LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (WALDTH00060023) on TOWN HIGHWAY 6, crossing STANNARD BROOK, WALDEN, VERMONT

Open-File Report 97-674

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 MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (WALDTH00060023) ON TOWN HIGHWAY 6, CROSSING STANNARD BROOK, WALDEN, VERMONT

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

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALDTH00060023 on Town Highway 6 crossing Stannard Brook, Walden, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in eastern Vermont. The 5.61-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the upstream surface cover is shrub and brushland with some trees. The downstream surface cover is forest.

In the study area, Stannard Brook has an incised, straight channel with a slope of approximately 0.02 ft/ft, an average channel top width of 54 ft and an average bank height of 9 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 64.0 mm (0.210 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 8, 1995, indicated that the reach was stable.

The Town Highway 6 crossing of Stannard Brook is a 59-ft-long (bottom width), two-lane pipe arch culvert consisting of one 22-foot corrugated plate pipe arch span (Vermont Agency of Transportation, written communication, March 28, 1995). The opening length of the structure parallel to the bridge face is 21.9 ft.The pipe arch is supported by vertical, concrete kneewalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the upstream end of the right kneewall during the Level I assessment. There was also a scour hole 0.5 ft deeper than the mean thalweg depth observed along the downstream end of the left kneewall. The scour counter measures at the site included type-3 stone fill (less than 48 inches diameter) at the upstream and downstream end of the left and right kneewall. There was also type-2 stone fill (less than 36 inches diameter) along the upstream right 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 others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is 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 kneewalls). 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 2.3 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was greater than the 100-year discharge. Left kneewall scour ranged from 11.7 to 16.8 ft. The worst-case left kneewall scour occurred at the 500-year discharge. Right kneewall scour ranged from 13.7 to 16.7 ft. The worst-case right kneewall scour occurred at the incipient roadway-overtopping 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. During the Level I survey ledge was discovered at the upstream end of the right abutment. The ledge in the channel may limit scour depths.

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

Caspian Lake and Stannard, VT. Quadrangle, 1:24,000, 1986

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 WALDTH00060023 ***Stream*** Stannard Brook

County Caledonia ***Road*** TH 6 ***District*** 7

Description of Bridge

Bridge length 23 ***ft*** ***Bridge width*** 35 ***ft*** ***Max span length*** 22 ***ft***

Alignment of bridge to road (on curve or straight) Straight, left; tee-intersection, right

Abutment type Vertical, concrete ***Embankment type*** Near vertical

Stone fill on abutment? No ***Date of inspection*** 8/8/95

Description of stone fill Type-3 stone fill at the upstream and downstream ends of the left and right kneewall. Type-2 stone fill along the upstream right bank.

Concrete kneewalls are supporting the pipe arch culvert. There is a 1.5 foot deep scour hole in front of the upstream end of the right kneewall. There is also a 0.5 ft deep scour hole in front of the downstream end of the left kneewall.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 10

There is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream end of the right kneewall.

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	8/8/95	0	0
Level II	8/8/95	0	0

Potential for debris Low. There were no tree debris in the channel. The upstream channel is laterally stable.

Describe any features near or at the bridge that may affect flow (include observation date) A point bar is located along the upstream left bank from 115 ft upstream to 5 ft under the bridge as of 8/8/95.

Description of the Geomorphic Setting

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

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

Date of inspection 8/8/95

DS left: Steep channel bank to moderately sloped overbank.

DS right: Steep channel bank to Town Highway 4 then the valley wall.

US left: Steep channel bank to a moderately sloped overbank.

US right: Steep channel bank to Town Highway 4 then the valley wall.

Description of the Channel

Average top width 54 ft ***Average depth*** 9 ft

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

Straight with non-alluvial channel boundaries.

8/8/95

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Brush, shrubs and some trees.

US left: Brush, shrubs and some trees.

US right:

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

The right kneewall obstructs flow causing an eddy current downstream of the upstream end of the kneewall as noted, 8/8/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.61 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,310 ***ft³/s*** ***Q500*** 2,110 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.61/4.6)exp 0.7] with bridge number 6 in Walden. Bridge number 6 crosses the Stannard Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 6 is 4.6 square miles. The drainage area adjusted discharge value is within a range defined by several empirical flood frequency curves and extended 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 Subtract 0.1 ft from the USGS arbitrary survey datum to obtain VTAOT plans' datum. Based on the assumption that the top of footing is the top of the concrete kneewall.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left kneewall (elev. 489.31 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left kneewall (elev. 489.27 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	-17	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	30	1	Road Grade section
APPRO	78	1	Approach section

[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.

[2] Cross-section development: (1) survey at SRD, (2) shift of survey data to SRD, (3) modification of survey data, (4) composite bridge section, (5) other.

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 0.055, and overbank "n" values ranged from 0.050 to 0.075.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.024 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The approach section (APPRO) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

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

A culvert routine model was developed for each discharge. The results of the model were compared to the bridge routine results. The bridge routine model was found to provide more conservative results.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.7 *ft*
Average low steel elevation 498.5 *ft*

100-year discharge 1,310 *ft³/s*
Water-surface elevation in bridge opening 490.4 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 104 *ft²*
Average velocity in bridge opening 12.6 *ft/s*
Maximum WSPRO tube velocity at bridge 16.0 *ft/s*

Water-surface elevation at Approach section with bridge 495.8
Water-surface elevation at Approach section without bridge 491.0
Amount of backwater caused by bridge 4.8 *ft*

500-year discharge 2,110 *ft³/s*
Water-surface elevation in bridge opening 498.5 *ft*
Road overtopping? Yes *Discharge over road* 51 *ft³/s*
Area of flow in bridge opening 226 *ft²*
Average velocity in bridge opening 9.2 *ft/s*
Maximum WSPRO tube velocity at bridge 11.7 *ft/s*

Water-surface elevation at Approach section with bridge 500.3
Water-surface elevation at Approach section without bridge 492.4
Amount of backwater caused by bridge 7.9 *ft*

Incipient overtopping discharge 1,910 *ft³/s*
Water-surface elevation in bridge opening 491.8 *ft*
Area of flow in bridge opening 132 *ft²*
Average velocity in bridge opening 14.5 *ft/s*
Maximum WSPRO tube velocity at bridge 18.7 *ft/s*

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 492.1
Amount of backwater caused by bridge 6.5 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for this discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and 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 (kneewall) scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.3	0.0	2.3
Depth to armoring	25.6	49.7	42.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	11.7	16.8	15.5
Left abutment	15.0	13.7	16.7
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} *in feet)*		
Abutments:	2.1	2.7	2.6
Left abutment	2.1	2.7	2.6
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

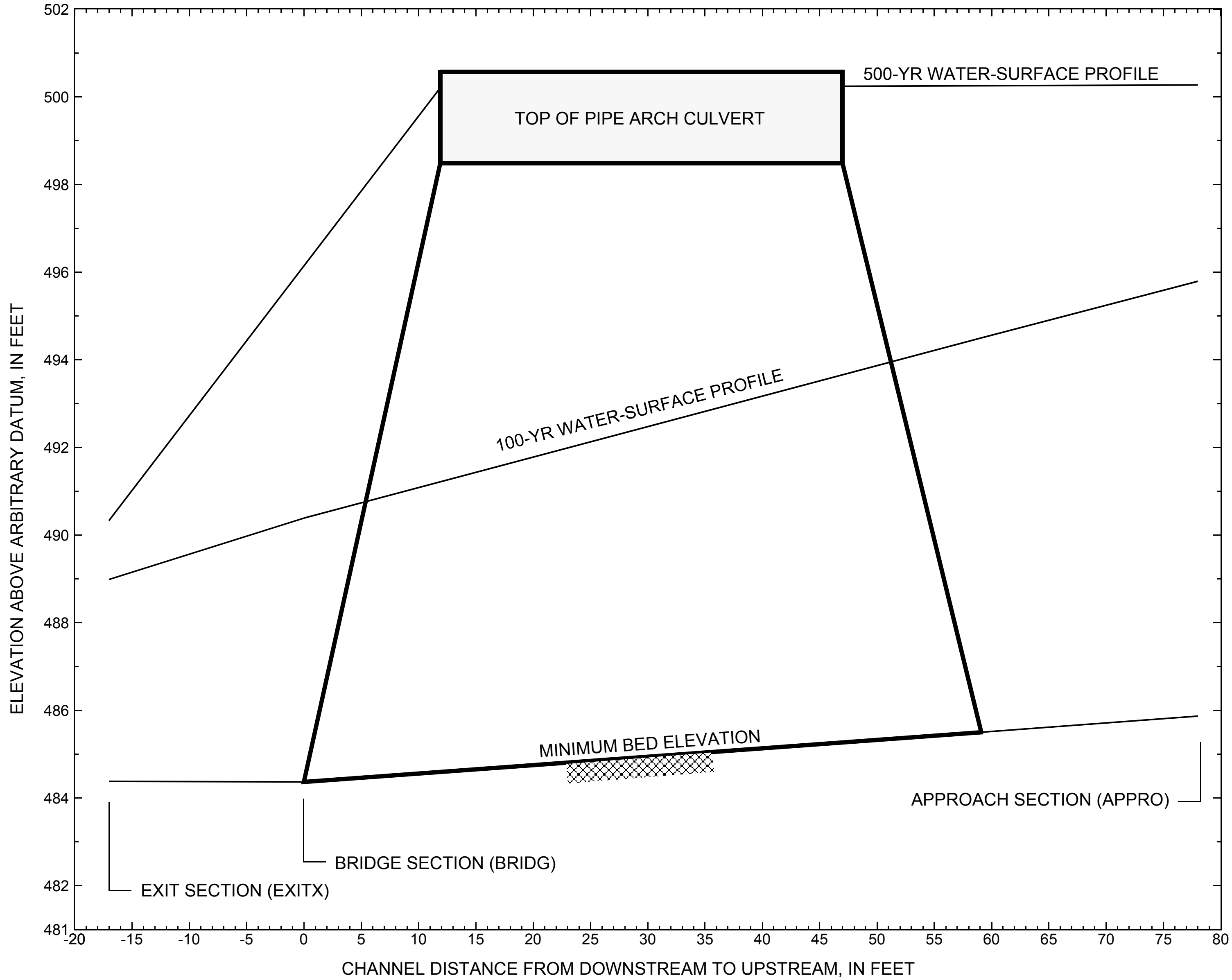

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WALDTH00060023 on Town Highway 6, crossing Stannard Brook, Walden, Vermont.

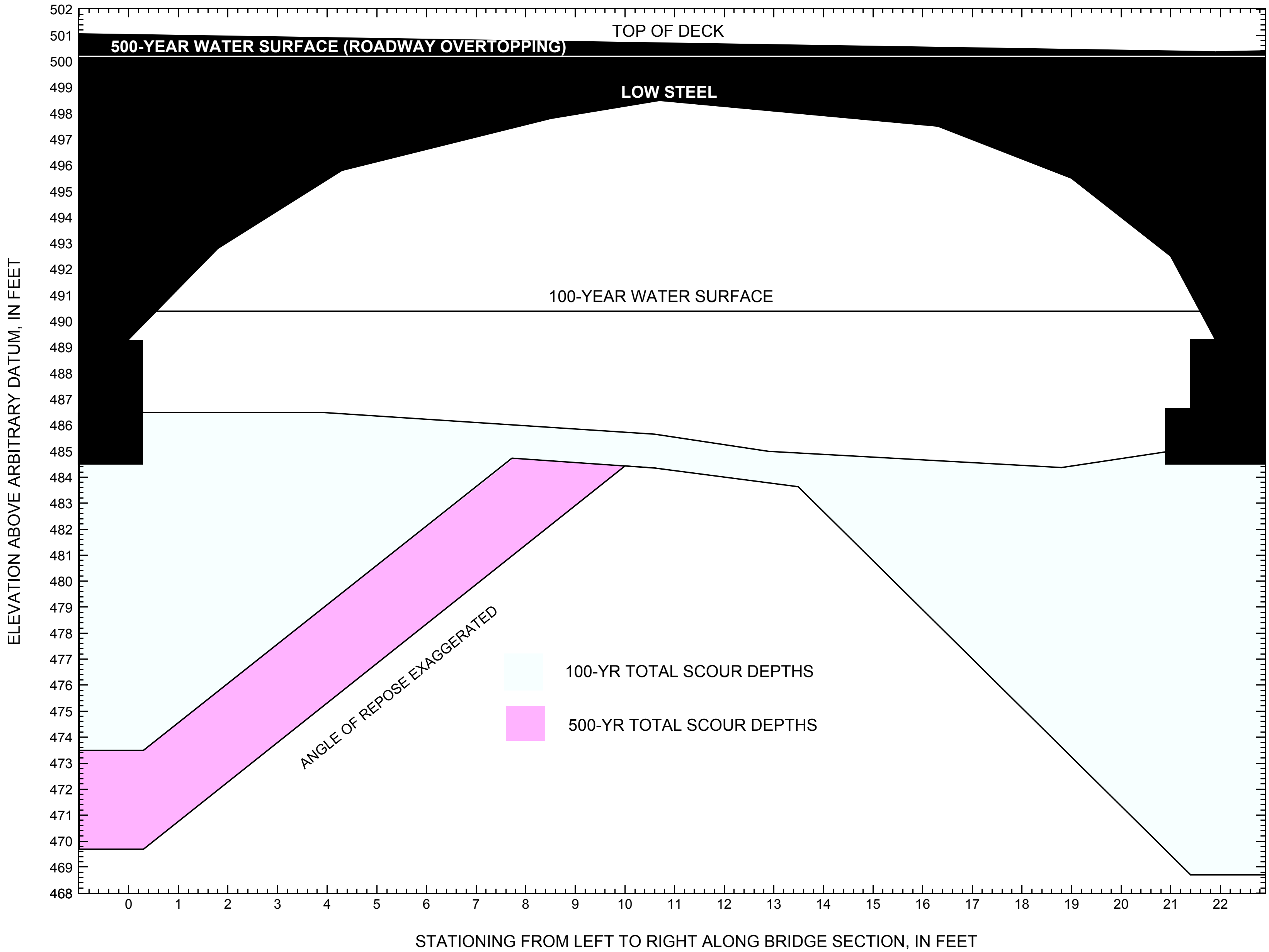

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WALDTH00060023 on Town Highway 6, crossing Stannard Brook, Walden, Vermont.

Table 1. Remaining footing/pile depth at kneewalls for the 100-year discharge at structure WALDTH00060023 on Town Highway 6, crossing Stannard Brook, Walden, Vermont.

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

Description	Station[1]	VTAOT minimum culvert seat elevation (feet)	Surveyed minimum culvert seat elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at kneewall/ pier[2] (feet)	Contraction scour depth (feet)	Kneewall 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 1,310 cubic-feet per second											
Left kneewall	0.0	489.2	489.3	484.5	486.5	1.3	11.7	--	13.0	473.5	-11.0
Right kneewall	21.9	489.2	489.3	484.5	485.0	1.3	15.0	--	16.3	468.7	-15.8

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at kneewalls for the 500-year discharge at structure WALDTH00060023 on Town Highway 6, crossing Stannard Brook, Walden, Vermont.

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

Description	Station[1]	VTAOT minimum culvert seat elevation (feet)	Surveyed minimum culvert seat elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at kneewall/ pier[2] (feet)	Contraction scour depth (feet)	Kneewall 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 2,110 cubic-feet per second											
Left kneewall	0.0	489.2	489.3	484.5	486.5	0.0	16.8	--	16.8	469.7	-14.8
Right kneewall	21.9	489.2	489.3	484.5	485.0	0.0	13.7	--	13.7	471.3	-13.2

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, Stannard, 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 wald023.wsp
T2        Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
T3        Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1310.0   2110.0  1910.0
SK          0.0240   0.0240  0.0240
*
XS   EXITX    -17
GR          -97.6, 505.37    -90.1, 502.82    -77.4, 502.59    -71.2, 499.04
GR          -45.5, 494.35      0.0, 492.68      8.1, 487.03     11.1, 485.42
GR           16.3, 484.48     22.3, 484.40     27.7, 484.38     29.7, 484.66
GR           34.3, 484.82     37.7, 485.33     41.0, 486.82     41.4, 487.44
GR           45.8, 490.58     54.9, 496.69     70.6, 498.54     84.3, 499.44
GR           99.7, 498.61    101.9, 498.50    103.4, 500.79
N           0.060        0.055        0.060
SA                 0.0          54.9
*
XS   FULLV       0  * * *
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    498.49       0.0
GR            0.0, 489.30      0.3, 486.49      3.9, 486.49      6.8, 486.15
GR           10.6, 485.65     12.9, 484.99     15.5, 484.72     18.8, 484.37
GR           20.9, 484.97     20.9, 486.61     21.4, 486.62     21.9, 489.29
GR           21.0, 492.50     19.0, 495.50     16.3, 497.50     10.7, 498.49
GR            8.5, 497.80      4.3, 495.80      1.8, 492.80      0.0, 489.30*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD            2      59.1    0.565    500.7
N           0.045
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     30      35.0     2
GR         -261.2, 521.22   -178.6, 510.84   -119.7, 505.94    -80.6, 503.75
GR            0.0, 501.02     12.6, 500.58     25.1, 500.36     76.5, 499.36
GR           86.2, 506.42
*
AS   APPRO     78            0.
GR         -168.2, 511.14    -90.9, 501.34    -10.1, 491.64     -4.9, 489.36
GR            0.0, 487.65      4.3, 487.57     10.7, 486.70     19.2, 486.71
GR           23.1, 485.87     28.0, 486.78     34.2, 490.15     42.2, 498.33
GR           57.4, 499.93     71.8, 499.43     77.7, 505.95
N           0.050        0.055        0.050        0.075
SA               -10.1        42.2        71.8
*
HP 1 BRIDG   490.39 1 490.39
HP 2 BRIDG   490.39 * * 1310
HP 1 APPRO   495.79 1 495.79
HP 2 APPRO   495.79 * * 1310
*
HP 1 BRIDG   498.49 1 498.49
HP 2 BRIDG   498.49 * * 2068
HP 1 BRIDG   492.06 1 492.06
HP 2 RDWAY   500.18 * * 51
HP 1 APPRO   500.27 1 500.27
HP 2 APPRO   500.27 * * 2110
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File wald023.wsp
         Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
         Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
            *** RUN DATE & TIME: 07-18-97  12:00
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      104      7687     21     31                         1305
    490.39           104      7687     21     31  1.00      0     22     1305


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

          WSEL     LEW     REW    AREA        K        Q    VEL
        490.39     0.0    21.9   103.6    7687.    1310.  12.64

 X STA.         0.0         2.6         4.2         5.5         6.7         7.9
   A(I)              9.4         6.1         5.3         5.2         4.9
   V(I)             6.96       10.79       12.46       12.65       13.34

 X STA.         7.9         8.9         9.9        10.8        11.7        12.6
   A(I)              4.7         4.6         4.4         4.4         4.3
   V(I)            14.07       14.31       14.89       14.96       15.16

 X STA.        12.6        13.3        14.1        14.8        15.5        16.3
   A(I)              4.1         4.2         4.1         4.1         4.4
   V(I)            15.94       15.67       15.82       16.02       15.02

 X STA.        16.3        17.0        17.8        18.7        19.6        21.9
   A(I)              4.3         4.6         5.0         5.7        10.0
   V(I)            15.33       14.23       13.14       11.43        6.54


     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      78.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       72      3461     35     35                          586
              2      375     37022     50     54                         5848
    495.79           447     40483     84     89  1.11    -44     40     5545


     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      78.

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.79   -44.7    39.7   447.1   40483.    1310.   2.93

 X STA.       -44.7       -16.3        -8.1        -4.0        -1.1         1.4
   A(I)             48.2        32.5        24.2        21.4        19.8
   V(I)             1.36        2.01        2.71        3.07        3.30

 X STA.         1.4         3.6         5.9         8.0        10.1        12.0
   A(I)             18.4        19.1        18.0        18.3        17.6
   V(I)             3.56        3.44        3.64        3.57        3.72

 X STA.        12.0        14.0        15.9        17.9        19.9        21.9
   A(I)             17.8        17.8        18.0        18.3        18.1
   V(I)             3.68        3.68        3.64        3.58        3.61

 X STA.        21.9        23.8        25.8        28.0        31.1        39.7
   A(I)             18.9        19.1        20.7        24.9        35.9
   V(I)             3.46        3.43        3.16        2.63        1.82
```

```
      U.S. Geological Survey WSPRO Input File wald023.wsp
      Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
      Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
         *** RUN DATE & TIME: 07-18-97  12:00
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      226     18227      0     59                            0
 498.49           226     18227      0     59  1.00      0     22        0

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     498.49     0.0    21.9   225.8   18227.    2068.   9.16
X STA.         0.0        3.6        5.1        6.2        7.2        8.1
  A(I)            20.8       13.8       11.9       10.9       10.3
  V(I)            4.96       7.50       8.70       9.45      10.05
X STA.         8.1        9.0        9.7       10.5       11.2       11.9
  A(I)             9.7        9.5        9.2        9.0        9.1
  V(I)           10.69      10.93      11.19      11.47      11.39
X STA.        11.9       12.5       13.2       13.9       14.6       15.3
  A(I)             8.8        8.9        8.9        9.2        9.3
  V(I)           11.72      11.66      11.55      11.22      11.12
X STA.        15.3       16.1       16.9       17.9       19.0       21.9
  A(I)             9.8       10.5       11.4       13.1       21.6
  V(I)           10.56       9.81       9.08       7.87       4.79

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      138     11460     20     35                         2064
 492.06           138     11460     20     35  1.00      0     22     2064

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      30.
       WSEL     LEW     REW    AREA        K        Q    VEL
     500.18    34.4    77.6    17.7     277.      51.   2.87
X STA.        34.4       48.4       52.7       55.5       57.8       59.8
  A(I)             1.9        1.3        1.1        1.0        0.9
  V(I)            1.32       1.91       2.30       2.60       2.73
X STA.        59.8       61.6       63.1       64.6       65.9       67.1
  A(I)             0.9        0.9        0.8        0.8        0.8
  V(I)            2.80       2.99       3.09       3.21       3.28
X STA.        67.1       68.3       69.4       70.4       71.4       72.4
  A(I)             0.8        0.7        0.7        0.7        0.7
  V(I)            3.35       3.45       3.56       3.54       3.68
X STA.        72.4       73.3       74.2       75.1       75.9       77.6
  A(I)             0.7        0.7        0.7        0.7        0.9
  V(I)            3.71       3.76       3.75       3.63       2.79

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      78.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      310     24383     72     72                         3656
           2      607     78943     52     58                        11721
           3       26       701     30     30                          137
           4        0         3      1      1                            1
 500.27           943    104030    155    161  1.18    -81     73    12190

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      78.
       WSEL     LEW     REW    AREA        K        Q    VEL
     500.27   -82.0    72.6   942.9  104030.    2110.   2.24
X STA.       -82.0      -41.4      -29.2      -20.8      -14.2       -8.4
  A(I)            98.9       68.7       57.0       51.6       49.5
  V(I)            1.07       1.54       1.85       2.05       2.13
X STA.        -8.4       -4.3       -0.9        2.0        4.8        7.6
  A(I)            42.3       39.1       36.9       35.5       36.2
  V(I)            2.49       2.70       2.86       2.97       2.91
X STA.         7.6       10.2       12.8       15.4       18.0       20.6
  A(I)            35.0       34.5       35.5       35.2       36.1
  V(I)            3.01       3.05       2.97       2.99       2.92
X STA.        20.6       23.3       25.9       28.9       33.0       72.6
  A(I)            37.2       37.4       40.6       48.3       87.3
  V(I)            2.83       2.82       2.60       2.18       1.21
```

```
      U.S. Geological Survey WSPRO Input File wald023.wsp
      Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
      Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
         *** RUN DATE & TIME: 07-18-97  12:00
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      132     10782     20     34                         1921
 491.76           132     10782     20     34  1.00      0     22     1921

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     491.76     0.0    21.9   131.7   10782.    1910.  14.50

X STA.         0.0        2.8        4.2        5.5        6.7        7.7
  A(I)            12.6        7.8        6.9        6.2        5.9
  V(I)            7.56      12.25      13.87      15.34      16.13

X STA.         7.7        8.7        9.6       10.5       11.4       12.2
  A(I)             5.7        5.6        5.5        5.4        5.3
  V(I)           16.62      17.15      17.29      17.66      18.10

X STA.        12.2       13.0       13.8       14.5       15.3       16.0
  A(I)             5.2        5.1        5.1        5.3        5.3
  V(I)           18.44      18.66      18.60      18.10      17.99

X STA.        16.0       16.8       17.6       18.5       19.5       21.9
  A(I)             5.6        5.9        6.4        7.5       13.3
  V(I)           17.07      16.13      14.83      12.74       7.21

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      78.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      199     13532     58     58                         2105
           2      517     60513     52     58                         9227
           3        0         2      2      2                            0
 498.56           717     74046    112    118  1.13    -67     44     9685

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      78.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.56   -67.7    44.4   716.8   74046.    1910.   2.66

X STA.       -67.7      -31.7      -21.5      -14.1       -8.3       -4.2
  A(I)            77.8       50.3       44.4       39.8       35.0
  V(I)            1.23       1.90       2.15       2.40       2.73

X STA.        -4.2       -1.1        1.5        4.1        6.6        9.1
  A(I)            31.1       28.9       28.4       27.9       27.9
  V(I)            3.07       3.30       3.37       3.42       3.42

X STA.         9.1       11.4       13.7       16.0       18.4       20.8
  A(I)            27.1       27.3       27.6       28.6       28.5
  V(I)            3.52       3.50       3.46       3.34       3.35

X STA.        20.8       23.1       25.5       28.2       31.7       44.4
  A(I)            28.6       29.6       32.2       37.9       57.6
  V(I)            3.33       3.23       2.97       2.52       1.66
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald023.wsp
        Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
        Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
           *** RUN DATE & TIME: 07-18-97  12:00

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

EXITX:XS   ******      5      138  1.40 *****  490.39  488.67    1310  488.99
       -16 ******     44     8455  1.00 ***** *******    0.88    9.49

FULLV:FV       17      4      167  0.96  0.31  490.68 *******    1310  489.72
         0     17     45    11135  1.00  0.00   -0.02    0.68    7.85
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85     490.98     490.60
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   489.22     511.14    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   489.22     511.14     490.60

APPRO:AS       78     -8      147  1.23  1.38  492.20  490.60    1310  490.97
        78     78     35     8700  1.00  0.14    0.00    0.85    8.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1310.     490.39
            <<<<<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       17      0      104  3.47 *****  493.86  490.39    1310  490.39
         0     17     22     7691  1.40 ***** *******    1.19   12.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       2. ****   1.  0.846 ******  498.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      30.        <<<<<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       19    -44      447  0.15  0.11  495.93  490.60    1310  495.79
        78     20     40    40441  1.11  1.96    0.00    0.24    2.93

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.497  0.427   23179.     3.    25.   495.74

     FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -17.     5.    44.   1310.    8455.     138.    9.49  488.99
   FULLV:FV       0.     4.    45.   1310.   11135.     167.    7.85  489.72
   BRIDG:BR       0.     0.    22.   1310.    7691.     104.   12.64  490.39
   RDWAY:RG      30.**************       0.******************    2.00********
   APPRO:AS      78.   -45.    40.   1310.   40441.     447.    2.93  495.79

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    25.   23179.
 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    488.67    0.88  484.38  505.37************  1.40  490.39  488.99
   FULLV:FV  ********    0.68  484.38  505.37  0.31  0.00  0.96  490.68  489.72
   BRIDG:BR    490.39    1.19  484.37  498.49************  3.47  493.86  490.39
   RDWAY:RG  ****************  499.36  521.22************************************
   APPRO:AS    490.60    0.24  485.87  511.14  0.11  1.96  0.15  495.93  495.79
```

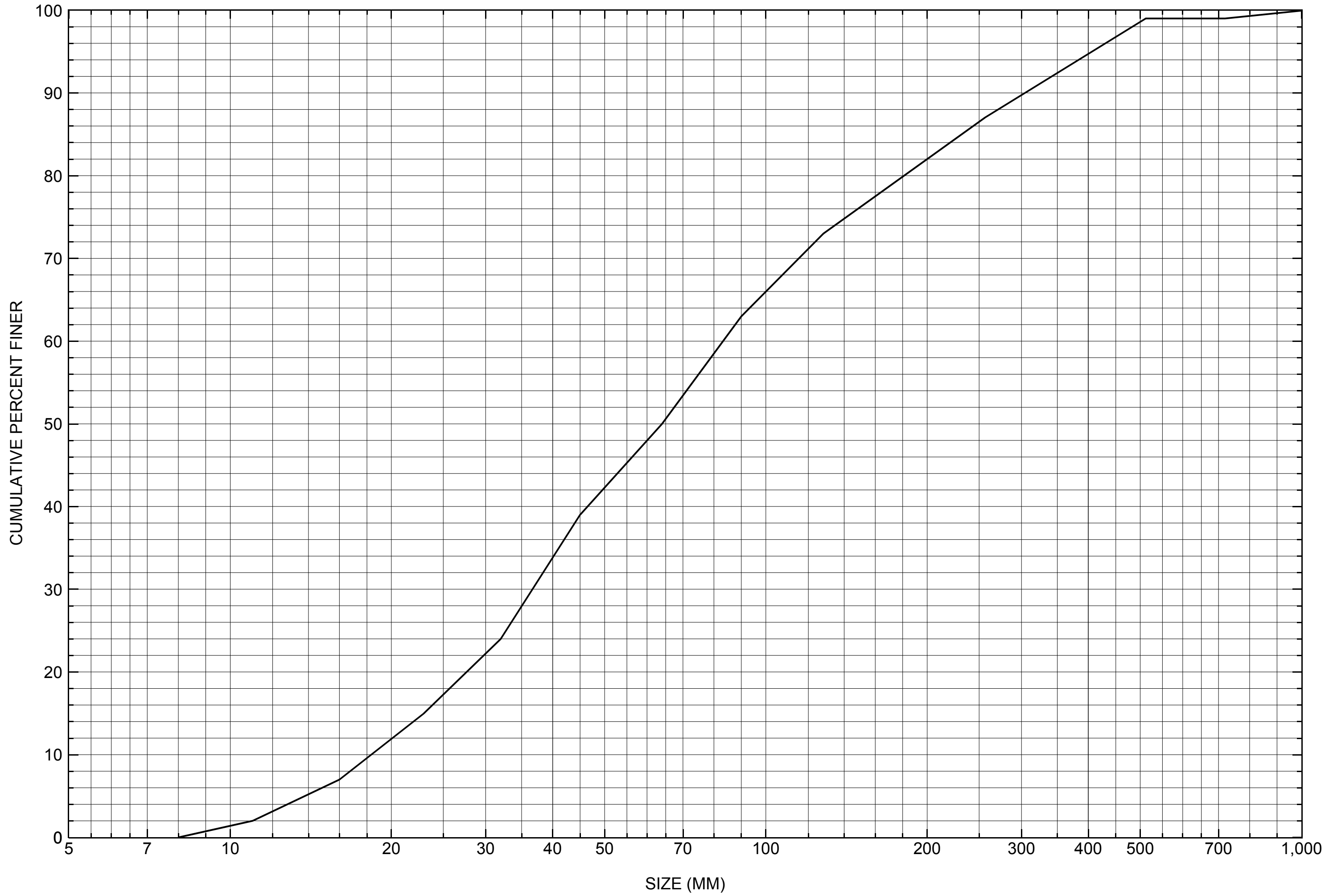
```
        U.S. Geological Survey WSPRO Input File wald023.wsp
        Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
        Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
           *** RUN DATE & TIME: 07-18-97  12:00

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

EXITX:XS   ******      3      192  1.88 *****  492.21  490.01    2110  490.33
       -16 ******     45    13609  1.00 ***** *******    0.91   11.00

FULLV:FV       17      2      230  1.30  0.31  492.52 *******    2110  491.22
         0     17     47    17667  1.00  0.00    0.00    0.71    9.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.87     492.40     491.81
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   490.72     511.14    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   490.72     511.14     491.81

APPRO:AS       78    -15      215  1.53  1.29  493.93  491.81    2110  492.40
        78     78     36    15240  1.02  0.11    0.00    0.87    9.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.52       0.00     492.15     499.36
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.15     499.42     499.51     498.49
 ===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       17      0      226  1.30 *****  499.79  492.06    2068  498.49
         0 ******     22    18227  1.00 ***** *******    0.50    9.16

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       2. ****   5.  0.432 ******  498.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      30.    43.  0.02  0.09  500.34    0.00     51.  500.18

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     2.    10.    12.   0.1   0.0   2.1  11.4   0.3   2.6
   RT:     51.    43.    34.    78.   0.8   0.4   3.1   2.9   0.6   2.7

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

APPRO:AS       19    -81      943  0.09  0.05  500.36  491.81    2110  500.27
        78     20     73   104008  1.18  2.11    0.00    0.17    2.24

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -17.     3.    45.   2110.   13609.     192.   11.00  490.33
   FULLV:FV       0.     2.    47.   2110.   17667.     230.    9.16  491.22
   BRIDG:BR       0.     0.    22.   2068.   18227.     226.    9.16  498.49
   RDWAY:RG      30.*******     0.     51.       0.*********    2.00  500.18
   APPRO:AS      78.   -82.    73.   2110.  104008.     943.    2.24  500.27

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    490.01    0.91  484.38  505.37************  1.88   492.21  490.33
   FULLV:FV  ********    0.71  484.38  505.37  0.31  0.00  1.30   492.52  491.22
   BRIDG:BR    492.06    0.50  484.37  498.49************  1.30   499.79  498.49
   RDWAY:RG  ****************  499.36  521.22  0.02******  0.09   500.34  500.18
   APPRO:AS    491.81    0.17  485.87  511.14  0.05  2.11  0.09   500.36  500.27
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald023.wsp
        Hydraulic analysis for structure WALDTH00060023   Date: 10-JUN-97
        Bridge 23 on Town Highway 6 over Stannard Brook, Walden, VT  by MAI
           *** RUN DATE & TIME: 07-18-97  12:00

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

EXITX:XS   ******      4      179  1.77 *****  491.79  489.69    1910  490.02
       -16 ******     45    12324  1.00 ***** *******    0.90   10.67

FULLV:FV       17      3      215  1.22  0.31  492.10 *******    1910  490.88
         0     17     46    16067  1.00  0.00    0.00    0.70    8.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.86     492.07     491.56
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   490.38     511.14    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   490.38     511.14     491.56

APPRO:AS       78    -13      197  1.47  1.32  493.53  491.56    1910  492.06
        78     78     36    13440  1.01  0.12   -0.02    0.86    9.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1910.     491.76
            <<<<<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       17      0      132  4.78 *****  496.54  491.76    1910  491.76
         0     17     22    10773  1.46 ***** *******    1.20   14.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       2. ****   1.  0.828 ******  498.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      30.        <<<<<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       19    -67      717  0.12  0.09  498.69  491.56    1910  498.56
        78     20     44    74064  1.13  2.05   -0.02    0.20    2.66

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.559  0.513   36208.     3.    25.   498.53

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -17.     4.    45.   1910.   12324.     179.   10.67  490.02
   FULLV:FV       0.     3.    46.   1910.   16067.     215.    8.86  490.88
   BRIDG:BR       0.     0.    22.   1910.   10773.     132.   14.51  491.76
   RDWAY:RG      30.**************      0.******************    2.00********
   APPRO:AS      78.   -68.    44.   1910.   74064.     717.    2.66  498.56

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    25.   36208.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.69    0.90  484.38  505.37************  1.77  491.79  490.02
   FULLV:FV  ********    0.70  484.38  505.37  0.31  0.00  1.22  492.10  490.88
   BRIDG:BR    491.76    1.20  484.37  498.49************  4.78  496.54  491.76
   RDWAY:RG  ****************  499.36  521.22**********************************
   APPRO:AS    491.56    0.20  485.87  511.14  0.09  2.05  0.12  498.69  498.56
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALDTH00060023, in Walden, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **WALDTH00060023**

General Location Descriptive

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

Date *(MM/DD/YY)* **03** / **28** / **95**

Highway District Number *(I - 2; nn)* **07**

County *(FIPS county code; I - 3; nnn)* **005**

Town *(FIPS place code; I - 4; nnnnn)* **75700**

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

Waterway *(I - 6)* **STANNARD BROOK**

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

Route Number **TH006**

Vicinity *(I - 9)* **AT JCT TH 6 + TH 4**

Topographic Map **Caspian Lake**

Hydrologic Unit Code: **01080102**

Latitude *(I - 16; nnnn.n)* **44324**

Longitude *(i - 17; nnnnn.n)* **72156**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10031500230315**

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

Maximum span length *(I - 48; nnnn)* **0023**

Year built *(I - 27; YYYY)* **1963**

Structure length *(I - 49; nnnnnn)* **000023**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000150**

Deck Width *(I - 52; nn.n)* **000**

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

Channel & Protection *(I - 61; n)* **7**

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

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

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

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

Structure type *(I - 43; nnn)* **319**

Year Reconstructed *(I - 106)* **0000**

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

Clear span (*nnn.n ft*) **023.0**

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

Vertical clearance from streambed (*nnn.n ft*) **008.9**

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

Waterway of full opening (*nnn.n ft*^{2}) **173.7**

Comments:

The structural inspection report of 6/2/93 indicates the structure is a corrugated, galvanized plate, pipe arch type culvert. The left and right ends of the arch pipe are resting on concrete kneewalls according to the report. The kneewalls have a few fine cracks and small leaks noted overall. The kneewalls were exposed at the surface upon construction. A new section of concrete footing (subfooting) has been constructed at the upstream end of the right kneewall side of the pipe arch to correct an undermining problem. Some stone and boulder fill is present along the up- and downstream banks. The banks reportedly are showing signs of minor erosion from previous flooding. **(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:

There are small pockets of localized channel scour reported. Point bars and debris accumulation problems are noted as minor at this bridge site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **5.61** mi^2 Lake/pond/swamp area **.032** mi^2

Watershed storage *(ST)* **.57** %

Bridge site elevation **1232** ft Headwater elevation **2451** ft

Main channel length **5.916** mi

10% channel length elevation **1326** ft 85% channel length elevation **2179** ft

Main channel slope *(S)* **192.25** 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / 1963

Project Number TH #6, B23 over Stannard Brook Minimum channel bed elevation: 488.4

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

Benchmark location description:

BM#1, spike in root of an 8 inch cherry tree, located on the downstream right bank, elevation 500.00. The tree is located about 45 feet from the centerline of the pipe to the middle of the intersection on the right bank side, then about 100 feet in a direction perpendicular to TH6 or roughly parallel with the stream, then about 30 feet toward the stream from the streamward edge of the TH04 roadway.

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

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

If 1: Footing Thickness 4.8 Footing bottom elevation: 484.4

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:

\-

Comments:

There are no other easily accessible points with elevations on the plans.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 3/21/96
Computerized by: RB Date: 3/26/96
Reviewd by: MAI Date: 7/24/97

Structure Number WALDTH00060023

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. Hammond Date *(MM/DD/YY)* 8 / 8 / 1995

2. Highway District Number 07 Mile marker -

County Caledonia (005) Town Walden (75700)

Waterway *(I - 6)* Stannard Brook Road Name -

Route Number TH 6 Hydrologic Unit Code: 01080102

3. Descriptive comments:

Located at the junction of TH 06 and TH 04.

B. Bridge Deck Observations

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

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

7. Bridge length 23 *(feet)* Span length 22 *(feet)* Bridge width 35(top) *(feet)*

Road approach to bridge:

8. LB 2 RB 0 *(**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	3	1	0	0
RBUS	3	1	0	0
RBDS	3	1	0	0
LBDS	3	1	0	0

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

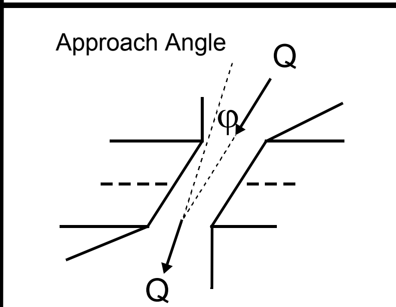
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

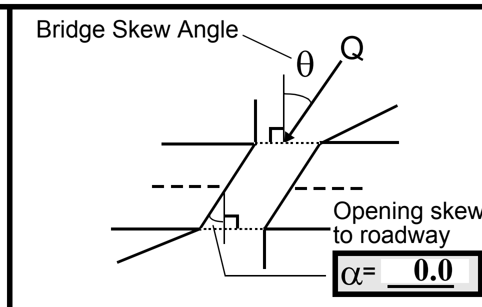
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*

Where? RB *(LB, RB)* Severity 1

Range? 90 feet US *(US, UB, DS)* to 12 feet US

Channel impact zone 2: Exist? N *(Y or N)*

Where? - *(LB, RB)* Severity -

Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: 2

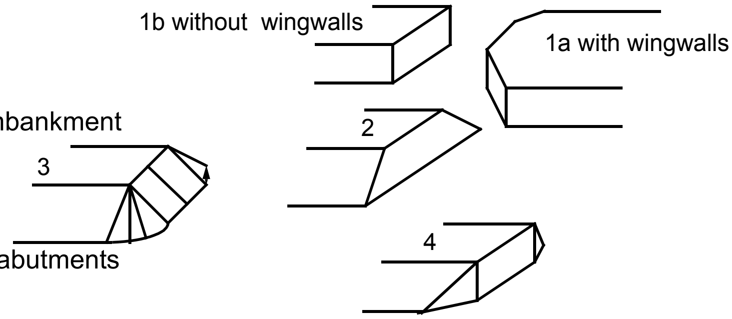
1a- Vertical abutments with wingwalls

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. On the right bank both, US and DS, a dirt road parallels the stream and shrubs line the immediate bank on the US side. On the US left bank there are shrubs near the bridge and then trees from 65 feet US and beyond.
7. Bridge dimension values are from the VT AOT files. The measured culvert width at the bottom is 59 feet and the culvert width at the top is 35 feet. The road width from rail to rail is 24 feet and the span is 22 feet.
17. The channel makes a bend into the right bank US of the culvert entrance then straightens through the culvert.
11. Road protection on the right bank is for TH 04 which parallels the stream.
18. The bridge is a single pipe arch culvert. It is a type 2 unless water heights are below the concrete kneewalls then it is more like a type 1b.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
32.5	4.0			11.5	2	1	432	7	1	1

23. Bank width **15.0** 24. Channel width **40.0** 25. Thalweg depth **52.5** 29. Bed Material **435**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **1**

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

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

26. The percent vegetation cover is low because of the shrubs on the immediate banks near the bridge.
27. On the right bank the material is type-5 road fill and there is a steep slope.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **55** 35. Mid-bar width: **20**

36. Point bar extent: **115** feet **US** *(US, UB)* to **5** feet **UB** *(US, UB, DS)* positioned **0** %LB to **80** %RB

37. Material: **453**

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

Fines were removed from the point bar by the August 5 and 6, 1995 high water.

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

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

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

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

NO CUT BANKS

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **5**

47. Scour dimensions: Length **20** Width **10** Depth : **1.5** Position **60** %LB to **100** %RB

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

Local scour behind many boulders in the US reach. Scour extends from 15 feet US to 5 feet under the bridge. Scour in the culvert opening is due to channel constriction by the culvert. On the right kneewall, there is a scour hole at the US end caused by the stream bending then crossing from the right bank to the left bank in the culvert. The right kneewall acts as an obstruction causing an eddy just DS of the US end of the kneewall. The right kneewall is set on a ledge that is exposed at the US end of the right kneewall.

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
24.0		0.5		2	7	7	0

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

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

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

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

4536

See the US channel scour comments.

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

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

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

70. Debris and Ice Comments:

1

Banks appear stable.

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	90	2	2	0.5	1	90.0
RABUT	1	0	90			2	3	22.0

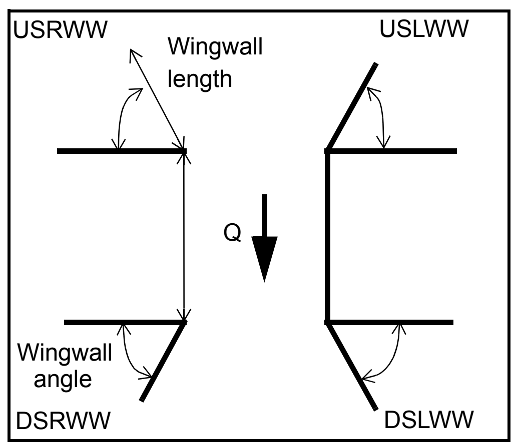
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

1.5
1.5
1
72. The kneewall slopes are 90 degrees to the top of the kneewalls and then the arch slopes inward.
74. Scour on the left kneewall is at the DS end. Scour on the right kneewall is at the US end. It is possible to penetrate 0.75 feet under the kneewall base where it sits on the ledge.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						22.0	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	59.0	
DSRWW:	-		-		-	59.0	



Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	4	4
Extent	-	-	-	0	0	3	3	-

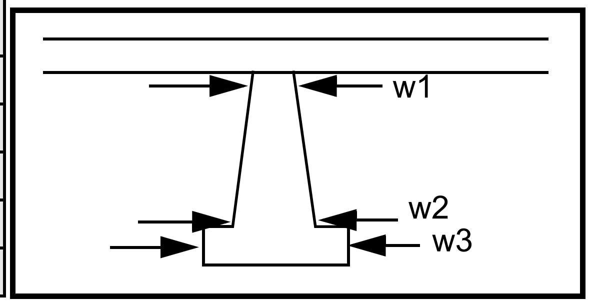
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **82.** *(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)	**There**	**both**	**of the**	**g the**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**are**	**the**	**knee**	**face**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**large**	**right**	**walls**	**of**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**boul-**	**and**	**. No**	**the**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**ders**	**left**	**place**	**knee**	*Y- yes; N- no*
91. Attack ∠ (BF)	**at**	**bank**	**d**	**walls**	
92. Pushed	**the**	**s**	**pro-**	**, but**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**US**	**that**	**tec-**	**there**	
95. Cross-members	**and**	**pro-**	**tion**	**is**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**DS**	**tect**	**exist**	**some**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**ends**	**the**	**s**	**nat-**	
98. Exposure depth	**of**	**ends**	**alon**	**ural**	

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

protection from the ledge at the US end of the right kneewall and scattered boulders under the culvert.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -____

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

-
-
-
-

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

Cut bank extent: RS____ feet ____ *(US, UB, DS)* to _____ feet ____ *(US, UB, DS)*

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

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

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: 4______

Scour dimensions: Length 4_____ Width 54_____ Depth: 54____ Positioned 2____ %LB to 1____ %RB

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

453
-
-
-

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

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

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

Confluence comments (eg. confluence name):

the ends of the left and right kneewalls only and there is natural protection along the banks further DS.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

109. G. Plan View Sketch

N

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: WALDTH00060023 Town: WALDEN
Road Number: TH 6 County: CALEDONIA
Stream: Stannard Brook

Initials MAI Date: 07/07/97 Checked: RF

I. 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	1310	2110	1910
Main Channel Area, ft2	375	607	517
Left overbank area, ft2	72	310	199
Right overbank area, ft2	0	26	0
Top width main channel, ft	50	52	52
Top width L overbank, ft	35	72	58
Top width R overbank, ft	0	31	2
D50 of channel, ft	0.21	0.21	0.21
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	11.7	9.9
y1, average depth, LOB, ft	2.1	4.3	3.4
y1, average depth, ROB, ft	ERR	0.8	0.0
Total conveyance, approach	40483	104030	74046
Conveyance, main channel	37022	78943	60513
Conveyance, LOB	3461	24383	13532
Conveyance, ROB	0	704	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0014
Qm, discharge, MC, cfs	1198.0	1601.2	1560.9
Ql, discharge, LOB, cfs	112.0	494.6	349.1
Qr, discharge, ROB, cfs	0.0	14.3	0.0
Vm, mean velocity MC, ft/s	3.2	2.6	3.0
Vl, mean velocity, LOB, ft/s	1.6	1.6	1.8
Vr, mean velocity, ROB, ft/s	ERR	0.5	ERR
Vc-m, crit. velocity, MC, ft/s	9.3	10.0	9.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1310	2110	1910
(Q) discharge thru bridge, cfs	1310	2068	1910
Main channel conveyance	7687	18227	10782
Total conveyance	7687	18227	10782
Q2, bridge MC discharge,cfs	1310	2068	1910
Main channel area, ft2	104	226	132
Main channel width (normal), ft	21.9	21.9	21.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.9	21.9	21.9
y_bridge (avg. depth at br.), ft	4.73	10.31	6.01
Dm, median (1.25*D50), ft	0.2625	0.2625	0.2625
y2, depth in contraction,ft	6.05	8.94	8.35
ys, scour depth (y2-ybridge), ft	1.32	-1.37	2.34

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	1310	2110	1910
Q, thru bridge MC, cfs	1310	2068	1910
Vc, critical velocity, ft/s	9.32	10.04	9.77
Va, velocity MC approach, ft/s	3.19	2.64	3.02
Main channel width (normal), ft	21.9	21.9	21.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.9	21.9	21.9
qbr, unit discharge, ft2/s	59.8	94.4	87.2
Area of full opening, ft2	103.6	225.8	131.7
Hb, depth of full opening, ft	4.73	10.31	6.01
Fr, Froude number, bridge MC	0	0.5	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	138	N/A
**Hb, depth at downstream face, ft	N/A	6.30	N/A
**Fr, Froude number at DS face	ERR	1.05	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A

Elevation of Low Steel, ft	0	498.49	0
Elevation of Bed, ft	-4.73	488.18	-6.01
Elevation of Approach, ft	0	500.27	0
Friction loss, approach, ft	0	0.05	0
Elevation of WS immediately US, ft	0.00	500.22	0.00
ya, depth immediately US, ft	4.73	12.04	6.01
Mean elevation of deck, ft	0	500.69	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	0.96	ERR
Ys, scour w/Chang equation, ft	N/A	-0.53	N/A
Ys, scour w/Umbrell equation, ft	N/A	-4.38	N/A

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

**Ys, scour w/Chang equation, ft	N/A	3.50	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-0.37	ERR

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

y2, from Laursen's equation, ft	6.05	8.94	8.35
WSEL at downstream face, ft	--	492.06	--
Depth at downstream face, ft	N/A	6.30	N/A
Ys, depth of scour (Laursen), ft	N/A	2.64	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	1310	2068	1910
Main channel area (DS), ft2	103.6	138	131.7
Main channel width (normal), ft	21.9	21.9	21.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.9	21.9	21.9
D90, ft	0.9960	0.9960	0.9960
D95, ft	1.3280	1.3280	1.3280
Dc, critical grain size, ft	0.9779	1.1984	1.1469
Pc, Decimal percent coarser than Dc	0.103	0.068	0.075
Depth to armoring, ft	25.55	49.67	42.31

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 kneewall   Right kneewall

Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1310	2110	1910	1310	2110	1910
a', abut.length blocking flow, ft	44.7	82	67.7	17.8	50.7	22.5
Ae, area of blocked flow ft2	135	418.6	290.6	119.5	215.2	172.2
Qe, discharge blocked abut.,cfs	290.8	771.2	613.4	327.5	--	431.8
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.15	1.84	2.11	2.74	2.05	2.51
ya, depth of f/p flow, ft	3.02	5.10	4.29	6.71	4.24	7.65
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.218	0.144	0.180	0.186	0.168	0.160
ys, scour depth, ft	11.66	16.81	15.48	15.03	13.67	16.68

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

a'(abut length blocked, ft)	44.7	82	67.7	17.8	50.7	22.5
y1 (depth f/p flow, ft)	3.02	5.10	4.29	6.71	4.24	7.65
a'/y1	14.80	16.06	15.77	2.65	11.94	2.94
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.22	0.14	0.18	0.19	0.17	0.16
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1.19	1.05	1.2	1.19	1.05	1.2
y, depth of flow in bridge, ft	4.73	6.30	6.01	4.73	6.30	6.01
Median Stone Diameter for riprap at: left kneewall				right kneewall, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.08	2.67	2.64	2.08	2.67	2.64