LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (BRADTH00270022) on TOWN HIGHWAY 27, crossing the WAITS RIVER, BRADFORD, VERMONT

Open-File Report 98-537

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

USGS

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (BRADTH00270022) on TOWN HIGHWAY 27, crossing the WAITS RIVER, BRADFORD, VERMONT

By EMILY C. WILD AND MICHAEL A. IVANOFF

U.S. Geological Survey
Open-File Report 98-537

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	NGVD	National Geodetic Vertical Datum
elev.	elevation	RAB	right abutment
f/p	flood plain	RABUT	face of right abutment
ft^2	square feet	RB	right bank
ft/ft	feet per foot	ROB	right overbank
FEMA	Federal Emergency Management Agency	RWW	right wingwall
FHWA	Federal Highway Administration	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
		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 22 (BRADTH00270022) ON TOWN HIGHWAY 27, CROSSING THE WAITS RIVER, BRADFORD, VERMONT

By **Emily C. Wild and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRADTH00270022 on Town Highway 27 crossing the Waits River, Bradford, 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, obtained from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 153-mi^2 drainage area is in a predominantly rural and forested basin. However, in the vicinity of the study site, the upstream and downstream left banks are suburban and the upstream and downstream right banks are shrub and brushland.

In the study area, the Waits River has an incised, sinuous channel with a slope of approximately 0.0002 ft/ft, an average channel top width of 125 ft and an average bank height of 4 ft. The channel bed material ranges from silt and clay to bedrock with a median grain size (D_{50}) of 0.393 mm (0.00129 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 7, 1995, indicated that the reach was stable.

The Town Highway 27 crossing of the Waits River is a 109-ft-long, one-lane bridge consisting of a 104-ft steel-truss span (Vermont Agency of Transportation, written communication, March 16, 1995). The opening length of the structure parallel to the bridge face is 99.2 ft. The bridge is supported by vertical, laid-up stone abutments. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is zero degrees.

No evidence of scour was observed during the Level I assessment. Scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream right and downstream left banks and type-3 stone fill (less than 48 inches diameter) along the left and right abutments. 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 2.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 11.8 to 18.8 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. 46). 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 BRADTH00270022 ***Stream*** Waits River

County Orange ***Road*** TH 27 ***District*** 7

Description of Bridge

Bridge length 109 ***ft*** ***Bridge width*** 16.0 ***ft*** ***Max span length*** 104 ***ft***

Alignment of bridge to road (on curve or straight) Straight, left and curved, right

Abutment type Vertical, laid-up stone ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 9/7/95

Description of stone fill Type-3 stone fill along the left and right abutments

Brief description of piers/abutments The abutments are laid-up stone with concrete caps.

Yes

Is bridge skewed to flood flow according to survey? ***Angle*** 30 No

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

9/7/95

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	0	0	9/7/95
Level II	0	0	Low.

Potential for debris

Approximately 1,300 feet downstream of this bridge, there is a hydroelectric dam, as observed on 9/7/95.

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

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain.

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

Date of inspection 9/7/95

DS left: Steep channel bank with a narrow flood plain

DS right: Steep channel bank with a moderately sloped overbank

US left: Steep channel bank with a narrow flood plain

US right: Steep channel bank with a moderately sloped overbank

Description of the Channel

Average top width 125 ***ft*** ***Average depth*** 4 ***ft***

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

Sinuous but stable with semi-alluvial channel boundaries.

9/7/95

Vegetative co

DS left: Grass and a few trees

DS right: Brush, grass, and a few trees

US left: Grass, brush and a few trees

US right: Trees and brush

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

None, 9/7/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 153 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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 7,500 ***ft³/s*** ***Q500*** 10,700 ***ft³/s***

The 100- and 500-year discharges are those at the mouth of the Waits River documented in the Flood Insurance Study for the Village of Bradford (Federal Emergency Management Agency, 1991). The values used were considered with a range of discharges defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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. To obtain the NGVD of 1929, subtract 24.9 ft from the USGS arbitrary survey datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment, near the bridge seat (elev. 495.89 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 500.86 ft, arbitrary survey datum). RM 25 (Town of Bradford Flood Insurance Study)/ RM4 (Village of Bradford Flood Insurance Study) is a State of Vermont survey tablet set in the curb of the southbound Interstate Route 91 bridge over the Waits River and State Route 25 at the northwest corner of the bridge deck (elev. 496.33, NGVD of 1929).

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-125	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPR1	105	1	Approach section

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. The channel "n" value for the reach was 0.030, and overbank "n" values ranged from 0.040 to 0.050.

At the exit section (EXIT1), the starting water surface was obtained from the flood profiles from the Flood Insurance Studies for the Town of Bradford and the Village of Bradford (Federal Emergency Management Agency, 1991a, 1991b). The surveyed approach section (APPR1) was modelled one bridge length upstream of the upstream face, as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 ***ft***
Average low steel elevation 497.9 ***ft***

100-year discharge 7,500 ***ft³/s***
Water-surface elevation in bridge opening 489.8 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 872 ***ft²***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.3 ***ft/s***

Water-surface elevation at Approach section with bridge 490.4
Water-surface elevation at Approach section without bridge 490.4
Amount of backwater caused by bridge 0.0 ***ft***

500-year discharge 10,700 ***ft³/s***
Water-surface elevation in bridge opening 491.5 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 1,045 ***ft²***
Average velocity in bridge opening 10.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 492.5
Water-surface elevation at Approach section without bridge 492.5
Amount of backwater caused by bridge 0.0 ***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 analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). 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-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	1.5	2.0	--
Clear-water scour	---	--	--
Depth to armoring	N/A N/	A --	--
Left overbank	--	--	--
Right overbank	--	--	11.8

Local scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
Abutment scour	14.2	--	15.7
Left abutment	18.8–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.4
Pier 3			

Riprap Sizing

	100-year discharge	*500-year discharge* *(D50 in feet)*	*Incipient overtopping discharge*
Abutments:	2.0	--	1.4
Left abutment	2.0	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

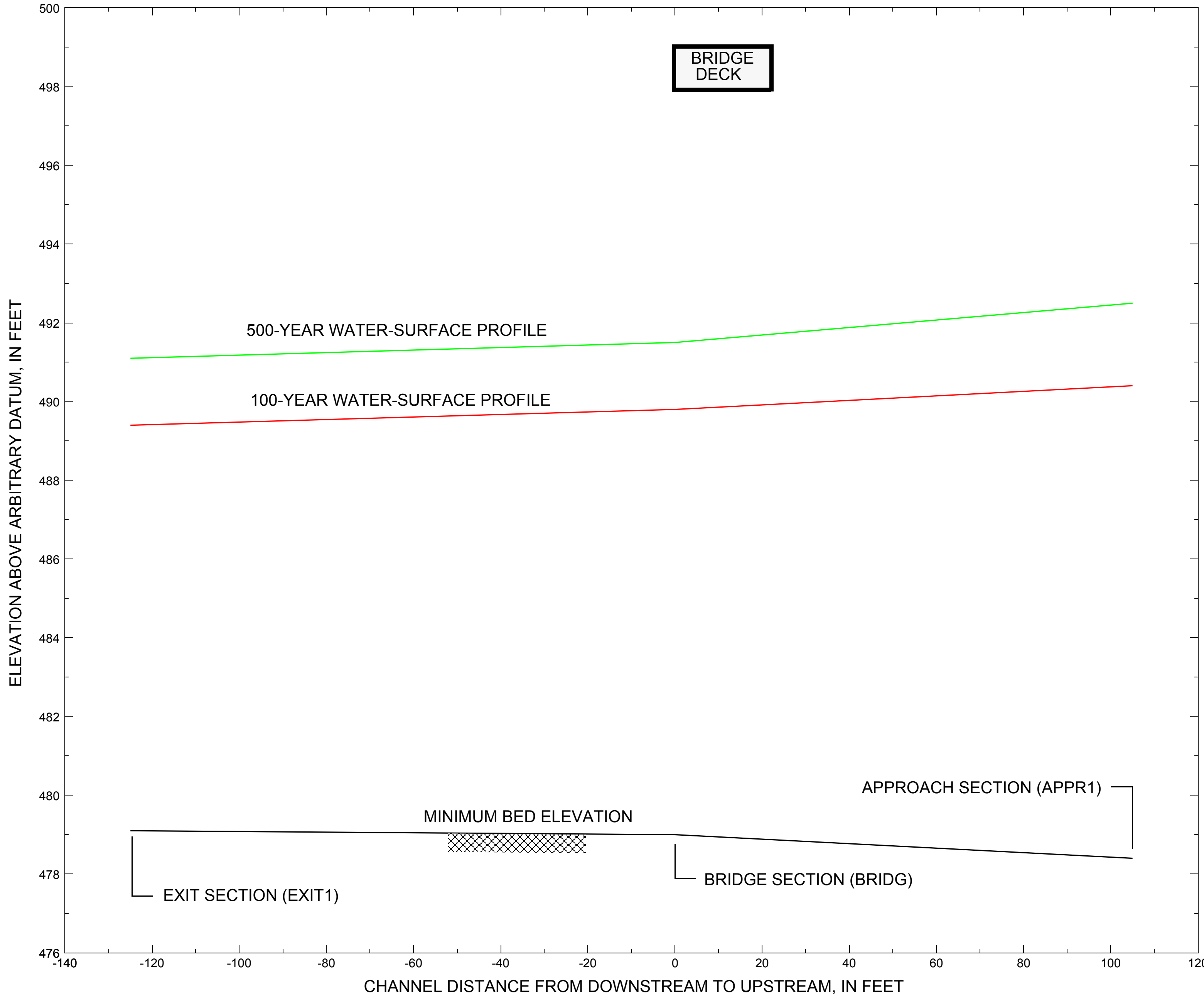


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BRADTH00270022 on Town Highway 27, crossing the Waits River, Bradford, Vermont.

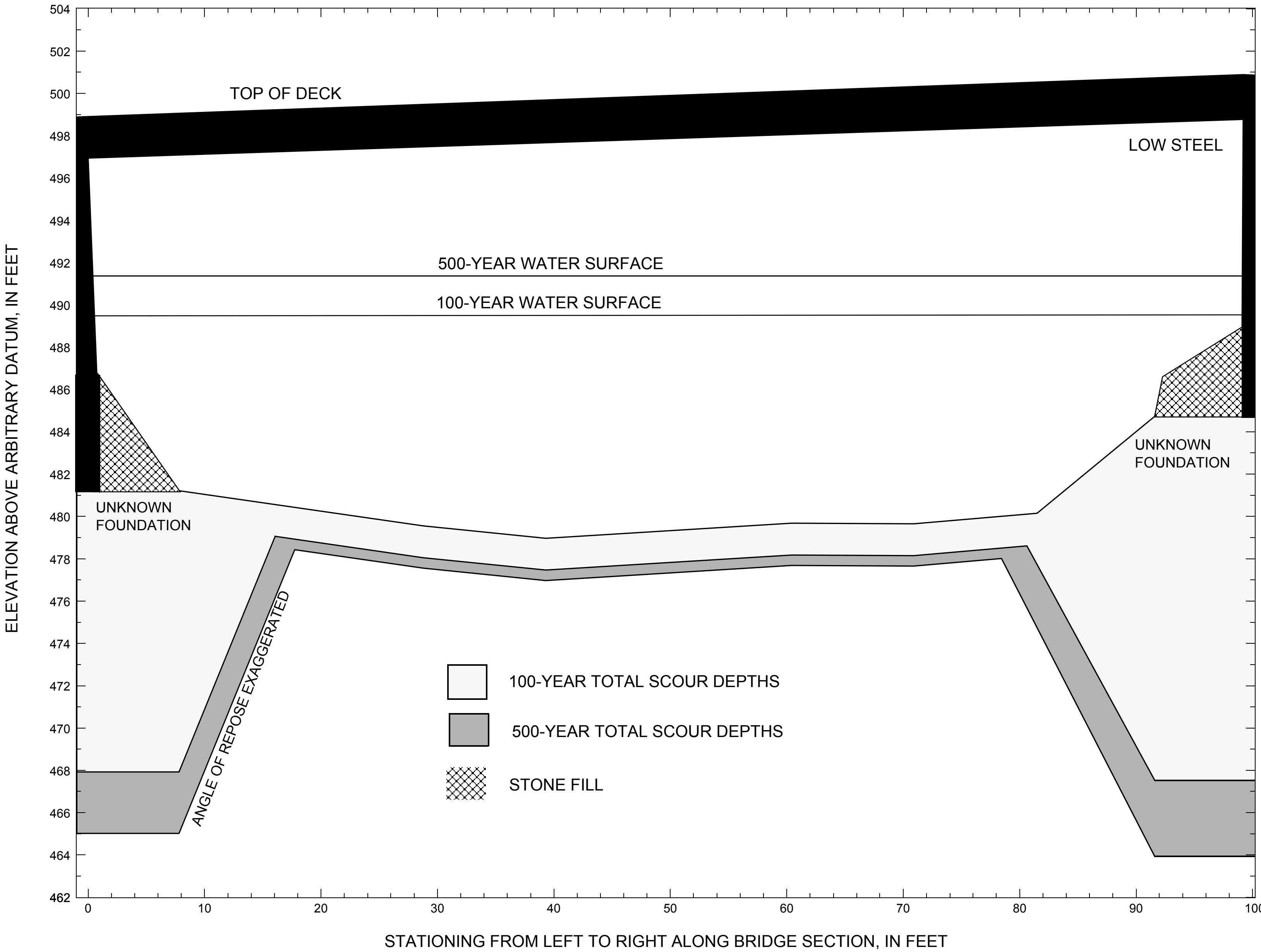


Figure 8. Scour elevations for the 100- and 500-year discharges at structure BRADTH00270022 on Town Highway 27, crossing the Waits River, Bradford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRADTH00270022 on Town Highway 27, crossing the Waits River, Bradford, 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 7,500 cubic-feet per second											
Left abutment	0.0	--	496.9	--	481.2	1.5	11.8	--	13.3	467.9	--
Right abutment	99.2	--	498.8	--	484.7	1.5	15.7	--	17.2	467.5	--

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 BRADTH00270022 on Town Highway 27, crossing the Waits River, Bradford, 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 10,700 cubic-feet per second											
Left abutment	0.0	--	496.9	--	481.2	2.0	14.2	--	16.2	465.0	--
Right abutment	99.2	--	498.8	--	484.7	2.0	18.8	--	20.8	463.9	--

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 Emergency Management Agency, 1991a, Flood Insurance Study, Town of Bradford, Orange County, Vermont: Washington, D.C., June 3, 1991.

——————, 1991b, Flood Insurance Study, Village of Bradford, Orange County, Vermont: Washington, D.C., June 3, 1991.

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.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 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

——————, 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, 1981, Fairlee, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brad022.wsp
T2        Hydraulic analysis for structure BRADTH00270022   Date: 07-MAY-98
T3        TH 27 CROSSING THE WAITS RIVER, BRADFORD, VT
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           7500.0  10700.0
WS           489.4    491.1
*
XS   EXIT1   -125           0.
GR         -199.4, 497.85   -147.5, 497.11    -19.9, 492.64    -12.3, 492.01
GR            0.0, 490.79      6.2, 487.59      7.7, 486.58      9.8, 482.33
GR           13.8, 481.05     24.5, 479.13     38.9, 479.11     74.1, 481.01
GR           90.5, 480.99    100.5, 486.56    101.3, 487.38    106.9, 490.20
GR          118.6, 493.82    132.6, 500.05    144.5, 506.35    190.0, 513.47
*
N           0.050        0.030
SA                   0.0
*
XS   FULLV       0  * * *   0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    497.86       0.0
GR            0.0, 496.94      0.9, 484.55      1.1, 486.48      7.8, 481.22
GR           28.8, 479.55     39.3, 478.97     50.0, 479.33     60.4, 479.68
GR           70.9, 479.65     81.5, 480.15     91.6, 484.73     92.3, 486.56
GR           99.1, 488.94     99.2, 498.77      0.0, 496.94
*
*         BRTYPE  BRWDTH
CD            1      20.9
N           0.030
*
*              SRD    EMBWID   IPAVE
XR   RDWAY      10      16.0     1
GR         -397.0, 511.97   -383.7, 505.30   -370.8, 502.97   -351.1, 498.13
GR         -290.7, 498.56   -283.5, 499.88   -251.4, 500.37   -205.3, 499.60
GR         -166.9, 498.81      0.0, 498.90    108.7, 500.88    158.7, 502.32
GR          180.8, 502.51    187.1, 505.23    212.5, 505.76    227.8, 510.35
GR          235.2, 513.58
*
*
AS   APPR1    105
GR         -662.1, 522.49   -489.1, 511.21   -385.6, 500.89   -281.6, 500.39
GR         -134.4, 499.17    -65.2, 495.09    -38.4, 494.51    -23.0, 490.97
GR            0.0, 486.57      2.4, 483.88      9.5, 481.14     32.1, 480.81
GR           65.2, 480.32     91.1, 478.42    103.5, 480.75    110.1, 486.49
GR          119.3, 492.68    123.0, 495.40    138.8, 497.96    158.4, 502.33
GR          189.8, 503.63    219.4, 504.51    254.8, 513.83
*
N           0.040        0.030
SA                 -38.5
*
HP 1 BRIDG 489.78 1 489.78
HP 2 BRIDG 489.78 * * 7500
HP 1 APPR1 490.43 1 490.43
HP 2 APPR1 490.43 * * 7500
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File brad022.wsp
     Hydraulic analysis for structure BRADTH00270022   Date: 07-MAY-98
     TH 27 CROSSING THE WAITS RIVER, BRADFORD, VT
        *** RUN DATE & TIME: 06-29-98  09:29
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     872.  171464.    99.   111.                      14709.
 489.78         872.  171464.    99.   111.  1.00     1.    99.  14709.

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

      WSEL     LEW     REW    AREA         K        Q    VEL
    489.78     0.5    99.1   871.7  171464.    7500.   8.60

X STA.        0.5       14.3       18.5       22.6       26.4       30.1
  A(I)           98.6       39.5       38.9       37.4       37.7
  V(I)           3.80       9.48       9.63      10.02       9.95

X STA.       30.1       33.6       37.1       40.5       44.0       47.5
  A(I)           36.7       36.6       36.6       37.3       36.9
  V(I)          10.23      10.24      10.24      10.05      10.16

X STA.       47.5       51.0       54.6       58.3       62.0       65.7
  A(I)           37.1       37.8       37.2       37.3       37.4
  V(I)          10.11       9.91      10.07      10.05      10.02

X STA.       65.7       69.5       73.1       77.0       80.7       99.1
  A(I)           38.3       36.4       39.0       36.8       98.1
  V(I)           9.80      10.31       9.63      10.19       3.82

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =     105.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2    1125.  222302.   136.   142.                      18359.
 490.43        1125.  222302.   136.   142.  1.00   -20.   116.  18359.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =     105.

      WSEL     LEW     REW    AREA         K        Q    VEL
    490.43   -20.2   116.0  1125.3  222302.    7500.   6.66

X STA.      -20.2       15.1       20.4       25.6       30.8       36.0
  A(I)          160.2       50.1       49.0       49.6       50.4
  V(I)           2.34       7.49       7.65       7.57       7.45

X STA.       36.0       41.0       46.0       51.0       55.9       60.5
  A(I)           48.3       49.3       49.1       48.7       46.1
  V(I)           7.76       7.61       7.63       7.70       8.14

X STA.       60.5       65.2       70.0       74.6       79.0       83.1
  A(I)           47.6       48.6       49.0       48.2       46.8
  V(I)           7.88       7.72       7.65       7.78       8.02

X STA.       83.1       87.2       91.0       94.9       99.3      116.0
  A(I)           47.0       45.2       45.4       47.8       99.0
  V(I)           7.98       8.30       8.26       7.85       3.79
```

```
        U.S. Geological Survey WSPRO Input File brad022.wsp
        Hydraulic analysis for structure BRADTH00270022   Date: 07-MAY-98
        TH 27 CROSSING THE WAITS RIVER, BRADFORD, VT
           *** RUN DATE & TIME: 06-29-98  09:29
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1045.  227288.    99.   114.                      19301.
   491.54         1045.  227288.    99.   114.  1.00     0.    99.  19301.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.54     0.4    99.1  1045.3  227288.   10700.  10.24

X STA.         0.4       14.3       18.5       22.5       26.4       30.1
  A(I)            123.5       46.2       45.6       45.0       44.2
  V(I)             4.33      11.57      11.74      11.88      12.11

X STA.        30.1       33.7       37.3       40.8       44.3       47.9
  A(I)             44.0       43.9       43.8       44.6       44.2
  V(I)            12.15      12.19      12.22      12.00      12.12

X STA.        47.9       51.6       55.3       59.1       62.8       66.6
  A(I)             45.3       44.8       44.8       44.1       45.0
  V(I)            11.82      11.94      11.93      12.12      11.89

X STA.        66.6       70.4       74.2       78.0       82.0       99.1
  A(I)             44.8       44.8       45.2       45.7      115.9
  V(I)            11.95      11.94      11.84      11.70       4.62

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =     105.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2    1416.  307228.   149.   155.                      24810.
   492.47         1416.  307228.   149.   155.  1.00   -30.   119.  24810.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =     105.

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.47   -29.5   119.0  1416.0  307228.   10700.   7.56

X STA.       -29.5       13.0       18.4       23.6       28.9       34.0
  A(I)            217.8       61.5       60.2       60.8       60.3
  V(I)             2.46       8.69       8.89       8.81       8.87

X STA.        34.0       39.2       44.3       49.3       54.3       59.0
  A(I)             60.5       60.2       59.9       59.4       56.1
  V(I)             8.84       8.89       8.93       9.01       9.54

X STA.        59.0       63.9       68.9       73.7       78.2       82.7
  A(I)             58.9       61.5       60.9       58.3       58.9
  V(I)             9.08       8.69       8.79       9.17       9.08

X STA.        82.7       86.9       91.0       95.3       99.8      119.0
  A(I)             57.8       57.4       58.1       57.3      130.0
  V(I)             9.25       9.31       9.20       9.34       4.11
```

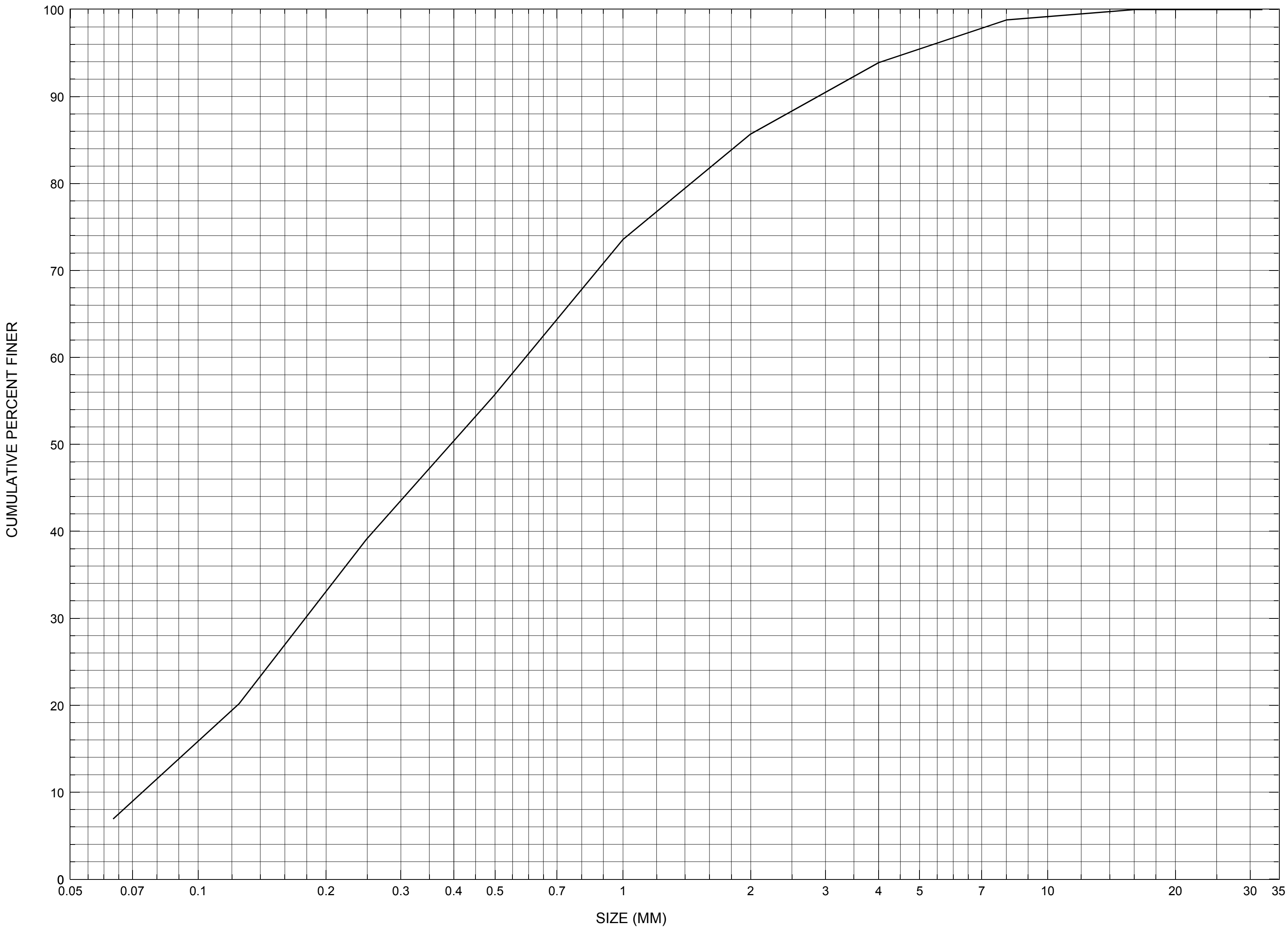
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File brad022.wsp
        Hydraulic analysis for structure BRADTH00270022   Date: 07-MAY-98
        TH 27 CROSSING THE WAITS RIVER, BRADFORD, VT
           *** RUN DATE & TIME: 06-29-98  09:29

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

 EXIT1:XS   ******     3.     824.  1.29 *****  490.69  486.52   7500.  489.40
      -125. ******   105.  158020.  1.00 ***** *******    0.57    9.10

 FULLV:FV     125.     2.     864.  1.17  0.26  490.96 *******   7500.  489.78
          0.   125.   106.  169163.  1.00  0.00    0.01    0.53    8.68
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR1:AS     105.   -20.    1124.  0.69  0.16  491.11 *******   7500.  490.42
       105.   105.   116.  221860.  1.00  0.00    0.00    0.41    6.67
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

 BRIDG:BR     125.     1.     872.  1.17  0.26  490.95  486.34   7500.  489.78
          0.   125.    99.  171417.  1.02  0.00   -0.01    0.51    8.61

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  0.991 ******  497.86 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPR1:AS      84.   -20.    1126.  0.69  0.14  491.12  485.89   7500.  490.43
       105.    91.   116.  222366.  1.00  0.04    0.01    0.41    6.66

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.275  0.016  218323.    14.   112.   490.33

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
    EXIT1:XS    -125.     3.   105.   7500.  158020.     824.     9.10  489.40
    FULLV:FV       0.     2.   106.   7500.  169163.     864.     8.68  489.78
    BRIDG:BR       0.     1.    99.   7500.  171417.     872.     8.61  489.78
    RDWAY:RG      10.**************      0.******************     1.00********
    APPR1:AS     105.   -20.   116.   7500.  222366.    1126.     6.66  490.43

     XSID:CODE   XLKQ   XRKQ       KQ
    APPR1:AS      14.   112.  218323.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN     YMAX    HF    HO   VHD      EGL    WSEL
    EXIT1:XS    486.52    0.57  479.11  513.47************  1.29  490.69  489.40
    FULLV:FV  ********    0.53  479.11  513.47  0.26  0.00  1.17  490.96  489.78
    BRIDG:BR    486.34    0.51  478.97  498.77  0.26  0.00  1.17  490.95  489.78
    RDWAY:RG  ****************  498.13  513.58**********************************
    APPR1:AS    485.89    0.41  478.42  522.49  0.14  0.04  0.69  491.12  490.43
```

```
         U.S. Geological Survey WSPRO Input File brad022.wsp
         Hydraulic analysis for structure BRADTH00270022   Date: 07-MAY-98
         TH 27 CROSSING THE WAITS RIVER, BRADFORD, VT
            *** RUN DATE & TIME: 06-29-98  09:29

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

 EXIT1:XS   ******    -3.    1005.  1.76 *****  492.86  488.20  10700.  491.10
      -125. ******   110.  209832.  1.00 ***** *******    0.63   10.64

 FULLV:FV     125.    -8.    1063.  1.58  0.30  493.18 *******  10700.  491.60
          0.   125.   111.  227288.  1.01  0.00    0.02    0.60   10.06
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR1:AS     105.   -29.    1415.  0.89  0.17  493.35 *******  10700.  492.46
        105.   105.   119.  306803.  1.00  0.00   -0.01    0.43    7.56
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

 BRIDG:BR     125.     0.    1045.  1.63  0.30  493.17  488.01  10700.  491.54
          0.   125.    99.  227295.  1.00  0.00   -0.01    0.55   10.24

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  497.86 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      10.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPR1:AS      84.   -30.    1416.  0.89  0.15  493.36  487.41  10700.  492.47
        105.    89.   119.  307178.  1.00  0.05    0.00    0.43    7.56

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.335  0.006  305296.    11.   110.   492.36

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS    -125.    -3.   110.  10700.  209832.    1005.   10.64  491.10
    FULLV:FV       0.    -8.   111.  10700.  227288.    1063.   10.06  491.60
    BRIDG:BR       0.     0.    99.  10700.  227295.    1045.   10.24  491.54
    RDWAY:RG      10.**************      0.******************    1.00********
    APPR1:AS     105.   -30.   119.  10700.  307178.    1416.    7.56  492.47

     XSID:CODE   XLKQ   XRKQ       KQ
    APPR1:AS      11.   110.  305296.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
    EXIT1:XS    488.20    0.63  479.11  513.47************  1.76  492.86  491.10
    FULLV:FV  ********    0.60  479.11  513.47  0.30  0.00  1.58  493.18  491.60
    BRIDG:BR    488.01    0.55  478.97  498.77  0.30  0.00  1.63  493.17  491.54
    RDWAY:RG  ****************  498.13  513.58**********************************
    APPR1:AS    487.41    0.43  478.42  522.49  0.15  0.05  0.89  493.36  492.47
   ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a sediment sample from the channel approach of structure BRADTH00270022, in Bradford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRADTH00270022

General Location Descriptive

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

Date (MM/DD/YY) 03 / 16 / 95

Highway District Number (I - 2; nn) 07

County (FIPS county code; I - 3; nnn) 017

Town (FIPS place code; I - 4; nnnnn) 07225

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

Waterway (I - 6) WAITS RIVER

Road Name (I - 7): -

Route Number TH027

Vicinity (I - 9) 0.4 MI JCT TH 27 + VT 25

Topographic Map Fairlee

Hydrologic Unit Code: 01080103

Latitude (I - 16; nnnn.n) 43593

Longitude (i - 17; nnnnn.n) 72077

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10090100220901

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0104

Year built (I - 27; YYYY) 1934

Structure length (I - 49; nnnnnn) 000109

Average daily traffic, ADT (I - 29; nnnnnn) 002000

Deck Width (I - 52; nn.n) 160

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 6

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

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) P

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

Structure type (I - 43; nnn) 310

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) 017.3

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

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

Comments:

The structural inspection report of 6/29/93 indicates the structure is a steel truss type bridge with a galvanized steel deck. The roadway on approach to the left abutment of this bridge is reported as having advanced settlement problems. The abutment walls are constructed of "laid-up" granite stone blocks with concrete caps. The caps have alligator type cracks and leaking reported, with some spalling along the top edges. The channel under the bridge is noted as deep and the flow slow moving. A large concrete dam is reported as extending across the downstream channel and the impounded water is used for municipal supply. The report indicates the bridge is on an unknown foundation. The **(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: Silt and sand

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

Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

footings are reported as not seen with no apparent undermining, but settlement is possible. The embankments are noted as slightly eroded. Stone fill protection is only shown present at the right abutment. Debris and gravel bars are noted as minor.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **152.85** mi^2 Lake/pond/swamp area **1.05** mi^2
Watershed storage *(ST)* **0.7** %
Bridge site elevation **460** ft Headwater elevation **3123** ft
Main channel length **24** mi
10% channel length elevation **500** ft 85% channel length elevation **1620** ft
Main channel slope *(S)* **62** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 10 / 1983

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

Neither benchmark information nor elevations are displayed on the plans.

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:

-

Comments:

These plans are for some minor modifications made primarily to the bridge deck and steel truss work. The plans provide no substructural information.

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 chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 2/23/96
Computerized by: RB Date: 2/23/96
Reviewd by: ECW Date: 7/2/98

Structure Number BRADTH00270022

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 09 / 07 / 1995
2. Highway District Number 7 Mile marker 0
County ORANGE (017) Town BRADFORD (07225)
Waterway *(I - 6)* WAITS RIVER Road Name -
Route Number TH27 Hydrologic Unit Code: 01080103
3. Descriptive comments:
The bridge is located 0.4 miles from the junction with VT 25

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 5 LBDS 2 RBDS 5 Overall 5
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 109 *(feet)* Span length 104 *(feet)* Bridge width 16 *(feet)*

Road approach to bridge:

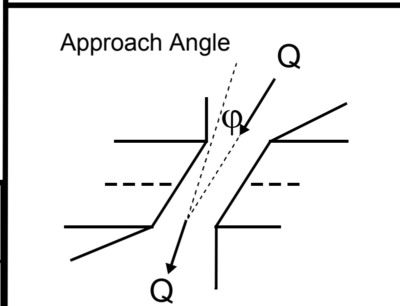
8. LB 0 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

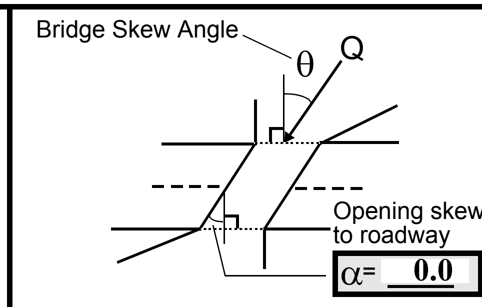
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	2	1	2	1
RBDS	5	1	0	0
LBDS	5	1	4	1

*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: 30





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 30 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: **1b**

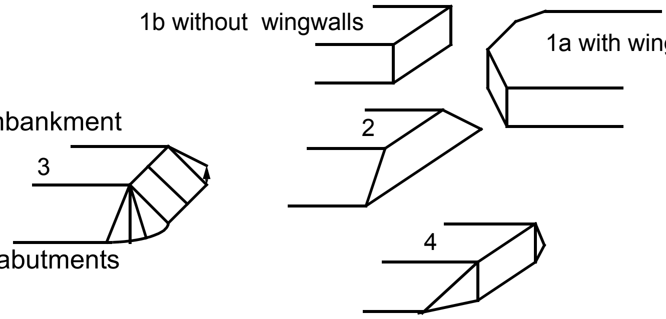
1a- Vertical abutments with wingwalls

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.)

7. The bridge dimensions are from the VTAOT files.
Measured bridge width is 16 feet, span length is 99 feet and bridge length is 109 feet.
13. The erosion of the upstream right bank consists of voids formed behind the concrete edge of the abutment. The DS left bank erosion consists of stones that have fallen out leaving a void 2.5 feet deep, 12 feet from the abutment face.

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
103.0	**4.5**			**6.0**	**1**	**2**	**341**	**456**	**1**	**1**

23. Bank width **10.0** 24. Channel width **35.0** 25. Thalweg depth **142.5** 29. Bed Material **235**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **1**

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.):

30. The right bank protection extends 160 feet from the bridge and then bedrock is exposed along the water line.
A layer of sand up to 2 feet thick covers coarser bed material up to 150 feet upstream. Above 150 feet upstream the bed material is gravel with boulders.

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
110.0		8.0		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.):

52

The water depth was 8.2 feet at the downstream bridge face.

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

-

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		30	90	2	0	0	0	90.0
RABUT	2	0	90			2	0	99.0

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

0

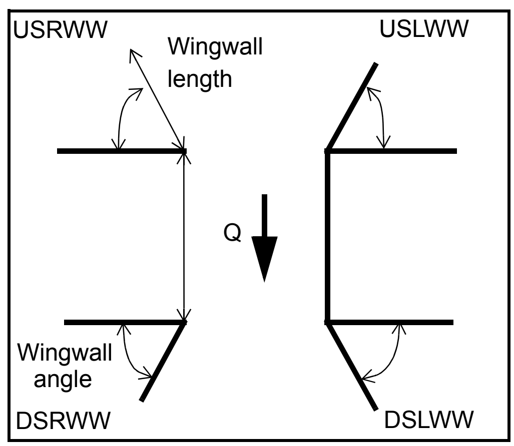
2

There are large stones at the base of the abutment footings and across the channel. The top of the footings are visible under the bridge. The maximum water depth is 8.2 feet at the DS bridge face.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						99.0	
USRWW:	N		-		-	7.5	
DSLWW:	-		-		N	21.0	
DSRWW:	-		-		-	21.0	

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	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	3	3	-

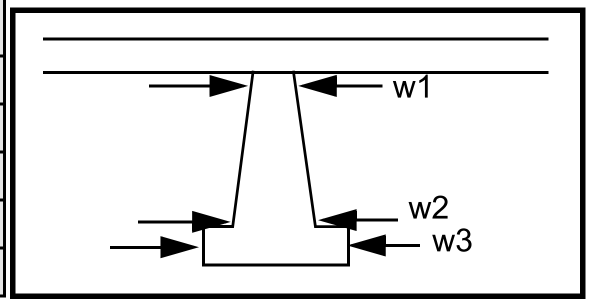
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

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



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	the	s have		-	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	base	been		-	**1**- Solid pier, **2**- column, **3**- bent
88. Material	s of	place		-	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	the	d as		-	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	left	pro-		-	Y- yes; N- no
91. Attack ∠ (BF)	and	tec-	N	-	
92. Pushed	right	tion.	-	-	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	abut		-	-	
95. Cross-members	ment		-	-	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	s,		-	-	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	large		-	-	
98. Exposure depth	stone		-	-	

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

E. Downstream Channel Assessment

100.

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

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

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):

1
2
124
63

106. Point/Side bar present? 0 (Y or N. if N type ctrl-n pb) Mid-bar distance: 0 Mid-bar width: 21

Point bar extent: 2 feet 0 (US, UB, DS) to 1 feet - (US, UB, DS) positioned Th %LB to e %RB

Material: left

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

bank material is mostly silt, sand and some stones. The right bank is bedrock along the water line. The water depth is 7.5 feet. The left bank protection extends 350 feet from the bridge, protecting the embankment for the factory.

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

Cut bank extent: _____ feet _____ (US, UB, DS) to _____ feet _____ (US, UB, DS)

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

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

N

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

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

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

RE

A dam for a hydro-power facility is downstream.

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

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

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

Confluence comments (eg. confluence name):

-

-

F. Geomorphic Channel Assessment

107. Stage of reach evolution -

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

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

-

NO POINT BARS

N

-

-

-

-

-

-

-

109. G. Plan View Sketch

N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BRADTH00270022 Town: BRADFORD
Road Number: TH 27 County: ORANGE
Stream: WAITS RIVER

Initials ECW Date: 6/29/98 Checked: EMB

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	7500	10700	0
Main Channel Area, ft2	1125	1416	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	136	149	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.001289	0.001289	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.3	9.5	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	222302	307228	0
Conveyance, main channel	222302	307228	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	7500.0	10700.0	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	7.6	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	1.7	1.8	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	1	1	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	7500	10700	0	7500	10700	0
Total conveyance	222302	307228	0	171464	227288	0
Main channel conveyance	222302	307228	0	171464	227288	0
Main channel discharge	7500	10700	ERR	7500	10700	ERR
Area - main channel, ft2	1125	1416	0	872	1045	0
(W1) channel width, ft	136	149	0	98.6	98.7	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	136	149	0	98.6	98.7	0
D50, ft	0.001289	0.001289	0.001289			
w, fall velocity, ft/s (p. 32)	0.057	0.057	0			
y, ave. depth flow, ft	8.27	9.50	N/A	8.84	10.59	ERR
S1, slope EGL	0.00143	0.00162	0			
P, wetted perimeter, MC, ft	142	155	0			
R, hydraulic Radius, ft	7.923	9.135	ERR			
V*, shear velocity, ft/s	0.604	0.690	N/A			
V*/w	10.596	12.111	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.69	0.69	0			
y2,depth in contraction, ft	10.33	12.63	ERR			
ys, scour depth, ft (y2-y_bridge)	1.48	2.04	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	7500	10700	N/A
Main channel area (DS), ft2	872	1045	0
Main channel width (normal), ft	98.6	98.7	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	98.6	98.7	0.0
D90, ft	0.0094	0.0094	0.0000
D95, ft	0.0153	0.0153	0.0000
Dc, critical grain size, ft	0.0855	0.1167	ERR

Pc, Decimal percent coarser than Dc	0.000	0.000	0.000
Depth to armoring, ft	ERR	ERR	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	7500	10700	0	7500	10700	0
a', abut.length blocking flow, ft	20.7	29.9	0	16.9	19.9	0
Ae, area of blocked flow ft2	93.94	153.23	0	101.17	138.91	0
Qe, discharge blocked abut.,cfs	219.9	376.39	0	392.05	618.22	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.34	2.46	ERR	3.88	4.45	ERR
ya, depth of f/p flow, ft	4.54	5.12	ERR	5.99	6.98	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.194	0.191	ERR	0.279	0.297	ERR
ys, scour depth, ft	11.81	14.18	N/A	15.73	18.83	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	20.7	29.9	0	16.9	19.9	0
y1 (depth f/p flow, ft)	4.54	5.12	ERR	5.99	6.98	ERR
a'/y1	4.56	5.83	ERR	2.82	2.85	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.19	N/A	0.28	0.30	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.51	0.55	0	0.51	0.55	0
y, depth of flow in bridge, ft	8.84	10.59	0.00	8.84	10.59	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.42	1.98	0.00	1.42	1.98	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR