35        5.08

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      19.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.78   -20.1    69.8    72.8    2102.     413.   5.67

X STA.       -20.1         2.7         8.0        12.1        15.6        18.6
 A(I)              7.3         4.0         3.6         3.3         3.2
 V(I)             2.84        5.16        5.77        6.19        6.53

X STA.        18.6        21.4        23.8        26.3        29.1        32.0
 A(I)              3.0         2.9         2.9         3.2         3.2
 V(I)             6.97        7.20        7.18        6.36        6.43

X STA.        32.0        34.8        37.8        40.8        43.9        47.0
 A(I)              3.2         3.3         3.3         3.3         3.3
 V(I)             6.42        6.30        6.18        6.20        6.20

X STA.        47.0        50.3        53.6        57.0        60.5        69.8
 A(I)              3.5         3.4         3.5         3.5         5.9
 V(I)             5.94        6.02        5.88        5.92        3.49

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1       9.     196.    23.    23.                         31.
           2     191.   15713.    27.    36.                       2921.
           3      60.    1761.    47.    47.                        387.
 501.78          261.   17671.    97.   107.  1.32   -27.    70.   2111.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.78   -26.6    70.1   260.6   17671.    1580.   6.06

X STA.       -26.6         3.1         3.8         4.5         5.3         6.0
 A(I)             46.7         7.3         7.5         7.6         7.7
 V(I)             1.69       10.90       10.59       10.34       10.27

X STA.         6.0         6.8         7.6         8.4         9.2        10.1
 A(I)              7.7         7.8         7.8         8.1         8.0
 V(I)            10.28       10.10       10.15        9.70        9.85

X STA.        10.1        11.0        11.9        12.9        13.9        14.9
 A(I)              8.5         8.3         8.5         8.5         8.5
 V(I)             9.27        9.50        9.30        9.27        9.34

X STA.        14.9        16.0        17.5        20.4        38.2        70.1
 A(I)              9.1        10.6        14.9        32.2        35.2
 V(I)             8.66        7.45        5.29        2.46        2.24
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       U.S. Geological Survey WSPRO Input File brat007.wsp
       Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
       TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
          *** RUN DATE & TIME: 01-07-98  13:58

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      89.    6292.     0.    42.                      4891410.
  497.62           89.    6292.     0.    42.  1.00     0.    22.4891410.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.62     0.0    21.9    89.2    6292.    1194.  13.39

X STA.        0.0        3.3        4.3        5.3        6.3        7.3
  A(I)            11.2        3.8        3.8        3.9        3.8
  V(I)            5.33      15.82      15.68      15.23      15.56

X STA.        7.3        8.2        9.2       10.1       10.9       11.8
  A(I)             3.8        3.8        3.8        3.7        3.7
  V(I)           15.90      15.80      15.88      16.29      16.12

X STA.       11.8       12.6       13.5       14.3       15.1       15.9
  A(I)             3.7        3.7        3.7        3.6        3.6
  V(I)           16.21      16.06      16.29      16.58      16.80

X STA.       15.9       16.7       17.5       18.2       19.0       21.9
  A(I)             3.6        3.6        3.5        3.4       11.7
  V(I)           16.68      16.70      17.03      17.49       5.12

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      19.

        WSEL     LEW     REW    AREA        K        Q    VEL
      502.43  -106.2    74.2   160.7    5861.    1079.   6.72

X STA.     -106.2      -32.2      -16.4       -6.3        0.6        6.0
  A(I)            20.7        9.7        8.7        8.2        7.4
  V(I)            2.61       5.55       6.20       6.59       7.30

X STA.        6.0       10.7       14.8       18.6       22.1       25.4
  A(I)             6.9        6.5        6.3        6.1        5.9
  V(I)            7.78       8.28       8.53       8.84       9.11

X STA.       25.4       28.9       32.7       36.5       40.3       44.2
  A(I)             6.4        6.7        6.8        6.8        6.8
  V(I)            8.48       8.04       7.99       7.99       7.96

X STA.       44.2       48.3       52.4       56.5       60.6       74.2
  A(I)             6.9        7.0        6.9        6.9       13.1
  V(I)            7.81       7.72       7.77       7.86       4.11

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      52.    1339.   109.   109.                          202.
            2     209.   18139.    27.    36.                         3323.
            3      92.    3379.    52.    52.                          702.
  502.43          353.   22857.   187.   197.  1.49  -113.    75.   2256.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

        WSEL     LEW     REW    AREA        K        Q    VEL
      502.43  -112.7    74.5   352.9   22857.    2250.   6.38

X STA.     -112.7       -5.3        3.0        3.9        4.8        5.6
  A(I)            48.6       45.2        9.2        9.4        9.2
  V(I)            2.32       2.49      12.24      11.98      12.21

X STA.        5.6        6.5        7.4        8.4        9.3       10.3
  A(I)             9.7        9.3        9.9        9.7       10.1
  V(I)           11.64      12.11      11.38      11.64      11.13

X STA.       10.3       11.3       12.4       13.5       14.7       15.9
  A(I)            10.3       10.4       10.4       10.6       10.8
  V(I)           10.90      10.85      10.82      10.60      10.44

X STA.       15.9       17.6       20.9       33.8       46.9       74.5
  A(I)            13.2       18.1       31.8       27.8       39.4
  V(I)            8.53       6.22       3.54       4.05       2.86
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        U.S. Geological Survey WSPRO Input File brat007.wsp
        Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
        TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
           *** RUN DATE & TIME: 01-07-98  13:58

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      89.    6292.     0.    42.                     4891410.
   497.62           89.    6292.     0.    42.  1.00     0.    22.4891410.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.62     0.0    21.9    89.2    6292.     870.   9.76

X STA.         0.0         3.3         4.3         5.3         6.3         7.3
  A(I)            11.2         3.8         3.8         3.9         3.8
  V(I)            3.88       11.53       11.42       11.10       11.34

X STA.         7.3         8.2         9.2        10.1        10.9        11.8
  A(I)             3.8         3.8         3.8         3.7         3.7
  V(I)           11.59       11.52       11.57       11.87       11.75

X STA.        11.8        12.6        13.5        14.3        15.1        15.9
  A(I)             3.7         3.7         3.7         3.6         3.6
  V(I)           11.81       11.70       11.87       12.08       12.24

X STA.        15.9        16.7        17.5        18.2        19.0        21.9
  A(I)             3.6         3.6         3.5         3.4        11.7
  V(I)           12.16       12.17       12.41       12.74        3.73

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      78.    7119.    15.    25.                         996.
   496.75           78.    7119.    15.    25.  1.00     0.    22.     996.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       0.       3.     3.     3.                           1.
             2     165.   12226.    27.    36.                        2330.
             3      16.     216.    40.    40.                          57.
   500.77          181.   12445.    70.    79.  1.15    -6.    63.   1549.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.77    -6.2    63.3   181.1   12445.     870.   4.80

X STA.        -6.2         3.3         4.0         4.6         5.2         5.9
  A(I)            34.2         5.7         5.6         5.8         5.8
  V(I)            1.27        7.60        7.70        7.52        7.47

X STA.         5.9         6.6         7.2         7.9         8.6         9.3
  A(I)             5.9         5.9         6.0         6.1         6.0
  V(I)            7.32        7.37        7.21        7.12        7.21

X STA.         9.3        10.0        10.8        11.6        12.4        13.3
  A(I)             6.4         6.5         6.5         6.4         6.5
  V(I)            6.78        6.72        6.67        6.76        6.69

X STA.        13.3        14.1        15.0        16.0        17.4        63.3
  A(I)             6.6         6.6         7.0         8.2        33.1
  V(I)            6.62        6.62        6.21        5.28        1.31
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       U.S. Geological Survey WSPRO Input File brat007.wsp
       Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
       TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
          *** RUN DATE & TIME: 01-07-98  13:58

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   497.28     497.49

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

EXITX:XS   ******   -76.     209.  1.09 *****  498.58  497.49   1580.  497.49
      -26. ******    24.   15066.  1.22 ***** *******    1.03    7.57

FULLV:FV      26.  -101.     281.  0.61  0.21  498.78 *******   1580.  498.17
        0.    26.    25.   20852.  1.23  0.00   -0.01    0.74    5.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.67     510.66    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.67     510.66     498.89
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   498.89     510.66     498.89

APPRO:AS      53.     0.     119.  2.74 *****  501.63  498.89   1580.  498.89
       53.    53.    22.    7974.  1.00 ***** *******    1.00   13.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   498.17     497.47

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

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

BRIDG:BR      26.     0.      89.  2.75 *****  500.37  497.33   1185.  497.62
        0. ******    22.    6292.  1.00 ***** *******    1.16   13.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.47 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      19.    33.  0.26  0.76  502.27    0.01    413.  501.78

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    88.    28.   -16.    12.   0.9   0.5   4.7   6.1   1.0   3.1
   RT:   325.    58.    12.    70.   1.2   1.0   5.6   5.6   1.5   3.1

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

APPRO:AS       5.   -27.     261.  0.76  0.08  502.54  498.89   1580.  501.78
       53.     5.    70.   17671.  1.32  0.00    0.01    0.75    6.06

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.   -76.    24.   1580.   15066.     209.    7.57  497.49
   FULLV:FV       0.  -101.    25.   1580.   20852.     281.    5.63  498.17
   BRIDG:BR       0.     0.    22.   1185.    6292.      89.   13.29  497.62
   RDWAY:RG      19.*******    88.    413.       0.*********    1.00  501.78
   APPRO:AS      53.   -27.    70.   1580.   17671.     261.    6.06  501.78

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    497.49    1.03  491.21  509.95************  1.09  498.58  497.49
   FULLV:FV  ********    0.74  491.26  510.00  0.21  0.00  0.61  498.78  498.17
   BRIDG:BR    497.33    1.16  490.64  497.62************  2.75  500.37  497.62
   RDWAY:RG  ****************  500.61  510.71  0.26******  0.76  502.27  501.78
   APPRO:AS    498.89    0.75  491.48  510.66  0.08  0.00  0.76  502.54  501.78
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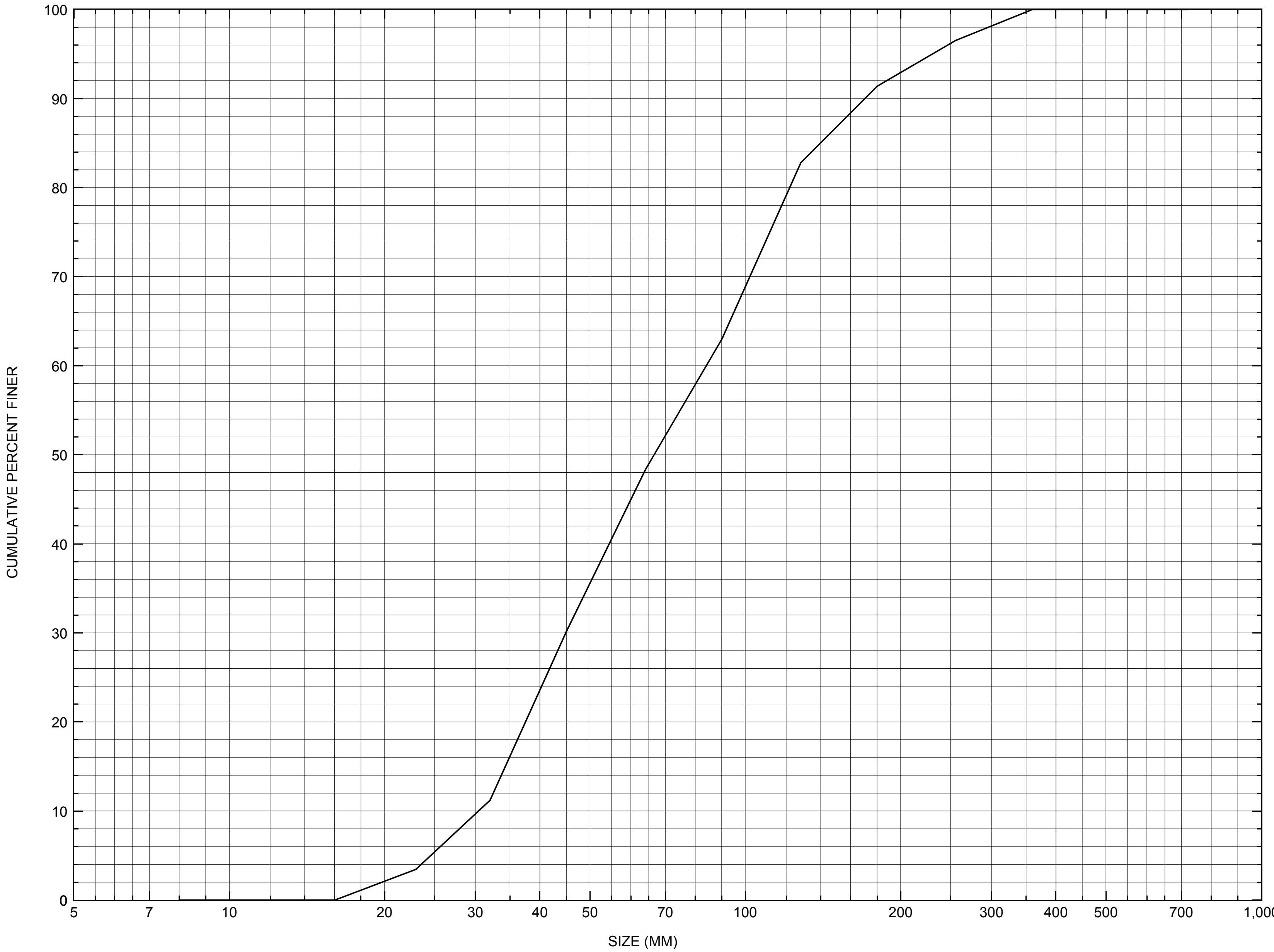
```
        U.S. Geological Survey WSPRO Input File brat007.wsp
        Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
        TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
           *** RUN DATE & TIME: 01-07-98  13:58

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =    497.96     498.23

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

EXITX:XS   ******  -105.     295.  1.11 *****  499.34  498.23   2250.  498.23
      -26. ******    26.   22037.  1.23 ***** *******    0.99    7.64

FULLV:FV      26.  -129.     382.  0.65  0.20  499.54 *******   2250.  498.89
        0.    26.    69.   29744.  1.20  0.00    0.00    0.74    5.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.39     510.66    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.39     510.66     501.70
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   501.70     510.66     501.70

APPRO:AS      53.   -16.     253.  1.60 *****  503.30  501.70   2250.  501.70
       53.    53.    70.   17226.  1.30 ***** *******    1.04    8.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   498.89     497.47

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

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

BRIDG:BR      26.     0.      89.  2.79 *****  500.41  497.33   1194.  497.62
        0. ******    22.    6292.  1.00 ***** *******    1.17   13.39

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.47 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      19.    33.  0.32  0.94  503.05    0.01   1079.  502.43

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    462.   118.  -106.    12.   1.6   0.5   5.1   7.3   1.2   3.1
   RT:    618.    62.    12.    74.   1.8   1.6   6.8   6.3   2.2   3.1

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

APPRO:AS       5.  -113.     353.  0.94  0.13  503.37  501.70   2250.  502.43
       53.     6.    75.   22847.  1.49  0.00    0.01    1.00    6.38

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.  -105.    26.   2250.   22037.     295.    7.64  498.23
   FULLV:FV       0.  -129.    69.   2250.   29744.     382.    5.89  498.89
   BRIDG:BR       0.     0.    22.   1194.    6292.      89.   13.39  497.62
   RDWAY:RG      19.*******   462.   1079.******************    1.00  502.43
   APPRO:AS      53.  -113.    75.   2250.   22847.     353.    6.38  502.43

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    498.23    0.99  491.21  509.95************  1.11  499.34  498.23
   FULLV:FV  ********    0.74  491.26  510.00  0.20  0.00  0.65  499.54  498.89
   BRIDG:BR    497.33    1.17  490.64  497.62************  2.79  500.41  497.62
   RDWAY:RG  ****************  500.61  510.71  0.32******  0.94  503.05  502.43
   APPRO:AS    501.70    1.00  491.48  510.66  0.13  0.00  0.94  503.37  502.43
```

```
        U.S. Geological Survey WSPRO Input File brat007.wsp
        Hydraulic analysis for structure BRATTH00120007   Date: 17-DEC-97
        TH 12 CROSSING HALLADAY BROOK IN BRATTLEBORO, VERMONT            RLB
           *** RUN DATE & TIME: 01-07-98  13:58

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

EXITX:XS   ******   -23.     108.  1.04 *****  497.15  495.63    870.  496.12
      -26. ******    22.    7453.  1.03 ***** *******    0.94    8.04

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     496.73     495.68
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.62     510.00    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.62     510.00     495.68

FULLV:FV      26.   -46.     142.  0.67  0.26  497.41  495.68    870.  496.75
        0.    26.    23.   10004.  1.13  0.00    0.00    0.81    6.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.93     497.02     496.83
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.25     510.66    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.25     510.66     496.83
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.47

APPRO:AS      53.     0.      81.  1.80  0.86  498.83  496.83    870.  497.03
       53.    53.    19.    4681.  1.00  0.57    0.00    0.93   10.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.32     498.68     498.75     497.47
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      26.     0.      89.  1.43 *****  499.05  496.25    854.  497.62
        0. ******    22.    6292.  1.00 ***** *******    0.84    9.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.500  0.000  497.47 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      19.         <<<<<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       5.    -6.     181.  0.41  0.05  501.18  496.83    870.  500.77
       53.     5.    63.   12435.  1.15  0.93   -0.02    0.56    4.81

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   500.61

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -26.   -23.    22.    870.    7453.     108.    8.04  496.12
   FULLV:FV       0.   -46.    23.    870.   10004.     142.    6.14  496.75
   BRIDG:BR       0.     0.    22.    854.    6292.      89.    9.57  497.62
   RDWAY:RG      19.**************      0.       0.       0.    1.00********
   APPRO:AS      53.    -6.    63.    870.   12435.     181.    4.81  500.77

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    495.63    0.94  491.21  509.95************  1.04  497.15  496.12
   FULLV:FV    495.68    0.81  491.26  510.00  0.26  0.00  0.67  497.41  496.75
   BRIDG:BR    496.25    0.84  490.64  497.62************  1.43  499.05  497.62
   RDWAY:RG  ***************  500.61  510.71************  0.41  501.02********
   APPRO:AS    496.83    0.56  491.48  510.66  0.05  0.93  0.41  501.18  500.77
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BRATTH00120007, in Brattleboro, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRATTH00120007

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 05 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 07900

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

Waterway *(I - 6)* HALLADAY BROOK

Road Name *(I - 7):* -

Route Number TH012

Vicinity *(I - 9)* 0.2 MI TO JCT W VT9

Topographic Map Brattleboro

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 42522

Longitude *(i - 17; nnnnn.n)* 72373

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10130200071302

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1920

Structure length *(I - 49; nnnnnn)* 000028

Average daily traffic, ADT *(I - 29; nnnnnn)* 001070

Deck Width *(I - 52; nn.n)* 202

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

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

Opening skew to Roadway *(I - 34; nn)* 45

Waterway adequacy *(I - 71; n)* 6

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) _______

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

Vertical clearance from streambed (*nnn.n ft*) 005.2

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

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

Comments:

The structural inspection report of 08/22/94 indicates the structure is a concrete slab bridge with an asphalt road surface. Both abutments are constructed of "laid-up" stone. They have some random small voids and slight bulges, but overall they reportedly are quite stable. The waterway makes a sharp turn into the structure. The upstream right wingwall has a corrugated, galvanized 12 inch diameter drain pipe sticking out of it. The downstream right wingwall is concrete. The streambed consists of stone and gravel and there is a shallow gravel point bar deposited along the left abutment. Stone fill consists of natural streambed material.

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)* 5.53 mi^2

Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 531.5 ft

Headwater elevation 1624 ft

Main channel length 5.8 mi

10% channel length elevation 587.3 ft

85% channel length elevation 1381.2 ft

Main channel slope *(S)* 181.8 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? **Yes** *If no, type ctrl-n xs*

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

Comments: **This cross section of the upstream bridge face was attached to a bridge inspection report dated 8/24/94. All measurements are in feet. The data has been converted to the elevation coordinates of this report based on the average low chord elevation. Mid-S. = mid-span.**

Station	0	-	22	-	-	-	-	-	-	-	-
Feature	LAB	Mid-S.	RAB	-	-	-	-	-	-	-	-
Low chord elevation	497.48	497.48	497.48	-	-	-	-	-	-	-	-
Bed elevation	492.48	491.98	491.48	-	-	-	-	-	-	-	-
Low chord to bed	5	5.5	6	-	-	-	-	-	-	-	-

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

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

Comments: -
-

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: RB Date: 01/23/97
Computerized by: RB Date: 05/15/97
Reviewd by: RB Date: 01/15/98

Structure Number BRATTH00120007

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 08 / 14 / 1996
2. Highway District Number 2 Mile marker -
County WINDHAM (025) Town BRATTLEBORO (07900)
Waterway *(I - 6)* HALLADAY BROOK Road Name SUNSET LAKE RD.
Route Number TH 12 Hydrologic Unit Code: 01080104
3. Descriptive comments:
This site is located about 0.2 miles north of the intersection of TH 12 and VT 9.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 28 *(feet)* Span length 25 *(feet)* Bridge width 20.2 *(feet)*

Road approach to bridge:

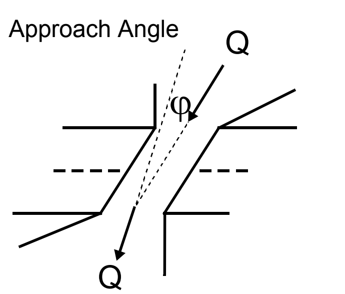
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

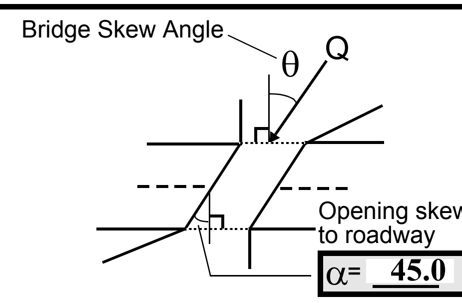
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	1	1
RBUS	5	1	0	0
RBDS	0	-	2	1
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 55





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 90 feet US *(US, UB, DS)* to 50 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 12 feet UB

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

18. Bridge Type: **1a**

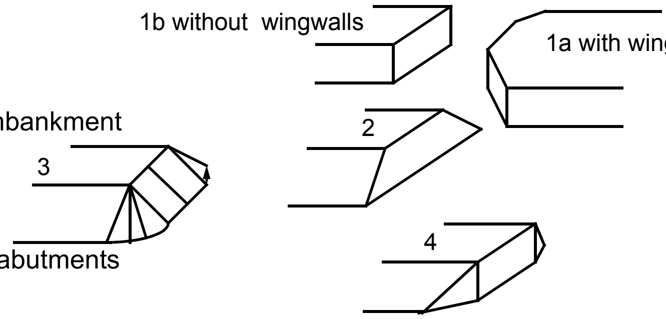
1a- Vertical abutments with wingwalls

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.)

4. The surface cover on the US left bank is lawn and TH 12 on the overbank with trees and brush on the immediate bank. The US right bank cover is also a lawn but nearly all forest further US with a side road that bisects the forest.

5. The channel is moderately sloping and generally riffle above 50 ft US. Between 50 ft US and the US bridge face, the water surface is pool and riffle. The channel is pooled under the bridge except for a small riffle at the US bridge face. The DS channel is a series of pools and riffles.

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
26.5	**6.0**			**6.5**	**2**	**3**	**234**	**324**	**2**	**1**

23. Bank width **85.0** 24. Channel width **40.0** 25. Thalweg depth **23.5** 29. Bed Material **346**

30 .Bank protection type: LB **5** RB **2** 31. Bank protection condition: LB **1** RB **1**

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

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

27,29. The bank and bed material noted was observed near 150 ft US beyond the fill and retaining walls on both banks US.

28. The channel impacts the road embankment on the US left bank from 90 ft US to 50 ft US. The left bank is cut nearly vertical US of the retaining wall.

30. A retaining wall extends from 50 ft US to the US end of the US left wingwall. Another retaining wall is on the right bank side from 0 ft US to 22 ft US which may also be considered as the US right wingwall. From 22 ft US to 55 ft US, stone fill protection is evident on the right bank.

The US reach is nearly straight and narrows at 50 ft US where the left bank retaining wall begins.
A bedrock outcrop at the bed elevation along the right bank side of the channel is between 25 ft and 40 ft US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **12UB** 35. Mid-bar width: **7**
36. Point bar extent: **8** feet **US** (US, UB) to **8** feet **DS** (US, UB, DS) positioned **0** %LB to **60** %RB
37. Material: **324**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This bar is present mostly under the bridge on the left bank side of the channel. The channel bends left into the bridge here.

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **LB** (LB or RB)
41. Mid-bank distance: **60** 42. Cut bank extent: **90** feet **US** (US, UB) to **50** feet **US** (US, UB, DS)
43. Bank damage: **2** (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
The bank is eroded severely at the US end of the left bank retaining wall. Tree roots are holding the upper half of the bank stable, but some undermining of the bank is evident.

45. Is channel scour present? **N** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **-**
47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
NO CHANNEL SCOUR

49. Are there major confluences? **N** (Y or if N type ctrl-n mc) 50. How many? **-**
51. Confluence 1: Distance **-** 52. Enters on **-** (LB or RB) 53. Type **-** (**1**- perennial; **2**- ephemeral)
Confluence 2: Distance **-** Enters on **-** (LB or RB) Type **-** (**1**- perennial; **2**- ephemeral)
54. Confluence comments (eg. confluence name):
NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
15.5		**0.5**		**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.):
324
63. The bed material is finer on the left side and becomes coarser, cobbles and large gravel, along the right side.

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? **2**___ *(Y or N)* Ice Blockage Potential **N**____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Overall, the channel is incised and stable with old growth trees on both banks US.

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		**-**	**90**	**2**	**0**	**0**	**-**	**90.0**
RABUT	**2**	**15**	**90**			**2**	**1**	**12.5**

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

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

1.0

-

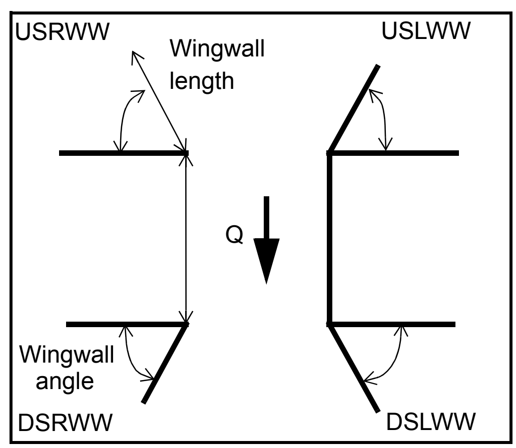
2

77. Both abutments are unmortared stone slab and block walls.

74. The flow is mainly along the right abutment and some scour is evident at the DS end. The scour hole is 28 ft long and 5 ft wide at 12 ft DS. At 8 ft DS, the hole is 1 ft deeper than the mean thalweg depth which is 0.5 ft. At the DS end of the right abutment a few stone slabs are pitched toward the stream where the abutment is settling into the scour hole.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**12.5**	
USRWW:	**Y**		**2**		**0**	**0.5**	
DSLWW:	**-**		**-**		**Y**	**39.0**	
DSRWW:	**2**		**0**		**-**	**36.0**	



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

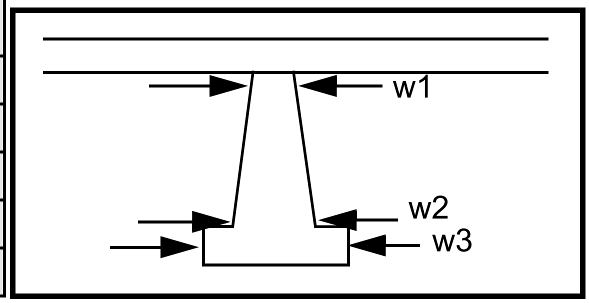
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
1
1
1

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				**10.0**	**34.0**	**150.0**
Pier 2			**9.5**	**30.0**	**145.0**	**0.0**
Pier 3		-	-	**21.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**wing-**	**right**	**con-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**US**	**wall**	**wing**	**sist-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**end**	**and**	**wall**	**ing**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**of**	**retai**	**is**	**of**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**ning**	**pro-**	**sand,**	*Y- yes; N- no*
91. Attack ∠ (BF)	**left**	**wall**	**tecte**	**grav**	
92. Pushed	**abut**	**is**	**d**	**el**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**ment**	**set-**	**with**	**and**	
95. Cross-members	**cor-**	**tling.**	**eart**	**cob-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**ner**	**82.**	**h**	**bles.**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**with**	**The**	**back**		
98. Exposure depth	**the**	**DS**	**fill**		

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

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.):

-
-
NO PIERS

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

Cut bank extent: _____ 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.):

1
1
234
234

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

Scour dimensions: Length **324** Width **0** Depth: **0** Positioned - %LB to - %RB

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

The reach is fairly straight DS of the bridge and is moderately sloping overall. Some boulders are also present on the bed.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

-

NO DROP STRUCTURE

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: BRATTH00120007 Town: BRATTLEBORO
Road Number: TH 12 County: WINDHAM
Stream: HALLADAY BROOK

Initials RLB Date: 1/7/98 Checked: ECW

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1580	2250	870
Main Channel Area, ft2	191	209	165
Left overbank area, ft2	9	52	0
Right overbank area, ft2	60	92	16
Top width main channel, ft	27	27	27
Top width L overbank, ft	23	109	0
Top width R overbank, ft	47	52	40
D50 of channel, ft	0.2186	0.2186	0.2186
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.1	7.7	6.1
y1, average depth, LOB, ft	0.4	0.5	ERR
y1, average depth, ROB, ft	1.3	1.8	0.4
Total conveyance, approach	17671	22857	12445
Conveyance, main channel	15713	18139	12226
Conveyance, LOB	196	1339	0
Conveyance, ROB	1761	3379	216
Percent discrepancy, conveyance	0.0057	0.0000	0.0241
Qm, discharge, MC, cfs	1404.9	1785.6	854.7
Ql, discharge, LOB, cfs	17.5	131.8	0.0
Qr, discharge, ROB, cfs	157.5	332.6	15.1
Vm, mean velocity MC, ft/s	7.4	8.5	5.2
Vl, mean velocity, LOB, ft/s	1.9	2.5	ERR
Vr, mean velocity, ROB, ft/s	2.6	3.6	0.9
Vc-m, crit. velocity, MC, ft/s	9.4	9.5	9.1
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	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1580	2250	870
(Q) discharge thru bridge, cfs	1185	1194	870
Main channel conveyance	6292	6292	6292
Total conveyance	6292	6292	6292
Q2, bridge MC discharge,cfs	1185	1194	870
Main channel area, ft2	89	89	89
Main channel width (normal), ft	15.5	15.5	15.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	15.5	15.5	15.5
y_bridge (avg. depth at br.), ft	5.75	5.75	5.75
Dm, median (1.25*D50), ft	0.27325	0.27325	0.27325
y2, depth in contraction,ft	7.38	7.43	5.66
ys, scour depth (y2-ybridge), ft	1.62	1.67	-0.09

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	1185	1194	870
Main channel area (DS), ft2	89.2	89.2	78
Main channel width (normal), ft	15.5	15.5	15.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	15.5	15.5	15.5
D90, ft	0.5592	0.5592	0.5592
D95, ft	0.7557	0.7557	0.7557
Dc, critical grain size, ft	0.7619	0.7736	0.5682
Pc, Decimal percent coarser than Dc	0.049	0.047	0.096
Depth to armoring, ft	**N/A**	**N/A**	**16.05**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc Cf=1.5*Fr^0.43 (<=1) Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1580	2250	870
Q, thru bridge MC, cfs	1185	1194	870
Vc, critical velocity, ft/s	9.36	9.50	9.13
Va, velocity MC approach, ft/s	7.36	8.54	5.18
Main channel width (normal), ft	15.5	15.5	15.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	15.5	15.5	15.5
qbr, unit discharge, ft2/s	76.5	77.0	56.1
Area of full opening, ft2	89.2	89.2	89.2
Hb, depth of full opening, ft	5.75	5.75	5.75
Fr, Froude number, bridge MC	1.16	1.17	0.84
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	78
**Hb, depth at downstream face, ft	N/A	N/A	5.03
**Fr, Froude number at DS face	ERR	ERR	0.88
**Cf, for downstream face (<=1.0)	N/A	N/A	1.00
Elevation of Low Steel, ft	497.47	497.47	497.47
Elevation of Bed, ft	491.72	491.72	491.72
Elevation of Approach, ft	501.78	502.43	500.77
Friction loss, approach, ft	0.08	0.13	0.05
Elevation of WS immediately US, ft	501.70	502.30	500.72
ya, depth immediately US, ft	9.98	10.58	9.00
Mean elevation of deck, ft	500.38	500.38	500.38
w, depth of overflow, ft (>=0)	1.32	1.92	0.34
Cc, vert contrac correction (<=1.0)	0.89	0.89	0.89
**Cc, for downstream face (<=1.0)	ERR	ERR	0.835572
Ys, scour w/Chang equation, ft	**3.41**	**3.34**	**1.14**
Ys, scour w/Umbrell equation, ft	2.98	3.94	1.13

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	N/A	N/A	2.32

**Ys, scour w/Umbrell equation, ft	N/A	N/A	1.86

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	7.38	7.43	5.66
WSEL at downstream face, ft	--	--	496.75
Depth at downstream face, ft	N/A	N/A	5.03
Ys, depth of scour (Laursen), ft	N/A	N/A	0.63

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	1580	2250	870	1580	2250	870
a', abut.length blocking flow, ft	16.1	16.1	6.2	54.6	59	47.8
Ae, area of blocked flow ft2	9.24	9.24	4.04	49.24	53.35	44.8
Qe, discharge blocked abut.,cfs	--	--	3.71	--	--	108.75
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.64	2.57	0.92	3.63	4.48	2.43
ya, depth of f/p flow, ft	0.57	0.57	0.65	0.90	0.90	0.94
--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	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.303	0.363	0.192	0.479	0.524	0.442
ys, scour depth, ft	**2.55**	**2.78**	**1.72**	7.50	8.12	7.00

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)	16.1	16.1	6.2	54.6	59	47.8
y1 (depth f/p flow, ft)	0.57	0.57	0.65	0.90	0.90	0.94
a'/y1	28.05	28.05	9.51	60.54	65.25	51.00
Skew correction (p. 49, fig. 16)	0.80	0.80	0.80	1.10	1.10	1.10
Froude no. f/p flow	0.30	0.36	0.19	0.48	0.52	0.44
Ys w/ corr. factor K1/0.55:						
vertical	2.25	2.39	ERR	5.66	5.84	5.73
vertical w/ ww's	1.85	1.96	ERR	**4.64**	**4.79**	**4.70**
spill-through	1.24	1.31	ERR	3.11	3.21	3.15

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	1.16	1.17	0.88	1.16	1.17	0.88
y, depth of flow in bridge, ft	5.75	5.75	5.03	5.75	5.75	5.03
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.51	2.51	2.03	2.51	2.51	2.03