LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (ROCHTH00370028) on TOWN HIGHWAY 37, crossing BRANDON BROOK, ROCHESTER, VERMONT

Open-File Report 98-273

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (ROCHTH00370028) on TOWN HIGHWAY 37, crossing BRANDON BROOK, ROCHESTER, VERMONT

By EMILY C. WILD and MATTHEW A. WEBER

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (ROCHTH00370028) ON TOWN HIGHWAY 37, CROSSING BRANDON BROOK, ROCHESTER, VERMONT

By **Emily C. Wild and Matthew A. Weber**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ROCHTH00370028 on Town Highway 37 crossing Brandon Brook, Rochester, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from 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 central Vermont. The 8.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the upstream left overbank although the immediate banks have dense woody vegetation. The upstream right overbank and downstream left and right overbanks are forested.

In the study area, the Brandon Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 44 ft and an average bank height of 7 ft. The channel bed material ranges from gravel to cobbles with a median grain size (D_{50}) of 84.2 mm (0.276 ft). The geomorphic assessment at the time of the Level I site visit on April 12, 1995 and Level II site visit on July 8, 1996, indicated that the reach was stable.

The Town Highway 37 crossing of the Brandon Brook is a 33-ft-long, one-lane bridge consisting of a 31-foot timber-stringer span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 29.6 ft. The bridge is supported by vertical, timber log cribbing abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the computed opening-skew-to-roadway is zero degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the upstream left wingwall and the left abutment during the Level I assessment. The only scour protection measure at the site was type-5 protection, an artificial levee, extending along the upstream right bank to the end of the upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows was zero ft. Left abutment scour ranged from 7.1 to 9.9 ft where the worst-case scour occurred at the 500-year discharge. Right abutment scour ranged from 4.4 to 5.1 ft where the worst-case scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results.” Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number ROCHTH00370028 ***Stream*** Brandon Brook

County Windsor ***Road*** TH37 ***District*** 4

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 16.0 ***ft*** ***Max span length*** 31 ***ft***

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

Abutment type Vertical, timber cribbing ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 4/12/95

Description of stone fill -

Abutments and wingwalls are creosoted, timber log cribbing. There is a one foot deep scour hole in front of the upstream left wingwall.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 5

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	4/12/95	0	0
Level II	7/8/96	0	0

Potential for debris Moderate. There is some debris caught on the channel banks upstream and downstream on the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) Natural material along the US right bank has been piled up to form an artificial levee that extends from the US end of the right wingwall to about 50 ft US, 7/8/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderately sloped valley.

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

Date of inspection 4/12/95

DS left: Steep valley wall.

DS right: Little to no flood plain with a moderately sloped overbank.

US left: Steep valley wall

US right: Little to no flood plain with a moderately sloped overbank

Description of the Channel

Average top width 44 *ft* ***Average depth*** 7 *ft*

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

Sinuous but stable

with semi-alluvial channel boundaries and little to no flood plain.

Vegetative co 4/12/95

Trees and brush.

DS left: Trees and brush.

DS right: Trees along the immediate bank with grass and a gravel road on the overbank.

US left: Trees and brush.

US right:

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

None, 4/12/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.0 ***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 2,300 ***ft³/s*** ***Q500*** 3,300 ***ft³/s***

The 100-year discharge is based on a drainage area relationship [(8.0/6.0)exp 0.67] with bridge number 16 in Rochester. Bridge number 16 crosses the Brandon Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 16 is 6.0 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The values were graphically extended to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a nail head on the center of an X, located on top of the upstream end of the right abutment (elev. 497.07 ft, arbitrary survey datum). RM2 is a nail in a telephone pole, located 12 feet left of the downstream end of the left abutment (elev. 505.22 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	-32	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	48	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.

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 0.055 to 0.065, and overbank "n" values ranged from 0.035 to 0.080.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0115 ft/ft, which was calculated from thalweg slopes surveyed downstream.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 498.2 ***ft***
Average low steel elevation 496.5 ***ft***

100-year discharge 2,300 ***ft³/s***
Water-surface elevation in bridge opening 496.5 ***ft***
Road overtopping? Y ***Discharge over road*** 673 ***ft³/s***
Area of flow in bridge opening 229 ***ft²***
Average velocity in bridge opening 6.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.6 ***ft/s***

Water-surface elevation at Approach section with bridge 497.5
Water-surface elevation at Approach section without bridge 495.4
Amount of backwater caused by bridge 2.1 ***ft***

500-year discharge 3,300 ***ft³/s***
Water-surface elevation in bridge opening 497.4 ***ft***
Road overtopping? Y ***Discharge over road*** 1220 ***ft³/s***
Area of flow in bridge opening 236 ***ft²***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.9 ***ft/s***

Water-surface elevation at Approach section with bridge 498.2
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 1.9 ***ft***

Incipient overtopping discharge 1,570 ***ft³/s***
Water-surface elevation in bridge opening 493.8 ***ft***
Area of flow in bridge opening 155 ***ft²***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.7 ***ft/s***

Water-surface elevation at Approach section with bridge 495.7
Water-surface elevation at Approach section without bridge 494.6
Amount of backwater caused by bridge 1.1 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

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

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

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	1.1	2.3	6.0
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	8.4	9.9	7.1
Right abutment	5.0	5.1	4.4
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.2	1.7	2.0
Right abutment	1.2	1.7	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

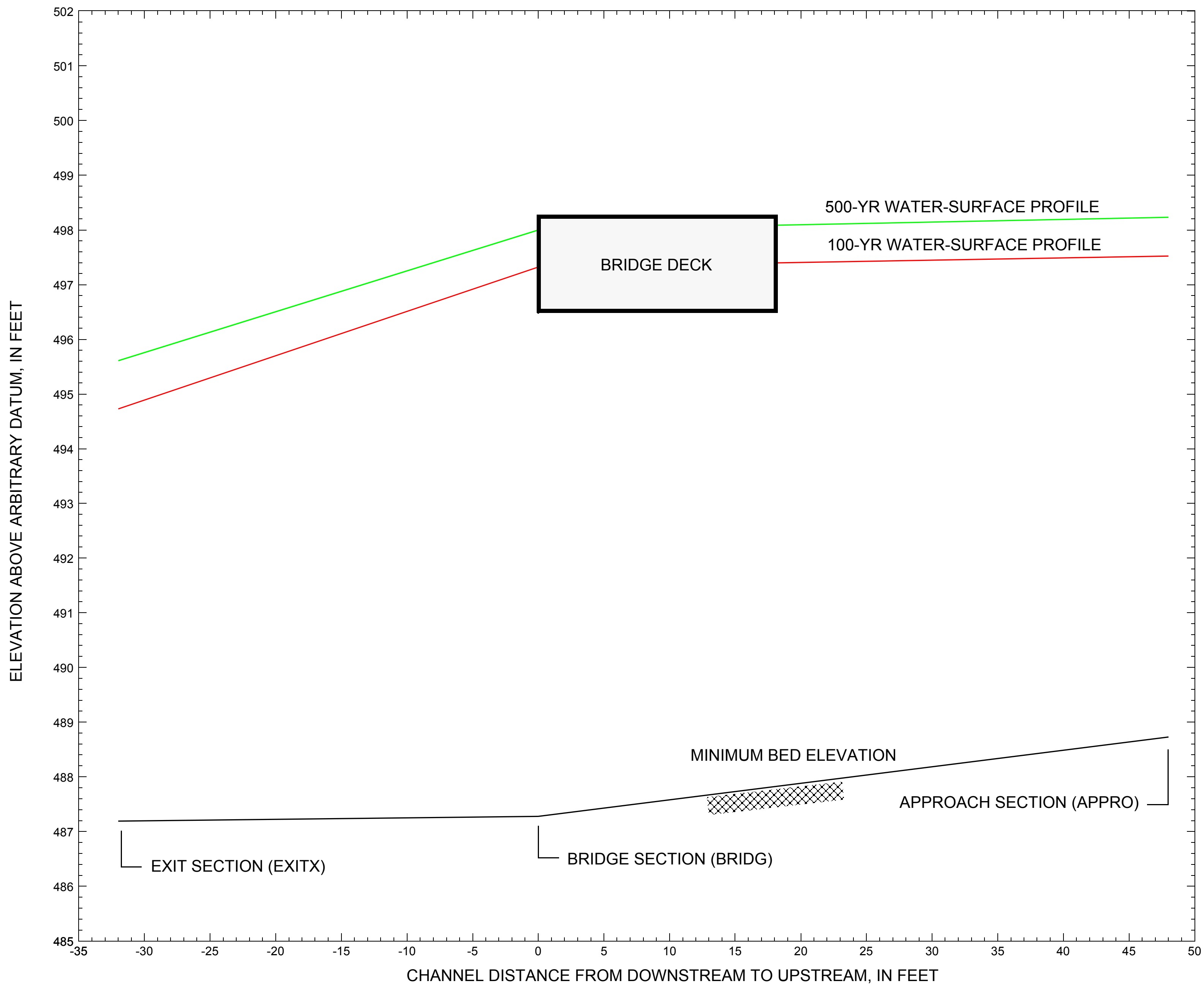

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ROCHTH00370028 on Town Highway 37, crossing Brandon Brook, Rochester, Vermont.

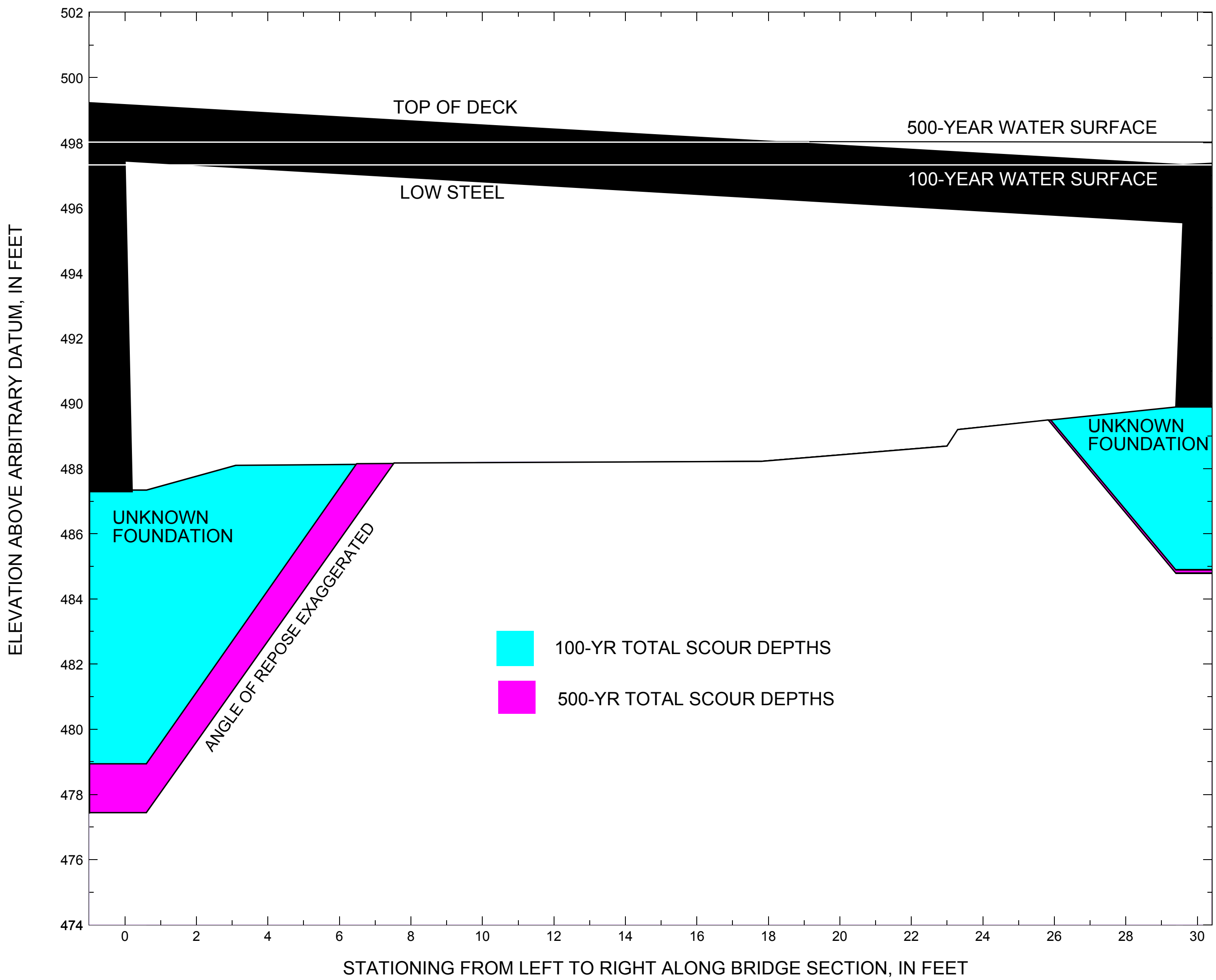

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ROCHTH00370028 on Town Highway 37, crossing Brandon Brook, Rochester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ROCHTH00370028 on Town Highway 37, crossing Brandon Brook, Rochester, 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 2,300 cubic-feet per second											
Left abutment	0.0	--	497.4	--	487.3	0.0	8.4	--	8.4	478.9	--
Right abutment	29.6	--	495.6	--	489.9	0.0	5.0	--	5.0	484.9	--

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 ROCHTH00370028 on Town Highway 37, crossing Brandon Brook, Rochester, 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 3,300 cubic-feet per second											
Left abutment	0.0	--	497.4	--	487.3	0.0	9.9	--	9.9	477.4	--
Right abutment	29.6	--	495.6	--	489.9	0.0	5.1	--	5.1	484.8	--

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, 1970, MT. Carmel, 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 roch028.wsp
T2        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
T3        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2300.0   3300.0   1570.0
SK          0.0115   0.0115   0.0115
*
XS   EXITX    -32           0.
GR          -22.2, 513.82      0.0, 498.59      4.8, 488.59      7.4, 487.67
GR           12.6, 487.93     22.3, 488.16     26.4, 487.19     34.0, 487.59
GR           36.9, 488.71     41.7, 493.12     61.6, 493.29    104.5, 493.14
GR          176.5, 494.12    204.2, 495.86    237.5, 497.18    272.4, 501.22
*
N           0.065        0.080
SA                  41.7
*
XS   FULLV      0  * * *   0.0029
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.49       0.0
GR            0.0, 497.44      0.2, 487.28      0.6, 487.34      3.1, 488.10
GR            9.9, 488.21     17.8, 488.22     23.0, 488.69     23.3, 489.20
GR           29.4, 489.89     29.6, 495.55      0.0, 497.44
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      24.8 * *     46.2      6.3
N           0.055
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      16.0     2
GR          -45.2, 508.80    -25.8, 500.20      0.0, 499.17     29.8, 497.32
GR           49.3, 496.17    100.0, 495.20    109.1, 495.62    132.0, 497.84
GR          168.3, 499.98    181.2, 502.62    283.2, 507.74
*
AS   APPRO     48           0.
GR          -80.2, 516.76    -62.4, 504.58    -41.6, 503.05    -20.3, 500.88
GR          -14.6, 497.56      0.0, 489.82      0.5, 489.08      3.8, 488.74
GR            7.4, 488.73     13.8, 488.87     22.2, 489.03     25.8, 490.03
GR           27.5, 489.80     31.8, 494.11     39.8, 494.36     70.1, 494.41
GR          109.1, 495.62    132.0, 497.84    168.3, 499.98    181.2, 502.62
GR          283.2, 507.74
*
N           0.035        0.055        0.055
SA                 -20.3        34.9
*
HP 1 BRIDG 496.49 1 496.49
HP 2 BRIDG 496.49 * * 1587
HP 1 BRIDG 495.26 1 495.26
HP 2 RDWAY 497.32 * * 673
HP 1 APPRO 497.52 1 497.52
HP 2 APPRO 497.52 * * 2300
*
HP 1 BRIDG 497.44 1 497.44
HP 2 BRIDG 497.44 * * 2020
HP 1 BRIDG 496.11 1 496.11
HP 2 RDWAY 498.00 * * 1223
HP 1 APPRO 498.23 1 498.23
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File roch028.wsp
        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
           *** RUN DATE & TIME: 06-08-98  14:17
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     229.   15240.    15.    59.                        5092.
   496.49          229.   15240.    15.    59.  1.00     0.    30.   5092.
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.49     0.0    29.6   228.7   15240.    1587.   6.94
X STA.        0.0        3.1        4.1        5.0        6.0        7.0
  A(I)            26.7        7.9        8.1        8.3        8.3
  V(I)            2.98      10.03       9.79       9.61       9.60

X STA.        7.0        8.0        9.1       10.1       11.2       12.1
  A(I)             8.5        8.4        8.8        8.7        7.5
  V(I)            9.29       9.50       9.02       9.08      10.62

X STA.       12.1       12.8       13.8       14.7       15.9       17.3
  A(I)             6.3        7.6        7.6       10.5       11.4
  V(I)           12.55      10.40      10.49       7.58       6.95

X STA.       17.3       18.8       20.3       21.9       23.8       29.6
  A(I)            11.3       11.7       12.2       13.7       35.2
  V(I)            7.01       6.75       6.52       5.78       2.25
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     199.   15001.    30.    43.                        2937.
   495.26          199.   15001.    30.    43.  1.00     0.    30.   2937.
    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.32    29.8   126.6   126.4    2946.     673.   5.32

X STA.       29.8       49.2       55.1       60.2       64.8       68.8
  A(I)            11.1        7.2        6.7        6.4        6.0
  V(I)            3.04       4.68       5.03       5.28       5.59

X STA.       68.8       72.6       76.1       79.4       82.6       85.5
  A(I)             5.9        5.8        5.6        5.5        5.3
  V(I)            5.71       5.85       6.02       6.11       6.29

X STA.       85.5       88.4       91.2       93.8       96.4       98.8
  A(I)             5.4        5.3        5.3        5.2        5.1
  V(I)            6.18       6.39       6.40       6.53       6.65

X STA.       98.8      101.2      103.8      106.6      109.8      126.6
  A(I)             5.0        5.1        5.3        5.6       13.8
  V(I)            6.71       6.54       6.40       6.01       2.44
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     324.   29067.    49.    54.                        4704.
             3     227.   11089.    94.    94.                        2006.
   497.52          551.   40156.   143.   148.  1.22   -15.   129.   5548.
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.52   -14.5   128.7   551.0   40156.    2300.   4.17

X STA.      -14.5        0.0        2.3        4.4        6.4        8.4
  A(I)            56.2       19.4       17.7       18.1       17.8
  V(I)            2.05       5.92       6.51       6.34       6.48

X STA.        8.4       10.5       12.6       14.7       16.9       19.0
  A(I)            18.1       18.0       18.4       18.7       18.6
  V(I)            6.35       6.40       6.27       6.15       6.18

X STA.       19.0       21.2       23.5       25.9       29.0       40.3
  A(I)            18.3       19.1       19.3       22.4       41.3
  V(I)            6.30       6.01       5.95       5.12       2.78

X STA.       40.3       51.5       62.3       73.8       87.1      128.7
  A(I)            35.1       33.9       35.8       37.1       67.8
  V(I)            3.27       3.40       3.21       3.10       1.70
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      U.S. Geological Survey WSPRO Input File roch028.wsp
      Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
      TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
         *** RUN DATE & TIME: 06-08-98  14:17
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      236.   13689.     0.    75.                          0.
 497.44          236.   13689.     0.    75.  1.00     0.    30.      0.
  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     497.44     0.0    29.6   235.8   13689.    2020.   8.57
X STA.         0.0        3.0        4.0        5.1        6.2        7.3
  A(I)            28.2        9.3        9.5        9.7        9.8
  V(I)            3.58      10.86      10.58      10.37      10.35

X STA.         7.3        8.4        9.5       10.7       11.9       13.1
  A(I)             9.7        9.8       10.0       10.1       10.0
  V(I)           10.42      10.29      10.12       9.98      10.07

X STA.        13.1       14.3       15.5       16.7       17.9       19.2
  A(I)            10.1       10.0       10.0       10.1       10.2
  V(I)           10.00      10.09      10.07      10.04       9.95

X STA.        19.2       20.6       22.0       23.6       25.3       29.6
  A(I)            10.5       10.5       11.5       11.3       25.5
  V(I)            9.65       9.62       8.78       8.97       3.96
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      222.   15631.    21.    53.                       4114.
 496.11          222.   15631.    21.    53.  1.00     0.    30.   4114.
  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
       WSEL     LEW     REW    AREA        K        Q    VEL
     498.00    18.8   134.7   198.4    5608.    1223.   6.16
X STA.        18.8       41.5       48.6       54.0       59.0       63.4
  A(I)            15.7       11.2       10.2        9.7        9.1
  V(I)            3.88       5.48       6.01       6.32       6.69

X STA.        63.4       67.7       71.7       75.5       79.2       82.6
  A(I)             9.2        8.8        8.9        8.7        8.4
  V(I)            6.67       6.93       6.90       7.04       7.28

X STA.        82.6       85.9       89.1       92.2       95.2       98.0
  A(I)             8.3        8.2        8.0        8.0        7.7
  V(I)            7.40       7.45       7.60       7.62       7.90

X STA.        98.0      100.9      103.8      107.0      110.5      134.7
  A(I)             7.9        7.8        8.3        8.3       26.0
  V(I)            7.71       7.86       7.40       7.37       2.35
  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2      359.   33980.    51.    55.                       5432.
          3      297.   16198.   104.   104.                       2850.
 498.23          656.   50178.   154.   159.  1.20   -16.   139.   7009.
  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
       WSEL     LEW     REW    AREA        K        Q    VEL
     498.23   -15.8   138.6   656.2   50178.    3300.   5.03

X STA.       -15.8       -0.2        2.4        4.6        6.9        9.1
  A(I)            64.9       23.8       21.0       21.5       21.0
  V(I)            2.54       6.93       7.87       7.67       7.84

X STA.         9.1       11.4       13.7       16.0       18.4       20.7
  A(I)            21.4       21.3       21.7       22.2       22.0
  V(I)            7.69       7.75       7.59       7.45       7.48

X STA.        20.7       23.2       25.9       29.3       39.3       49.0
  A(I)            22.0       23.3       26.9       43.4       37.5
  V(I)            7.49       7.07       6.13       3.80       4.40

X STA.        49.0       58.8       68.5       78.9       91.7      138.6
  A(I)            37.7       37.1       38.7       42.7       85.9
  V(I)            4.38       4.44       4.26       3.87       1.92
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        U.S. Geological Survey WSPRO Input File roch028.wsp
        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
           *** RUN DATE & TIME: 06-08-98  14:17
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     155.   10358.    29.    40.                       2018.
   493.76          155.   10358.    29.    40.  1.00     0.    30.   2018.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.76     0.1    29.5   155.0   10358.    1570.  10.13

X STA.         0.1        3.6        4.7        5.8        6.9        8.1
  A(I)           21.0        6.3        6.2        6.3        6.3
  V(I)           3.74      12.49      12.70      12.49      12.49

X STA.         8.1        9.2       10.3       11.5       12.6       13.8
  A(I)            6.2        6.4        6.3        6.4        6.4
  V(I)          12.60      12.27      12.47      12.18      12.19

X STA.        13.8       15.0       16.1       17.3       18.4       19.6
  A(I)            6.4        6.4        6.3        6.4        6.4
  V(I)          12.19      12.19      12.49      12.33      12.30

X STA.        19.6       20.8       22.0       23.5       25.1       29.5
  A(I)            6.4        6.5        7.4        7.1       17.9
  V(I)          12.28      11.99      10.67      11.10       4.38

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     237.   18164.    46.    50.                       3053.
             3      74.    1965.    75.    75.                        413.
   495.70          311.   20129.   121.   125.  1.28   -11.   110.   2497.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.70   -11.1   109.9   310.5   20129.    1570.   5.06

X STA.       -11.1        0.2        2.0        3.5        5.0        6.5
  A(I)           33.9       11.7       10.5       10.3       10.6
  V(I)           2.32       6.71       7.44       7.66       7.38

X STA.         6.5        8.0        9.5       11.1       12.7       14.3
  A(I)           10.6       10.5       10.7       10.9       10.9
  V(I)           7.42       7.46       7.30       7.17       7.21

X STA.        14.3       15.9       17.5       19.1       20.7       22.3
  A(I)           10.8       10.8       10.9       10.7       10.9
  V(I)           7.25       7.28       7.23       7.32       7.21

X STA.        22.3       24.1       26.0       28.3       56.1      109.9
  A(I)           11.2       11.6       13.1       44.9       44.9
  V(I)           6.99       6.76       5.99       1.75       1.75
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        U.S. Geological Survey WSPRO Input File roch028.wsp
        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
           *** RUN DATE & TIME: 06-08-98  14:17
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******     2.     427.  0.75 *****  495.48  494.22   2300.  494.73
      -32. ******   186.   21435.  1.67 ***** *******    0.81    5.39
FULLV:FV      32.     2.     508.  0.53  0.31  495.79 *******   2300.  495.26
        0.    32.   193.   25749.  1.66  0.00    0.00    0.63    4.52
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    1.05     495.40     495.31
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   494.76     516.76    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   494.76     516.76     495.31
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.69

APPRO:AS      48.   -11.     275.  1.35  0.56  496.75  495.31   2300.  495.40
       48.    48.   102.   17768.  1.24  0.41    0.00    1.05    8.36
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
            WS1,WSSD,WS3,RGMIN =   498.03       0.00     494.25     495.20
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                    WS,QBO,QRD =   499.55         0.      2300.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      32.     0.     229.  0.75 *****  497.24  492.98   1587.  496.49
        0. ******    30.   15240.  1.00 ***** *******    0.44    6.94
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.384  0.000  496.49 ****** ****** ******
    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    32.  0.11  0.33  497.75   -0.02    673.  497.32
             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     3.    11.    14.   0.2   0.1   3.6  19.1   0.8   2.8
   RT:    673.    97.    30.   127.   2.1   1.3   6.0   5.3   1.7   3.1

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

APPRO:AS      23.   -15.     551.  0.33  0.16  497.85  495.31   2300.  497.52
       48.    25.   129.   40147.  1.22  0.00   -0.02    0.41    4.18

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.     2.   186.   2300.   21435.     427.    5.39  494.73
   FULLV:FV       0.     2.   193.   2300.   25749.     508.    4.52  495.26
   BRIDG:BR       0.     0.    30.   1587.   15240.     229.    6.94  496.49
   RDWAY:RG       9.*******     0.    673.       0.*********    2.00  497.32
   APPRO:AS      48.   -15.   129.   2300.   40147.     551.    4.18  497.52

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.22    0.81  487.19  513.82************  0.75  495.48  494.73
   FULLV:FV  ********    0.63  487.28  513.91  0.31  0.00  0.53  495.79  495.26
   BRIDG:BR    492.98    0.44  487.28  497.44************  0.75  497.24  496.49
   RDWAY:RG  ****************  495.20  508.80  0.11******  0.33  497.75  497.32
   APPRO:AS    495.31    0.41  488.73  516.76  0.16  0.00  0.33  497.85  497.52
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File roch028.wsp
        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
           *** RUN DATE & TIME: 06-08-98  14:17

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******     1.     595.  0.78 *****  496.39  495.01   3300.  495.61
      -32. ******   200.   30760.  1.63 ***** *******    0.72    5.54

FULLV:FV      32.     1.     678.  0.59  0.32  496.70 *******   3300.  496.11
        0.    32.   208.   35766.  1.60  0.00   -0.01    0.60    4.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.03     496.21     496.32
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.61     516.76    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.61     516.76     496.32
 ===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 =   496.32     516.76     496.32

APPRO:AS      48.   -12.     388.  1.44 *****  497.76  496.32   3300.  496.32
       48.    48.   116.   25917.  1.28 ***** *******    0.98    8.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.55       0.00     495.67     495.20
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.21     497.74     498.01     496.49
 ===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      32.     0.     236.  1.14 *****  498.58  493.77   2020.  497.44
        0. ******    30.   13689.  1.00 ***** *******    0.54    8.57
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.439  0.000  496.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    32.  0.14  0.47  498.57   -0.02   1223.  498.00
            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     3.     9.    13.   0.2   0.1   3.7  18.0   0.8   2.8
   RT:   1223.   116.    19.   135.   2.8   1.7   6.9   6.1   2.3   3.1

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

APPRO:AS      23.   -16.     657.  0.47  0.27  498.70  496.32   3300.  498.23
       48.    26.   139.   50207.  1.20  0.51   -0.02    0.47    5.03

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.     1.   200.   3300.   30760.     595.    5.54  495.61
   FULLV:FV       0.     1.   208.   3300.   35766.     678.    4.87  496.11
   BRIDG:BR       0.     0.    30.   2020.   13689.     236.    8.57  497.44
   RDWAY:RG       9.*******     0.   1223.       0.*********    2.00  498.00
   APPRO:AS      48.   -16.   139.   3300.   50207.     657.    5.03  498.23

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

 SECOND USER DEFINED TABLE.
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        U.S. Geological Survey WSPRO Input File roch028.wsp
        Hydraulic analysis for structure ROCHTH00370028   Date: 15-OCT-97
        TOWN HIGHWAY 37, BRANDON BROOK, ROCHESTER, VERMONT            ECW
           *** RUN DATE & TIME: 06-08-98  14:17

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

EXITX:XS   ******     2.     274.  0.72 *****  494.57  491.98   1570.  493.85
      -32. ******   157.   14636.  1.41 ***** *******    0.90    5.74

FULLV:FV      32.     2.     342.  0.52  0.31  494.88 *******   1570.  494.35
        0.    32.   179.   17423.  1.59  0.00   -0.01    0.73    4.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.96    494.60     493.51
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.85     516.76    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.85     516.76     493.51

APPRO:AS      48.    -9.     197.  1.06  0.53  495.67  493.51   1570.  494.61
       48.    48.    77.   12850.  1.08  0.27    0.00    0.96    7.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   495.70       0.00     493.76     495.20
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   495.62      1537.        33.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.07     497.00     497.08
 ===270 REJECTED 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      32.     0.     155.  1.59  0.52  495.36  492.88   1570.  493.76
        0.    32.    30.   10362.  1.00  0.26    0.00    0.78   10.12

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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      23.   -11.     311.  0.51  0.29  496.21  493.51   1570.  495.70
       48.    24.   110.   20166.  1.28  0.57    0.00    0.63    5.05

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.656  0.100   18139.    -1.    28.   495.51

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.     2.   157.   1570.   14636.     274.    5.74  493.85
   FULLV:FV       0.     2.   179.   1570.   17423.     342.    4.59  494.35
   BRIDG:BR       0.     0.    30.   1570.   10362.     155.   10.12  493.76
   RDWAY:RG       9.**************      0.       0.       0.    2.00********
   APPRO:AS      48.   -11.   110.   1570.   20166.     311.    5.05  495.70

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    28.   18139.
```
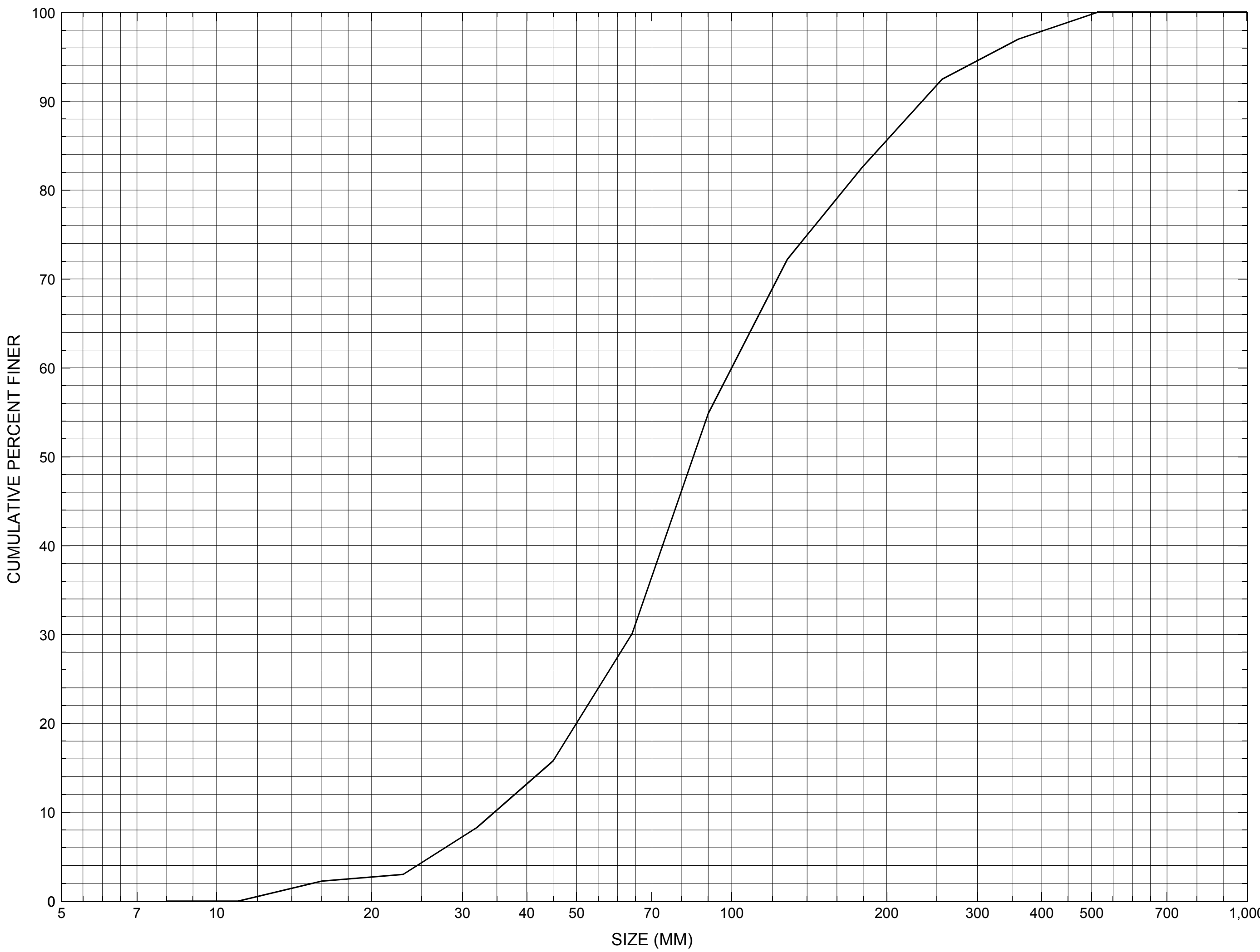

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ROCHTH00370028, in Rochester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ROCHTH00370028

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 22 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 60100

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

Waterway *(I - 6)* BRANDON BROOK

Road Name *(I - 7):* -

Route Number TH037

Vicinity *(I - 9)* AT JCT TH 37 + VT 73

Topographic Map Mount Carmel

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43512

Longitude *(i - 17; nnnnn.n)* 72540

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141500281415

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1919

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000040

Deck Width *(I - 52; nn.n)* 160

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 702

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.0

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

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

Comments:

The structural inspection report of 5/21/93 indicates the structure is a single span, treated timber stringer type bridge with a timber plank deck. The abutment walls and wingwalls are creosoted, timber log cribbing. The wingwalls have areas of moss growth on the tops. Tree growth is reported in addition to some moss growth on the top of the upstream left wingwall. The streambed and banks are noted as consisting of stone and gravel with several randomly distributed boulders. The waterway is slightly skewed relative to the trend of the abutment walls. There are large trees noted on the banks. Local scour is reported as minor but noticeable at the upstream left wingwall. The abutments are reported as **(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:

apparently not undermined or settled. The type of foundation indicated on the report is an unknown foundation. Hence, while the footings are not in view, the abutment walls may not have a distinctive footing, per se.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **7.992** mi^2 Lake/pond/swamp area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1200** ft Headwater elevation **3366** ft
Main channel length **4082** mi
10% channel length elevation **1280** ft 85% channel length elevation **2380** ft
Main channel slope *(S)* **304.29** ft / mi

Watershed Precipitation Data

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

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

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

Comments:
NO PLANS.

Cross-sectional Data

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

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

Comments: **The station and low chord to bed differences are taken from a sketch dated 5/21/93 that is attached to a bridge inspection report. The low chord elevations are from the 7/8/96 survey done for this report. This section is of the US bridge face.**

Station	**0**	**7**	**25**	**31**	-	-	-	-	-	-	-
Feature	**LAB**	-	-	**RAB**	-	-	-	-	-	-	-
Low chord elevation	**497.44**	**497.38**	**495.92**	**495.55**	-	-	-	-	-	-	-
Bed elevation	**485.44**	**488.71**	**488.92**	**488.55**	-	-	-	-	-	-	-
Low chord to bed	**12.00**	**8.67**	**7.00**	**7.00**	-	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **09/30/96**

Computerized by: **RB** Date: **09/30/96**

Reviewd by: **EW** Date: **12/18/97**

Structure Number **ROCHTH00370028**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. WEBER** Date *(MM/DD/YY)* **04** / **12** / 19**95**

2. Highway District Number **04** Mile marker **0000**

County **WINDSOR (027)** Town **ROCHESTER (60100)**

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

Route Number **TH037** Hydrologic Unit Code: **01080105**

3. Descriptive comments:

Located at the junction of TH37 and VT 73. This is a timber bridge with abutments and wingwalls made of log cribbing.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** 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 **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **33** *(feet)* Span length **31** *(feet)* Bridge width **16** *(feet)*

Road approach to bridge:

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

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

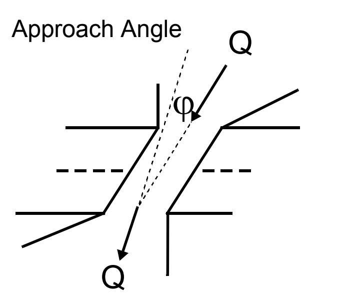
10. Embankment slope (*run / rise in feet / foot*):
US left **1.4:1** US right **3.8:1**

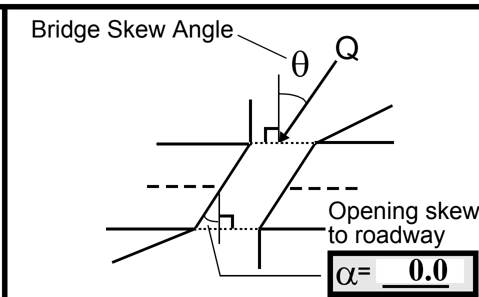
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	3	1
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **10** 16. Bridge skew: **5**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **10** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **30** feet **DS** *(US, UB, DS)* to **90** feet **DS**

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

18. Bridge Type: 4

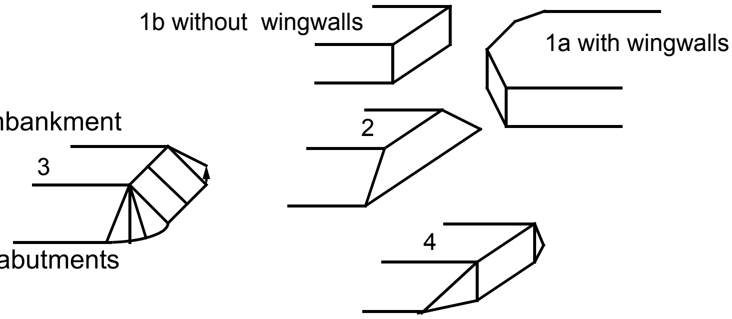
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

7. Values are from the VTAOT files. Measured bridge length is 32 ft, span length is 30 ft and the bridge width is 16 ft. The lengths were measured at the US bridge face.
4. The US right and the DS right banks are forested and VT 73 runs parallel to the stream about 130 ft from the right end of the bridge deck. On the US left bank there is a gravel driveway that leads to a house and a large lawn about 50 ft US.
17. Impact zone 1 is at the US left wingwall.
11. There is one type 3 boulder on the DS right road approach and gravel road fill at all corners of the road approach.

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
32.0	7.5			4.5	2	4	3245	3245	1	1

23. Bank width	24. Channel width	25. Thalweg depth	29. Bed Material
30.0	45.0	46.5	435

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.):

27. The bank material is gravel, sand, cobble and boulder.
29. The bed material is cobble, gravel and boulder.
A small culvert empties into the channel about 130 ft US on the left bank.

07/08/96 Natural material along the US right bank has been piled up to form an artificial levee that extends from the US end of the right wingwall to about 50 ft US. It is type 5 protection in good condition. RLB

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

There is a cobble, gravel, boulder and sand side bar from about 120 ft to 200 ft US on the right bank. The width is 30 ft and it is positioned from 50% LB to 100% RB. It is lightly vegetated with grasses and shrubs.

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

Some local scour is around boulders in the channel at 90 ft US.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
27.5		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

63. Bed material is gravel, cobble, and boulder.

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

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

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

70. Debris and Ice Comments:

1

65. There are some logs and branches caught on the banks US and DS.

68. The capture efficiency is moderate because the ambient thalweg impacts the US left wingwall and left abutment so debris coming DS would become caught in against the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	1	1	0	90.0
RABUT	4	5	90			2	0	29.5

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.):

-

-

4

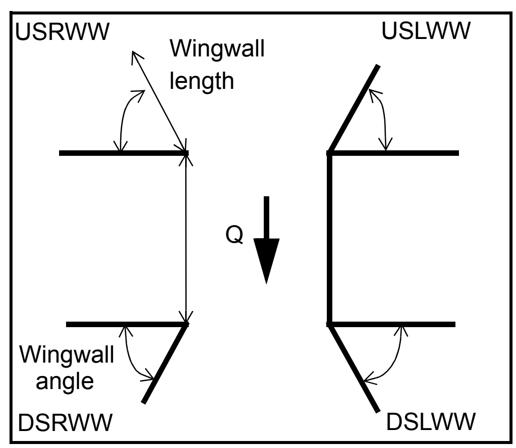
71. The attack angle is on the right abutment, but there is no scour evident.

74. Scour on the left abutment is at the US end of the abutment and at the DS end of the US left wingwall where they protrude into the flow.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						29.5	
USRWW:	Y		4		1	2.0	
DSLWW:	1		0		Y	18.5	
DSRWW:	4		0		-	18.0	

*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	-	0	Y	-	-	-	-	-
Condition	Y	-	4	-	-	-	-	-
Extent	4	-	0	0	0	0	0	-

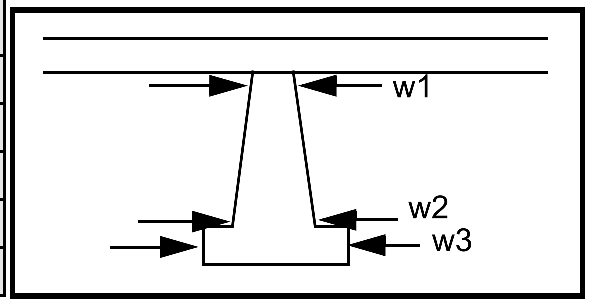
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **80.** *(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				**45.0**	**11.0**	**45.0**
Pier 2	**7.0**			**45.0**	**11.0**	**45.0**
Pier 3		-	-	**11.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**Scour**	**DS end**	**82.**	**tion**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**is**	**and**	**Ther**	**alon**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**evi-**	**at**	**e is**	**g the**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**dent**	**the**	**nat-**	**entir**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**at**	**US**	**ural**	**e**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**end**	**cob-**	**base**	
92. Pushed	**US**	**of**	**ble**	**lengt**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**left**	**the**	**and**	**hs of**	
95. Cross-members	**wing**	**left**	**boul-**	**all**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wall**	**abut**	**der**	**the**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**at**	**ment**	**pro-**	**wing**	
98. Exposure depth	**the**	**.**	**tec-**	**walls**	

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

except the US left wingwall.

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 3245____ Depth: 3245____ Positioned 2____ %LB to 1____ %RB

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

345
0
0
-

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

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

Confluence 2: Distance is____ Enters on grav____ *(LB or RB)* Type el,____ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

sand, cobble and boulder. The bed material is gravel, cobble and boulder. A minor roadwash inflow is present at 10 ft DS on the left bank. Also, an intermittent tributary enters at 115 ft DS on the left bank. The chan-

F. Geomorphic Channel Assessment

107. Stage of reach evolution nel____

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)*:

is locally anabranched with a mid channel island from about 160 ft to 280 ft DS. There are mature trees growing on the island. The DS right bank is low but not flat and is wet in some places.

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: ROCHTH00370028 Town: ROCHESTER
Road Number: TH 37 County: WINDSOR
Stream: BRANDON BROOK

Initials ECW Date: 12/11/97 Checked: MAI

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2300	3300	1570
Main Channel Area, ft2	324	359	237
Left overbank area, ft2	0	0	0
Right overbank area, ft2	227	297	74
Top width main channel, ft	49	51	46
Top width L overbank, ft	0	0	0
Top width R overbank, ft	94	104	75
D50 of channel, ft	0.2761	0.2761	0.2761
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.6	7.0	5.2
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	2.4	2.9	1.0
Total conveyance, approach	40156	50178	20129
Conveyance, main channel	29067	33980	18164
Conveyance, LOB	0	0	0
Conveyance, ROB	11089	16198	1965
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1664.9	2234.7	1416.7
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	635.1	1065.3	153.3
Vm, mean velocity MC, ft/s	5.1	6.2	6.0
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.8	3.6	2.1
Vc-m, crit. velocity, MC, ft/s	10.0	10.1	9.6
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	2300	3300	1570
(Q) discharge thru bridge, cfs	1587	2020	1570
Main channel conveyance	15240	13689	10358
Total conveyance	15240	13689	10358
Q2, bridge MC discharge,cfs	1587	2020	1570
Main channel area, ft2	229	236	155
Main channel width (normal), ft	29.6	29.6	29.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.6	29.6	29.4
y_bridge (avg. depth at br.), ft	7.74	7.97	5.27
Dm, median (1.25*D50), ft	0.345125	0.345125	0.345125
y2, depth in contraction,ft	5.09	6.26	5.07
ys, scour depth (y2-ybridge), ft	-2.64	-1.71	-0.20

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	1587	2054	1570
Main channel area (DS), ft2	199	222	155
Main channel width (normal), ft	29.6	29.6	29.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.6	29.6	29.4
D90, ft	0.7681	0.7681	0.7681
D95, ft	1.0160	1.0160	1.0160
Dc, critical grain size, ft	0.2939	0.3777	0.5276
Pc, Decimal percent coarser than Dc	0.455	0.330	0.208
Depth to armoring, ft	1.06	2.30	6.04

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	2300	3300	1570
Q, thru bridge MC, cfs	1587	2054	1570
Vc, critical velocity, ft/s	10.00	10.11	9.59
Va, velocity MC approach, ft/s	5.14	6.22	5.98
Main channel width (normal), ft	29.6	29.6	29.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.6	29.6	29.4
qbr, unit discharge, ft2/s	53.6	69.4	53.4
Area of full opening, ft2	229.0	236.0	155.0
Hb, depth of full opening, ft	7.74	7.97	5.27
Fr, Froude number, bridge MC	0.44	0.54	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	199	222	N/A
**Hb, depth at downstream face, ft	6.72	7.50	N/A
**Fr, Froude number at DS face	0.54	0.60	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	496.49	496.49	0
Elevation of Bed, ft	488.75	488.52	-5.27
Elevation of Approach, ft	497.52	498.23	0
Friction loss, approach, ft	0.16	0.27	0
Elevation of WS immediately US, ft	497.36	497.96	0.00
ya, depth immediately US, ft	8.61	9.44	5.27
Mean elevation of deck, ft	498.245	498.245	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.96	1.00
**Cc, for downstream face (<=1.0)	0.938712	0.943049	ERR
Ys, scour w/Chang equation, ft	-2.23	-0.81	N/A
Ys, scour w/Umbrell equation, ft	-1.39	-0.20	N/A

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

**Ys, scour w/Chang equation, ft	-1.01	-0.22	N/A

**Ys, scour w/Umbrell equation, ft	-0.37	0.27	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	5.09	6.26	5.07
WSEL at downstream face, ft	495.26	496.11	--
Depth at downstream face, ft	6.72	7.50	N/A
Ys, depth of scour (Laursen), ft	-1.63	-1.24	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	2300	3300	1570	2300	3300	1570
a', abut.length blocking flow, ft	14.5	15.8	11.2	99.1	109	80.4
Ae, area of blocked flow ft2	56.2	66.73	33.6	122.18	130.77	87.86
Qe, discharge blocked abut.,cfs	115	177.69	77.81	--	--	153.61
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.05	2.66	2.32	2.75	3.57	1.75
ya, depth of f/p flow, ft	3.88	4.22	3.00	1.23	1.20	1.09
--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	0.183	0.228	0.236	0.306	0.367	0.295
ys, scour depth, ft	8.39	9.85	7.07	8.58	9.62	7.22

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)	14.5	15.8	11.2	99.1	109	80.4
y1 (depth f/p flow, ft)	3.88	4.22	3.00	1.23	1.20	1.09
a'/y1	3.74	3.74	3.73	80.38	90.85	73.57
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.18	0.23	0.24	0.31	0.37	0.29
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	6.07	6.27	5.31
vertical w/ ww's	ERR	ERR	ERR	4.97	5.14	4.35
spill-through	ERR	ERR	ERR	3.34	3.45	2.92

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.54	0.6	0.78	0.55	0.6	0.78
y, depth of flow in bridge, ft	6.72	7.50	5.27	6.72	7.50	5.27
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.21	1.67	1.98	1.26	1.67	1.98
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR