LEVEL II SCOUR ANALYSIS FOR BRIDGE 53 (CAMBTH00750053) on TOWN HIGHWAY 75, crossing the BREWSTER RIVER, CAMBRIDGE, VERMONT

U.S. Geological Survey
Open-File Report 97-647

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

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By MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 53 (CAMBTH00750053) ON TOWN HIGHWAY 75, CROSSING THE BREWSTER RIVER, CAMBRIDGE, VERMONT

By **Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CAMBTH00750053 on Town Highway 75 crossing the Brewster River, Cambridge, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in northwestern Vermont. The 4.30-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest, except for the downstream right overbank area which has a barn surrounded by grass and shrubs.

In the study area, the Brewster River has an incised, straight channel with a slope of approximately 0.05 ft/ft, an average channel top width of 62 ft and an average bank height of 12 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 84.4 mm (0.277 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 11, 1995, indicated that the reach was stable.

The Town Highway 75 crossing of the Brewster River is a 28-ft-long, two-lane bridge consisting of one 24-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, March 8, 1995). The opening length of the structure parallel to the bridge face is 22.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway as surveyed is 10 degrees.

A scour hole 1 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. The scour counter-measures at the site included type-3 stone fill (less than 48 inches diameter) along the entire base length of the upstream left wingwall. There was also type-4 stone fill (less than 60 inches diameter) along the downstream end of the downstream right wingwall. 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 others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 1.1 to 1.4 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 10.7 to 17.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Mount Mansfield, VT. Quadrangle, 1:24,000, 1948

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 CAMBTH00750053 ***Stream*** Brewster River

County Lamoille ***Road*** TH 75 ***District*** 8

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 25.0 ***ft*** ***Max span length*** 24 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 7/11/95

Description of stone fill Type-3 stone fill along the entire base length of the upstream left wingwall. Type-4 stone fill along the downstream end of the downstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one foot deep scour hole along the left abutment.

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

There is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the flow impacts the left abutment.

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	7/11/95	0	0
Level II	7/11/95	0	0

Potential for debris Moderate. There is some debris caught on boulders and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) There was a point bar along the right abutment and some large boulders in the downstream channel as of 7/11/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with steep valley walls on both sides.

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

Date of inspection 7/11/95

DS left: Steep channel bank to a narrow terrace.

DS right: Steep channel bank to a narrow terrace.

US left: Steep valley wall.

US right: Steep channel bank to a narrow terrace.

Description of the Channel

Average top width 62 ***ft*** ***Average depth*** 12 ***ft***

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

Straight with non-alluvial channel boundaries and no flood plain.

Vegetative co 7/11/95

Trees and brush.

DS left: Grass and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right:

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

There is mass wasting along the upstream left bank from run-off on the bank and some erosion of the right bank due to flow around a boulder.

Describe any obstructions in channel and date of observation.

The assessment of 7/11/95 noted a point bar along the right abutment and several large boulders across the downstream reach. In addition, some debris is caught on boulders in the channel upstream.

Hydrology

Drainage area 4.3 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,700 ***ft³/s*** ***Q500*** 2,430 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.3/20.0)exp 0.7] with the discharges computed for the Brewster River in the Flood Insurance Study for Jeffersonville, VT (Federal Emergency Management Agency, 1982). The drainage area at the mouth of the Brewster River is 20.0 square miles. The drainage area adjusted discharge values are within a range defined by several empirical flood frequency curves (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 within a chiseled square on top of the downstream curb above the right abutment (elev. 999.89 ft, arbitrary survey datum). RM2 is a chiseled X within a chiseled square on the top step of the upstream end of the left abutment and upstream left wingwall (elev. 993.48 ft, arbitrary survey datum). RM3 is the top of a metal rod protruding from the downstream end of the left abutment top step (elev. 994.78 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	-18	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	49	2	Modelled Approach section (Templated from APTEM)
APTEM	59	1	Approach section as surveyed (Used as a template)

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 0.050 to 0.075.

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 0.05 ft/ft, which was measured from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0369 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 100-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 was 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 999.4 ***ft***
Average low steel elevation 996.3 ***ft***

100-year discharge 1,700 ***ft^3/s***
Water-surface elevation in bridge opening 991.6 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 122 ***ft^2***
Average velocity in bridge opening 13.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.6 ***ft/s***

Water-surface elevation at Approach section with bridge 995.9
Water-surface elevation at Approach section without bridge 991.8
Amount of backwater caused by bridge 4.1 ***ft***

500-year discharge 2,430 ***ft^3/s***
Water-surface elevation in bridge opening 996.3 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 221 ***ft^2***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.2 ***ft/s***

Water-surface elevation at Approach section with bridge 999.5
Water-surface elevation at Approach section without bridge 993.0
Amount of backwater caused by bridge 6.5 ***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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year 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 others, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour at the 500-year discharge was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and the results are presented in Appendix F. Furthermore, for the 500-year discharge contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in Appendix F.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.4	1.1	--
Depth to armoring	33.3	48.5	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	10.7	13.8	--
Right abutment	15.0	17.3	--
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	3.0	--
Right abutment	2.5	3.0	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

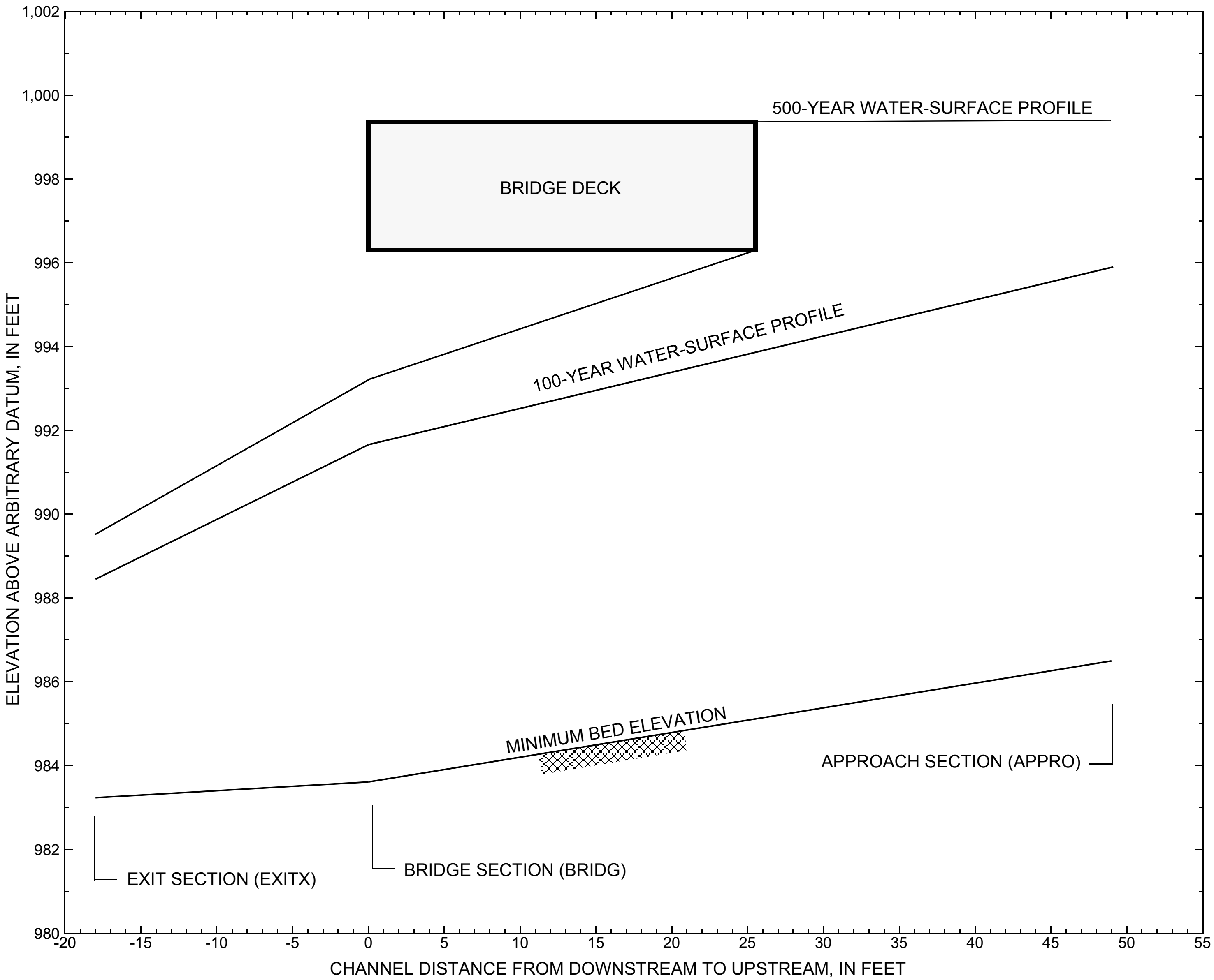

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CAMBTH00750053 on Town Highway 75, crossing the Brewster River, Cambridge, Vermont.

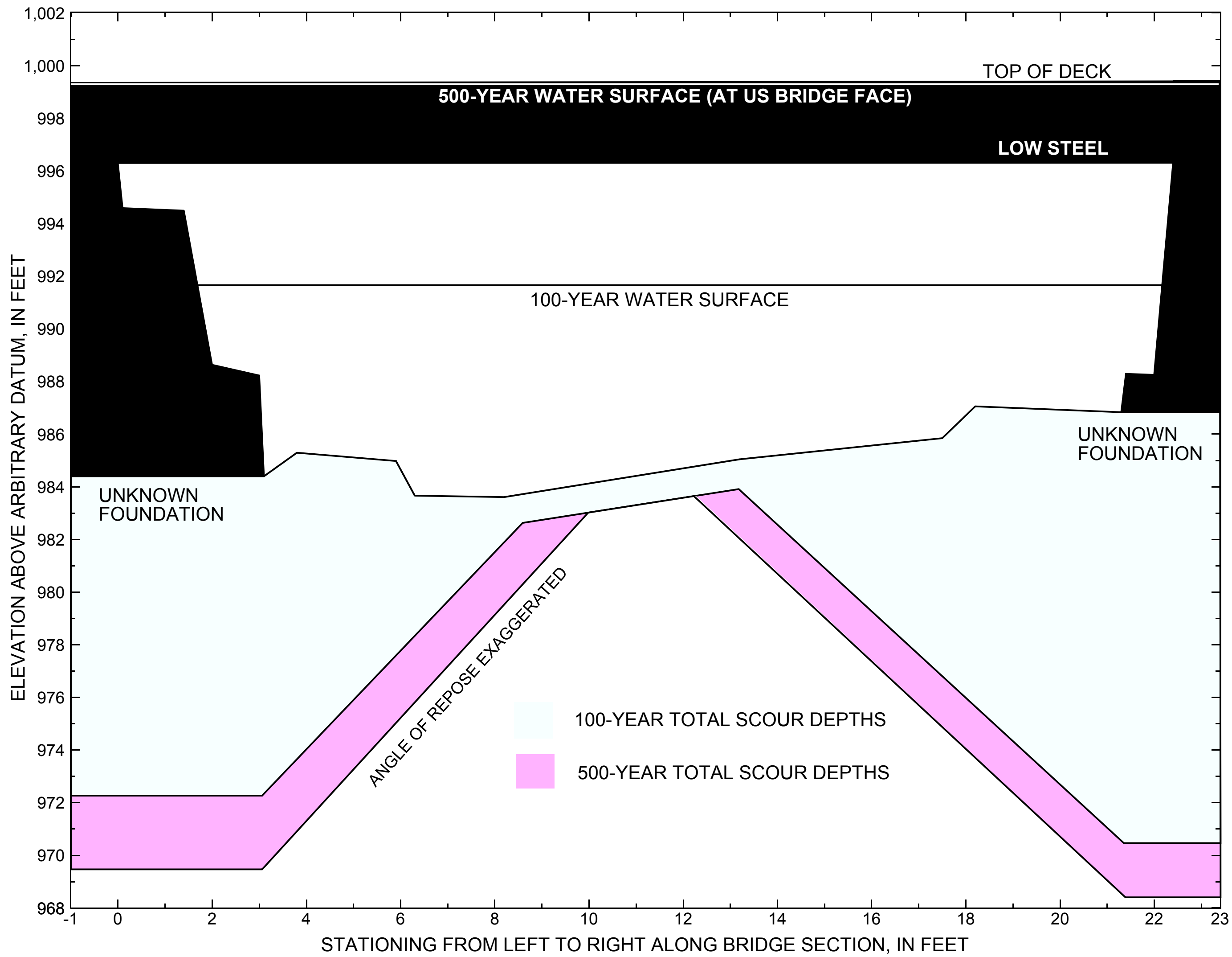

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure CAMBTH00750053 on Town Highway 75, crossing the Brewster River, Cambridge, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CAMBTH00750053 on Town Highway 75, crossing the Brewster River, Cambridge, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year. discharge is 1,700 cubic-feet per second											
Left abutment	0.0	--	996.3	--	984.4	1.4	10.7	--	12.1	972.3	--
Right abutment	22.4	--	996.3	--	986.8	1.4	15.0	--	16.4	970.4	--

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 CAMBTH00750053 on Town Highway 75, crossing the Brewster River, Cambridge, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year. discharge is 2,430 cubic-feet per second											
Left abutment	0.0	--	996.3	--	984.4	1.1	13.8	--	14.9	969.5	--
Right abutment	22.4	--	996.3	--	986.8	1.1	17.3	--	18.4	968.4	--

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, 1948, Mount Mansfield, 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 camb053.wsp
T2        Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
T3        TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
*
J1          * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1700.0   2430.0
SK          0.050    0.050
*
XS   EXITX    -18
GR          -36.7, 1010.72  -31.7, 1003.72    -27.2, 1002.08   -15.9, 992.84
GR           -8.5, 984.84    -0.9, 984.84      -0.7, 983.74     13.5, 983.23
GR           17.4, 983.28    22.7, 985.05      25.7, 985.50     31.9, 991.00
GR           40.6, 999.04    54.9, 1000.98     59.9, 1010.98
*
N           0.075
*
*
XS   FULLV      0  * * *   0.0166
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    996.31      10.0
GR            0.0, 996.30      0.1, 994.58      1.4, 994.49      2.0, 988.63
GR            3.0, 988.22      3.1, 984.40      3.8, 985.29      5.9, 984.98
GR            6.3, 983.66      8.2, 983.61     13.2, 985.04     17.5, 985.84
GR           18.2, 987.05     21.3, 986.83     21.4, 988.29     22.0, 988.25
GR           22.4, 996.31      0.0, 996.30
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      36.9 * *     55.3      5.4
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     14      25.0     2
GR          -49.2, 1000.24     2.2, 999.34
GR            2.2, 999.58      25.6, 999.82      25.6, 999.40     56.0, 1000.48
GR          167.3, 1011.63
*
*
XT   APTEM     59
GR          -15.4, 1010.91   -10.4, 1000.91   -10.3, 995.90     -5.7, 992.66
GR            0.0, 989.22     15.8, 987.43     21.3, 986.87     28.3, 987.43
GR           33.2, 989.24     33.3, 992.60     45.1, 999.81     65.3, 1000.64
GR          167.3, 1011.63
*
AS   APPRO     49  * * * 0.0369
GT
N           0.070
*
HP 1 BRIDG   991.59 1 991.59
HP 2 BRIDG   991.59 * * 1700
HP 1 APPRO   995.87 1 995.87
HP 2 APPRO   995.87 * * 1700
*
HP 1 BRIDG   996.31 1 996.31
HP 2 BRIDG   996.31 * * 2430
* fullvalley WSEL
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File camb053.wsp
     Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
     TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
        *** RUN DATE & TIME: 07-16-97  15:35
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA         K   TOPW   WETP ALPH    LEW    REW     QCR
          1     122.    8587.    20.    34.                        1703.
991.59          122.    8587.    20.    34. 1.00     2.    22.   1703.



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

      WSEL     LEW     REW    AREA        K        Q    VEL
    991.59     1.7    22.2   122.0    8587.    1700.  13.93

X STA.        1.7        4.5        5.6        6.6        7.3        8.0
  A(I)            12.9        7.3        7.1        5.6        5.2
  V(I)            6.59      11.59      11.91      15.31      16.45

X STA.        8.0        8.6        9.2        9.9       10.5       11.2
  A(I)             4.9        4.8        4.7        4.7        4.6
  V(I)           17.19      17.76      18.08      18.10      18.56

X STA.       11.2       11.8       12.5       13.3       14.0       14.8
  A(I)             4.7        4.7        4.9        4.9        5.0
  V(I)           18.17      18.11      17.49      17.45      16.94

X STA.       14.8       15.7       16.7       17.8       19.4       22.2
  A(I)             5.3        5.6        6.5        7.4       11.4
  V(I)           16.05      15.22      13.16      11.48       7.49


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     328.   22511.    50.    57.                         4787.
995.87          328.   22511.    50.    57.  1.00   -10.    39.   4787.



 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

      WSEL     LEW     REW    AREA        K        Q    VEL
    995.87   -10.3    39.3   328.0   22511.    1700.   5.18

X STA.      -10.3       -1.6        1.2        3.5        5.6        7.5
  A(I)            28.6       19.4       16.6       15.6       14.9
  V(I)            2.97       4.38       5.11       5.45       5.70

X STA.        7.5        9.3       11.1       12.7       14.3       15.8
  A(I)            14.5       14.1       13.7       13.6       13.5
  V(I)            5.85       6.02       6.19       6.25       6.32

X STA.       15.8       17.3       18.8       20.2       21.7       23.2
  A(I)            13.4       13.2       13.3       13.7       13.9
  V(I)            6.35       6.44       6.39       6.20       6.11

X STA.       23.2       24.7       26.4       28.2       30.5       39.3
  A(I)            14.0       14.9       16.4       18.8       31.8
  V(I)            6.06       5.70       5.19       4.53       2.67
```

```
     U.S. Geological Survey WSPRO Input File camb053.wsp
     Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
     TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
        *** RUN DATE & TIME: 07-16-97  15:35
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     221.   14682.     0.    66.                           0.
996.31          221.   14682.     0.    66.  1.00     0.    22.      0.

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

     WSEL     LEW     REW    AREA        K        Q    VEL
   996.31     0.0    22.4   220.9   14682.    2430.  11.00

X STA.        0.0        3.9        5.2        6.2        7.1        7.8
  A(I)            23.4       13.2       12.3       10.2        9.7
  V(I)            5.19       9.19       9.89      11.91      12.52

X STA.        7.8        8.6        9.3       10.0       10.7       11.5
  A(I)             9.1        9.0        8.7        8.7        8.6
  V(I)           13.41      13.54      13.99      13.90      14.14

X STA.       11.5       12.2       13.0       13.8       14.6       15.5
  A(I)             8.6        8.7        8.8        9.1        9.0
  V(I)           14.19      14.02      13.83      13.33      13.43

X STA.       15.5       16.4       17.4       18.6       19.9       22.4
  A(I)             9.7       10.0       11.7       12.1       20.3
  V(I)           12.46      12.11      10.38      10.07       5.97

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     155.   12081.    20.    37.                        2435.
993.24          155.   12081.    20.    37.  1.00     2.    22.   2435.

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     517.   42684.    56.    68.                        8908.
999.46          517.   42684.    56.    68.  1.00   -10.    46.   8908.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

     WSEL     LEW     REW    AREA        K        Q    VEL
   999.46   -10.4    45.6   516.6   42684.    2430.   4.70

X STA.      -10.4       -3.4       -0.2        2.1        4.3        6.3
  A(I)            44.1       29.8       25.3       23.7       23.1
  V(I)            2.76       4.08       4.80       5.14       5.26

X STA.        6.3        8.2       10.1       11.8       13.6       15.3
  A(I)            21.5       21.8       20.6       21.0       20.7
  V(I)            5.64       5.58       5.90       5.78       5.87

X STA.       15.3       16.9       18.6       20.2       21.9       23.6
  A(I)            20.7       20.9       20.7       21.3       22.1
  V(I)            5.88       5.80       5.86       5.70       5.49

X STA.       23.6       25.4       27.3       29.5       32.3       45.6
  A(I)            23.1       23.6       27.4       32.0       53.2
  V(I)            5.25       5.15       4.44       3.80       2.28
```

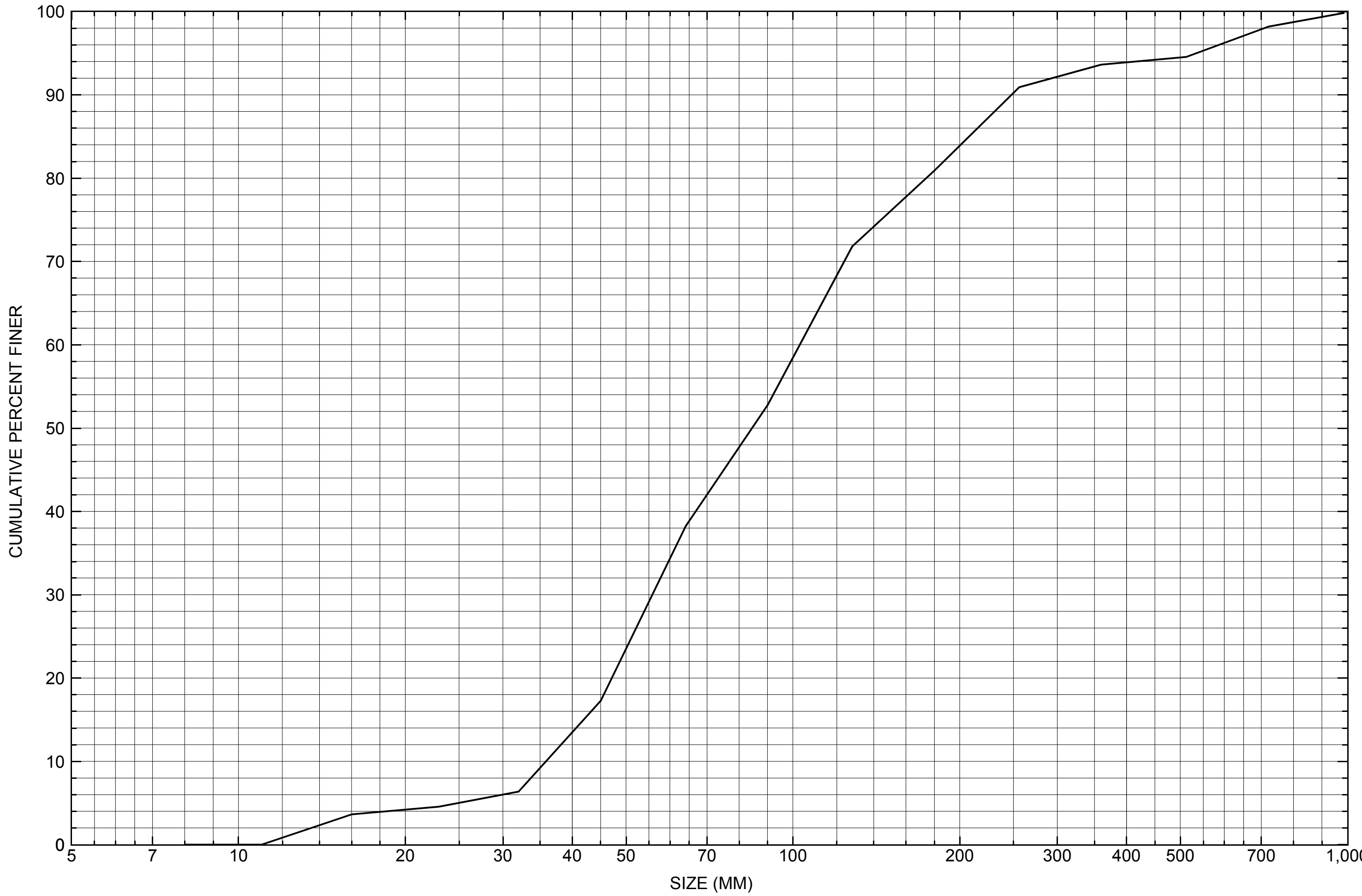
```
       U.S. Geological Survey WSPRO Input File camb053.wsp
       Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
       TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
          *** RUN DATE & TIME: 07-16-97  15:35

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

EXITX:XS   ******   -12.     162.  1.71 *****  990.16  988.24   1700.  988.45
      -18. ******    29.    7602.  1.00 ***** *******    0.93   10.48

FULLV:FV      18.   -13.     202.  1.10  0.65  990.81 *******   1700.  989.71
        0.    18.    30.   10557.  1.00  0.00    0.00    0.68    8.40
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.28     991.19     991.83
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   989.21    1011.26    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   989.21    1011.26     991.83
 ===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 =   991.83    1011.26     991.83

APPRO:AS      49.    -5.     151.  1.98 *****  993.81  991.83   1700.  991.83
       49.    49.    33.    7468.  1.00 ***** *******    1.00   11.28
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1700.     991.59

           <<<<<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      18.     2.     122.  3.02 *****  994.61  991.59   1700.  991.59
        0.    18.    22.    8588.  1.00 ***** *******    1.00   13.93

    TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
      1. ****   1.  1.000 ******  996.31 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      12.   -10.     328.  0.42  0.24  996.29  991.83   1700.  995.87
       49.    16.    39.   22535.  1.00  1.45    0.00    0.35    5.18

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.472  0.273   16401.     9.    29.   995.74

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -18.   -12.    29.   1700.    7602.     162.   10.48  988.45
   FULLV:FV       0.   -13.    30.   1700.   10557.     202.    8.40  989.71
   BRIDG:BR       0.     2.    22.   1700.    8588.     122.   13.93  991.59
   RDWAY:RG      14.**************      0.*****************     2.00********
   APPRO:AS      49.   -10.    39.   1700.   22535.     328.    5.18  995.87
```

```
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       9.    29.   16401.

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    988.24     0.93  983.23 1010.98************  1.71  990.16  988.45
   FULLV:FV  ********     0.68  983.53 1011.28  0.65  0.00  1.10  990.81  989.71
   BRIDG:BR    991.59     1.00  983.61  996.31************  3.02  994.61  991.59
   RDWAY:RG  ****************  999.34 1011.63**********************************
   APPRO:AS    991.83     0.35  986.50 1011.26  0.24  1.45  0.42  996.29  995.87

         U.S. Geological Survey WSPRO Input File camb053.wsp
         Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
         TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
            *** RUN DATE & TIME: 07-16-97  15:35

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

 EXITX:XS   ******   -13.     206.  2.16 *****  991.66  989.33   2430.  989.50
      -18. ******    30.   10861.  1.00 ***** *******    0.95   11.78

 FULLV:FV      18.   -14.     255.  1.42  0.66  992.31 *******   2430.  990.89
        0.    18.    31.   14781.  1.00  0.00   -0.01    0.71    9.54
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    1.26     992.20     992.99
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   990.39    1011.26    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   990.39    1011.26     992.99
  ===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 =   992.99    1011.26     992.99

 APPRO:AS      49.    -7.     197.  2.38 *****  995.37  992.99   2430.  992.99
       49.    49.    35.   10961.  1.00 ***** *******    1.00   12.36
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   993.24     998.08     998.29     996.31
  ===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      18.     0.     221.  1.88 *****  998.19  993.24   2427.  996.31
        0. ******    22.   14682.  1.00 ***** *******    0.62   10.99

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.476 ******  996.31 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS      12.   -10.     517.  0.34  0.14  999.81  992.99   2430.  999.46
       49.    15.    46.   42673.  1.00  1.49    0.00    0.27    4.70
```

```
      U.S. Geological Survey WSPRO Input File camb053.wsp
      Hydraulic analysis for structure CAMBTH00750053   Date: 18-APR-97
      TH 75 crossing the Brewster River 0.3 miles to junction with VT 108
         *** RUN DATE & TIME: 07-16-97  15:35
 FIRST USER DEFINED TABLE.

   XSID:CODE     SRD     LEW     REW       Q         K      AREA      VEL    WSEL
  EXITX:XS      -18.    -13.     30.   2430.   10861.      206.    11.78  989.50
  FULLV:FV        0.    -14.     31.   2430.   14781.      255.     9.54  990.89
  BRIDG:BR        0.      0.     22.   2427.   14682.      221.    10.99  996.31
  RDWAY:RG       14.**************       0.        0.        0.     2.00********
  APPRO:AS       49.    -10.     46.   2430.   42673.      517.     4.70  999.46

SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS      FR#     YMIN     YMAX     HF     HO   VHD      EGL     WSEL
  EXITX:XS     989.33     0.95   983.23 1010.98************  2.16   991.66   989.50
  FULLV:FV   ********     0.71   983.53 1011.28   0.66   0.00  1.42   992.31   990.89
  BRIDG:BR     993.24     0.62   983.61  996.31************  1.88   998.19   996.31
  RDWAY:RG   ****************   999.34 1011.63************  0.34   999.73********
  APPRO:AS     992.99     0.27   986.50 1011.26   0.14   1.49  0.34   999.81   999.46
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CAMBTH00750053, in Cambridge, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CAMBTH00750053

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 08 / 95

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

County *(FIPS county code; I - 3; nnn)* 015

Town *(FIPS place code; I - 4; nnnnn)* 11500

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

Waterway *(I - 6)* BREWSTER RIVER

Road Name *(I - 7):* -

Route Number TH075

Vicinity *(I - 9)* 0.3 MI TO JCT W VT 108

Topographic Map Mount Mansfield

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44351

Longitude *(i - 17; nnnnn.n)* 72473

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10080200530802

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

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

Year built *(I - 27; YYYY)* 1929

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

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

Deck Width *(I - 52; nn.n)* 250

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

Channel & Protection *(I - 61; n)* 4

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 22.5

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

Vertical clearance from streambed (*nnn.n ft*) 11.7

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

Waterway of full opening (*nnn.n* ft^2) 263.3

Comments:

The structural inspection report of 10/31/94 indicates the structure is a concrete T-beam type bridge. The abutment walls and wingwalls appear to be stone that was faced with concrete. The bottoms of the walls were cased in concrete footings constructed some time after the bridge. The concrete facing on the upstream right wingwall is badly spalled, and nearly half the concrete is eroded. The facing on the downstream right wingwall also is badly spalled, with cracks and large areas of section loss. The right abutment concrete has some random vertical cracks. About 80% of the left abutment and the entire upstream left wingwall have been covered with an additional concrete facing. **(Continued, page 32)**

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:

The remaining original concrete facing has deep spalls and vertical cracks visible in places. There is a 10 foot section at the upstream end of the left abutment where the constructed footing is undermined up to 3 feet with 2 - 3 inches of penetration and a bedrock outcrop showing under the right half of the 10 foot section. There is a large point bar along the right abutment that blocks half the channel. Large boulders and some bedrock is noted as part of the bank material upstream and downstream. No settlement is noted. The flow is mainly along the left abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **4.30** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1110** ft   Headwater elevation **3008** ft

Main channel length **2.36** mi

10% channel length elevation **1160** ft   85% channel length elevation **2280** ft

Main channel slope *(S)* **632.77** 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 available.

-

-

-

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:

Possibly some bedrock as structural notes indicate outcrops upstream and downstream and even showing from underneath the left abutment.

Comments:

No plans are available.

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 7/11/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 10/31/94. The sketch was done on 6/16/92.**

Station	0	7.5	11	14	22.5	-	-	-	-	-	-
Feature	LAB				RAB	-	-	-	-	-	-
Low chord elevation	996.3	996.3	996.3	996.3	996.3	-	-	-	-	-	-
Bed elevation	994.4	983.7	984.9	985.6	988.1	-	-	-	-	-	-
Low chord - bed length	1.9	12.6	11.4	10.7	8.2	-	-	-	-	-	-

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

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/14/96**

Computerized by: **RB** Date: **3/15/96**

Reviewd by: **MAI** Date: **7/2/97**

Structure Number **CAMBTH00750053**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **7** / **11** / 19**95**

2. Highway District Number **8** Mile marker **0**

County **LAMOILLE (015)** Town **CAMBRIDGE (11500)**

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

Route Number **TH75** Hydrologic Unit Code: **02010005**

3. Descriptive comments:
The site is located 0.3 miles from the junction with VT 108.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **5** 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 **2** DS **2** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **28** *(feet)* Span length **24** *(feet)* Bridge width **25** *(feet)*

Road approach to bridge:

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

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

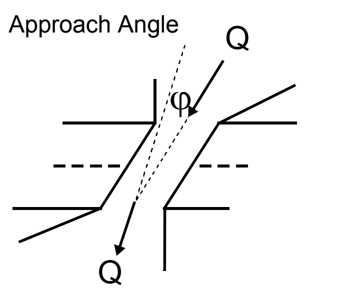
10. Embankment slope (*run / rise in feet / foot*):
US left **4.0:1** US right **1.9:1**

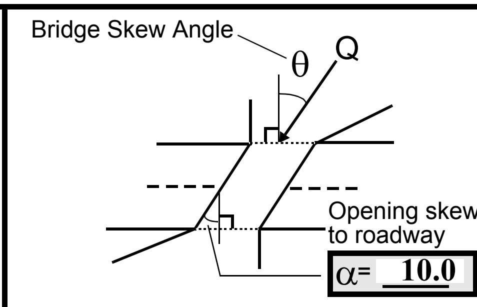
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	2	1	2	1
RBUS	0	-	1	1
RBDS	3	1	2	1
LBDS	2	1	2	1

*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: **50** 16. Bridge skew: **40**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **50** feet **US** *(US, UB, DS)* to **20** feet **US**

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

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

18. Bridge Type: **1a**

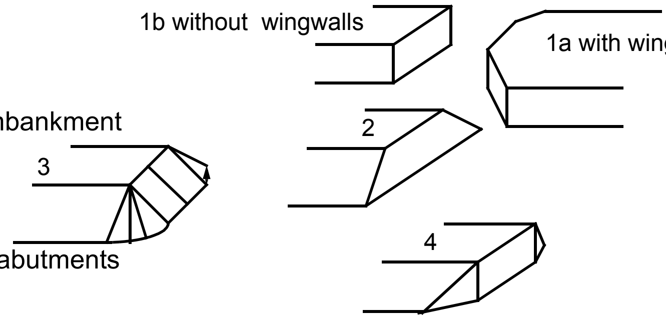
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abutment 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. The bridge dimensions measured matched the values in the VT AOT files.
11. The left bank US and right bank DS have broken slabs of concrete laid in place to minimize erosion. The left bank DS is a rock wall.
17. The upstream left bank impact zone severity is high due to the sharp turn in the river.
18. The wingwalls are sloping from the low chord to about 1 foot below then vertical.
On the left bank, a step footing extends beyond the end of the wingwall about 4 feet.

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
32.0	**6.5**			**12.5**	**4**	**4**	**5**	**5**	**3**	**2**

23. Bank width **30.0** 24. Channel width **35.0** 25. Thalweg depth **55.5** 29. Bed Material **4**

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

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

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

28. The left bank is steep and there is mass wasting above the channel on the bank. There is no cut bank apparent on the left bank due to the slumped material. On the right bank there is a cut bank on the inside of the bend.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 80 35. Mid-bar width: 15

36. Point bar extent: 100 feet US (US, UB) to 20 feet US (US, UB, DS) positioned 30 %LB to 100 %RB

37. Material: 435

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

At the start of this point bar is a big boulder across the channel that directs the flow towards the left bank.

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

41. Mid-bank distance: 70 42. Cut bank extent: 100 feet US (US, UB) to 40 feet US (US, UB, DS)

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

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

The cut bank is due to flow going over the boulder causing turbulence at high flows against the bank.

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

47. Scour dimensions: Length 30 Width 8 Depth : 1 Position 0 %LB to 40 %RB

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

The scour was located 10 feet US to 20 feet DS of the US face of the bridge. Scour is due to flow hitting the left abutment and footing at a severe angle.

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

There is a small drainage on the left bank side of the bridge at the end of the wingwall.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
28.5		0.5		2	7	7	0

58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 90.0 63. Bed Material 0

*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.):

435

-

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

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

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

70. Debris and Ice Comments:

2

There is some constriction plus a severe angle of approach into the bridge. There is also some debris caught on boulders and trees leaning over the channel upstream.

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		**40**	**90**	**2**	**3**	**1**	**3.5**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**3**	**21.5**

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

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

0

1.5

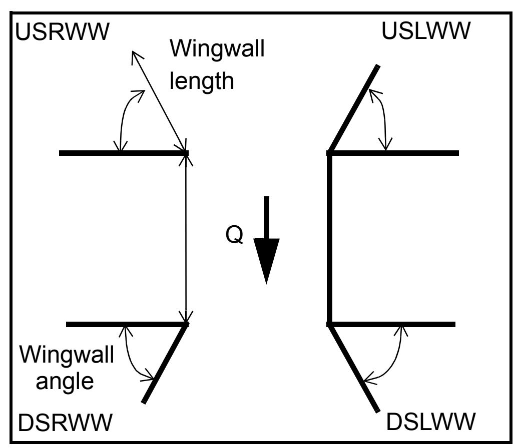
1

The bottom of the left abutment footing is exposed and undermined about 10 feet from each bridge face. Penetration under the footing is about 1 ft. The depth from the bottom of the footing to the channel bed is about 0.3 foot.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**21.5**	
USRWW:	**Y**		**1**		**2**	**2.0**	
DSLWW:	**0**		**3**		**Y**	**29.5**	
DSRWW:	**1**		**2**		**0**	**26.5**	

*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	**3**	**-**	**Y**	**0**	**1**	**-**	**-**	**-**
Condition	**N**	**-**	**1**	**1**	**1**	**-**	**-**	**-**
Extent	**-**	**-**	**2**	**3**	**0**	**0**	**0**	**-**

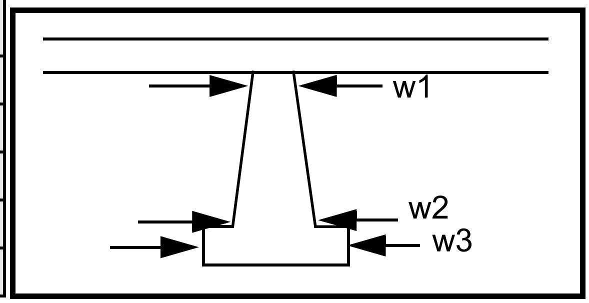
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
4
1
1

Piers:

84. Are there piers? **Th** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**85.0**	**16.0**	**25.0**
Pier 2		**-**		**10.0**	**-**	**60.0**
Pier 3	**9.5**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e top of**	**ing**	**occurr**	**is**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**the**	**alon**	**ed.**	**dum**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**foot-**	**g the**	**The**	**ped**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**ings**	**left**	**dow**	**con-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**are**	**abut**	**nstre**	**crete**	*Y- yes; N- no*
91. Attack ∠ (BF)	**high**	**ment**	**am**	**slabs**	
92. Pushed	**and**	**foot-**	**right**	**.**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**expo**	**ing**	**wing**		
95. Cross-members	**sed**	**wher**	**wall**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**with**	**e**	**pro-**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**unde**	**scou**	**tec-**		
98. Exposure depth	**rmin**	**r has**	**tion**		

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: NO

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

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 3 (US, UB, DS)

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

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

5
5
1
2

Is channel scour present? 543 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length 5 Width - Depth: 1 Positioned The %LB to rig %RB

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

ht bank protection consists of construction debris and concrete slabs.

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

Y

20

8

5

UB

109. G. Plan View Sketch

- 15

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: CAMBTH00750053 Town: Cambridge
Road Number: TH 75 CountyVP1VPamoille
Stream: Brewster River

Initials MAI Date: 06/27/97 Checked: EMB

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	1700	2430	0
Main Channel Area, ft2	328	517	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	50	56	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.27699	0.27699	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.6	9.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	22511	42684	0
Conveyance, main channel	22511	42684	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1700.0	2430.0	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	5.2	4.7	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.0	10.6	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1700	2430	0
(Q) discharge thru bridge, cfs	1700	2430	0
Main channel conveyance	8587	14682	0
Total conveyance	8587	14682	0
Q2, bridge MC discharge,cfs	1700	2430	ERR
Main channel area, ft2	122	221	0
Main channel width (normal), ft	20.2	22.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.2	22.1	0
y_bridge (avg. depth at br.), ft	6.04	10.00	ERR
Dm, median (1.25*D50), ft	0.346238	0.346238	0
y2, depth in contraction,ft	7.49	9.41	ERR
ys, scour depth (y2-ybridge), ft	**1.45**	-0.59	N/A

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	1700	2430	0
Q, thru bridge MC, cfs	1700	2430	N/A
Vc, critical velocity, ft/s	10.00	10.58	N/A
Va, velocity MC approach, ft/s	5.18	4.70	N/A
Main channel width (normal), ft	20.2	22.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.2	22.1	0.0
qbr, unit discharge, ft2/s	84.2	110.0	ERR
Area of full opening, ft2	122.0	221.0	0.0
Hb, depth of full opening, ft	6.04	10.00	ERR
Fr, Froude number, bridge MC	0	0.62	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	155	0
**Hb, depth at downstream face, ft	N/A	7.01	ERR
**Fr, Froude number at DS face	ERR	1.04	ERR

**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	996.31	0
Elevation of Bed, ft	-6.04	986.31	N/A
Elevation of Approach, ft	0	999.46	0
Friction loss, approach, ft	0	0.14	0
Elevation of WS immediately US, ft	0.00	999.28	0.00
ya, depth immediately US, ft	6.04	13.01	N/A
Mean elevation of deck, ft	0	999.7	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.93	ERR
**Cc, for downstream face (<=1.0)	ERR	1.00	ERR
Ys, scour w/Chang equation, ft	N/A	**1.12**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-1.21	N/A

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

**Ys, scour w/Chang equation, ft	N/A	3.38	N/A
**Ys, scour w/Umbrell equation, ft	ERR	1.75	ERR

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	7.49	9.41	0.00
WSEL at downstream face, ft	--	993.26	993.16
Depth at downstream face, ft	N/A	7.01	N/A
Ys, depth of scour (Laursen), ft	N/A	2.40	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	1700	2430	N/A
Main channel area (DS), ft2	122	155	0
Main channel width (normal), ft	20.2	22.1	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	20.2	22.1	0.0
D90, ft	0.8134	0.8134	0.0000
D95, ft	1.7529	1.7529	0.0000
Dc, critical grain size, ft	0.9640	1.1432	ERR
Pc, Decimal percent coarser than Dc	0.080	0.066	0.000
Depth to armoring, ft	33.26	48.53	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	1700	2430	0	1700	2430	0
a', abut.length blocking flow, ft	12.2	10.5	0	17.2	23.4	0

Ae, area of blocked flow ft2	53	77.2	0	106.1	177.5	0
Qe, discharge blocked abut.,cfs	196	259	0	487	708	0

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

Ve, (Qe/Ae), ft/s	3.70	3.35	ERR	4.59	3.99	ERR
ya, depth of f/p flow, ft	4.34	7.35	ERR	6.17	7.59	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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.313	0.218	ERR	0.326	0.255	ERR
ys, scour depth, ft	10.67	13.78	N/A	14.96	17.32	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)	12.2	10.5	0	17.2	23.4	0
y1 (depth f/p flow, ft)	4.34	7.35	ERR	6.17	7.59	ERR
a'/y1	2.81	1.43	ERR	2.79	3.08	ERR
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.31	0.22	N/A	0.33	0.26	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1.04	0	1	1.04	0
y, depth of flow in bridge, ft	6.04	7.01	0.00	6.04	7.01	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.)	2.53	2.96	ERR	2.53	2.96	ERR