LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (JAY-TH00230013) on TOWN HIGHWAY 23, crossing the JAY BRANCH of the MISSISQUOI RIVER, JAY, VERMONT

U.S. Geological Survey
Open-File Report 98-059

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and

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

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (JAY-TH00230013) on TOWN HIGHWAY 23, crossing the JAY BRANCH of the MISSISQUOI RIVER, JAY, VERMONT

By ERICK M. BOEHMLER AND LAURA MEDALIE

U.S. Geological Survey
Open-File Report 98-059

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

Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting 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
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (JAY-TH00230013) ON TOWN HIGHWAY 23, CROSSING THE JAY BRANCH OF THE MISSISQUOI RIVER, JAY, VERMONT

By **Erick M. Boehmler and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure JAY-TH00230013 on Town Highway 23 crossing the Jay Branch of the Missisquoi River, Jay, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in northern Vermont. The 8.63-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly forest. The forest is divided by an open area of short grass and a house on the right bank upstream.

In the study area, the Jay Branch of the Missisquoi River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 39 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 48.9 mm (0.160 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 6, 1995, indicated that the reach was stable.

The Town Highway 23 crossing of the Jay Branch of the Missisquoi River is a 38-ft-long, one-lane bridge consisting of one 36-foot steel pony-truss span (Vermont Agency of Transportation, written communication, March 6, 1995). The opening length of the structure parallel to the bridge face is 34.0 feet. The bridge is supported by vertical, concrete abutments with one concrete wingwall at the upstream end of the right abutment. The channel is skewed approximately 10 degrees to the opening. VTAOT records indicate the opening-skew-to-roadway is zero degrees but 5 degrees was computed from surveyed points.

The scour protection measures at the site were type-1 stone fill (less than 12 inches diameter) on the roadway embankments and the upstream left wingwall, type-2 stone fill (less than 36 inches diameter) on the left abutment, and type-3 stone fill (less than 48 inches diameter) on the upstream right wingwall and the upstream quarter of the right abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 1.5 to 1.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.2 to 10.5 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number JAY-TH00230013 ***Stream*** Jay Branch of the Missisquoi River

County Orleans ***Road*** TH 23 ***District*** 9

Description of Bridge

Bridge length 38 ***ft*** ***Bridge width*** 13.9 ***ft*** ***Max span length*** 36 ***ft***

Alignment of bridge to road (on curve or straight) Slight curve right

Abutment type Vertical, concrete ***Embankment type*** None, left; sloping, right

Stone fill on abutment? Yes ***Date of inspection*** 6/6/95

Description of stone fill Type-1 on the upstream left wingwall, type-2 on the left abutment, and type-3 on the upstream right wingwall and upstream one-quarter of the right abutment.

The abutments and wingwalls are concrete.

Yes

10 Yes

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

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	6/6/95	0	0
Level II	6/6/95	0	0

Potential for debris Moderate. While there is significant vegetation growth on the banks, the channel is laterally stable.

Describe any features near or at the bridge that may affect flow (include observation date) There are large boulders across the channel immediately downstream of the bridge that form a drop-structure-like feature with a 3 foot deep scour hole immediately downstream of this feature noted in the assessment of 6/6/95.

Description of the Geomorphic Setting

General topography The channel is located in a high relief valley setting with no flood plain and steep valley walls on both sides.

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

Date of inspection 6/6/95

DS left: Moderately sloping channel bank and the VT 242 roadway on the over-bank.

DS right: Steep channel bank to a narrow, irregular overbank.

US left: Extremely steep channel bank and the VT 242 roadway on the over-bank.

US right: Extremely steep channel bank to a narrow, slightly irregular over-bank.

Description of the Channel

Average top width 39 ft ***Average depth*** 5 ft

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

Perennial, incised and sinuous with non-alluvial channel boundaries.

6/6/95

Vegetative co Grass and trees.

DS left: Trees.

DS right: Trees.

US left: Trees.

US right:

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

There were none indicated in the assessment of 6/6/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.63 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

-

-

Calculated Discharges

Q100 1,700 ***ft³/s*** ***Q500*** 2,050 ***ft³/s***

The 100- and 500-year discharges are based on discharge-frequency values available in the VTAOT database (written communication, VTAOT, May 1995) for bridge 11 in Jay over a tributary to Jay Branch adjusted by drainage area relationship [(8.63/4.3)exp 0.67] and those computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957; and Talbot, 1887). Each discharge frequency curve was extrapolated to the 500-year event and the median discharge from the range defined by the curves was selected for the hydraulic analyses.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the concrete at the downstream end of the left abutment (elev. 499.35 feet, arbitrary survey datum). RM2 is a chiseled "X" on top of the concrete at the upstream end of the right abutment (elev. 499.82 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-50	1	Second exit section.
EXIT1	-20	1	First exit section.
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	52	2	Modelled Approach section (Templated from APTEM)
APTEM	59	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 analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.055, and overbank "n" values ranged from 0.035 to 0.060.

Normal depth at the second section surveyed downstream of this site (EXIT2) 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 0.0108 ft/ft, which was computed from the surveyed channel points downstream of the site.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0243 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 location also provides a consistent method for determining scour variables.

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be assumed that the water surface profile falls through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.2 ***ft***
Average low steel elevation 497.2 ***ft***

100-year discharge 1,700 ***ft³/s***
Water-surface elevation in bridge opening 491.7 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 142 ***ft²***
Average velocity in bridge opening 12.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 494.1
Water-surface elevation at Approach section without bridge 491.3
Amount of backwater caused by bridge 2.8 ***ft***

500-year discharge 2,050 ***ft³/s***
Water-surface elevation in bridge opening 492.3 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 162 ***ft²***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.2 ***/s***

Water-surface elevation at Approach section with bridge 494.9
Water-surface elevation at Approach section without bridge 491.9
Amount of backwater caused by bridge 3.0 ***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 --
Water-surface elevation at Approach section without bridge --
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 Davis, 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 the scour depths are presented graphically in figure 8.

Contraction scour for each modeled discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.5	1.9	--
Depth to armoring	25.0	29.9	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	8.7	10.5	--
Left abutment	6.2	6.6	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.9	2.1	--
Left abutment	1.9	2.1	--
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

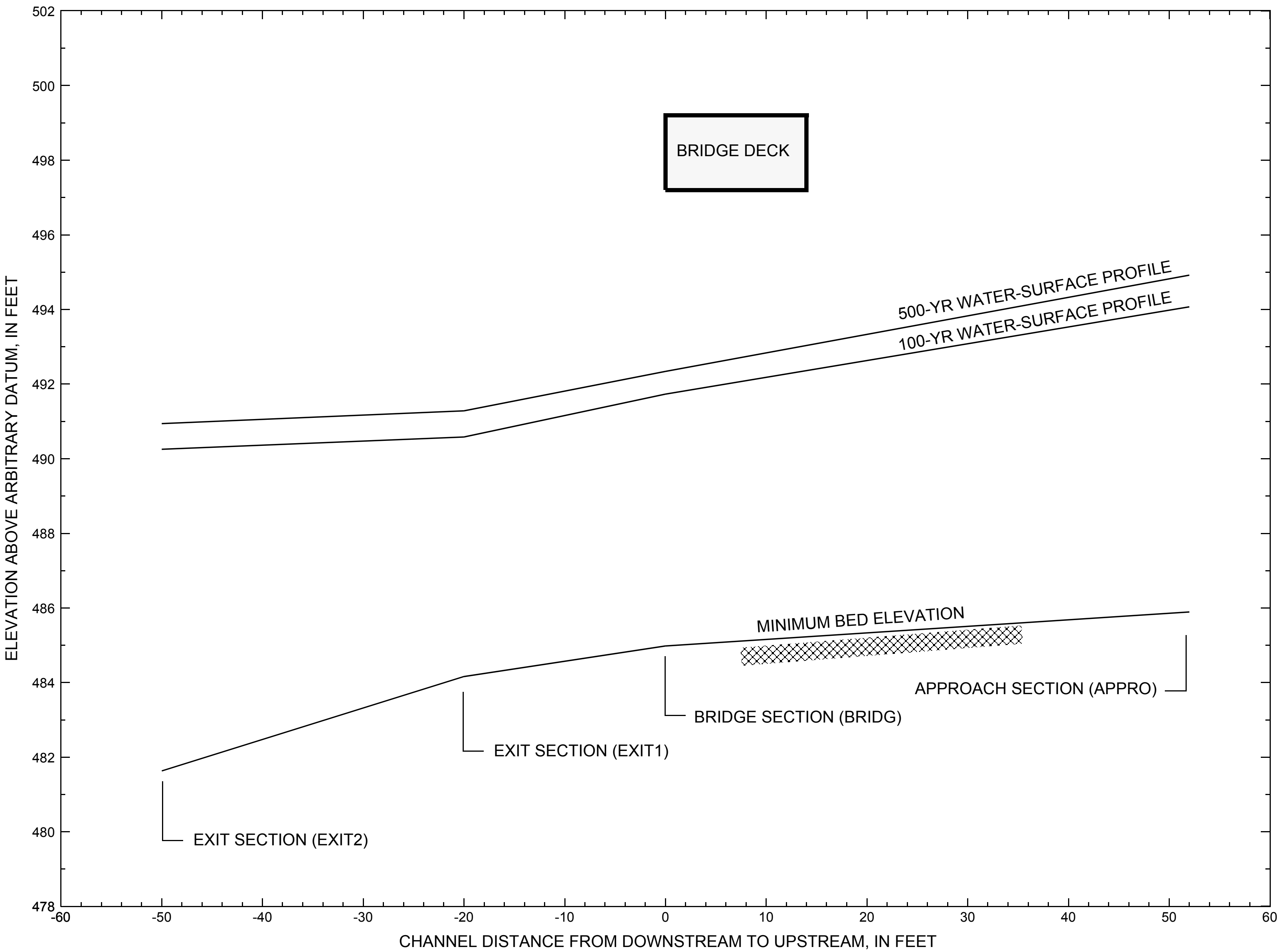


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure JAY-TH00230013 on Town Highway 23, crossing the Jay Branch of the Missisquoi River, Jay, Vermont.

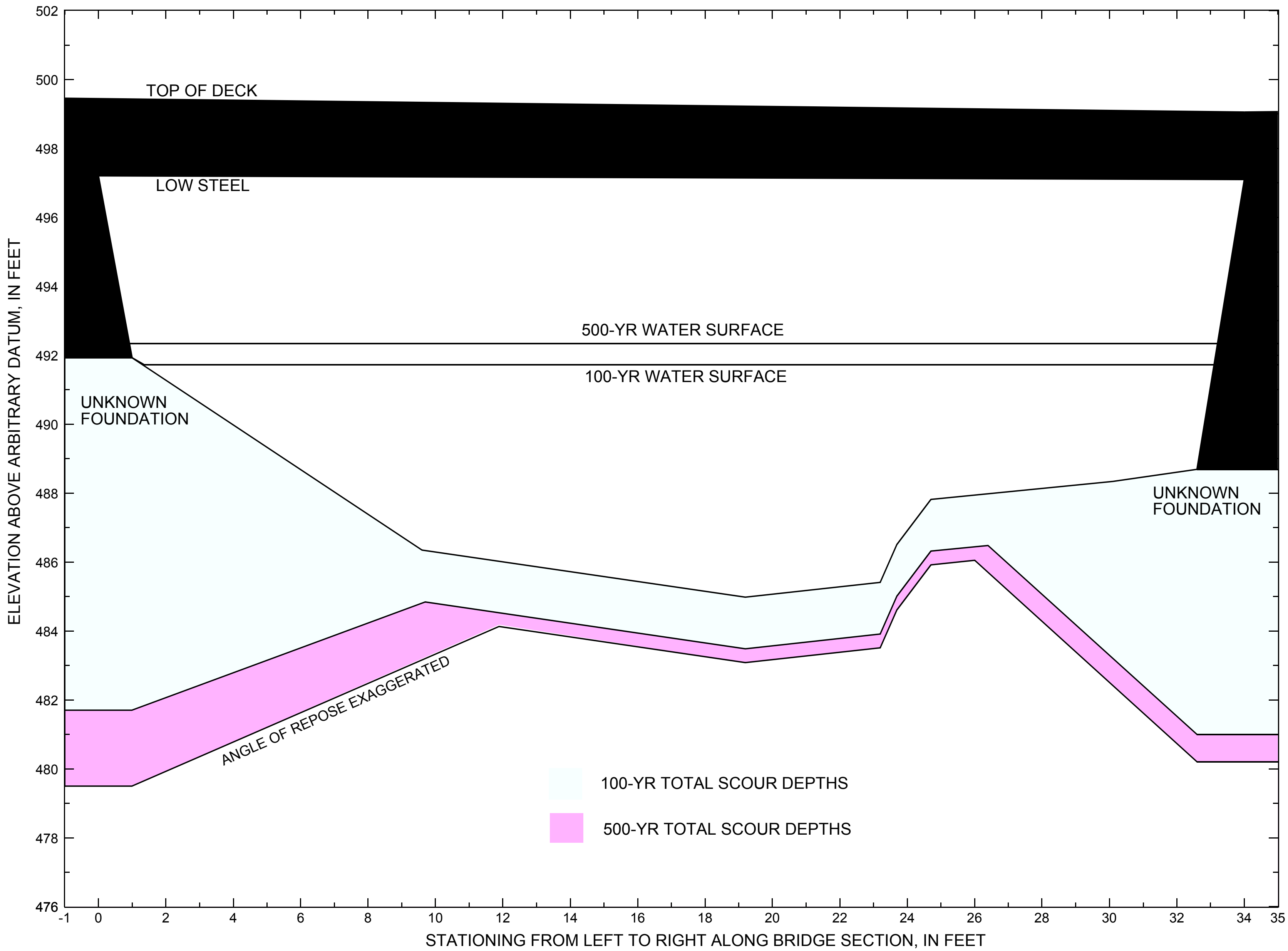


Figure 8. Scour elevations for the 100- and 500-yr discharges at structure JAY-TH00230013 on Town Highway 23, crossing the Jay Branch of the Missisquoi River, Jay, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure JAY-TH00230013 on Town Highway 23, crossing the Jay Branch of the Missisquoi River, Jay, 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/pile 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-year discharge is 1,700 cubic-feet per second											
Left abutment	0.0	--	497.2	--	491.9	1.5	8.7	--	10.2	481.7	--
Right abutment	34.0	--	497.1	--	488.7	1.5	6.2	--	7.7	481.0	--

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 JAY-TH00230013 on Town Highway 23, crossing the Jay Branch of the Missisquoi River, Jay, 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/pile 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-year discharge is 2,050 cubic-feet per second											
Left abutment	0.0	--	497.2	--	491.9	1.9	10.5	--	12.4	479.5	--
Right abutment	34.0	--	497.1	--	488.7	1.9	6.6	--	8.5	480.2	--

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.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File test.wsp
T2        Hydraulic analysis for structure JAY-TH00230013   Date: 14-APR-97
T3        Town Highway 23 over Jay Branch Missisquoi River in Jay, VT     EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1700.0   2050.0
SK          0.0108   0.0108
*
XS   EXIT2    -50
GR          -23.7, 495.27     -7.5, 489.85      0.0, 488.90      8.4, 486.47
GR            8.8, 483.86      8.9, 481.63     18.6, 482.59     24.3, 482.58
GR           30.2, 483.87     37.2, 486.34     37.7, 491.65     97.7, 491.65
*
N           0.055        0.060
SA                  37.7
*
XS   EXIT1    -20
GR          -16.9, 496.60    -15.0, 495.45     -5.4, 490.05      0.0, 485.80
GR            9.2, 485.47     18.4, 484.27     27.3, 484.16     34.9, 485.39
GR           50.1, 496.34
N           0.055
*
XS   FULLV      0  * * *   0.03
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.16       5.0
GR            0.0, 497.21      1.0, 491.93      9.6, 486.35     19.2, 484.98
GR           23.2, 485.41     23.7, 486.52     24.7, 487.82     30.1, 488.34
GR           32.6, 488.69     34.0, 497.10      0.0, 497.21
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      19.8 * *    20        5.0
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      14.0     2
GR          -24.8, 501.05      0.0, 499.45     35.3, 499.06     67.3, 497.23
GR          110.0, 497.37
*
*             0.0, 499.40      5.2, 503.28     33.5, 502.87     39.2, 498.26
*
XT   APTEM     59
GR          -35.4, 503.59    -14.2, 493.82      0.0, 490.69      1.1, 487.34
GR            8.6, 486.06     22.4, 486.73     31.6, 487.25     32.8, 490.96
GR           36.8, 493.79     87.1, 496.29    101.0, 497.17
*
AS   APPRO     52
GT             -0.17
N           0.055        0.035
SA                  36.8
*
HP 1 BRIDG 491.73 1 491.73
HP 2 BRIDG 491.73 * * 1700
HP 1 APPRO 494.07 1 494.07
HP 2 APPRO 494.07 * * 1700
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure JAY-TH00230013   Date: 14-APR-97
       Town Highway 23 over Jay Branch Missisquoi River in Jay, VT     EMB
          *** RUN DATE & TIME: 12-15-97  13:02

   CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     142.  12890.    32.    37.                        1708.
  491.73          142.  12890.    32.    37.  1.00     1.    33.   1708.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      491.73     1.3    33.1   142.1   12890.    1700.  11.96

X STA.        1.3        8.9       10.1       11.2       12.2       13.1
  A(I)           18.8        6.1        5.8        5.7        5.6
  V(I)           4.52      14.00      14.54      14.83      15.24

X STA.       13.1       14.1       15.0       15.9       16.8       17.6
  A(I)            5.6        5.6        5.5        5.6        5.6
  V(I)          15.06      15.27      15.46      15.10      15.27

X STA.       17.6       18.5       19.3       20.1       20.9       21.7
  A(I)            5.5        5.4        5.3        5.4        5.3
  V(I)          15.56      15.78      15.91      15.87      16.16

X STA.       21.7       22.5       23.8       25.8       27.8       33.1
  A(I)            5.4        7.4        8.5        7.3       16.8
  V(I)          15.73      11.56      10.05      11.61       5.05

   CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      52.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     279.  21447.    52.    59.                        3675.
            2       2.     32.     9.     9.                           5.
  494.07          281.  21479.    61.    68.  1.01   -15.    46.   3411.

   VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      52.

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.07   -15.1    45.9   281.3   21479.    1700.   6.04

X STA.      -15.1        4.1        5.4        6.8        8.1        9.4
  A(I)           55.3       10.4       10.4       10.5       10.4
  V(I)           1.54       8.17       8.16       8.12       8.19

X STA.        9.4       10.6       11.9       13.2       14.6       15.9
  A(I)           10.3       10.3       10.6       10.4       10.3
  V(I)           8.27       8.22       8.05       8.21       8.28

X STA.       15.9       17.2       18.7       20.2       21.7       23.1
  A(I)           10.8       11.4       11.1       11.3       11.1
  V(I)           7.88       7.47       7.68       7.50       7.66

X STA.       23.1       24.6       26.1       27.7       29.3       45.9
  A(I)           11.2       10.9       11.4       11.3       32.1
  V(I)           7.58       7.80       7.45       7.55       2.65
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure JAY-TH00230013   Date: 14-APR-97
        Town Highway 23 over Jay Branch Missisquoi River in Jay, VT     EMB
           *** RUN DATE & TIME: 12-15-97  13:02

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     162.  15589.    32.    39.                        2056.
   492.34          162.  15589.    32.    39.  1.00     1.    33.   2056.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.34     0.9    33.2   161.6   15589.    2050.  12.68

X STA.         0.9        8.5        9.8       10.9       11.9       12.9
  A(I)            21.1        7.5        6.5        6.4        6.4
  V(I)            4.85      13.76      15.84      16.08      16.07

X STA.        12.9       13.9       14.8       15.8       16.7       17.6
  A(I)             6.5        6.4        6.3        6.4        6.3
  V(I)           15.89      16.13      16.35      15.98      16.18

X STA.        17.6       18.5       19.3       20.1       21.0       21.8
  A(I)             6.2        6.1        6.1        6.1        6.1
  V(I)           16.48      16.72      16.87      16.82      16.71

X STA.        21.8       22.7       24.2       26.1       28.0       33.2
  A(I)             6.0        9.2        8.8        8.0       19.4
  V(I)           17.03      11.15      11.68      12.85       5.29

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      52.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     324.  26879.    54.    61.                        4517.
             2      17.    543.    26.    26.                          78.
   494.92          341.  27422.    80.    87.  1.05   -17.    63.   3911.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      52.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.92   -17.0    63.0   341.2   27422.    2050.   6.01

X STA.       -17.0        3.2        4.8        6.2        7.6        9.0
  A(I)            65.4       12.7       12.2       12.6       12.2
  V(I)            1.57       8.08       8.37       8.11       8.40

X STA.         9.0       10.4       11.7       13.2       14.6       15.9
  A(I)            12.2       12.4       12.4       12.6       11.7
  V(I)            8.43       8.25       8.25       8.16       8.75

X STA.        15.9       17.4       19.0       20.5       22.1       23.7
  A(I)            12.8       13.5       13.2       13.5       13.2
  V(I)            7.99       7.57       7.79       7.60       7.76

X STA.        23.7       25.3       26.9       28.6       30.3       63.0
  A(I)            13.0       13.3       13.1       13.4       45.6
  V(I)            7.89       7.69       7.80       7.67       2.25
```

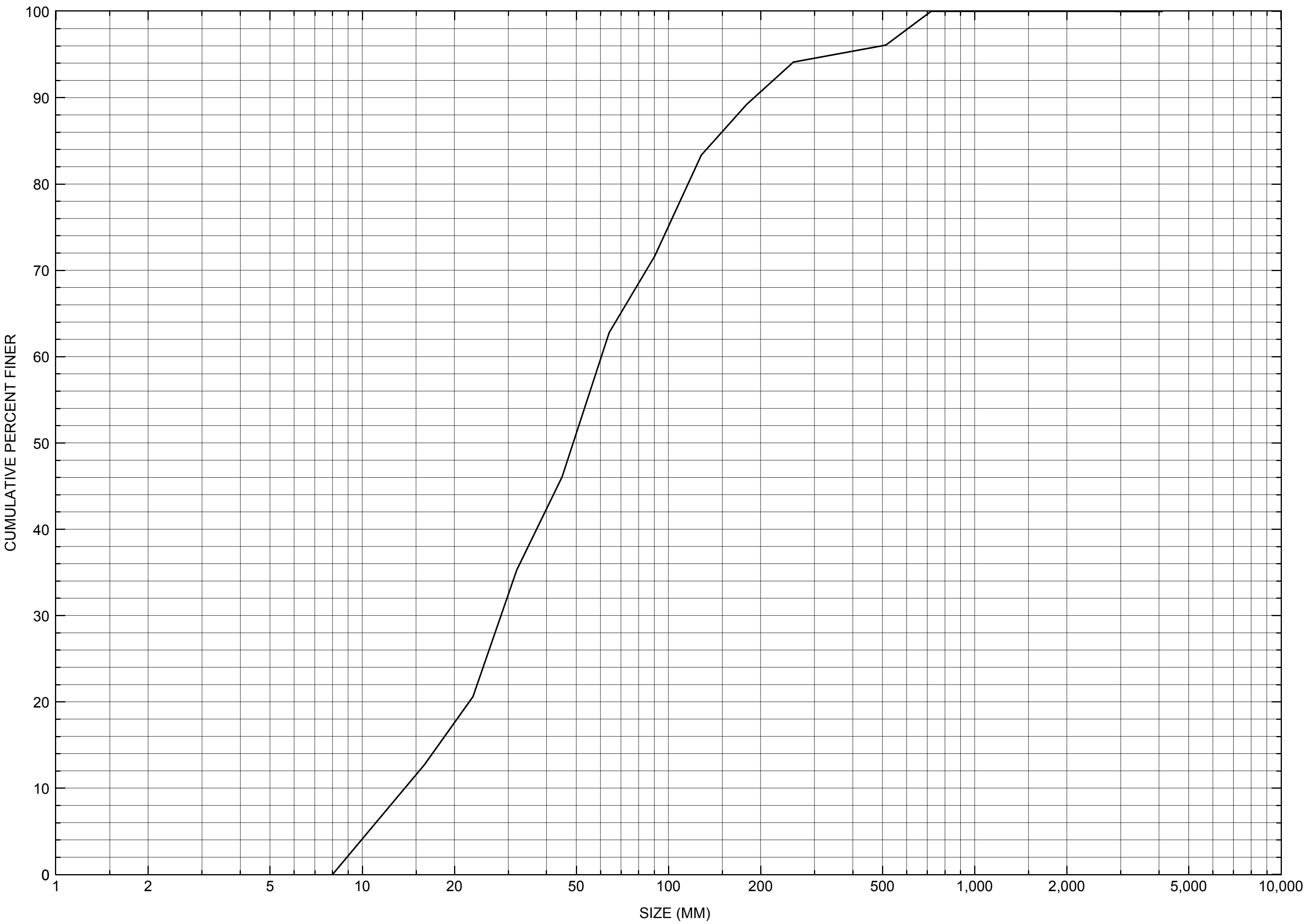
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure JAY-TH00230013   Date: 14-APR-97
        Town Highway 23 over Jay Branch Missisquoi River in Jay, VT     EMB
           *** RUN DATE & TIME: 12-15-97  13:02

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

EXIT2:XS   ******    -9.     232.  0.84 *****  491.08  488.12   1700.  490.25
      -50. ******    38.   16343.  1.00 ***** *******    0.58    7.33

EXIT1:XS      30.    -6.     232.  0.83  0.31  491.41 *******   1700.  490.58
      -20.    30.    42.   17057.  1.00  0.00    0.02    0.59    7.33

FULLV:FV      20.    -5.     209.  1.03  0.23  491.73 *******   1700.  490.70
        0.    20.    41.   14696.  1.00  0.10   -0.01    0.68    8.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     491.30     491.13

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.20     503.42    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.20     503.42     491.13

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.67

APPRO:AS      52.    -4.     154.  1.89  1.04  493.19  491.13   1700.  491.30
       52.    52.    34.    9856.  1.00  0.43    0.00    0.95   11.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1700.     491.73

            <<<<<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      20.     1.     142.  2.23 *****  493.96  491.73   1700.  491.73
        0.    20.    33.   12883.  1.00 ***** *******    1.00   11.97

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.16 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      32.   -15.     282.  0.57  0.34  494.65  491.13   1700.  494.07
       52.    33.    46.   21499.  1.01  0.34    0.00    0.50    6.04

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.190  0.000   23386.     0.    31.   493.84

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS      -50.    -9.    38.   1700.   16343.     232.    7.33  490.25
   EXIT1:XS      -20.    -6.    42.   1700.   17057.     232.    7.33  490.58
   FULLV:FV        0.    -5.    41.   1700.   14696.     209.    8.12  490.70
   BRIDG:BR        0.     1.    33.   1700.   12883.     142.   11.97  491.73
   RDWAY:RG        9.**************      0.******************    2.00********
   APPRO:AS       52.   -15.    46.   1700.   21499.     282.    6.04  494.07

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    31.   23386.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    488.12    0.58  481.63  495.27************  0.84  491.08  490.25
   EXIT1:XS  ********    0.59  484.16  496.60  0.31  0.00  0.83  491.41  490.58
   FULLV:FV  ********    0.68  484.76  497.20  0.23  0.10  1.03  491.73  490.70
   BRIDG:BR    491.73    1.00  484.98  497.21************  2.23  493.96  491.73
   RDWAY:RG ***************  497.23  501.05*********************************
   APPRO:AS    491.13    0.50  485.89  503.42  0.34  0.34  0.57  494.65  494.07
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure JAY-TH00230013   Date: 14-APR-97
        Town Highway 23 over Jay Branch Missisquoi River in Jay, VT     EMB
           *** RUN DATE & TIME: 12-15-97  13:02

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

EXIT2:XS   ******   -11.     265.  0.93 *****  491.88  488.77   2050.  490.94
      -50. ******    38.   19711.  1.00 ***** *******    0.58    7.74

EXIT1:XS      30.    -8.     267.  0.92  0.31  492.20 *******   2050.  491.28
      -20.    30.    43.   20841.  1.00  0.00    0.02    0.59    7.68

FULLV:FV      20.    -7.     243.  1.11  0.22  492.51 *******   2050.  491.40
        0.    20.    42.   18186.  1.00  0.10   -0.01    0.67    8.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.96     491.94     491.81

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.90     503.42    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.90     503.42     491.81

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.65

APPRO:AS      52.    -6.     179.  2.04  1.01  493.98  491.81   2050.  491.94
       52.    52.    34.   11890.  1.00  0.46    0.00    0.96   11.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2050.     492.34

            <<<<<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      20.     1.     162.  2.50 *****  494.84  492.34   2050.  492.34
        0.    20.    33.   15598.  1.00 ***** *******    1.00   12.68

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      32.   -17.     341.  0.59  0.32  495.51  491.81   2050.  494.92
       52.    33.    63.   27421.  1.05  0.34   -0.01    0.52    6.01

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.236  0.000   28113.    -1.    32.   494.71

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXIT2:XS     -50.   -11.    38.   2050.   19711.     265.    7.74  490.94
   EXIT1:XS     -20.    -8.    43.   2050.   20841.     267.    7.68  491.28
   FULLV:FV       0.    -7.    42.   2050.   18186.     243.    8.45  491.40
   BRIDG:BR       0.     1.    33.   2050.   15598.     162.   12.68  492.34
   RDWAY:RG       9.**************      0.******************    2.00********
   APPRO:AS      52.   -17.    63.   2050.   27421.     341.    6.01  494.92

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    32.   28113.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT2:XS    488.77    0.58  481.63  495.27************  0.93  491.88  490.94
   EXIT1:XS  ********    0.59  484.16  496.60  0.31  0.00  0.92  492.20  491.28
   FULLV:FV  ********    0.67  484.76  497.20  0.22  0.10  1.11  492.51  491.40
   BRIDG:BR    492.34    1.00  484.98  497.21************  2.50  494.84  492.34
   RDWAY:RG  ****************  497.23  501.05**********************************
   APPRO:AS    491.81    0.52  485.89  503.42  0.32  0.34  0.59  495.51  494.92
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure JAY-TH00230013, in Jay, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number JAY-TH00230013

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 06 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 36325

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

Waterway *(I - 6)* Jay Branch Missisquoi River

Road Name *(I - 7):* -

Route Number TH023

Vicinity *(I - 9)* 0.01 MI TO JCT W VT242

Topographic Map North.Troy

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44564

Longitude *(i - 17; nnnnn.n)* 72276

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101200131012

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

Maximum span length *(I - 48; nnnn)* 0036

Year built *(I - 27; YYYY)* 1955

Structure length *(I - 49; nnnnnn)* 000038

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 139

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

Channel & Protection *(I - 61; n)* 8

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

Waterway adequacy *(I - 71; n)* 5

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

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*) -

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

Vertical clearance from streambed (*nnn.n ft*) 11.0

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

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

Comments:

The structural inspection report of 6/1/93 indicates the structure is a steel stringer type bridge with a timber deck. Both abutments are concrete, which has some minor cracks reported. The left abutment concrete has some minor spalling located half-way up the wall at the upstream end. The right abutment has a new concrete subfooting reported, which was constructed since the last inspection. The report indicates that the footing appears to be holding up well aside from some minor undermining at the downstream end. The streambed consists of large boulders. Some free-poured concrete is noted on the streambed at left abutment. The waterway makes a slight turn into structure. The streambed **(Continued, page 31)**

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: Stone and gravel, numerous large 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)* : - Debris *(Heavy, Moderate, Light)*: -

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

makes a 4 foot drop at the upstream face, which the report indicates may be from contraction scour. The right abutment subfooting concrete has minor voids reported below it. No apparent settlement is noted. Streambank erosion is noted as minor. The waterway opening is constricted.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.63** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1096** ft Headwater elevation **3858** ft

Main channel length **4.32** mi

10% channel length elevation **1181** ft 85% channel length elevation **2146** ft

Main channel slope *(S)* **297.49** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 04/09/96
Computerized by: EW Date: 04/10/96
Reviewd by: EMB Date: 10/7/97

Structure Number JAY-TH00230013

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE   Date *(MM/DD/YY)* 06 / 06 / 1995
2. Highway District Number 09   Mile marker 000000
County ORLEANS (019)   Town JAY (36325)
Waterway *(I - 6)* Jay Branch of the Missisquoi River   Road Name LUCIER FARM ROAD
Route Number TH023   Hydrologic Unit Code: 02010007
3. Descriptive comments:
Located 0.01 mile from the intersection of Town Highway 23 with State Route 242.

B. Bridge Deck Observations

4. Surface cover... LBUS 6   RBUS 6   LBDS 6   RBDS 6   Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2   UB 1   DS 2   *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 38 *(feet)*   Span length 36 *(feet)*   Bridge width 13.9 *(feet)*

Road approach to bridge:

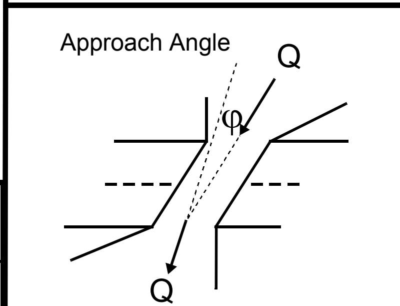
8. LB 2+ RB 1- *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

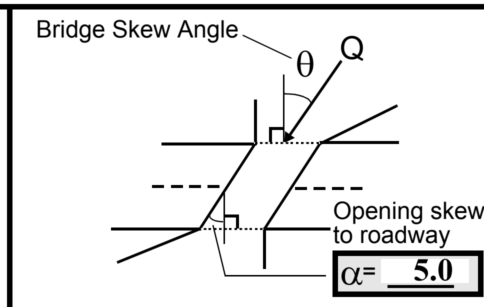
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	3	3	1
RBUS	1	3	3	1
RBDS	1	3	3	1
LBDS	1	3	3	1

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? RB *(LB, RB)*   Severity 1
Range? 15 feet US *(US, UB, DS)* to 150 feet US
Channel impact zone 2:   Exist? Y *(Y or N)*
Where? RB *(LB, RB)*   Severity 2
Range? 25 feet DS *(US, UB, DS)* to 100 feet DS
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: 1a

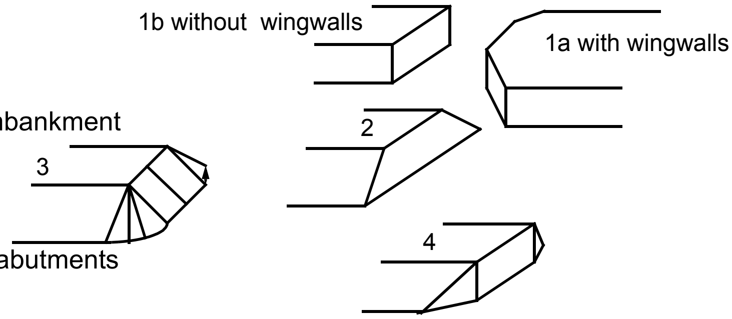
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The surface cover on the left overbank upstream and downstream is forest, which is divided by the State Route 242 roadway. The right overbank downstream is completely forest. There is a dirt road and a house with a grass covered yard on the right overbank upstream with forest adjacent to the yard.
There is an additional impact zone upstream along the left bank from 120 feet US to 25 feet US. At the DS impact zone, three trees are leaning toward the channel almost horizontally.
The opening has a five-foot-long wingwall on the right side and a 2 foot long wingwall on the left. There is minimal stone-fill protection at end of each wingwall. Protection on the downstream right road embankment consists of about 12 large stone slabs and roadway fill. Roadway fill was dumped down the downstream left road embankment to VT242.

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
46.0	3.5			3.5	4	4	453	453	1	1

23. Bank width 65.0 24. Channel width 75.0 25. Thalweg depth 33.0 29. Bed Material 453

30 .Bank protection type: LB 0 RB 5 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 right bank protection is a mortared-stone retaining wall, which extends from 200 feet upstream to about 150 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 60 35. Mid-bar width: 6

36. Point bar extent: 40 feet US (US, UB) to 80 feet US (US, UB, DS) positioned 40 %LB to 60 %RB

37. Material: 543

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

This is a mid-channel bar, which is not vegetated.

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

41. Mid-bank distance: 75 42. Cut bank extent: 15 feet US (US, UB) to 150 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.):

An additional less severe cut-bank exists on LB. It is stabilized by natural boulders in bank. It extends from 25 feet US to 120 feet US.

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 250 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):

This is an unnamed tributary.

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
30.5		1.0		2	7	7	-

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

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

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

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

453

Four large boulders protect the right abutment footing at the US end.

The channel narrows and the flow deepens considerably under bridge.

Some free-poured concrete extends from the edge of the left abutment footing down to water elevation.

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

Constricted opening at BF; water flows through in about 1/2 or less width of average channel for both US and DS sections. However, moderate gradient and banks look stable.

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	65	2	2	-	2.5	90.0
RABUT	1	0	75			2	2	34.0

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

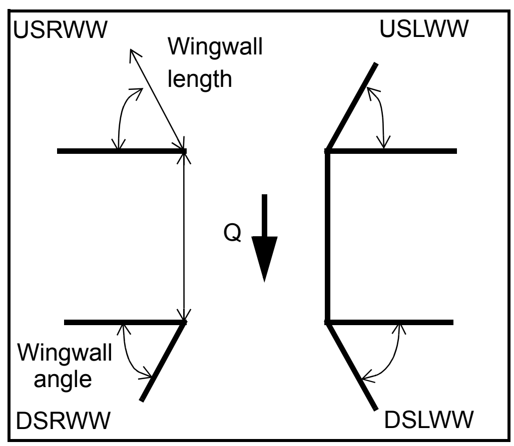
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
1.0
1
VTAOT records indicated the right abutment footing was recently added. Minor erosion noted on top and at US end.
#76: Area around LABUT footing well protected by boulders, cobbles, and an extra section of poured concrete.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						34.0	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	17.5	
DSRWW:	1		0		-	18.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	2	1	1	1
Condition	N	-	-	-	1	1	1	4
Extent	-	-	-	1	3	2	3	-

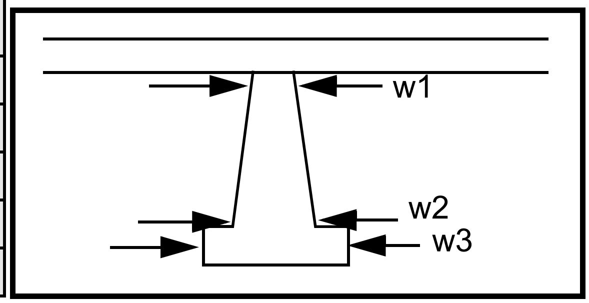
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? __#82__ *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-		6.5	-	40.0	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	:	abut-	center	is a	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	RAB	ment	line	mix	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	UT	.	UB	of	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	pro-		to 2	cob-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	tec-	LAB	feet	bles	*Y- yes; N- no*
91. Attack ∠ (BF)	tion	UT	DS.	and	
92. Pushed	cov-	pour		grav	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	ers	ed	USL	el	
95. Cross-members	80%	con-	WW	whic	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	of	crete	pro-	h is	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	lengt	skirt	tec-	cru	
98. Exposure depth	h of	from	tion	mbly	

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

and covers all but 30% of wingwall.

N

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - Thalweg depth - 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: 3

Scour dimensions: Length 4 Width 453 Depth: 453 Positioned 0 %LB to 2 %RB

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

432
0
0
-

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

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

Confluence 2: Distance (4x15 Enters on x10) (LB or RB) Type fro (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

m mid-bank to center of channel. DS (behind) of huge boulder, bank is highly eroded.
RB: moderately eroded - judged by presence of three 6 inch diameter trees growing out horizontally.

F. Geomorphic Channel Assessment

107. Stage of reach evolution Be

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)*:

d material grades from sand to gravel on LB, to cobbles in the center of channel, and to boulders and cobbles on RB.

N

109. G. Plan View Sketch

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: JAY-TH00230013 Town: Jay
Road Number: TH 23 County: Orleans
Stream: Jay Branch Missisquoi River

Initials EMB Date: 7/17/97 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	1700	2050	0
Main Channel Area, ft2	279	324	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	2	17	0
Top width main channel, ft	52	54	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	9	26	0
D50 of channel, ft	0.1604	0.1604	0.1604
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.4	6.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	0.2	0.7	ERR
Total conveyance, approach	21479	27422	0
Conveyance, main channel	21447	26879	0
Conveyance, LOB	0	0	0
Conveyance, ROB	32	543	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1697.5	2009.4	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	2.5	40.6	ERR
Vm, mean velocity MC, ft/s	6.1	6.2	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.3	2.4	ERR
Vc-m, crit. velocity, MC, ft/s	8.1	8.2	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1700	2050	N/A
Main channel area (DS), ft2	142	162	0
Main channel width (normal), ft	31.7	32.2	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	31.7	32.2	0.0
D90, ft	0.6248	0.6248	0.0000
D95, ft	1.1415	1.1415	0.0000
Dc, critical grain size, ft	0.7227	0.7672	ERR
Pc, Decimal percent coarser than Dc	0.080	0.071	0.000
Depth to armoring, ft	25.04	29.93	ERR

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1700	2050	0
(Q) discharge thru bridge, cfs	1700	2050	0
Main channel conveyance	12890	15589	0
Total conveyance	12890	15589	0
Q2, bridge MC discharge,cfs	1700	2050	ERR
Main channel area, ft2	142	162	0
Main channel width (normal), ft	31.7	32.2	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.7	32.2	0
y_bridge (avg. depth at br.), ft	4.48	5.03	ERR
Dm, median (1.25*D50), ft	0.2005	0.2005	0.2005
y2, depth in contraction,ft	5.95	6.89	ERR
ys, scour depth (y2-ybridge), ft	1.47	1.86	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1700	2050	0	1700	2050	0
a', abut.length blocking flow, ft	16.4	17.9	0	13.1	29.9	0
Ae, area of blocked flow ft2	36.1	50.4	0	20.7	34.4	0
Qe, discharge blocked abut.,cfs	112.3	173.8	0	70.3	97.3	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.11	3.45	ERR	3.40	2.83	ERR
ya, depth of f/p flow, ft	2.20	2.82	ERR	1.58	1.15	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.369	0.362	ERR	0.476	0.465	ERR
ys, scour depth, ft	8.70	10.49	N/A	6.19	6.56	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)	16.4	17.9	0	13.1	29.9	0
y1 (depth f/p flow, ft)	2.20	2.82	ERR	1.58	1.15	ERR
a'/y1	7.45	6.36	ERR	8.29	25.99	ERR
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.37	0.36	N/A	0.48	0.46	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	6.37	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	5.22	ERR
spill-through	ERR	ERR	ERR	ERR	3.50	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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	4.48	5.03	0.00	4.48	5.03	0.00

Median Stone Diameter for riprap at: left abutment right abutment, ft

Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.87	2.10	ERR	1.87	2.10	ERR