LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (LOWETH00080039) on TOWN HIGHWAY 8, crossing POTTER BROOK, LOWELL, VERMONT

U.S. Geological Survey
Open-File Report 97-629

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

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By ERICK M. BOEHMLER and JAMES R. DEGNAN

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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

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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	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 39 (LOWETH00080039) ON TOWN HIGHWAY 8, CROSSING POTTER BROOK, LOWELL, VERMONT

By **Erick M. Boehmler and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LOWETH00080039 on Town Highway 8 crossing Potter Brook, Lowell, 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 4.69-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of shrub and brushland, except for the left overbank upstream which is forest.

In the study area, Potter Brook has a sinuous channel with a slope of approximately 0.004 ft/ft, an average channel top width of 34 feet and an average bank height of 3 ft. The predominant channel bed materials are gravel and sand with a median grain size (D_{50}) of 18.7 mm (0.0613 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 15, 1995, indicated that the reach was laterally unstable. This assessment of the reach was primarily due to the meandering of the channel with cut-banks and narrow point bars and the fine bank and bed material near the site.

The Town Highway 8 crossing of Potter Brook is a 23-ft-long, one-lane bridge consisting of one 21-foot steel-beam span (Vermont Agency of Transportation, written communication, March 7, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.0 feet deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. There were no scour protection measures evident at the site. 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 0.0 to 0.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 1.8 to 5.5 feet. The worst-case abutment scour occurred at the 100-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.

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 LOWETH00080039 ***Stream*** Potter Brook

County Orleans ***Road*** TH 8 ***District*** 9

Description of Bridge

Bridge length 23 ***ft*** ***Bridge width*** 14.4 ***ft*** ***Max span length*** 21 ***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*** 6/15/95

Description of stone fill There was no stone fill evident near this bridge site.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a 2.0 foot deep scour hole along the left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 20

There is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the flow 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	6/15/95	0	0
Level II	6/15/95	0	0

Potential for debris High. There is significant vegetation on the banks upstream of a laterally unstable channel.

Describe any features near or at the bridge that may affect flow (include observation date) None were evident on 6/15/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with irregular flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 6/15/95

DS left: Moderately sloping bank and a wide flood plain.

DS right: Moderately sloping bank and a narrow flood plain.

US left: Moderately sloping bank and a narrow flood plain.

US right: Moderately sloping bank and a narrow flood plain.

Description of the Channel

Average top width 34 ***Average depth*** 3

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

Meandering and swampy with alluvial channel boundaries and narrow point bars.

6/15/95

Vegetative co Shrubs and brush

DS left: Shrubs and brush

DS right: Trees and shrubs with some tall grass.

US left: Shrubs and brush.

US right:

Do banks appear stable? No

On 6/15/95, the channel was noted as meandering and had many cut-banks with moderately eroding bank material and narrow point bars.

date of observation.

None noted on 6/15/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.69 ***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 1,070 ***ft³/s*** ***Q500*** 1,500 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.69/2.22)exp 0.67] with bridge number 13 in Lowell. Bridge number 13 crosses Leclair Brook, a characteristically similar nearby watershed, and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 13 is 2.22 square miles. The computed discharges from this area relationship were within a range of discharges computed by use of empirical methods (Benson, 1962; FHWA, 1983; Johnson and Laraway, 1972; Johnson and Tasker, 1974; Potter, 1957; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a nail at the center point of a chiseled "X" at the right end of the 4x4, wooden curb on the downstream side of the bridge deck (elev. 500.70 feet, arbitrary survey datum). RM2 is a nail at the center point of a chiseled "X" at the left end of the 4x4, wooden curb on the upstream side of the bridge deck (elev. 500.63 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-23	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPR1	39	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 0.035 to 0.040, and overbank "n" values ranged from 0.055 to 0.10.

Normal depth at the exit section (EXIT1) 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 0.0043 ft/ft, which was estimated from surveyed thalweg points downstream of the site.

The approach section (APPR1) 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 500.1 ***ft***
Average low steel elevation 497.9 ***ft***

100-year discharge 1,070 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 439 ***ft³/s***
Area of flow in bridge opening 117 ***ft²***
Average velocity in bridge opening 5.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 6.6 ***ft/s***

Water-surface elevation at Approach section with bridge 499.8
Water-surface elevation at Approach section without bridge 499.2
Amount of backwater caused by bridge 0.6 ***ft***

500-year discharge 1,500 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 819 ***ft³/s***
Area of flow in bridge opening 117 ***ft²***
Average velocity in bridge opening 5.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.1 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 499.4
Amount of backwater caused by bridge 0.7 ***ft***

Incipient overtopping discharge 590 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Area of flow in bridge opening 117 ***ft²***
Average velocity in bridge opening 5.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 6.2 ***ft/s***

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 498.6
Amount of backwater caused by bridge 0.2 ***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, the modeled discharges resulted in submerged 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. Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell equation (Richardson and others, 1995,
p. 144). Results from these equations are presented in Appendix F.

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) for most discharges because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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.

Abutment scour for the left abutment at the incipient overtopping discharge was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation are defined the same as those defined for the HIRE 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	0.3	0.0
Depth to armoring	0.3	0.5	0.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	5.5	2.2	4.9
Right abutment	3.0	3.3	1.8
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	0.6	0.6	0.5
Right abutment	0.6	0.6	0.5
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

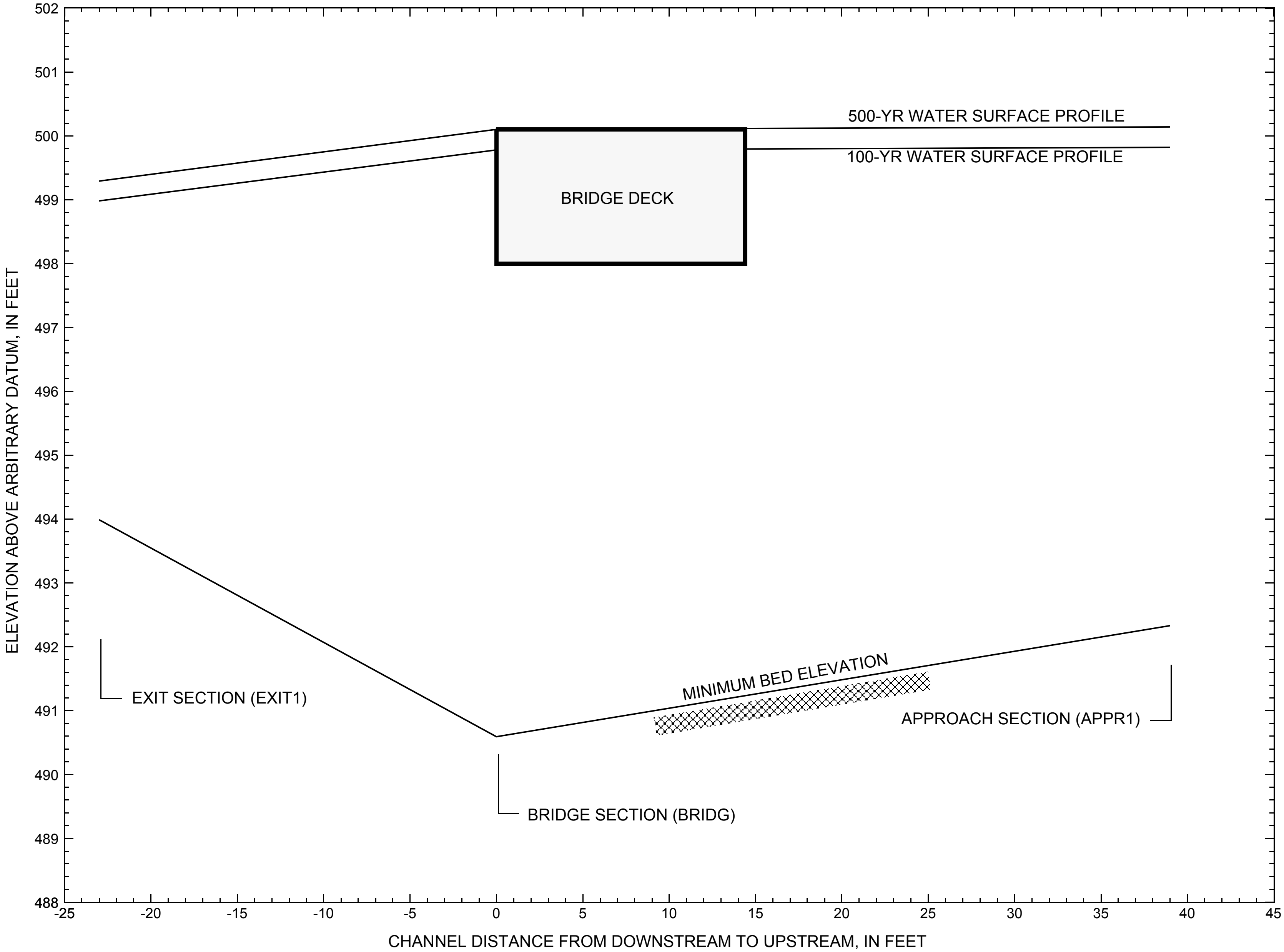

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LOWETH00080039 on Town Highway 8, crossing Potter Brook, Lowell, Vermont.

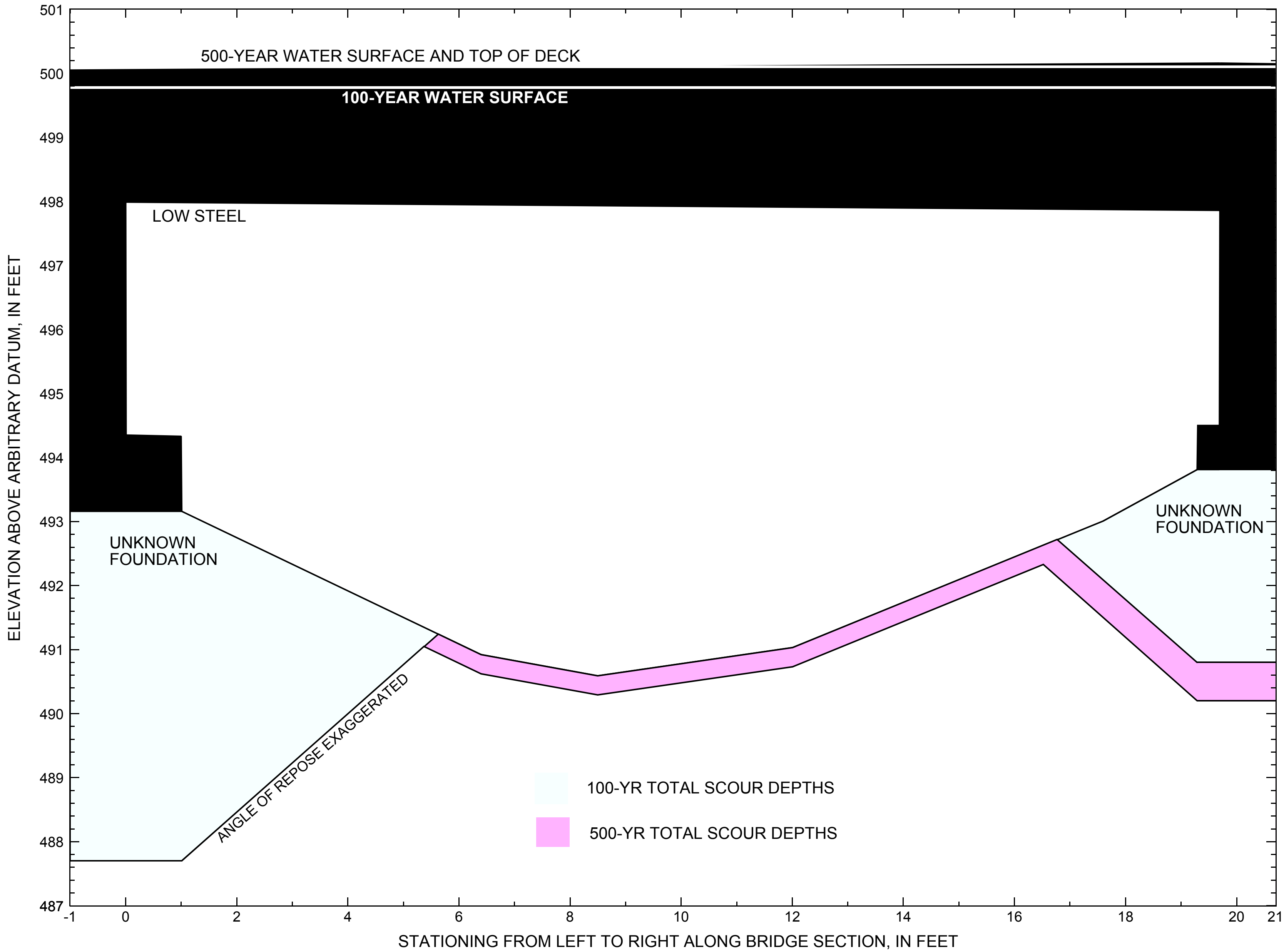

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure LOWETH00080039 on Town Highway 8, crossing Potter Brook, Lowell, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LOWETH00080039 on Town Highway 8, crossing Potter Brook, Lowell, 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 1,070 cubic-feet per second											
Left abutment	0.0	--	498.0	--	493.2	0.0	5.5	--	5.5	487.7	--
Right abutment	19.7	--	497.9	--	493.8	0.0	3.0	--	3.0	490.8	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure LOWETH00080039 on Town Highway 8, crossing Potter Brook, Lowell, 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 1,500 cubic-feet per second											
Left abutment	0.0	--	498.0	--	493.2	0.3	2.2	--	2.5	490.7	--
Right abutment	19.7	--	497.9	--	493.8	0.3	3.3	--	3.6	490.2	--

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

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U.S. Geological Survey, 1986, Lowell, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1981; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File lowe039.wsp
T2        Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
T3        Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
*
J1         * *  0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1070.0   1500.0    590.0
SK          0.0043   0.0043   0.0043
WS          498.96   499.28   498.22
*
XS   EXIT1    -23
GR         -625.0, 506.00   -500.0, 498.83    -58.3, 498.83    -39.5, 498.21
GR          -20.9, 498.49     -8.2, 498.65     -2.3, 497.13     -1.0, 494.68
GR            0.0, 493.99      4.9, 494.82      8.9, 494.46     17.3, 494.71
GR           22.6, 494.38     26.0, 494.70     29.5, 497.24     40.8, 496.86
GR           56.6, 498.17     96.5, 498.28    196.5, 498.28    272.0, 506.00
*
N           0.075        0.040        0.055
SA                  -8.2         29.5
*
XS   FULLV      0  * * * 0.0
*
*             SRD     LSEL
BR   BRIDG     0    497.92
GR            0.0, 497.99      0.0, 494.35      1.0, 494.33      1.0, 493.16
GR            6.4, 490.92      8.5, 490.59     12.0, 491.03     17.6, 493.01
GR           19.3, 493.81     19.3, 494.50     19.7, 494.28     19.7, 497.86
GR            0.0, 497.99
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD          4      16.1      6.3    500.1     58.1
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      14.4     2
GR         -625.0, 506.00   -550.0, 500.69    -95.8, 500.69    -54.0, 500.39
GR            0.0, 500.06     20.1, 500.16     61.5, 499.27    113.6, 498.83
GR          138.9, 499.10    250.0, 499.27    325.0, 506.00
*
AS   APPR1     39
GR         -525.0, 506.00   -450.0, 500.69    -46.8, 499.84    -37.2, 499.64
GR          -19.8, 497.59     -9.7, 498.11     -5.1, 497.21     -1.2, 494.90
GR            0.0, 494.48      7.0, 492.33     10.2, 492.98     17.1, 494.26
GR           22.6, 494.82     25.9, 496.43     33.0, 496.49     40.9, 498.73
GR           57.9, 497.62     79.5, 498.33     89.9, 498.64    250.0, 498.64
GR          325.0, 506.00
*
N           0.100        0.040        0.065
SA                  -5.1         25.9
*
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```
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HP 2 RDWAY 499.78 * * 439
HP 1 APPR1 499.82 1 499.82
HP 2 APPR1 499.82 * * 1070
HP 1 EXIT1 498.98 1 498.98
*
HP 1 BRIDG 497.99 1 497.99
HP 2 BRIDG 497.99 * * 674
HP 2 RDWAY 500.10 * * 819
HP 1 APPR1 500.14 1 500.14
HP 2 APPR1 500.14 * * 1500
HP 1 EXIT1 499.29 1 499.29
*
HP 1 BRIDG 497.99 1 497.99
HP 2 BRIDG 497.99 * * 590
HP 1 APPR1 498.82 1 498.82
HP 2 APPR1 498.82 * * 590
HP 1 EXIT1 498.22 1 498.22
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File lowe039.wsp
Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
Town Highway 8 crossing Potter Brook, Lowell, VT                   EMB
   *** RUN DATE & TIME: 05-23-97  15:34

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

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      117      8892     0     50                              0
497.99           117      8892     0     50  1.00      0     20        0

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

    WSEL     LEW     REW    AREA        K        Q    VEL
  497.99     0.0    19.7   117.5    8892.     634.   5.40

X STA.         0.0         2.3         3.5         4.5         5.4         6.2
  A(I)            10.3         6.7         6.0         5.7         5.3
  V(I)            3.07        4.77        5.28        5.54        5.99

X STA.         6.2         6.9         7.6         8.2         8.9         9.6
  A(I)             5.0         4.9         4.8         4.8         4.8
  V(I)            6.31        6.43        6.56        6.57        6.64

X STA.         9.6        10.2        10.9        11.6        12.4        13.1
  A(I)             4.8         4.8         4.9         5.1         5.2
  V(I)            6.56        6.64        6.42        6.21        6.11

X STA.        13.1        14.0        15.0        16.0        17.4        19.7
  A(I)             5.4         5.8         6.1         6.8        10.1
  V(I)            5.91        5.45        5.17        4.66        3.13

VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

    WSEL     LEW     REW    AREA        K        Q    VEL
  499.78    37.8   255.7   132.3    2568.     439.   3.32

X STA.        37.8        69.0        80.8        90.2        97.8       104.7
  A(I)            10.1         7.4         6.7         6.0         5.8
  V(I)            2.17        2.98        3.30        3.67        3.78

X STA.       104.7       110.9       116.6       122.9       129.7       137.8
  A(I)             5.6         5.3         5.6         5.6         5.9
  V(I)            3.92        4.13        3.94        3.92        3.71

X STA.       137.8       147.0       156.6       166.4       176.8       187.7
  A(I)             6.2         6.3         6.4         6.5         6.7
  V(I)            3.52        3.48        3.46        3.36        3.28

X STA.       187.7       198.9       210.9       223.7       236.8       255.7
  A(I)             6.7         6.9         7.1         7.1         8.3
  V(I)            3.28        3.16        3.07        3.09        2.64

CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1       52       896    41     41                            329
          2      174     19855    31     33                           2346
          3      319      8927   236    237                           2104
499.82           545     29678   308    310  3.01    -45    262     2372

VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

    WSEL     LEW     REW    AREA        K        Q    VEL
  499.82   -45.8   262.0   544.9   29678.    1070.   1.96

X STA.       -45.8        -2.7         0.5         2.7         4.7         6.4
  A(I)            59.7        15.4        13.1        12.6        11.8
  V(I)            0.90        3.48        4.07        4.24        4.54

X STA.         6.4         7.9         9.5        11.1        12.9        14.9
  A(I)            11.1        11.4        11.3        11.9        12.0
  V(I)            4.82        4.69        4.73        4.49        4.46

X STA.        14.9        17.1        19.5        22.1        26.0        38.7
  A(I)            12.7        13.2        13.5        16.7        37.7
  V(I)            4.20        4.06        3.97        3.20        1.42

X STA.        38.7        65.7       103.9       153.9       202.2       262.0
  A(I)            47.2        54.2        58.9        57.0        63.5
  V(I)            1.13        0.99        0.91        0.94        0.84
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     U.S. Geological Survey WSPRO Input File lowe039.wsp
     Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
     Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
        *** RUN DATE & TIME: 05-23-97  15:34

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

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      117      8892     0     50                              0
 497.99          117      8892     0     50  1.00      0     20        0

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    497.99     0.0    19.7   117.5    8892.     674.   5.74

X STA.        0.0        2.3        3.5        4.5        5.4        6.2
  A(I)           10.3        6.7        6.0        5.7        5.3
  V(I)           3.26       5.07       5.61       5.89       6.37

X STA.        6.2        6.9        7.6        8.2        8.9        9.6
  A(I)            5.0        4.9        4.8        4.8        4.8
  V(I)           6.70       6.84       6.97       6.99       7.06

X STA.        9.6       10.2       10.9       11.6       12.4       13.1
  A(I)            4.8        4.8        4.9        5.1        5.2
  V(I)           6.97       7.06       6.83       6.60       6.50

X STA.       13.1       14.0       15.0       16.0       17.4       19.7
  A(I)            5.4        5.8        6.1        6.8       10.1
  V(I)           6.28       5.79       5.50       4.95       3.32

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.10    -6.5   259.2   205.2    5128.     819.   3.99

X STA.       -6.5       61.4       74.4       84.8       94.0      102.1
  A(I)           16.2       11.5       10.2        9.8        9.2
  V(I)           2.52       3.55       4.01       4.18       4.46

X STA.      102.1      109.5      116.4      123.7      131.7      140.9
  A(I)            8.9        8.6        8.7        9.0        9.4
  V(I)           4.58       4.76       4.68       4.53       4.34

X STA.      140.9      150.5      160.5      170.8      181.2      191.9
  A(I)            9.6        9.7        9.9        9.8       10.0
  V(I)           4.29       4.22       4.16       4.18       4.10

X STA.      191.9      203.1      214.6      226.7      239.4      259.2
  A(I)           10.2       10.3       10.6       10.9       12.7
  V(I)           4.02       3.98       3.88       3.77       3.21

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1       86       775   184    184                            335
          2      184     21774    31     33                           2549
          3      395     12634   239    240                           2880
 500.14          666     35183   454    457  3.23   -188    265     2545

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.14  -189.1   265.3   665.6   35183.    1500.   2.25

X STA.     -189.1       -2.0        1.1        3.4        5.4        7.2
  A(I)           98.4       16.7       14.7       14.2       13.1
  V(I)           0.76       4.50       5.12       5.27       5.72

X STA.        7.2        8.8       10.6       12.6       14.7       17.1
  A(I)           12.7       13.1       13.5       13.7       14.5
  V(I)           5.92       5.73       5.54       5.47       5.16

X STA.       17.1       19.6       22.5       27.6       43.0       65.9
  A(I)           14.7       15.8       21.7       42.9       49.4
  V(I)           5.12       4.74       3.45       1.75       1.52

X STA.       65.9       95.2      134.7      173.9      213.9      265.3
  A(I)           52.8       59.3       58.8       60.0       65.6
  V(I)           1.42       1.27       1.28       1.25       1.14
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       U.S. Geological Survey WSPRO Input File lowe039.wsp
       Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
       Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
          *** RUN DATE & TIME: 05-23-97  15:34

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

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      117      8892     0     50                            0
  497.99           117      8892     0     50  1.00      0     20        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.99     0.0    19.7   117.5    8892.     590.   5.02

X STA.        0.0        2.3        3.5        4.5        5.4        6.2
  A(I)           10.3        6.7        6.0        5.7        5.3
  V(I)           2.85       4.43       4.91       5.16       5.57

X STA.        6.2        6.9        7.6        8.2        8.9        9.6
  A(I)            5.0        4.9        4.8        4.8        4.8
  V(I)           5.87       5.99       6.10       6.12       6.18

X STA.        9.6       10.2       10.9       11.6       12.4       13.1
  A(I)            4.8        4.8        4.9        5.1        5.2
  V(I)           6.10       6.18       5.98       5.78       5.69

X STA.       13.1       14.0       15.0       16.0       17.4       19.7
  A(I)            5.4        5.8        6.1        6.8       10.1
  V(I)           5.50       5.07       4.81       4.34       2.91

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1       22       289    25     25                          113
            2      143     14327    31     33                         1749
            3       88      1075   226    226                          312
  498.82           253     15690   282    284  2.37    -29    252      882

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      39.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.82   -30.2   251.8   252.9   15690.     590.   2.33

X STA.      -30.2       -1.9        0.4        2.2        3.6        4.9
  A(I)           29.7        9.3        8.5        7.5        7.3
  V(I)           0.99       3.16       3.47       3.91       4.03

X STA.        4.9        6.1        7.1        8.2        9.3       10.4
  A(I)            7.0        6.6        6.7        6.7        6.7
  V(I)           4.24       4.44       4.43       4.39       4.42

X STA.       10.4       11.6       12.9       14.3       15.8       17.5
  A(I)            6.9        7.0        7.3        7.5        7.9
  V(I)           4.29       4.20       4.05       3.92       3.75

X STA.       17.5       19.3       21.3       23.5       32.1      251.8
  A(I)            8.0        8.3        8.9       21.7       73.4
  V(I)           3.68       3.56       3.31       1.36       0.40
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        U.S. Geological Survey WSPRO Input File lowe039.wsp
        Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
        Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
           *** RUN DATE & TIME: 05-23-97  15:34

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

EXIT1:XS   ******   -502      384  0.37 *****  499.36  498.74    1070  498.98
       -22 ******    203    16304  3.08 ***** *******    1.17    2.79

FULLV:FV       23   -506      546  0.21  0.08  499.43 *******    1070  499.21
         0     23    206    20960  3.56  0.00   -0.01    0.75    1.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       39    -33      370  0.38  0.10  499.61 *******    1070  499.23
        39     39    256    20591  2.93  0.08    0.00    0.77    2.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   499.21     497.92

            <<<<<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       23      0      117  0.45 *****  498.44  495.14     634  497.99
         0 ******     20     8892  1.00 ***** *******    0.39    5.40

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****    6.  0.800  0.000  497.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    25.  0.03  0.18  499.97    0.00    439.  499.78

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    93.   -83.    10.   0.5   0.3   3.4   4.9   0.7   2.8
   RT:   439.   218.    38.   256.   1.0   0.6   3.8   3.3   0.8   2.8

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

APPR1:AS       23    -45      546  0.18  0.08  500.00  497.60    1070  499.82
        39     30    262    29729  3.01  0.00    0.00    0.45    1.96

       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
   EXIT1:XS     -23.  -503.   203.   1070.   16304.     384.    2.79  498.98
   FULLV:FV       0.  -507.   206.   1070.   20960.     546.    1.96  499.21
   BRIDG:BR       0.     0.    20.    634.    8892.     117.    5.40  497.99
   RDWAY:RG       8.*******     0.    439.       0.*********    2.00  499.78
   APPR1:AS      39.   -46.   262.   1070.   29729.     546.    1.96  499.82

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT1:XS    498.74    1.17  493.99  506.00************  0.37  499.36  498.98
   FULLV:FV  ********    0.75  493.99  506.00  0.08  0.00  0.21  499.43  499.21
   BRIDG:BR    495.14    0.39  490.59  497.99************  0.45  498.44  497.99
   RDWAY:RG  ****************  498.83  506.00  0.03******  0.18  499.97  499.78
   APPR1:AS    497.60    0.45  492.33  506.00  0.08  0.00  0.18  500.00  499.82
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        U.S. Geological Survey WSPRO Input File lowe039.wsp
        Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
        Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
           *** RUN DATE & TIME: 05-23-97  15:34

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

EXIT1:XS   ******   -507      603  0.35 *****  499.64  499.21    1500  499.29
       -22 ******    206    22857  3.59 ***** *******    0.90    2.49

FULLV:FV       23   -510      737  0.23  0.08  499.71 *******    1500  499.48
         0     23    208    27753  3.49  0.00   -0.02    0.66    2.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.88     499.43     499.24

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.98     506.00    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.98     506.00     499.24

APPR1:AS       39    -34      427  0.58  0.14  500.00  499.24    1500  499.43
        39     39    258    23367  3.00  0.18   -0.01    0.89    3.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   499.48     497.92

            <<<<<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       23      0      117  0.51 *****  498.50  495.28     674  497.99
         0 ******     20     8892  1.00 ***** *******    0.41    5.74

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  497.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    25.  0.04  0.25  500.35    0.00    819.  500.10

            Q    WLEN    LEW    REW   DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      5.    14.    -6.     8.    0.0   0.0   2.0  19.5   0.3   2.6
   RT:    814.   236.    23.   259.    1.3   0.9   4.6   4.0   1.1   2.9

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

APPR1:AS       23   -189      667  0.25  0.12  500.40  499.24    1500  500.14
        39     31    265    35222  3.23  0.00    0.00    0.59    2.25

       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
   EXIT1:XS     -23.  -508.   206.   1500.   22857.     603.    2.49  499.29
   FULLV:FV       0.  -511.   208.   1500.   27753.     737.    2.04  499.48
   BRIDG:BR       0.     0.    20.    674.    8892.     117.    5.74  497.99
   RDWAY:RG       8.*******     5.    819.       0.*********    2.00  500.10
   APPR1:AS      39.  -190.   265.   1500.   35222.     667.    2.25  500.14

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  **********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD     EGL    WSEL
   EXIT1:XS    499.21    0.90  493.99  506.00************  0.35  499.64  499.29
   FULLV:FV  ********    0.66  493.99  506.00  0.08  0.00  0.23  499.71  499.48
   BRIDG:BR    495.28    0.41  490.59  497.99************  0.51  498.50  497.99
   RDWAY:RG  ****************  498.83  506.00  0.04******  0.25  500.35  500.10
   APPR1:AS    499.24    0.59  492.33  506.00  0.12  0.00  0.25  500.40  500.14
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        U.S. Geological Survey WSPRO Input File lowe039.wsp
        Hydraulic analysis for structure LOWETH00080039   Date: 08-MAY-97
        Town Highway 8 crossing Potter Brook, Lowell, VT                  EMB
           *** RUN DATE & TIME: 05-23-97  15:34

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

EXIT1:XS   ******    -39      138  0.37 *****  498.59  496.96     590  498.22
       -22 ******     75     8989  1.28 ***** *******    0.66    4.29

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.97     498.35     496.96

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   497.72     506.00    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   497.72     506.00     496.96

FULLV:FV       23    -43      157  0.35  0.09  498.69  496.96     590  498.34
         0     23    197     9429  1.57  0.00    0.01    0.98    3.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPR1"     KRATIO =  1.48

APPR1:AS       39    -27      192  0.24  0.10  498.79 *******     590  498.55
        39     39     87    13917  1.64  0.00    0.00    0.53    3.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   498.34     497.92

            <<<<<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       23      0      117  0.40 *****  498.39  495.01     593  497.99
         0 ******     20     8892  1.00 ***** *******    0.36    5.05

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   3.  0.800  0.000  497.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       23    -29      253  0.20  0.06  499.02  496.38     590  498.82
        39     25    252    15708  2.38  0.00    0.00    0.67    2.33

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.79

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -23.   -40.    75.    590.    8989.     138.    4.29  498.22
   FULLV:FV       0.   -44.   197.    590.    9429.     157.    3.77  498.34
   BRIDG:BR       0.     0.    20.    593.    8892.     117.    5.05  497.99
   RDWAY:RG       8.**************      0.       0.*********    2.00********
   APPR1:AS      39.   -30.   252.    590.   15708.     253.    2.33  498.82

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  **********************

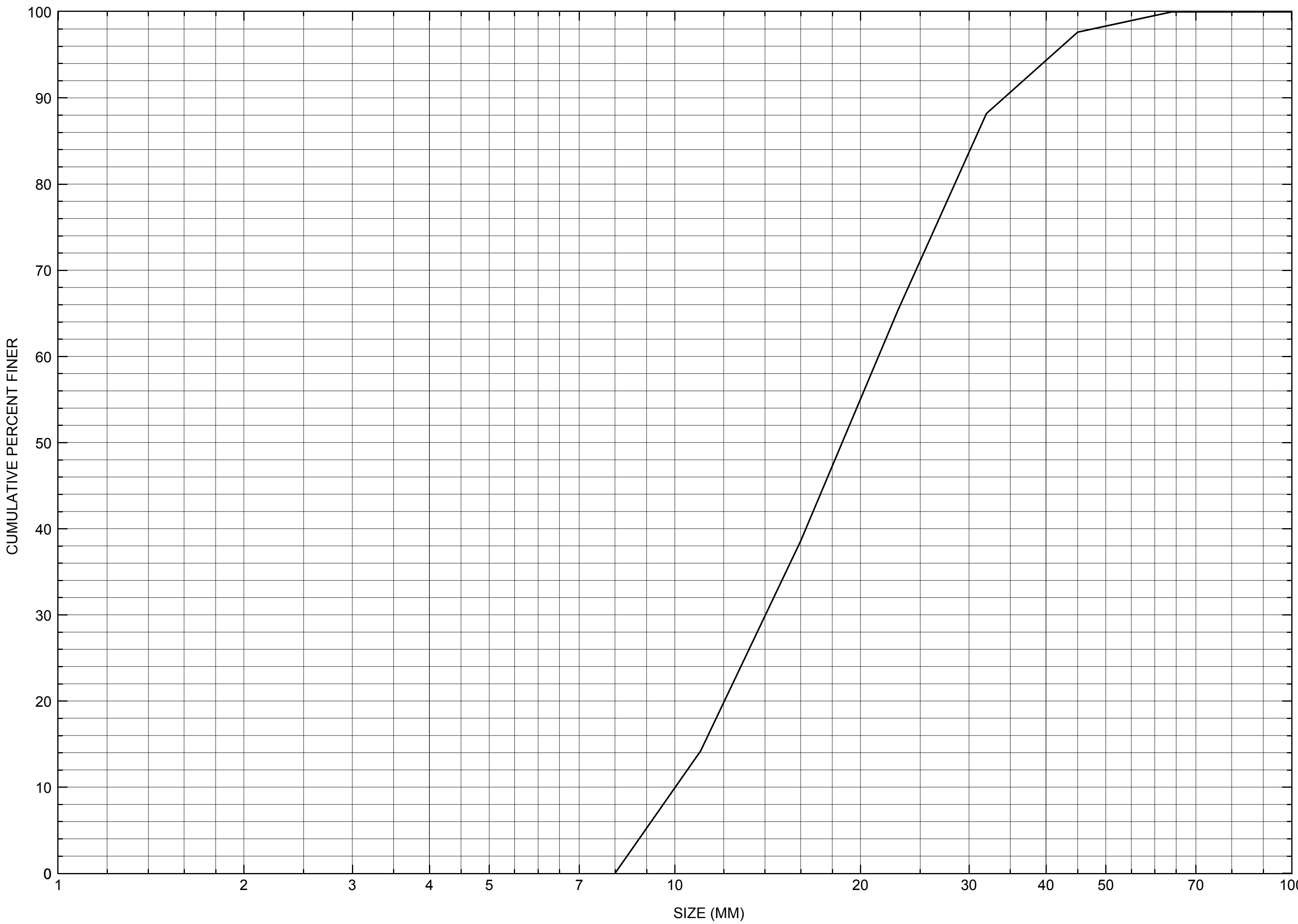
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    496.96    0.66  493.99  506.00************  0.37  498.59  498.22
   FULLV:FV    496.96    0.98  493.99  506.00  0.09  0.00  0.35  498.69  498.34
   BRIDG:BR    495.01    0.36  490.59  497.99************  0.40  498.39  497.99
   RDWAY:RG  ****************  498.83  506.00************  0.11  499.39********
   APPR1:AS    496.38    0.67  492.33  506.00  0.06  0.00  0.20  499.02  498.82
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LOWETH00080039, in Lowell, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LOWETH00080039

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 40525

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

Waterway *(I - 6)* POTTER BROOK

Road Name *(I - 7):* -

Route Number TH 8

Vicinity *(I - 9)* 0.1 MI TO JCT W CL2 TH3

Topographic Map Lowell

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44474

Longitude *(i - 17; nnnnn.n)* 72296

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101300391013

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

Maximum span length *(I - 48; nnnn)* 0021

Year built *(I - 27; YYYY)* 1958

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 144

Year of ADT *(I - 30; YY)* 94

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 20.0

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

Vertical clearance from streambed (*nnn.n ft*) 3.5

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

Waterway of full opening (*nnn.n* ft^2) 70.0

Comments:

The structural inspection report of 6/1/93 indicates the structure is a steel stringer type bridge with a timber deck. Both abutment walls have only minor concrete spalling reported. The left abutment footing is exposed such that the adjacent streambed level is up to 1.5 feet below the top of the footing, with no apparent undermining. The waterway takes a moderate to sharp turn just upstream. Some minor bank erosion is reported upstream from the end of the left abutment. There is a shallow, silty sand point bar in front of right abutment. The wingwalls are noted as leaning forward slightly. There is no stone fill protection reported at this site. The streambed material consists of mostly silt and clay with some sand.

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: **Mainly silt and clay with some sand**

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*): -   Frequency: -

Relief Elevation (*ft*): -   Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): - *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 (*ft²*): -

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)* **4.69** mi^2 Lake/pond/swamp area **0.06** mi^2

Watershed storage *(ST)* **1.2** %

Bridge site elevation **1190** ft Headwater elevation **3196** ft

Main channel length **3.96** mi

10% channel length elevation **1202** ft 85% channel length elevation **2382** ft

Main channel slope *(S)* **397.64** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: NO CROSS SECTION INFORMATION

-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low 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*)? NO

Comments: CROSS SECTION INFORMATION

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 4/9/96
Computerized by: RB Date: 4/12/96
Reviewd by: EMB Date: 5/27/97

Structure Number LOWETH00080039

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 6 / 15 / 1995

2. Highway District Number 09 Mile marker 000

County ORLEANS (019) Town LOWELL (40525)

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

Route Number TH 8 Hydrologic Unit Code: 02010007

3. Descriptive comments:

This site is located 0.1 mile from the intersection of TH 8 with TH 3.

B. Bridge Deck Observations

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

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

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

7. Bridge length 23 *(feet)* Span length 21 *(feet)* Bridge width 14.4 *(feet)*

Road approach to bridge:

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

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

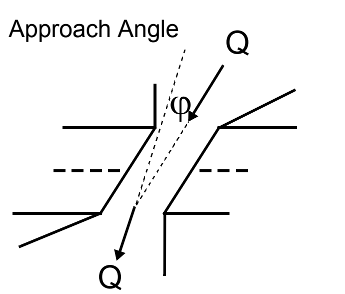
10. Embankment slope (*run / rise in feet / foot*):
US left 8.1:1 US right 4.5:1

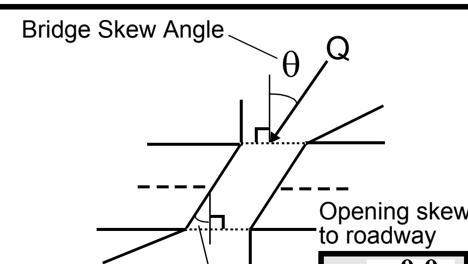
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	2	1	2	1
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 25 16. Bridge skew: 20





α= 0.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 30 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

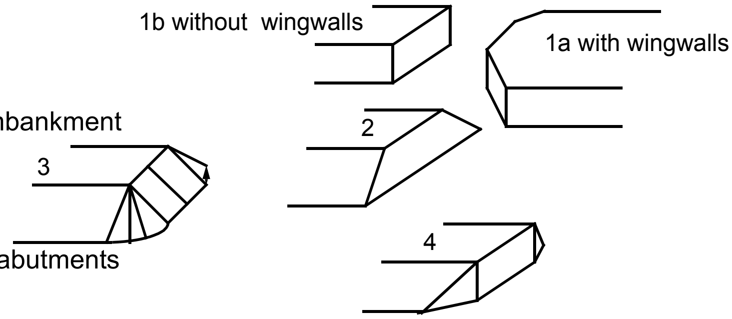
1a- Vertical abutments with wingwalls

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.)

The impact zone on the upstream left bank is complicated by a small confluence.
The road approach protection on the upstream right bank consists of only 2 boulders.
The bridge dimensions measured in the field were the same as the historical values shown on the previous page.

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
25.0	2.5			1.5	2	1	23	23	2	1

23. Bank width 25.0 24. Channel width 25.0 25. Thalweg depth 31.0 29. Bed Material 32

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.):

The bank protection on the left bank may be material left after the erosion of the top soil.
There is a minor inflow on the left bank. Since the bridge and the roadway constrict flow through the bordering low lands, there are many dry channels on both banks spilling into the main channel just before the bridge.

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? **LB** (LB or RB)

41. Mid-bank distance: **15** 42. Cut bank extent: **30** feet **US** (US, UB) to **0** feet **UB** (US, UB, DS)

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

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

-

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

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

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

NO CHANNEL SCOUR

The middle of the scour hole is under the bridge and it is described in the under bridge channel assessment section.

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

The minor inflow on the left bank is not presently flowing.

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
22.5		**2.5**		**2**	**7**	**7**	**0**

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

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

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

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

05

Some boulders are at the US end of the scour hole. Twigs and leaves have accumulated along the abutments below the water surface.

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

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

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

70. Debris and Ice Comments:

2

The bridge constricts and the low chord is not very high so at high flows debris and ice will get caught. There are some twigs caught in the I-beams.

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		**20**	**90**	**2**	**3**	**2**	**2**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**2**	**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

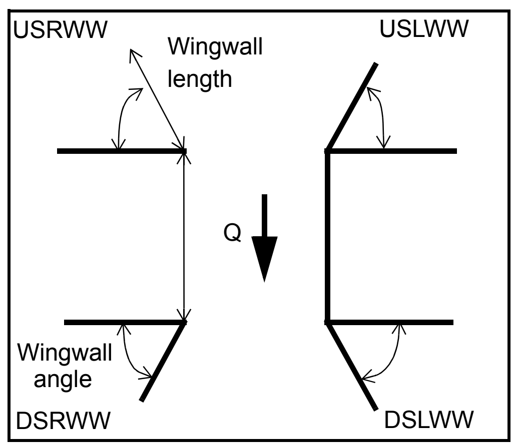
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
1
1

There is a scour hole that is continuous from 30 feet US of the bridge to 10 feet DS of the bridge. The bridge constricts the main channel flow upstream where several tributaries enter. The hole is 60 feet long, 16 feet wide, and the maximum depth is 3 feet below the average thalweg depth elsewhere in the reach.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**19.5**	
USRWW:	**Y**		**1**		**2**	**4.5**	
DSLWW:	**0**		**1**		**Y**	**16.0**	
DSRWW:	**1**		**0**		**0**	**16.0**	



*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**	**0**	**-**	**-**	**-**	**-**
Condition	**Y**	**0**	**1**	**-**	**-**	**-**	**-**	**-**
Extent	**1**	**0.2**	**0**	**0**	**0**	**0**	**0**	**-**

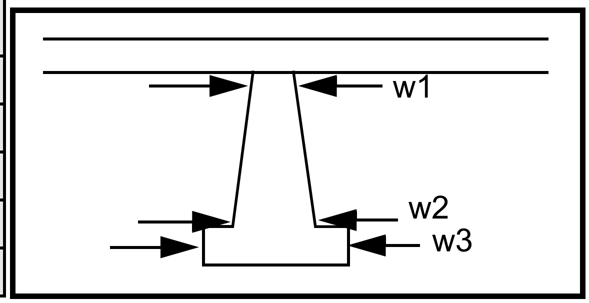
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length; **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? **Th** *(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				**60.0**	**10.5**	**60.0**
Pier 2			**6.0**	**10.5**	**40.0**	**40.0**
Pier 3	**8.5**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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.):
-
-
-
-
-
NO PIERS

101. Is a drop structure present? **1** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
2
2
2
2
32
0

106. Point/Side bar present? 0 (Y or N. if N type ctrl-n pb) Mid-bar distance: - Mid-bar width: -

Point bar extent: The feet hig (US, UB, DS) to h feet vel (US, UB, DS) positioned oci %LB to ty %RB

Material: of

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

water going through the bridge opening has transported a large quantity of gravel, which deposited DS of the bridge creating a short section of "braided" stream.

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

Cut bank extent: ____ 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.):

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

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

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

Confluence comments (eg. confluence name):

-

-

F. Geomorphic Channel Assessment

107. Stage of reach evolution -

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

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

-

NO POINT BARS

Y
LB
22.5
5
DS
40
DS
1

109. G. Plan View Sketch

- T

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: LOWETH00080039 Town: Lowell
Road Number: TH 8 County: Orleans
Stream: Potter Brook

Initials EMB Date: 5/27/97 Checked: SAO 6/2/97

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	1070	1500	590
Main Channel Area, ft2	174	184	143
Left overbank area, ft2	52	86	22
Right overbank area, ft2	319	395	88
Top width main channel, ft	31	31	31
Top width L overbank, ft	41	184	25
Top width R overbank, ft	236	239	226
D50 of channel, ft	0.0613	0.0613	0.0613
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.6	5.9	4.6
y1, average depth, LOB, ft	1.3	0.5	0.9
y1, average depth, ROB, ft	1.4	1.7	0.4
Total conveyance, approach	29678	35183	15690
Conveyance, main channel	19855	21774	14327
Conveyance, LOB	896	775	289
Conveyance, ROB	8927	12634	1075
Percent discrepancy, conveyance	0.0000	0.0000	-0.0064
Qm, discharge, MC, cfs	715.8	928.3	538.7
Ql, discharge, LOB, cfs	32.3	33.0	10.9
Qr, discharge, ROB, cfs	321.9	538.6	40.4
Vm, mean velocity MC, ft/s	4.1	5.0	3.8
Vl, mean velocity, LOB, ft/s	0.6	0.4	0.5
Vr, mean velocity, ROB, ft/s	1.0	1.4	0.5
Vc-m, crit. velocity, MC, ft/s	5.9	5.9	5.7
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

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	634	674	590
Main channel area (DS), ft2	117.5	117.5	117.5
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.7	19.7	19.7
D90, ft	0.1121	0.1121	0.1121
D95, ft	0.1342	0.1342	0.1342
Dc, critical grain size, ft	0.0700	0.0792	0.0607
Pc, Decimal percent coarser than Dc	0.402	0.313	0.507
Depth to armoring, ft	0.31	0.52	0.18

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	1070	1500	590
(Q) discharge thru bridge, cfs	634	674	590
Main channel conveyance	8892	8892	8892
Total conveyance	8892	8892	8892
Q2, bridge MC discharge,cfs	634	674	590
Main channel area, ft2	118	118	118
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.7	19.7	19.7
y_bridge (avg. depth at br.), ft	5.96	5.96	5.96
Dm, median (1.25*D50), ft	0.076625	0.076625	0.076625
y2, depth in contraction,ft	5.05	5.33	4.75
ys, scour depth (y2-ybridge), ft	-0.91	-0.64	-1.21

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	1070	1500	590
Q, thru bridge MC, cfs	634	674	590
Vc, critical velocity, ft/s	5.89	5.95	5.70
Va, velocity MC approach, ft/s	4.11	5.05	3.77
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.7	19.7	19.7
qbr, unit discharge, ft2/s	32.2	34.2	29.9
Area of full opening, ft2	117.5	117.5	117.5
Hb, depth of full opening, ft	5.96	5.96	5.96
Fr, Froude number, bridge MC	0.39	0.41	0.36
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.97
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	497.92	497.92	497.92
Elevation of Bed, ft	491.96	491.96	491.96
Elevation of Approach, ft	499.82	500.14	498.82
Friction loss, approach, ft	0.08	0.12	0.06
Elevation of WS immediately US, ft	499.74	500.02	498.76
ya, depth immediately US, ft	7.78	8.06	6.80
Mean elevation of deck, ft	500.1	500.1	500.1
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.93	0.92	0.97
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	-0.11	0.26	-0.35
Ys, scour w/Umbrell equation, ft	0.94	2.08	-0.12

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

**Ys, scour w/Chang equation, ft	N/A	N/A	N/A
**Ys, scour w/Umbrell equation, ft	N/A	N/A	N/A

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	5.05	5.33	4.75
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), 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	1070	1500	590	1070	1500	590
a', abut.length blocking flow, ft	45.8	189.1	30.2	242.3	245.6	232.1
Ae, area of blocked flow ft2	72.7	107.2	37.4	215.4	225	110.6
Qe, discharge blocked abut.,cfs	98.6	--	53.9	--	--	112.1
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.36	1.13	1.44	1.22	1.58	1.01
ya, depth of f/p flow, ft	1.59	0.57	1.24	0.89	0.92	0.48
--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	0.190	0.262	0.228	0.179	0.211	0.259
ys, scour depth, ft	6.14	6.24	4.93	7.35	8.22	6.04

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)	45.8	189.1	30.2	242.3	245.6	232.1
y1 (depth f/p flow, ft)	1.59	0.57	1.24	0.89	0.92	0.48
a'/y1	28.85	333.57	24.39	272.56	268.09	487.07
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.26	0.23	0.18	0.21	0.26
Ys w/ corr. factor K1/0.55:						
vertical	6.67	2.65	ERR	3.66	3.99	2.22
vertical w/ ww's	5.47	2.17	ERR	3.00	3.27	1.82
spill-through	3.67	1.46	ERR	2.02	2.19	1.22

The ratio of a'/y1 was set to 25.00 from 24.39 to force computation of abutment scour for the incipient discharge at the left abutment.

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	0.39	0.41	0.36	0.39	0.41	0.36
y, depth of flow in bridge, ft	5.96	5.96	5.96	5.96	5.96	5.96
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.56	0.62	0.48	0.56	0.62	0.48
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR