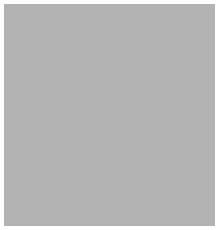
LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (EDENTH00170013) on TOWN HIGHWAY 17, crossing the GIHON RIVER, EDEN, VERMONT

U.S. Geological Survey
Open-File Report 97-392



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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (EDENTH00170013) on TOWN HIGHWAY 17, crossing the GIHON RIVER, EDEN, VERMONT

By MICHAEL A. IVANOFF

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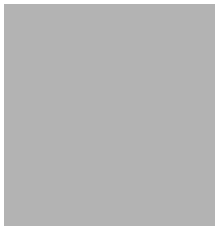

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

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Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (EDENTH00170013) ON TOWN HIGHWAY 17, CROSSING THE GIHON RIVER, EDEN, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure EDENTH00170013 on Town Highway 17 crossing the Gihon River, Eden, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 16.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover upstream is shrub and brushland along the left bank and forested along the right bank. The downstream left overbank surface cover is cut grass while the immediate bank has dense woody vegetation. The downstream right bank is forested.

In the study area, the Gihon River has an incised, sinuous channel with a slope of approximately 0.018 ft/ft, an average channel top width of 32 ft and an average bank height of 2 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 51.5 mm (0.169 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 26, 1995, indicated that the reach was laterally unstable.

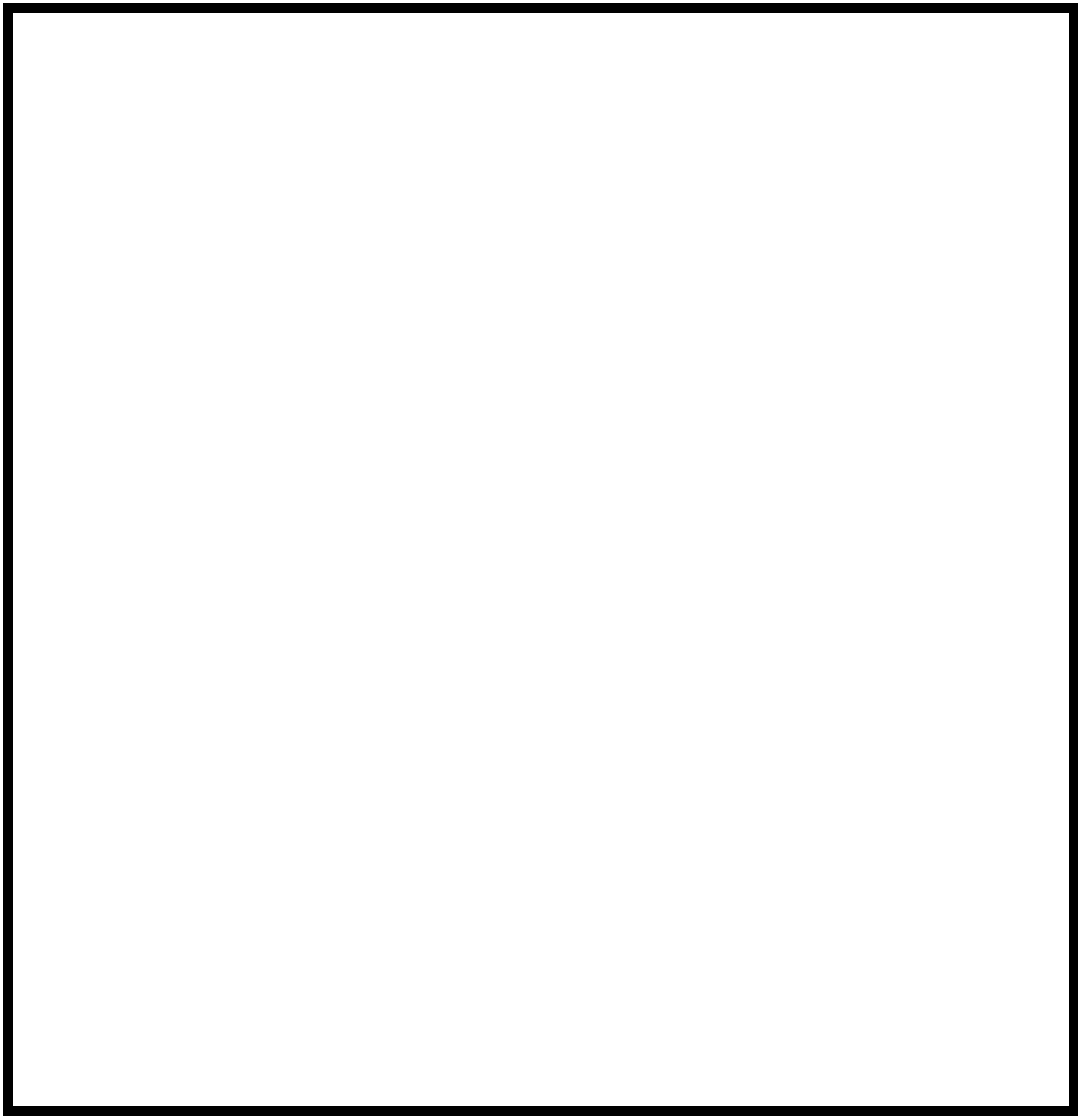
The Town Highway 17 crossing of the Gihon River is a 23-ft-long, two-lane bridge consisting of one 20-foot concrete slab span (Vermont Agency of Transportation, written communication, June 8, 1995). The opening length of the structure parallel to the bridge face is 19.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left and right wingwalls and at the downstream end of the downstream left and right wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.3 to 2.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.1 to 16.4 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

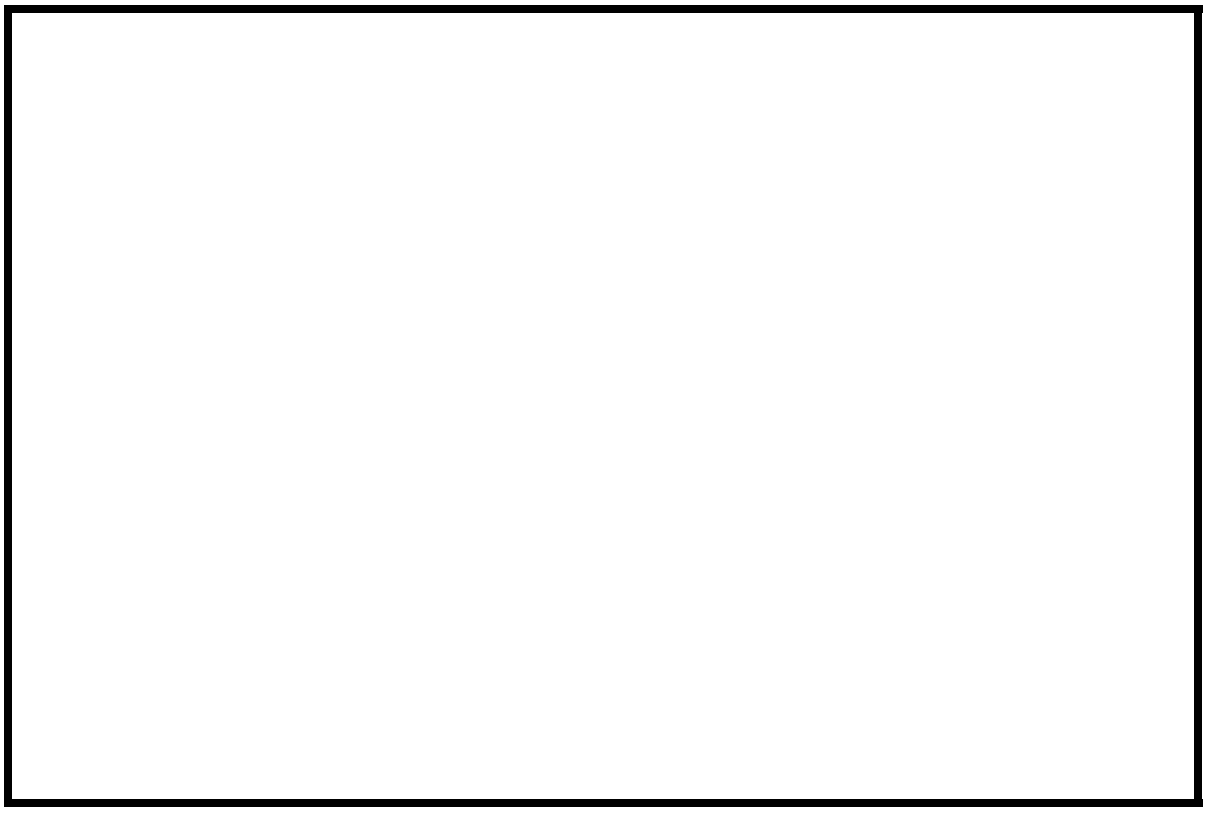


Eden, VT. Quadrangle, 1:24,000, 1986

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 EDENTH00170013 ***Stream*** Gihon River

County Lamoille ***Road*** TH17 ***District*** 8

Description of Bridge

Bridge length 23 ***ft*** ***Bridge width*** 23.2 ***ft*** ***Max span length*** 20 ***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*** 06/26/95

Description of stone fill Type-2, around the upstream end of the upstream left and right wingwalls and around the downstream end of the left and right wingwalls.

Brief description of bridge (abutments, piers, etc.) Abutments and wingwalls are concrete. There is a 1.5 foot deep scour hole in front of the left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 15

There is a moderate. channel bend into the bridge. The scour hole has developed in the location where the bend impacts the left abutment.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	06/26/95	0	0
Level II	06/26/95	0	0

Potential for debris Low. There is some debris along the upstream banks and some brush and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None 06/26/95.

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 06/26/95

DS left: Steep channel bank to a narrow flood plain.

DS right: Moderately sloped channel bank to the valley wall.

US left: Moderately sloped channel bank to a terrace.

US right: Moderately sloped overbank

Description of the Channel

Average top width 32.0 ***Average depth*** 2.0

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

Sinuous with semi-alluvial channel boundaries and a narrow flood plain.

06/26/95

Vegetative co Trees and brush with cut grass on the flood plain.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: No

Do banks appear stable? There is some fluvial erosion along the upstream right bank. The stream meanders upstream and downstream of the bridge as observed on ***date of observation.*** 06/26/95.

None noted on 06/26/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 16.3 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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 2,200 ***ft³/s*** ***Q500*** 3,000 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(16.3/29.8)exp 0.7] with bridge number 27 in Eden. Bridge number 27 crosses the Gihon River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 27 is 29.8 square miles. These values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.56 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 499.48 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	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	46	1	Approach section as surveyed

[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 0.035 to 0.055, and overbank "n" values ranged from 0.040 to 0.070.

Critical depth was used as the starting water surface elevation at the exit section (EXITX) for each discharge. Normal depth was computed as approximately 0.1 foot below critical depth by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.018 ft/ft which was from surveyed thalweg points downstream of the bridge.

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.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.5 *ft*
Average low steel elevation 497.9 *ft*

100-year discharge 2,200 *ft³/s*
Water-surface elevation in bridge opening 498.0 *ft*
Road overtopping? Yes *Discharge over road* 743 *ft³/s*
Area of flow in bridge opening 139 *ft²*
Average velocity in bridge opening 10.3 *ft/s*
Maximum WSPRO tube velocity at bridge 12.4 *ft/s*

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 4.9 *ft*

500-year discharge 3,000 *ft³/s*
Water-surface elevation in bridge opening 498.0 *ft*
Road overtopping? Yes *Discharge over road* 1,446 *ft³/s*
Area of flow in bridge opening 139 *ft²*
Average velocity in bridge opening 10.8 *ft/s*
Maximum WSPRO tube velocity at bridge 13.0 *ft/s*

Water-surface elevation at Approach section with bridge 501.7
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 4.8 *ft*

Incipient overtopping discharge 1,150 *ft³/s*
Water-surface elevation in bridge opening 498.0 *ft*
Area of flow in bridge opening 139 *ft²*
Average velocity in bridge opening 8.3 *ft/s*
Maximum WSPRO tube velocity at bridge 9.9 *ft/s*

Water-surface elevation at Approach section with bridge 499.5
Water-surface elevation at Approach section without bridge 495.3
Amount of backwater caused by bridge 4.2 *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.

At this site, all 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 was computed by use of the Chang equation (Richardson and others, 1995,p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For the discharges resulting in orifice flow, estimates of contraction scour were 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 are 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 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	2.0	2.3	0.3
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank			

Local scour:			
Abutment scour	15.2	16.4	13.0
Left abutment	10.2	11.0	8.1
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:	2.3	2.4	2.0
Left abutment	2.3	2.4	2.0
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

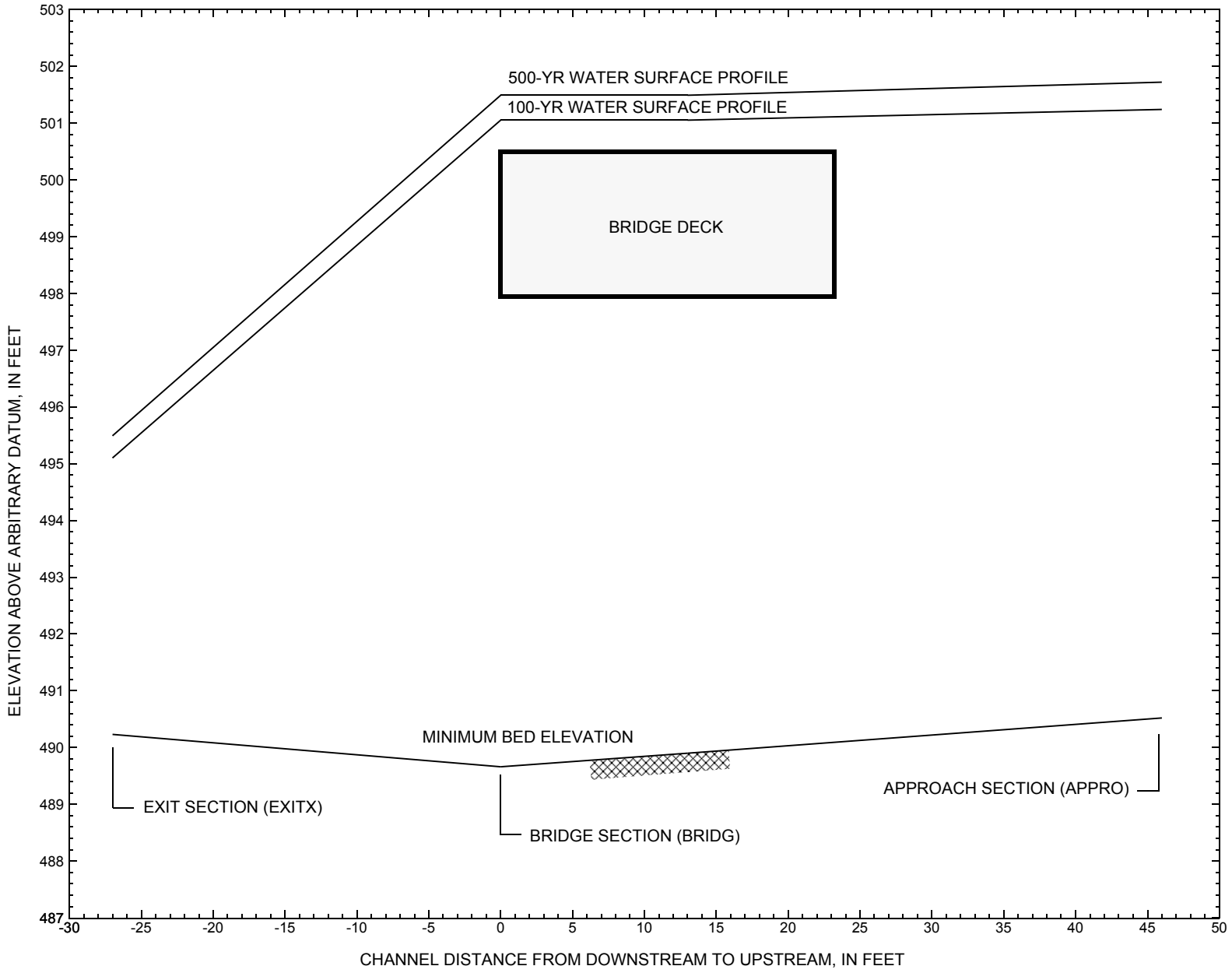


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure EDENTH00170013 on Town Highway 17, crossing the Gihon River, Eden, Vermont.

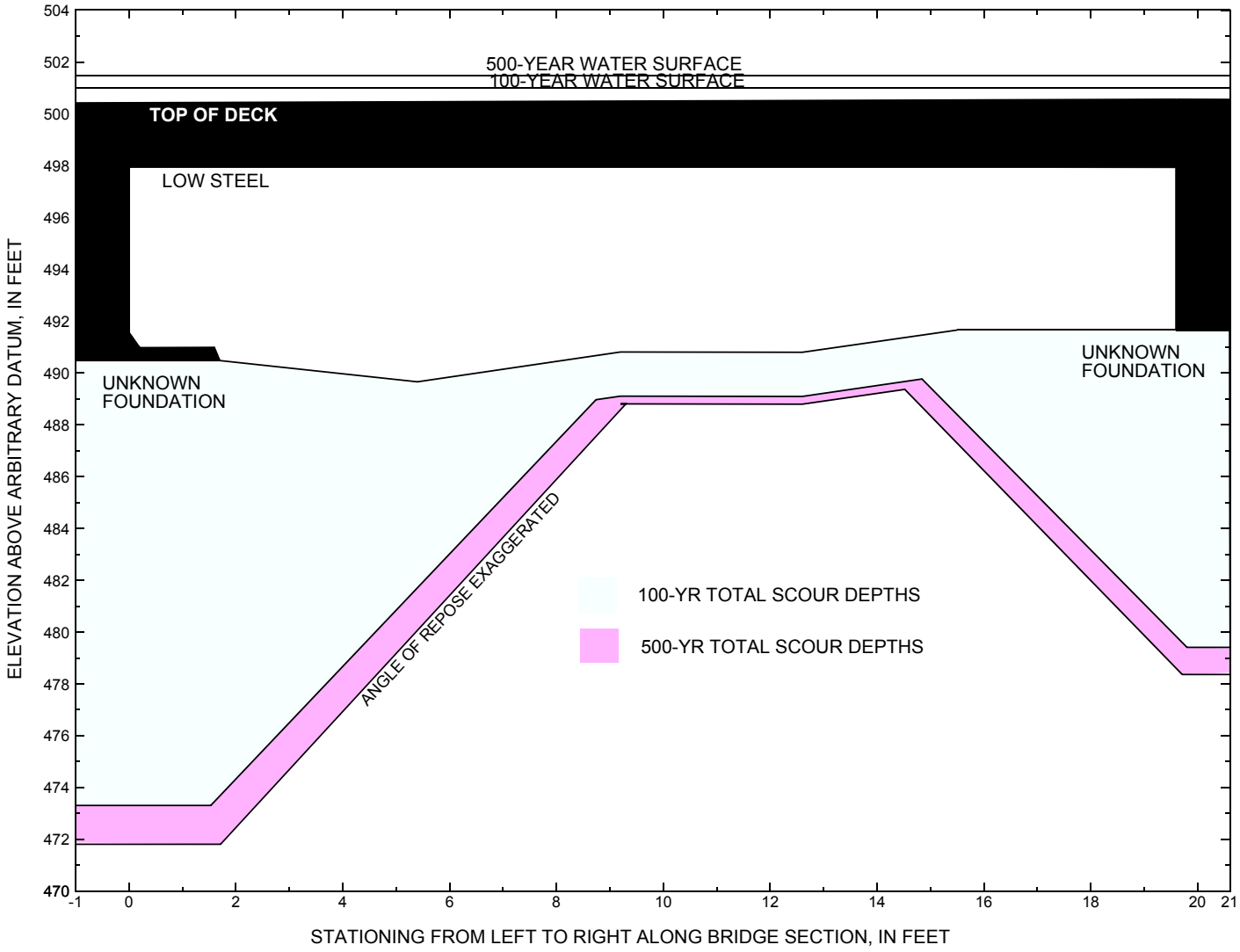


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure EDENTH00170013 on Town Highway 17, crossing the Gihon River, Eden, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure EDENTH00170013 on Town Highway 17, crossing the Gihon River, Eden, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,200 cubic-feet per second											
Left abutment	0.0	--	498.0	--	490.5	2.0	15.2	--	17.2	473.3	--
Right abutment	19.6	--	497.9	--	491.6	2.0	10.2	--	12.2	479.4	--

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

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure EDENTH00170013 on Town Highway 17, crossing the Gihon River, Eden, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,000 cubic-feet per second											
Left abutment	0.0	--	498.0	--	490.5	2.3	16.4	--	18.7	471.8	--
Right abutment	19.6	--	497.9	--	491.6	2.3	11.0	--	13.3	478.3	--

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, Eden, 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 eden013.wsp
T2        Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
T3        Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2200.0   3000.0  1150.0
SK          0.0184    0.0184   0.0184
*
XS   EXITX    -27
GR         -242.0, 504.63   -166.2, 495.56    -87.0, 492.93    -16.5, 494.50
GR            0.0, 493.94      3.1, 491.49     11.0, 490.62     19.5, 490.23
GR           25.1, 490.58     33.4, 491.05     35.5, 491.84     39.4, 496.88
GR          176.4, 503.18
N           0.040        0.055        0.070
SA                  0.0         39.4
*
XS   FULLV      0  * * *   0.00
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.94       0.0
GR            0.0, 497.97      0.1, 491.57      0.2, 490.98      1.6, 490.99
GR            1.7, 490.48      5.4, 489.66      9.2, 490.81     12.6, 490.80
GR           15.5, 491.66     19.6, 491.63     19.6, 497.91      0.0, 497.97
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      26.1      5.0    500.5     51.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      23.2     1
GR         -242.0, 504.63   -174.7, 501.33    -97.6, 499.67      0.0, 500.44
GR           20.5, 500.57     81.9, 500.79    176.4, 503.18    305.2, 510.08
*
AS   APPRO     46           0.
GR          -97.0, 502.45    -82.1, 498.02    -66.1, 494.82    -12.4, 493.99
GR            0.0, 492.74      1.9, 491.51     10.0, 490.89     18.3, 490.52
GR           21.7, 491.37     28.9, 494.02     33.0, 495.92     45.8, 498.72
GR          101.4, 500.92    208.4, 504.15
N           0.065        0.055        0.050
SA                  0.0         45.8
*
HP 1 BRIDG   497.97 1 497.97
HP 2 BRIDG   497.97 * * 1439
HP 1 BRIDG   496.35 1 496.35
HP 2 RDWAY   501.04 * * 743
HP 1 APPRO   501.24 1 501.24
HP 2 APPRO   501.24 * * 2200
*
HP 1 BRIDG   497.97 1 497.97
HP 2 BRIDG   497.97 * * 1498
HP 1 BRIDG   496.49 1 496.49
HP 2 RDWAY   501.49 * * 1446
HP 1 APPRO   501.72 1 501.72
HP 2 APPRO   501.72 * * 3000
*
HP 1 BRIDG   497.97 1 497.97
HP 2 BRIDG   497.97 * * 1150
HP 1 BRIDG   495.51 1 495.51
HP 1 APPRO   499.49 1 499.49
HP 2 APPRO   499.49 * * 1150
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File eden013.wsp
        Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
        Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
           *** RUN DATE & TIME: 06-27-97  14:59
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     139.    8782.     0.    53.                          0.
   497.97          139.    8782.     0.    53.  1.00     0.    20.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.97     0.0    19.6   139.4    8782.    1439.  10.33

X STA.          0.0         1.9         2.9         3.7         4.5         5.2
  A(I)             12.7         7.7         6.8         6.3         6.0
  V(I)             5.66        9.40       10.65       11.48       11.95

X STA.          5.2         5.9         6.7         7.4         8.2         9.0
  A(I)              5.8         5.8         5.8         5.9         5.9
  V(I)            12.44       12.36       12.42       12.26       12.28

X STA.          9.0         9.8        10.7        11.5        12.4        13.2
  A(I)              6.0         6.0         6.0         6.0         6.2
  V(I)            12.03       12.04       11.90       11.99       11.60

X STA.         13.2        14.2        15.2        16.4        17.7        19.6
  A(I)              6.7         6.7         7.3         7.8        12.2
  V(I)            10.81       10.81        9.91        9.17        5.89

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     108.    8372.    20.    30.                       1444.
   496.35          108.    8372.    20.    30.  1.00     0.    20.   1444.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.04  -161.2    91.8   174.0    5193.     743.   4.27

X STA.       -161.2      -125.2      -115.1      -107.5      -101.6       -96.6
  A(I)             13.9         9.0         8.2         7.1         6.7
  V(I)             2.67        4.12        4.55        5.20        5.53

X STA.        -96.6       -91.8       -86.8       -81.7       -76.5       -70.9
  A(I)              6.5         6.5         6.4         6.4         6.6
  V(I)             5.75        5.73        5.77        5.80        5.65

X STA.        -70.9       -65.1       -58.9       -52.1       -44.8       -36.8
  A(I)              6.6         6.8         7.0         7.2         7.4
  V(I)             5.61        5.50        5.31        5.15        5.04

X STA.        -36.8       -27.7       -16.7        -3.5        21.9        91.8
  A(I)              7.8         8.5         8.9        13.8        22.7
  V(I)             4.77        4.35        4.15        2.70        1.64
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     559.   42156.    93.    94.                       7785.
             2     358.   37371.    46.    47.                       5691.
             3      81.    2740.    66.    66.                        505.
   501.24          998.   82266.   205.   208.  1.16   -93.   112.  11603.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.24   -92.9   112.0   998.4   82266.    2200.   2.20

X STA.        -92.9       -67.9       -58.5       -50.2       -42.2       -34.7
  A(I)             83.5        60.3        54.6        54.0        51.5
  V(I)             1.32        1.83        2.01        2.04        2.14

X STA.        -34.7       -27.4       -20.2       -13.4        -7.0        -1.3
  A(I)             50.9        50.5        48.9        48.3        46.0
  V(I)             2.16        2.18        2.25        2.28        2.39

X STA.         -1.3         3.0         6.3         9.7        12.9        16.2
  A(I)             38.9        33.1        34.0        33.4        34.5
  V(I)             2.83        3.32        3.23        3.29        3.19

X STA.         16.2        19.5        23.3        28.4        38.6       112.0
  A(I)             35.4        38.1        42.5        55.2       104.7
  V(I)             3.11        2.89        2.59        1.99        1.05
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File eden013.wsp
        Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
        Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
           *** RUN DATE & TIME: 06-27-97  14:59
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     139.    8782.     0.    53.                          0.
   497.97          139.    8782.     0.    53.  1.00     0.    20.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.97     0.0    19.6   139.4    8782.    1498.  10.75

X STA.          0.0         1.9         2.9         3.7         4.5         5.2
  A(I)             12.7         7.7         6.8         6.3         6.0
  V(I)             5.89        9.79       11.09       11.95       12.44

X STA.          5.2         5.9         6.7         7.4         8.2         9.0
  A(I)              5.8         5.8         5.8         5.9         5.9
  V(I)            12.95       12.87       12.93       12.76       12.78

X STA.          9.0         9.8        10.7        11.5        12.4        13.2
  A(I)              6.0         6.0         6.0         6.0         6.2
  V(I)            12.52       12.53       12.39       12.48       12.07

X STA.         13.2        14.2        15.2        16.4        17.7        19.6
  A(I)              6.7         6.7         7.3         7.8        12.2
  V(I)            11.26       11.25       10.32        9.55        6.13

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     111.    8675.    20.    31.                       1499.
   496.49          111.    8675.    20.    31.  1.00     0.    20.   1499.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.49  -178.0   109.6   296.3    10810.    1446.   4.88

X STA.       -178.0      -135.7      -122.0      -112.3      -104.4       -97.7
  A(I)             22.8        15.8        13.6        12.5        11.7
  V(I)             3.17        4.59        5.31        5.78        6.17

X STA.        -97.7       -91.6       -85.3       -78.9       -72.2       -65.4
  A(I)             10.9        11.1        10.8        11.0        10.9
  V(I)             6.64        6.51        6.68        6.60        6.61

X STA.        -65.4       -58.0       -50.3       -42.1       -33.3       -23.5
  A(I)             11.2        11.5        11.6        11.8        12.5
  V(I)             6.43        6.28        6.24        6.12        5.78

X STA.        -23.5       -12.5        -0.3        20.4        46.7       109.6
  A(I)             13.0        13.4        20.5        22.9        36.5
  V(I)             5.55        5.39        3.53        3.15        1.98

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     604.   47393.    95.    95.                       8668.
             2     380.   41268.    46.    47.                       6223.
             3     116.    4366.    82.    82.                        785.
   501.72         1101.   93027.   222.   225.  1.18   -95.   128.  12799.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.72   -94.5   127.9  1101.0    93027.    3000.   2.72

X STA.        -94.5       -68.6       -59.1       -50.7       -42.6       -34.9
  A(I)             91.1        65.3        59.4        58.7        55.8
  V(I)             1.65        2.30        2.53        2.56        2.69

X STA.        -34.9       -27.5       -20.3       -13.4        -6.8        -1.0
  A(I)             55.2        54.7        53.0        52.2        49.6
  V(I)             2.72        2.74        2.83        2.87        3.02

X STA.         -1.0         3.3         6.8        10.3        13.6        17.0
  A(I)             41.5        37.3        37.0        36.2        37.4
  V(I)             3.61        4.03        4.06        4.15        4.01

X STA.         17.0        20.5        24.7        30.8        44.3       127.9
  A(I)             38.9        42.2        49.3        65.2       121.0
  V(I)             3.85        3.55        3.04        2.30        1.24
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File eden013.wsp
        Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
        Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
           *** RUN DATE & TIME: 06-27-97  14:59
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      139.     8782.     0.    53.                         0.
   497.97           139.     8782.     0.    53.  1.00     0.    20.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.97     0.0    19.6   139.4    8782.    1150.   8.25

X STA.          0.0         1.9         2.9         3.7         4.5         5.2
  A(I)             12.7         7.7         6.8         6.3         6.0
  V(I)             4.53        7.51        8.51        9.18        9.55

X STA.          5.2         5.9         6.7         7.4         8.2         9.0
  A(I)              5.8         5.8         5.8         5.9         5.9
  V(I)             9.94        9.88        9.93        9.80        9.81

X STA.          9.0         9.8        10.7        11.5        12.4        13.2
  A(I)              6.0         6.0         6.0         6.0         6.2
  V(I)             9.61        9.62        9.51        9.58        9.27

X STA.         13.2        14.2        15.2        16.4        17.7        19.6
  A(I)              6.7         6.7         7.3         7.8        12.2
  V(I)             8.64        8.64        7.92        7.33        4.71


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

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       92.     6609.    20.    29.                      1128.
   495.51            92.     6609.    20.    29.  1.00     0.    20.   1128.


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      402.    25415.    87.    88.                      4898.
             2      278.    24511.    46.    47.                      3894.
             3        7.      118.    19.    19.                        26.
   499.49           688.    50044.   152.   155.  1.10   -87.    65.   7902.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.49   -87.0    65.3   687.6    50044.    1150.   1.67

X STA.        -87.0       -64.8       -55.8       -47.4       -39.8       -32.3
  A(I)             58.8        42.9        41.0        38.4        38.3
  V(I)             0.98        1.34        1.40        1.50        1.50

X STA.        -32.3       -25.2       -18.3       -11.7        -5.8        -0.8
  A(I)             37.5        36.7        35.9        34.6        32.4
  V(I)             1.53        1.57        1.60        1.66        1.77

X STA.         -0.8         2.9         5.8         8.6        11.4        14.1
  A(I)             27.2        23.4        24.0        23.7        23.9
  V(I)             2.11        2.46        2.39        2.43        2.41

X STA.         14.1        17.0        19.9        23.3        28.6        65.3
  A(I)             25.1        25.7        28.2        34.6        55.3
  V(I)             2.29        2.24        2.04        1.66        1.04
```

WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File eden013.wsp
       Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
       Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
          *** RUN DATE & TIME: 06-27-97  14:59

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                            WSI,CRWS =   494.99     495.09

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

EXITX:XS   ******  -152.     334.  0.77 *****  495.87  495.09   2200.  495.09
      -27. ******    38.   17601.  1.15 ***** *******    0.94    6.58

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.59

FULLV:FV      27.  -168.     464.  0.37  0.27  496.12 *******   2200.  495.74
        0.    27.    39.   27948.  1.07  0.00   -0.02    0.57    4.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.24     504.15    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.24     504.15     496.31

 ===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 =   496.31     504.15     496.31

APPRO:AS      46.   -74.     290.  1.16 *****  497.46  496.31   2200.  496.31
       46.    46.    35.   15176.  1.29 ***** *******    0.93    7.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   502.93       0.00     497.91     499.67
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.99     500.88     501.00     497.94
 ===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      27.     0.     139.  1.66 *****  499.63  496.35   1439.  497.97
        0. ******    20.    8782.  1.00 ***** *******    0.68   10.32

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.492  0.000  497.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    23.  0.02  0.09  501.31   -0.01    743.  501.04

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    618.   170.  -161.     9.   1.4   0.8   4.9   4.3   1.1   3.1
   RT:    125.    83.     9.    92.   0.5   0.4   3.6   4.3   0.6   3.1

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

APPRO:AS      20.   -93.     998.  0.09  0.11  501.33  496.31   2200.  501.24
       46.    23.   112.   82246.  1.16  0.78   -0.01    0.19    2.20

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.  -152.    38.   2200.   17601.     334.    6.58  495.09
   FULLV:FV       0.  -168.    39.   2200.   27948.     464.    4.74  495.74
   BRIDG:BR       0.     0.    20.   1439.    8782.     139.   10.32  497.97
   RDWAY:RG      13.*******   618.    743.******************    1.00  501.04
   APPRO:AS      46.   -93.   112.   2200.   82246.     998.    2.20  501.24

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.09     0.94  490.23  504.63************  0.77  495.87  495.09
   FULLV:FV  ********     0.57  490.23  504.63  0.27  0.00  0.37  496.12  495.74
   BRIDG:BR    496.35     0.68  489.66  497.97************  1.66  499.63  497.97
   RDWAY:RG  ***************  499.67  510.08  0.02******  0.09  501.31  501.04
   APPRO:AS    496.31     0.19  490.52  504.15  0.11  0.78  0.09  501.33  501.24
```

WSPRO OUTPUT FILE (continued)

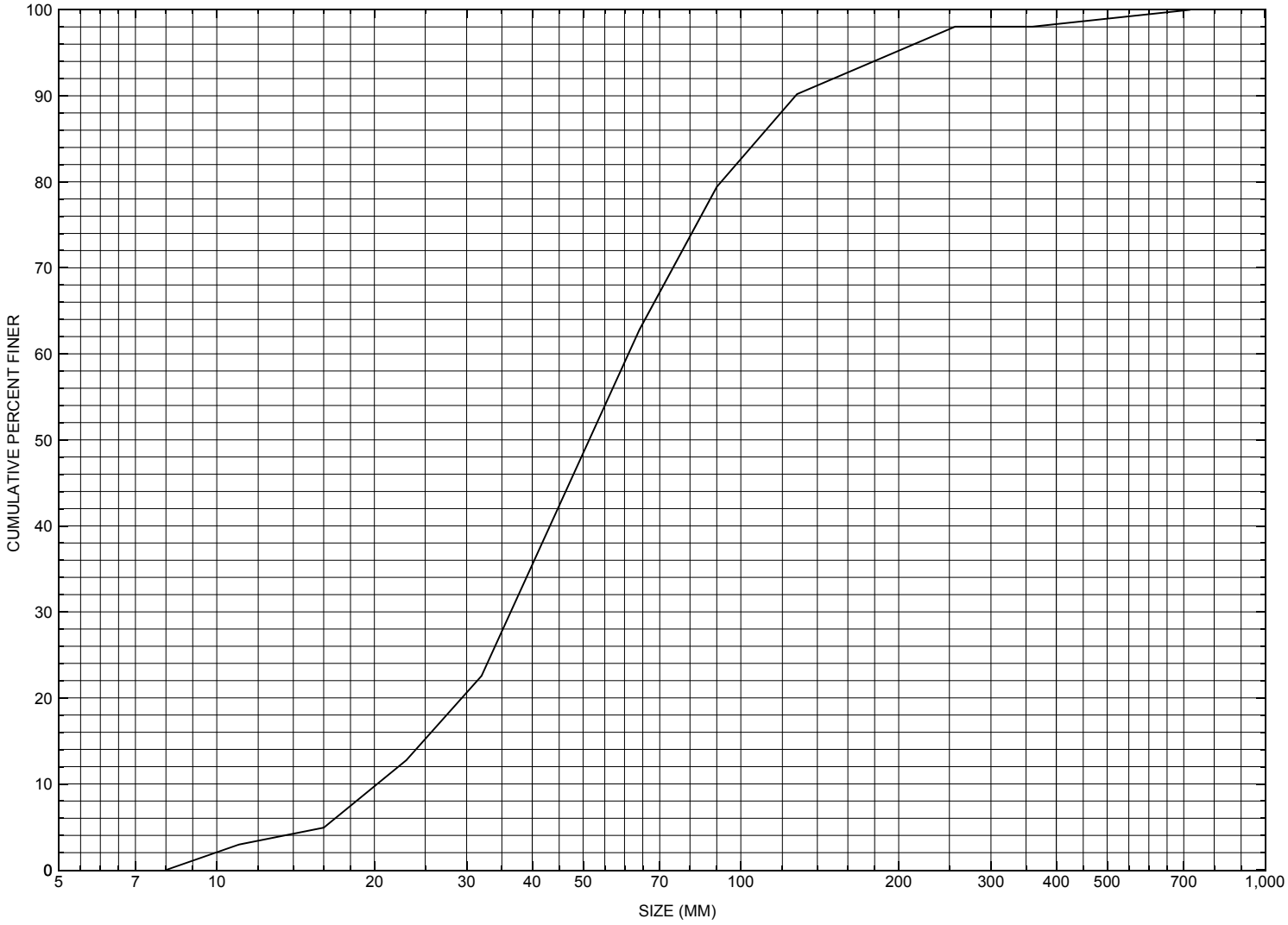
```
       U.S. Geological Survey WSPRO Input File eden013.wsp
       Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
       Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
          *** RUN DATE & TIME: 06-27-97  14:59

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                            WSI,CRWS =   495.40     495.47

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

EXITX:XS   ******  -163.     407.  0.93 *****  496.39  495.47   3000.  495.47
      -27. ******    38.   23079.  1.10 ***** *******    0.96    7.36

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.62

FULLV:FV      27.  -172.     563.  0.45  0.28  496.67 *******   3000.  496.22
        0.    27.    39.   37446.  1.03  0.00    0.00    0.58    5.33
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.72     504.15    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.72     504.15     496.87
 ===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 =   496.87     504.15     496.87

APPRO:AS      46.   -76.     353.  1.37 *****  498.24  496.87   3000.  496.87
       46.    46.    37.   19603.  1.22 ***** *******    0.94    8.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===230 REJECTED FLOW CLASS 1 SOLUTION.
              WS1,WSSD,WS3 =   504.15       0.00     497.95
                      CRWS =   496.87   ********     497.95
                      YMAX =   504.15   ********     497.97
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.32     501.36     501.51     497.94
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    1446.      1296.    1.12

             <<<<<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      27.     0.      139.  1.80 *****  499.77  496.49   1498.  497.97

        0. ******    20.    8782.  1.00 ***** *******    0.71   10.75

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.495  0.000  497.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    23.  0.02  0.14  501.84   -0.02   1446.  501.48

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1113.   187.  -178.     9.   1.8   1.2   5.7   5.0   1.6   3.1
   RT:    333.   100.     9.   109.   1.0   0.7   4.7   4.8   1.1   3.1

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

APPRO:AS      20.   -95.    1102.  0.14  0.15  501.86  496.87   3000.  501.72
       46.    24.   128.   93125.  1.18  0.80   -0.02    0.23    2.72

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.  -163.    38.   3000.   23079.     407.    7.36  495.47
   FULLV:FV       0.  -172.    39.   3000.   37446.     563.    5.33  496.22
   BRIDG:BR       0.     0.    20.   1498.    8782.     139.   10.75  497.97
   RDWAY:RG      13.******* 1113.   1446.******************    1.00  501.48
   APPRO:AS      46.   -95.   128.   3000.   93125.    1102.    2.72  501.72

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.47    0.96  490.23  504.63************  0.93  496.39  495.47
   FULLV:FV  ********    0.58  490.23  504.63  0.28  0.00  0.45  496.67  496.22
   BRIDG:BR    496.49    0.71  489.66  497.97************  1.80  499.77  497.97
   RDWAY:RG  ****************  499.67  510.08  0.02******  0.14  501.84  501.48
   APPRO:AS    496.87    0.23  490.52  504.15  0.15  0.80  0.14  501.86  501.72
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File eden013.wsp
       Hydraulic analysis for structure EDENTH00170013   Date: 16-APR-97
       Bridge 13 on Town Highway 17 over Gihon River in Eden, by MAI
          *** RUN DATE & TIME: 06-27-97  14:59

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                            WSI,CRWS =   494.22     494.33

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

EXITX:XS   ******  -129.     199.  0.66 *****  494.99  494.33   1150.  494.33
      -27. ******    37.    9256.  1.28 ***** *******    1.01    5.77

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.72

FULLV:FV      27.  -148.     311.  0.25  0.24  495.22 *******   1150.  494.97
        0.    27.    38.   15945.  1.17  0.00   -0.02    0.55    3.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.25     494.99     495.29
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.47     504.15    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.47     504.15     495.29
 ===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 =   495.29     504.15     495.29

APPRO:AS      46.   -68.     185.  0.87 *****  496.16  495.29   1150.  495.29
       46.    46.    32.    8628.  1.44 ***** *******    0.97    6.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.58     498.88     498.98     497.94
 ===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      27.     0.     139.  1.02 *****  498.99  495.51   1130.  497.97
        0. ******    20.    8782.  1.00 ***** *******    0.54    8.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.448  0.000  497.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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      20.   -87.     688.  0.05  0.07  499.54  495.29   1150.  499.49
       46.    22.    65.   50083.  1.10  0.98   -0.02    0.15    1.67

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.  -129.    37.   1150.     9256.     199.    5.77  494.33
   FULLV:FV       0.  -148.    38.   1150.    15945.     311.    3.70  494.97
   BRIDG:BR       0.     0.    20.   1130.     8782.     139.    8.11  497.97
   RDWAY:RG      13.**************       0.******************    1.00********
   APPRO:AS      46.   -87.    65.   1150.    50083.     688.    1.67  499.49

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.33    1.01  490.23  504.63************  0.66  494.99  494.33
   FULLV:FV  ********    0.55  490.23  504.63  0.24  0.00  0.25  495.22  494.97
   BRIDG:BR    495.51    0.54  489.66  497.97************  1.02  498.99  497.97
   RDWAY:RG  ***************  499.67  510.08************  0.03  501.07********
   APPRO:AS    495.29    0.15  490.52  504.15  0.07  0.98  0.05  499.54  499.49
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure EDENTH00170013, in Eden, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number EDENTH00170013

General Location Descriptive

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

Date *(MM/DD/YY)* 06 / 08 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 23500

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

Waterway *(I - 6)* GIHON RIVER

Road Name *(I - 7):* -

Route Number TH 17

Vicinity *(I - 9)* 0.3 MI JCT TH 17 & TH 19

Topographic Map Eden

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44422

Longitude *(i - 17; nnnnn.n)* 072326

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 100803001208031

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

Maximum span length *(I - 48; nnnn)* 0020

Year built *(I - 27; YYYY)* 1930

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

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

Deck Width *(I - 52; nn.n)* 23.2

Year of ADT *(I - 30; YY)* 91

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

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

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span *(nnn.n ft)* 19.5

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

Vertical clearance from streambed *(nnn.n ft)* 006.1

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

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

Comments:

Structural inspection report of 6/21/93 indicates a concrete slab with an asphalt overlay bridge. The abutments and wingwalls are concrete. They have some spalling at the waterline. The concrete footing is exposed on the left abutment for most of its length. A few boulders are showing along the up and downstream channel embankments. The channel is scoured down approximately 2.5 feet along most of the left abutment, and 0.5 to 1 feet at the right abutment. This bridge is no longer a 'long structure' and is located in the short structure system by the state of Vermont.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.266** mi^2 Lake and pond area **0.671** mi^2

Watershed storage *(ST)* **4.1** %

Bridge site elevation **994.1** ft Headwater elevation **2559** ft

Main channel length **5.777** mi

10% channel length elevation **1023.6** ft 85% channel length elevation **1486.2** ft

Main channel slope *(S)* **106.77** ft / mi

Watershed Precipitation Data

Average site precipitation _____ in Average headwater precipitation _____ in

Maximum 2yr-24hr precipitation event *(I24,2)* _____ in

Average seasonal snowfall *(Sn)* _____ ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

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:

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

-

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 02/28/96
Computerized by: EW Date: 02/28/96
Reviewd by: MAI Date: 05/01/97

Structure Number EDENTH00170013

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 06 / 26 / 1995

2. Highway District Number 08
County LAMOILLE (015)
Waterway *(I - 6)* GIHON RIVER
Route Number TH17
Mile marker 0
Town EDEN (23500)
Road Name -
Hydrologic Unit Code: 02010005

3. Descriptive comments:
The site is located 0.3 miles from the junction of Town Highway 17 with Town Highway 19.

B. Bridge Deck Observations

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

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

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

7. Bridge length 23.0 *(feet)* Span length 20.0 *(feet)* Bridge width 23.2 *(feet)*

Road approach to bridge:

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

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

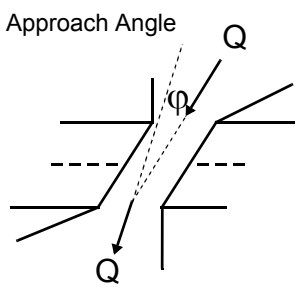
10. Embankment slope (*run / rise in feet / foot*):
US left 3.1:1 US right 6.8:1

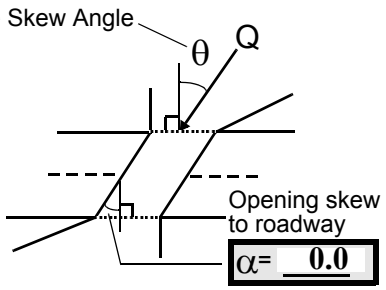
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	2	1	0	-
RBDS	2	1	0	-
LBDS	2	1	0	-

*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: 30 16. Bridge skew: 15





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 25 feet US *(US, UB, DS)* to 5 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? _____ *(LB, RB)* Severity ____
Range? _____ feet ____*(US, UB, DS)* to _____feet ____

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

18. Bridge Type: **4**

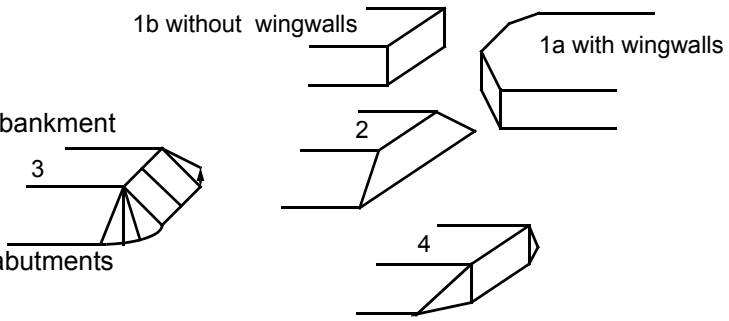
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: The DS left bank has trees along the roadway and stream bank with a mowed lawn beyond, covering the flood plain.

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
23.5	**1.0**			**2.5**	**3**	**4**	**345**	**345**	**0**	**0**

23. Bank width **30.0** 24. Channel width **20.0** 25. Thalweg depth **29.0** 29. Bed Material **342**

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

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

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

#31: There were some boulders extending 10 feet US of the wingwalls mostly at the ends

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 60 42. Cut bank extent: 20 feet US *(US, UB)* to 130 feet US *(US, UB, DS)*

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

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

The bank has tree roots exposed and the finer bank material removed, leaving behind cobbles and gravel.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
21.5		1.0		2	7	7	-

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

345

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 **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

#67: There were some small 2-3 inch diameter trees US on the banks and in the channel.

#68: The bridge opening is about 80% of the US bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**15**	**90**	**2**	**2**	**1.5**	**1.5**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**0**	**19.5**

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.):

-

-

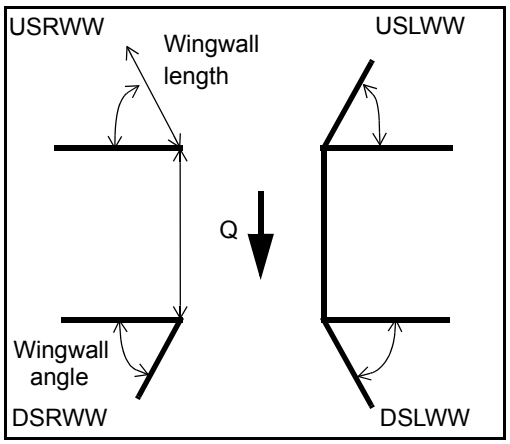
1

#71: The water attacks the abutment on the US end of the USLWW.

#75: The footing is exposed a maximum of 1.5 feet, 8 feet from the US bridge face. The average thalweg is 0.5 feet above the footing.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**19.5**	
USRWW:	**Y**		**1**		**2**	**2.0**	
DSLWW:	**0.5**		**0.5**		**Y**	**26.0**	
DSRWW:	**1**		**0**		**-**	**26.0**	



*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	-	**2**	**Y**	-	**1**	**1**	-	-
Condition	**Y**	**0.5**	**1**	-	**2**	**2**	-	-
Extent	**1**	**0.5**	**0**	**2**	**2**	**0**	**0**	-

*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

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

*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

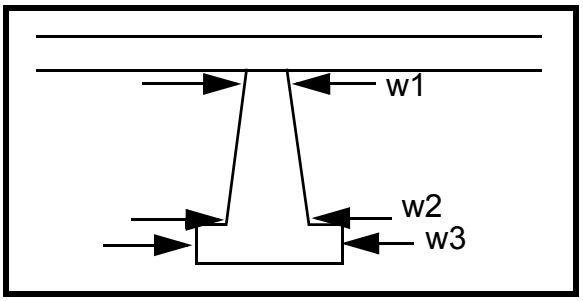
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
1
3
2
1
3

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				**55.0**	**11.0**	**50.0**
Pier 2				**12.0**	**55.0**	**10.5**
Pier 3		**9.0**	-	**50.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4
86. Location (BF)	**: Both**	**foot-**		**nding**
87. Type	**of**	**ing**	**The**	**from**
88. Material	**the**	**expo**	**DS**	**its**
89. Shape	**left**	**sed**	**right**	**end**
90. Inclined?	**wing**	**with**	**wing**	**but**
91. Attack ∠ (BF)	**walls**	**the**	**wall**	**no**
92. Pushed	**have**	**ends**	**has a**	**pro-**
93. Length (feet)	-	-	-	-
94. # of piles	**half**	**pro-**	**stone**	**tec-**
95. Cross-members	**of**	**tecte**	**-**	**tion**
96. Scour Condition	**the**	**d by**	**piled**	**at**
97. Scour depth	**lengt**	**stone**	**wall**	**the**
98. Exposure depth	**h of**	**-fill.**	**exte**	**base**

LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP

***1**- Solid pier, **2**- column, **3**- bent*

***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*

***1**- Round; **2**- Square; **3**- Pointed*

Y- yes; N- no

LB or RB

***0**- none; **1**- laterals; **2**- diagonals; **3**- both*

***0**- not evident; **1**- evident (comment);*
***2**- footing exposed; **3**- piling exposed;*
***4**- undermined footing; **5**- settled; **6**- failed*

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

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length **4** Width **435** Depth: **435** Positioned **0** %LB to **0** %RB

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

345

-
-
-

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

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

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

Confluence comments (eg. confluence name):

distributed large boulders extending well beyond 100 feet from the bridge.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

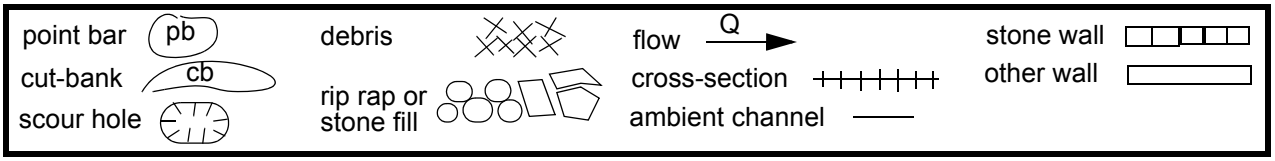
N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

- N



APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: EDENTH00170013 Town: Eden
Road Number: TH 17 County: Lamoille
Stream: Gihon River

Initials MAI Date: 04/24/97 Checked: RLB

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	2200	3000	1150
Main Channel Area, ft2	358	380	278
Left overbank area, ft2	559	604	402
Right overbank area, ft2	81	116	7
Top width main channel, ft	46	46	46
Top width L overbank, ft	93	95	87
Top width R overbank, ft	66	82	19
D50 of channel, ft	0.1688	0.1688	0.1688
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.8	8.3	6.0
y1, average depth, LOB, ft	6.0	6.4	4.6
y1, average depth, ROB, ft	1.2	1.4	0.4
Total conveyance, approach	82266	93027	50044
Conveyance, main channel	37371	41268	24511
Conveyance, LOB	42156	47393	25415
Conveyance, ROB	2740	4366	118
Percent discrepancy, conveyance	-0.0012	0.0000	0.0000
Qm, discharge, MC, cfs	999.4	1330.8	563.3
Ql, discharge, LOB, cfs	1127.4	1528.4	584.0
Qr, discharge, ROB, cfs	73.3	140.8	2.7
Vm, mean velocity MC, ft/s	2.8	3.5	2.0
Vl, mean velocity, LOB, ft/s	2.0	2.5	1.5
Vr, mean velocity, ROB, ft/s	0.9	1.2	0.4
Vc-m, crit. velocity, MC, ft/s	8.7	8.8	8.4
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	2200	3000	1150
(Q) discharge thru bridge, cfs	1439	1498	1150
Main channel conveyance	8782	8782	8782
Total conveyance	8782	8782	8782
Q2, bridge MC discharge,cfs	1439	1498	1150
Main channel area, ft2	139	139	139
Main channel width (normal), ft	19.6	19.6	19.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.6	19.6	19.6
y_bridge (avg. depth at br.), ft	7.10	7.11	7.11
Dm, median (1.25*D50), ft	0.211	0.211	0.211
y2, depth in contraction,ft	7.67	7.94	6.33
ys, scour depth (y2-ybridge), ft	0.57	0.83	-0.78

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	2200	3000	1150
Q, thru bridge MC, cfs	1439	1498	1150
Vc, critical velocity, ft/s	8.72	8.81	8.36
Va, velocity MC approach, ft/s	2.79	3.50	2.03
Main channel width (normal), ft	19.6	19.6	19.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.6	19.6	19.6
qbr, unit discharge, ft2/s	73.4	76.4	58.7
Area of full opening, ft2	139.2	139.4	139.4
Hb, depth of full opening, ft	7.10	7.11	7.11
Fr, Froude number, bridge MC	0.68	0.71	0.54
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	108	111	92
**Hb, depth at downstream face, ft	5.51	5.66	4.69
**Fr, Froude number at DS face	1.00	1.00	1.02
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	497.94	497.94	497.94

Elevation of Bed, ft	490.84	490.83	490.83
Elevation of Approach, ft	501.24	501.72	499.49
Friction loss, approach, ft	0.11	0.15	0.07
Elevation of WS immediately US, ft	501.13	501.57	499.42
ya, depth immediately US, ft	10.29	10.74	8.59
Mean elevation of deck, ft	500.5	500.5	500.5
w, depth of overflow, ft (>=0)	0.63	1.07	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.95
**Cc, for downstream face (<=1.0)	0.79	0.79	0.79
Ys, scour w/Chang equation, ft	2.03	2.29	0.25
Ys, scour w/Umbrell equation, ft	-1.61	-0.74	-3.08
**=for UNsubmerged orifice flow only.			
**Ys, scour w/Chang equation, ft	5.15	5.32	4.19
**Ys, scour w/Umbrell equation, ft	-0.02	0.71	-0.67

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

y2, from Laursen's equation, ft	7.67	7.94	6.33
WSEL at downstream face, ft	496.35	496.49	495.51
Depth at downstream face, ft	5.51	5.66	4.69
Ys, depth of scour (Laursen), ft	2.16	2.28	1.64

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	1439	1498	1150
Main channel area (DS), ft2	108	111	92
Main channel width (normal), ft	19.6	19.6	19.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.6	19.6	19.6
D90, ft	0.4173	0.4173	0.4173
D95, ft	0.6392	0.6392	0.6392
Dc, critical grain size, ft	0.6932	0.7036	0.6505
Pc, Decimal percent coarser than Dc	0.041	0.039	0.048
Depth to armoring, ft	N/A	N/A	N/A

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2200	3000	1150	2200	3000	1150
a', abut.length blocking flow, ft	92.9	94.5	87	92.4	108.3	45.7
Ae, area of blocked flow ft2	470.77	470.4	402.4	215.6	227.5	120.8
Qe, discharge blocked abut.,cfs	--	--	587.4	--	--	178.4

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

Ve, (Qe/Ae), ft/s	2.02	2.54	1.46	1.83	2.22	1.48
ya, depth of f/p flow, ft	5.07	4.98	4.63	2.33	2.10	2.64
--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	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	0.145	0.177	0.120	0.200	0.240	0.160
ys, scour depth, ft	15.21	16.40	12.95	10.25	11.02	8.12
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)	92.9	94.5	87	92.4	108.3	45.7
y1 (depth f/p flow, ft)	5.07	4.98	4.63	2.33	2.10	2.64
a'/y1	18.33	18.98	18.81	39.60	51.56	17.29
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.15	0.18	0.12	0.20	0.24	0.16
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	9.98	9.54	ERR
vertical w/ ww's	ERR	ERR	ERR	8.18	7.82	ERR
spill-through	ERR	ERR	ERR	5.49	5.25	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	1.02	1	1	1.02
y, depth of flow in bridge, ft	5.51	5.66	4.69	5.51	5.66	4.69
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.)	2.30	2.37	1.97	2.30	2.37	1.97