LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (TOWNTH00290037) on TOWN HIGHWAY 29, crossing MILL BROOK, TOWNSHEND, VERMONT

Open-File Report 98-152

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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By RONDA L. BURNS and LAURA MEDALIE

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Pembroke, New Hampshire

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U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (TOWNTH00290037) ON TOWN HIGHWAY 29, CROSSING MILL BROOK, TOWNSHEND, VERMONT

By **Ronda L. Burns and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure TOWNTH00290037 on Town Highway 29 crossing Mill Brook, Townshend, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in southeastern Vermont. The 13.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream of the bridge. Downstream of the bridge the surface cover is pasture on the left bank and shrub and brushland on the right bank.

In the study area, Mill Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 53 ft and an average bank height of 8 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 70.0 mm (0.230 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 14, 1996, indicated that the reach was laterally unstable. There are large cut-banks and point bars upstream and downstream of the bridge. There is also moderate fluvial erosion on the upstream left bank and downstream right bank.

The Town Highway 29 crossing of Mill Brook is a 33-ft-long, one-lane bridge consisting of one 30-foot steel-girder span (Vermont Agency of Transportation, written communication, April 7, 1995). The opening length of the structure parallel to the bridge face is 24.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls, the downstream left wingwall, however, is “laid-up” stone. The channel is skewed approximately 45 degrees to the opening while the computed opening-skew-to-roadway is 25 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. This scour hole continues downstream along the right bank and deepens to 1.5 ft deeper than the mean thalweg. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream left and right banks and along the upstream right wingwall. Type-3 stone fill (less than 48 inches diameter) was along the downstream right wingwall and downstream right bank and a short stone wall is on the downstream left bank. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 2.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.7 to 8.7 ft. The worst-case left abutment scour occurred at the incipient roadway-overtopping discharge. Right abutment scour ranged from 7.8 to 9.5 ft. The worst-case right abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number TOWNTH00290037 ***Stream*** Mill Brook

County Windham ***Road*** TH 29 ***District*** 2

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 14.2 ***ft*** ***Max span length*** 30 ***ft***

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

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

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

Description of stone fill Type-2, along the upstream right wingwall. Type-3, along the downstream right wingwall.

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

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 45

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

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/14/96	0	0
Level II	8/14/96	0	0

Potential for debris Moderate. There are some small scattered pieces of debris on the upstream banks.

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

Description of the Geomorphic Setting

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

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

Date of inspection 8/14/96

DS left: Narrow flood plain

DS right: Moderately sloped overbank

US left: Steep valley wall

US right: Moderately sloped overbank

Description of the Channel

Average top width 53 ***ft*** ***Average depth*** 8 ***ft***

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

Sinuous and laterally unstable with semi-alluvial channel boundaries and wide point bars.

Vegetative co[...] 8/14/96

Few trees and short grass

DS left: Shrubs and brush

DS right: Trees and brush

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

US right:

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

There are large point bars and cut-banks upstream and downstream of the bridge as of 8/14/96.

Describe any obstructions in channel and date of observation.

None as of 8/14/96.

Hydrology

Drainage area 13.9 ***mi^2***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

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

Is there a lake/p No

Calculated Discharges

Q100 3,390 ***ft^3/s*** ***Q500*** 4,600 ***ft^3/s***

The 100- and 500-year discharges are based on a drainage area relationship [(13.9/13.3)exp 0.67] with bridge number 18 in Townshend. Bridge number 18 crosses Mill Brook upstream of this site and has flood frequency estimates available from the VTAOT database (Vermont Agency of Transportation, written communication, May 1995). The drainage area above bridge number 18 is 13.3 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 495.46 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 497.28 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	-30	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APTEM	48	1	Approach section as surveyed (Used as a template)
APPRO	52	2	Modelled Approach section (Templated from APTEM)

[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 0.045 to 0.060, and overbank "n" values ranged from 0.040 to 0.080.

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 0.0056 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0345 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 499.7 ***ft***
Average low steel elevation 497.2 ***ft***

100-year discharge 3,390 ***ft^3/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,170 ***ft^3/s***
Area of flow in bridge opening 205 ***ft^2***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.0 ***ft/s***

Water-surface elevation at Approach section with bridge 500.7
Water-surface elevation at Approach section without bridge 495.7
Amount of backwater caused by bridge 5.0 ***ft***

500-year discharge 4,600 ***ft^3/s***
Water-surface elevation in bridge opening 497.4 ***ft***
Road overtopping? Yes ***Discharge over road*** 2,150 ***ft^3/s***
Area of flow in bridge opening 206 ***ft^2***
Average velocity in bridge opening 11.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.2 ***ft/s***

Water-surface elevation at Approach section with bridge 501.3
Water-surface elevation at Approach section without bridge 496.8
Amount of backwater caused by bridge 4.5 ***ft***

Incipient overtopping discharge 1,770 ***ft^3/s***
Water-surface elevation in bridge opening 497.4 ***ft***
Area of flow in bridge opening 206 ***ft^2***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.4 ***ft/s***

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 494.1
Amount of backwater caused by bridge 4.8 ***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.

At this site, the 100-year, 500-year, and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

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

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

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

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.7	2.1	0.0
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.7	7.3	8.7
Right abutment	8.9	9.5	7.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	2.9	3.1	2.4
Right abutment	2.9	3.1	2.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

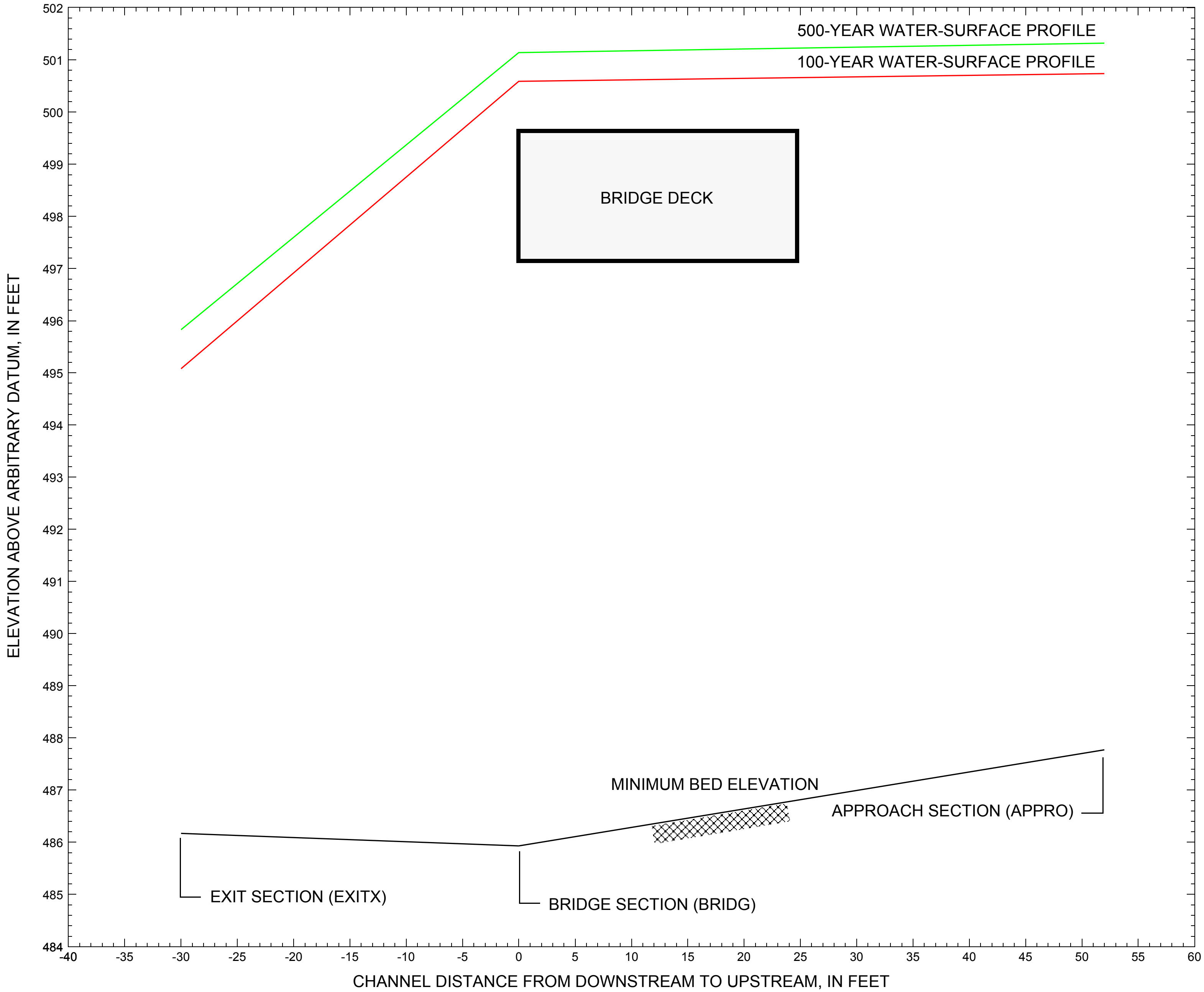

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure TOWNTH00290037 on Town Highway 29, crossing Mill Brook, Townshend, Vermont.

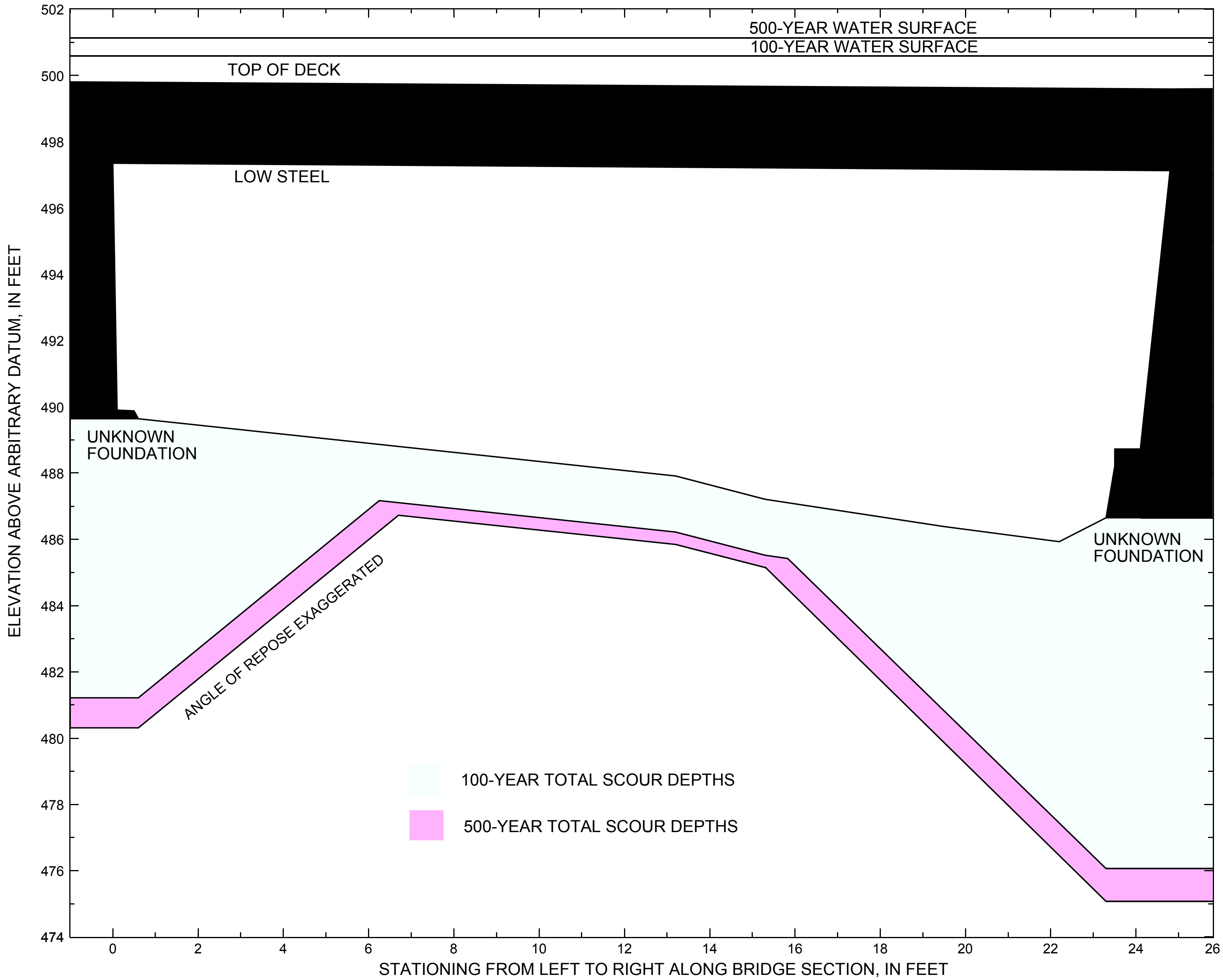

Figure 8. Scour elevations for the 100- and 500-year discharges at structure TOWNTH00290037 on Town Highway 29, crossing Mill Brook, Townshend, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure TOWNTH00290037 on Town Highway 29, crossing Mill Brook, Townshend, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,390 cubic-feet per second											
Left abutment	0.0	--	497.4	--	489.6	1.7	6.7	--	8.4	481.2	--
Right abutment	24.8	--	497.1	--	486.7	1.7	8.9	--	10.6	476.1	--

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 TOWNTH00290037 on Town Highway 29, crossing Mill Brook, Townshend, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 4,600 cubic-feet per second											
Left abutment	0.0	--	497.4	--	489.6	2.1	7.3	--	9.4	480.2	--
Right abutment	24.8	--	497.1	--	486.7	2.1	9.5	--	11.6	475.1	--

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 town037.wsp
T2        Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
T3        TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3390.0   4600.0   1770.0
SK          0.0056   0.0056   0.0056
*
XS   EXITX    -30          0.
GR         -235.0, 513.69   -200.2, 499.99   -153.4, 498.42   -130.2, 494.27
GR          -70.9, 491.20     -1.4, 492.57      0.0, 489.76     13.3, 487.84
GR           15.1, 486.85     17.5, 486.17     20.6, 487.06     22.7, 487.52
GR           27.5, 488.14     34.0, 494.01     42.0, 497.81    140.8, 497.97
GR          197.0, 502.89    303.3, 507.02
*
N           0.040        0.055        0.050
SA                  -1.4         42.0
*
XS   FULLV      0  * * *   0.0065
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.24      25.0
GR            0.0, 497.35      0.1, 489.90      0.5, 489.88      0.6, 489.64
GR           11.2, 488.17     13.2, 487.91     15.3, 487.21     19.5, 486.39
GR           22.2, 485.93     23.3, 486.65     23.5, 488.21     23.5, 488.72
GR           24.1, 488.72     24.8, 497.13      0.0, 497.35
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      33.8 * *     47.5      4.2
N          0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      14.2     2
GR         -234.6, 513.91   -162.6, 504.42    -79.2, 499.87      0.0, 499.80
GR           24.4, 499.59    109.0, 498.78    177.2, 501.30    320.8, 507.28
*
XT   APTEM     48          0.
GR         -197.0, 509.55   -101.5, 500.74    -51.3, 499.52    -16.7, 499.83
GR           -5.8, 493.78      4.0, 488.25      6.0, 487.91      8.8, 487.63
GR           12.3, 487.78     16.5, 487.70     20.1, 488.19     24.8, 490.59
GR           30.5, 490.80     46.0, 494.44     52.2, 497.39    141.7, 498.29
GR          201.3, 499.75    208.3, 501.01    352.2, 507.12
* GR           83.8, 500.32    127.3, 500.52
*
AS   APPRO     52  * * *  0.0345
GT
N          0.050        0.060        0.080
SA                 -16.7         52.2
*
HP 1 BRIDG  497.24 1 497.24
HP 2 BRIDG  497.24 * * 2254
HP 1 BRIDG  495.26 1 495.26
HP 2 RDWAY  500.59 * * 1171
HP 1 APPRO  500.74 1 500.74
HP 2 APPRO  500.74 * * 3390
*
HP 1 BRIDG  497.35 1 497.35
HP 2 BRIDG  497.35 * * 2365
HP 1 BRIDG  496.02 1 496.02
HP 2 RDWAY  501.14 * * 2154
HP 1 APPRO  501.32 1 501.32
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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      U.S. Geological Survey WSPRO Input File town037.wsp
      Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
      TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
         *** RUN DATE & TIME: 02-12-98  10:32

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     205.  17080.    11.    51.                         4973.
  497.24          205.  17080.    11.    51.  1.00     0.    25.   4973.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.24     0.0    24.8   205.1   17080.    2254.  10.99

X STA.        0.0        3.4        4.4        5.4        6.4        7.4
  A(I)             23.7        7.4        7.3        7.4        7.6
  V(I)             4.75      15.27      15.46      15.16      14.79

X STA.        7.4        8.4        9.3       10.3       11.2       12.1
  A(I)              7.5        7.6        7.7        7.8        6.7
  V(I)            15.00      14.73      14.63      14.50      16.74

X STA.       12.1       12.8       13.9       15.0       16.0       16.9
  A(I)              6.6        9.3        9.3        8.9        8.8
  V(I)            16.99      12.18      12.12      12.68      12.82

X STA.       16.9       17.8       18.7       19.6       20.5       24.8
  A(I)              8.7        8.5        8.6        8.4       37.2
  V(I)            12.91      13.29      13.09      13.38       3.03

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     161.  14438.    22.    36.                         2464.
  495.26          161.  14438.    22.    36.  1.00     0.    25.   2464.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.59   -92.4   158.0   249.6    7934.    1171.   4.69

X STA.      -92.4      -63.0      -45.6      -28.9      -12.1        5.2
  A(I)             16.5       12.9       12.7       12.9       13.7
  V(I)             3.54       4.53       4.62       4.53       4.26

X STA.        5.2       22.8       36.1       47.1       56.1       64.3
  A(I)             16.0       14.0       12.9       11.4       11.0
  V(I)             3.66       4.19       4.55       5.15       5.31

X STA.       64.3       71.7       78.6       85.1       91.2       97.0
  A(I)             10.4       10.3       10.0        9.8        9.8
  V(I)             5.62       5.70       5.83       5.98       5.98

X STA.       97.0      102.4      107.6      112.9      119.4      158.0
  A(I)              9.2        9.3        9.3       10.0       27.5
  V(I)             6.36       6.30       6.28       5.87       2.13

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      52.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      56.   1332.    79.    79.                          268.
            2     603.  60817.    69.    74.                        10122.
            3     343.  10925.   154.   154.                         2913.
  500.74         1003.  73074.   302.   307.  1.62   -96.   206.   8136.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      52.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.74   -95.8   206.0  1002.6   73074.    3390.   3.38

X STA.      -95.8       -2.0        1.6        4.2        6.5        8.7
  A(I)            128.0       36.0       30.3       28.7       28.4
  V(I)             1.32       4.70       5.59       5.91       5.96

X STA.        8.7       10.9       13.1       15.4       17.6       20.0
  A(I)             28.5       28.2       29.0       29.2       29.5
  V(I)             5.96       6.01       5.84       5.80       5.74

X STA.       20.0       22.6       25.8       29.0       32.4       36.3
  A(I)             30.9       32.8       32.1       32.9       34.5
  V(I)             5.49       5.16       5.28       5.16       4.91

X STA.       36.3       41.3       49.9       81.8      118.8      206.0
  A(I)             39.2       52.3       99.2      101.1      151.8
  V(I)             4.33       3.24       1.71       1.68       1.12
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       U.S. Geological Survey WSPRO Input File town037.wsp
       Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
       TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
          *** RUN DATE & TIME: 02-12-98  10:32

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      206.   15030.     0.    63.                     ********
  497.35           206.   15030.     0.    63.  1.00     0.    25.********

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.35     0.0    24.8   205.8   15030.    2365.  11.49

X STA.        0.0         3.6         4.9         6.0         7.2         8.3
  A(I)            25.6         9.2         8.7         8.8         8.7
  V(I)            4.63       12.90       13.62       13.45       13.52

X STA.        8.3         9.4        10.5        11.5        12.5        13.5
  A(I)             8.8         8.6         8.5         8.6         8.5
  V(I)           13.44       13.72       13.97       13.73       13.96

X STA.       13.5        14.5        15.5        16.4        17.2        18.1
  A(I)             8.6         8.4         8.3         8.1         8.1
  V(I)           13.68       14.11       14.19       14.61       14.61

X STA.       18.1        18.9        19.7        20.5        21.3        24.8
  A(I)             8.1         7.8         7.8         7.9        28.7
  V(I)           14.57       15.17       15.12       14.97        4.12

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      178.   16597.    22.    38.                       2858.
  496.02           178.   16597.    22.    38.  1.00     0.    25.   2858.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.14  -102.5   172.9   394.2   15823.    2154.   5.46

X STA.     -102.5       -69.2       -55.4       -41.5       -28.0       -14.8
  A(I)            27.5        17.7        18.0        17.8        17.4
  V(I)            3.91        6.08        5.97        6.06        6.18

X STA.      -14.8        -1.6        15.2        29.5        42.0        52.4
  A(I)            17.5        23.6        21.8        20.8        18.4
  V(I)            6.16        4.56        4.94        5.18        5.86

X STA.       52.4        61.7        70.5        78.7        86.5        93.7
  A(I)            17.4        17.1        16.7        16.3        15.8
  V(I)            6.19        6.30        6.44        6.63        6.81

X STA.       93.7       100.7       107.3       114.1       122.3       172.9
  A(I)            15.7        15.4        15.4        16.5        47.3
  V(I)            6.87        7.00        6.98        6.51        2.28

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      52.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      106.    3533.    90.    90.                        654.
            2      643.   67682.    69.    74.                      11145.
            3      434.   15698.   160.   160.                       4053.
  501.32          1183.   86914.   319.   324.  1.65  -106.   212.  10066.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      52.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.32  -106.3   212.4  1182.9   86914.    4600.   3.89

X STA.     -106.3        -4.9        -0.1         3.1         5.7         8.2
  A(I)           160.5        44.3        37.3        33.6        32.7
  V(I)            1.43        5.19        6.16        6.84        7.04

X STA.        8.2        10.6        13.0        15.5        18.0        20.6
  A(I)            32.9        32.6        33.5        33.2        34.4
  V(I)            6.99        7.05        6.87        6.93        6.68

X STA.       20.6        23.6        27.1        30.7        34.6        39.3
  A(I)            36.0        37.5        36.9        38.9        41.4
  V(I)            6.39        6.13        6.22        5.91        5.56

X STA.       39.3        45.5        68.2        97.7       131.5       212.4
  A(I)            47.2        95.3       102.8       106.9       165.0
  V(I)            4.87        2.41        2.24        2.15        1.39
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         U.S. Geological Survey WSPRO Input File town037.wsp
         Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
         TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
            *** RUN DATE & TIME: 02-12-98  10:32

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

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     206.  15030.     0.    63.                      ********
    497.35          206.  15030.     0.    63.  1.00     0.    25.********

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.35     0.0    24.8   205.8   15030.    1770.   8.60

 X STA.         0.0         3.6         4.9         6.0         7.2         8.3
   A(I)             25.6         9.2         8.7         8.8         8.7
   V(I)             3.46        9.66       10.19       10.07       10.12

 X STA.         8.3         9.4        10.5        11.5        12.5        13.5
   A(I)              8.8         8.6         8.5         8.6         8.5
   V(I)            10.06       10.27       10.46       10.27       10.45

 X STA.        13.5        14.5        15.5        16.4        17.2        18.1
   A(I)              8.6         8.4         8.3         8.1         8.1
   V(I)            10.24       10.56       10.62       10.94       10.94

 X STA.        18.1        18.9        19.7        20.5        21.3        24.8
   A(I)              8.1         7.8         7.8         7.9        28.7
   V(I)            10.91       11.35       11.32       11.21        3.09

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

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     132.  10916.    22.    34.                        1837.
    493.96          132.  10916.    22.    34.  1.00     0.    25.    1837.

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      52.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              2     477.  41936.    67.    71.                        7215.
              3      86.   1372.   108.   108.                         435.
    498.89          563.  43309.   175.   180.  1.27   -15.   161.    5081.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      52.

          WSEL     LEW     REW    AREA        K        Q    VEL
        498.89   -14.8   160.6   562.5   43309.    1770.   3.15

 X STA.       -14.8         0.3         2.7         4.7         6.4         8.2
   A(I)             63.3        21.8        20.5        18.4        19.3
   V(I)             1.40        4.06        4.31        4.80        4.59

 X STA.         8.2         9.9        11.6        13.4        15.1        16.9
   A(I)             18.9        19.3        18.9        19.4        19.5
   V(I)             4.69        4.58        4.67        4.55        4.54

 X STA.        16.9        18.6        20.5        22.6        25.2        27.9
   A(I)             19.1        19.8        20.6        22.4        21.5
   V(I)             4.65        4.47        4.30        3.95        4.11

 X STA.        27.9        30.6        33.7        37.3        42.4       160.6
   A(I)             21.8        23.3        24.9        29.2       120.5
   V(I)             4.06        3.80        3.55        3.03        0.73
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File town037.wsp
        Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
        TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
           *** RUN DATE & TIME: 02-12-98  10:32

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

EXITX:XS   ******  -135.     591.  0.52 *****  495.60  493.99   3390.  495.08
      -30. ******    36.   45292.  1.01 ***** *******    0.55    5.73

FULLV:FV      30.  -135.     589.  0.52  0.17  495.79 *******   3390.  495.26
        0.    30.    36.   45041.  1.01  0.00    0.02    0.55    5.75
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.76     509.69    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.76     509.69     495.66
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                   WSBEG,WSEND,CRWS =   495.66     509.69     495.66

APPRO:AS      52.    -9.     273.  2.40 *****  498.05  495.66   3390.  495.66
       52.    52.    48.   18546.  1.00 ***** *******    1.00   12.41
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.45       0.00     497.00     498.78
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   502.15         1.      3389.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      30.     0.     205.  1.88 *****  499.12  494.85   2254.  497.24
        0. ******    25.   17080.  1.00 ***** *******    0.67   10.99

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.490  0.000  497.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    38.  0.08  0.29  500.95    0.01   1171.  500.59

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    340.   106.   -92.    14.   0.9   0.7   4.5   4.5   1.1   2.9
   RT:    831.   144.    14.   158.   1.8   1.2   5.5   4.8   1.6   3.0

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

APPRO:AS      18.   -96.    1003.  0.29  0.12  501.03  495.66   3390.  500.74
       52.    19.   206.   73096.  1.62  0.00    0.01    0.42    3.38

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -30.  -135.    36.   3390.   45292.     591.    5.73  495.08
   FULLV:FV       0.  -135.    36.   3390.   45041.     589.    5.75  495.26
   BRIDG:BR       0.     0.    25.   2254.   17080.     205.   10.99  497.24
   RDWAY:RG      15.*******   340.   1171.******************    2.00  500.59
   APPRO:AS      52.   -96.   206.   3390.   73096.    1003.    3.38  500.74

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    493.99    0.55  486.17  513.69************  0.52  495.60  495.08
   FULLV:FV  ********    0.55  486.37  513.89  0.17  0.00  0.52  495.79  495.26
   BRIDG:BR    494.85    0.67  485.93  497.35************  1.88  499.12  497.24
   RDWAY:RG  ****************  498.78  513.91  0.08******  0.29  500.95  500.59
   APPRO:AS    495.66    0.42  487.77  509.69  0.12  0.00  0.29  501.03  500.74
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        U.S. Geological Survey WSPRO Input File town037.wsp
        Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
        TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
           *** RUN DATE & TIME: 02-12-98  10:32

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

EXITX:XS   ******  -139.     722.  0.63 *****  496.47  494.54   4600.  495.83
      -30. ******    38.   61444.  1.00 ***** *******    0.56    6.37

FULLV:FV      30.  -139.     721.  0.63  0.17  496.65 *******   4600.  496.02
        0.    30.    38.   61252.  1.00  0.00    0.02    0.56    6.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.52     509.69    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.52     509.69     496.84
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   496.84     509.69     496.84

APPRO:AS      52.   -11.     343.  2.79 *****  499.63  496.84   4600.  496.84
       52.    52.    51.   25704.  1.00 ***** *******    1.00   13.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   507.42       0.00     497.22     498.78
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.38     500.74     500.95     497.24
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      30.     0.     206.  2.05 *****  499.40  495.07   2365.  497.35
        0. ******    25.   15030.  1.00 ***** *******    0.70   11.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.493  0.000  497.24 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       15.    38.  0.11  0.39  501.61   -0.02   2154.  501.14

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    730.   116.  -102.    14.   1.5   1.2   5.7   5.3   1.6   3.0
   RT:   1423.   159.    14.   173.   2.4   1.6   6.4   5.6   2.1   3.0

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

APPRO:AS      18.  -106.    1184.  0.39  0.19  501.71  496.84   4600.  501.32
       52.    20.   212.   87026.  1.65  0.94   -0.02    0.46    3.88

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.  -139.    38.   4600.   61444.     722.    6.37  495.83
   FULLV:FV       0.  -139.    38.   4600.   61252.     721.    6.38  496.02
   BRIDG:BR       0.     0.    25.   2365.   15030.     206.   11.49  497.35
   RDWAY:RG      15.*******   730.   2154.******************    2.00  501.14
   APPRO:AS      52.  -106.   212.   4600.   87026.    1184.    3.88  501.32

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     494.54    0.56  486.17  513.69************  0.63  496.47  495.83
   FULLV:FV   ********    0.56  486.37  513.89  0.17  0.00  0.63  496.65  496.02
   BRIDG:BR     495.07    0.70  485.93  497.35************  2.05  499.40  497.35
   RDWAY:RG  ***************  498.78  513.91  0.11******  0.39  501.61  501.14
   APPRO:AS     496.84    0.46  487.77  509.69  0.19  0.94  0.39  501.71  501.32
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File town037.wsp
        Hydraulic analysis for structure TOWNTH00290037   Date: 30-JAN-98
        TH 29 CROSSING MILL BROOK IN TOWNSHEND, WINDHAM CO, VERMONT  RLB
           *** RUN DATE & TIME: 02-12-98  10:32

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

EXITX:XS   ******  -121.     377.  0.38 *****  494.16  493.00   1770.  493.78
      -30. ******    34.   23632.  1.10 ***** *******    0.55    4.69

FULLV:FV      30.  -120.     374.  0.38  0.17  494.34 *******   1770.  493.96
        0.    30.    34.   23369.  1.10  0.00    0.01    0.56    4.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.86     494.08      493.63
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.46     509.69    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.46     509.69     493.63
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.47

APPRO:AS      52.    -6.     189.  1.36  0.63  495.46  493.63   1770.  494.10
       52.    52.    44.   11007.  1.00  0.49    0.00    0.85    9.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.81     497.36     497.54     497.24
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      30.     0.     206.  1.15 *****  498.50  493.81   1766.  497.35
        0. ******    25.   15030.  1.00 ***** *******    0.53    8.58

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.440  0.000  497.24 ****** ****** ******

    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      18.   -15.     563.  0.19  0.09  499.09  493.63   1770.  498.89
       52.    19.   161.   43346.  1.27  0.95    0.00    0.35    3.14

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.83

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.  -121.    34.   1770.   23632.     377.    4.69  493.78
   FULLV:FV       0.  -120.    34.   1770.   23369.     374.    4.73  493.96
   BRIDG:BR       0.     0.    25.   1766.   15030.     206.    8.58  497.35
   RDWAY:RG      15.**************      0.       0.       0.    2.00********
   APPRO:AS      52.   -15.   161.   1770.   43346.     563.    3.14  498.89

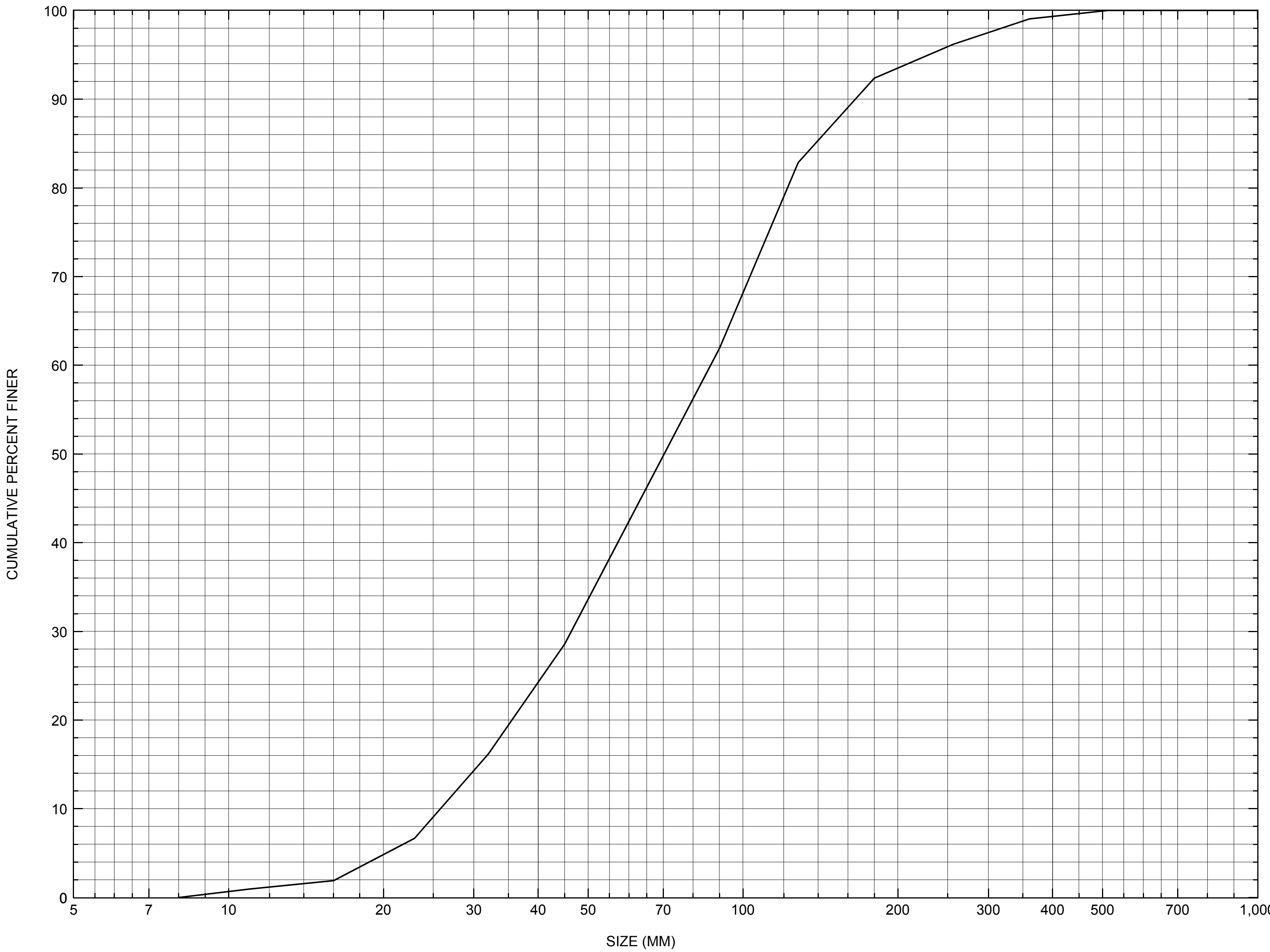
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN     YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.00    0.55  486.17  513.69************  0.38  494.16  493.78
   FULLV:FV  ********    0.56  486.37  513.89  0.17  0.00  0.38  494.34  493.96
   BRIDG:BR    493.81    0.53  485.93  497.35************  1.15  498.50  497.35
   RDWAY:RG  ****************  498.78  513.91************  0.19  499.02********
   APPRO:AS    493.63    0.35  487.77  509.69  0.09  0.95  0.19  499.09  498.89
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TOWNTH00290037, in Townshend, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number TOWNTH00290037

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 07 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 73300

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

Waterway *(I - 6)* MILL BROOK

Road Name *(I - 7):* -

Route Number TH029

Vicinity *(I - 9)* 0.1 MI JCT TH 29 & VT 35

Topographic Map Townshend

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43028

Longitude *(i - 17; nnnnn.n)* 72398

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10131700371317

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

Maximum span length *(I - 48; nnnn)* 0030

Year built *(I - 27; YYYY)* 1939

Structure length *(I - 49; nnnnnn)* 000033

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 142

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

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

Opening skew to Roadway *(I - 34; nn)* 20

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

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

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

Structure type *(I - 43; nnn)* 303

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.5

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

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

Comments:

The structural inspection report of 07/11/94 indicates the structure is a single span, steel beam type bridge with a concrete deck and an asphalt roadway surface. Both abutments are laid up stone with new reinforced concrete facings. The laid up stone walls also have older concrete bearing caps. The right abutment facing is roughly 18 inches below the bottom flanges of the main beams. At the left abutment the newer concrete facing covers the full wall height. Newer concrete footings are in view, but there is no apparent undermining. The waterway makes a moderate to sharp turn through the structure, and much of the flow is along the right abutment. The streambed consists of stone and gravel with some **(Continued, page 33)**

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:
moderately sized boulders. The bank protection consists of stone and some boulders.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 13.86 mi^2 Lake/pond/swamp area 0.04 mi^2
Watershed storage *(ST)* 0.3 %
Bridge site elevation 532 ft Headwater elevation 2028 ft
Main channel length 5.49 mi
10% channel length elevation 610 ft 85% channel length elevation 1476 ft
Main channel slope *(S)* 210.36 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / -

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

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

Comments:
NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **11/08/96**
Computerized by: **RB** Date: **11/08/96**
Reviewd by: **RB** Date: **2/18/98**

Structure Number **TOWNTH00290037**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L**. **MEDALIE** Date *(MM/DD/YY)* **08** / **14** / 19**96**

2. Highway District Number **02** Mile marker **0000**

County **WINDHAM (025)** Town **TOWNSHEND (73300)**

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

Route Number **TH29** Hydrologic Unit Code: **01080107**

3. Descriptive comments:
Located 0.1 miles from the junction of TH 29 and VT 35. A conversation with a nearby resident revealed that several beaver dams US broke this past year and some clear-cutting has been done in the area. This has increased the water levels causing the DS left overbank to flood, which was not a common occurrence previously. Also, some of the stream water from US is diverted into a fire pond on the US right bank.

B. Bridge Deck Observations

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

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

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

7. Bridge length **33** *(feet)* Span length **30** *(feet)* Bridge width **14.2** *(feet)*

Road approach to bridge:

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

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

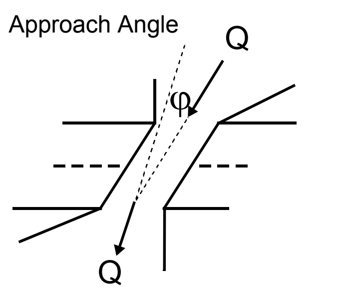
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

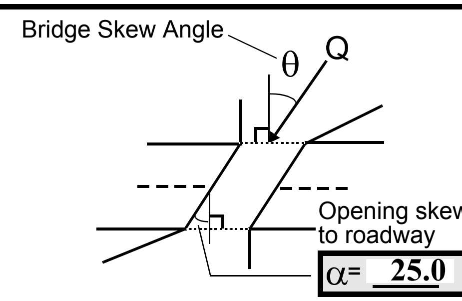
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	2
RBUS	2	1	2	1
RBDS	1	1	0	-
LBDS	2	1	2	2

*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: **65** 16. Bridge skew: **45**





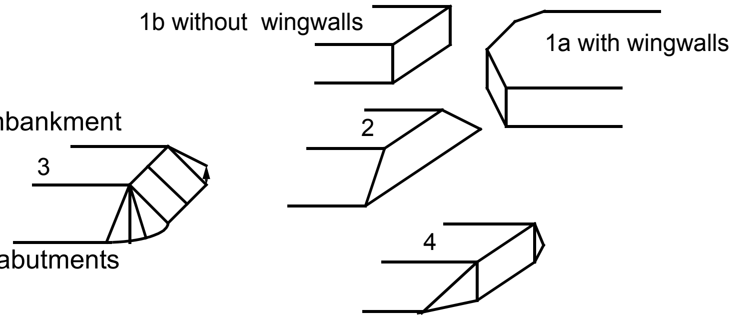
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **14** feet **US** *(US, UB, DS)* to **10** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **120** feet **US** *(US, UB, DS)* to **170** feet **US**

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

18. Bridge Type: **1a**

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



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

4. The left bank DS is lined with trees, but the overbank is a mix of grass and a hard packed dirt area with cars, logs and sheds. The right bank DS also has some trees, but is mostly a dirt parking area. The right bank US has an area of trees near the bridge then there is a house and lawn beyond.
7. Values are from the VTAOT files. Measured bridge width is 14.1 ft, bridge length is 30.9 ft, and the span length is 24.1 ft.
11. On the right DS road embankment, there are a few stones mostly buried in the grass. The US right road embankment has boulders piled on top of the wingwall. On the left bank US the embankment is steep from the road to the channel and there is some vegetation, but not extensive enough to prevent erosion. The left road embankment protection DS is sparce.

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
29.0	**11.5**			**9.0**	**4**	**3**	**23**	**54**	**2**	**1**

23. Bank width **30.0** 24. Channel width **15.0** 25. Thalweg depth **62.0** 29. Bed Material **453**

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

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

32. Comments (bank material variation, minor inflows, protection extent, etc.):
27. The left bank natural material is sand and gravel and the extensive protection is boulders and cobbles.
30. The right bank protection extends from the end of the wingwall at 6 ft US to 17 ft US. The left bank protection extends from the end of the wingwall at 24 ft US to over 100 ft US to preventing the high bank from eroding.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 140 35. Mid-bar width: 26

36. Point bar extent: 77 feet US (US, UB) to 190 feet US (US, UB, DS) positioned 35 %LB to 95 %RB

37. Material: 435

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

-

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

41. Mid-bank distance: 110 42. Cut bank extent: 50 feet US (US, UB) to >200 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? Y (Y or if N type ctrl-n mc) 50. How many? 1

51. Confluence 1: Distance 17 52. Enters on RB (LB or RB) 53. Type 2 (*1- perennial; 2- ephemeral*)

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

54. Confluence comments (eg. confluence name):

Part of the stream is diverted US into a fire pond which drains back into this stream and forms a minor confluence near the bridge. This small tributary could be called an anabranch.

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
16.0		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.):

435

-

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 N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

2

There is a small accumulation of scattered debris US.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	0	0.3-	90.0
RABUT	1.3	1	25			90	2	22.5

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.):

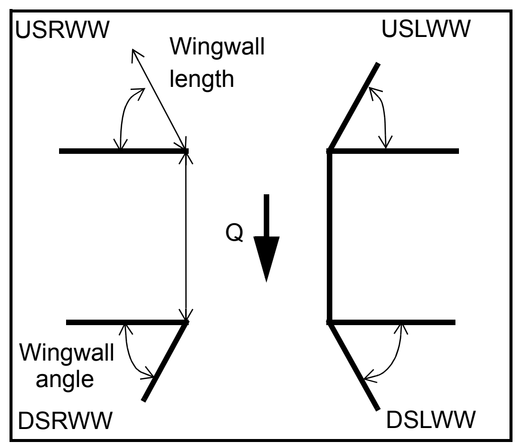
3
1
2
1

75. Average thalweg depth is 1 ft.
74. The right abutment footing is undermined in several spots from 0.5 ft to as much as 1 ft deep.
76. The left abutment footing is exposed 0.3 ft at the downstream end and 1.3 ft at the upstream end.
77. The right abutment is laid-up stone with a concrete facing. The steel beams sit on top of the stone abutment with the top of the concrete facing 1.25 ft below the low chord.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						22.5	
USRWW:			Y		1	1.0	
DSLWW:	2		0		1.75	26.0	
DSRWW:	Y		1		0	32.5	

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

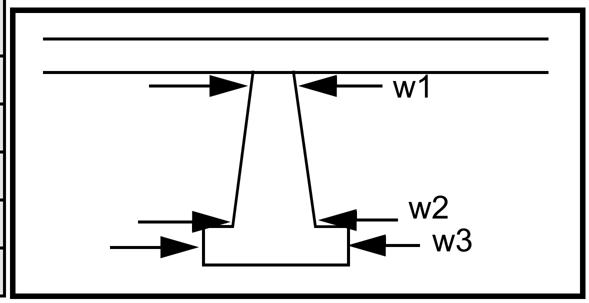
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
-
0
-
-
3
1

Piers:

84. Are there piers? **1** *(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		**7.0**	**5.5**	**40.0**	**55.0**	**25.0**
Pier 2	**7.0**	**6.5**	-	**170.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**80. A**	**and**		-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**boul-**	**the**		-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**der**	**DS**		-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**at**	**right**		-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**wing**		-	*Y- yes; N- no*
91. Attack ∠ (BF)	**cor-**	**wall**		-	
92. Pushed	**ner**	**is**		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**of**	**unde**		-	
95. Cross-members	**the**	**rmin**		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**right**	**ed**		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**abut**	**abou**	**N**	-	
98. Exposure depth	**ment**	**t 1 ft.**	-	-	

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
-	-			-	-	-	-	-	-	-

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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-

NO PIERS

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: **1** Mid-bar width: **1**

Point bar extent: **2345** feet **435** *(US, UB, DS)* to **1** feet **2** *(US, UB, DS)* positioned **345** %LB to **5** %RB

Material: **3**

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

1
2
On the left bank there are no trees from the bridge face to 32 ft DS, then the vegetation cover increases to 51% to 75%. The right bank has no trees, just shrubs, for 68 ft DS then it also increases to 51% to 75%.

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

Cut bank extent: **bank** feet **at** *(US, UB, DS)* to **the** feet **exit** *(US, UB, DS)*

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

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

tion is sand and gravel. A cobble and boulder stone wall extends along the top of the bank beginning at 24 ft DS and continuing to 110 ft DS. Three large, type-2 boulders have been placed between the bridge and 21 ft DS on the left bank. The right bank protection extends from the end of the DS right wingwall to 32 ft DS.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

N
-
NO DROP STRUCTURE

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

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

Confluence 2: Distance **Y** Enters on **110** *(LB or RB)* Type **22** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

4
US

F. Geomorphic Channel Assessment

107. Stage of reach evolution **150**

- ***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)*:

DS
0
60
435
This point bar is mostly gravel from the bridge to 28 ft DS and then is cobbles and boulders further DS.

Y
RB
105
31
DS

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: TOWNTH00290037 Town: TOWNSHEND
Road Number: TH 29 County: WINDHAM
Stream: MILL BROOK

Initials RLB Date: 2/11/98 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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3390	4600	1770
Main Channel Area, ft2	603	643	477
Left overbank area, ft2	56	106	0
Right overbank area, ft2	343	434	86
Top width main channel, ft	69	69	67
Top width L overbank, ft	79	90	0
Top width R overbank, ft	154	160	108
D50 of channel, ft	0.2298	0.2298	0.2298
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.7	9.3	7.1
y1, average depth, LOB, ft	0.7	1.2	ERR
y1, average depth, ROB, ft	2.2	2.7	0.8
Total conveyance, approach	73074	86914	43309
Conveyance, main channel	60817	67682	41936
Conveyance, LOB	1332	3533	0
Conveyance, ROB	10925	15698	1372
Percent discrepancy, conveyance	0.0000	0.0012	0.0023
Qm, discharge, MC, cfs	2821.4	3582.1	1713.9
Ql, discharge, LOB, cfs	61.8	187.0	0.0
Qr, discharge, ROB, cfs	506.8	830.8	56.1
Vm, mean velocity MC, ft/s	4.7	5.6	3.6
Vl, mean velocity, LOB, ft/s	1.1	1.8	ERR
Vr, mean velocity, ROB, ft/s	1.5	1.9	0.7
Vc-m, crit. velocity, MC, ft/s	9.9	10.0	9.5
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

	100 yr	500 yr	other Q
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3390	4600	1770
(Q) discharge thru bridge, cfs	2254	2365	1770
Main channel conveyance	17080	15030	15030
Total conveyance	17080	15030	15030
Q2, bridge MC discharge,cfs	2254	2365	1770
Main channel area, ft2	205	206	206
Main channel width (normal), ft	22.5	22.5	22.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.5	22.5	22.5
y_bridge (avg. depth at br.), ft	9.11	9.16	9.16
Dm, median (1.25*D50), ft	0.28725	0.28725	0.28725
y2, depth in contraction,ft	9.17	9.55	7.45
ys, scour depth (y2-ybridge), ft	0.06	0.40	-1.70

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	2254	2365	1770
Main channel area (DS), ft2	161	178	132
Main channel width (normal), ft	22.5	22.5	22.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	22.5	22.5	22.5
D90, ft	0.5423	0.5423	0.5423
D95, ft	0.7524	0.7524	0.7524
Dc, critical grain size, ft	0.7655	0.6631	0.7605
Pc, Decimal percent coarser than Dc	0.048	0.064	0.049
Depth to armoring, ft	**N/A**	**N/A**	**N/A**

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	3390	4600	1770
Q, thru bridge MC, cfs	2254	2365	1770
Vc, critical velocity, ft/s	9.85	9.96	9.52
Va, velocity MC approach, ft/s	4.68	5.57	3.59
Main channel width (normal), ft	22.5	22.5	22.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.5	22.5	22.5
qbr, unit discharge, ft2/s	100.2	105.1	78.7
Area of full opening, ft2	205.0	206.0	206.0
Hb, depth of full opening, ft	9.11	9.16	9.16
Fr, Froude number, bridge MC	0.67	0.7	0.53
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	161	178	132
**Hb, depth at downstream face, ft	7.16	7.91	5.87
**Fr, Froude number at DS face	0.92	0.83	0.98
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	497.24	497.24	497.24
Elevation of Bed, ft	488.13	488.08	488.08
Elevation of Approach, ft	500.74	501.32	498.89
Friction loss, approach, ft	0.12	0.19	0.09
Elevation of WS immediately US, ft	500.62	501.13	498.80
ya, depth immediately US, ft	12.49	13.05	10.72
Mean elevation of deck, ft	499.7	499.7	499.7
w, depth of overflow, ft (>=0)	0.92	1.43	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.94	0.96
**Cc, for downstream face (<=1.0)	0.866419	0.900036	0.79
Ys, scour w/Chang equation, ft	**1.69**	**2.06**	**-0.57**
Ys, scour w/Umbrell equation, ft	-0.72	0.29	-2.60

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

**Ys, scour w/Chang equation, ft	4.58	3.81	4.59

**Ys, scour w/Umbrell equation, ft	1.23	1.53	0.69

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

y2, from Laursen's equation, ft	9.17	9.55	7.45
WSEL at downstream face, ft	495.26	496.02	493.96
Depth at downstream face, ft	7.16	7.91	5.87
Ys, depth of scour (Laursen), ft	2.01	1.64	1.59

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	3390	4600	1770	3390	4600	1770
a', abut.length blocking flow, ft	97	107.5	16	182.3	188.7	136.9
Ae, area of blocked flow ft2	95.42	101.8	71.47	401.84	430.86	254.12
Qe, discharge blocked abut.,cfs	--	--	121.69	--	--	582.06
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.00	2.52	1.70	2.60	3.08	2.29
ya, depth of f/p flow, ft	0.98	0.95	4.47	2.20	2.28	1.86
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.275	0.310	0.142	0.260	0.287	0.296
ys, scour depth, ft	**6.73**	**7.27**	**8.66**	14.64	15.96	12.65

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

a'(abut length blocked, ft)	97	107.5	16	182.3	188.7	136.9
y1 (depth f/p flow, ft)	0.98	0.95	4.47	2.20	2.28	1.86
a'/y1	98.61	113.52	3.58	82.70	82.64	73.75
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.06	1.06	1.06
Froude no. f/p flow	0.28	0.31	0.14	0.26	0.29	0.30
Ys w/ corr. factor K1/0.55:						
vertical	4.28	4.29	ERR	10.85	11.62	9.54
vertical w/ ww's	3.51	3.52	ERR	**8.90**	**9.52**	**7.82**
spill-through	2.36	2.36	ERR	5.97	6.39	5.25

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.92	0.83	0.98	0.92	0.83	0.98
y, depth of flow in bridge, ft	7.16	7.91	5.87	7.16	7.91	5.87
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.93	3.14	2.44	2.93	3.14	2.44