LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (MNTGTH00020004) on TOWN HIGHWAY 2, crossing WADE BROOK, MONTGOMERY, VERMONT

U.S. Geological Survey
Open-File Report 96-561

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (MNTGTH00020004) on TOWN HIGHWAY 2, crossing WADE BROOK, MONTGOMERY, VERMONT

By Erick M. Boehmler

U.S. Geological Survey
Open-File Report 96-561

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

Pembroke, New Hampshire
1996

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

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

For additional information write to:

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

Copies of this report may be purchased from:

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

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (MNTGTH00020004) ON TOWN HIGHWAY 2, CROSSING WADE BROOK, MONTGOMERY, VERMONT

***By* Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MNTGTH00020004 on town highway 2 crossing Wade Brook, Montgomery, 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). A Level I study is included in Appendix E of this report. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from VTAOT files, was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the Green Mountain physiographic province of north-central Vermont in the town of Montgomery. The 1.68-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have woody vegetation coverage.

In the study area, Wade Brook has an incised, sinuous channel with a slope of approximately 0.0454 ft/ft, an average channel top width of 30 ft and an average channel depth of 2 ft. The predominant channel bed materials are gravel and cobbles (D_{50} is 77.7 mm or 0.255 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 8, 1994, indicated that the reach was degraded. There were no scour holes observed during the Level I assessment. However, general streambed lowering was evident as both abutments were undermined equally with no localized scour on one abutment over the other.

The town highway 2 crossing of Wade Brook is a 23-ft-long, two-lane bridge consisting of one 20-foot concrete slab span (Vermont Agency of Transportation, written communication, August 3, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 30 degrees to the opening while the computed opening-skew-to-roadway is 25 degrees.

The scour protection measures at the site were type-1 stone fill (less than 12 inches diameter) on the upstream right wingwall and all road approach embankments, type-2 stone fill (less than 36 inches diameter) on the left abutment, and a “laid-up” stone wall at the upstream end of the upstream left wingwall and in front of the upstream left bank. 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 was 0.1 ft. The worst-case contraction scour occurred at the 100-year and 500-year discharges. Abutment scour ranged from 3.9 to 5.2 ft. The worst-case abutment scour also 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). Many factors, including historical performance during flood events, the geomorphic assessment, scour protection measures, and the results of the hydraulic analyses, must be considered to properly assess the validity of abutment scour results. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein, based on the consideration of additional contributing factors and experienced engineering judgement.

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 MNTGTH00020004 ***Stream*** Wade Brook

County Franklin ***Road*** TH 2 ***District*** 08

Description of Bridge

Bridge length 23 ***ft*** ***Bridge width*** 26.0 ***ft*** ***Max span length*** 20 ***ft***

Alignment of bridge to road (on curve or straight) On a Curve

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

Stone fill on abutment? Yes ***Date of inspection*** 11/08/94

Description of stone fill Type-1, on all road approach embankments and the upstream right wingwall and a "laid-up" stone wall on the upstream left bank to the upstream end of the upstream left wingwall.

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

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 30

There is a moderate 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	11/08/94	0	0
Level II	11/08/94	0	0

Potential for debris Moderate. There is some debris scattered around the channel but no significant accumulation in any one location.

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

Description of the Geomorphic Setting

General topography The channel is located within a narrow, high relief valley setting, with little to no flood plain and steep valley walls on both sides.

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

Date of inspection 11/08/94

DS left: Steep channel bank to TH 2 roadway and valley wall.

DS right: Steep channel bank to a narrow flood plain and valley wall.

US left: Steep channel bank to a narrow flood plain and valley wall.

US right: Steep channel bank to valley wall.

Description of the Channel

Average top width 30 ***ft*** ***Average depth*** 2.5 ***ft***

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

[illegible] Perennial, incised, and sinuous but laterally stable with non-alluvial channel boundaries.

11/08/94

Vegetative co[illegible] Town highway 2 roadway surface and forest.

DS left: Forest.

DS right: Forest.

US left: Forest.

US right:

Do banks appear stable? Y [illegible] ***date of observation.***

None evident on 11/08/94.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 1.68 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
Green Mountain	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 460 ***ft³/s*** ***Q500*** 490 ***ft³/s***

The 100-year discharge is based on the results of several empirical relationships (FHWA, 1983; Johnson and Tasker, 1974; Potter 1957a&b; and Talbot, 1887). The flood frequency curves for each empirical relationship were extrapolated and the 500-year discharge applied was based on the extrapolated curve estimates from each relationship.

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 the center point of a chiseled "X" on top of the DS end of the right abutment: elev. 496.02 ft, arbitrary survey datum. RM2 is the center point of a chiseled "X" on top of a boulder located approximately 30 feet upstream on the left bank side of the channel: elev. 497.72 ft, arbitrary survey datum.

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-19	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	46	2	Modelled Approach section (Templated from APTEM)
APTEM	58	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, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.065, and the overbank "n" value applied was 0.035.

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 0.0454 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0680 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.

For the 100- and 500-year discharge, WSPRO assumes critical depth at the at the bridge section. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, the results indicate that the water surface profile passes 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 496.9 *ft*
Average low steel elevation 494.0 *ft*

100-year discharge 460 *ft³/s*
Water-surface elevation in bridge opening 490.4 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 49 *ft²*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 493.1
Water-surface elevation at Approach section without bridge 492.5
Amount of backwater caused by bridge 0.6 *ft*

500-year discharge 490 *ft³/s*
Water-surface elevation in bridge opening 490.5 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 51 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.8 *ft/s*

Water-surface elevation at Approach section with bridge 493.3
Water-surface elevation at Approach section without bridge 492.6
Amount of backwater caused by bridge 0.7

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 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. For contraction scour computations, the average depth in the contracted section (AREA/ TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

Abutment scour for each modeled discharge was computed by use of the Froehlich 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.

The length to depth ratio of the embankment blocking flow exceeded 25 for the 100-year discharge at both abutments. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Since the equation was developed from Army Corp. of Engineers' data obtained for spurs dikes in the Mississippi River, the HIRE equation was not adopted for the narrow, incised, upland valley at this site.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.1	0.1	--
Depth to armoring	12.1	13.0	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	4.3	5.2	--
Right abutment	3.9	4.0	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

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

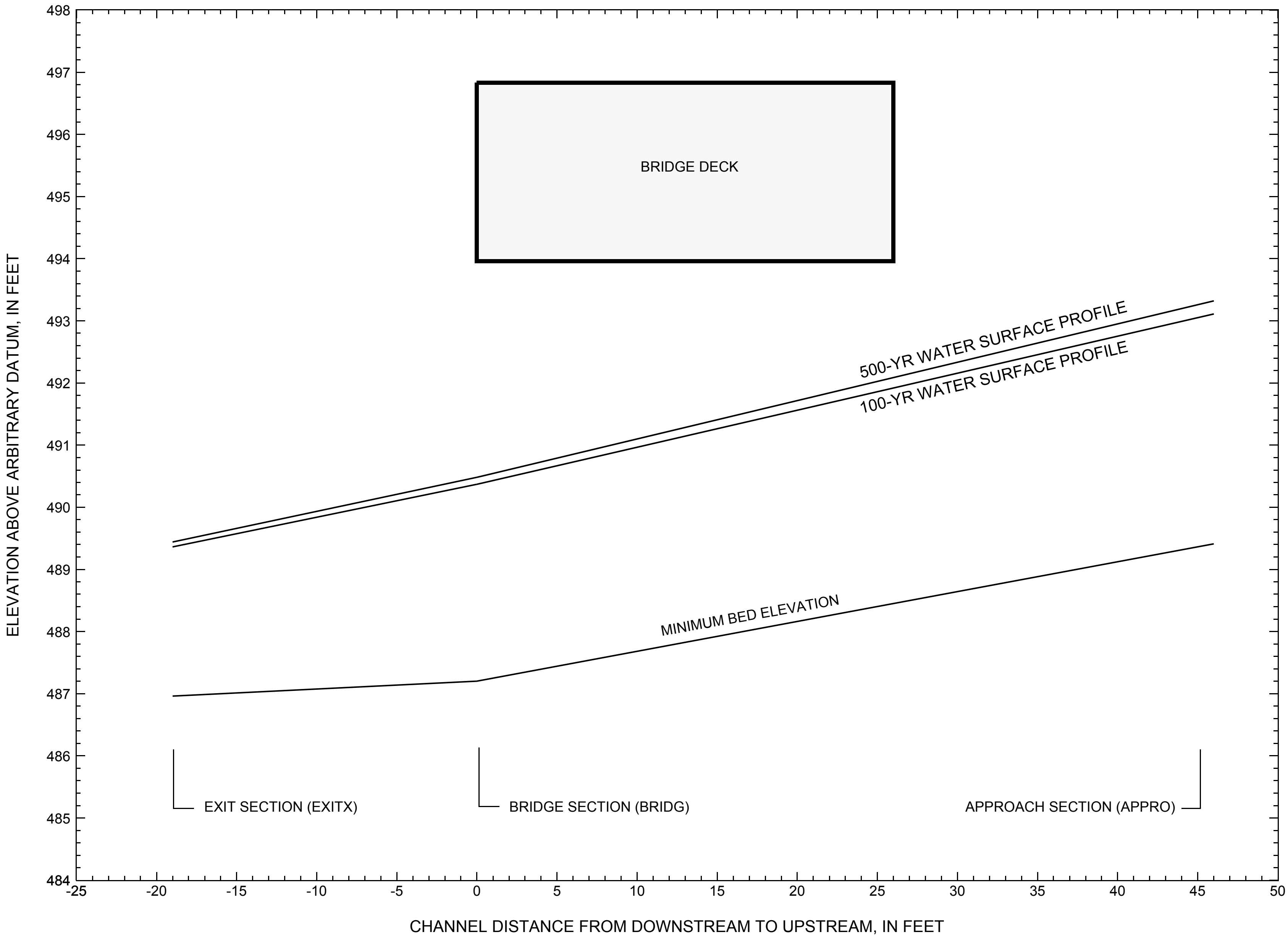


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MNTGTH00020004 on town highway 2, crossing Wade Brook, Montgomery, Vermont.

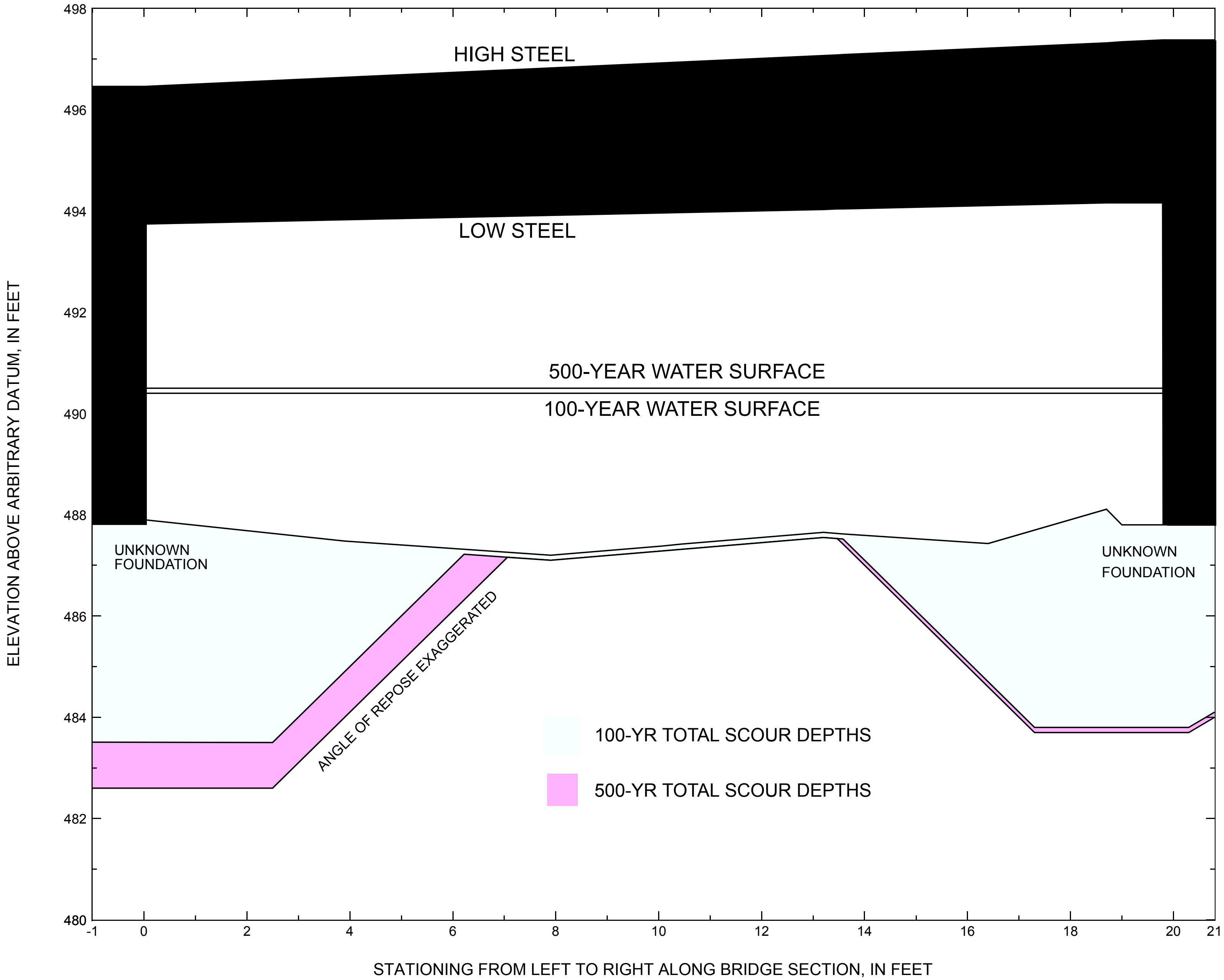


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MNTGTH00020004 on town highway 2, crossing Wade Brook, Montgomery, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MNTGTH00020004 on Town Highway 2, crossing Wade Brook, Montgomery, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 460 cubic-feet per second											
Left abutment	0.0	--	493.5	--	487.9	0.1	4.3	--	4.4	483.5	--
Right abutment	19.8	--	494.4	--	487.8	0.1	3.9	--	4.0	483.8	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure MNTGTH00020004 on Town Highway 2, crossing Wade Brook, Montgomery, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 490 cubic-feet per second											
Left abutment	0.0	--	493.5	--	487.9	0.1	5.2	--	5.3	482.6	--
Right abutment	19.8	--	494.4	--	487.8	0.1	4.0	--	4.1	483.7	--

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.

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, Hazens Notch, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; aerial photography, 1980, contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mntg004.wsp
T2        Hydraulic analysis for structure MNTGTH00020004   Date: 08-MAR-96
T3        Town Highway 2 (VT 58) Bridge Crossing Wade Brook, Montgomery, VT  EMB
Q            460.0    490.0
SK          0.0454   0.0454
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -19           0.
GR         -100.8, 506.89    -84.9, 493.40    -51.9, 494.49    -22.5, 493.76
GR          -13.0, 490.42     -9.5, 487.89     -6.4, 487.61      0.0, 487.15
GR            7.2, 486.96     10.1, 487.01     15.8, 487.31     20.8, 488.52
GR           24.1, 491.40     43.6, 493.78     76.6, 509.45
*
N           0.035        0.065
SA                 -22.5
*
XS   FULLV      0  * * *   0.0454
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    493.96      25.0
GR            0.0, 493.48      0.1, 487.89      0.2, 488.14      3.9, 487.48
GR            7.9, 487.20     13.2, 487.65     16.4, 487.43     18.7, 488.11
GR           19.0, 487.82     19.8, 494.45      0.0, 493.48
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      34.8 * *     48        5.0
N           0.055
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     15      26.0      2
GR         -117.5, 505.00   -102.8, 493.40    -70.0, 494.49     -6.1, 496.43
GR           -5.9, 500.75     -3.4, 500.78      0.0, 500.61     14.4, 501.49
GR           16.9, 501.53     18.2, 501.33     18.3, 497.31     58.4, 500.22
GR          118.5, 506.69
*
XT   APTEM     58
GR          -96.8, 506.17    -71.0, 499.73    -26.0, 499.83    -19.8, 493.73
GR           -3.7, 493.43      0.0, 491.42      3.4, 490.65      6.1, 490.23
GR            8.9, 490.52     12.6, 490.53     15.0, 491.16     19.2, 493.10
GR           22.4, 495.73    108.0, 502.29    129.8, 513.35
*
AS   APPRO     46   *  *  *  0.0680
GT
N           0.065
*
HP 1 BRIDG   490.37 1 490.37
HP 2 BRIDG   490.37 * *  460
HP 1 APPRO   493.05 1 493.05
HP 2 APPRO   493.05 * *  460
*
HP 1 BRIDG   490.48 1 490.48
HP 2 BRIDG   490.48 * *  490
```

APPENDIX B:

WSPRO OUTPUT FILE

```
   T1        U.S. Geological Survey WSPRO Input File mntg004.wsp
   T2        Hydraulic analysis for structure MNTGTH00020004   Date: 08-MAR-96
   T3        Town Highway 2 (VT 58) Bridge Crossing Wade Brook, Montgomery, VT  EMB

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       49      2189     17     23                          460
    490.37            49      2189     17     23  1.00      0     19      460

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        490.37     0.1    19.3    48.6    2189.     460.   9.46

 X STA.         0.1        2.1        3.2        4.2        5.0        5.8
   A(I)              4.3        2.7        2.5        2.3        2.2
   V(I)             5.30       8.47       9.35      10.17      10.59

 X STA.         5.8        6.6        7.3        8.0        8.7        9.5
   A(I)              2.1        2.0        2.0        2.0        2.1
   V(I)            10.80      11.35      11.35      11.34      11.21

 X STA.         9.5       10.2       11.0       11.8       12.6       13.5
   A(I)              2.0        2.0        2.1        2.1        2.2
   V(I)            11.34      11.23      10.76      10.73      10.66

 X STA.        13.5       14.4       15.3       16.2       17.2       19.3
   A(I)              2.2        2.3        2.3        2.7        4.3
   V(I)            10.33       9.81       9.79       8.65       5.34

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       68      2172     40     42                          505
    493.11            68      2172     40     42  1.00    -19     20      505

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

          WSEL     LEW     REW    AREA        K        Q    VEL
        493.11   -20.0    20.2    68.3    2172.     460.   6.74

 X STA.       -20.0       -0.6        1.4        2.8        4.0        4.9
   A(I)              9.7        5.3        4.1        3.8        3.3
   V(I)             2.37       4.32       5.55       6.12       7.05

 X STA.         4.9        5.8        6.6        7.3        8.1        8.8
   A(I)              3.1        2.9        2.7        2.7        2.6
   V(I)             7.51       7.96       8.37       8.66       8.86

 X STA.         8.8        9.6       10.3       11.0       11.8       12.5
   A(I)              2.5        2.5        2.5        2.4        2.4
   V(I)             9.13       9.14       9.36       9.41       9.55

 X STA.        12.5       13.2       14.1       15.1       16.3       20.2
   A(I)              2.5        2.7        2.8        3.2        4.7
   V(I)             9.17       8.57       8.23       7.30       4.93
1
```

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       51      2320     17     23                          488
    490.48            51      2320     17     23  1.00      0     19      488

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        490.48     0.1    19.3    50.5    2320.     490.   9.70

 X STA.         0.1        2.1        3.2        4.2        5.0        5.8
   A(I)              4.5        2.8        2.6        2.3        2.3
   V(I)             5.40       8.66       9.59      10.44      10.87

 X STA.         5.8        6.6        7.3        8.0        8.7        9.5
   A(I)              2.2        2.1        2.1        2.1        2.1
   V(I)            11.09      11.67      11.40      11.80      11.66

 X STA.         9.5       10.2       11.0       11.8       12.6       13.5
   A(I)              2.1        2.1        2.2        2.2        2.3
   V(I)            11.56      11.44      11.34      11.04      10.71

 X STA.        13.5       14.4       15.3       16.2       17.2       19.3
   A(I)              2.3        2.4        2.5        2.8        4.5
   V(I)            10.57      10.35       9.75       8.88       5.46

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       77      2615     41     42                          598
    493.32            77      2615     41     42  1.00    -19     20      598

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

          WSEL     LEW     REW    AREA        K        Q    VEL
        493.32   -20.2    20.5    76.8    2615.     490.   6.38

 X STA.       -20.2       -2.8        0.3        1.9        3.2        4.3
   A(I)              9.9        6.2        4.9        4.2        3.7
   V(I)             2.47       3.94       5.01       5.88       6.55

 X STA.         4.3        5.2        6.0        6.8        7.6        8.4
   A(I)              3.4        3.3        3.1        3.0        2.9
   V(I)             7.18       7.47       7.95       8.22       8.40

 X STA.         8.4        9.2       10.0       10.8       11.5       12.3
   A(I)              2.9        2.8        2.8        2.8        2.8
   V(I)             8.42       8.73       8.81       8.67       8.72

 X STA.        12.3       13.1       14.0       15.0       16.4       20.5
   A(I)              2.9        2.9        3.2        3.6        5.3
   V(I)             8.48       8.36       7.62       6.74       4.59
1
   EX
```

```
 +++ BEGINNING PROFILE CALCULATIONS --   2
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File mntg004.wsp
         Hydraulic analysis for structure MNTGTH00020004   Date: 08-MAR-96
         Town Highway 2 (VT 58) Bridge Crossing Wade Brook, Montgomery, VT  EMB
            *** RUN DATE & TIME: 04-30-96  10:59

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

 EXITX:XS   ******    -11       63  0.83 *****  490.19  489.28     460  489.36
       -18 ******     22     2158  1.00 ***** *******    0.94    7.32

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.93     490.23     490.14

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   488.86     510.31    0.50

  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   488.86     510.31     490.14

 FULLV:FV       19    -11       63  0.83  0.86  491.06  490.14     460  490.23
         0     19     22     2174  1.00  0.00    0.01    0.93    7.28
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===120 YTOL NOT SATISFIED AT SECID "APPRO":  TRIALS CONTINUED.
                        YTOL,WSLIM1,WSLIM2 =  0.02     489.73     490.73

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.16     492.50     493.02

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   489.73     512.53    0.50

  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   489.73     512.53     493.02

  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   493.02     512.53     493.02

 APPRO:AS       46    -19       65  0.79 *****  493.81  493.02     460  493.02
        46     46     20     1988  1.00 ***** *******    0.99    7.12
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =     460.     490.37

             <<<<<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       19      0       49  1.39 *****  491.76  490.37     460  490.37
         0     19     19     2190  1.00 ***** *******    1.00    9.46

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  493.96 ****** ****** ******

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

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

 APPRO:AS       11    -19       68  0.71  0.51  493.82  493.02     460  493.11
        46     12     20     2172  1.00  1.54   -0.01    0.91    6.74

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.519  0.000    2664.     0.    19.   492.22

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

WSPRO OUTPUT FILE (continued)

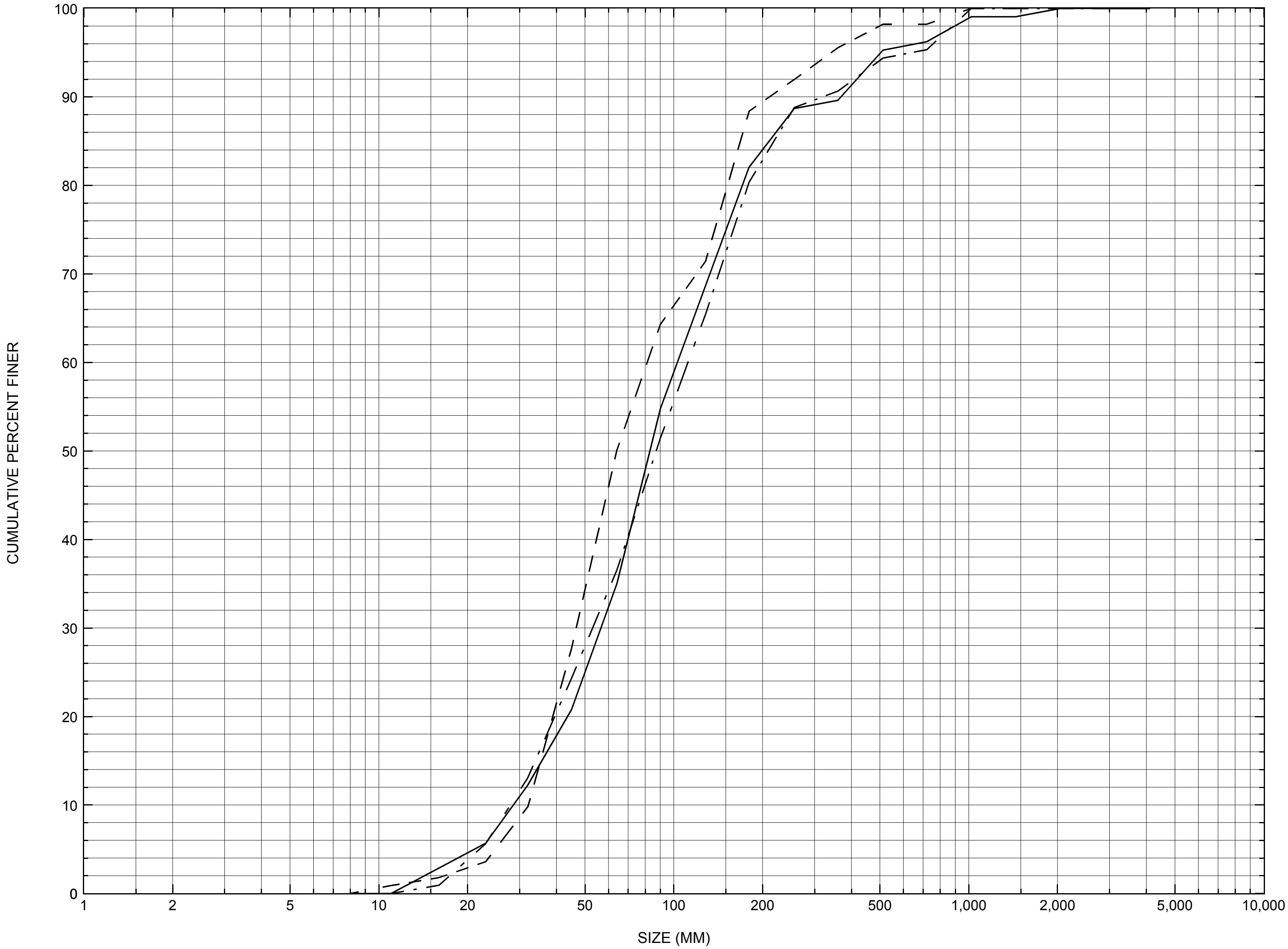
```
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -19.   -12.    22.    460.    2158.      63.    7.32  489.36
   FULLV:FV       0.   -12.    22.    460.    2174.      63.    7.28  490.23
   BRIDG:BR       0.     0.    19.    460.    2190.      49.    9.46  490.37
   RDWAY:RG      15.**************      0.******************    2.00********
   APPRO:AS      46.   -20.    20.    460.    2172.      68.    6.74  493.11

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    19.    2664.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.28    0.94  486.96  509.45************  0.83  490.19  489.36
   FULLV:FV    490.14    0.93  487.82  510.31  0.86  0.00  0.83  491.06  490.23
   BRIDG:BR    490.37    1.00  487.20  494.45************  1.39  491.76  490.37
   RDWAY:RG  ****************  493.40  506.69**********************************
   APPRO:AS    493.02    0.91  489.41  512.53  0.51  1.54  0.71  493.82  493.11

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

EXITX:XS   ******    -11       65  0.87 *****  490.31  489.35     490  489.44
       -18 ******     22     2299  1.00 ***** *******    0.94    7.48

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.94     490.31     490.22

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   488.94     510.31    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   488.94     510.31     490.22

FULLV:FV       19    -11       66  0.86  0.86  491.17  490.22     490  490.31
         0     19     22     2316  1.00  0.00    0.01    0.94    7.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===120 YTOL NOT SATISFIED AT SECID "APPRO":  TRIALS CONTINUED.
                       YTOL,WSLIM1,WSLIM2 =  0.02     489.81     490.81

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.17     492.86     493.07

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.81     512.53    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.81     512.53     493.07

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   493.07     512.53     493.07

APPRO:AS       46    -19       67  0.84 *****  493.91  493.07     490  493.07
        46     46     20     2095  1.00 ***** *******    1.00    7.34
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     490.     490.48

            <<<<<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       19      0       51  1.46 *****  491.94  490.48     490  490.48
         0     19     19     2321  1.00 ***** *******    1.00    9.69

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  493.96 ****** ****** ******

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

WSPRO OUTPUT FILE (continued)

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

APPRO:AS       11    -19       77  0.63  0.45  493.95  493.07     490  493.32
        46     12     20     2621  1.00  1.55   -0.02    0.82    6.37

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.520  0.000    3020.     0.    19.  492.64

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -19.   -12.    22.    490.    2299.      65.    7.48  489.44
   FULLV:FV        0.   -12.    22.    490.    2316.      66.    7.45  490.31
   BRIDG:BR        0.     0.    19.    490.    2321.      51.    9.69  490.48
   RDWAY:RG       15.**************      0.******************    2.00********
   APPRO:AS       46.   -20.    20.    490.    2621.      77.    6.37  493.32

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    19.    3020.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.35    0.94  486.96  509.45************  0.87  490.31  489.44
   FULLV:FV    490.22    0.94  487.82  510.31  0.86  0.00  0.86  491.17  490.31
   BRIDG:BR    490.48    1.00  487.20  494.45************  1.46  491.94  490.48
   RDWAY:RG  ****************  493.40  506.69**********************************
   APPRO:AS    493.07    0.82  489.41  512.53  0.45  1.55  0.63  493.95  493.32
  ER

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 MNTGTH00020004, in Montgomery, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MTNGTH00020004

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 03 / 94

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 45850

Mile marker *(I - 11; nnn.nnn)* 003960

Waterway *(I - 6)* WADE BROOK

Road Name *(I - 7):* -

Route Number TH002

Vicinity *(I - 9)* 3.0 MI E JCT. VT.118

Topographic Map Hazens.Notch

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44509

Longitude *(i - 17; nnnnn.n)* 72328

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20030800040610

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

Maximum span length *(I - 48; nnnn)* 0020

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

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 260

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

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

Opening skew to Roadway *(I - 34; nn)* 30

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

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

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

Structure type *(I - 43; nnn)* 101

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*) 006.0

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

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

Comments:

Structural inspection report of 9/26/92 indicates a full depth crack has developed in the left abutment from top to bottom near the center and has been undermined. However, the same inspection indicates channel scour is minor. Embankment erosion was noted on the right embankment upstream and both downstream. The channel makes a moderate bend into and through bridge. The report indicates no rip-rap protection present. debris had collected on the banks.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Boulder

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)*: 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} (*ft³/ 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 (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 1.68 mi^2 Lake and pond area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 1326 ft Headwater elevation 3196 ft
Main channel length 1.93 mi
10% channel length elevation 1427 ft 85% channel length elevation 2657 ft
Main channel slope *(S)* 852.16 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:

-

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: MAI Date: 2/7/95
Computerized by: EMB Date: 2/7/95
Reviewd by: SAO Date: 5/23/96

Structure Number MTNGTH00020004

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 11 / 08 / 1994

2. Highway District Number 09 Mile marker 3.960

County FRANKLIN (011) Town MONTGOMERY (45850)

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

Route Number TH02 Hydrologic Unit Code: 02010007

3. Descriptive comments:

Structure is a concrete slab type bridge with tall concrete guard walls on each side located about 3.0 miles east from the intersection of TH02 with VT118 and about 1.3 miles west of the Hazen Notch on TH02.

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 2 DS 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 23.0 *(feet)* Span length 20.0 *(feet)* Bridge width 26.0 *(feet)*

Road approach to bridge:

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

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

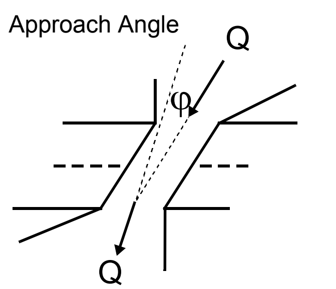
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

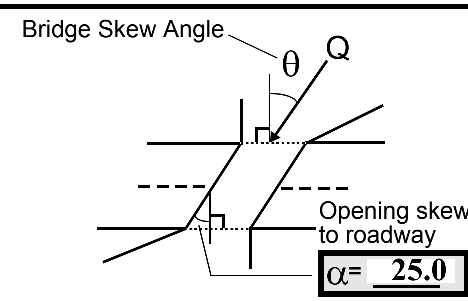
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	1	1	2	1
RBDS	1	1	2	2
LBDS	1	1	2	2

*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: 20 16. Bridge skew: 30





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 90 feet US *(US, UB, DS)* to 65 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 10 feet DS *(US, UB, DS)* to 55 feet DS

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

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

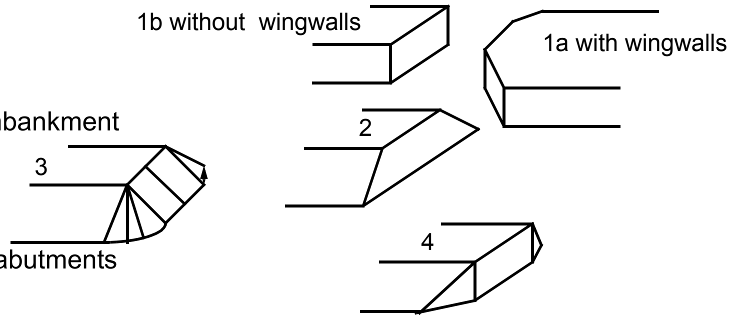
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The roadway embankments at three of the four corners of the bridge are vertical. Only that of the downstream left bank exists with roughly a 5:1 slope. The surface coverage indicated is actual with little or no deviation. Measurements of the bridge dimensions were the same as those found on the historical form. Roadwash around the end of the downstream left and right wingwalls and at the downstream left road approach embankment are the locations of the most severe erosion. Particularly the downstream left road embankment where gullying has developed in the embankment fill perhaps mostly during periods of roadway overflow. Protection on the upstream left embankment is placed such that it channels the water under the bridge until the level rises above the bridge deck level roughly.

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
28.5	2.0			2.0	3	4	5	5	1	1

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **23.0** 29. Bed Material **4**

30 .Bank protection type: LB **5** RB **0** 31. Bank protection condition: LB **1** 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 left bank is protected to 15 feet upstream from the upstream end of the left wingwall. The protection is a dry masonry wall constructed with field stones stacked about 4 diameters high. the channel makes a moderate bend upstream but flows fairly straight through the bridge. The bank material is incohesive as area is mostly boulders with a very thin topsoil layer over them. While non-cohesive, the bank material in part is very large and erosion is not evident upstream except in very localized areas particularly near the impact zone. Although the impact is moderate due to a moderate right bend in the channel, the influence of the impact on the left bank is very slight.

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? N *(Y or if N type ctrl-n cb)* 40. Where? - *(LB or RB)*

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
15.0		1.0		2	7	7	-

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

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

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

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

4

The channel gradient reduces from the upstream reach to the under bridge and downstream reach, but remains enough that the water surface continues riffled through the entire reach. For the most part, the bed material is the same as upstream. However, here the bed material is more compact with fewer voids between the larger stones, more sand and gravel, and a smoother texture.

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

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

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

70. Debris and Ice Comments:

1

Tree stems, branches, and leaves are scattered about in the channel upstream but not all accumulated in one mass at any one particular location. The steep channel gradient and high velocity flows probably would align debris parallel with the bridge abutments and allow debris to pass through the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**0**	**2**	**0**	**1.5**	**90.0**
RABUT	**1**	**0**	**90**			**0**	**3**	**18.0**

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

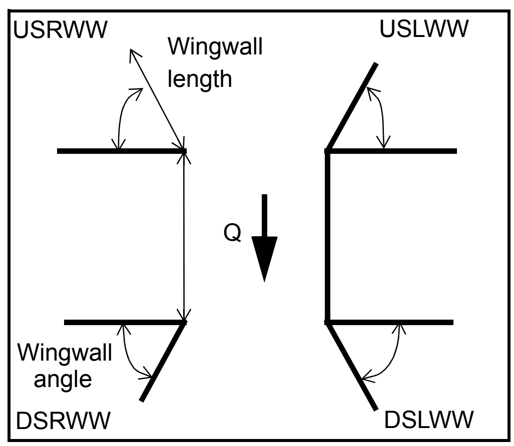
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
2.0
1

A two inch wide crack appears at the road center line under the bridge roughly completely through the right abutment footing. The footing has settled from undermining most likely as the footer and right abutment wall are separated slightly by a 0.5 inch crack which runs its length. A large vertical crack has developed in the right abutment wall and is displaced from the footing's crack between two and three feet downstream. The left abutment footing is undermined mainly from concrete deterioration and subsequent erosion rather than by channel erosion. The most significant deterioration and erosion of the concrete left abutment footing is from the upstream end to approximately the roadway center line under the bridge. Both footings appear at

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	**most**		**2**		**feet**	**18.0**	
USRWW:	**thick**		**and**		**set-**	**1.0**	
DSLWW:	**tling**		**of**		**the**	**29.0**	
DSRWW:	**right**		**abut**		**ment**	**29.0**	



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	**give**	**ear-**	**no**	**inin**	**und**	**g**	**babl**	**ut**
Condition	**s**	**ance**	**und**	**g.**	**erm**	**was**	**y**	**0.5**
Extent	**app**	**of**	**erm**	**The**	**inin**	**pro**	**abo**	**feet**

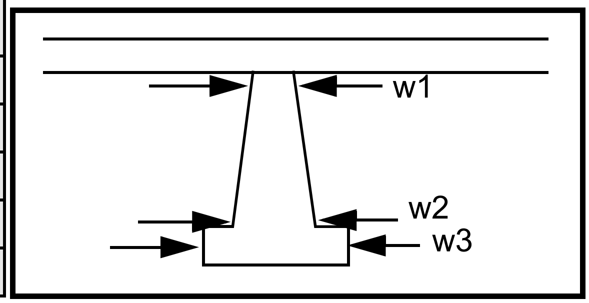
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
at most prior to the settlement. The concrete deterioration at the base of both abutments makes it difficult to decipher exposure depths.
Y
1
1
0
0
Y
1
0
-

Piers:

84. Are there piers? __-___ *(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		7.5	7.5	65.0	30.0	35.0
Pier 2	8.5	9.0	-	85.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	Y	2	-	dete-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	1	1	-	rio-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	2	1	-	ratio	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	0	2	-	n	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	1.5	2	0	and	*Y- yes; N- no*
91. Attack ∠ (BF)	Y	1	-	sub-	
92. Pushed	1	2	-	sequ	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	3	0	0	ent	
95. Cross-members	0	-	-	ero-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	2.0	-	-	sion	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	5	-	Con-	has	
98. Exposure depth	1	-	crete	occu	

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

rred at the downstream end of the upstream left wingwall at the corner where the wingwall meets the abutment wall. Protection is in place where the footing's concrete has eroded. Rangepole penetration under the upstream left wingwall and left abutment from footer erosion is between 0.5 and 1 foot. The deterioration has affected mostly the footing as opposed to the abutment wall. The abutment wall concrete appears in good condition. The downstream right wingwall footing is about 1.5 feet thick. The concrete footing of the downstream left wingwall and the downstream end of the left abutment has deteriorated and eroded away completely except for some fragments of concrete that remain on the streambed adjacent to the walls presumably from the wingwall / abutment footings.

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
-	-			-		N	-	-	-	-

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

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

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

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

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

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

Point bar extent: - ____ feet - ____ *(US, UB, DS)* to - ____ feet - ____ *(US, UB, DS)* positioned - ____ %LB to - ____ %RB

Material: - ____

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

-
-
-
-

Is a cut-bank present? - ____ *(Y or if N type ctrl-n cb)* Where? - ____ *(LB or RB)* Mid-bank distance: **NO**

Cut bank extent: **PIE** feet **RS** *(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: ____

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

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

2
4
0
0

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

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

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

Confluence comments (eg. confluence name):

is a composite type with equal thicknesses of soil on top and alluvial, somewhat bouldery gravelly sand on the bottom. The soil appears more cohesive and less erodible as roots and the soil layer are clearly overhanging

F. Geomorphic Channel Assessment

107. Stage of reach evolution **the**

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)*:

underlying material. When the overhanging soil layer does fail and the material slumps into the channel, the block is washed away perhaps quickly by rather swift currents, particularly along the right bank near the impact zone.

109. G. Plan View Sketch

- N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	MNTGTH00020004	Town:	Montgomery
Road Number:	TH 2	County:	Franklin
Stream:	Wade Brook		

Initials EMB Date: 4/30/96 Checked: SAO 5/6/96

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	460	490	0
Main Channel Area, ft2	68.3	76.8	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	40.2	40.7	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.255	0.255	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	1.7	1.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	2172	2615	0
Conveyance, main channel	2172	2615	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	460.0	490.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	6.7	6.4	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	7.8	7.9	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	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	68.3	76.8	0
Main channel width, ft	40.2	40.7	0
y1, main channel depth, ft	1.70	1.89	ERR
Bridge Section			
(Q) total discharge, cfs	460	490	0
(Q) discharge thru bridge, cfs	460	490	
Main channel conveyance	2189	2321	
Total conveyance	2189	2321	
Q2, bridge MC discharge,cfs	460	490	ERR
Main channel area, ft2	49	51	0
Main channel width (skewed), ft	17.4	17.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	17.4	17.4	0
y_bridge (avg. depth at br.), ft	2.79	2.90	ERR
Dm, median (1.25*D50), ft	0.31875	0.31875	0
y2, depth in contraction,ft	2.84	3.00	ERR
ys, scour depth (y2-ybridge), ft	0.05	0.10	N/A
ys, scour depth (y2-y1), ft	1.14	1.11	N/A

ARMORING			
D90	0.8606	0.8606	
D95	1.5382	1.5382	
Critical grain size,Dc, ft	0.6670	0.6866	ERR
Decimal-percent coarser than Dc	0.142	0.137	
Depth to armoring,ft	12.09	12.98	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	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	460	490	0	460	490	0
a', abut.length blocking flow, ft	20	20.2	0	2.8	3.1	0
Ae, area of blocked flow ft2	11.29	15.5	0	3.4	4	0
Qe, discharge blocked abut.,cfs	29.9	46.6	0	16.5	18.5	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	2.65	3.01	ERR	4.85	4.63	ERR
ya, depth of f/p flow, ft	0.56	0.77	ERR	1.21	1.29	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	115	115	0	65	65	0
K2	1.03	1.03	0.00	0.96	0.96	0.00
Fr, froude number f/p flow	0.621	0.605	ERR	0.776	0.718	ERR
ys, scour depth, ft	4.33	5.20	N/A	3.87	4.03	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)	20	2.8	2.8	20.2	3.1	0
y1 (depth f/p flow, ft)	0.56	1.21	1.21	0.77	1.29	ERR
a'/y1	35.43	2.31	2.31	26.33	2.40	ERR
Skew correction (pg. 49, fig. 16)	1.06	1.06	1.06	0.92	0.92	0.92
Froude no. f/p flow	0.62	0.60	N/A	0.78	0.72	N/A
Ys w/ corr. factor K1/0.55:						
vertical w/ ww's	3.04	ERR	ERR	3.86	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	2.79	2.9		2.79	2.9	
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.)	1.17	1.21	ERR	1.17	1.21	ERR