LEVEL II SCOUR ANALYSIS FOR BRIDGE 166 (BARTUS00050166) on U. S. ROUTE 5, crossing BARTON RIVER, BARTON, VERMONT

U.S. Geological Survey
Open-File Report 96-746

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

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By JOSEPH D. AYOTTE and ROBERT E. HAMMOND

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Pembroke, New Hampshire
1996

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

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Denver, CO 80225

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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 166 (BARTUS00050166) ON U.S. ROUTE 5, CROSSING BARTON RIVER, BARTON, VERMONT

By **Joseph D. Ayotte and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BARTUS00050166 on U. S. Route 5 crossing the Barton 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 65.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have a combination of dense woody vegetation coverage, brush, and field grasses.

In the study area, the Barton River has an incised, sinuous-to-meandering channel with a slope of approximately 0.0065 ft/ft, an average channel top width of 58 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel (D_{50} is 75.6 mm or 0.25 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 19, 1994, indicated that the reach was stable.

The U. S. Route 5 crossing of the Barton River is a 126-ft-long, two-lane bridge consisting of one 60-foot steel beam span with two steel-beam approach spans (Vermont Agency of Transportation, written communication, August 4, 1994). The bridge is supported by two concrete piers. The left bank has a concrete retaining wall that is attached to the US face of the left pier; consequently this pier functions as an abutment for the analysis because no flow occurs to the left of the pier. For the purposes of computing scour, this pier was considered an abutment. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 25 degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed along the right pier during the Level I assessment. Scour protection measures at the site consist of type-1 stone fill (less than 12 inches diameter) along the entire base length of both piers. 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, 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 1.1 to 2.4 ft. Abutment-type scour was computed for the left pier; scour ranged from 9.1 to 11.3 ft. Abutment scour at the right abutment ranged from 6.1 to 11.3 ft. Pier scour, computed for the right pier, ranged from 31.3 to 33.3 ft. The severity of the pier scour was directly related to the attack angle of 25 degrees. The worst-case scour in all computations occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number BARTUS00050166 ***Stream*** Barton River

County Orleans ***Road*** US 5 ***District*** 9

Description of Bridge

Bridge length 126 ***ft*** ***Bridge width*** 35 ***ft*** ***Max span length*** 60 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Y ***Date of inspection*** 10/19/94

Description of stone fill Type-1, along the length of both piers; hydraulically, pier 1 (left) functions as an abutment and an abutment scour computation was made.

Brief description of piers/abutments Abutments and piers are concrete. There is a 0.5 foot deep scour hole along the right pier. The left pier is at the toe of the left bank and is connected to a concrete retaining wall which begins US of the bridge and pier.

Y 40

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

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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*
	10/19/94	0	0
Level I	10/19/94	--	--
Level II	Low. There was no debris at the bridge at the time of the site visit.		

Potential for debris None as of 10/19/94.

Describe any features near or at the bridge that may affect flow (include observation date)

Description of the Geomorphic Setting

General topography The channel is located at an 800-ft wide part of the valley just DS of a natural channel constriction. The valley is generally less than 500 ft wide.

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

Date of inspection 10/19/94

DS left: Moderate floodplain to steep valley wall

DS right: Moderate floodplain to steep valley wall

US left: Moderate floodplain to steep valley wall

US right: Moderate floodplain to steep valley wall

Description of the Channel

Average top width 58 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Gravel ***Bank material*** Gravel/cobbles

Sinuous-to-meandering but stable with semi-alluvial channel boundaries.

10/19/94

Vegetative co Forest

DS left: Trees and brush

DS right: Brush and field grass

US left: Brush and field grass

US right: Y

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

The assessment of 10/19/94 noted flow conditions up to bank-full level do not impact the area left of the left pier (pier 1). Therefore pier one is treated as an abutment for the purposes of this study--10/19/94.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 65.2 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,820 ***ft³/s*** ***Q500*** 8,000 ***ft³/s***

The 100-year and 500-year discharge is based on several empirical relationships (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a & b; Talbot, 1887). Flood frequency curves were extrapolated to obtain the 500-year discharge. The discharge used is the median (Benson, 1962) of the values obtained by these methods.

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 698.0 to USGS survey to obtain VTAOT plans datum.

Description of reference marks used to determine USGS datum. BM N55 is a brass tablet on the end post of the bridge rail of the US end of the right abutment (elev. 812.05 ft, VTAOT datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-142	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
APPRO	105	2	Modelled Approach section (Templated from APTEM)
APTEM	160	1	Approach section as surveyed (Used as a template)

[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 0.045 to 0.052, and overbank "n" values ranged from 0.048 to 0.085.

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 0.0065 ft/ft which was estimated from points surveyed at the EXITX and BRIDG cross sections.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0066 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 113.6 *ft*
Average low steel elevation 104.7 *ft*

100-year discharge 5,820 *ft³/s*
Water-surface elevation in bridge opening 99.7 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 456 *ft²*
Average velocity in bridge opening 12.8 *ft/s*
Maximum WSPRO tube velocity at bridge 15.5 *ft/s*

Water-surface elevation at Approach section with bridge 102.6 *ft*
Water-surface elevation at Approach section without bridge 100.6 *ft*
Amount of backwater caused by bridge 2.0 *ft*

500-year discharge 8,000 *ft³/s*
Water-surface elevation in bridge opening 100.9 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 539 *ft²*
Average velocity in bridge opening 14.8 *ft/s*
Maximum WSPRO tube velocity at bridge 18.2 *ft/s*

Water-surface elevation at Approach section with bridge 105.0 *ft*
Water-surface elevation at Approach section without bridge 102.1 *ft*
Amount of backwater caused by bridge 2.9 *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, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 100-year and 500-year discharges. Streambed armoring depths computed suggest that the depth of contraction scour will not be limited by armoring.

The left pier of this bridge (see Figure 3) hydraulically functions as an abutment for all modelled discharges. Therefore, scour at the left pier was computed by use of the Froehlich abutment scour equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the right abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation. The right abutment is a spill-through-type abutment. Because the effect of scour processes on the spill-through embankment material are uncertain, the abutment scour depths were applied for the entire spill-through embankment below the elevation at the toe of the embankment and extended to the vertical concrete abutment wall as shown in figure 8.

Scour at the right pier was computed by use of the Colorado State University (CSU) pier scour equation (Richardson and others, 1995, p. 36, equation 21). The variables used by the CSU equation include pier dimensions, flow approach depth and velocity, Froude number, and multiplicative factors for pier shape, attack angle, bed conditions, and armoring. In this case, the attack angle factor has a pronounced effect on the depth of scour computed (see appendix F). The armoring factor, K4 was applied because the D50 of the channel bed material was greater than 0.2 ft.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.1	2.4	--
Depth to armoring	20.9	49.2	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	9.1	11.3	--
Left abutment	6.1	11.3	--
Right abutment			
Pier scour	see left abutment, above		--
Pier 1	31.3	33.3	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.8	3.3	--
Left abutment	2.8	3.3	--
Right abutment	see left abutment, above		--
Piers:	2.1	2.8	--
Pier 1	--	--	--
Pier 2			

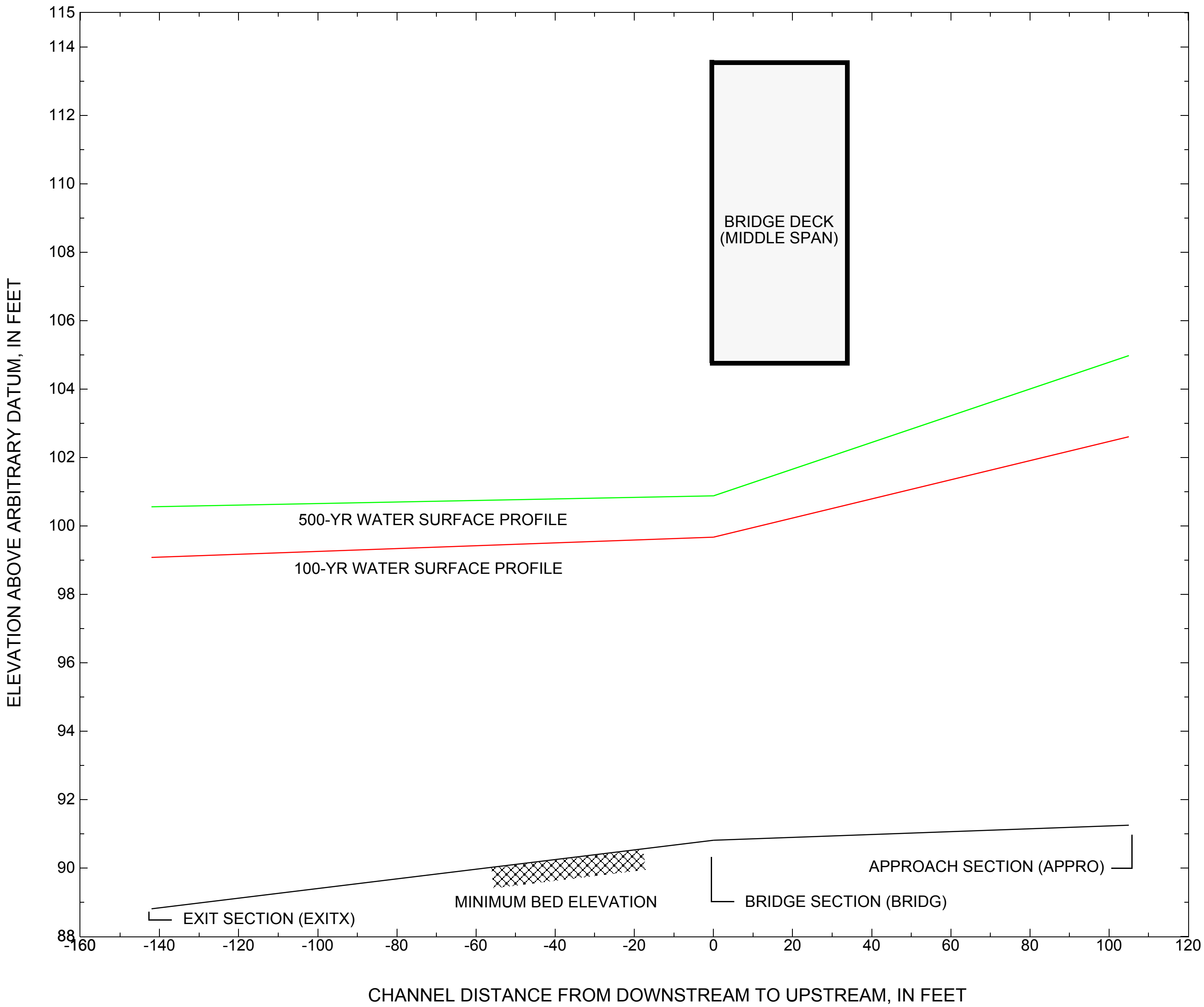


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BARTUS00050166 on U. S. Route 5, crossing Barton River, Barton, Vermont.

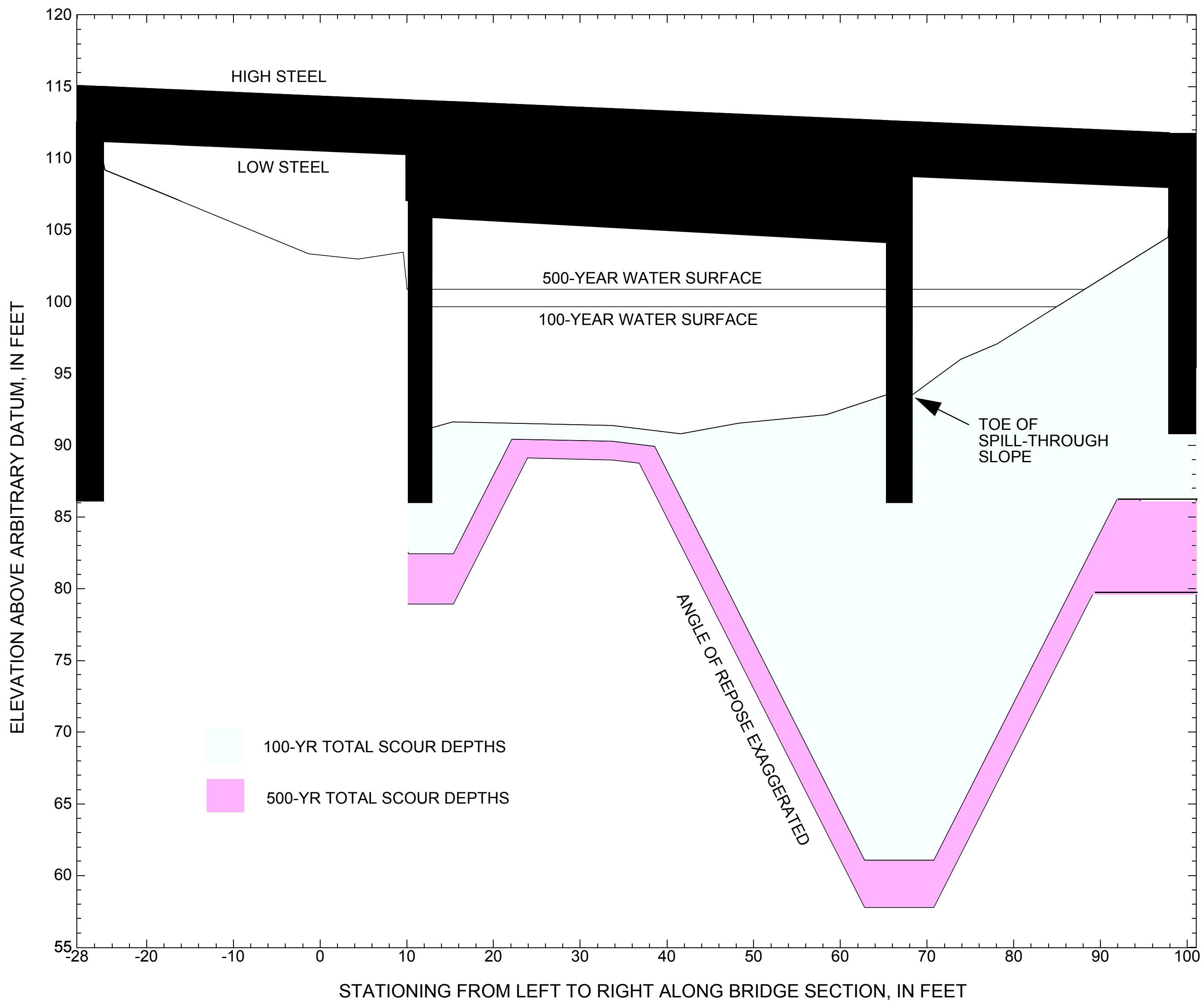


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BARTUS00050166 on U. S. Route 5, crossing Barton River, Barton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BARTUS00050166 on U. S. Route 5, crossing Barton River, Barton, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat 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 5,820 cubic-feet per second											
Left Abutment	-25.0	809.6	111.6	86	--	--	--	--	--	--	--
Pier 1[3]	11.4	--	105.6	86	92.6	1.1	9.1	--	10.2	82.4	-4
Pier 2	66.8	--	103.7	86	93.5	1.1	--	31.3	32.4	61.1	-25
Toe, Right Abutment	68.1	--	--	--	93.4	1.1	6.1	--	7.2	86.2	--
Right Abutment	98.0	805.5	107.9	91	--	--	--	--	--	--	-5

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.
3. Abutment scour computation reported

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure BARTUS00050166 on U. S. Route 5, crossing Barton River, Barton, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat 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 8,000 cubic-feet per second											
Left Abutment	-25.0	809.6	111.6	86	--	--	--	--	--	--	--
Pier 1[3]	11.4	--	105.6	86	92.6	2.4	11.3	--	13.7	78.9	-7
Pier 2	66.8	--	103.7	86	93.5	2.4	--	33.9	36.3	57.2	-29
Toe, Right Abutment	68.1	--	--	--	93.4	2.4	11.3	--	13.7	79.7	--
Right Abutment	98.0	805.5	107.9	91	--	--	--	--	--	--	-11

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.
3. Abutment scour computation reported

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., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 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., 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 bart166.wsp
T2        Hydraulic analysis for structure BARTUS00050166   Date: 05-APR-96
T3        Hydraulic analysis of bridge 166, Barton.        JDA
Q           5820.0   8000.0
SK          0.0065   0.0065
*
J3          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX   -142           0.
GR          -47.7, 106.72    -27.6, 105.95      0.0,  96.97      9.2,  95.77
GR           11.6,  91.29     15.2,  89.88     29.1,  89.18     34.6,  89.01
GR           56.6,  88.81     64.5,  91.61     73.3,  95.26     80.7,  96.43
GR          136.4,  98.36    171.7, 100.02
*
N           0.085        0.052        0.081
SA                   9.2         73.3
*
*
XS   FULLV      0  * * *   0.0065
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    109.73      25.0
GR          -25.0, 111.59    -24.8, 109.20     -1.3, 103.36      4.4, 102.98
GR            9.6, 103.47     11.9,  92.64     12.3,  91.12     15.3,  91.64
GR           33.7,  91.38     41.6,  90.81     48.3,  91.55     58.4,  92.13
GR           65.4,  93.53     68.1,  93.43     73.9,  95.99     78.1,  97.08
GR           97.8, 104.51     98.0, 107.86     70.4, 108.86     69.5, 103.89
GR            5.1, 106.08      3.6, 110.86    -25.0, 111.59
*
*         BRTYPE  BRWDTH
CD          1      36.9
N           0.050
PW          93.4, 3.0  103.8,3  103.8,0
*
*
XT   APTEM    160
GR          -31.6, 120.33      9.0,  99.83     16.1,  97.28     24.9,  93.59
GR           29.8,  93.29     37.1,  92.68     48.8,  92.45     53.0,  91.61
GR           62.3,  92.74     63.7,  93.17     65.8,  93.43     68.5,  96.69
GR           70.9,  97.33    110.4,  98.45    117.3, 101.09    154.8, 102.22
GR          169.7, 101.69    197.8, 101.27    209.9, 101.37    238.1, 101.68
GR          263.2, 105.47    270.7, 106.71    279.8, 112.69
*
AS   APPRO    105  * * * 0.0066
GT
N           0.045        0.048
SA                  70.9
*
HP 1 BRIDG   99.67 1 99.67
HP 2 BRIDG   99.67 * * 5820
HP 2 BRIDG   100.29 * * 5820
HP 1 APPRO   102.61 1 102.61
```

```
HP 2 APPRO   102.61 * * 5820
*






HP 1 BRIDG   100.88 1 100.88
HP 2 BRIDG   100.88 * * 8000
HP 2 BRIDG   101.61 * * 8000
HP 1 APPRO   104.98 1 104.98
HP 2 APPRO   104.98 * * 8000
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File bart166.wsp
        Hydraulic analysis for structure BARTUS00050166   Date: 05-APR-96
        Hydraulic analysis of bridge 166, Barton.        JDA
           *** RUN DATE & TIME: 04-23-96  08:56
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     455.  44723.    68.    76.                         6709.
    99.67          455.  44723.    68.    76.  1.00    10.    85.   6709.
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
        99.67    10.4    85.0   455.4   44723.    5820.  12.78

X STA.        10.4       16.3       19.5       22.4       25.2       27.9
  A(I)            37.3       23.5       21.7       20.3       19.9
  V(I)            7.81      12.39      13.42      14.34      14.59

X STA.        27.9       30.5       33.1       35.6       38.1       40.5
  A(I)            19.8       19.2       19.2       19.0       18.8
  V(I)           14.69      15.16      15.17      15.33      15.50

X STA.        40.5       42.9       45.3       47.9       50.8       53.6
  A(I)            19.0       19.1       19.8       20.5       20.6
  V(I)           15.31      15.22      14.73      14.18      14.13

X STA.        53.6       56.7       60.0       64.1       69.0       85.0
  A(I)            21.3       22.8       25.0       27.5       41.2
  V(I)           13.69      12.77      11.62      10.60       7.05
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       100.29    10.3    86.6   497.8   50879.    5820.  11.69

X STA.        10.3       16.4       19.6       22.6       25.4       28.1
  A(I)            41.4       25.7       23.7       22.1       21.8
  V(I)            7.03      11.34      12.29      13.14      13.37

X STA.        28.1       30.8       33.4       36.0       38.5       40.9
  A(I)            21.6       20.9       20.9       20.4       20.8
  V(I)           13.46      13.90      13.90      14.27      14.00

X STA.        40.9       43.3       45.8       48.5       51.3       54.3
  A(I)            20.3       21.0       21.4       22.3       22.4
  V(I)           14.35      13.85      13.60      13.03      12.97

X STA.        54.3       57.3       60.7       64.9       69.8       86.6
  A(I)            23.2       24.7       27.2       30.2       45.8
  V(I)           12.55      11.76      10.72       9.65       6.35
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     105.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     565.  73974.    68.    72.                         9240.
             2     396.  21057.   176.   176.                         3370.
   102.61          961.  95031.   244.   248.  1.43     3.   247.   9061.
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     105.

         WSEL     LEW     REW    AREA        K        Q    VEL
       102.61     2.8   246.7   961.1   95031.    5820.   6.06

X STA.         2.8       19.9       25.1       29.2       32.8       36.2
  A(I)            65.6       43.3       39.2       35.7       33.7
  V(I)            4.43       6.72       7.42       8.15       8.64

X STA.        36.2       39.4       42.5       45.6       48.6       51.4
  A(I)            33.1       32.2       32.0       31.7       30.6
  V(I)            8.78       9.04       9.08       9.18       9.52

X STA.        51.4       54.2       56.9       59.8       62.9       66.6
  A(I)            30.8       30.2       30.7       32.4       35.2
  V(I)            9.46       9.62       9.47       8.97       8.26
```

WSPRO OUTPUT FILE (continued)

```
X STA.        66.6       75.7       87.9      102.2      142.9      246.7
  A(I)             55.2       65.4       70.8       98.6      134.5
  V(I)             5.27       4.45       4.11       2.95       2.16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     539.  57069.    71.    81.                         8446.
   100.88          539.  57069.    71.    81.  1.00    10.    88.   8446.
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       100.88    10.2    88.2   539.1   57069.    8000.  14.84

X STA.        10.2       16.5       19.8       22.8       25.7       28.3
  A(I)             45.4       27.7       25.5       24.5       22.8
  V(I)             8.81      14.46      15.67      16.34      17.53

X STA.        28.3       31.1       33.7       36.3       38.8       41.2
  A(I)             23.3       22.6       22.6       22.3       22.0
  V(I)            17.18      17.74      17.72      17.93      18.17

X STA.        41.2       43.7       46.3       49.1       51.9       54.9
  A(I)             22.6       22.6       23.4       23.6       24.4
  V(I)            17.73      17.67      17.06      16.94      16.37

X STA.        54.9       58.0       61.5       65.7       70.9       88.2
  A(I)             25.3       26.8       29.4       33.5       48.8
  V(I)            15.82      14.95      13.60      11.92       8.20
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       101.61    10.0    90.1   591.4   65176.    8000.  13.53

X STA.        10.0       16.4       19.9       23.0       25.9       28.7
  A(I)             49.4       31.4       28.0       26.8       25.6
  V(I)             8.10      12.76      14.30      14.91      15.65

X STA.        28.7       31.4       34.0       36.7       39.2       41.7
  A(I)             24.9       24.7       24.8       24.1       24.5
  V(I)            16.06      16.20      16.16      16.63      16.35

X STA.        41.7       44.2       46.9       49.7       52.6       55.6
  A(I)             24.2       25.0       25.6       25.9       26.8
  V(I)            16.56      15.98      15.63      15.47      14.93

X STA.        55.6       58.8       62.4       66.6       72.0       90.1
  A(I)             27.7       29.1       32.2       36.4       54.6
  V(I)            14.43      13.76      12.41      10.99       7.33
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     105.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     732.  108649.    73.    77.                        13178.
             2     831.   68439.   191.   192.                         9823.
   104.98         1563.  177088.   264.   269.  1.26    -2.   262.  19245.
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     105.

         WSEL     LEW     REW    AREA        K        Q    VEL
       104.98    -1.9   262.4  1563.3  177088.    8000.   5.12

X STA.        -1.9       19.0       25.4       30.5       35.2       39.5
  A(I)            103.6       68.0       61.1       57.5       54.0
  V(I)             3.86       5.88       6.55       6.96       7.40

X STA.        39.5       43.6       47.6       51.5       55.1       59.0
  A(I)             52.5       51.7       51.1       49.1       50.9
  V(I)             7.62       7.74       7.83       8.14       7.86

X STA.        59.0       63.0       68.7       78.1       88.7      100.4
  A(I)             51.1       63.1       75.1       81.9       85.5
  V(I)             7.83       6.33       5.32       4.88       4.68

X STA.       100.4      114.2      145.2      182.9      211.5      262.4
  A(I)             93.8      121.9      131.6      114.0      145.7
  V(I)             4.26       3.28       3.04       3.51       2.75
```

WSPRO OUTPUT FILE (continued)

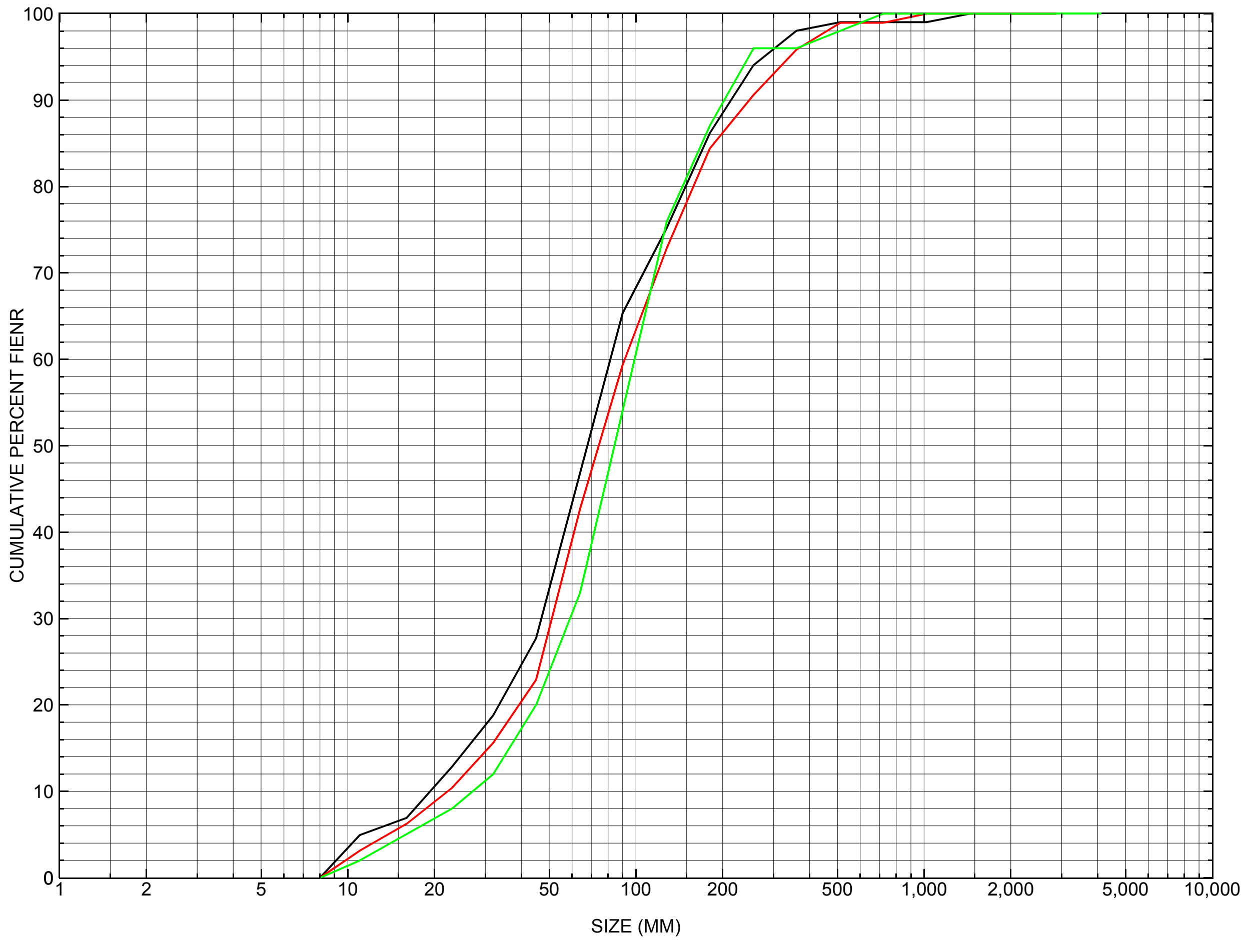
```
+++ BEGINNING PROFILE CALCULATIONS --   2
  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

 EXITX:XS   ******    -6.     730.  1.35 *****  100.43   96.52   5820.   99.08
      -142. ******   152.   72132.  1.37 ***** *******    0.76    7.97

 FULLV:FV     142.    -7.     732.  1.34  0.92  101.36 *******   5820.  100.01
         0.   142.   152.   72331.  1.37  0.00    0.01    0.76    7.95
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    0.86     100.59     100.14

  ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =    99.51     119.97    0.50

  ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =    99.51     119.97     100.14

 APPRO:AS     105.     7.     562.  1.88  0.86  102.48  100.14   5820.  100.60
       105.   105.   117.   57371.  1.13  0.27    0.00    0.86   10.35
          <<<<<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     142.    10.     456.  2.54  1.49  102.21   99.20   5820.   99.67
         0.   142.    85.   44748.  1.00  0.29    0.00    0.87   12.77

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1.   0.   1.  1.000  0.041  109.73 ****** ****** ******

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

 APPRO:AS      68.     3.     962.  0.81  0.60  103.43  100.14   5820.  102.61
       105.    75.   247.   95120.  1.43  0.62    0.01    0.64    6.05

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.315  0.098   85517.    19.    93.   102.36

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS    -142.    -6.   152.   5820.   72132.     730.    7.97   99.08
    FULLV:FV       0.    -7.   152.   5820.   72331.     732.    7.95  100.01
    BRIDG:BR       0.    10.    85.   5820.   44748.     456.   12.77   99.67
    APPRO:AS     105.     3.   247.   5820.   95120.     962.    6.05  102.61

     XSID:CODE   XLKQ   XRKQ       KQ
   SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS     96.52    0.76   88.81  106.72************  1.35  100.43   99.08
    FULLV:FV  ********    0.76   89.73  107.64  0.92  0.00  1.34  101.36  100.01
    BRIDG:BR     99.20    0.87   90.81  111.59  1.49  0.29  2.54  102.21   99.67
    APPRO:AS    100.14    0.64   91.25  119.97  0.60  0.62  0.81  103.43  102.61
   APPRO:AS      19.    93.   85517.


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

 EXITX:XS   ******   -11.     989.  1.56 *****  102.13   98.55   8000.  100.56
      -142. ******   172.   99164.  1.54 ***** *******    0.76    8.09

  ===140 AT SECID “FULLV”:  END OF CROSS SECTION EXTENDED VERTICALLY.
                              WSEL,YLT,YRT =   101.50     107.64     100.94

 FULLV:FV     142.   -11.     992.  1.56  0.92  103.06 *******   8000.  101.50
         0.   142.   172.   99505.  1.54  0.00    0.01    0.76    8.07
```

WSPRO OUTPUT FILE (continued)

```
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.10     102.08     100.73

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   101.00     119.97    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   101.00     119.97     100.73

APPRO:AS     105.     4.     829.  2.10  0.84  104.17  100.73   8000.  102.06
      105.   105.   243.   80373.  1.45  0.27   -0.01    1.10    9.65
         <<<<<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     142.    10.     539.  3.42  1.60  104.31  100.83   8000.  100.88
        0.   142.    88.   57104.  1.00  0.57    0.00    0.95   14.83

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.042  109.73 ****** ****** ******

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

APPRO:AS      68.    -2.    1564.  0.51  0.47  105.49  100.73   8000.  104.98
      105.    74.   262.  177194.  1.26  0.72    0.01    0.42    5.12

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.666  0.261  130785.    18.    96.   104.84

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -142.   -11.   172.   8000.   99164.     989.    8.09  100.56
   FULLV:FV       0.   -11.   172.   8000.   99505.     992.    8.07  101.50
   BRIDG:BR       0.    10.    88.   8000.   57104.     539.   14.83  100.88
   APPRO:AS     105.    -2.   262.   8000.  177194.    1564.    5.12  104.98

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      18.    96.  130785.
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     98.55    0.76   88.81  106.72************  1.56  102.13  100.56
   FULLV:FV  ********    0.76   89.73  107.64  0.92  0.00  1.56  103.06  101.50
   BRIDG:BR    100.83    0.95   90.81  111.59  1.60  0.57  3.42  104.31  100.88
   APPRO:AS    100.73    0.42   91.25  119.97  0.47  0.72  0.51  105.49  104.98
     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 BARTUS00050166, in Barton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BARTUS00050166

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)* 007110

Waterway *(I - 6)* Barton river

Road Name *(I - 7):* -

Route Number US 005

Vicinity *(I - 9)* 1.4 MI N JCT. VT.16

Topographic Map Orleans

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44458

Longitude *(i - 17; nnnnn.n)* 72122

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20011301661002

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0060

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000126

Average daily traffic, ADT *(I - 29; nnnnnn)* 002200

Deck Width *(I - 52; nn.n)* 350

Year of ADT *(I - 30; YY)* 92

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

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

Structure type *(I - 43; nnn)* 303

Year Reconstructed *(I - 106)* 1964

Approach span structure type *(I - 44; nnn)* 302

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.5

Number of approach spans *(I - 46; nnnn)* 0002

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

Comments:

Structural inspection report of 10/14/93 indicated a recent rehabilitation. The deck asphalt is cracked on top of both abutments with some leakage and rust of girders. There is deep spalling on the retainer wall upstream left bank. The waterway is straight through the skewed structure. The banks are well protected with riprap. The right abutment has minor cracks with some patches from previous spalling. The footings are not in view.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: -

Terrain character: -

Stream character & type: -

Streambed material: **Stones and gravel and boulders**

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)* : **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: -

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 65.18 mi^2

Lake and pond area 2.95 mi^2

Watershed storage *(ST)* 4.5 %

Bridge site elevation 876 ft

Headwater elevation 2656 ft

Main channel length 14.76 mi

10% channel length elevation 840 ft

85% channel length elevation 1632 ft

Main channel slope *(S)* 71.55 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)*: 08 / 1963

Project Number ST 41 - L Minimum channel bed elevation: 792.0

Low superstructure elevation: USLAB 809.55 DSLAB 810.40 USRAB 805.51 DSRAB 806.83

Benchmark location description:

Vermont posted benchmark on the end post of the bridge rail at the upstream right abutment end, elevation 812.05.

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

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

If 1: Footing Thickness * 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:

-

Comments:

*** Each abutment has two concrete columns set in the earth. On the right abutment the bottom of footing elevation varies from 787.25 (4 feet thick) downstream to 789.14 (2 feet thick) at the upstream column. The footing bottom elevations for the left abutment columns are both at 784.0 with a 2.5 feet thickness. The low superstructure elevations for the piers: pier 1 (left) upstream 803.61 and downstream 804.53; pier 2 (right) upstream 801.79 and downstream 802.81. The footing bottom elevation for both piers is 784.0 with a 4 feet thickness. Bridge deck low superstructure is lower at the piers to accommodate the large span beams.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MAI Date: 1/26/95
Computerized by: MAI Date: 3/14/95
Reviewd by: JDA Date: 5/9/96

Structure Number BARTUS00050166

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 10 / 19 / 1994

2. Highway District Number 09 Mile marker 007110

County ORLEANS (019) Town BARTON (03550)

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

Route Number US005 Hydrologic Unit Code: 01110000

3. Descriptive comments:

1.4 miles north of junction with VT 16

B. Bridge Deck Observations

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

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

7. Bridge length 126 *(feet)* Span length 60 *(feet)* Bridge width 35 *(feet)*

Road approach to bridge:

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

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

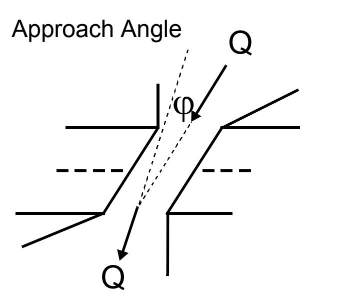
10. Embankment slope (*run / rise in feet / foot*):
US left 1.6:1 US right 2.4:1

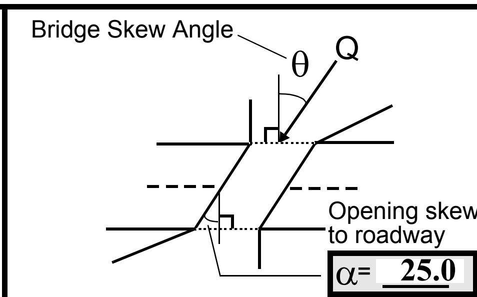
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*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: 40





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 90 feet US *(US, UB, DS)* to 55 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 0 feet DS

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

18. Level II Bridge Type: **1b**

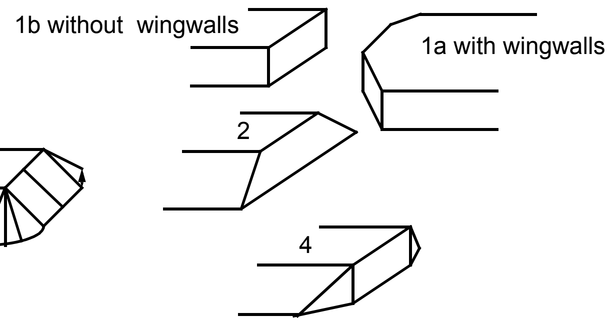
1a- Vertical abutments with wingwalls

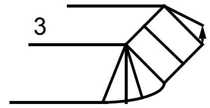
1b- Vertical abutments without wingwalls

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.)

5. Riffle is predominant in downstream section with some pooling.
7. Measured bridge length: 125, span: 60, and width: 35 feet.
17. Impact zone 2: the right bank pier is angled to flow and impacted.
18. Type 1b however Left bank upstream road embankment protection will act as wingwall thus type 1a Left 1b Right bank.
See notes and diagram on the field form.

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
156.8	3.5			3.5	3	1	134	134	1	1

23. Bank width **25.0**   24. Channel width **50.0**   25. Thalweg depth **52.5**   29. Bed Material **435**

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

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

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

28. Both banks are vertically cut from ambient to bank full height.

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: **135** 42. Cut bank extent: **230** feet **US** (*US, UB*) to **100** feet **US** (*US, UB, DS*)

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

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

43. Both banks are cut about same distance from start to end; left bank is more severely cut.

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

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

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

NO CHANNEL SCOUR

Some scour downstream of large boulders in channel about 135 and 115 ft. upstream, however should be considered as local to the boulders and not indicative of general channel conditions.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB ***** 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
34.0		**1.5**		**1**	**7**	**4**	**0**

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **90.0** 63. Bed Material **1**

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.):

435

55. * Pier acts as an abutment. No flow behind pier due to concrete road embankment protection wall (acts like a wingwall) thus for hydraulic purposes; Left bank pier should be treated as an abutment.

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

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

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

70. Debris and Ice Comments:

1

67. No debris accumulation near the bridge, upstream is laterally stable, has few cut banks, and consists of cobble material.

68. High channel gradient and span length is more than approximately 80% of the upstream bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	0	1	0	-	-	90.0
RABUT	1	0	0			1	0	123.0

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.):

-

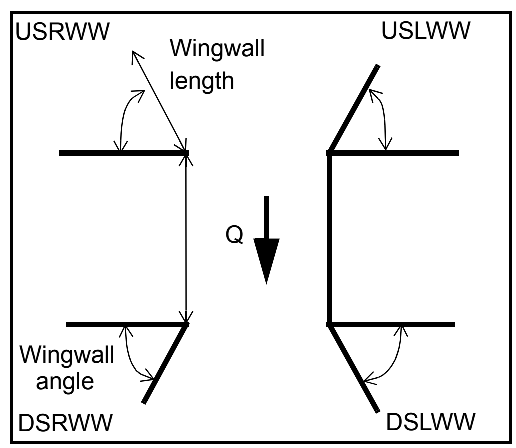
-

1

Type 1 stone fill is present along piers and extends upward toward the abutments.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						46.5	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	40.5	
DSRWW:	-		-		-	33.0	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	-	-
Condition	N	-	-	-	-	-	-	-
Extent	-	-	-	-	-	-	-	-

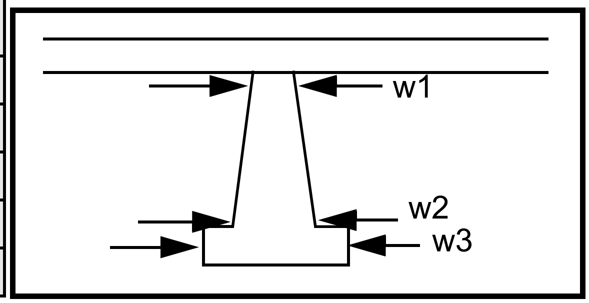
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? 79. (Y or if N type ctrl-n pr)

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	4.5	5.0	-	103.5	92.6
Pier 3	0.0	3.0	3.0	0.0	105.5	93.5
Pier 4	0.0	-	-	0.0	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	USL	pier.	exce	d. It	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	WW	Esse	pt at	is	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	not	ntiall	stage	not a	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	attac	y the	s just	wing	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	hed	wall	belo	wall;	*Y- yes; N- no*
91. Attack ∠ (BF)	to	bloc	w	but	
92. Pushed	the	ks	the	'hyd	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	abut	flow	cen-	rau-	
95. Cross-members	ment	from	ter	licall	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	but	the	span	y'	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	to	abut	low	this	
98. Exposure depth	the	ment	chor	acts	

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

as a wingwall. The wall should also be called bank protection. Also, there is type 1 protection along the base length of both piers on the channel sides and in between columns on the left pier.

Y

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
-	**-**			**-**	**LB**	**2**	**2**	**2**	**N**	**0**

Bank width (BF) **-** Channel width (Amb) **34.9** Thalweg depth (Amb) **34.9** Bed Material **0**

Bank protection type (Qmax): LB **2*** RB **1** Bank protection condition: LB **0** 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.):

-
RB
1
2
2
N
25
RB
-
-
1
0.5
-

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? **94.** *(Y or if N type ctrl-n cb)* Where? **Pier** *(LB or RB)* Mid-bank distance: **1: ***

Cut bank extent: **Two** feet **con** *(US, UB, DS)* to **crete** feet **col-** *(US, UB, DS)*

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

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

ns form the pier with a cross member along the top most part of the pier; see photo 15.
See notes and diagram on field form for further dimensions of the piers.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned **4** %LB to **4** %RB

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

234
234
2
1

Are there major confluences? **43** *(Y or if N type ctrl-n mc)* How many? **5**

Confluence 1: Distance **0** Enters on **0** *(LB or RB)* Type **-** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

protection is present but appears to be natural. Ranges from classes 4 to 5 along both banks.
Bed material near the bridge is riffle cobble to boulder; near the bend is pooled silt/ clay to sand; at the bend

F. Geomorphic Channel Assessment

107. Stage of reach evolution **is**

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)*:

riffle with cobble material.

109. G. Plan View Sketch

142 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: BARTUS00050166 Town: Barton
Road Number: US 5 County: Orleans
Stream: Barton River

Initials JDA Date: 4/22/96 Checked: SAO

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	5820	8000	0
Main Channel Area, ft2	565	732	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	396	831	0
Top width main channel, ft	68	73	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	176	191	0
D50 of channel, ft	0.248	0.248	0.248
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	8.3	10.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	2.3	4.4	ERR
Total conveyance, approach	95031	177088	0
Conveyance, main channel	73974	108649	0
Conveyance, LOB	0	0	0
Conveyance, ROB	21057	68439	0
Percent discrepancy, conveyeance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	4530.4	4908.2	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	1289.6	3091.8	ERR
Vm, mean velocity MC, ft/s	8.0	6.7	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	3.3	3.7	ERR
Vc-m, crit. velocity, MC, ft/s	10.0	10.3	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	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

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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	565	732	0
Main channel width, ft	68	73	0
y1, main channel depth, ft	8.31	10.03	ERR

Bridge Section			
(Q) total discharge, cfs	5820	8000	0
(Q) discharge thru bridge, cfs	5820	8000	
Main channel conveyance	44723	57069	
Total conveyance	44723	57069	
Q2, bridge MC discharge,cfs	5820	8000	ERR
Main channel area, ft2	455	539	0
Main channel width (skewed), ft	67.6	70.7	0.0
Cum. width of piers in MC, ft	3.0	3.0	0.0
W, adjusted width, ft	64.6	67.7	0
y_bridge (avg. depth at br.), ft	7.05	7.96	ERR
Dm, median (1.25*D50), ft	0.31	0.31	0.31
y2, depth in contraction,ft	8.19	10.34	ERR
ys, scour depth (y2-ybridge), ft	1.14	2.37	N/A

ARMORING			
D90	0.713	0.713	
D95	0.9829	0.9829	
Critical grain size,Dc, ft	0.7307	0.9362	ERR
Decimal-percent coarser than Dc	0.095	0.054	
Depth to armoring,ft	20.88	49.20	ERR

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)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	5820	8000	0	5820	8000	0
a', abut.length blocking flow, ft	7.6	12.1	0	168.7	181.5	0
Ae, area of blocked flow ft2	29.16	59.98	0	357	752.8	0
Qe, discharge blocked abut.,cfs	129.33	231.58	0	1109	2694	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	4.44	3.86	ERR	3.11	3.58	ERR
ya, depth of f/p flow, ft	3.84	4.96	ERR	2.12	4.15	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.55	0.55	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	65	65	0	115	115	0
K2	0.96	0.96	0.00	1.03	1.03	0.00
Fr, froude number f/p flow	0.399	0.306	ERR	0.376	0.310	ERR
ys, scour depth, ft	9.08	11.26	N/A	11.99	17.43	N/A

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)	7.6	12.1	0	168.7	181.5	0
y1 (depth f/p flow, ft)	3.84	4.96	ERR	2.12	4.15	ERR
a'/y1	1.98	2.44	ERR	79.72	43.76	ERR
Froude no. f/p flow	0.40	0.31	N/A	0.38	0.31	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	11.15	20.49	ERR
vertical w/ ww's	ERR	ERR	ERR	9.14	16.80	ERR
spill-through	ERR	ERR	ERR	6.13	11.27	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.87	0.95		0.87	0.95	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.05	7.96		7.05	7.96	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.84	3.28	ERR	2.84	3.28	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (spillthrough abut.)	2.51	2.90	ERR	2.51	2.90	ERR

Pier Scour(both live-bed and clear water scour)

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	65.4	65.4	0
Area of WSPRO flow tube, ft2	20.3	24.1	0
Skewed width of flow tube, ft	2.2	2.3	0
y1, pier approach depth, ft	9.23	10.48	ERR
y1 in meters	2.812	3.194	N/A
V1, pier approach velocity, ft/s	14.4	16.63	0
a, pier width, ft	3	3	0

L, pier length, ft	35	35	0
Fr1, Froude number at pier	0.835	0.905	ERR
Pier attack angle, degrees	25	25	0
K1, shape factor	1.1	1.1	0
K2, attack factor	3.147866	3.147866	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.2482	0.2482	0
D50, m	0.075648	0.075648	0
D90, ft	0.713	0.713	0
D90, m	0.217312	0.217312	0
Vc50,critical velocity(D50),m/s	3.110	3.177	N/A
Vc90,critical velocity(D90),m/s	4.421	4.516	N/A
Vi,incipient velocity,m/s	1.758	1.796	ERR
Vr, velocity ratio	0.988	1.203	ERR
K4, armor factor	1.00	0.98	N/A
ys, scour depth (K4 applicable), ft	31.34	33.29	ERR

Pier rip-rap sizing

D50=0.692(K*V)^2/(Ss-1)*2*g

(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.7	1.7	0
V, char. aver. velocity, ft/s	10.5	12.2	0
D50, median stone diameter, ft	2.07	2.80	0.00