LEVEL II SCOUR ANALYSIS FOR BRIDGE 55 (WILMTH00230055) on TOWN HIGHWAY 23, crossing BEAVER BROOK, WILMINGTON, VERMONT

Open-File Report 98-007

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 55 (WILMTH00230055) on TOWN HIGHWAY 23, crossing BEAVER BROOK, WILMINGTON, VERMONT

By RONDA L. BURNS and JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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 55 (WILMTH00230055) ON TOWN HIGHWAY 23, CROSSING BEAVER BROOK, WILMINGTON, VERMONT

By **Ronda L. Burns and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WILMTH00230055 on Town Highway 23 crossing Beaver Brook, Wilmington, 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 south-central Vermont. The 7.49-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the left bank upstream and downstream of the bridge with dense woody vegetation on the immediate bank. The right bank upstream and downstream of the bridge is forested.

In the study area, Beaver Brook has an incised, straight channel with a slope of approximately 0.008 ft/ft, an average channel top width of 49 ft and an average bank height of 6 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 53.0 mm (0.174 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 7, 1996, indicated that the reach was stable.

The Town Highway 23 crossing of Beaver Brook is a 37-ft-long, one-lane bridge consisting of one 29-ft steel-beam span (Vermont Agency of Transportation, written communication, September 28, 1995). The opening length of the structure parallel to the bridge face is 27.6 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 20 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed in the downstream channel during the Level I assessment. The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the right bank upstream and downstream of the bridge and along the right abutment and type-2 stone fill (less than 36 inches diameter) along the left bank upstream and downstream of the bridge and along the left abutment. 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) for the 100- and 500-year discharges. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.3 to 1.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 11.2 to 13.7 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. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number WILMTH00230055 ***Stream*** Beaver Brook

County Windham ***Road*** TH 23 ***District*** 1

Description of Bridge

Bridge length 37 ***ft*** ***Bridge width*** 22.2 ***ft*** ***Max span length*** 29 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/7/96

Description of stone fill Type-1, along the entire base length of the right abutment. Type-2, along the entire base length of the left abutment.

Brief description of piers/abutments … Abutments are concrete.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 20

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe) [illegible]

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/7/96	0	0
Level II	8/7/96	0	0

Potential for debris Moderate. There is some debris caught on the side bars upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 8/7/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 8/7/96

DS left: Steep channel bank to a mildly sloped overbank

DS right: Moderately sloped valley wall

US left: Steep channel bank to a moderately sloped overbank

US right: Moderately sloped valley wall

Description of the Channel

Average top width 49 ***ft*** ***Average depth*** 6 ***ft***

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

Straight and stable with non-alluvial channel boundaries.

8/7/96

Vegetative co Trees and brush with pasture on the overbank

DS left: Trees and brush

DS right: Trees and brush with pasture on the overbank

US left: Trees and brush

US right: Yes

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

None as of 8/7/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.49 ***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? Yes

USGS gage description Beaver Brook at Wilmington, VT

USGS gage number 01167800 (discontinued)

Gage drainage area 6.38 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,600 ***ft³/s*** ***Q500*** 2,200 ***ft³/s***

The 100-year and 500-year discharges are the median values from a range defined by flood frequency curves developed from several empirical methods that were extended graphically to the 500-year discharge (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 nail in the center of a chiseled X on top of the first guardrail post from the upstream end of the left abutment (elev. 503.58 ft, arbitrary survey datum). RM2 is a nail in the center of a chiseled X on top of the first guardrail post from the downstream end of the right abutment (elev. 503.59 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	-39	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	48	2	Modelled Approach section (Templated from APTEM)
APTEM	62	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 0.065, and overbank "n" values ranged from 0.070 to 0.085.

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 0.0083 ft/ft which was estimated from the 100-year water surface profile downstream of the bridge in the Flood Insurance Study for the Town of Wilmington, VT (U.S. Department of Housing and Urban Development, November 1977).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0334 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.8 *ft*
Average low steel elevation 498.8 *ft*

100-year discharge 1,600 *ft^3/s*
Water-surface elevation in bridge opening 495.2 *ft*
Road overtopping? No *Discharge over road* - *ft^3/s*
Area of flow in bridge opening 162 *ft^2*
Average velocity in bridge opening 9.9 *ft/s*
Maximum WSPRO tube velocity at bridge 12.6 *ft/s*

Water-surface elevation at Approach section with bridge 496.8
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 0.7 *ft*

500-year discharge 2,200 *ft^3/s*
Water-surface elevation in bridge opening 495.9 *ft*
Road overtopping? No *Discharge over road* - *ft^3/s*
Area of flow in bridge opening 181 *ft^2*
Average velocity in bridge opening 12.2 *ft/s*
Maximum WSPRO tube velocity at bridge 15.7 *ft/s*

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 497.1
Amount of backwater caused by bridge 1.3 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

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

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.3	1.6	--
Depth to armoring	7.1	20.8	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	11.2	12.7	--
Right abutment	11.3	13.7	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:			
Left abutment	1.9	2.7	--
Right abutment	1.9	2.7	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

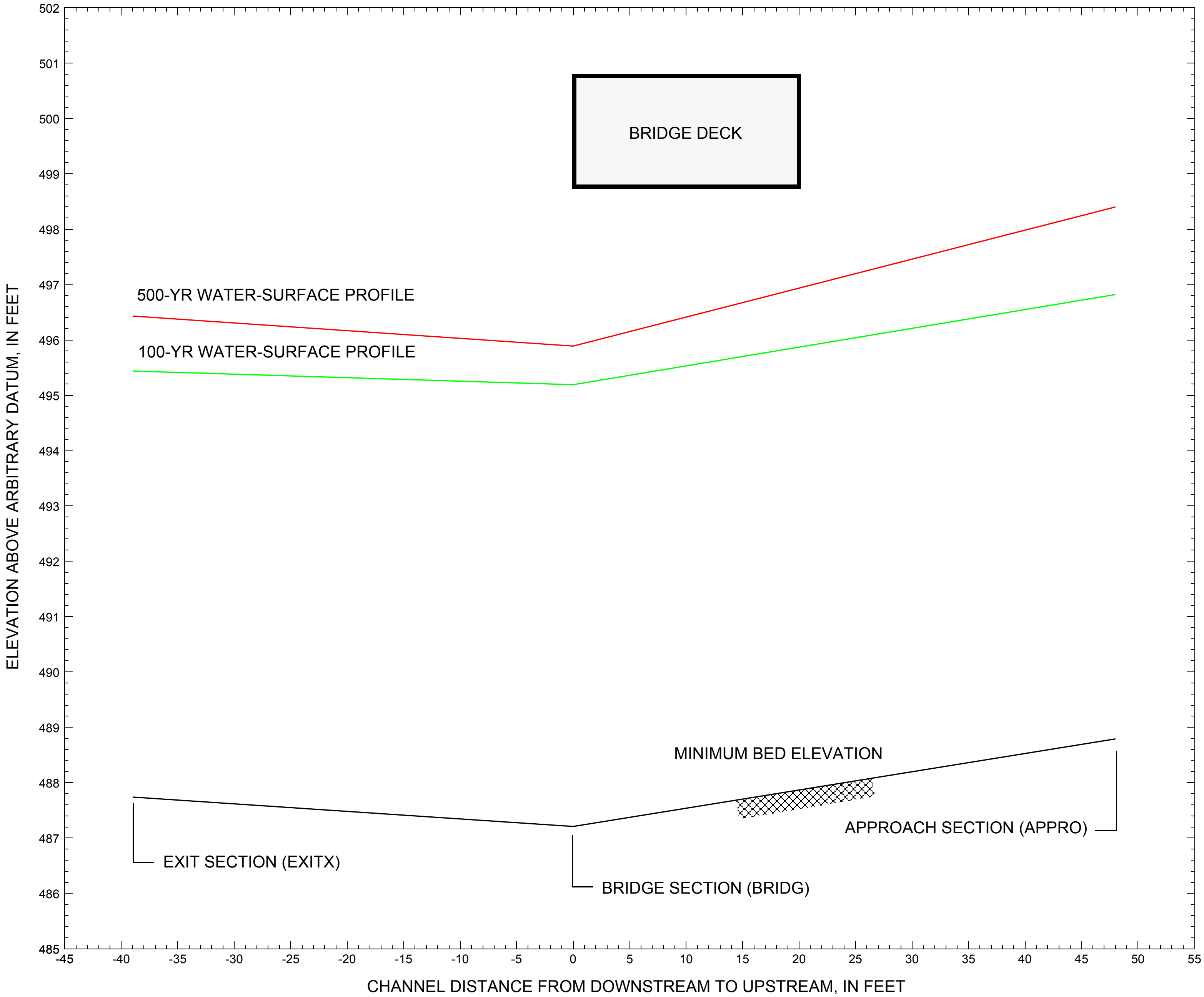

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WILMTH00230055 on Town Highway 23, crossing Beaver Brook, Wilmington, Vermont.

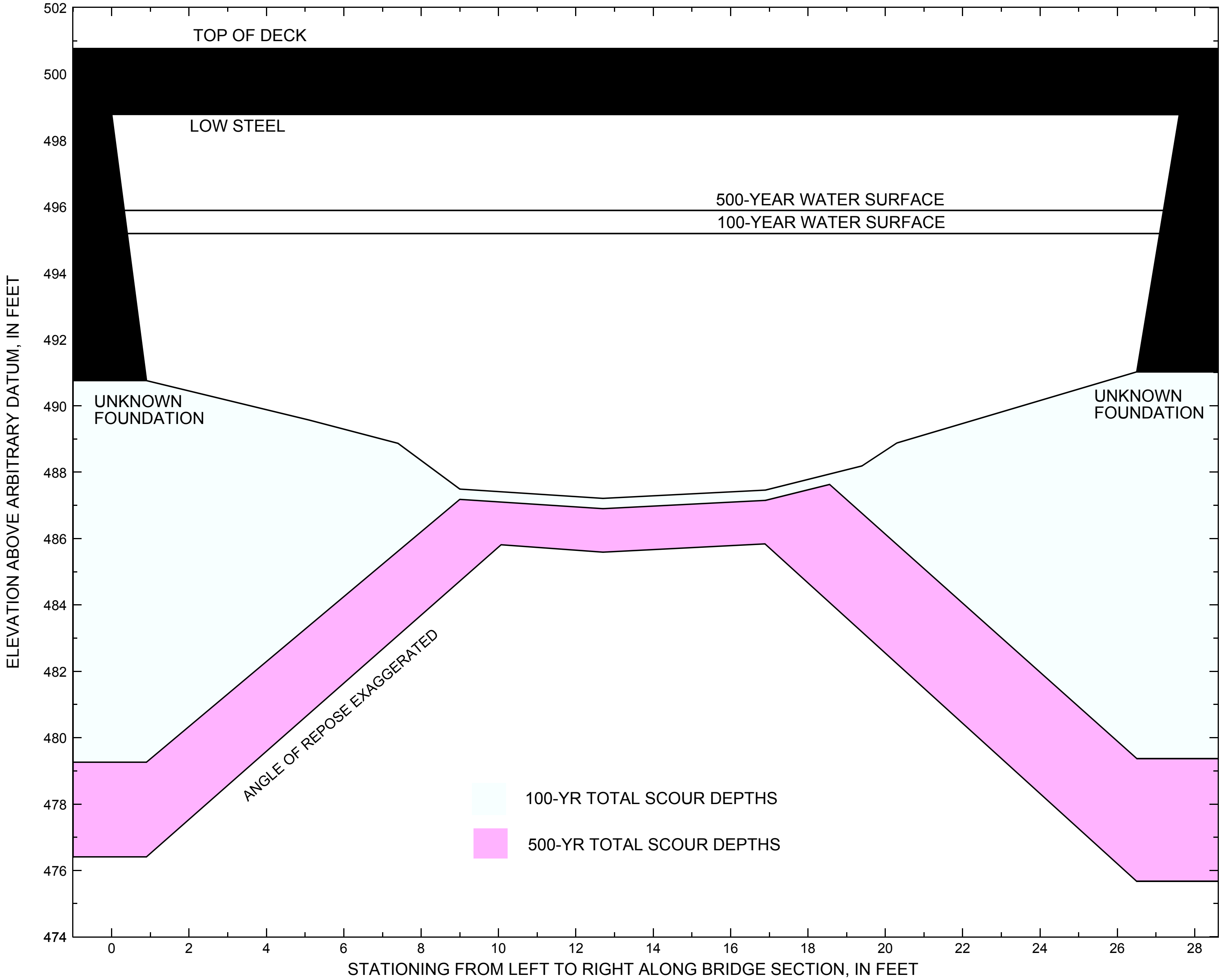

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WILMTH00230055 on Town Highway 23, crossing Beaver Brook, Wilmington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WILMTH00230055 on Town Highway 23, crossing Beaver Brook, Wilmington, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,600 cubic-feet per second											
Left abutment	0.0	--	498.8	--	490.8	0.3	11.2	--	11.5	479.3	--
Right abutment	27.6	--	498.8	--	491.0	0.3	11.3	--	11.6	479.4	--

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 WILMTH00230055 on Town Highway 23, crossing Beaver Brook, Wilmington, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,200 cubic-feet per second											
Left abutment	0.0	--	498.8	--	490.8	1.6	12.7	--	14.3	476.5	--
Right abutment	27.6	--	498.8	--	491.0	1.6	13.7	--	15.3	475.7	--

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

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U.S. Geological Survey, 1986, West Dover, 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 wilm055.wsp
T2        Hydraulic analysis for structure WILMTH00230055   Date: 12-NOV-97
T3        TH 23 CROSSING BEAVER BROOK IN WILLMINGTON, VT                    RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1600.0   2200.0
SK          0.0083   0.0083
*
XS   EXITX    -39           0.
GR         -213.6, 506.58   -176.1, 499.23   -113.7, 498.94    -46.3, 496.80
GR          -18.7, 495.86    -15.3, 495.17     -4.8, 489.70      0.0, 488.86
GR            0.6, 488.41      5.2, 488.24      8.3, 487.74     12.1, 488.06
GR           15.1, 487.94     16.1, 488.88     30.8, 492.74     48.5, 494.05
GR           70.7, 495.64    128.2, 501.73    169.5, 516.75
*
N           0.070        0.065        0.085
SA                 -18.7         30.8
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.78       5.0
GR            0.0, 498.78      0.9, 490.76      5.1, 489.57      7.4, 488.87
GR            9.0, 487.49     12.7, 487.21     16.9, 487.46     19.4, 488.19
GR           20.3, 488.88     26.5, 491.02     27.6, 498.77      0.0, 498.78
*
*         BRTYPE  BRWDTH
CD            1      20.4
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      22.2     2
GR         -158.7, 508.64   -126.1, 501.22    -22.1, 500.64      0.0, 500.76
GR           26.5, 500.76     79.7, 501.45    138.7, 502.90    169.5, 516.75
*
XT   APTEM     62           0.
GR         -126.2, 510.79    -81.8, 501.58    -49.9, 500.57    -20.2, 498.46
GR          -13.0, 497.33      0.0, 490.03      8.8, 489.97      9.8, 489.45
GR           14.2, 489.26     19.9, 489.44     24.0, 489.59     24.7, 489.96
GR           27.6, 490.40     35.0, 494.76     45.4, 495.01     55.5, 498.54
GR           72.8, 500.17    107.7, 502.74    169.5, 516.75
*
AS   APPRO     48  * * *   0.0334
GT
N           0.070        0.065        0.080
SA                 -13.0         35.0
*
HP 1 BRIDG  495.19 1 495.19
HP 2 BRIDG  495.19 * * 1600
HP 1 APPRO  496.82 1 496.82
HP 2 APPRO  496.82 * * 1600
*
HP 1 BRIDG  495.89 1 495.89
HP 2 BRIDG  495.89 * * 2200
HP 1 APPRO  498.40 1 498.40
HP 2 APPRO  498.40 * * 2200
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File wilm055.wsp
     Hydraulic analysis for structure WILMTH00230055   Date: 12-NOV-97
     TH 23 CROSSING BEAVER BROOK IN WILLMINGTON, VT                    RLB
        *** RUN DATE & TIME: 11-18-97  14:13

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      162     13462     26     35                         2279
495.19           162     13462     26     35  1.00      0     27     2279

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    495.19     0.4    27.0   162.3   13462.    1600.   9.86

X STA.        0.4        3.8        5.5        7.0        8.2        9.3
  A(I)            14.9        9.5        8.6        8.2        7.7
  V(I)            5.38       8.43       9.25       9.74      10.39

X STA.        9.3       10.1       11.0       11.8       12.6       13.4
  A(I)             6.8        6.6        6.6        6.3        6.4
  V(I)           11.77      12.11      12.13      12.61      12.59

X STA.       13.4       14.2       15.1       15.9       16.7       17.6
  A(I)             6.4        6.4        6.4        6.6        6.9
  V(I)           12.44      12.51      12.45      12.11      11.60

X STA.       17.6       18.6       19.7       21.1       23.0       27.0
  A(I)             7.1        7.8        8.6       10.0       14.4
  V(I)           11.19      10.30       9.28       8.04       5.56

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          2      291     21264     48     51                         4076
          3       32       917     17     17                          255
496.82           324     22182     65     69  1.09    -12     52     3923

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.82   -12.9    51.9   323.7   22182.    1600.   4.94

X STA.      -12.9       -2.9        0.0        2.2        4.2        6.2
  A(I)            28.0       18.8       16.1       14.8       14.6
  V(I)            2.86       4.26       4.98       5.41       5.49

X STA.        6.2        8.1       10.0       11.6       13.3       14.9
  A(I)            13.8       14.3       12.9       13.0       12.7
  V(I)            5.79       5.60       6.22       6.14       6.29

X STA.       14.9       16.5       18.1       19.7       21.4       23.0
  A(I)            12.8       12.7       12.8       13.1       12.9
  V(I)            6.25       6.29       6.25       6.09       6.21

X STA.       23.0       24.8       26.8       29.2       33.4       51.9
  A(I)            13.6       14.4       15.5       19.8       37.2
  V(I)            5.88       5.56       5.17       4.05       2.15
```

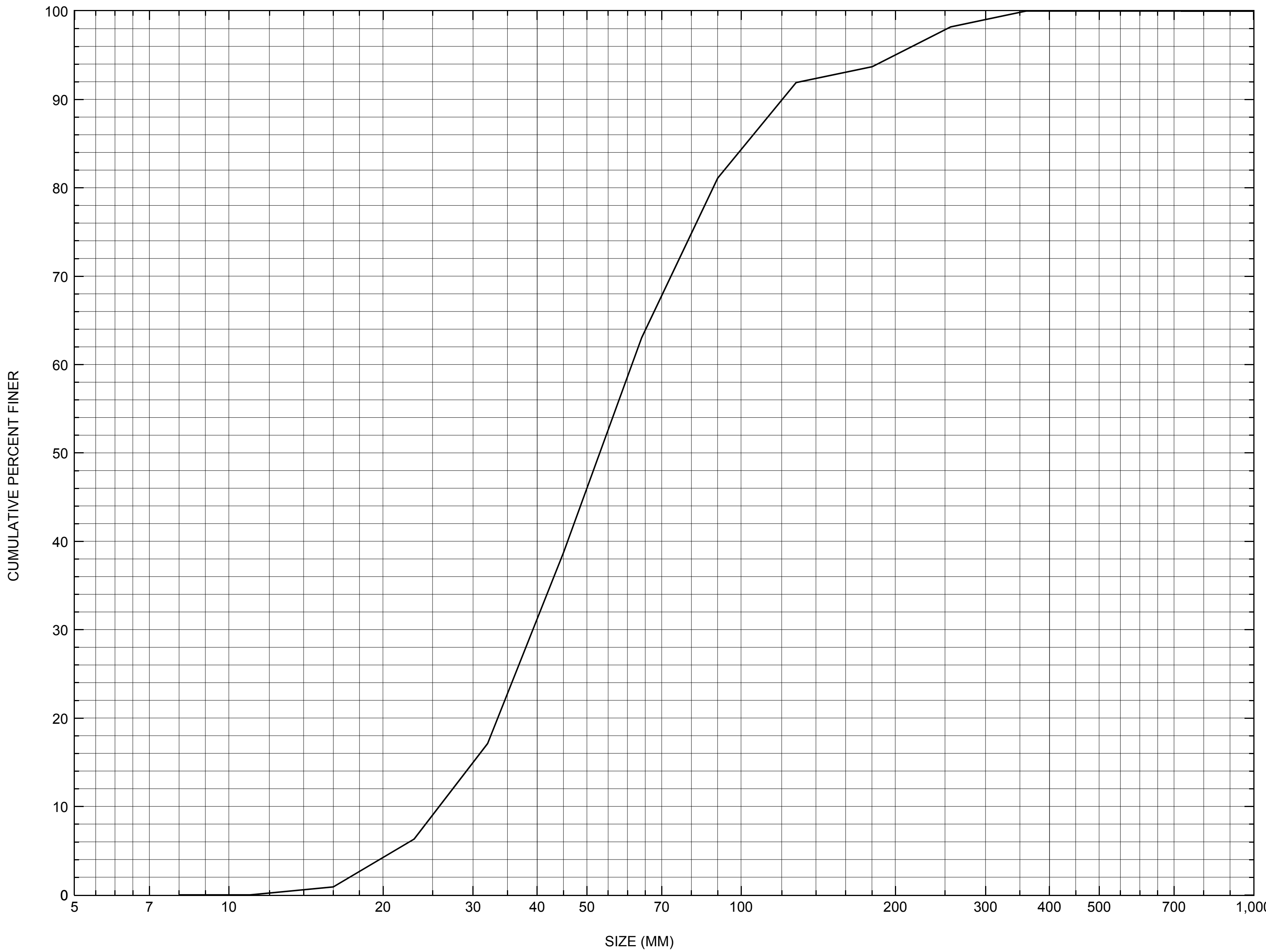
```
      U.S. Geological Survey WSPRO Input File wilm055.wsp
      Hydraulic analysis for structure WILMTH00230055   Date: 12-NOV-97
      TH 23 CROSSING BEAVER BROOK IN WILLMINGTON, VT                    RLB
         *** RUN DATE & TIME: 11-18-97  14:13

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      181     15712     27     36                         2672
 495.89           181     15712     27     36  1.00      0     27     2672

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.89     0.3    27.1   180.9   15712.    2200.  12.16

X STA.        0.3        3.7        5.5        6.9        8.2        9.2
  A(I)           16.9       10.8        9.3        9.2        8.4
  V(I)           6.49      10.21      11.83      11.95      13.16

X STA.        9.2       10.1       11.0       11.8       12.6       13.5
  A(I)            7.7        7.3        7.3        7.0        7.0
  V(I)          14.26      15.01      15.05      15.65      15.63

X STA.       13.5       14.3       15.1       16.0       16.8       17.8
  A(I)            7.2        7.1        7.2        7.4        7.7
  V(I)          15.38      15.47      15.38      14.96      14.35

X STA.       17.8       18.8       19.9       21.3       23.1       27.1
  A(I)            8.0        8.6        9.6       10.8       16.4
  V(I)          13.82      12.73      11.42      10.22       6.69

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1        8       127     13     13                           37
           2      367     31234     48     51                         5762
           3       63      2204     24     25                          581
 498.40           438     33566     85     89  1.16    -25     59     5243

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.40   -25.9    59.0   438.5   33566.    2200.   5.02

X STA.      -25.9       -4.9       -1.3        1.1        3.2        5.4
  A(I)           39.2       25.2       20.8       19.1       19.0
  V(I)           2.81       4.36       5.29       5.76       5.80

X STA.        5.4        7.4        9.5       11.3       13.1       14.9
  A(I)           18.2       18.3       17.6       17.0       17.1
  V(I)           6.06       6.01       6.25       6.48       6.44

X STA.       14.9       16.7       18.4       20.2       22.0       23.9
  A(I)           16.9       16.8       16.9       17.0       17.4
  V(I)           6.50       6.54       6.50       6.46       6.33

X STA.       23.9       25.9       28.2       31.3       38.0       59.0
  A(I)           18.1       19.5       22.1       31.3       51.0
  V(I)           6.08       5.64       4.97       3.51       2.16
```

```
        U.S. Geological Survey WSPRO Input File wilm055.wsp
        Hydraulic analysis for structure WILMTH00230055   Date: 12-NOV-97
        TH 23 CROSSING BEAVER BROOK IN WILLMINGTON, VT                    RLB
           *** RUN DATE & TIME: 11-18-97  14:13

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

EXITX:XS   ******    -16      297  0.54 *****  495.99  493.32    1600  495.44
       -38 ******     68    17545  1.20 ***** *******    0.56    5.38

FULLV:FV       39    -18      332  0.44  0.29  496.28 *******    1600  495.83
         0     39     73    19701  1.23  0.00    0.00    0.49    4.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       48    -11      280  0.55  0.34  496.67 *******    1600  496.12
        48     48     50    18225  1.08  0.05    0.00    0.49    5.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       39      0      162  1.51  0.42  496.70  493.87    1600  495.19
         0     39     27    13471  1.00  0.29    0.00    0.70    9.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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       28    -12      324  0.42  0.25  497.23  493.65    1600  496.82
        48     29     52    22167  1.09  0.29    0.01    0.41    4.94

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.565  0.200   17678.     2.    28.   496.68

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -39.   -17.    68.   1600.   17545.     297.    5.38  495.44
   FULLV:FV       0.   -19.    73.   1600.   19701.     332.    4.82  495.83
   BRIDG:BR       0.     0.    27.   1600.   13471.     162.    9.86  495.19
   RDWAY:RG      10.**************      0.*****************    2.00********
   APPRO:AS      48.   -13.    52.   1600.   22167.     324.    4.94  496.82

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    28.   17678.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    493.32    0.56  487.74  516.75************  0.54  495.99  495.44
   FULLV:FV  ********    0.49  487.74  516.75  0.29  0.00  0.44  496.28  495.83
   BRIDG:BR    493.87    0.70  487.21  498.78  0.42  0.29  1.51  496.70  495.19
   RDWAY:RG  ****************  500.64  516.75**********************************
   APPRO:AS    493.65    0.41  488.79  516.28  0.25  0.29  0.42  497.23  496.82
```

```
        U.S. Geological Survey WSPRO Input File wilm055.wsp
        Hydraulic analysis for structure WILMTH00230055   Date: 12-NOV-97
        TH 23 CROSSING BEAVER BROOK IN WILLMINGTON, VT                    RLB
           *** RUN DATE & TIME: 11-18-97  14:13

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

EXITX:XS   ******    -34      392  0.63 *****  497.05  494.30    2200  496.43
      -38 ******     78    24125  1.28 ***** *******    0.60    5.61

FULLV:FV       39    -46      441  0.52  0.28  497.34 *******    2200  496.83
         0     39     82    27500  1.33  0.00    0.00    0.55    4.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       48    -13      341  0.71  0.35  497.79 *******    2200  497.08
        48     48     53    23874  1.10  0.10    0.00    0.53    6.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       39      0      181  2.30  0.50  498.19  495.05    2200  495.89
         0     39     27    15706  1.00  0.64    0.00    0.82   12.17

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.78 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      10.        <<<<<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       28    -25      438  0.46  0.26  498.85  494.65    2200  498.40
        48     29     59    33548  1.16  0.40    0.01    0.42    5.02

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.596  0.273   24346.     2.    29.   498.29

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
  EXITX:XS     -39.   -35.    78.   2200.   24125.     392.     5.61  496.43
  FULLV:FV       0.   -47.    82.   2200.   27500.     441.     4.99  496.83
  BRIDG:BR       0.     0.    27.   2200.   15706.     181.    12.17  495.89
  RDWAY:RG      10.**************      0.******************     2.00********
  APPRO:AS      48.   -26.    59.   2200.   33548.     438.     5.02  498.40

   XSID:CODE   XLKQ   XRKQ       KQ
  APPRO:AS       2.    29.   24346.

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
  EXITX:XS    494.30    0.60  487.74  516.75************  0.63  497.05  496.43
  FULLV:FV  ********    0.55  487.74  516.75  0.28  0.00  0.52  497.34  496.83
  BRIDG:BR    495.05    0.82  487.21  498.78  0.50  0.64  2.30  498.19  495.89
  RDWAY:RG  ****************  500.64  516.75**********************************
  APPRO:AS    494.65    0.42  488.79  516.28  0.26  0.40  0.46  498.85  498.40
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WILMTH00230055, in Wilmington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WILMTH00230055

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 09 / 28 / 95

Highway District Number *(I - 2; nn)* 01

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

Town *(FIPS place code; I - 4; nnnnn)* 84700

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

Waterway *(I - 6)* BEAVER BROOK

Road Name *(I - 7)*: WHITE ROAD

Route Number C3023

Vicinity *(I - 9)* 0.1 MI TO JCT W VT9

Topographic Map Jacksonville

Hydrologic Unit Code: 1080203

Latitude *(I - 16; nnnn.n)* 42519

Longitude *(i - 17; nnnnn.n)* 72513

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10132200551322

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1954

Structure length *(I - 49; nnnnnn)* 000037

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 222

Year of ADT *(I - 30; YY)* 93

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

Opening skew to Roadway *(I - 34; nn)* 15

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

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

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

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

Year Reconstructed *(I - 106)* 1993

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

Clear span (*nnn.n ft*) 22

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

Vertical clearance from streambed (*nnn.n ft*) 9.25

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

Waterway of full opening (*nnn.n* ft^2) 203.4

Comments:

According to the structural inspection reported dated 9/27/93, the structure has been under construction and may not be 100% complete. The deck consists of 2x6's on edge. Rails and decking are treated lumber. The abutments, retaining walls, and backwalls are concrete. The backwalls are fairly new. The abutments have a few fine cracks and small spalls overall. Some stone fill has been placed in front of the abutments and around their ends. There are random boulders and ledge outcrops showing along the upstream and downstream channel banks. Minor debris and gravel bars are noted.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -
-

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / - / - Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -
-
-
-
-
-
-

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -
-

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

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

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

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft^2*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 7.49 mi^2 Lake/pond/swamp area 0.129 mi^2
Watershed storage *(ST)* 1.79 %
Bridge site elevation 1532 ft Headwater elevation 2382 ft
Main channel length 4.99 mi
10% channel length elevation 1575 ft 85% channel length elevation 1969 ft
Main channel slope *(S)* 105.28 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 BENCKMARK INFORMATION

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION

Comments:

-

Cross-sectional Data

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

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

Comments: **This cross section was attached to a 9/29/93 town bridge inspection report. All measurements are in feet. This represents the upstream face of the bridge opening. The low chord elevations have been set to the elevations surveyed for this report. The stationings are missing.**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	**LAB**	-	-	-	**RAB**	-	-	-	-	-	-
Low chord elevation	**498.78**	**498.78**	**498.78**	**498.78**	**498.78**	-	-	-	-	-	-
Bed elevation	**489.88**	**488.78**	**488.18**	**488.18**	**490.88**	-	-	-	-	-	-
Low chord to bed	**8.9**	**10**	**10.6**	**10.6**	**7.9**	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **11/07/96**
Computerized by: **RB** Date: **11/12/96**
Reviewd by: **RB** Date: **12/2/97**

Structure Number **WILMTH00230055**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **J** . **DEGNAN** Date *(MM/DD/YY)* **08** / **07** / 19**96**

2. Highway District Number **01** Mile marker **0000**

County **WINDHAM 025** Town **WILMINGTON 84700**

Waterway *(I - 6)* **BEAVER BROOK** Road Name **WHITE ROAD**

Route Number **TH23** Hydrologic Unit Code: **1080203**

3. Descriptive comments:

This wood decked bridge is 0.1 miles from the junction with VT 9.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** LBDS **4** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **37** *(feet)* Span length **29** *(feet)* Bridge width **22.2** *(feet)*

Road approach to bridge:

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

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

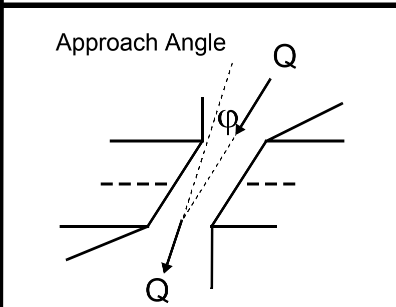
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

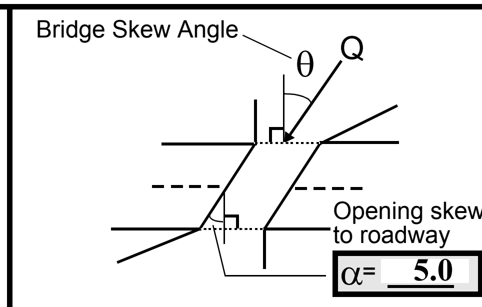
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **20**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **25** feet **US** *(US, UB, DS)* to **0** feet **DS**

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: **1b**

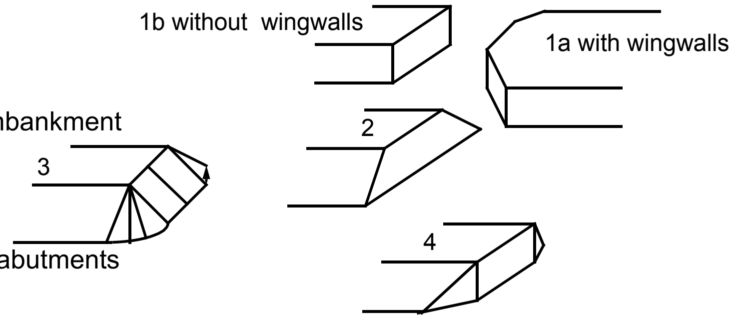
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The US and DS left banks have trees and brush along the banks and field on the overbanks.
7. The bridge dimensions are from the VTAOT files. Measured bridge dimensions match those from the VTAOT files.

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
39.5	**7.5**			**4.5**	**3**	**3**	**432**	**432**	**1**	**1**

23. Bank width **30.0** 24. Channel width **30.0** 25. Thalweg depth **48.0** 29. Bed Material **432**

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.):

30. The left bank protection extends from 10 ft US to 0 ft US. The right bank protection extends from 15 ft US to 0 ft US. The protection is dumped stone and is the same as the protection under the bridge.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **275** 35. Mid-bar width: **22**

36. Point bar extent: **350** feet **US** (US, UB) to **0** feet **US** (US, UB, DS) positioned **0** %LB to **70** %RB

37. Material: **432**

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

This side bar is vegetated with grass. There is an additional side bar on the right bank extending from 80 ft to 50 ft US with a mid-bar distance of 55 ft US and a width of 10 ft. The material is cobble, gravel and sand and it is vegetated with grass. Similar bars extend along both channel sides throughout the stream.

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: **210** 42. Cut bank extent: **280** feet **US** (US, UB) to **115** 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.):

-

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
27.5		0.5		2	7	7	-

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

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

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

432

-

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

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

70. Debris and Ice Comments:

2

There are ice scars on the trees. The side bars provide a good place for debris and ice to accumulate.

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		10	80	2	0	0	0	90.0
RABUT	1	-	80			2	0	27.5

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

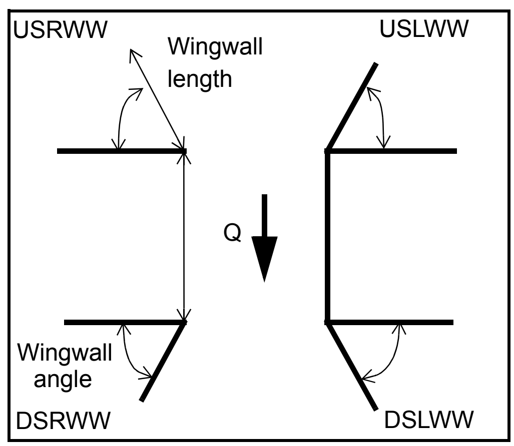
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
0
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						27.5	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	20.5	
DSRWW:	-		-		-	20.5	

*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	-	-	N	-	-	-	2	2
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	2	1	-

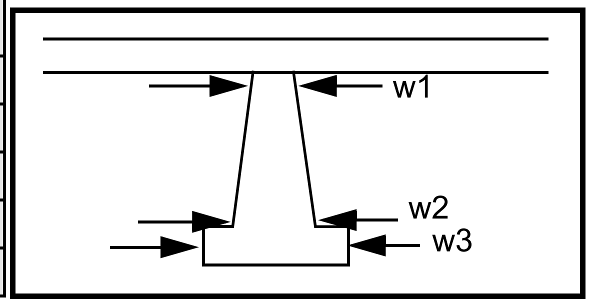
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? __-__ *(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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	N	-	-	-	
98. Exposure depth	-	-	-	-	

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

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
-	-			-	-	NO	PIE	RS		

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.):

3
3
432
432
1
1
432
2
1
1
1
The right bank protection is dumped stone extending from 0 ft DS to 13 ft DS. The left bank protection is dumped stone extending from 0 ft DS to 20 ft DS. A stone wall protects the right bank from 40 ft DS to 150 ft

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

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

105. Drop structure comments (eg. downstream scour depth):
where there is bedrock extending into the channel. A stone wall protects the left bank from 80 ft DS to 100 ft DS.

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **22** feet **4** *(US, UB, DS)* to **0** feet **DS** *(US, UB, DS)*

Bank damage: **26** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
90
100
432

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

Scour dimensions: Length **point** Width **bar** Depth: **is** Positioned **veg** %LB to **etat** %RB

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

ed with grass.

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

Confluence 1: Distance **60** Enters on **55** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **75** Enters on **DS** *(LB or RB)* Type **1** *(**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)*:

Y
22
40
10
1.5
0
85
The scour extent is from 4 ft under the bridge to 36 ft DS.

N

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WILMTH00230055 Town: WILMINGTON
Road Number: TH 23 County: WINDHAM
Stream: BEAVER BROOK

Initials RLB Date: 11/18/97 Checked: MAI

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	1600	2200	0
Main Channel Area, ft2	291	367	0
Left overbank area, ft2	0	8	0
Right overbank area, ft2	32	63	0
Top width main channel, ft	48	48	0
Top width L overbank, ft	0	13	0
Top width R overbank, ft	17	24	0
D50 of channel, ft	0.1738	0.1738	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.1	7.6	ERR
y1, average depth, LOB, ft	ERR	0.6	ERR
y1, average depth, ROB, ft	1.9	2.6	ERR
Total conveyance, approach	22182	33566	0
Conveyance, main channel	21264	31234	0
Conveyance, LOB	0	127	0
Conveyance, ROB	917	2204	0
Percent discrepancy, conveyance	0.0045	0.0030	ERR
Qm, discharge, MC, cfs	1533.8	2047.2	ERR
Ql, discharge, LOB, cfs	0.0	8.3	ERR
Qr, discharge, ROB, cfs	66.1	144.5	ERR
Vm, mean velocity MC, ft/s	5.3	5.6	ERR
Vl, mean velocity, LOB, ft/s	ERR	1.0	ERR
Vr, mean velocity, ROB, ft/s	2.1	2.3	ERR
Vc-m, crit. velocity, MC, ft/s	8.4	8.8	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	1600	2200	0
(Q) discharge thru bridge, cfs	1600	2200	0
Main channel conveyance	13462	15712	0
Total conveyance	13462	15712	0
Q2, bridge MC discharge,cfs	1600	2200	ERR
Main channel area, ft2	162	181	0
Main channel width (normal), ft	26.5	26.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.5	26.7	0
y_bridge (avg. depth at br.), ft	6.12	6.78	ERR
Dm, median (1.25*D50), ft	0.21725	0.21725	0
y2, depth in contraction,ft	6.43	8.40	ERR
ys, scour depth (y2-ybridge), ft	0.31	1.62	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	1600	2200	N/A
Main channel area (DS), ft2	162.3	180.9	0
Main channel width (normal), ft	26.5	26.7	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	26.5	26.7	0.0
D90, ft	0.3948	0.3948	0.0000
D95, ft	0.6541	0.6541	0.0000
Dc, critical grain size, ft	0.3565	0.5223	ERR
Pc, Decimal percent coarser than Dc	0.131	0.070	0.000
Depth to armoring, ft	7.10	20.82	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	1600	2200	0	1600	2200	0
a', abut.length blocking flow, ft	13.4	26.3	0	24.9	31.9	0
Ae, area of blocked flow ft2	50.46	79.13	0	71.21	113.73	0
Qe, discharge blocked abut.,cfs	178.18	297.92	0	233.33	382.61	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.53	3.76	ERR	3.28	3.36	ERR
ya, depth of f/p flow, ft	3.77	3.01	ERR	2.86	3.57	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	0	1	1	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	95	95	0	85	85	0
K2	0.99	0.99	0.00	1.01	1.01	0.00
Fr, froude number f/p flow	0.321	0.383	ERR	0.341	0.314	ERR
ys, scour depth, ft	11.19	12.73	N/A	11.34	13.73	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

	Left 100 yr Q	Left 500 yr Q	Left Other Q	Right 100 yr Q	Right 500 yr Q	Right Other Q
a'(abut length blocked, ft)	13.4	26.3	0	24.9	31.9	0
y1 (depth f/p flow, ft)	3.77	3.01	ERR	2.86	3.57	ERR
a'/y1	3.56	8.74	ERR	8.71	8.95	ERR
Skew correction (p. 49, fig. 16)	1.01	1.01	1.00	0.98	0.98	1.00
Froude no. f/p flow	0.32	0.38	N/A	0.34	0.31	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.7	0.82	0	0.7	0.82	0
y, depth of flow in bridge, ft	6.12	6.78	0.00	6.12	6.78	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.85	ERR	0.00	1.85	ERR	0.00
Fr>0.8 (vertical abut.)	ERR	2.68	ERR	ERR	2.68	ERR