LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (BARTTH00080037) on TOWN HIGHWAY 8, crossing the WILLOUGHBY RIVER, BARTON, VERMONT

U.S. Geological Survey
Open-File Report 96-405

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (BARTTH00080037) on TOWN HIGHWAY 8, crossing the WILLOUGHBY RIVER, BARTON, VERMONT

By JOSEPH D. AYOTTE and ERICK M. BOEHMLER

U.S. Geological Survey
Open-File Report 96-405

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

Pembroke, New Hampshire

1996

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

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

For additional information
write to:

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

Copies of this report may be
purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Federal Center
Denver, CO 80225

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (BARTTH00080037) ON TOWN HIGHWAY 8, CROSSING THE WILLOUGHBY RIVER, BARTON, VERMONT

By **Joseph D. Ayotte and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BARTTH00080037 on town highway 8 crossing the Willoughby River, Barton, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province of north-central Vermont in the town of Barton. The 60.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have sparse to moderate woody vegetation coverage.

In the study area, the Willoughby River is probably incised, has a sinuous channel with a slope of approximately 0.009 ft/ft, an average channel top width of 108 ft and an average channel depth of 6 ft. The predominant channel bed material is cobble (D_{50} is 95.1 mm or 0.312 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 20, 1994, indicated that the reach was stable.

The town highway 8 crossing of the Willoughby River is a 96-ft-long, two-lane bridge consisting of one 94-foot steel-beam span (Vermont Agency of Transportation, written communication, August 4, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 10 degrees.

No scour was reported in the channel or along abutments or wingwalls during the Level I assessment. Type-2 stone fill (less than 24 inches diameter) was reported at each abutment and all four wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. Data in appendix D (Vermont Agency of Transportation, written communication, August 4, 1994) indicate that the right abutment may be founded on or near marble bedrock which may limit scour depths. Bedrock was not detected by borings in the vicinity of the left abutment. The scour analysis results are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for all modelled flows was 0 ft. Abutment scour ranged from 7.3 to 10.7 ft and the worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, 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.

Orleans, VT. Quadrangle, 1:24,000, 1986
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 BARTTH00080037 ***Stream*** Willoughby River

County Orleans ***Road*** TH034 ***District*** 04

Description of Bridge

Bridge length 96 ***ft*** ***Bridge width*** 25.4 ***ft*** ***Max span length*** 94 ***ft***

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

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 10/20/94

Description of stone fill Type-2, around both abutments and all four wingwalls, in good condition.

Brief description of piers/abutments Abutments and wingwalls are concrete.

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

Is there a channel bend in the upstream reach? If so, describe (mild, moderate, severe) There is a mild channel bend in the upstream reach.

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	10/20/94	0	0
Level II	10/20/94	--	--

Potential for debris Moderate. There is a source of debris from trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 11/08/94.

Description of the Geomorphic Setting

General topography The channel is located at a constriction in the Willoughby R near a major bend in the river.

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

Date of inspection 10/20/94

DS left: Narrow terrace to steep valley wall

DS right: Moderate flood plain to steep valley wall

US left: Narrow flood plain to steep valley wall

US right: Moderate flood plain to steep valley wall

Description of the Channel

Average top width 108 ***ft*** ***Average depth*** 6 ***ft***

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

Sinuous but stable with semi-alluvial to non-alluvial channel boundaries and a narrow flood plain.

10/20/94

Vegetative co Trees and brush and Vt. Rte 58

DS left: Trees and brush

DS right: Trees and brush and Vt. Rte 58

US left: Trees and brush

US right: Y

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

11/8/95 none.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 60.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization:*** None. There are a couple houses on the upstream left overbank area beyond Vt. Rte. 58.

Is there a USGS gage on the stream of interest? N

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p N

Calculated Discharges

Q100 3,830 ***ft³/s*** ***Q500*** 5,600 ***ft³/s***

The 100- and 500-year discharges were selected from a range of discharge values computed by several empirical relationships (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; Talbot, 1887). Because of the wide range of values resulting from the empirical relationships, a median value was selected for each discharge.

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 Add 308 to USGS survey to obtain VTAOT plans' datum (to the nearest foot).

Description of reference marks used to determine USGS datum. RM1 is brass tablet on top of the US end of the left abutment and wingwall joint (elev. 498.23 ft, arbitrary datum). RM2 is a chiseled X on top of the DS end of the right abutment and wingwall joint (elev. 500.59 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[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 analysis reported herein reflects 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 0.054 to 0.056, and overbank "n" values ranged from 0.025 to 0.100.

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 0.0085 ft/ft which was estimated from the slope between common EXITX and BRIDG cross section points.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.00513 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.5 *ft*
Average low steel elevation 495.0 *ft*

100-year discharge 3,830 *ft³/s*
Water-surface elevation in bridge opening 493.1 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 412 *ft²*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 11.3 *ft/s*

Water-surface elevation at Approach section with bridge 495.2 *ft*
Water-surface elevation at Approach section without bridge 494.4 *ft*
Amount of backwater caused by bridge 0.8 *ft*

500-year discharge 5,600 *ft³/s*
Water-surface elevation in bridge opening 495.8 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 579 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.1 *ft/s*

Water-surface elevation at Approach section with bridge 498.3 *ft*
Water-surface elevation at Approach section without bridge 495.6 *ft*
Amount of backwater caused by bridge 2.7 *ft*

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

Water-surface elevation at Approach section with bridge ____ *ft*
Water-surface elevation at Approach section without bridge ____ *ft*
Amount of backwater caused by bridge ____ *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, 1993). 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.

The 500-year discharge resulted in unsubmerged orifice flow. Contraction socur 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). Therefore, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18) for the 100-year discharge. For contraction scour computations using the Laursen's equation, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F. In this case, neither discharge resulted in reportable contraction scour.

Abutment scour for the both abutments at all modelled discharges was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	3.7	3.1	--
Left overbank	--	--	--
Right overbank	--	--	

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	8.0	10.3	-- 7.3
Left abutment	10.7	--	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.6
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.8	--	1.6
Left abutment	1.8	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

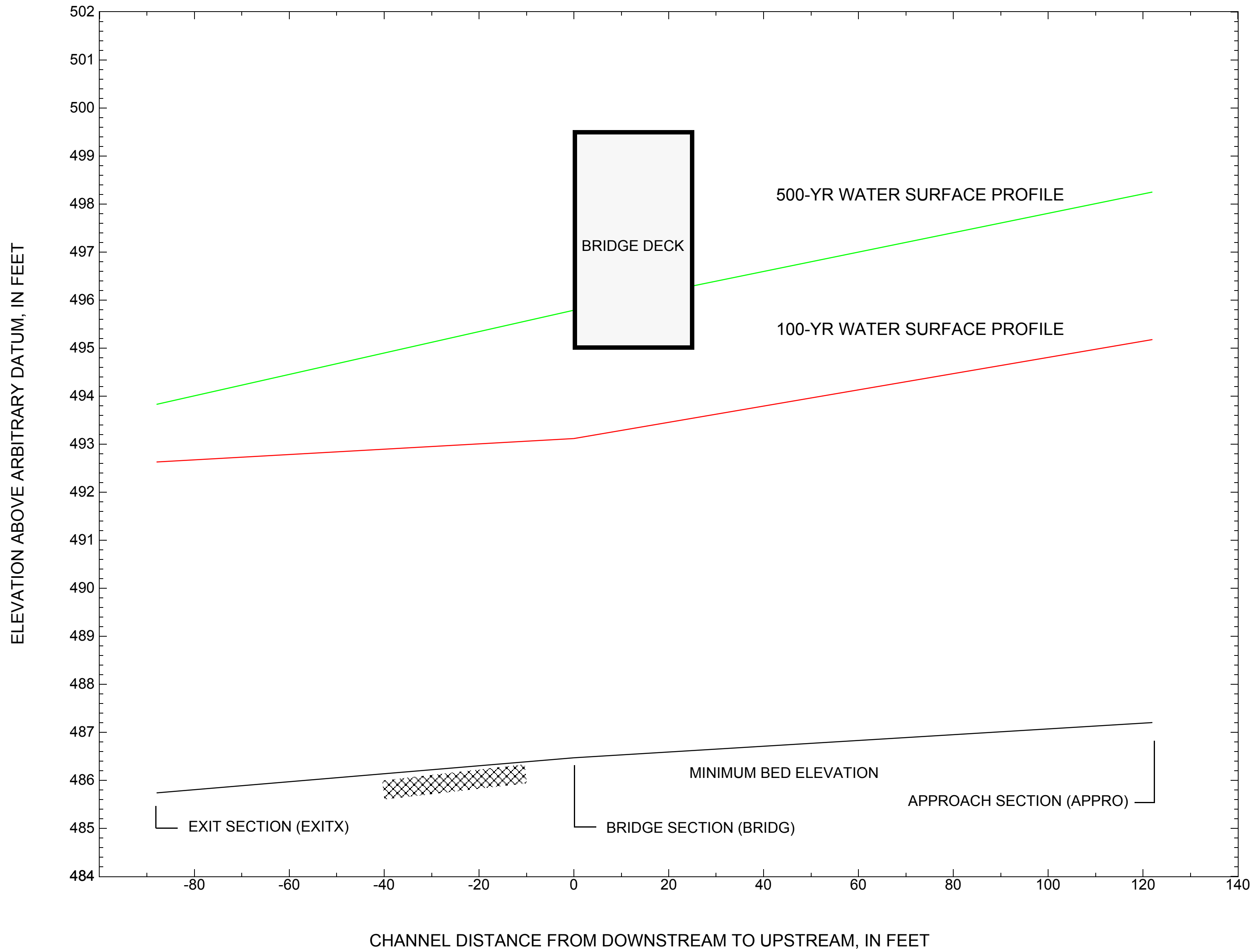


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BARTTH00080037 on town highway 8, crossing Willoughby River, Barton, Vermont.

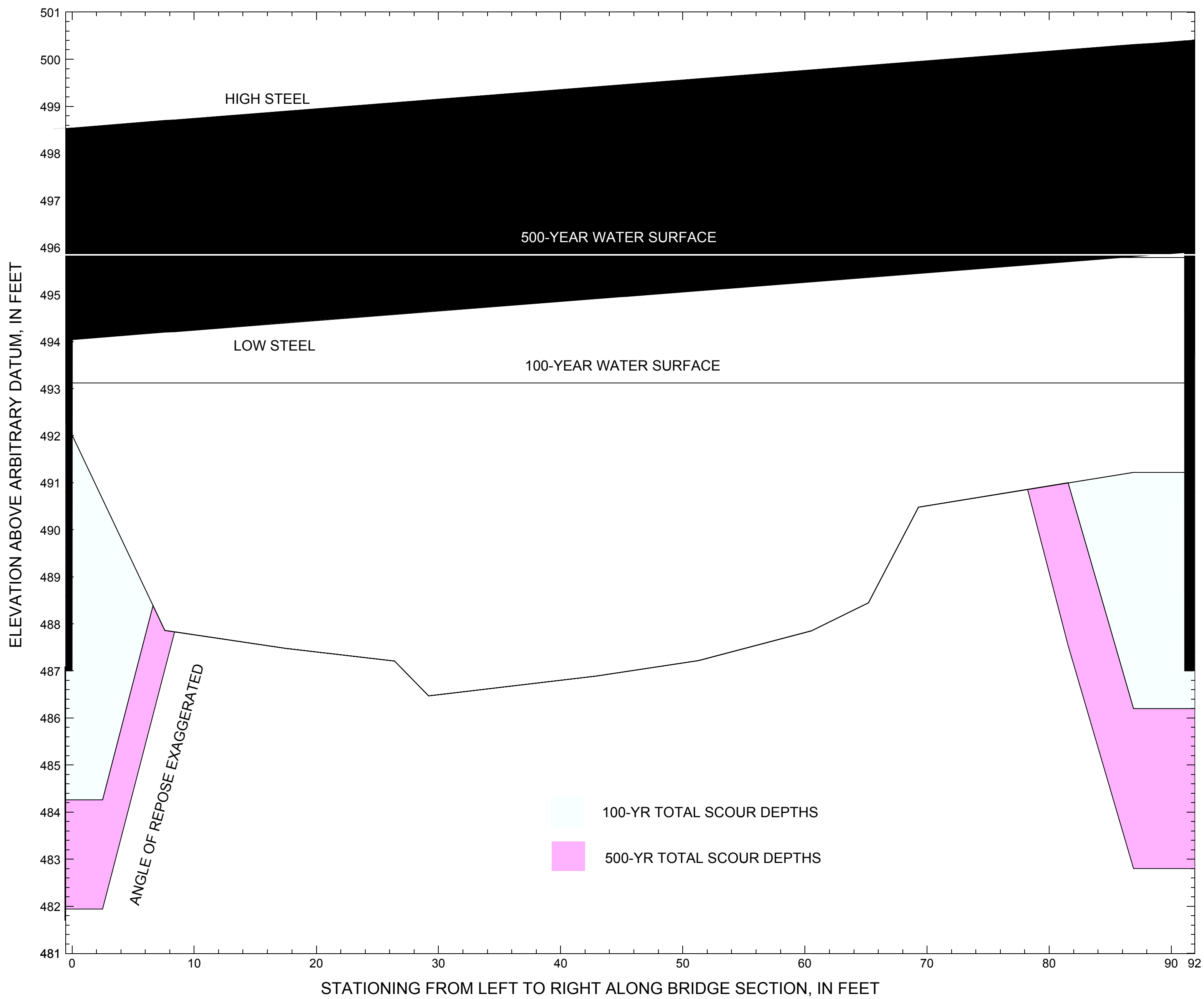


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BARTTH00080037 on town highway 8, crossing Willoughby River, Barton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BARTTH00080037 on Town Highway 8, crossing Willoughby River, Barton, 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 3,830 cubic-feet per second											
Left abutment	0.0	802.3	494.0	487	492.3	0.0	8.0	--	8.0	484.3	-3
Right abutment	91.4	804.2	496.0	487	493.5	0.0	7.3	--	7.3	486.2	-1

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure BARTTH00080037 on Town Highway 8, crossing Willoughby River, Barton, 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 5,600 cubic-feet per second											
Left abutment	0.0	802.3	494.0	487	492.3	0.0	10.3	--	10.3	482.0	-5
Right abutment	91.4	804.2	496.0	487	493.5	0.0	10.7	--	10.7	482.8	-4

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Richardson, J.R., Chang, F., 1991, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 195 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 131 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1986, Orleans, 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 bart037.wsp
T2        Hydraulic analysis for structure BARTTH00080037   Date: 08-APR-96
T3        Barton br 37 on th 8, crossing Willoughby R.    JDA
Q           3830.0   5600.0
SK          0.0085   0.0085
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -88           0.
GR         -183.8, 509.30   -163.1, 499.90   -145.0, 496.98    -67.7, 496.92
GR          -55.9, 497.09    -41.0, 496.34    -27.6, 492.18    -18.4, 491.28
GR            0.0, 487.05     11.7, 486.48     19.3, 485.74     32.3, 485.87
GR           47.5, 486.43     56.4, 487.15     67.3, 489.63     93.2, 489.47
GR          106.3, 494.25    177.4, 498.06    197.8, 503.09
N             0.025     0.054     0.080
SA                 -55.9     106.3
*
XS   FULLV      0  * * *   0.0085
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    494.98      10.0
GR            0.0, 494.01      0.0, 492.28      7.6, 487.86     17.5, 487.48
GR           26.4, 487.21     29.2, 486.47     42.9, 486.89     51.3, 487.22
GR           60.5, 487.85     65.2, 488.45     69.3, 490.48     86.9, 491.22
GR           91.1, 493.47     91.4, 495.96      0.0, 494.01
*
*          BRTYPE  BRWDTH        WWANGL    WWWID
CD              1     34.2   * *    35.0      4.0
N            0.055
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      25.4     1
GR         -190.6, 513.42   -168.1, 503.90   -147.3, 502.06    -93.9, 498.20
GR          -55.4, 497.75      0.0, 498.34      1.4, 498.48     46.0, 499.28
GR           93.8, 500.60     95.7, 500.42    168.1, 503.83    232.4, 507.75
GR          357.2, 519.27
*
XT   APTEM    101           0.
GR         -193.6, 508.82   -154.1, 502.83    -64.4, 498.30    -49.9, 498.65
GR           -5.4, 495.87      7.0, 488.40     15.6, 487.38     26.5, 487.09
GR           38.1, 487.13     50.4, 487.38     53.4, 487.99     57.3, 489.80
GR           62.2, 490.73     86.2, 493.29    114.2, 493.81    124.2, 501.02
*
AS   APPRO    122  * * * 0.00513
GT
N             0.025     0.056     0.100
SA                  -0.4      91.2
```

```
*
HP 1 BRIDG  493.12 1 493.12
HP 2 BRIDG  493.12 * * 3830
HP 1 APPRO  495.18 1 495.18
HP 2 APPRO  495.18 * * 3830
*
HP 1 BRIDG  495.79 1 495.79
HP 2 BRIDG  495.79 * * 5638
HP 1 APPRO  498.25 1 498.25
HP 2 APPRO  498.25 * * 5600
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File bart037.wsp
       Hydraulic analysis for structure BARTTH00080037   Date: 08-APR-96
       Barton br 37 on th 8, crossing Willoughby R.    JDA
          *** RUN DATE & TIME: 04-17-96  10:53
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     412.   30260.    89.    92.                       5028.
  493.12          412.   30260.    89.    92.  1.00     0.    90.   5028.
   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.12     0.0    90.4   412.0   30260.    3830.   9.30

X STA.        0.0        8.7       12.7       16.2       19.6       22.7
  A(I)           28.7       20.8       19.4       18.7       17.8
  V(I)           6.67       9.21       9.89      10.27      10.78

X STA.       22.7       25.9       28.7       31.3       34.0       36.7
  A(I)           18.2       17.4       16.9       16.9       17.2
  V(I)          10.53      11.02      11.32      11.34      11.13

X STA.       36.7       39.4       42.2       45.2       48.3       51.5
  A(I)           17.0       17.9       17.9       18.5       19.1
  V(I)          11.25      10.71      10.71      10.38      10.05

X STA.       51.5       55.0       58.9       63.4       71.1       90.4
  A(I)           20.0       21.3       22.9       27.7       38.0
  V(I)           9.59       9.01       8.37       6.92       5.04
   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     122.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1       4.     234.     4.     4.                         24.
            2     521.   43482.    92.    94.                       7042.
            3      35.     651.    25.    25.                        237.
  495.18          560.   44367.   120.   123.  1.09    -4.   116.   6564.
   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     122.

        WSEL     LEW     REW    AREA        K        Q    VEL
      495.18    -4.1   116.0   559.7   44367.    3830.   6.84

X STA.       -4.1        6.8       10.4       13.7       16.7       19.5
  A(I)           35.4       25.0       24.2       22.3       22.4
  V(I)           5.41       7.66       7.91       8.59       8.56

X STA.       19.5       22.4       25.1       27.9       30.6       33.4
  A(I)           22.1       21.9       21.7       22.2       22.2
  V(I)           8.66       8.75       8.82       8.61       8.62

X STA.       33.4       36.3       39.1       42.1       45.2       48.4
  A(I)           22.7       22.7       23.6       24.1       24.4
  V(I)           8.44       8.45       8.12       7.94       7.83

X STA.       48.4       51.8       56.1       63.4       74.7      116.0
  A(I)           26.3       29.3       35.1       40.7       71.3
  V(I)           7.27       6.54       5.46       4.70       2.69
```

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     579.  34342.     8.   178.                       28231.
   495.79          579.  34342.     8.   178.  1.00     0.    91.  28231.
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.79     0.0    91.4   578.6   34342.    5638.  9.74

X STA.         0.0        9.4       14.2       18.5       22.6       26.6
  A(I)            41.1       31.2       29.3       28.3       28.2
  V(I)            6.85       9.03       9.61       9.95       9.99

X STA.        26.6       29.9       33.1       36.4       39.6       42.8
  A(I)            26.0       25.8       25.9       25.5       25.4
  V(I)           10.83      10.93      10.88      11.05      11.09

X STA.        42.8       46.1       49.3       52.8       56.2       59.8
  A(I)            25.8       25.6       26.6       26.4       26.8
  V(I)           10.93      11.01      10.60      10.69      10.53

X STA.        59.8       63.6       68.5       75.6       83.2       91.4
  A(I)            27.6       30.6       35.2       35.8       31.4
  V(I)           10.22       9.21       8.01       7.87       8.97
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     122.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      60.   4543.    41.    42.                         412.
             2     802.  89318.    92.    94.                       13461.
             3     118.   4315.    29.    30.                        1343.
   498.25          980.  98176.   162.   166.  1.16   -42.   120.  12713.
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     122.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.25   -41.8   120.2   979.6   98176.    5600.  5.72

X STA.       -41.8        0.5        7.2       11.3       15.2       18.8
  A(I)            65.5       52.5       40.7       40.7       38.9
  V(I)            4.27       5.33       6.87       6.87       7.19

X STA.        18.8       22.3       25.8       29.2       32.7       36.2
  A(I)            38.5       38.0       37.7       38.5       38.5
  V(I)            7.28       7.36       7.44       7.27       7.28

X STA.        36.2       39.7       43.3       47.0       50.7       55.0
  A(I)            39.0       38.8       40.4       40.5       43.4
  V(I)            7.17       7.21       6.93       6.91       6.45

X STA.        55.0       61.0       68.3       77.3       89.4      120.2
  A(I)            50.1       52.1       56.5       62.6      126.4
  V(I)            5.59       5.37       4.95       4.47       2.22
```

WSPRO OUTPUT FILE (continued)

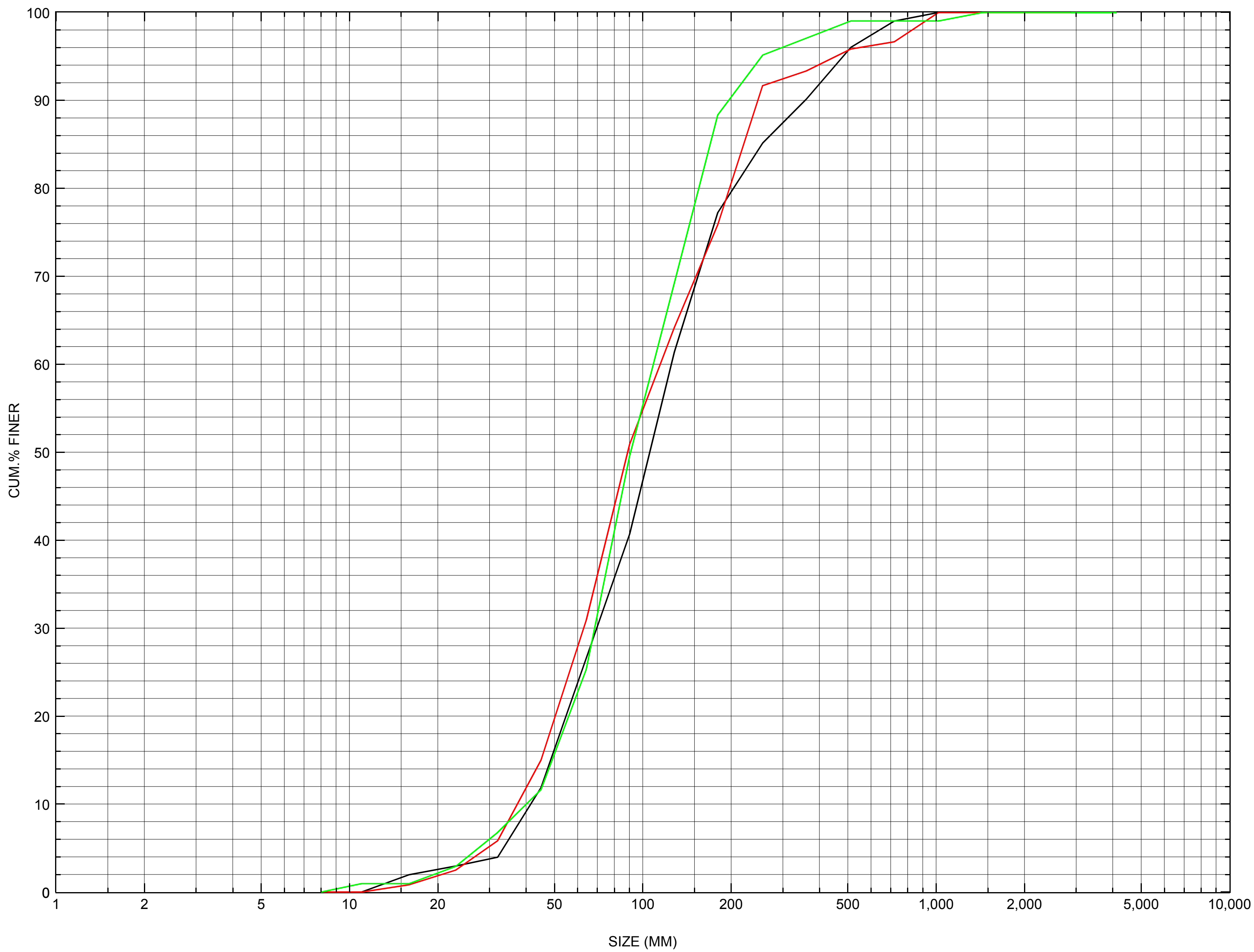
```
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -29.     569.  0.70 *****  493.33  491.05   3830.  492.63
      -88. ******   102.   41506.  1.00 ***** *******    0.57    6.73

FULLV:FV      88.   -29.     570.  0.70  0.75  494.08 *******   3830.  493.38
        0.    88.   102.   41582.  1.00  0.00    0.00    0.57    6.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     122.    -3.     472.  1.09  1.24  495.53 *******   3830.  494.44
      122.   122.   115.   34729.  1.06  0.19    0.01    0.74    8.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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      88.     0.     412.  1.35  1.03  494.46  492.33   3830.  493.12
        0.    88.    90.   30238.  1.00  0.10    0.00    0.76    9.30

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  494.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      88.    -4.     560.  0.79  0.97  495.98  493.17   3830.  495.18
      122.    88.   116.   44392.  1.09  0.55    0.00    0.58    6.84

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.228  0.005   44122.    -5.    86.   494.46

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -88.   -29.   102.   3830.   41506.     569.    6.73  492.63
   FULLV:FV       0.   -29.   102.   3830.   41582.     570.    6.72  493.38
   BRIDG:BR       0.     0.    90.   3830.   30238.     412.    9.30  493.12
   RDWAY:RG      15.**************      0.*****************    1.00********
   APPRO:AS     122.    -4.   116.   3830.   44392.     560.    6.84  495.18

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    86.   44122.
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.05    0.57  485.74  509.30************  0.70  493.33  492.63
   FULLV:FV  ********    0.57  486.49  510.05  0.75  0.00  0.70  494.08  493.38
   BRIDG:BR    492.33    0.76  486.47  495.96  1.03  0.10  1.35  494.46  493.12
   RDWAY:RG  ****************  497.75  519.27**********************************
   APPRO:AS    493.17    0.58  487.20  508.93  0.97  0.55  0.79  495.98  495.18
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -33.     731.  0.91 *****  494.74  492.08   5600.  493.83
      -88. ******   105.   60712.  1.00 ***** *******    0.59    7.66

FULLV:FV      88.   -33.     732.  0.91  0.75  495.50 *******   5600.  494.58
        0.    88.   105.   60800.  1.00  0.00    0.00    0.59    7.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     122.    -5.     607.  1.46  1.26  497.03 *******   5600.  495.57
      122.   122.   116.   49938.  1.10  0.27    0.00    0.76    9.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.16     495.79     496.80     494.98

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
```

WSPRO OUTPUT FILE (continued)

```
           <<<<<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      88.     0.     579.  1.48 *****  497.27  493.50   5638.  495.79
        0. ******    91.   34345.  1.00 ***** *******    0.68    9.74

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.488 ******  494.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      88.   -42.     979.  0.59  0.82  498.84  494.50   5600.  498.25
      122.    88.   120.   98153.  1.16  0.68    0.01    0.44    5.72

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.93
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -88.   -33.   105.   5600.   60712.     731.    7.66  493.83
   FULLV:FV       0.   -33.   105.   5600.   60800.     732.    7.65  494.58
   BRIDG:BR       0.     0.    91.   5638.   34345.     579.    9.74  495.79
   RDWAY:RG      15.**************      0.       0.       0.    1.00********
   APPRO:AS     122.   -42.   120.   5600.   98153.     979.    5.72  498.25

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.08    0.59  485.74  509.30************  0.91  494.74  493.83
   FULLV:FV  ********    0.59  486.49  510.05  0.75  0.00  0.91  495.50  494.58
   BRIDG:BR    493.50    0.68  486.47  495.96************  1.48  497.27  495.79
   RDWAY:RG  ****************  497.75  519.27************  0.59  498.52********
   APPRO:AS    494.50    0.44  487.20  508.93  0.82  0.68  0.59  498.84  498.25
     END OF FILE ON PRIMARY INPUT UNIT  55

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BARTTH00080037, in Barton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BARTTH00080037

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 04 / 94

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

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

Town *(FIPS place code; I - 4; nnnnn)* 03550

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

Waterway *(I - 6)* WILLOUGHBY RIVER

Road Name *(I - 7)*: -

Route Number TH08

Vicinity *(I - 9)* 0.01 MI JCT TH 8 + VT 58

Topographic Map Orleans

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44482

Longitude *(i - 17; nnnnn.n)* 72108

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100200371002

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

Maximum span length *(I - 48; nnnn)* 0094

Year built *(I - 27; YYYY)* 1987

Structure length *(I - 49; nnnnnn)* 000096

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

Deck Width *(I - 52; nn.n)* 254

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

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

Opening skew to Roadway *(I - 34; nn)* 12

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 090.0

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

Vertical clearance from streambed (*nnn.n ft*) 007.5

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

Waterway of full opening (*nnn.n* ft^2) 675.0

Comments:

The structural inspection report of 7/18/92 indicates a single span steel stringer bridge. The abutments and wingwalls are like new. No noted channel scour. There is minor embankment erosion 100 feet upstream. A point bar has developed on the right abutment. The channel aligned straight through bridge. There is good stone fill coverage.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 57.4

Terrain character: Mountainous to hilly

Stream character & type: -

Streambed material: Stone and gravel with random boulders

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 2000 Q_{25} 2650

Q_{50} 3150 Q_{100} 3650 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)*: Moderate

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: Abutment of old truss bridge is partially in stream on the upstream left bank.

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*))	-	799.1	799.7	800.3	800.7
Velocity (*ft / sec*)	-	-	10.6	-	-

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} (*ft³/ sec*): -

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

Upstream distance (*miles*): 1 Town: Brownington Year Built: 1928

Highway No. : TH 1 Structure No. : 9 Structure Type: Concrete T-beam

Clear span (*ft*): 57 Clear Height (*ft*): - Full Waterway (*ft²*): -

Downstream distance (*miles*): **0.6** Town: **Barton** Year Built: **-**
Highway No. : **TH 3** Structure No. : **1** Structure Type: **I-beam side girder**
Clear span (*ft*): **50** Clear Height (*ft*): **-** Full Waterway (ft^2): **-**

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **60.39** mi^2 Lake and pond area **1.94** mi^2
Watershed storage *(ST)* **3.2** %
Bridge site elevation **807.4** ft Headwater elevation **2655.8** ft
Main channel length **17.54** mi
10% channel length elevation **885.8** ft 85% channel length elevation **1169.6** ft
Main channel slope *(S)* **21.57** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **02** / **1987**

Project Number **BRZ 1449(13)** Minimum channel bed elevation: **794.9**

Low superstructure elevation: USLAB **802.25** DSLAB **802.33** USRAB **804.23** DSRAB **804.31**

Benchmark location description:

BM #1A, chiseled square in concrete head wall south east corner of square, located at middle of rightmost lane VT 58 north of bridge (downstream) elevation 800.94. BM #1, chiseled square at top of north west corner of right abutment (downstream right abutment), elevation 806.79.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **795.0**

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? **Y** *If no, type ctrl-n bi* Number of borings taken: **4**

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

Briefly describe material at foundation bottom elevation or around piles:

Spreadfooting in mainly a silt material. Borings 3 and 4 show drilling into 10 and 11 feet of rock. Bedrock noted as a gray quartzose crystalline limestone (marble), at location of right abutment. Bedrock was not reached at the location of left abutment in borings 1and 2.

Comments:

Some bridge plans in bridge record. Hydrologic data on plans: Q2.33=900 elevation=797.5, Q10=2000 at elevation=799.1, Q25=2650 at elevation=799.7, Q50=3150 at elevation=800.3, Q100=3650 at elevation=800.7, velocity at Q25=10.6 feet per second.

Cross-sectional Data

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

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

Comments: **Cross-sections available.**

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

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

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

Comments:

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: **MAI** Date: **1/26/95**
Computerized by: **MAI** Date: **2/23/95**
Reviewd by: **JDA** Date: **4/24/96**

Structure Number **BARTTH00080037**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **10** / **20** / 19**94**

2. Highway District Number **09** Mile marker **-**

County **ORLEANS (019)** Town **BARTON (03550)**

Waterway *(I - 6)* **WILLOUGHBY RIVER** Road Name **-**

Route Number **TH08** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

The structure is a steel stringer type bridge located about 20 feet from the intersection of TH08 with state route 58.

B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **6** LBDS **2** RBDS **4** Overall **2**
*(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 **96.0** *(feet)* Span length **94.0** *(feet)* Bridge width **25.4** *(feet)*

Road approach to bridge:

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

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

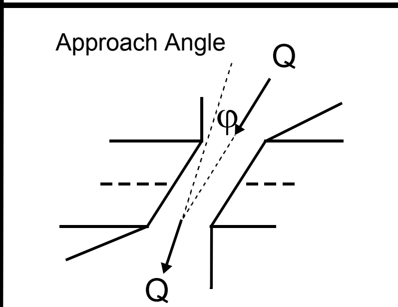
10. Embankment slope (*run / rise in feet / foot*):
US left **-:1** US right **6.6:1**

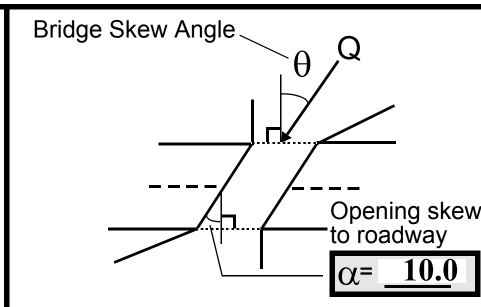
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	2	2
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **155** feet **US** *(US, UB, DS)* to **70** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **150** feet **DS** *(US, UB, DS)* to **250** feet **DS**

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

18. Level II Bridge Type: **1A/4**

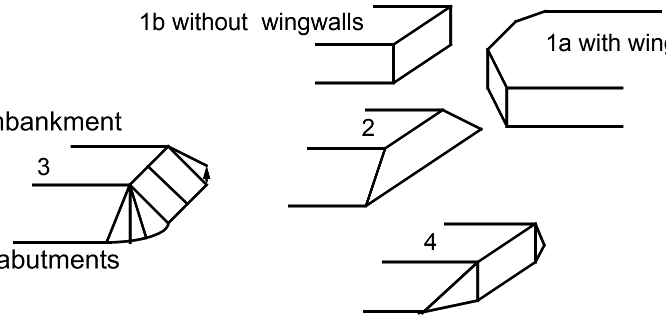
1a- Vertical abutments with wingwalls

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.)

Upstream and downstream left bank coverage is mainly the roadway and homes except at the immediate channel edge where some trees and brush are present. Coverage on the downstream right bank is mainly pasture during the off season but may have row crops during the summer months. The right bank downstream coverage is all forested except for brush on a narrow land area just adjacent to the channel. Measured bridge dimensions were, 1) bridge length = 96.0 feet, span length = 94.0 feet, and roadway width = 25.0 feet.

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
82.9	**7.5**			**6.0**	**3**	**4**	**3**	**3**	**2**	**0**

23. Bank width **30.0** 24. Channel width **10.0** 25. Thalweg depth **91.5** 29. Bed Material **4**

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 material is mainly fine to coarse gravel and sand with a few boulders. The bed material is boulder and cobble size mainly in a fine to coarse sand and fine gravel. For the most part, the banks are unprotected. An old abutment remains on the left bank upstream which provides bank protection in the area from the bridge to about 40 feet upstream. There was no protection further upstream from the old left abutment. Some class 2 (cut stone) riprap protects the upstream right bank mainly from roadwash but sits back about 40 feet from the channel.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **200** 35. Mid-bar width: **43**

36. Point bar extent: **325** feet **US** (US, UB) to **150** feet **DS** (US, UB, DS) positioned **85** %LB to **100** %RB

37. Material: **4**

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

The point bar is composed of cobbles and boulder size material with some coarse gravel and fine to coarse sand. It does not appear active as brush and shrubs are growing on it. The point bar is inconspicuous somewhat due to the growth on it but extends along the inside of a long, slight channel bend. Local sources indicate the point bar area is submerged nearly every year during spring runoff.

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: **210** 42. Cut bank extent: **350** feet **US** (US, UB) to **70** feet **US** (US, UB, DS)

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

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

No protection is present at the cut bank location. Some native cobble and boulder bank material that remains has formed a shallower slope from the toe of the bank to roughly one half the bank height.

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

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

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

NO CHANNEL SCOUR

49. Are there major confluences? **Y** (Y or if N type ctrl-n mc) 50. How many? **1**

51. Confluence 1: Distance **200** 52. Enters on **LB** (LB or RB) 53. Type **1** (1- perennial; 2- ephemeral)

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

54. Confluence comments (eg. confluence name):

The tributary is perennial but not named.

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
46.5		1.0		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.):

3

The point bar indicated on the right bank upstream continues under the bridge to about 50 feet downstream and might be considered a natural bank under the bridge. The point bar (natural bank) material under the bridge is fine to medium sand, coarse gravel and a few boulders with no evident erosion. The under bridge bed material on the surface is a coarse gravel with some cobbles and a few scattered boulders.

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

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

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

70. Debris and Ice Comments:

1

A local source noted periods of ice flows with water levels high enough such that blocks of ice loudly hit the steel I-beams. Ice blocks are frequently deposited in the field on the right overbank downstream. Trees are undermined on banks and some are leaning (horizontal) on the right bank upstream. Hence, the potential for debris production is probably moderate.

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	0	-	-	90.0
RABUT	1	0	90			0	0	91.0

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

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

-

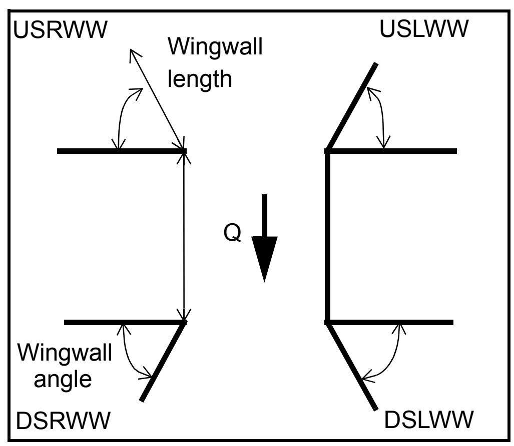
-

1

The abutments are in good condition.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						53.0	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	30.0	
DSRWW:	1		0		-	30.5	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	1	1	1
Condition	Y	-	1	-	1	1	1	1
Extent	1	-	0	2	2	2	2	-

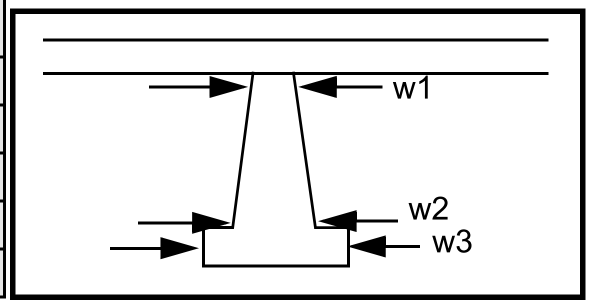
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
2
1
1

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		5.0	8.0	20.0	50.0	50.0
Pier 2	5.0	8.5	-	25.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	dow	ng	de-	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	pro-	nstre	out	vel-	1- Solid pier, 2- column, 3- bent
88. Material	tec-	am	from	oped	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	tion	right	area	a	1- Round; 2- Square; 3- Pointed
90. Inclined?	foun	wing	due	gul-	Y- yes; N- no
91. Attack ∠ (BF)	d at	wall	to	ly	
92. Pushed	the	is	road	be-	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	ex-	slum	wash	hind	
95. Cross-members	trem	ping	.	the	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	e end	and/	Ero-	wing	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	of	or	sion	wall.	
98. Exposure depth	the	erodi	has	The	

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

abutment protection forms a 35 to 40 degree slope from the toe to the concrete walls and sits up high covering nearly two thirds of each abutment's face.

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: 2______

Scour dimensions: Length 3_____ Width 4_____ Depth: 4_____ Positioned 1____ %LB to 1____ %RB

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

5
0
0
-

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

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

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

Confluence comments (eg. confluence name):

htly on the right bank and at the upstream end of the point bar on left bank in the impact zone downstream.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

109. G. Plan View Sketch

- N

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BARTTH00080037 Town: Barton
Road Number: TH37 County: Orleans
Stream: Willoughby River

Initials JDA Date: 4/17/96 Checked: Date:

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

Neills Equation
Vc=11.52*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1993, p. 31, eq. 14)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3830	5600	0
Main Channel Area, ft2	521	802	0
Left overbank area, ft2	4	60	0
Right overbank area, ft2	35	118	0
Top width main channel, ft	92	92	0
Top width L overbank, ft	4	41	0
Top width R overbank, ft	25	29	0
D50 of channel, ft	0.312	0.312	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.7	8.7	ERR
y1, average depth, LOB, ft	1.0	1.5	ERR
y1, average depth, ROB, ft	1.4	4.1	ERR
Total conveyance, approach	44367	98176	0
Conveyance, main channel	43482	89318	0
Conveyance, LOB	234	4543	0
Conveyance, ROB	651	4315	0
Percent discrepancy, conveyance	0	0	ERR
Qm, discharge, MC, cfs	3753.602	5094.736	ERR
Ql, discharge, LOB, cfs	20.20015	259.1346	ERR
Qr, discharge, ROB, cfs	56.19785	246.1294	ERR
Vm, mean velocity MC, ft/s	7.2	6.4	ERR
Vl, mean velocity, LOB, ft/s	5.1	4.3	ERR
Vr, mean velocity, ROB, ft/s	1.6	2.1	ERR
Vc-m, crit. velocity, MC, ft/s	10.4	11.2	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(120*Dm^(2/3)*W2^2))^(3/7)
ys=y2-y_bridge or ys=y2-y1
(Richardson and others, 1993, p. 35, eq. 18, 19)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	521	802	0
Main channel width, ft	92	92	0
y1, main channel depth, ft	5.663043	8.717391	ERR

Bridge Section			
(Q) total discharge, cfs	3830	5600	0
(Q) discharge thru bridge, cfs	3830	5638	
Main channel conveyance	30260	34342	
Total conveyance	30260	34342	
Q2, bridge MC discharge,cfs	3830	5638	ERR
Main channel area, ft2	412	579	0
Main channel width (skewed), ft	90.0	90.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	90	90	0
y_bridge (avg. depth at br.), ft	4.577778	6.433333	ERR
Dm, median (1.25*D50), ft	0.39	0.39	0
y2, depth in contraction,ft	4.188025	5.833726	ERR
ys, scour depth (y2-ybridge), ft	-0.39	-0.60	N/A
ys, scour depth (y2-y1), ft	-1.48	-2.88	N/A
ys, scour depth (y2-yfullv), ft	N/A	-0.2	N/

A

ARMORING			
D90	0.819	0.819	
D95	1.38	1.38	
Critical grain size,Dc, ft	0.4886	0.459207	ERR
Decimal-percent coarser than Dc	0.282	0.309	
Depth to armoring,ft	3.732071	3.0807	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	0	5600	0
Vc, critical velocity, ft/s	0	11.2	0
Vc, critical velocity, m/s	0	3.413593	0
Main channel width (skewed), ft	0	90	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	90	0
qbr, unit discharge, ft^2/s	ERR	62.22222	ERR
qbr, unit discharge, m^2/s	N/A	5.780069	N/A
Area of full opening, ft^2	0	579	0
Hb, depth of full opening, ft	ERR	6.433333	ERR
Hb, depth of full opening, m	N/A	1.960784	N/A
Fr, Froude number MC	1	0.68	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
Elevation of Low Steel, ft	0	494.98	0
Elevation of Bed, ft	N/A	488.5467	N/A
Elevation of approach WS, ft	0	498.25	0
HF, bridge to approach, ft	0	0.82	0
Elevation of WS immediately US, ft	0	497.43	0
ya, depth immediately US, ft	N/A	8.883333	N/A
ya, depth immediately US, m	N/A	2.760514	N/A
Mean elev. of deck, ft	0	--	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.918142	ERR
Ys, depth of scour (chang), ft	N/A	-0.38246	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, 1993, p. 49, eq. 24)

	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	3830	5600	0	3830	5600	0
a', abut.length blocking flow, ft	4.8	42.5	0	25.3	29.5	0
Ae, area of blocked flow ft2	15.6	67.07	0	43.68	121.06	0
Qe, discharge blocked abut.,cfs	84.33	288.36	0	117.31	268.18	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	5.405769	4.299389	ERR	2.685668	2.215265	ERR
ya, depth of f/p flow, ft	3.25	1.58	ERR	1.73	4.10	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	0	100	100	0
K2	0.984805	0.984805	0	1.013791	1.013791	0
Fr, froude number f/p flow	0.53	0.60	ERR	0.36	0.19	ERR
ys, scour depth, ft	8.02	10.34	N/A	7.27	10.73	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1993, p. 50, eq. 25)

a'(abut length blocked, ft)	4.8	42.5	0	25.3	29.5	0
y1 (depth f/p flow, ft)	3.25	1.58	ERR	1.73	4.10	ERR
a'/y1	1.48	26.93	ERR	14.65	7.19	ERR
Skew correction (p. 49 fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.53	0.60	N/A	0.36	0.19	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	9.71	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	7.96	ERR	ERR	ERR	ERR
spill-through	ERR	5.34	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1993, p118-119, eq. 93,94)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.76	0.68				
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.58	6.43				
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.64	1.84	0.00	0.00	0.00	0
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR