LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (WODSTH00750041) on TOWN HIGHWAY 75, crossing HAPPY VALLEY BROOK, WOODSTOCK, VERMONT

U.S. Geological Survey
Open-File Report 96-567

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1996

U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

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 41 (WODSTH00750041) ON TOWN HIGHWAY 75, CROSSING HAPPY VALLEY BROOK, WOODSTOCK, VERMONT

By Scott A. Olson

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WODSTH00750041 on town highway 75 crossing Happy Valley Brook, Woodstock, 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 New England Upland section of the New England physiographic province of east-central Vermont. The 3.45-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is brush with scattered trees.

In the study area, Happy Valley Brook has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 23 ft and an average channel depth of 5 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 82.8 mm (0.272 ft). The geomorphic assessment at the time of the Level II site visits on September 13, 1994 and December 14, 1994, indicated that the reach was degrading. Five logs are embedded across the channel under the bridge in an attempt to prevent further degradation (see Figures 5 and 6).

The town highway 75 crossing of Happy Valley Brook is a 27-ft-long, two-lane bridge consisting of one 25-foot steel-beam span. The clear span is 17 ft. (Vermont Agency of Transportation, written communication, August 3, 1994). The bridge is supported by vertical, stone abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening and the opening-skew-to-roadway is also 40 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and 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 1.3 to 2.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.2 to 12.0 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.

Quechee, VT. Quadrangle, 1:24,000, 1959
Photorevised 1980

NORTH

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

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

LEVEL II SUMMARY

Structure Number WODSTH00750041 *Stream* Happy Valley Brook

County Windsor *Road* TH75 *District* 4

Description of Bridge

Bridge length 27 *ft* *Bridge width* 17.2 *ft* *Max span length* 25 *ft*

Alignment of bridge to road (on curve or straight) Slight curve.

Abutment type Vertical, stone *Embankment type* Vertical

Stone fill on abutment? No *Date of inspection* 9/13/94 and 12/14/94

Description of stone fill --

Brief description of piers/abutments Abutments and wingwalls are stone. The left abutment is leaning slightly streamward.

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

There is a mild sinuosity through the reach.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	9/13/94 and 12/14/94	0	0
Level II	9/13/94	0	0

Potential for debris Moderate.

Describe any features near or at the bridge that may affect flow (include observation date) September 13, 1994 and December 14, 1994. None.

Description of the Geomorphic Setting

General topography The channel is located in a steep, upland, valley with no flood plains.

9/13/94 and 12/14/94

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

Date of inspection Steep channel bank to high terrace.

DS left:

DS right: Steep channel bank to high terrace.

US left: Steep channel bank to high terrace.

US right: Steep channel bank to high terrace.

Description of the Channel

Average top width 23 ***ft*** ***Average depth*** 5 ***ft***

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

Incised and sinuous with semi-alluvial channel boundaries.

9/13/94 and 12/14/94

Vegetative co

DS left: Brush with scattered trees.

DS right: Brush with scattered trees.

US left: Brush with scattered trees.

US right: Brush with scattered trees.

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

September 13, 1994 and December 14, 1994. *Banks appear laterally stable, however, the channel under the bridge is experiencing long-term degradation. Five logs are embedded across the channel spaced between the upstream and downstream face as a preventative measure.

Describe any obstructions in channel and date of observation. None; September 13, 1994 and December 14, 1994.

Hydrology

Drainage area 3.4 ***mi²***

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***: There are a several residences in the vicinity of the structure.

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 940 ***ft³/s*** ***Q500*** 1,330 ***ft³/s***

The 100-year discharge was taken from the VTAOT database (VTAOT, written communication, May, 1995). The 500-year discharge was determined from a graphical extrapolation of the flood frequency values in the database. The discharges were within a range defined 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 in concrete on top of the upstream right corner of the bridge deck (elev. 502.04 ft, arbitrary survey datum). RM2 is a chiseled X in concrete on top of the upstream left corner of the bridge deck (elev. 503.15 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXIT1	-50	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	43	2	Modelled Approach section (Templated from APTEM)
APTEM	53	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 0.050 to 0.063. The overbank "n" value was 0.085.

Normal depth at the exit section (EXIT1) 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 0.034 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1959).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.027 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 approach also provides a consistent method for determining scour variables.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 502.0 *ft*
Average low steel elevation 500.1 *ft*

100-year discharge 940 *ft³/s*
Water-surface elevation in bridge opening 489.0 *ft*
Road overtopping? N *Discharge over road* -- *s*
Area of flow in bridge opening 69.3 *ft²*
Average velocity in bridge opening 13.6 *ft/s*
Maximum WSPRO tube velocity at bridge 18.4 *ft/s*

Water-surface elevation at Approach section with bridge 493.2
Water-surface elevation at Approach section without bridge 489.8
Amount of backwater caused by bridge 3.4 *t*

500-year discharge 1,330 *ft³/s*
Water-surface elevation in bridge opening 490.5 *ft*
Road overtopping? N *Discharge over road* --
Area of flow in bridge opening 87.7 *ft²*
Average velocity in bridge opening 15.2 *ft/s*
Maximum WSPRO tube velocity at bridge 21.0 */s*

Water-surface elevation at Approach section with bridge 495.6
Water-surface elevation at Approach section without bridge 490.6
Amount of backwater caused by bridge 5.0

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

Water-surface elevation at Approach section with bridge --
Water-surface elevation at Approach section without bridge --
Amount of backwater caused by bridge -- *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 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 was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The large depths to armoring indicate that armoring will not limit contraction scour.

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	1.3	2.2	--
Depth to armoring	27.8	47.2	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.3	12.0	--
Right abutment	7.2	10.3	--
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	2.4	3.0	--
Right abutment	2.4	3.0	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

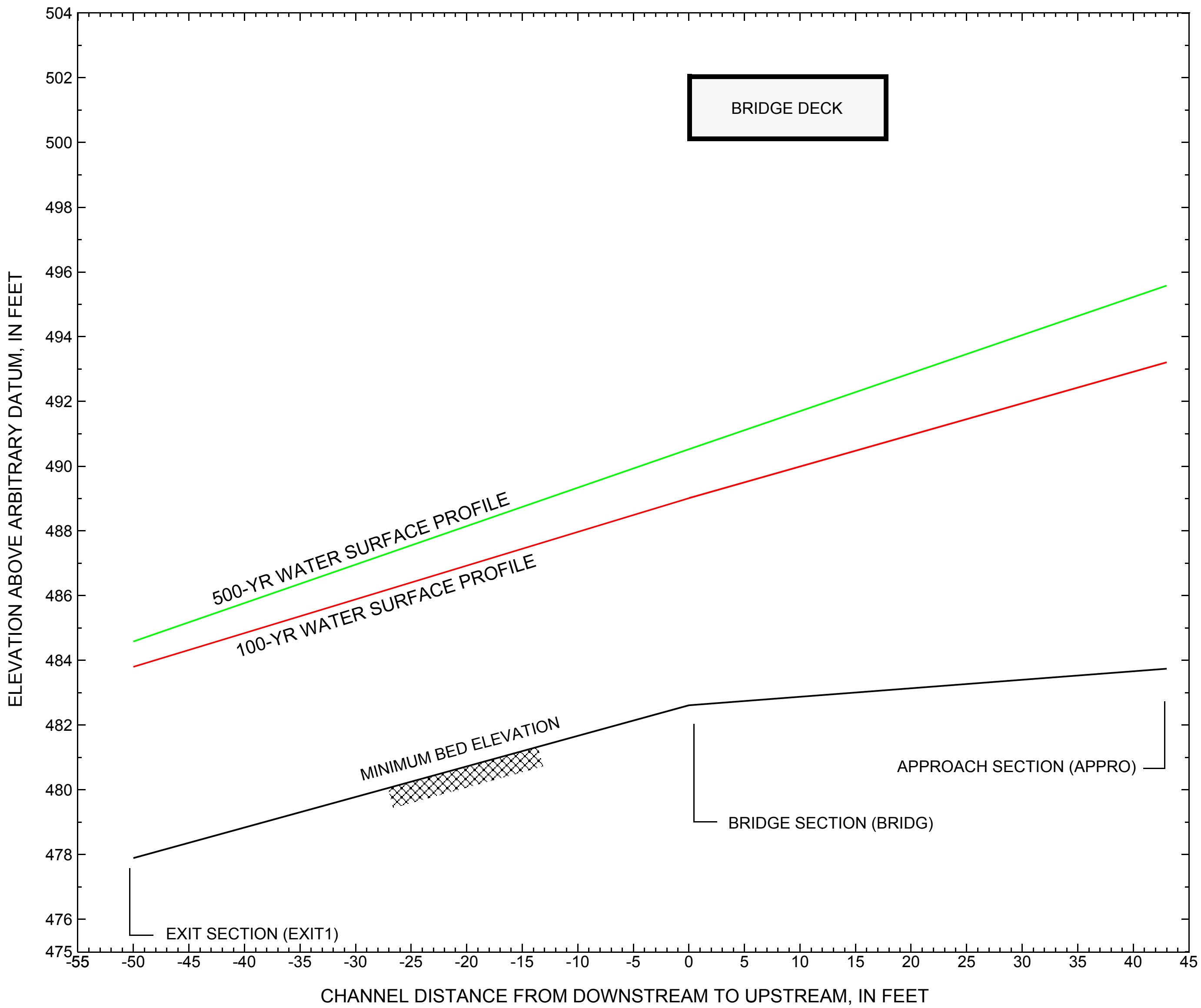

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WODSTH00750041 on town highway 75, crossing Happy Valley Brook, Woodstock, Vermont.

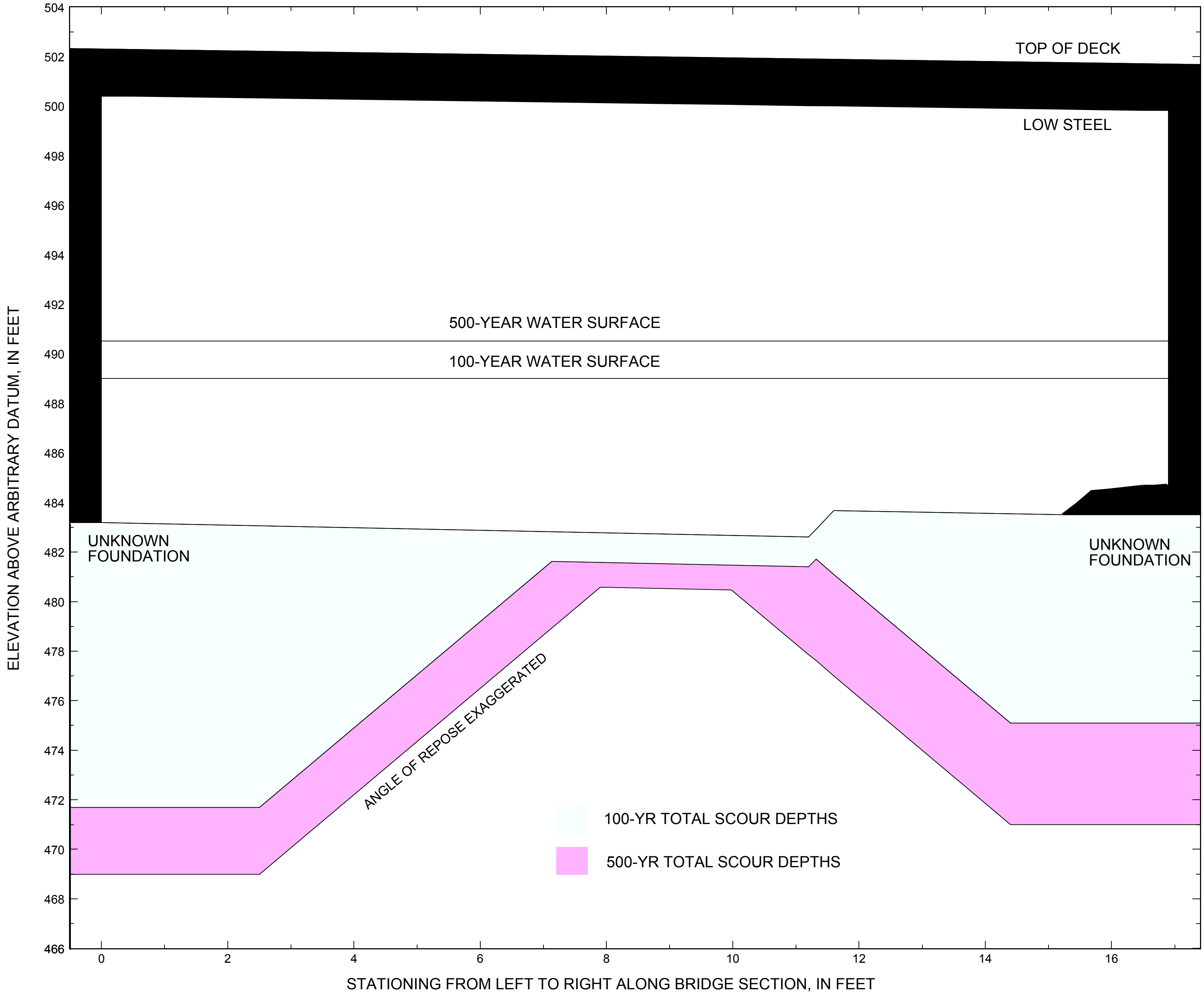

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WODSTH00750041 on town highway 75, crossing Happy Valley Brook, Woodstock, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WODSTH00750041 on Town Highway 75, crossing Happy Valley Brook, Woodstock, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 940 cubic-feet per second											
Left abutment	0.0	--	500.2	--	483.2	1.3	10.3	--	11.6	471.6	--
Right abutment	16.9	--	500.1	--	483.5	1.3	7.2	--	8.5	475.0	--

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 WODSTH00750041 on Town Highway 75, crossing Happy Valley Brook, Woodstock, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,330 cubic-feet per second											
Left abutment	0.0	--	500.2	--	483.2	2.2	12.0	--	14.2	469.0	--
Right abutment		--	500.1	--	483.5	2.2	10.3	--	12.5	471.0	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wods041.wsp
T2        Hydraulic analysis for structure WODSTH00750041   Date: 30-APR-96
T3        HYDRAULIC ANALYSIS OF BRIDGE 41 IN WOODSTOCK, VT      SAO
*
Q           940 1330
SK          0.034 0.034
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXIT1  -50
GR          -24.0, 491.58    -10.4, 483.97      0.0, 479.32      4.7, 478.57
GR            5.4, 477.89     10.0, 478.67     11.5, 478.69     16.2, 482.17
GR           25.1, 483.77     42.2, 495.58
N             0.061
*
XS   FULLV   0 * * * 0.094
*
BR   BRIDG   0 500.1 40
GR            0.0, 500.17      1.2, 483.19     11.2, 482.61     11.6, 483.67
GR           15.2, 483.51     15.7, 484.47     16.5, 484.70     16.9, 500.08
GR            0.0, 500.17
N             0.050
CD           1 33.2 * * 23 12.3
*
XR   RDWAY   15 17 1
GR          -52.2, 505.18    -19.2, 502.93      0.0, 502.33     18.2, 501.69
GR          124.7, 500.54
*
XT   APTEM   53
GR          -18.2, 503.82     -2.0, 489.45      0.0, 484.70      0.9, 484.60
GR            5.3, 484.01      8.1, 484.54     14.3, 485.77     18.0, 491.36
GR           24.6, 491.29     41.5, 500.51
*
AS   APPRO   43
GT           -0.27
N            0.063     0.085
SA                18.0
*
HP 1 BRIDG    489.01 1 489.01
HP 2 BRIDG    489.01 * * 940
HP 1 APPRO    493.21 1 493.21
HP 2 APPRO    493.21 * * 940
*
HP 1 BRIDG    490.52 1 490.52
HP 2 BRIDG    490.52 * * 1330
HP 1 APPRO    495.58 1 495.58
HP 2 APPRO    495.58 * * 1330
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wods041.wsp
        Hydraulic analysis for structure WODSTH00750041   Date: 30-APR-96
        HYDRAULIC ANALYSIS OF BRIDGE 41 IN WOODSTOCK, VT      SAO
           *** RUN DATE & TIME: 05-01-96  11:30
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       69      4261     12     23                          940
   489.01            69      4261     12     23  1.00      1     17      940

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      489.01     0.8    16.6    69.3    4261.     940.  13.57
X STA.         0.8        2.7        3.6        4.3        5.0        5.6
  A(I)            7.5        4.1        3.4        3.1        2.9
  V(I)           6.26      11.50      13.87      15.09      16.03

X STA.         5.6        6.2        6.8        7.3        7.9        8.4
  A(I)            2.8        2.7        2.7        2.6        2.6
  V(I)          16.99      17.52      17.61      18.36      18.26

X STA.         8.4        9.0        9.5       10.0       10.6       11.2
  A(I)            2.6        2.6        2.6        2.6        2.8
  V(I)          18.19      18.10      17.80      17.85      16.61

X STA.        11.2       12.1       12.8       13.7       14.6       16.6
  A(I)            3.9        3.1        3.4        4.1        7.2
  V(I)          11.94      15.02      13.85      11.60       6.51

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      166     11640     25     32                         2447
             2       19       459     11     11                          140
   493.21           184     12099     35     44  1.11     -6     29     2279

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
        WSEL     LEW     REW    AREA        K        Q    VEL
      493.21    -6.5    28.6   184.5   12099.     940.   5.10
X STA.        -6.5       -0.4        0.9        2.0        2.9        3.7
  A(I)           18.8       11.4        9.1        8.4        7.7
  V(I)           2.49       4.13       5.17       5.62       6.10

X STA.         3.7        4.5        5.2        6.0        6.7        7.4
  A(I)            7.3        7.0        6.9        6.7        6.6
  V(I)           6.43       6.70       6.78       6.97       7.07

X STA.         7.4        8.2        8.9        9.7       10.6       11.4
  A(I)            6.8        6.7        6.9        7.1        7.0
  V(I)           6.95       7.06       6.86       6.64       6.73

X STA.        11.4       12.3       13.3       14.4       16.5       28.6
  A(I)            7.5        7.9        8.7       12.7       23.4
  V(I)           6.28       5.97       5.40       3.70       2.01
```

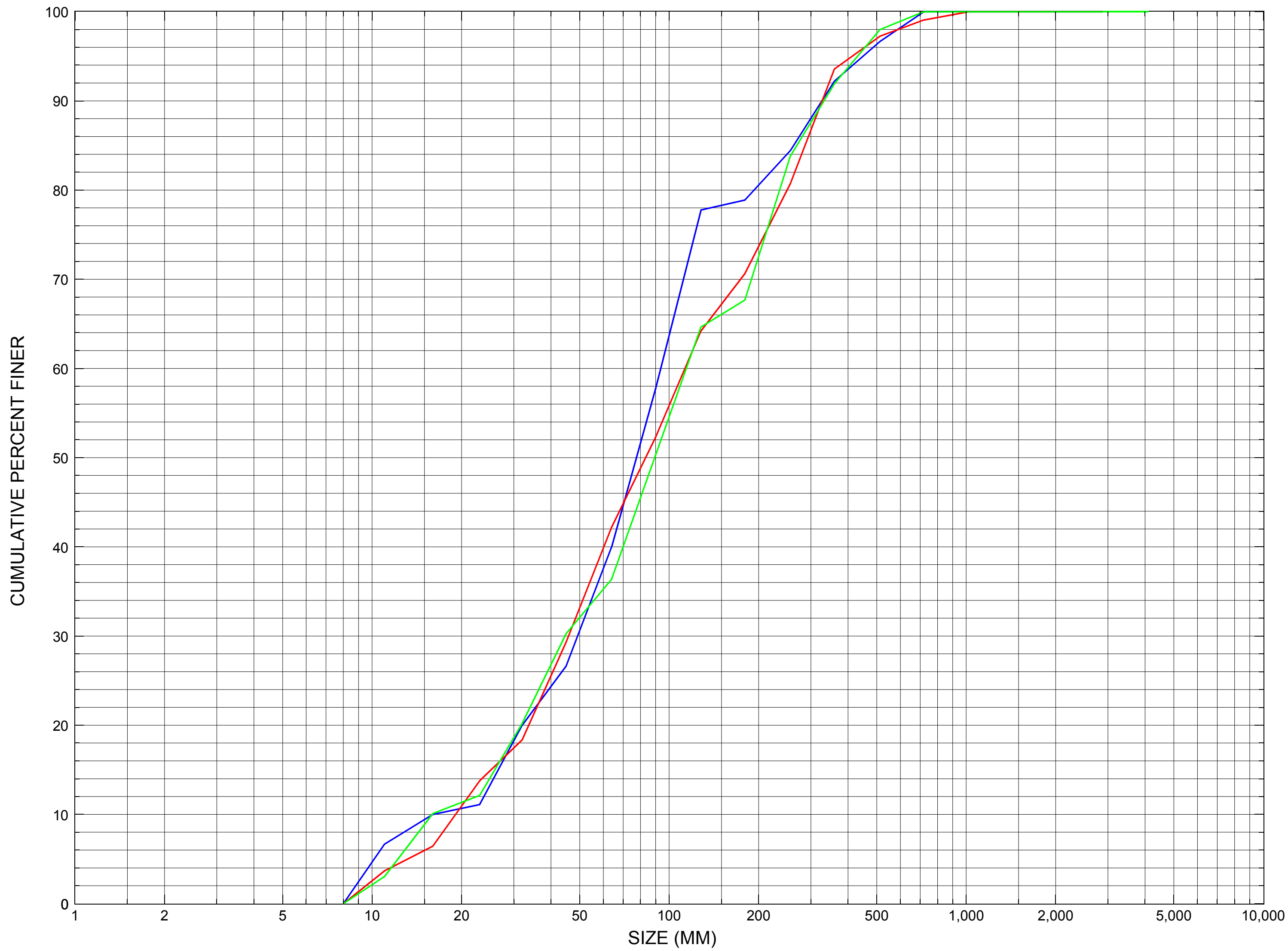
```
        U.S. Geological Survey WSPRO Input File wods041.wsp
        Hydraulic analysis for structure WODSTH00750041   Date: 30-APR-96
        HYDRAULIC ANALYSIS OF BRIDGE 41 IN WOODSTOCK, VT      SAO
           *** RUN DATE & TIME: 05-01-96  11:30
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       88      5816     12     26                         1332
   490.52            88      5816     12     26  1.00      1     17     1332

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       490.52     0.7    16.7    87.7    5816.    1330.  15.17
X STA.         0.7        2.7        3.6        4.4        5.1        5.7
  A(I)            9.9        5.2        4.4        4.0        3.7
  V(I)           6.73      12.90      15.19      16.65      18.22

X STA.         5.7        6.3        6.8        7.4        7.9        8.5
  A(I)            3.4        3.3        3.2        3.2        3.2
  V(I)          19.33      19.96      20.55      20.70      20.62

X STA.         8.5        9.0        9.5       10.1       10.6       11.2
  A(I)            3.2        3.2        3.2        3.4        3.7
  V(I)          20.97      20.89      20.56      19.81      18.17

X STA.        11.2       12.1       12.8       13.7       14.6       16.7
  A(I)            4.6        4.0        4.4        5.1        9.5
  V(I)          14.53      16.79      15.06      12.95       7.02

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      227     18344     27     36                         3725
             2       49      1797     15     16                          502
   495.58           276     20141     42     52  1.14     -8     33     3757

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.58    -9.2    33.0   276.1   20141.    1330.   4.82
X STA.        -9.2       -1.7        0.4        1.6        2.7        3.7
  A(I)           25.2       20.2       13.3       12.2       11.5
  V(I)           2.64       3.29       5.00       5.44       5.78

X STA.         3.7        4.6        5.4        6.3        7.1        8.0
  A(I)           10.6       10.0       10.1        9.8        9.7
  V(I)           6.26       6.63       6.61       6.78       6.88

X STA.         8.0        8.9        9.7       10.6       11.5       12.5
  A(I)            9.7        9.5        9.8       10.0       10.2
  V(I)           6.86       6.97       6.76       6.66       6.49

X STA.        12.5       13.5       14.8       17.1       22.0       33.0
  A(I)           10.5       12.8       17.2       22.9       30.7
  V(I)           6.32       5.21       3.86       2.91       2.16
```

```
       U.S. Geological Survey WSPRO Input File wods041.wsp
       Hydraulic analysis for structure WODSTH00750041   Date: 30-APR-96
       HYDRAULIC ANALYSIS OF BRIDGE 41 IN WOODSTOCK, VT      SAO
          *** RUN DATE & TIME: 05-01-96  11:30

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

EXIT1:XS   ******     -9      105  1.24 *****  485.03  483.56     940  483.80
       -49 ******     25     5093  1.00 ***** *******    0.91    8.93

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   483.30     500.28    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   483.30     500.28     488.26

 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   488.26     500.28     488.26

FULLV:FV       50     -8       97  1.45 *****  489.71  488.26     940  488.26
         0     50     24     4609  1.00 ***** *******    1.00    9.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     489.84     489.35

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   487.76     503.55    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   487.76     503.55     489.35

APPRO:AS       43     -2       90  1.70  1.69  491.53  489.35     940  489.83
        43     43     17     4874  1.00  0.13    0.00    0.87   10.47
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     940.     489.01

            <<<<<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       50      1       69  2.86 *****  491.87  489.01     940  489.01
         0     50     17     4265  1.00 ***** *******    1.00   13.56

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  500.10 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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       10     -6      185  0.45  0.17  493.66  489.35     940  493.21
        43     10     29    12110  1.11  1.61    0.00    0.41    5.09

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.208  0.000   12590.    -1.    15.   493.06

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -50.   -10.    25.    940.    5093.     105.    8.93  483.80
   FULLV:FV       0.    -9.    24.    940.    4609.      97.    9.66  488.26
   BRIDG:BR       0.     1.    17.    940.    4265.      69.   13.56  489.01
   RDWAY:RG      15.**************      0.*****************     1.00********
   APPRO:AS      43.    -7.    29.    940.   12110.     185.    5.09  493.21

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    15.   12590.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    483.56    0.91  477.89  495.58************  1.24  485.03  483.80
   FULLV:FV    488.26    1.00  482.59  500.28************  1.45  489.71  488.26
   BRIDG:BR    489.01    1.00  482.61  500.17************  2.86  491.87  489.01
   RDWAY:RG  ***************  500.54  505.18********************************
   APPRO:AS    489.35    0.41  483.74  503.55  0.17  1.61  0.45  493.66  493.21
```

```
        U.S. Geological Survey WSPRO Input File wods041.wsp
        Hydraulic analysis for structure WODSTH00750041   Date: 30-APR-96
        HYDRAULIC ANALYSIS OF BRIDGE 41 IN WOODSTOCK, VT      SAO
           *** RUN DATE & TIME: 05-01-96  11:30

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

EXIT1:XS   ******    -10      134  1.54 *****  486.11  484.39    1330  484.58
      -49 ******     26     7212  1.00 ***** *******    0.93    9.94

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   484.08     500.28    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   484.08     500.28     489.09

 ===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 "FULLV"
                 WSBEG,WSEND,CRWS =   489.09     500.28     489.09

FULLV:FV       50    -10      127  1.71 *****  490.80  489.09    1330  489.09
         0     50     26     6659  1.00 ***** *******    1.00   10.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    1.00     490.59     490.57

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   488.59     503.55    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   488.59     503.55     490.57

APPRO:AS       43     -3      106  2.47  1.88  493.06  490.57    1330  490.59
        43     43     18     6062  1.00  0.38    0.00    1.00   12.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =   1330.     490.52

            <<<<<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       50      1       88  3.58 *****  494.10  490.52    1330  490.52
         0     50     17     5814  1.00 ***** *******    1.00   15.17

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  500.10 ****** ****** ******

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

APPRO:AS       10     -8      276  0.41  0.15  495.99  490.57    1330  495.58
        43     10     33    20142  1.14  1.74    0.00    0.35    4.82

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.256  0.065   18846.    -1.    15.   495.47

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q       K     AREA     VEL    WSEL
   EXIT1:XS    -50.   -11.    26.   1330.    7212.     134.    9.94  484.58
   FULLV:FV      0.   -11.    26.   1330.    6659.     127.   10.50  489.09
   BRIDG:BR      0.     1.    17.   1330.    5814.      88.   15.17  490.52
   RDWAY:RG     15.**************      0.******************    1.00********
   APPRO:AS     43.    -9.    33.   1330.   20142.     276.    4.82  495.58

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -1.    15.   18846.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS     484.39    0.93  477.89  495.58************  1.54  486.11  484.58
   FULLV:FV     489.09    1.00  482.59  500.28************  1.71  490.80  489.09
   BRIDG:BR     490.52    1.00  482.61  500.17************  3.58  494.10  490.52
   RDWAY:RG   ****************  500.54  505.18**********************************
   APPRO:AS     490.57    0.35  483.74  503.55  0.15  1.74  0.41  495.99  495.58
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the channel approach of structure WODSTH00750041 in Woodstock, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WODSTH00750041

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 03 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 85975

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

Waterway *(I - 6)* HAPPY VALLEY BROOK

Road Name *(I - 7):* -

Route Number TH075

Vicinity *(I - 9)* 0.2 MI JCT TH 75 + VT 4

Topographic Map Quechee

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43378

Longitude *(i - 17; nnnnn.n)* 72282

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142400411424

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

Year built *(I - 27; YYYY)* 1915

Average daily traffic, ADT *(I - 29; nnnnnn)* 000075

Year of ADT *(I - 30; YY)* 90

Opening skew to Roadway *(I - 34; nn)* 33

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

Structure type *(I - 43; nnn)* 302

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

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

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

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

Structure length *(I - 49; nnnnnn)* 000027

Deck Width *(I - 52; nn.n)* 172

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

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

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

Year Reconstructed *(I - 106)* 0000

Clear span (*nnn.n ft*) 17.0

Vertical clearance from streambed (*nnn.n ft*) 016.0

Waterway of full opening (*nnn.n ft*^{2}) 272.0

Comments:
-

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **3.43**

Terrain character: **Hilly and mountainous**

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ **200** Q_{10} **440** Q_{25} **640**

Q_{50} **790** Q_{100} **940** 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*)	**3.4**	**5.0**	**6.2**	**7.0**	**7.9**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **U** Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): **Y** *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): **1.4** Town: **WOODSTOCK** Year Built: -

Highway No. : **TH76** Structure No. : **42** Structure Type: **CONC. SLAB**

Clear span (*ft*): **9.0** Clear Height (*ft*): **4.0** Full Waterway (*ft²*): **36.0**

Downstream distance (*miles*): 0.20 Town: WOODSTOCK Year Built: -
Highway No. : TH80 Structure No. : 46 Structure Type: STEEL BEAM
Clear span (*ft*): 18.0 Clear Height (*ft*): 7.0 Full Waterway (ft^2): 126.0

Comments:

Bridge was damaged by a flood on 6/30/73, and subsequently repaired. Design flow for the bridge is at the Q25.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 3.45 mi^2 Lake and pond area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 670 ft Headwater elevation 1510 ft
Main channel length 3.51 mi
10% channel length elevation 740 ft 85% channel length elevation 1290 ft
Main channel slope *(S)* 208.69 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:

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EMB** Date: **2/16/95**
Computerized by: **MAI** Date: **2/21/95**
Reviewd by: **SAO** Date: **8/8/96**

Structure Number **WODSTH00750041**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. WEBER** Date *(MM/DD/YY)* **9** / **13** / 19**94**

2. Highway District Number **4** Mile marker **0**

County **WINDSOR(027)** Town **WOODSTOCK(85975)**

Waterway *(I - 6)* **HAPPY VALLEY BROOK** Road Name **HAPPY VALLEY BROOK RD**

Route Number **TH075** Hydrologic Unit Code: **01080106**

3. Descriptive comments:
0.02 mile to the junction of TH 75 and VT 4. Structure is a steel stringer type bridge. This site was re-visited on 12/14/94 for quality assurance and to collect additional data.

B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **5** LBDS **5** RBDS **5** Overall **5**
*(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 **27** *(feet)* Span length **25** *(feet)* Bridge width **17.2** *(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)*

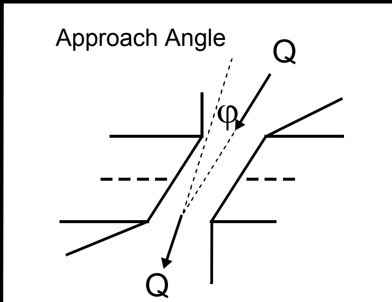
10. Embankment slope (*run / rise in feet / foot*):
US left **0.0:1** US right **0.0:1**

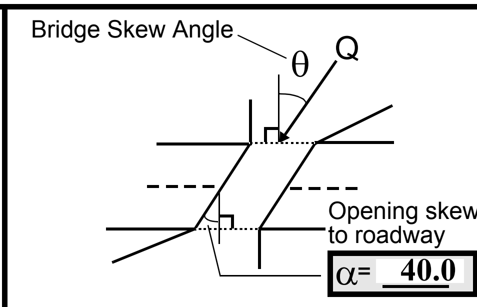
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	2	2
LBDS	0	-	2	1

*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: **0** 16. Bridge skew: **40**





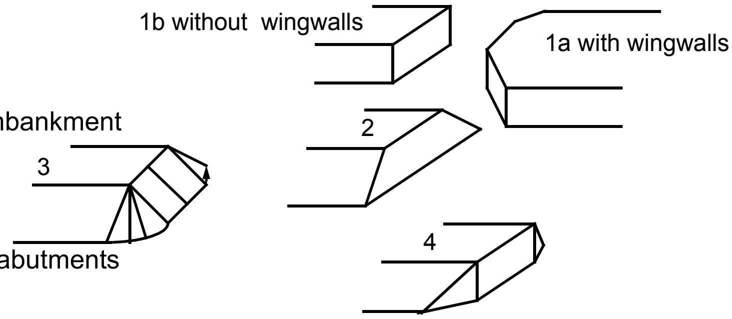
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **0** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **35** feet **US** *(US, UB, DS)* to **50** feet **US**

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

18. Level II Bridge Type: **1A**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. RBUS: Suburban lawn high on bank.
7. Measured bridge length: 25, span: 23, and width: 17.5 feet. Values entered in item #7 are from VTAOT I-codes.
17. Impact zone 1: Caused by the right abutment protruding into bank full flow. Slight impact zone exists 30 to 50 ft. downstream on the downstream left bank.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
52.9	**4.5**			**5.5**	**2**	**2**	**324**	**324**	**0**	**0**

23. Bank width **65.0** 24. Channel width **55.0** 25. Thalweg depth **20.0** 29. Bed Material **43**

30 .Bank protection type: LB **2** RB **1** 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.):

26. Well forested banks beyond 70 ft. upstream.
28. LB: the upstream left abutment has been rip rapped hiding possible erosion.
30. LB: Heavier near upstream left abutment extending 50 ft. upstream. RB: Small protection at right edge of water 0 to 30 ft. upstream; there is a low stone wall about 1.5 ft. high 30 to 50 ft. upstream.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
8.0		0.5		2	7	7	0

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

345

No real thalweg under bridge, pools between log drop structures are 0.5 ft. deep. Log drop structures will cause complex under-bridge hydraulics. Series of 5 log drop structures under bridge. Upstream end of downstream left wingwall is leaning towards the channel.

The upstream left abutment appears to be sliding towards the stream: there is a gap near the upstream end of left abutment stonework running vertically.

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:

1

67. No debris accumulation near the bridge, upstream channel is laterally stable, has few cut banks, consisting of some cobble bank material.

68. Moderate channel gradient, single span with abutments, with a span length between 80 - 50% of upstream bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	93	2	3	0.5	-	90.0
RABUT	2	0	90			2	2	17.0

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

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

-
2
2

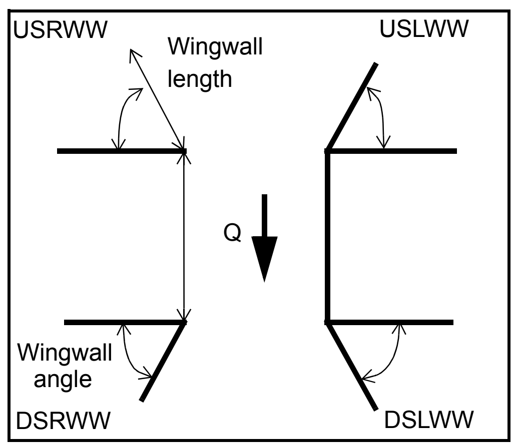
72. Tipping slightly towards the stream.

74. LABUT: Scour is at downstream end of LABUT. Last two drop structures under bridge are presently preventing additional stream bed degradation.

76 & 77. RABUT: Downstream end (1/3) is concrete (probably poured over original stone work) and 2 ft. of footing is exposed.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						-	
USRWW:	Y		2		0	-	
DSLWW:	-		-		Y	30.5	
DSRWW:	2		0		-	30.5	



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

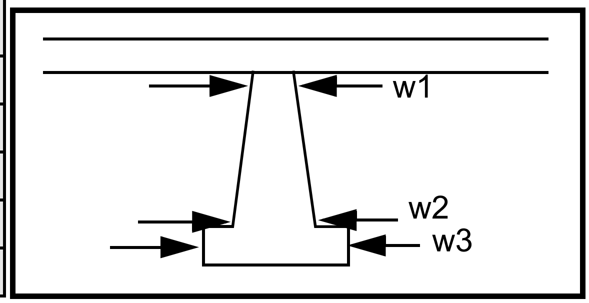
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**0.0**			**6.0**	**45.0**	**18.0**
Pier 2			-	**115.0**	**25.0**	**5.0**
Pier 3		-	-	**29.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**BUT**	**base**	**dicul**	**(see**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**:**	**of**	**ar to**	**sketc**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**Ligh**	**the**	**the**	**h).**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**t**	**upst**	**strea**	**DSL**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**cov-**	**ream**	**m.**	**WW**	*Y- yes; N- no*
91. Attack ∠ (BF)	**erag**	**end**	**Also**	**:**	
92. Pushed	**e**	**with**	**some**	**Con-**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**(type**	**the**	**at**	**sist**	
95. Cross-members	**-1**	**abut**	**dow**	**of 3**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**stone**	**ment**	**nstre**	**ft.**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**fill)**	**per-**	**am**	**con-**	
98. Exposure depth	**at**	**pen-**	**end**	**crete**	

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

cubes. Section at upstream end is tipping towards the stream.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

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

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

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

Is channel scour present? ____ (Y or if N type ctrl-n cs) Mid-scour distance: 2

Scour dimensions: Length 2 Width 231 Depth: 231 Positioned 0 %LB to 0 %RB

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

435
1
1
3

Are there major confluences? 3 (Y or if N type ctrl-n mc) How many? Ban

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

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

Confluence comments (eg. confluence name):

LB: extends from the end of DSLWW (25 ft.) to 75 ft. RB: extends from end of RABUT to 60 ft.
Stone fill on both banks is unsorted and of all classes with an average class 1.

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)*:

Y
4

109. G. Plan View Sketch

- Fi

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:	WODSTH00750041	Town:	Woodstock
Road Number:	TH75	County:	Windsor

Stream: Happy Valley Brook

Initials SAO Date: 6/19/96 Checked: EMB 7/25/96

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	940	1330	0
Main Channel Area, ft2	166	227	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	19	49	0
Top width main channel, ft	25	27	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	11	15	0
D50 of channel, ft	0.272	0.272	0
D50 left overbank, ft	--	--	0
D50 right overbank, ft	--	--	0
y1, average depth, MC, ft	6.6	8.4	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.7	3.3	ERR
Total conveyance, approach	12099	20141	0
Conveyance, main channel	11640	18344	0
Conveyance, LOB	0	0	0
Conveyance, ROB	459	1797	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	904.3	1211.3	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	35.7	118.7	ERR
Vm, mean velocity MC, ft/s	5.4	5.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.9	2.4	ERR
Vc-m, crit. velocity, MC, ft/s	10.0	10.4	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	N/A
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	N/A

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)

 Approach Section                     Q100     Q500    Qother

   Main channel Area, ft2           166      227      0
   Main channel width, ft           25       27       0
 y1, main channel depth, ft           6.64     8.41   ERR

 Bridge Section

   (Q) total discharge, cfs         940      1330     0
   (Q) discharge thru bridge, cfs   940      1330

   Main channel conveyance          4261     5816
   Total conveyance                 4261     5816
 Q2, bridge MC discharge,cfs        940      1330     ERR
   Main channel area, ft2           69       88       0
   Main channel width (skewed), ft  12.1     12.3     0.0
   Cum. width of piers in MC, ft    0.0      0.0      0.0
 W, adjusted width, ft              12.1     12.3     0
 y_bridge (avg. depth at br.), ft   5.73     7.13     ERR
 Dm, median (1.25*D50), ft          0.34     0.34     0
 y2, depth in contraction,ft          7.03     9.33   ERR

 ys, scour depth (y2-ybridge), ft   1.30     2.20     N/A



 ARMORING
 D90                                1.078    1.078
 D95                                1.412    1.412
 Critical grain size,Dc, ft         1.0657   1.2027   ERR
 Decimal-percent coarser than Dc    0.103    0.071
 Depth to armoring,ft               27.84    47.21    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	940	1330	0	940	1330	0
a', abut.length blocking flow, ft	9.1	11.7	0	13.9	18.2	0
Ae, area of blocked flow ft2	44.9	68.7	0	34.3	70.8	0
Qe, discharge blocked abut.,cfs	172.3	253.9	0	87.3	199.5	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.84	3.70	ERR	2.55	2.82	ERR
ya, depth of f/p flow, ft	4.93	5.87	ERR	2.47	3.89	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	50	50	50	130	130	130
K2	0.93	0.93	0.93	1.05	1.05	1.05
Fr, froude number f/p flow	0.304	0.269	ERR	0.286	0.252	ERR
ys, scour depth, ft	10.29	11.98	N/A	7.18	10.25	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)	9.1	11.7	0	13.9	18.2	0
y1 (depth f/p flow, ft)	4.93	5.87	ERR	2.47	3.89	ERR
a'/y1	1.84	1.99	ERR	5.63	4.68	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.30	0.27	N/A	0.29	0.25	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.73	7.13		5.73	7.13	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.40	2.98	ERR	2.40	2.98	ERR