LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (REDSTH00360025) on TOWN HIGHWAY 36, crossing the WEST BRANCH DEERFIELD RIVER, READSBORO, VERMONT

U.S. Geological Survey
Open-File Report 97-653

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (REDSTH00360025) on TOWN HIGHWAY 36, crossing the WEST BRANCH DEERFIELD RIVER, READSBORO, VERMONT

By ROBERT H. FLYNN AND RONDA L. BURNS

U.S. Geological Survey
Open-File Report 97-653

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

Pembroke, New Hampshire

1997

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
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	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 25 (REDSTH00360025) ON TOWN HIGHWAY 36, CROSSING THE WEST BRANCH DEERFIELD RIVER, READSBORO, VERMONT

By **Robert H. Flynn and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure REDSTH00360025 on Town Highway 36 crossing the West Branch Deerfield River, Readsboro, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 14.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the upstream right bank and forest on the upstream left bank. The surface cover on the downstream right and left banks is primarily grass, shrubs and brush.

In the study area, the West Branch Deerfield River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 65 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulders, with a median grain size (D_{50}) of 117 mm (0.383 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 1, 1996, indicated that the reach was stable.

The Town Highway 36 crossing of the West Branch Deerfield River is a 59-ft-long, two-lane bridge consisting of one 57-foot concrete T-beam span (Vermont Agency of Transportation, written communication, September 28, 1995). The opening length of the structure parallel to the bridge face is 54 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 30 degrees.

During the Level I assessment, a scour hole approximately 2 ft deeper than the mean thalweg depth was observed along the upstream right wingwall and a scour hole approximately 1 ft deeper than the mean thalweg depth was observed along the downstream left wingwall. The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the downstream end of the downstream left wingwall, at the upstream end of the upstream right wingwall, at the downstream end of the right abutment, along the entire base length of the downstream right wingwall, along the upstream right bank and along the downstream left bank. A stone wall was noted along 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 recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.6 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Abutment scour ranged from 15.1 to 16.3 ft along the left abutment and from 7.4 to 9.2 ft along the right abutment. The worst-case abutment scour occurred at the incipient-overtopping and 500-year discharges for the left abutment and at the 500-year discharge for the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in
tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Stamford, VT. Quadrangle, 1:24,000, 1954 and
Readsboro, VT. Quadrangle, 1:24,000, 1987

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 REDSTH00360025 ***Stream*** West Branch Deerfield River

County Bennington ***Road*** TH36 ***District*** 1

Description of Bridge

Bridge length 59 ***ft*** ***Bridge width*** 23.4 ***ft*** ***Max span length*** 57 ***ft***

Alignment of bridge to road (on curve or straight) Curve, left; straight, right

Abutment type Vertical, concrete ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 8/1/96 Type-

Description of stone fill 2 stone fill at the downstream end of the downstream left wingwall, at the upstream end of the upstream right wingwall, at the downstream end of the right abutment and along the entire base length of the downstream right wingwall.

The abutments and wingwalls are concrete. A two feet deep scour hole exists in front of the upstream right wingwall and a one foot deep scour hole exists in front of the downstream left wingwall.

Yes 50

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

There is a severe channel bend in both the upstream and downstream reach. The scour holes have developed in the locations where the flow impacts the wingwalls.

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	8/1/96	0	0
Level II	8/1/96	0	0

Potential for debris Low. There is no debris in the channel near the bridge and the upstream channel is stable.

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

There is a point bar along the upstream left bank and a mid-channel bar underneath the bridge. There is a bridge approximately 310 ft downstream of this site, creating a potential for backwater at higher flows (8/1/96).

Description of the Geomorphic Setting

General topography The channel is located in a narrow, irregular flood plain within a moderate relief valley setting.

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

Date of inspection 8/1/96

DS left: Steeply sloped channel bank.

DS right: Moderately sloped channel bank to narrow flood plain and VT100

US left: Moderately sloped channel bank.

US right: Steeply sloped channel bank to narrow flood plain and VT100.

Description of the Channel

Average top width 65 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Boulder / Cobbles ***Bank material*** Boulder/Cobbles

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

8/1/96

Vegetative co Grass, shrubs and brush

DS left: Trees and brush

DS right: Trees

US left: Trees and pasture

US right:

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

The assessment of 8/1/96 noted flow conditions are influenced by a point bar on the upstream left bank and a mid-channel bar under the bridge as well as a bridge approximately 310 ft downstream of this site.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 14.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,020 ***ft³/s*** ***Q500*** 4,750 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans None.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 501.51 ft, arbitrary survey datum). RM2 is a VTAOT survey disk on top of the downstream right concrete rail on the downstream bridge (VT100) (elev. 496.90 ft, arbitrary survey datum). RM3 is a chiseled X on top of the downstream end of the right abutment (elev. 501.84 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-502	1	VT100 bridge exit section.
FLV2	-352	2	VT100 bridge Full-valley section (Templated from EXIT2).
DSBRG	-352	1	VT100 bridge section.
RDWY2	-332	1	VT100 Road Grade section.
APPR2	-257	2	Modelled Approach section of VT100 Bridge (Templated from APTM2).
APTM2	-61	1	TH36 exit section as surveyed (Used as a template).
EXIT3	-150	2	TH36 Bridge exit section (Templated from APTM2).
EXIT1	-61	2	TH36 Bridge exit section (As surveyed).
FULLV	0	2	TH36 Full-valley section (Templated from EXIT1).
BRIDG	0	1	TH36 Bridge section.
RDWAY	14	1	TH36 Road grade section.
APPRO	76	2	Modelled TH36 Approach section (Templated from APTEM).
APTEM	122	1	TH36 approach section as surveyed (Used as a template).

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E. For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.055, and overbank "n" values ranged from 0.045 to 0.065.

Critical depth at the VT100 bridge exit section (EXIT2), approximately 500 ft downstream of this site, 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 0.0158 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1954, 1987). This slope resulted in a normal depth slightly less than critical depth and WSPRO defaulted to critical depth. Critical depth in the downstream reach for the flows modelled is considered to be a satisfactory solution.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0098 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 100-year and incipient-overtopping discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass 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 501.8 *ft*
Average low steel elevation 497.8 *ft*

100-year discharge 3,020 *ft^3/s*
Water-surface elevation in bridge opening 493.5 *ft*
Road overtopping? No *Discharge over road* - *ft^3/s*
Area of flow in bridge opening 237 *ft^2*
Average velocity in bridge opening 12.8 *ft/s*
Maximum WSPRO tube velocity at bridge 15.6 *ft/s*

Water-surface elevation at Approach section with bridge 497.3
Water-surface elevation at Approach section without bridge 494.4
Amount of backwater caused by bridge 2.9 *ft*

500-year discharge 4,750 *ft^3/s*
Water-surface elevation in bridge opening 498.0 *ft*
Road overtopping? Yes *Discharge over road* 355 *ft^3/s*
Area of flow in bridge opening 441 *ft^2*
Average velocity in bridge opening 10.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.5 */s*

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 495.5
Amount of backwater caused by bridge 5.1 *ft*

Incipient overtopping discharge 3,580 *ft^3/s*
Water-surface elevation in bridge opening 494.1 *ft*
Area of flow in bridge opening 265 *ft^2*
Average velocity in bridge opening 13.5 *ft/s*
Maximum WSPRO tube velocity at bridge 16.2 *ft/s*

Water-surface elevation at Approach section with bridge 498.2
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 3.4 *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.

Contraction scour for the 100-year and incipient-overtopping discharge was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. Additional estimates of contraction scour for the 500-year discharge were also computed by use of Laursen's clear-water scour equation and the results presented in Appendix F. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Abutment scour for the left abutment 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.

Scour at the right abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

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	0.4	0.0	0.6
Depth to armoring	24.8 2.8	27.8	--
Left overbank	--	--	--
Right overbank	--	--	15.1

Local scour:			
Abutment scour	16.3	16.3 9.0	9.2
Left abutment	7.4–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.1	2.2
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.4	2.1	2.2
Left abutment	2.4	--	--
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--		

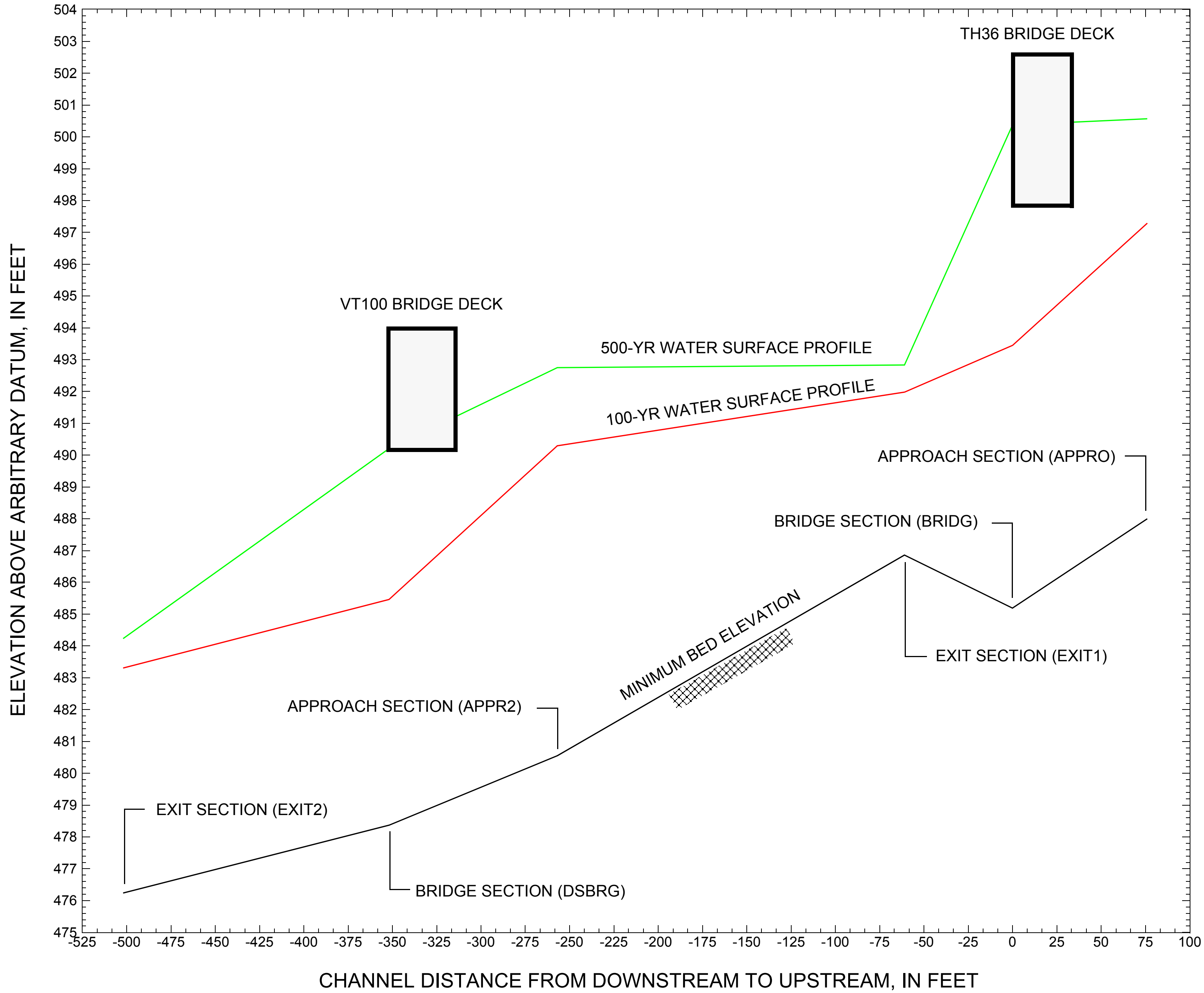


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure REDSTH00360025 on Town Highway 36, crossing the West Branch Deerfield River, Readsboro, Vermont.

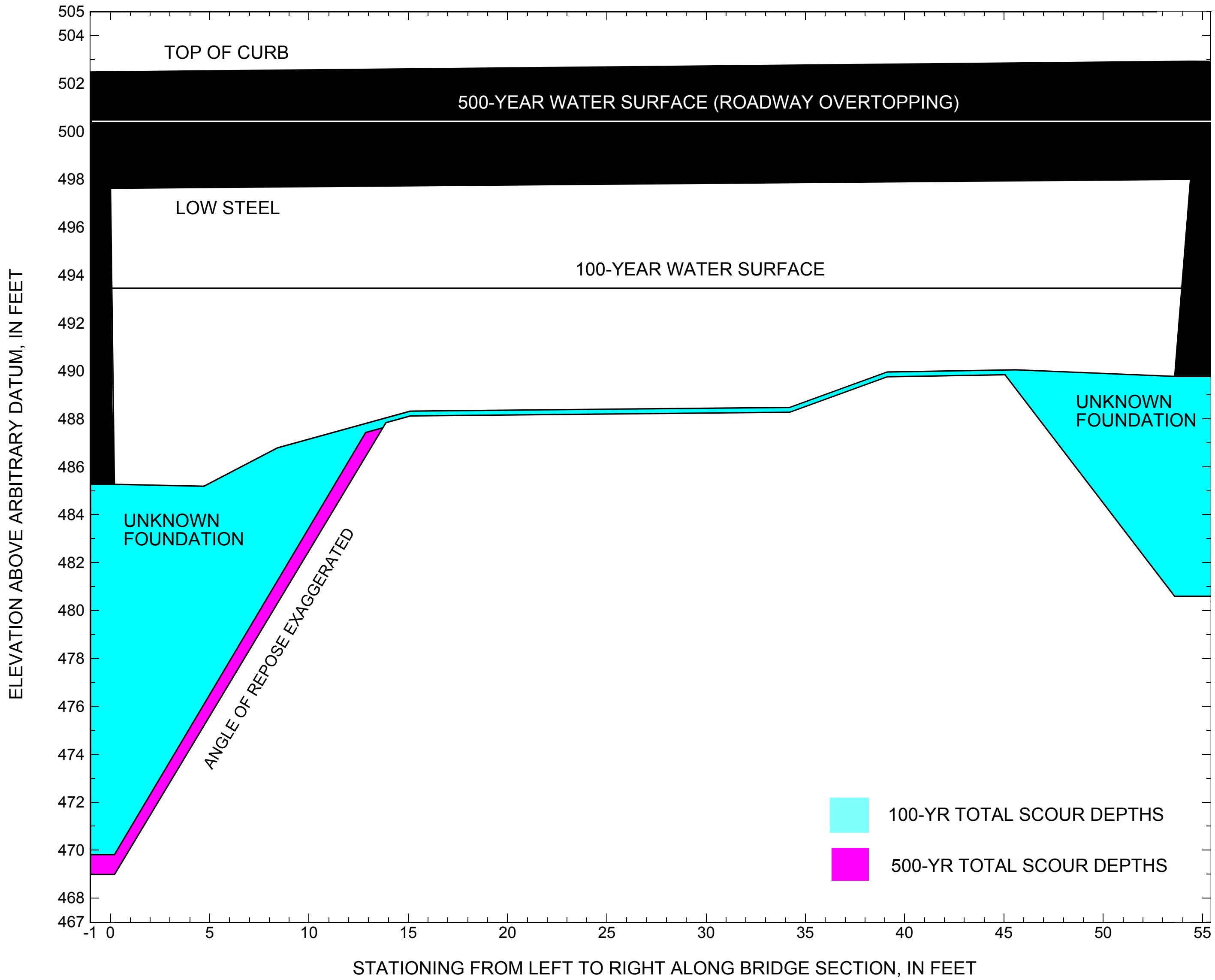


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure REDSTH00360025 on Town Highway 36, crossing the West Branch Deerfield River, Readsboro, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure REDSTH00360025 on Town Highway 36, crossing the West Branch Deerfield River, Readsboro, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 3,020 cubic-feet per second											
Left abutment	0.2	-	497.6	-	485.3	0.4	15.1	--	15.5	469.8	-
Right abutment	53.6	-	498.0	-	489.8	0.4	9.0	--	9.4	480.4	-

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 REDSTH00360025 on Town Highway 36, crossing the West Branch Deerfield River, Readsboro, 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 4,750 cubic-feet per second											
Left abutment	0.2	-	497.6	-	485.3	0.0	16.3	--	16.3	469.0	-
Right abutment	53.6	-	498.0	-	489.8	0.0	9.2	--	9.2	480.6	-

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

SELECTED REFERENCES

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

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

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

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

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

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

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

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

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

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, 1987, Readsboro, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

U.S. Geological Survey, 1954, Stamford, 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 reds025.wsp
T2        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
T3        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3020.0   4750.0   3580.0
SK          0.0158   0.0158   0.0158
*
XS   EXIT2   -502
GR         -422.0, 500.69   -364.8, 494.77   -248.7, 493.20   -166.2, 493.35
GR         -126.5, 493.16    -66.1, 491.95    -40.8, 485.43    -10.7, 484.98
GR           -5.7, 481.29      0.0, 479.21      3.9, 477.97     11.2, 476.72
GR           22.4, 476.24     26.0, 477.46     32.0, 476.76     38.1, 479.56
GR           47.0, 482.79     83.7, 481.63    137.3, 482.18    175.9, 489.85
GR          467.8, 502.51
*
N           0.045        0.05        0.05
SA                 -10.7        47.0
*
XS   FLV2      -352 * * *  0.01
*
BR   DSBRG    -352    489.91     30.0
GR            0.0, 489.61      0.1, 489.41      0.2, 484.70     12.4, 480.23
GR           16.0, 478.83     26.7, 478.37     33.8, 479.39     42.3, 480.51
GR           53.6, 482.09     63.0, 487.73     63.7, 489.89
GR           63.9, 490.20      0.0, 489.61
*
*          BRTYPE   BRWDTH  EMBSS   EMBELV
CD            3       40     1.7    494.09
N            0.055
*
*             SRD     EMBWID    IPAVE
XR   RDWY2   -332      35.0       1
GR         -422.0, 500.69   -137.8, 492.96     -0.9, 493.81      0.0, 494.64
GR           73.9, 495.19     82.4, 495.22     84.4, 494.24    216.9, 495.57
GR          467.8, 502.51
*
XT   APTM2    -61
GR         -302.5, 511.68   -190.8, 499.28    -46.8, 498.87    -11.7, 496.70
GR           -7.4, 495.61      0.0, 490.28      5.5, 488.31      7.9, 487.66
GR           14.4, 487.18     19.0, 486.86     24.6, 487.85     32.0, 488.45
GR           48.1, 489.72     99.7, 490.70    175.9, 489.85    221.8, 496.50
GR          461.1, 504.19
*
AS   APPR2    -257 * * * 0.0322
GT
N           0.045        0.05        0.05
SA                  -7.4        48.1
*
XS   EXIT3   -150 * * * 0.0322
GT
N           0.045        0.05        0.05
SA                  -7.4        48.1
*
XS   EXIT1    -61 * * * 0.0
```

```
GT
N           0.045        0.05        0.05
SA                  -7.4         48.1
*
XS   FULLV       0  * * *   0.0
*



*             SRD     LSEL    XSSKEW
BR   BRIDG      0    497.81      30.0
GR             0.0, 497.63      0.1, 488.71      0.2, 485.27      4.7, 485.19
GR             8.4, 486.79     15.2, 488.32     24.4, 488.42     34.2, 488.48
GR            36.6, 489.21     39.1, 489.96     45.6, 490.05     53.6, 489.77
GR            54.4, 498.00      0.0, 497.63
*
*          BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      34.4 * *      43.6      9.8
N           0.055
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     14      23.4     1
GR          -378.0, 514.13   -310.9, 502.00   -195.0, 503.11   -143.1, 502.52
GR          -101.5, 501.72    -77.4, 501.37    -25.4, 502.22     -1.8, 501.68
GR            -1.4, 502.44      0.0, 502.49     55.1, 502.93     57.2, 502.96
GR            57.6, 501.87     60.5, 501.74    144.1, 499.71    186.6, 499.00
GR           331.2, 503.45    532.4, 512.07
*
XT   APTEM   122
GR          -195.0, 506.00   -195.0, 503.11   -143.1, 502.52
GR          -101.5, 501.72    -53.9, 498.42    -49.7, 492.69    -37.2, 493.24
GR             0.0, 493.82     44.8, 490.11     47.5, 489.27     55.4, 488.45
GR            60.5, 488.88     65.2, 490.17     68.4, 490.55     72.5, 495.78
GR            81.4, 497.04    260.1, 498.88    396.3, 499.50    424.8, 509.83
*
AS   APPRO     76 * * * 0.0098
GT
N           0.060        0.065        0.050         0.040
SA                 -53.9         0.0          81.4
*
HP 1 BRIDG   493.45 1 493.45
HP 2 BRIDG   493.45 * * 3020
HP 1 APPRO   497.29 1 497.29
HP 2 APPRO   497.29 * * 3020
*
HP 1 BRIDG   498.00 1 498.00
HP 2 BRIDG   498.00 * * 4398
HP 2 BRIDG   494.02 1 494.02
HP 2 RDWAY   500.37 * * 355
HP 1 APPRO   500.57 1 500.57
HP 2 APPRO   500.57 * * 4750
*
HP 1 BRIDG   494.06 1 494.06
HP 2 BRIDG   494.06 * * 3580
HP 1 APPRO   498.16 1 498.16
HP 2 APPRO   498.16 * * 3580
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
           *** RUN DATE & TIME: 06-24-97  14:22
    CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       237     16195     47     59                         3024
   493.45           237     16195     47     59  1.00      0     54     3024

    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.45     0.0    54.0   236.7   16195.    3020.  12.76

X STA.        0.0        2.9        4.6        6.1        7.6        9.3
  A(I)           20.1       11.7       10.4       10.0        9.8
  V(I)           7.52      12.95      14.48      15.08      15.47

X STA.        9.3       11.1       13.1       15.3       17.7       20.0
  A(I)            9.7       10.0       10.2       10.4       10.3
  V(I)          15.58      15.16      14.74      14.54      14.62

X STA.       20.0       22.4       24.8       27.2       29.8       32.3
  A(I)           10.6       10.5       10.6       10.9       11.0
  V(I)          14.31      14.38      14.27      13.84      13.71

X STA.       32.3       34.9       38.4       43.1       47.9       54.0
  A(I)           11.2       12.6       14.1       14.2       18.4
  V(I)          13.44      11.98      10.68      10.62       8.22


    CROSS-SECTION PROPERTIES:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            2       226     13105     53     56                         2633
            3       490     47068     81     85                         6817
            4        24       442     68     68                           80
   497.29           739     60615    203    209  1.18    -52    149     7386

    VELOCITY DISTRIBUTION:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.29   -53.4   149.5   739.3   60615.    3020.   4.08

X STA.      -53.4      -39.9      -28.8      -17.0       -4.4        6.4
  A(I)           56.7       49.8       50.2       51.7       44.3
  V(I)           2.66       3.03       3.01       2.92       3.41

X STA.        6.4       14.1       20.5       25.9       30.8       35.2
  A(I)           36.4       34.4       31.5       30.9       28.9
  V(I)           4.15       4.39       4.80       4.88       5.22

X STA.       35.2       39.2       43.0       46.6       49.6       52.6
  A(I)           28.3       27.8       27.6       25.9       26.6
  V(I)           5.33       5.42       5.48       5.82       5.68

X STA.       52.6       55.5       58.5       61.8       66.2      149.5
  A(I)           26.2       27.5       29.5       34.5       70.7
  V(I)           5.77       5.48       5.12       4.37       2.14
```

```
        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
           *** RUN DATE & TIME: 06-24-97  14:22
    CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      441     29341      0    115                            0
   498.00           441     29341      0    115  1.00      0     54        0

    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.00     0.0    54.4   441.3   29341.    4398.   9.96

X STA.         0.0        3.4        5.4        7.4        9.4       11.6
  A(I)            35.7       22.0       20.1       19.1       19.4
  V(I)            6.16      10.01      10.94      11.53      11.33

X STA.        11.6       13.9       16.3       18.7       21.1       23.5
  A(I)            19.7       19.9       19.4       19.8       19.8
  V(I)           11.16      11.08      11.36      11.10      11.12

X STA.        23.5       26.0       28.4       30.9       33.3       35.9
  A(I)            19.8       19.8       20.0       19.9       20.4
  V(I)           11.11      11.11      10.97      11.06      10.78

X STA.        35.9       38.9       42.2       45.6       49.1       54.4
  A(I)            21.9       23.1       23.0       24.1       34.6
  V(I)           10.04       9.53       9.56       9.12       6.36

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = RDWAY;  SRD =      14.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.37   116.9   231.1    82.6    1983.     355.   4.30

X STA.       116.9      142.1      149.7      155.5      160.2      164.3
  A(I)             7.7        5.2        4.6        4.2        3.9
  V(I)            2.30       3.39       3.87       4.23       4.50

X STA.       164.3      167.9      171.2      174.1      176.9      179.6
  A(I)             3.7        3.6        3.4        3.3        3.3
  V(I)            4.81       4.96       5.27       5.31       5.44

X STA.       179.6      182.1      184.5      186.9      189.3      192.0
  A(I)             3.2        3.2        3.2        3.2        3.4
  V(I)            5.54       5.54       5.62       5.52       5.25

X STA.       192.0      195.1      198.7      203.1      209.4      231.1
  A(I)             3.6        3.8        4.1        4.8        7.3
  V(I)            4.97       4.71       4.33       3.69       2.44

    CROSS-SECTION PROPERTIES:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       49      1441     38     38                          316
             2      402     34005     54     57                         6237
             3      757     97201     81     85                        13094
             4      800     54908    319    319                         7181
   500.57          2007    187554    492    498  1.29    -90    400    20286
```

```
   VELOCITY DISTRIBUTION:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.57   -91.4   400.5  2007.4  187554.    4750.   2.37

X STA.       -91.4      -39.5      -25.8      -11.6        2.5       12.9
  A(I)           154.1      106.0      106.4      102.5       81.5
  V(I)            1.54       2.24       2.23       2.32       2.91

X STA.        12.9       21.5       29.2       36.1       42.6       48.4
  A(I)            74.2       72.4       68.1       68.1       64.4
  V(I)            3.20       3.28       3.49       3.49       3.69

X STA.        48.4       53.6       58.6       64.3       76.3      106.0
  A(I)            62.7       62.5       67.6       95.1      117.0
  V(I)            3.79       3.80       3.51       2.50       2.03

X STA.       106.0      138.3      176.3      226.3      296.0      400.5
  A(I)           115.1      121.5      137.4      152.0      178.7
  V(I)            2.06       1.96       1.73       1.56       1.33


       U.S. Geological Survey WSPRO Input File reds025.wsp
       Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
       Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
          *** RUN DATE & TIME: 06-24-97  14:22
   CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      265     19307     47     60                         3584
   494.06           265     19307     47     60  1.00      0     54     3584

   VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.06     0.0    54.0   265.2   19307.    3580.  13.50

X STA.         0.0        3.1        4.9        6.5        8.2       10.0
  A(I)            23.2       13.3       11.7       11.3       11.1
  V(I)            7.71      13.43      15.30      15.77      16.17

X STA.        10.0       11.9       14.0       16.3       18.6       20.9
  A(I)            11.2       11.5       11.4       11.5       11.5
  V(I)           16.00      15.62      15.67      15.55      15.62

X STA.        20.9       23.3       25.7       28.1       30.6       33.1
  A(I)            11.7       11.6       11.7       12.1       12.2
  V(I)           15.35      15.42      15.28      14.82      14.67

X STA.        33.1       35.8       39.4       43.6       48.1       54.0
  A(I)            12.6       14.2       15.0       15.6       20.8
  V(I)           14.26      12.59      11.95      11.49       8.59


   CROSS-SECTION PROPERTIES:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1        0         1      3      3                            0
             2      272     17755     54     57                         3475
             3      561     58949     81     85                         8348
             4      120      3799    153    153                          603
   498.16           953     80505    291    297  1.27    -56    234     8681

   VELOCITY DISTRIBUTION:  ISEQ = 11;  SECID = APPRO;  SRD =      76.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.16   -56.7   234.0   953.1   80505.    3580.   3.76

X STA.       -56.7      -39.7      -28.8      -17.3       -5.3        5.6
  A(I)            70.0       58.0       59.6       59.5       53.5
  V(I)            2.56       3.08       3.00       3.01       3.35
```

```
X STA.         5.6       13.3       19.9       25.7       30.9       35.6
  A(I)             43.1       40.8       38.4       37.0       35.6
  V(I)             4.15       4.39       4.66       4.84       5.02

X STA.        35.6       40.0       44.1       47.8       51.2       54.5
  A(I)             34.7       34.0       33.0       32.6       32.1
  V(I)             5.16       5.26       5.43       5.48       5.58

X STA.        54.5       57.7       61.2       65.6       79.0      234.0
  A(I)             33.1       34.4       38.7       60.9      124.0
  V(I)             5.40       5.20       4.62       2.94       1.44
```

```
        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
           *** RUN DATE & TIME: 06-24-97  14:22

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT2":  USED WSI = CRWS.
                            WSI,CRWS =   483.11     483.31

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

EXIT2:XS   ******     -7      389  1.22 *****  484.53  483.31    3020  483.31
      -501 ******    143    26405  1.29 ***** *******    0.97    7.77

FLV2 :FV      150     -8      458  0.86  1.59  486.12 *******    3020  485.26
      -351    150    145    32501  1.26  0.00    0.00    0.76    6.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR2:AS       95     -2      555  0.51  0.78  486.89 *******    3020  486.38
      -256     95    195    34065  1.11  0.00   -0.01    0.61    5.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   485.46     490.03     490.30     489.91
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.10     490.65     490.77
 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "DSBRG"     Q,CRWS =    3020.     485.46

            <<<<<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

DSBRG:BR      150      0      244  3.32 *****  488.78  485.46    3020  485.46
      -351    150     59    17933  1.39 ***** *******    1.18   12.39
```

```
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.848 ******  489.91 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY2:RG    -332.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR2:AS       55    -10     1398  0.07  0.26  490.36  485.67    3020  490.29
      -256     72    225   137867  1.03  1.32   -0.01    0.16    2.16

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.705  0.667   45968.    24.    83.   490.26

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

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "EXIT3"     KRATIO =  0.31

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

EXIT3:XS      107     -3      651  0.36  0.16  490.66 *******    3020  490.30
      -149    107    199    43330  1.09  0.14   -0.01    0.48    4.64

 ===110 WSEL NOT FOUND AT SECID "EXIT1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.80     511.68    0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.80     511.68     491.98
 ===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 "EXIT1"
                  WSBEG,WSEND,CRWS =   491.98     511.68     491.98

EXIT1:XS       89     -1      417  0.97 *****  492.95  491.98    3020  491.98
       -60     89    191    22249  1.19 ***** *******    0.95    7.24

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.94

FULLV:FV       61     -3      650  0.36  0.58  493.52 *******    3020  493.16
         0     61    199    43198  1.09  0.00   -0.01    0.48    4.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.66     509.38    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.66     509.38     494.45
 ===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 =   494.45     509.38     494.45

        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
           *** RUN DATE & TIME: 06-24-97  14:22

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

APPRO:AS       76    -50      349  1.40 *****  495.85  494.45    3020  494.45
        76     76     72    21499  1.20 ***** *******    0.99    8.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3020.     493.45

              <<<<<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       61      0      236  2.54 *****  495.98  493.45    3020  493.45
        0      61     54    16171  1.00 ***** *******    1.00   12.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.81 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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       42    -52      739  0.31  0.41  497.59  494.45    3020  497.29
       76      44    149    60571  1.18  1.20    0.00    0.41    4.09

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.562  0.418   35241.    27.    81.  497.16

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

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -502.    -8.   143.   3020.   26405.     389.    7.77  483.31
   FLV2 :FV    -352.    -9.   145.   3020.   32501.     458.    6.59  485.26
   DSBRG:BR    -352.     0.    59.   3020.   17933.     244.   12.39  485.46
   RDWY2:RG    -332.**************      0.*********       0.    1.00********
   APPR2:AS    -257.   -11.   225.   3020.  137867.    1398.    2.16  490.29

   XSID:CODE   XLKQ   XRKQ       KQ
   APPR2:AS      24.    83.   45968.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT3:XS    -150.    -4.   199.   3020.   43330.     651.    4.64  490.30
   EXIT1:XS     -61.    -2.   191.   3020.   22249.     417.    7.24  491.98
   FULLV:FV       0.    -4.   199.   3020.   43198.     650.    4.65  493.16
   BRIDG:BR       0.     0.    54.   3020.   16171.     236.   12.77  493.45
   RDWAY:RG      14.**************      0.******************    1.00********
   APPRO:AS      76.   -53.   149.   3020.   60571.     739.    4.09  497.29

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      27.    81.   35241.

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    483.31    0.97  476.24  502.51************  1.22  484.53  483.31
   FLV2 :FV  ********    0.76  477.74  504.01  1.59  0.00  0.86  486.12  485.26
   DSBRG:BR    485.46    1.18  478.37  490.20************  3.32  488.78  485.46
   RDWY2:RG  ****************  492.96  502.51************  0.02  493.79********
   APPR2:AS    485.67    0.16  480.55  505.37  0.26  1.32  0.07  490.36  490.29
   EXIT3:XS  ********    0.48  483.99  508.81  0.16  0.14  0.36  490.66  490.30
   EXIT1:XS    491.98    0.95  486.86  511.68************  0.97  492.95  491.98
   FULLV:FV  ********    0.48  486.86  511.68  0.58  0.00  0.36  493.52  493.16
   BRIDG:BR    493.45    1.00  485.19  498.00************  2.54  495.98  493.45
   RDWAY:RG  ****************  499.00  514.13**********************************
   APPRO:AS    494.45    0.41  488.00  509.38  0.41  1.20  0.31  497.59  497.29
        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF

  ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT2":  USED WSI = CRWS.
                              WSI,CRWS =   484.12     484.23

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

EXIT2:XS   ******     -9      531  1.53 *****  485.76  484.23    4750  484.23
      -501 ******    148    39564  1.23 ***** *******    0.95    8.95

FLV2 :FV      150    -10      641  1.01  1.67  487.43 *******    4750  486.42
      -351    150    151    51269  1.18  0.00    0.00    0.71    7.42
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
```

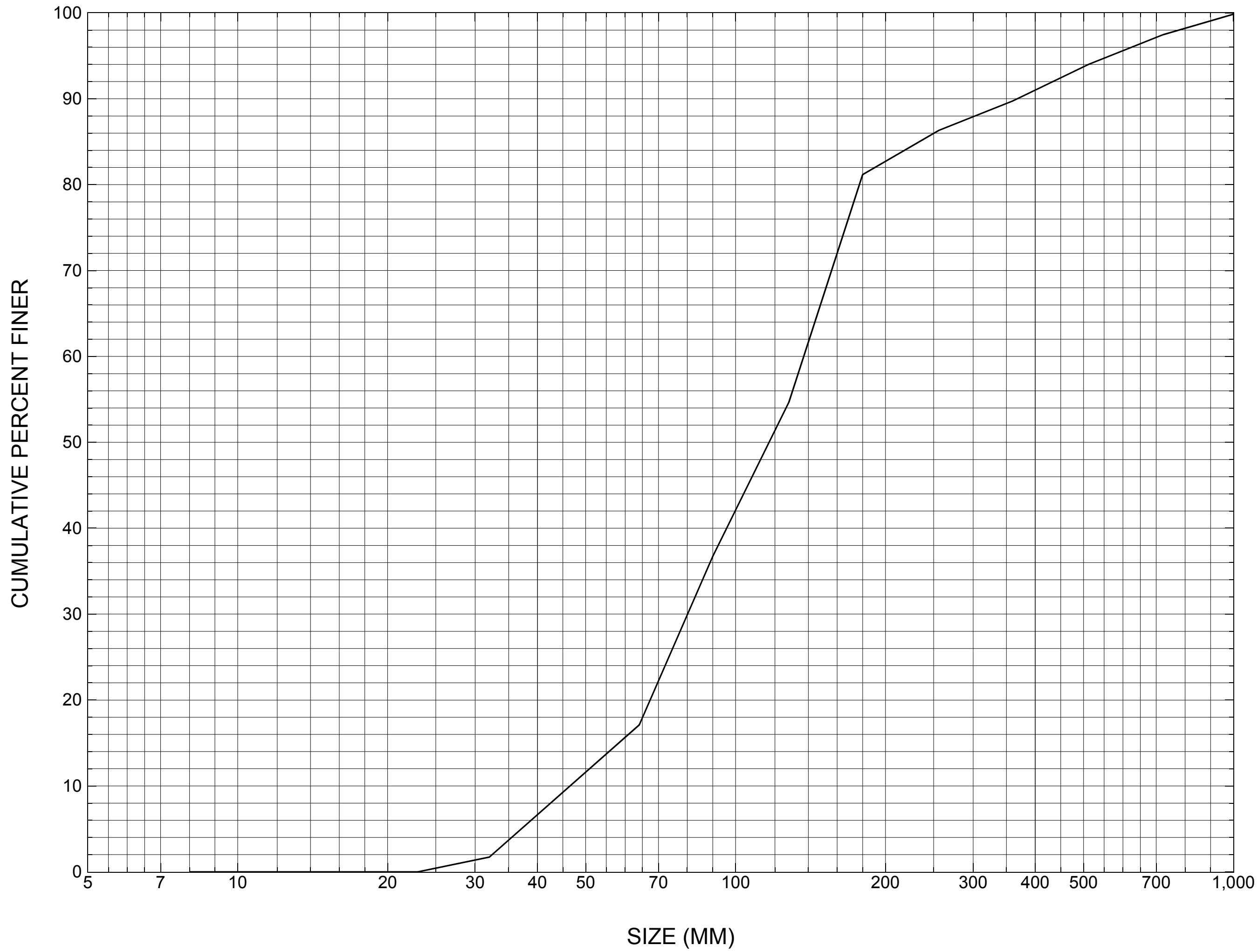
```
APPR2:AS       95     -4      793  0.59  0.72  488.13 *******    4750  487.54
      -256     95    204    58420  1.06  0.00   -0.01    0.56    5.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   487.21     492.18     492.45     489.91
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<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

DSBRG:BR      150      0      483  1.50 *****  491.70  487.21    4743  490.20
      -351 ******     64    32963  1.00 ***** *******    0.63    9.83

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   2.  0.482 ******  489.91 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY2:RG    -332.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPR2:AS       55   -112     2125  0.09  0.23  492.84  486.38    4750  492.75
      -256     76    301   223842  1.13  1.16    0.00    0.18    2.24

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   492.72

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "EXIT3"     KRATIO =  0.47

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT3:XS      107     -6     1175  0.26  0.10  493.02 *******    4750  492.76
      -149    107    216   106282  1.03  0.09    0.00    0.31    4.04

 ===125 FR# EXCEEDS FNTEST AT SECID "EXIT1":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88     492.84     492.69
 ===110 WSEL NOT FOUND AT SECID "EXIT1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.26     511.68    0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.26     511.68     492.69
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "EXIT1"     KRATIO =  0.35

EXIT1:XS       89     -3      584  1.14  0.51  493.97  492.69    4750  492.83
       -60     89    196    36739  1.10  0.44   -0.01    0.88    8.13

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.70

FULLV:FV       61     -4      827  0.54  0.60  494.56 *******    4750  494.02
         0     61    205    62305  1.05  0.00   -0.01    0.52    5.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.52     509.38    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.52     509.38     495.51
 ===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 =   495.51     509.38     495.51

        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF

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

```
APPRO:AS       76    -51      480  1.79 *****  497.29  495.51    4750  495.51
       76     76     74    33975  1.18 ***** *******    0.97    9.89
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   499.92       0.00     495.24     499.00
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.17     499.52     499.79     497.81
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

           <<<<<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       61      0      441  1.54 *****  499.54  494.90    4398  498.00
        0 ******     54    29341  1.00 ***** *******    0.62    9.96

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.478 ******  497.81 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    53.  0.03  0.11  500.65    0.00    355.  500.37

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.   286.  -316.    21.   1.5   0.7   5.6   8.0   1.4   3.1
   RT:    355.   114.   117.   231.   1.4   0.7   4.7   4.3   1.0   3.1

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       42    -90     2006  0.11  0.17  500.68  495.51    4750  500.57
       76     44    400   187350  1.29  1.16    0.00    0.23    2.37

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -502.   -10.   148.   4750.   39564.     531.    8.95  484.23
   FLV2 :FV    -352.   -11.   151.   4750.   51269.     641.    7.42  486.42
   DSBRG:BR    -352.     0.    64.   4743.   32963.     483.    9.83  490.20
   RDWY2:RG    -332.**************       0.*********       0.    1.00********
   APPR2:AS    -257.  -113.   301.   4750.  223842.    2125.    2.24  492.75

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR2:AS  ***********************
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT3:XS    -150.    -7.   216.   4750.  106282.    1175.    4.04  492.76
   EXIT1:XS     -61.    -4.   196.   4750.   36739.     584.    8.13  492.83
   FULLV:FV      0.    -5.   205.   4750.   62305.     827.    5.74  494.02
   BRIDG:BR      0.     0.    54.   4398.   29341.     441.    9.96  498.00
   RDWAY:RG     14.*******     0.    355.       0.*********    1.00  500.37
   APPRO:AS     76.   -91.   400.   4750.  187350.    2006.    2.37  500.57

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    484.23    0.95  476.24  502.51************  1.53  485.76  484.23
   FLV2 :FV  ********    0.71  477.74  504.01  1.67  0.00  1.01  487.43  486.42
   DSBRG:BR    487.21    0.63  478.37  490.20************  1.50  491.70  490.20
   RDWY2:RG  ****************  492.96  502.51************  0.06  493.82********
   APPR2:AS    486.38    0.18  480.55  505.37  0.23  1.16  0.09  492.84  492.75
   EXIT3:XS  ********    0.31  483.99  508.81  0.10  0.09  0.26  493.02  492.76
   EXIT1:XS    492.69    0.88  486.86  511.68  0.51  0.44  1.14  493.97  492.83
   FULLV:FV  ********    0.52  486.86  511.68  0.60  0.00  0.54  494.56  494.02
   BRIDG:BR    494.90    0.62  485.19  498.00************  1.54  499.54  498.00
   RDWAY:RG  ****************  499.00  514.13  0.03******  0.11  500.65  500.37
```

```
   APPRO:AS    495.51    0.23  488.00  509.38  0.17  1.16  0.11  500.68  500.57



        U.S. Geological Survey WSPRO Input File reds025.wsp
        Hydraulic analysis for structure REDSTH00360025   Date: 07-MAR-97
        Bridge #25 over West Br. Deerfield River in Stamford, VT.  RHF
           *** RUN DATE & TIME: 06-24-97  14:22

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT2":  USED WSI = CRWS.
                           WSI,CRWS =   483.47     483.64

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

EXIT2:XS   ******     -8      438  1.32 *****  484.96  483.64    3580  483.64
      -501 ******    145    30687  1.27 ***** *******    0.96    8.17

FLV2 :FV      150     -9      522  0.90  1.62  486.58 *******    3580  485.68
      -351    150    147    38675  1.23  0.00    0.00    0.74    6.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR2:AS       95     -3      636  0.54  0.75  487.32 *******    3580  486.78
      -256     95    198    41825  1.09  0.00   -0.01    0.58    5.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   486.07     490.61     490.89     489.91
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<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

DSBRG:BR      150      0      483  0.85 *****  491.05  486.06    3575  490.20
      -351 ******     64    32963  1.00 ***** *******    0.48    7.41

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   2.  0.416 ******  489.91 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY2:RG    -332.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR2:AS       55    -23     1619  0.08  0.17  491.24  485.92    3580  491.16
      -256     73    252   163813  1.06  1.26    0.00    0.17    2.21

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   491.13

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

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "EXIT3"     KRATIO =  0.38

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

EXIT3:XS      107     -4      831  0.30  0.13  491.48 *******    3580  491.17
      -149    107    205    62827  1.05  0.11    0.00    0.39    4.31

 ===110 WSEL NOT FOUND AT SECID "EXIT1":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   490.67     511.68    0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT1":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   490.67     511.68     492.23
 ===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 "EXIT1"
                 WSBEG,WSEND,CRWS =   492.23     511.68     492.23
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure REDSTH00360025, in Readsboro, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number REDSTH00360025

General Location Descriptive

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

Date (MM/DD/YY) 09 / 28 / 95

Highway District Number (I - 2; nn) 01

County (FIPS county code; I - 3; nnn) 003

Town (FIPS place code; I - 4; nnnnn) 58600

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

Waterway (I - 6) West Branch Deerfield River

Road Name (I - 7): -

Route Number C3036

Vicinity (I - 9) 0.11 mi. to jct. with VT100

Topographic Map Stamford

Hydrologic Unit Code: 02020003

Latitude (I - 16; nnnn.n) 42496

Longitude (i - 17; nnnnn.n) 73002

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10020900250209

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0057

Year built (I - 27; YYYY) 1929

Structure length (I - 49; nnnnnn) 000059

Average daily traffic, ADT (I - 29; nnnnnn) 000020

Deck Width (I - 52; nn.n) 234

Year of ADT (I - 30; YY) 93

Channel & Protection (I - 61; n) 5

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

Waterway adequacy (I - 71; n) 7

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 104

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) -

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

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

Comments:

According to the structural inspection report dated 9/27/93, the structure is a concrete T-beam bridge with an asphalt road surface. Abutments, wingwalls and backwalls are concrete. The left abutment con crete has several fine vertical cracks with alligator cracks and leaks on the ends of both abutments and wingwalls. The ends of both wingwalls on the left abutment have areas of deep spalling. The channel flow is along the upstream end and wingwall of the right abutment, and is diverted against the face of the left abutment. The channel is at least 2.5-3' deep along the upstream right abutment and 1.5-2.5' deep along the left abutment. A few boulders are present in front of the downstream right **(Continued, p. 37)**

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: boulders

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} - Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): - *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:

abutment, with boulders showing at the ends of the wingwalls and along the channel embankments. Minor debris and poor channel alignment were noted in the VT AOT files. No undermining or footing seen. There is a remark in the report that "water is quite swift and deep - hard to check for undermining".

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **14.45** mi^2

Lake/pond/swamp area **0.901** mi^2

Watershed storage *(ST)* **6.24** %

Bridge site elevation **1808** ft

Headwater elevation **3064** ft

Main channel length **5.16** mi

10% channel length elevation **1940** ft

85% channel length elevation **2300** ft

Main channel slope *(S)* **73.03** 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? No *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:
No benchmark information is available.

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? No *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 is available.

Comments:
-

Cross-sectional Data

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

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

Comments: **This cross section is along the upstream face. The low chord elevations are from the survey log completed for this report on 8/1/96. The low chord to bed length data are from the sketch attached to a bridge inspection report dated 9/27/93.**

Station	0	26	39	54	-	-	-	-	-	-	-
Feature	LAB			RAB	-	-	-	-	-	-	-
Low cord elevation	497.6	497.8	497.9	498.0	-	-	-	-	-	-	-
Bed elevation	487.4	488.2	487.0	487.5	-	-	-	-	-	-	-
Low cord to bed length	10.2	9.6	10.9	10.5	-	-	-	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 10/30/96

Computerized by: EW Date: 10/30/96

Reviewd by: RF Date: 6/16/97

Structure Number REDSTH00360025

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 08 / 01 / 1996

2. Highway District Number 01 Mile marker 000000

County Bennington 003 Town Readsboro 58600

Waterway *(I - 6)* West Branch Deerfield River Road Name -

Route Number C3036 Hydrologic Unit Code: 02020003

3. Descriptive comments:

Located 0.11 miles from junction with vt 100.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 5 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 2 UB 2 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 59 *(feet)* Span length 57 *(feet)* Bridge width 23.4 *(feet)*

Road approach to bridge:

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

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

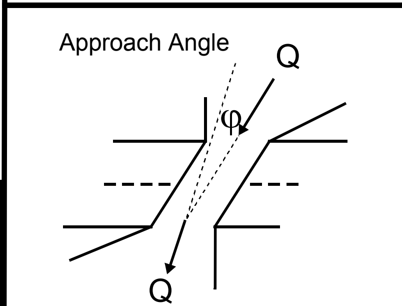
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

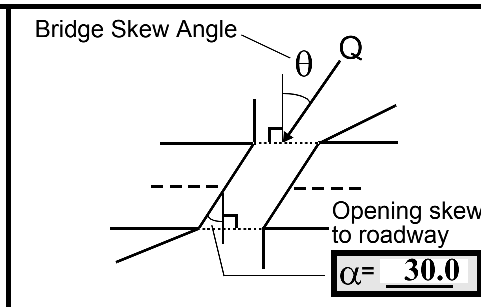
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	2	1
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

*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: 50 16. Bridge skew: 50





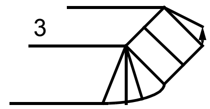
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 30 feet US *(US, UB, DS)* to 0 feet US

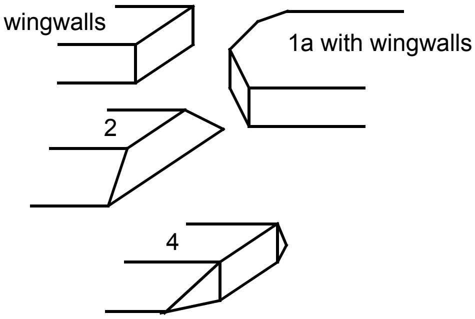
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 0 feet US *(US, UB, DS)* to 10 feet DS

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

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

#4. There are trees along the upstream left and right banks, as well as along the downstream right bank. The upstream right overbank is a mowed hay field. The downstream right and left overbanks have tall weeds and shrubs. The road is along the downstream left overbank. The upstream left bank has a wide area of trees and is forested beyond two bridge lengths from the stream with a clearing and gravel road beyond the forested area.

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
86.0	**3.5**			**5.0**	**3**	**3**	**543**	**543**	**0**	**0**

23. Bank width **5.0** 24. Channel width **50.0** 25. Thalweg depth **73.5** 29. Bed Material **543**

30 .Bank protection type: LB **5** RB **2** 31. Bank protection condition: LB **3** 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.):

The bank protection on both the right and the left banks extends well beyond two bridge lengths; to at least 1000 feet upstream. On the upstream left bank, there are the remains of an old mill. Various stone walls extend along the bank and there is another wall closer to the gravel road. These walls have slumped and eroded in places.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **46** 35. Mid-bar width: **16**

36. Point bar extent: **100** feet **US** (US, UB) to **30** feet **US** (US, UB, DS) positioned **0** %LB to **15** %RB

37. Material: **543**

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

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? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **10 US**

47. Scour dimensions: Length **40** Width **7** Depth : **2** Position **60** %LB to **100** %RB

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

Scour depth is 2 feet, based on a 1 foot thalweg. The scour is in front of the USRWW and RABUT. The mid-scour point is at the corner, but it is 10 feet upstream measured from the center of the upstream bridge face, due to 50 degree bridge skew. Scour is from 40 feet upstream to 0 feet upstream.

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
25.5		1.5		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.):

543

At the present water level, the water is deflected by the USRWW, flows parallel to the bridge face and impacts the left abutment. At higher flows, the channel flow is straight under the bridge as the left and right banks are low.

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		45	90	2	1	2	0	90.0
RABUT	1	-	90			2	1	47.0

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.):

2

0

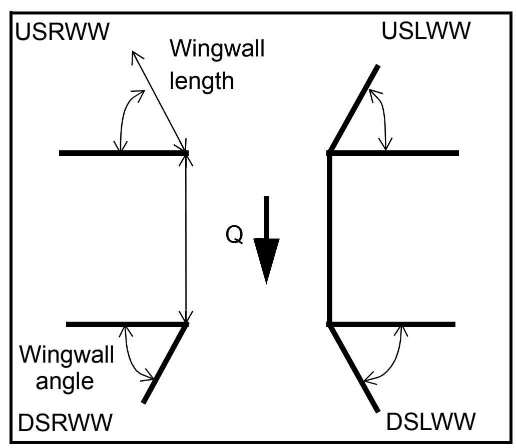
1

The channel turns at the upstream bridge face. Scour along the left abutment extends along the entire base length. Scour is only along the upstream half of the right abutment. The downstream half of the right abutment has been filled in with stones (type-2).

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						47.0	
USRWW:	Y		1		0	2.0	
DSLWW:	-		-		Y	28.5	
DSRWW:	1		1		2	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	-	1	Y	-	-	1	-	1
Condition	Y	1	1	-	-	2	-	3
Extent	1	-	0	0	2	0	2	-

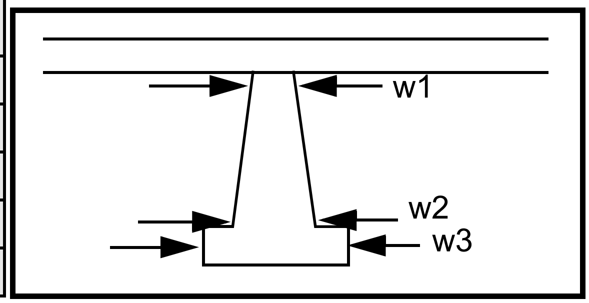
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		8.5		75.0	10.0	18.0
Pier 2				30.0	14.5	85.0
Pier 3	9.0	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	wall		by an	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	upst	are	The	old	1- Solid pier, 2- column, 3- bent
88. Material	ream	pro-	USL	stone	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	right	tecte	WW	wall.	1- Round; 2- Square; 3- Pointed
90. Inclined?	wing	d on	is		Y- yes; N- no
91. Attack ∠ (BF)	wall	the	pro-	Ther	
92. Pushed	and	ends	tecte	e is	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	dow	by	d on	also	
95. Cross-members	nstre	bank	the	stone	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	am	pro-	upst	in	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	left	tec-	ream	front	
98. Exposure depth	wing	tion.	end	of	

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

the DSRWW, but is natural (not placed).

The channel impacts the USRWW at approximately a 50 degree angle. The streambed is scoured for approximately the entire base length of the wingwall.

The DSLWW is scoured along its entire base length and scour is caused by a combination of the flow along the LABUT and eddy currents.

N

-

-

E. Downstream Channel Assessment

100.

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

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: **-**

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

-
-
NO PIERS

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.):

1
2
543
543

Is channel scour present? **0** (Y or if N type ctrl-n cs) Mid-scour distance: **0**

Scour dimensions: Length **543** Width **2** Depth: **0** Positioned **1** %LB to **-** %RB

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

There is a bridge 350 feet downstream for state route 100.

Left bank protection extends from the end of the downstream left wingwall to the upstream face of the state route 100 bridge. It is dumped native stone.

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

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

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

Confluence comments (eg. confluence name):

downstream and the downstream right bank is very low and flat. There is a lot of stone among the vegetation on the bank and water will go over the bank during high flow.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

-

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: REDSTH00360025 Town: Readsboro
Road Number: C3036 County: Bennington
Stream: West Branch Deerfield River

Initials RHF Date: 6/24/97 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 others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3020	4750	3580
Main Channel Area, ft2	490	757	561
Left overbank area, ft2	226	451	272
Right overbank area, ft2	24	800	120
Top width main channel, ft	81	81	81
Top width L overbank, ft	53	92	57
Top width R overbank, ft	68	319	153
D50 of channel, ft	0.3829	0.3829	0.3829
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	9.3	6.9
y1, average depth, LOB, ft	4.3	4.9	4.8
y1, average depth, ROB, ft	0.4	2.5	0.8
Total conveyance, approach	60615	187554	80505
Conveyance, main channel	47068	97201	58949
Conveyance, LOB	13105	35446	17755
Conveyance, ROB	442	54908	3799
Percent discrepancy, conveyance	0.0000	-0.0005	0.0025
Qm, discharge, MC, cfs	2345.1	2461.7	2621.4
Ql, discharge, LOB, cfs	652.9	897.7	789.6
Qr, discharge, ROB, cfs	22.0	1390.6	168.9
Vm, mean velocity MC, ft/s	4.8	3.3	4.7
Vl, mean velocity, LOB, ft/s	2.9	2.0	2.9
Vr, mean velocity, ROB, ft/s	0.9	1.7	1.4
Vc-m, crit. velocity, MC, ft/s	11.0	11.8	11.2
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

ARMORING

D90	1.206	1.206	1.206

D95	1.853	1.853	1.853
Critical grain size,Dc, ft	1.0591	0.4834	1.1200
Decimal-percent coarser than Dc	0.1135	0.3436	0.1079
Depth to armoring,ft	24.82	2.77	27.78

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	490	757	561
Main channel width, ft	81	81	81
y1, main channel depth, ft	6.05	9.35	6.93

Bridge Section			
(Q) total discharge, cfs	3020	4750	3580
(Q) discharge thru bridge, cfs	3020	4398	3580
Main channel conveyance	16195	29341	19307
Total conveyance	16195	29341	19307
Q2, bridge MC discharge,cfs	3020	4398	3580
Main channel area, ft2	237	441	265
Main channel width (skewed), ft	46.8	47.1	46.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	46.765	47.11	46.765
y_bridge (avg. depth at br.), ft	5.06	9.37	5.67
Dm, median (1.25*D50), ft	0.478625	0.478625	0.478625
y2, depth in contraction,ft	5.44	7.46	6.29
ys, scour depth (y2-ybridge), ft	0.38	-1.91	0.62

Pressure Flow Scour (contraction scour for orifice flow conditions)
Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richarson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q, total, cfs	3020	4750	3580
Q, thru bridge, cfs	3020	4395	3580
Total Conveyance, bridge	16195	29341	19307
Main channel(MC) conveyance, bridge	16195	29341	19307
Q, thru bridge MC, cfs	3020	4395	3580
Vc, critical velocity, ft/s	10.99	11.81	11.24
Vc, critical velocity, m/s	3.35	3.60	3.43
Main channel width (skewed), ft	46.8	47.1	46.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	46.8	47.1	46.8
qbr, unit discharge, ft2/s	64.6	93.3	76.6
qbr, unit discharge, m2/s	6.0	8.7	7.1
Area of full opening, ft2	236.7	441.3	265.2
Hb, depth of full opening, ft	5.06	9.37	5.67
Hb, depth of full opening, m	1.54	2.86	1.73
Fr, Froude number, bridge MC	0	0.62	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00

Elevation of Low Steel, ft	0	497.81	0
Elevation of Bed, ft	-5.06	488.44	-5.67
Elevation of Approach, ft	0	500.57	0
Friction loss, approach, ft	0	0.17	0
Elevation of WS immediately US, ft	0.00	500.40	0.00
ya, depth immediately US, ft	5.06	11.96	5.67
ya, depth immediately US, m	1.54	3.64	1.73
Mean elevation of deck, ft	0	501.77	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.94	1.00
Ys, depth of scour, ft	N/A	-0.96	N/A

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	5.439139	7.459696	6.292925
Full valley WSEL, ft	0	494.02	0
Full valley depth, ft	5.061478	5.577438	5.670908
Ys, depth of scour (y2-yfullv), ft	N/A	1.882259	N/A

Abutment Scour

Froehlich's Abutment Scour

$Ys/Y1 = 2.27*K1*K2*(a'/Y1)^{0.43}*Fr1^{0.61}+1$

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3020	4750	3580	3020	4750	3580
a', abut.length blocking flow, ft	57	95	60.3	99.1	349.8	183.6
Ae, area of blocked flow ft2	241.2	477.6	290.8	207.9	999.3	330.9
Qe, discharge blocked abut.,cfs	715.9	975.12	862.16	865.7	2270	1116.1
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.97	2.04	2.96	4.16	2.10	3.37
ya, depth of f/p flow, ft	4.23	5.03	4.82	2.10	2.86	1.80
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	120	120	120	60	60	60
K2	1.04	1.04	1.04	0.95	0.95	0.95
Fr, froude number f/p flow	0.254	0.160	0.238	0.507	0.210	0.443
ys, scour depth, ft	15.08	16.29	16.32	14.94	18.25	15.94

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)	57	95	60.3	99.1	349.8	183.6
y1 (depth f/p flow, ft)	4.23	5.03	4.82	2.10	2.86	1.80
a'/y1	13.47	18.90	12.50	47.24	122.45	101.87
Skew correction (p. 49, fig. 16)	1.07	1.07	1.07	0.90	0.90	0.90
Froude no. f/p flow	0.25	0.16	0.24	0.51	0.21	0.44
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	10.97	11.17	9.02
vertical w/ ww's	ERR	ERR	ERR	9.00	9.16	7.39
spill-through	ERR	ERR	ERR	6.03	6.14	4.96

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	Q100	Q500	Qother
Fr, Froude Number	1	0.62	1	1	0.62	1
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.06	9.37	5.67	5.06	9.37	5.67
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.23	ERR	ERR	2.23	ERR
Fr>0.8 (vertical abut.)	2.12	ERR	2.37	2.12	ERR	2.37
Fr<=0.8 (spillthrough abut.)	ERR	1.94	ERR	ERR	1.94	ERR
Fr>0.8 (spillthrough abut.)	1.87	ERR	2.10	1.87	ERR	2.10