LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (CABOTH00410037) on TOWN HIGHWAY 41, crossing the WINOOSKI RIVER, CABOT, VERMONT

U.S. Geological Survey
Open-File Report 97-781

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (CABOTH00410037) on TOWN HIGHWAY 41, crossing the WINOOSKI RIVER, CABOT, VERMONT

By ROBERT H. FLYNN AND LAURA MEDALIE

U.S. Geological Survey
Open-File Report 97-781

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
Mark Schaefer, 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 37 (CABOTH00410037) ON TOWN HIGHWAY 41, CROSSING THE WINOOSKI RIVER, CABOT, VERMONT

By **Robert H. Flynn and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CABOTH00410037 on Town Highway 41 crossing the Winooski River (also referred to as Coit's Pond Brook), Cabot, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 21.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is primarily shrub and brushland while the immediate banks have dense woody vegetation.

In the study area, the Winooski River has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 53 ft and an average bank height of 4 ft. The channel bed material is primarily cobbles and boulder with a median grain size (D_{50}) of 64.5 mm (0.212 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 16, 1996, indicated that the reach was stable.

The Town Highway 41 crossing of the Winooski River is a 29-ft-long, one-lane bridge consisting of one 26-foot span (Vermont Agency of Transportation, written communication, October 13, 1995) with four steel I-beams and a wooden deck . The opening length of the structure parallel to the bridge face is 26 ft.The bridge is supported by "laid up" granite block abutments with concrete footings. The channel is skewed approximately 35 degrees to the opening while the computed opening-skew-to-roadway is 15 degrees. The VTAOT computed opening-skew-to-roadway is zero degrees.

The only scour protection measure observed at the site during the Level I assessment was type-2 stone fill (less than 36 inches diameter) along the entire base length of the left abutment and upstream right wingwall, along the upstream left bank and along the downstream left and right banks. 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) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping and maximum free-surface flow discharges were determined and analyzed as two other potential worst-case scour scenarios. 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 2.7 ft. The worst-case contraction scour occurred at the maximum free-surface flow (with road overflow) discharge, which was less than the 100-year discharge. Abutment scour ranged from 9.8 to 10.7 ft along the left abutment and from 16.2 to 19.9 ft along the right abutment. 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 and Hire equations (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.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number CABOTH00410037 ***Stream*** Winooski River

County Washington ***Road*** TH41 ***District*** 6

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 16.0 ***ft*** ***Max span length*** 26 ***ft***

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

Abutment type "Laid up" Granite Blocks ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 7/16/96

Description of stone fill Type-2, along the entire base length of the left abutment and upstream right wingwall.

The upstream right wingwall and both of the abutments are "laid up" granite block. The abutments have concrete footings.

Y 35

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

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	7/16/96	0	0
Level II	7/16/96	0	0

Potential for debris Low. Upstream channel banks are lined primarily with brush with few trees and the channel is laterally stable.

A dam and waterfall are located approximately 250 feet upstream. Noted on 7/16/96.

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 narrow, slightly irregular flood plain within a moderate relief valley setting.

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

Date of inspection 7/16/96

DS left: Steep channel bank to floodplain.

DS right: Moderately sloped channel bank to a moderately sloped overbank.

US left: Moderately sloped channel bank to flood plain.

US right: Steep channel bank to a narrow terrace.

Description of the Channel

Average top width 53 ft ***Average depth*** 4 ft

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

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

7/16/96

Vegetative co Trees and brush.

DS left: Trees, shrubs and brush

DS right: Trees and brush.

US left: Short grass and brush with a few trees.

US right:

Y

Do banks appear stable?

date of observation.

The assessment of 7/16/96 noted flow conditions are influenced by a small island, approximately 200 ft upstream in the center of the channel and a dam which is approximately 250 ft upstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 21.4 ***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 3,000 ***ft³/s*** ***Q500*** 4,100 ***ft³/s***

The 100-year discharge is based on the FHWA discharge frequency curve value which was selected due to its' central tendency 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 downstream end of the right abutment (elev. 499.76 ft, arbitrary survey datum). RM2 is a nail in a telephone pole (GMP Corp 3/30 and CTC VT 61-35), two ft above the ground, on the upstream left road approach, 30 ft bankward of the left abutment (elev. 507.27ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	47	2	Modelled Approach section (Templated from APTEM)
APTEM	65	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.075, and overbank "n" values ranged from 0.060 to 0.120.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0104 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0303 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.3 ***ft***
Average low steel elevation 498.8 ***ft***

100-year discharge 3,000 ***ft^3/s***
Water-surface elevation in bridge opening 498.9 ***ft***
Road overtopping? Y ***Discharge over road*** 541 ***ft^3/s***
Area of flow in bridge opening 270 ***ft^2***
Average velocity in bridge opening 9.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.4 ***ft/s***

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 3.1 ***ft***

500-year discharge 4,100 ***ft^3/s***
Water-surface elevation in bridge opening 498.9 ***ft***
Road overtopping? Y ***Discharge over road*** 1,361 ***ft^3/s***
Area of flow in bridge opening 270 ***ft^2***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.7 ***ft/s***

Water-surface elevation at Approach section with bridge 501.3
Water-surface elevation at Approach section without bridge 498.6
Amount of backwater caused by bridge 2.7 ***ft***

Incipient overtopping discharge 2,430 ***ft^3/s***
Water-surface elevation in bridge opening 494.7 ***ft***
Area of flow in bridge opening 169 ***ft^2***
Average velocity in bridge opening 14.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.7 ***ft/s***

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 496.7
Amount of backwater caused by bridge 1.9 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the incipient roadway-overtopping and maximum free-surface flow through the bridge (with road overflow) discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges 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 for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was computed by the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and the Laursen clear-water contraction scour equation and presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

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*	*Maximum Free-Surface discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.3	2.7
Depth to armoring	9.4 8.3	41.9	--
Left overbank	--	--	--
Right overbank	--	--	10.1

Local scour:			
Abutment scour			
Left abutment	10.7	9.8 15.2	16.3
Right abutment	13.2–	---	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	2.4	2.4

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Maximum Free-Surface discharge*
		(D_{50} in feet)	
Abutments:	2.9	2.4	2.4
Left abutment	2.9	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

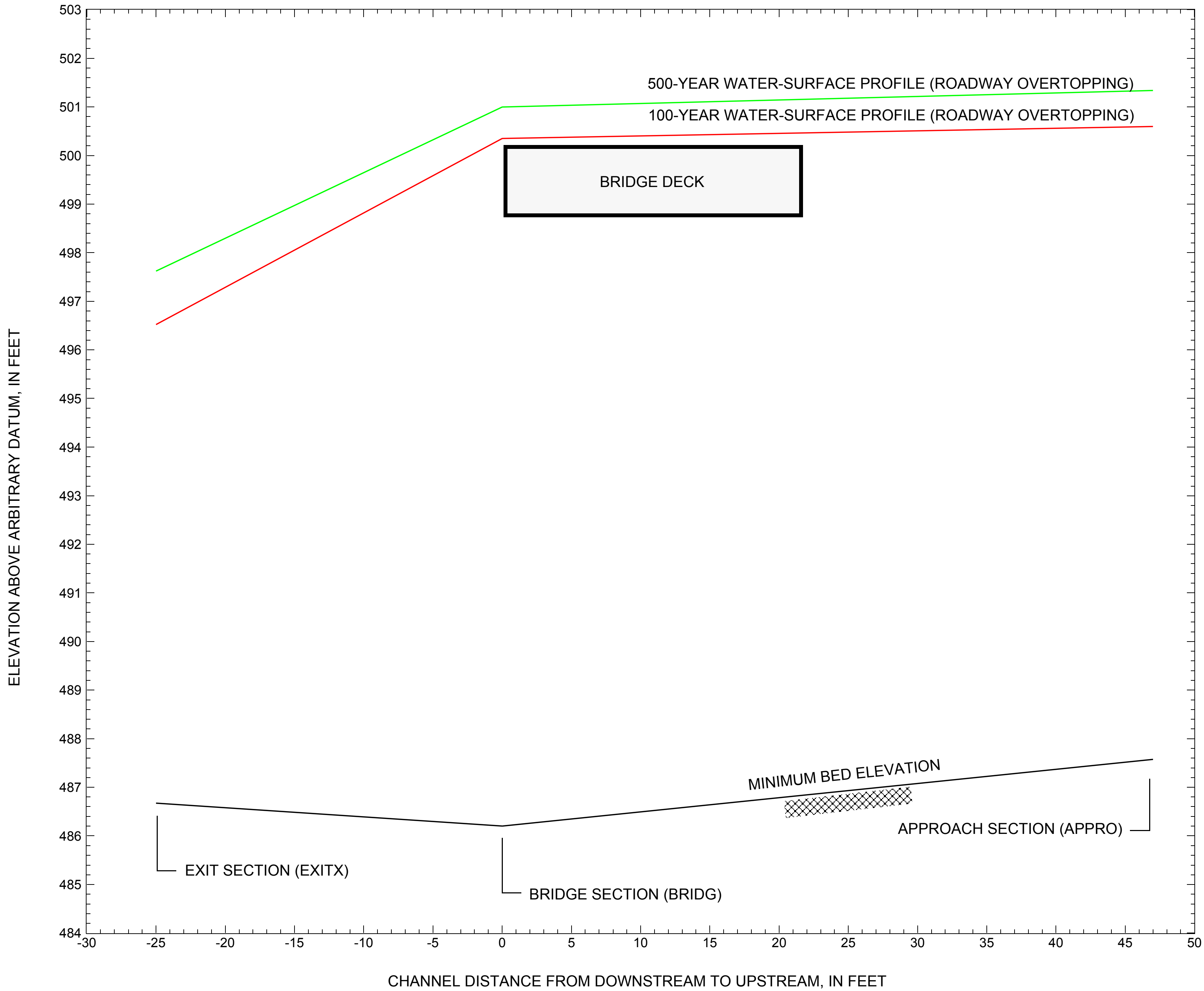


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CABOTH00410037 on Town Highway 41, crossing the Winooski River, Cabot, Vermont.

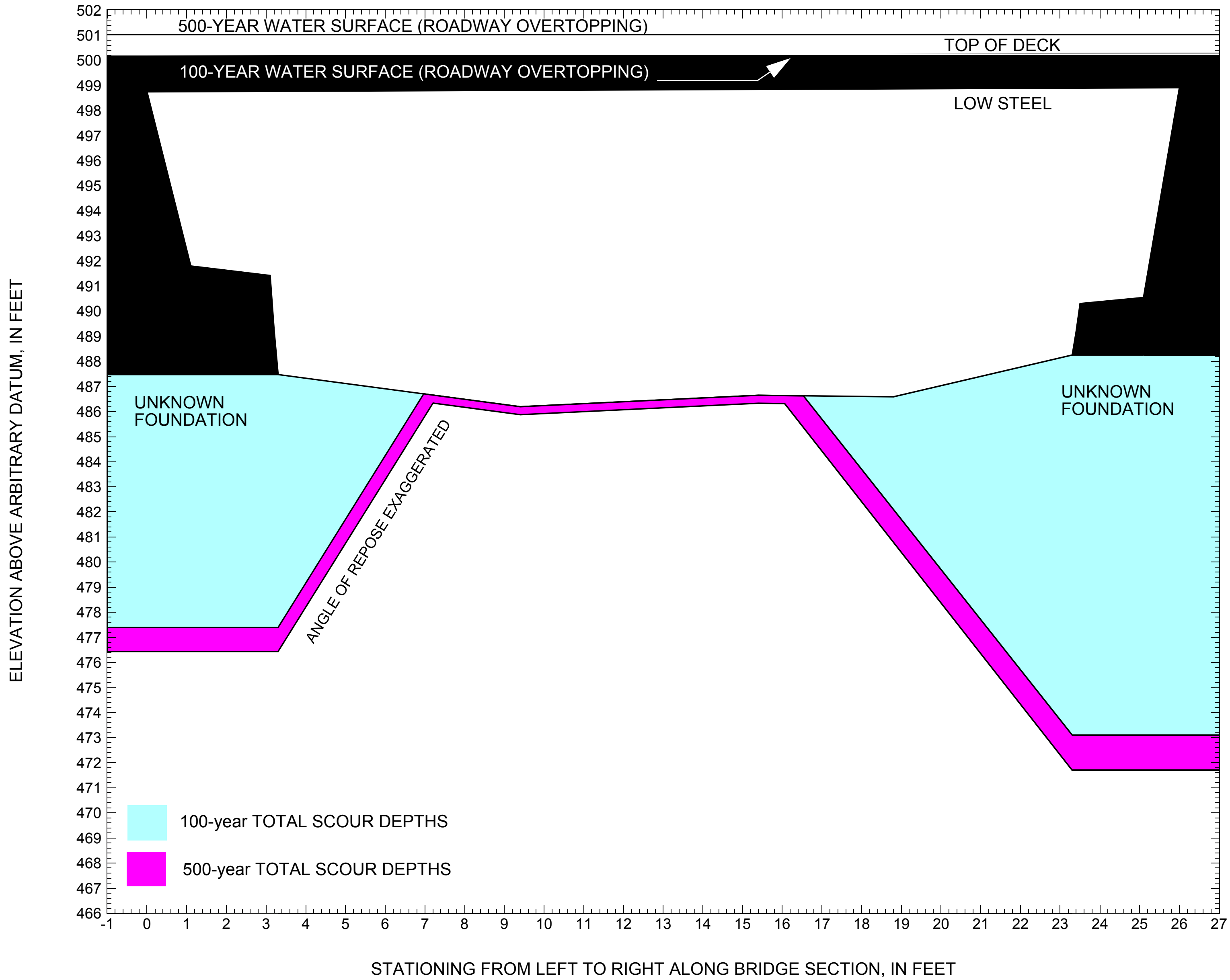


Figure 8. Scour elevations for the 100-year and 500-year discharges at structure CABOTH00410037 on Town Highway 41, crossing the Winooski River, Cabot, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CABOTH00410037 on Town Highway 41, crossing the Winooski River, Cabot, 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 3,000 cubic-feet per second											
Left abutment	0.0	-	498.8	-	487.5	0.0	10.1	--	10.1	477.4	-
Right abutment	26.0	-	498.9	-	488.3	0.0	15.2	--	15.2	473.1	-

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 CABOTH00410037 on Town Highway 41, crossing the Winooski River, Cabot, 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 4,100 cubic-feet per second											
Left abutment	0.0	-	498.8	-	487.5	0.3	10.7	--	11.0	476.5	-
Right abutment	26.0	-	498.9	-	488.3	0.3	16.3	--	16.6	471.7	-

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

SELECTED REFERENCES

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

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

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, 1986, Cabot, 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 cabo037b.wsp
T2        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
T3        Bridge #37 over Winooski River in Cabot, 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
*
*           Q100     Q500    Qincip.   Qmax.type.4
Q           3000.0   4100.0   2430.0   2570.0
SK          0.0104   0.0104   0.0104   0.0104
*
XS   EXITX   -25
GR         -135.6, 502.95   -103.2, 500.95    -63.3, 498.95    -39.4, 497.94
GR          -18.6, 497.27    -12.7, 496.12     -8.6, 494.55      0.0, 489.21
GR            6.6, 487.19     10.9, 487.02     14.5, 486.71     18.1, 486.67
GR           23.3, 487.94     29.2, 489.13     33.4, 490.91     45.3, 492.65
GR           68.5, 494.90     97.2, 496.63    177.8, 503.17
*
N           0.100        0.075        0.065
SA                -12.7         33.4
*
XS   FULLV      0  * * *   0.0209
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.83      15.0
GR            0.0, 498.75      1.1, 491.80      3.1, 491.43      3.2, 489.24
GR            3.3, 487.48      9.4, 486.20     15.4, 486.65     18.8, 486.59
GR           23.3, 488.26     23.4, 489.18     23.5, 490.31     25.1, 490.55
GR           26.0, 498.91      0.0, 498.75
*
*         BRTYPE  BRWDTH
CD          1      21.7
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      16.0     2
GR         -285.5, 514.48   -160.1, 503.89    -93.5, 501.14    -37.0, 500.26
GR            0.0, 500.20     22.3, 500.31     36.2, 500.22     89.7, 498.57
GR          126.7, 499.58    164.1, 502.13    192.1, 506.12    211.7, 507.79
*
XT   APTEM    65
GR         -203.8, 505.02     -63.5, 500.22   -27.8, 497.88    -18.4, 494.74
GR            0.0, 491.94       8.2, 489.98    11.1, 488.39     16.1, 488.71
GR           22.7, 488.75      27.3, 488.12    33.9, 488.28     38.5, 488.58
GR           45.6, 488.14      48.8, 489.59    52.5, 491.05     60.1, 495.15
GR           85.9, 497.42     119.0, 498.65   154.5, 498.43    169.1, 505.91
*
AS   APPRO    47 * * * 0.0303
GT
N           0.120        0.070        0.060
SA                 0.0         60.1
*
HP 1 BRIDG  498.91 1 498.91
HP 2 BRIDG  498.91 * * 2457
HP 1 BRIDG  496.75 1 496.75
HP 2 RDWAY  500.35 * * 541
HP 1 APPRO  500.60 1 500.60
HP 2 APPRO  500.60 * * 3000
*
HP 1 BRIDG  498.91 1 498.91
HP 2 BRIDG  498.91 * * 2740
HP 1 BRIDG  497.84 1 497.84
HP 2 RDWAY  501.00 * * 1361
HP 1 APPRO  501.34 1 501.34
HP 2 APPRO  501.34 * * 4100
*
HP 1 BRIDG  494.70 1 494.70
HP 2 BRIDG  494.70 * * 2430
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
             1      270     19832     0    70                     18245246
   498.91           270     19832     0    70  1.00      0     26 18245246

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.91     0.0    26.0   270.2   19832.    2457.   9.09

X STA.         0.0         4.0         5.4         6.6         7.6         8.6
  A(I)             26.8        15.8        13.7        12.5        12.0
  V(I)             4.59        7.79        8.97        9.86       10.28

X STA.         8.6         9.6        10.5        11.4        12.3        13.2
  A(I)             11.5        11.0        11.0        10.9        10.8
  V(I)            10.70       11.15       11.12       11.31       11.37

X STA.        13.2        14.1        15.1        16.0        16.9        17.9
  A(I)             10.9        10.8        10.9        11.3        11.2
  V(I)            11.28       11.34       11.25       10.86       10.96

X STA.        17.9        18.9        20.0        21.2        22.6        26.0
  A(I)             12.1        12.2        13.6        15.4        25.8
  V(I)            10.15       10.03        9.03        7.99        4.76

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0
     WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
             1      218     20002    25    41                         3696
   496.75           218     20002    25    41  1.00      0     26     3696


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.35   -42.8   138.0   110.6    2364.     541.   4.89

X STA.       -42.8        54.6        63.1        68.9        73.3        77.1
  A(I)             15.6         7.0         6.1         5.3         5.0
  V(I)             1.73        3.87        4.44        5.09        5.36

X STA.        77.1        80.3        83.2        85.9        88.3        90.6
  A(I)              4.7         4.4         4.3         4.1         4.0
  V(I)             5.73        6.11        6.30        6.54        6.72

X STA.        90.6        92.9        95.4        98.0       100.8       104.0
  A(I)              4.0         4.1         4.2         4.2         4.5
  V(I)             6.71        6.55        6.51        6.37        6.02

X STA.       104.0       107.4       111.3       116.0       122.1       138.0
  A(I)              4.6         4.8         5.4         5.9         8.2
  V(I)             5.90        5.61        5.03        4.59        3.30


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
     WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
             1      276      7179    91    91                         2740
             2      697     74064    60    62                        13463
             3      328     17928   100   100                         3377
   500.60          1301     99171   250   254  1.55    -90    160    13504

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.60   -90.5   159.8  1301.2   99171.    3000.   2.31

X STA.       -90.5        -7.0         3.1         7.8        11.8        15.2
  A(I)            215.3        90.8        49.1        48.3        43.4
  V(I)             0.70        1.65        3.05        3.10        3.46

X STA.        15.2        18.7        22.2        25.8        29.0        32.3
  A(I)             43.1        43.5        44.6        42.4        42.3
  V(I)             3.48        3.45        3.36        3.54        3.54

X STA.        32.3        35.7        39.1        42.6        46.0        50.2
  A(I)             43.9        43.2        43.9        44.3        49.9
  V(I)             3.42        3.47        3.41        3.39        3.01

X STA.        50.2        56.2        67.9        84.6       114.0       159.8
  A(I)             57.6        71.4        76.7        94.8       112.7
  V(I)             2.60        2.10        1.96        1.58        1.33
```

```
    U.S. Geological Survey WSPRO Input File cabo037b.wsp
    Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
    Bridge #37 over Winooski River in Cabot, Vt.  RHF

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      270     19832     0     70                     18245246
 498.91          270     19832     0     70  1.00      0     26 18245246

 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    498.91     0.0    26.0   270.2   19832.    2740.  10.14

X STA.        0.0        4.0        5.4        6.6        7.6        8.6
  A(I)            26.8       15.8       13.7       12.5       12.0
  V(I)            5.12       8.69      10.00      11.00      11.46

X STA.        8.6        9.6       10.5       11.4       12.3       13.2
  A(I)            11.5       11.0       11.0       10.9       10.8
  V(I)           11.93      12.44      12.40      12.61      12.68

X STA.       13.2       14.1       15.1       16.0       16.9       17.9
  A(I)            10.9       10.8       10.9       11.3       11.2
  V(I)           12.58      12.64      12.54      12.11      12.23

X STA.       17.9       18.9       20.0       21.2       22.6       26.0
  A(I)            12.1       12.2       13.6       15.4       25.8
  V(I)           11.32      11.19      10.07       8.91       5.31


 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      245     23442    25     43                         4375
 497.84          245     23442    25     43  1.00      0     26     4375


 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
      WSEL     LEW     REW    AREA        K        Q    VEL
    501.00   -84.5   147.5   244.8    6192.    1361.   5.56

X STA.      -84.5      -16.2        8.8       34.5       49.8       58.6
  A(I)            33.3       19.6       18.7       14.8       11.6
  V(I)            2.04       3.48       3.64       4.59       5.85

X STA.       58.6       65.1       70.6       75.4       79.8       83.6
  A(I)            10.3        9.7        9.2        9.0        8.4
  V(I)            6.60       7.05       7.44       7.56       8.07

X STA.       83.6       87.2       90.6       94.2       98.0      102.1
  A(I)             8.3        8.2        8.4        8.6        8.8
  V(I)            8.18       8.34       8.14       7.89       7.69

X STA.      102.1      106.6      111.8      117.8      125.3      147.5
  A(I)             9.1        9.8       10.5       11.7       16.8
  V(I)            7.46       6.93       6.49       5.82       4.05


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      351      9296   112    113                         3529
          2      741     82109    60     62                        14773
          3      402     24928   101    102                         4554
 501.34         1495    116333   273    278  1.58   -111    161    15805

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
      WSEL     LEW     REW    AREA        K        Q    VEL
    501.34  -112.2   161.2  1495.0  116333.    4100.   2.74

X STA.     -112.2      -10.3        2.4        7.4       11.7       15.3
  A(I)           257.2      118.6       55.5       54.2       49.0
  V(I)            0.80       1.73       3.70       3.78       4.18

X STA.       15.3       19.0       22.8       26.5       30.0       33.5
  A(I)            48.7       49.9       49.3       48.2       48.0
  V(I)            4.21       4.11       4.15       4.25       4.27

X STA.       33.5       37.2       40.8       44.5       48.5       53.7
  A(I)            49.3       48.8       50.1       52.7       59.1
  V(I)            4.16       4.20       4.09       3.89       3.47

X STA.       53.7       63.4       76.5       96.0      124.3      161.2
  A(I)            75.7       76.8       89.1      101.7      113.1
  V(I)            2.71       2.67       2.30       2.01       1.81
```

WSPRO OUTPUT FILE (continued)

```
     U.S. Geological Survey WSPRO Input File cabo037b.wsp
     Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
     Bridge #37 over Winooski River in Cabot, Vt.  RHF

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#    AREA        K  TOPW   WETP  ALPH    LEW    REW      QCR
          1     169    13954    24     36                          2533
494.70          169    13954    24     36  1.00      1     26      2533

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.70     0.6    25.5   168.6   13954.    2430.  14.41

X STA.        0.6        4.7        6.1        7.2        8.2        9.1
  A(I)           17.8        9.9        8.6        8.0        7.3
  V(I)           6.82      12.33      14.14      15.16      16.62

X STA.        9.1       10.0       10.8       11.6       12.4       13.3
  A(I)            6.9        6.8        6.7        6.6        6.5
  V(I)          17.64      17.81      18.18      18.53      18.67

X STA.       13.3       14.1       14.9       15.8       16.6       17.5
  A(I)            6.6        6.6        6.6        6.7        7.1
  V(I)          18.33      18.48      18.39      18.14      17.20

X STA.       17.5       18.5       19.5       20.6       22.0       25.5
  A(I)            7.2        7.7        8.5       10.0       16.7
  V(I)          16.98      15.78      14.31      12.16       7.29


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      47.

  WSEL  SA#    AREA        K  TOPW   WETP  ALPH    LEW    REW      QCR
          1     148     3849    48     48                          1473
          2     579    54396    60     62                         10198
          3     136     4275    96     96                           923
498.64          863    62519   204    207  1.48    -47    156      8274

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      47.

      WSEL     LEW     REW    AREA        K        Q    VEL
    498.64   -47.7   156.0   863.0   62519.    2430.   2.82

X STA.      -47.7       -2.9        3.8        8.0       11.4       14.3
  A(I)          127.2       49.5       36.3       34.2       31.2
  V(I)           0.96       2.46       3.35       3.56       3.90

X STA.       14.3       17.2       20.2       23.2       26.0       28.8
  A(I)           30.9       31.1       30.7       31.0       29.9
  V(I)           3.94       3.91       3.96       3.93       4.06

X STA.       28.8       31.5       34.3       37.2       40.1       43.0
  A(I)           30.4       30.2       31.2       31.2       31.2
  V(I)           4.00       4.02       3.89       3.90       3.89

X STA.       43.0       45.9       49.4       54.2       67.5      156.0
  A(I)           31.5       35.9       39.9       60.7      108.8
  V(I)           3.85       3.38       3.05       2.00       1.12
```

```
        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      172     14376    24     37                          2613
   494.85           172     14376    24     37  1.00      1     26      2613


    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       494.85     0.6    25.6   172.2   14376.    2554.  14.83

X STA.         0.6        4.7        6.0        7.2        8.2        9.1
  A(I)            18.3       10.1        8.8        8.0        7.6
  V(I)            6.99      12.70      14.57      16.00      16.70

X STA.         9.1        9.9       10.8       11.6       12.4       13.2
  A(I)             7.0        7.0        6.8        6.7        6.6
  V(I)           18.19      18.37      18.74      19.10      19.24

X STA.        13.2       14.1       14.9       15.8       16.7       17.5
  A(I)             6.8        6.7        6.7        7.0        7.1
  V(I)           18.90      19.04      18.95      18.32      18.05

X STA.        17.5       18.5       19.5       20.6       22.1       25.6
  A(I)             7.3        7.9        8.7       10.2       17.1
  V(I)           17.49      16.26      14.74      12.50       7.47


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.99    76.1   105.1     6.1      49.      16.   2.63

X STA.        76.1       82.1       83.8       85.1       86.0       86.9
  A(I)             0.6        0.4        0.3        0.3        0.3
  V(I)            1.44       2.17       2.51       2.76       2.97

X STA.        86.9       87.6       88.3       88.9       89.5       90.0
  A(I)             0.3        0.2        0.2        0.2        0.2
  V(I)            3.15       3.22       3.40       3.42       3.54

X STA.        90.0       90.6       91.2       91.9       92.6       93.4
  A(I)             0.2        0.2        0.2        0.3        0.3
  V(I)            3.44       3.36       3.35       3.17       3.03

X STA.        93.4       94.3       95.4       96.7       98.6      105.1
  A(I)             0.3        0.3        0.3        0.4        0.6
  V(I)            2.90       2.69       2.39       2.06       1.40


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      166      4363    53     54                          1666
             2      601     57922    60     62                         10791
             3      172      6257    97     97                          1302
   499.01           940     68542   210    214  1.50    -52    157      9192


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      47.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.01   -53.4   156.7   939.5   68542.    2570.   2.74

X STA.       -53.4       -3.6        3.6        7.9       11.4       14.4
  A(I)           140.1       55.6       38.0       36.6       33.4
  V(I)            0.92       2.31       3.38       3.51       3.85

X STA.        14.4       17.5       20.6       23.6       26.6       29.4
  A(I)            33.1       33.3       33.0       33.4       32.1
  V(I)            3.88       3.86       3.90       3.85       4.00

X STA.        29.4       32.3       35.1       38.1       41.2       44.2
  A(I)            32.5       32.3       33.3       33.5       33.7
  V(I)            3.96       3.98       3.86       3.84       3.82

X STA.        44.2       47.3       51.3       57.9       76.1      156.7
  A(I)            35.2       39.3       48.3       70.4      112.6
  V(I)            3.65       3.27       2.66       1.82       1.14

  EX
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF
           *** RUN DATE & TIME: 07-21-97  09:28

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

EXITX:XS   ******    -14      475  0.72 *****  497.24  494.25    3000  496.52
       -24 ******     95    29399  1.16 ***** *******    0.58    6.31

FULLV:FV       25    -12      443  0.82  0.28  497.56 *******    3000  496.75
         0     25     91    26923  1.15  0.05   -0.01    0.62    6.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.79

APPRO:AS       47    -29      661  0.41  0.33  497.89 *******    3000  497.47
        47     47    102    48094  1.29  0.00    0.00    0.41    4.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.33       0.00     495.56     498.57
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.43     499.67     499.86     498.83
 ===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       25      0      270  1.29 *****  500.20  494.56    2457  498.91
         0 ******     26    19832  1.00 ***** *******    0.50    9.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.429  0.000  498.83 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      11.    31.  0.03  0.13  500.70    0.00    541.  500.35

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    47.    56.   -43.    13.   0.1   0.1   2.7   7.7   0.5   2.7
   RT:   494.   125.    13.   138.   1.8   0.8   5.0   4.7   1.2   3.0

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

APPRO:AS       25    -90     1302  0.13  0.11  500.73  493.23    3000  500.60
        47     29    160    99258  1.55  0.68    0.00    0.22    2.30

        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.   -15.    95.   3000.   29399.     475.    6.31  496.52
   FULLV:FV       0.   -13.    91.   3000.   26923.     443.    6.76  496.75
   BRIDG:BR       0.     0.    26.   2457.   19832.     270.    9.09  498.91
   RDWAY:RG      11.*******    47.    541.       0.*********    2.00  500.35
   APPRO:AS      47.   -91.   160.   3000.   99258.    1302.    2.30  500.60

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.25    0.58  486.67  503.17************  0.72  497.24  496.52
   FULLV:FV  ********    0.62  487.19  503.69  0.28  0.05  0.82  497.56  496.75
   BRIDG:BR    494.56    0.50  486.20  498.91************  1.29  500.20  498.91
   RDWAY:RG ****************  498.57  514.48  0.03******  0.13  500.70  500.35
   APPRO:AS    493.23    0.22  487.57  505.36  0.11  0.68  0.13  500.73  500.60
```

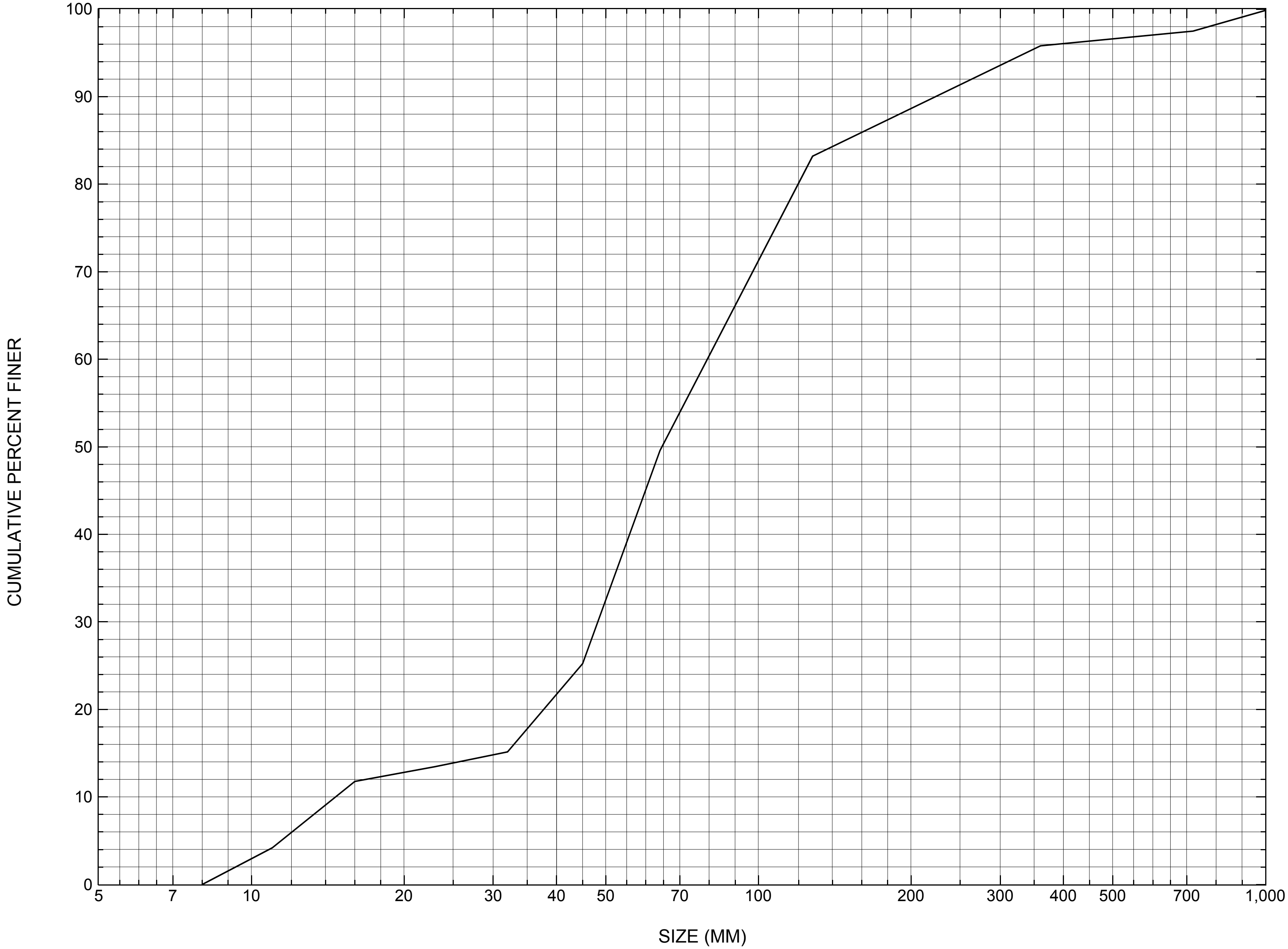
```
        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

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

EXITX:XS   ******    -28      609  0.83 *****  498.45  495.42    4100  497.62
       -24 ******    109    40189  1.18 ***** *******    0.62    6.74

FULLV:FV       25    -19      568  0.94  0.28  498.78 *******    4100  497.84
         0     25    106    36960  1.17  0.06   -0.01    0.65    7.21
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.67

APPRO:AS       47    -46      853  0.53  0.35  499.12 *******    4100  498.59
        47     47    156    61755  1.48  0.00   -0.01    0.50    4.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.39       0.00     497.41     498.57
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.42     500.89     501.05     498.83
 ===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       25      0      270  1.60 *****  500.51  495.10    2740  498.91
         0 ******     26    19832  1.00 ***** *******    0.55   10.14

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.455  0.000  498.83 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    31.  0.04  0.18  501.48    0.00   1361.  501.00

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    307.    98.   -84.    13.   0.8   0.6   4.5   5.5   1.1   2.9
   RT:   1054.   134.    13.   147.   2.4   1.4   6.2   5.6   1.9   3.0

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

APPRO:AS       25   -111     1494  0.18  0.15  501.52  494.33    4100  501.34
        47     30    161   116282  1.58  0.42    0.00    0.26    2.74

        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -25.    -29.    109.   4100.   40189.     609.    6.74  497.62
   FULLV:FV       0.    -20.    106.   4100.   36960.     568.    7.21  497.84
   BRIDG:BR       0.      0.     26.   2740.   19832.     270.   10.14  498.91
   RDWAY:RG      11.*******    307.   1361.        0.*********    2.00  501.00
   APPRO:AS      47.   -112.    161.   4100.  116282.    1494.    2.74  501.34


 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    495.42    0.62  486.67  503.17************  0.83  498.45  497.62
   FULLV:FV  ********    0.65  487.19  503.69  0.28  0.06  0.94  498.78  497.84
   BRIDG:BR    495.10    0.55  486.20  498.91************  1.60  500.51  498.91
   RDWAY:RG  ****************  498.57  514.48  0.04******  0.18  501.48  501.00
   APPRO:AS    494.33    0.26  487.57  505.36  0.15  0.42  0.18  501.52  501.34
```

```
       U.S. Geological Survey WSPRO Input File cabo037b.wsp
       Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
       Bridge #37 over Winooski River in Cabot, Vt.  RHF

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

EXITX:XS   ******    -11      400  0.65 *****  496.44  493.49    2430  495.79
       -24 ******     83    23807  1.14 ***** *******    0.56    6.08

FULLV:FV       25    -10      373  0.75  0.28  496.76 *******    2430  496.02
         0     25     78    21968  1.13  0.05   -0.01    0.60    6.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.84

APPRO:AS       47    -25      572  0.35  0.31  497.07 *******    2430  496.73
        47     47     84    40431  1.23  0.00    0.00    0.37    4.25
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.64       0.00     494.70     498.57
 ===260 ATTEMPTING FLOW CLASS 4 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       25      1      169  3.27  0.44  497.96  494.50    2430  494.70
         0     25     26    13948  1.01  1.08    0.00    0.97   14.42

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.995 ******  498.83 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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       25    -47      863  0.18  0.20  498.82  492.61    2430  498.64
        47     30    156    62540  1.48  0.66    0.01    0.29    2.81

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.771  0.559   27553.    15.    40. ********

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

       U.S. Geological Survey WSPRO Input File cabo037b.wsp
       Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
       Bridge #37 over Winooski River in Cabot, Vt.  RHF

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.   -12.    83.   2430.   23807.     400.    6.08  495.79
   FULLV:FV       0.   -11.    78.   2430.   21968.     373.    6.52  496.02
   BRIDG:BR       0.     1.    26.   2430.   13948.     169.   14.42  494.70
   RDWAY:RG      11.**************      0.       0.       0.    2.00********
   APPRO:AS      47.   -48.   156.   2430.   62540.     863.    2.81  498.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      15.    40.   27553.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    493.49    0.56  486.67  503.17************  0.65  496.44  495.79
   FULLV:FV  ********    0.60  487.19  503.69  0.28  0.05  0.75  496.76  496.02
   BRIDG:BR    494.50    0.97  486.20  498.91  0.44  1.08  3.27  497.96  494.70
   RDWAY:RG  ***************  498.57  514.48  0.05******  0.18  498.76********
   APPRO:AS    492.61    0.29  487.57  505.36  0.20  0.66  0.18  498.82  498.64
```

```
        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

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

 EXITX:XS   ******    -11      420  0.67 *****  496.66  493.70    2570  495.99
        -24 ******     87    25178  1.14 ***** *******    0.56    6.12

 FULLV:FV       25    -11      391  0.76  0.28  496.98 *******    2570  496.22
          0     25     82    23236  1.14  0.05   -0.01    0.60    6.57
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.83

 APPRO:AS       47    -26      595  0.36  0.31  497.29 *******    2570  496.93
         47     47     87    42479  1.24  0.00    0.00    0.37    4.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.05       0.00     494.82     498.57
  ===260 ATTEMPTING FLOW CLASS 4 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       25      1      172  3.45  0.45  498.30  494.75    2554  494.85
          0     25     26    14377  1.01  1.19    0.00    0.98   14.83

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   4.  0.995 ******  498.83 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      11.    31.  0.04  0.18  499.13    0.00     16.  498.99

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:      0.   114.  -101.    13.   1.2   0.9   5.4   5.9   1.5   3.0
    RT:     16.    29.    76.   105.   0.4   0.2   2.3   2.5   0.3   2.6

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

 APPRO:AS       25    -52      940  0.18  0.20  499.19  492.77    2570  499.01
         47     30    157    68558  1.50  0.68    0.01    0.28    2.73

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.778  0.573   29199.    15.    40. ********

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

        U.S. Geological Survey WSPRO Input File cabo037b.wsp
        Hydraulic analysis for structure CABOTH00410037   Date: 11-JUL-97
        Bridge #37 over Winooski River in Cabot, Vt.  RHF

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -25.   -12.    87.   2570.   25178.     420.    6.12  495.99
    FULLV:FV       0.   -12.    82.   2570.   23236.     391.    6.57  496.22
    BRIDG:BR       0.     1.    26.   2554.   14377.     172.   14.83  494.85
    RDWAY:RG      11.*******     0.     16.       0.*********    2.00  498.99
    APPRO:AS      47.   -53.   157.   2570.   68558.     940.    2.73  499.01

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      15.    40.   29199.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS    493.70    0.56  486.67  503.17************  0.67  496.66  495.99
    FULLV:FV  ********    0.60  487.19  503.69  0.28  0.05  0.76  496.98  496.22
    BRIDG:BR    494.75    0.98  486.20  498.91  0.45  1.19  3.45  498.30  494.85
    RDWAY:RG  ****************  498.57  514.48  0.04******  0.18  499.13  498.99
    APPRO:AS    492.77    0.28  487.57  505.36  0.20  0.68  0.18  499.19  499.01
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CABOTH00410037, in Cabot, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CABOTH00410037

General Location Descriptive

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

Date *(MM/DD/YY)* 10 / 13 / 95

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 023

Town *(FIPS place code; I - 4; nnnnn)* 11125

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

Waterway *(I - 6)* Winooski River

Road Name *(I - 7)*:

Route Number C3041

Vicinity *(I - 9)* 0.1 MI TO JCT W CL2 TH1

Topographic Map Cabot

Hydrologic Unit Code: -

Latitude *(I - 16; nnnn.n)* 44234

Longitude *(i - 17; nnnnn.n)* 72198

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10120400371204

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1930

Structure length *(I - 49; nnnnnn)* 000029

Average daily traffic, ADT *(I - 29; nnnnnn)* 000075

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

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

Channel & Protection *(I - 61; n)* 5

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

Waterway adequacy *(I - 71; n)* 6

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) 24

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

Vertical clearance from streambed (*nnn.n ft*) 9

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

Waterway of full opening (*nnn.n ft*^{2}) 216

Comments:

According to the structural inspection report dated 10/4/93, the deck of the structure consists of wood planks with wood runners and the decking is untreated lumber. The abutments, wingwalls and backwalls are laid up granite blocks with gravel filled bags making up much of the backwalls on either side of the centerline. New concrete footings have been added on each abutment and on a section of the upstream wingwalls. The Rabut has a concrete cap which has 1” to 2” cracks under 2 of the beams. The laid up stone has small voids overall in both the abutments and wingwalls. The Labut face bulges out at least 6” under the upstream fascia beam. Boulder riprap has been added **(continued p. 35)**

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: -

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:

along the bottom of the upstream right wingwall, and around the upstream end of the upstream left wingwall.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **21.53** mi^2 Lake/pond/swamp area **0.39** mi^2

Watershed storage *(ST)* **1.82** %

Bridge site elevation **925** ft Headwater elevation **1831** ft

Main channel length **6.09** mi

10% channel length elevation **955** ft 85% channel length elevation **1437** ft

Main channel slope *(S)* **105.33** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

No benchmark information 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? N *If no, type ctrl-n bi* Number of borings taken: -

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

Briefly describe material at foundation bottom elevation or around piles:

No foundation material information is available.

Comments:

No bridge plan data is available.

Cross-sectional Data

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

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

Comments: **No cross section data is available.**

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

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: 11/6/96
Computerized by: EW Date: 11/6/96
Reviewd by: RF Date: 7/30/97

Structure Number CABOTH00410037

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 07 / 16 / 1996

2. Highway District Number 06 Mile marker 000000

County Washington (023) Town CABOT (11125)

Waterway *(I - 6)* Winooski River Road Name -

Route Number C3041 Hydrologic Unit Code: 02010003

3. Descriptive comments:

The bridge is located 0.1 miles from the junction with cl2 th1. The bridge deck is wooden.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 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 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 29 *(feet)* Span length 26 *(feet)* Bridge width 16 *(feet)*

Road approach to bridge:

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

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

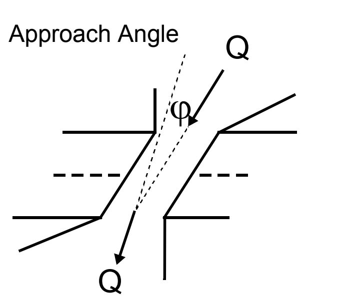
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

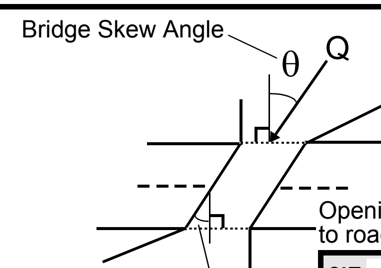
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 35





α= 15.0

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

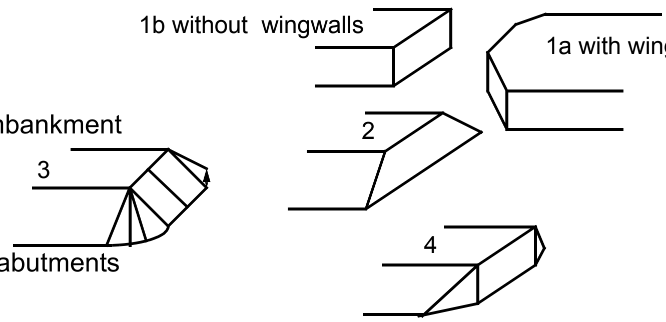
1a- Vertical abutments with wingwalls

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.)

4: The upstream left bank is marginal between forest cover and shrub/ brush.
7: Values are from VT AOT. Measured bridge length = 31.6 feet; bridge span = 26.5 feet; and deck width = 16 feet (between outside edges).
13: RBDS erosion exists only at the downstream end of the right abutment. LBUS protection consists of only a couple large boulders. Both the RBDS and LBUS have minor erosion with a lot of brush protection to prevent additional erosion.
18: Bridge type is type 1b for the upstream left and downstream section of bridge (no wingwalls exist). There is a wingwall extending upstream from the right abutment. The upstream right wingwall blends in with the protection material as it is all laid-up stone. The bridge type for the upstream section is considered to be 1b for contraction scour calculations but for abutment scour calculations, the USRWW was considered.

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
47.0	**2.0**			**5.5**	**4**	**4**	**52**	**7**	**1**	**-**

23. Bank width **15.0** 24. Channel width **25.0** 25. Thalweg depth **60.0** 29. Bed Material **45**

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

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

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

26: Immediate right bank is 100% covered with brush, although there are no trees.
27: Laid-up stone right wingwall extends to 36 feet upstream.
30: Left bank protection extends from upstream end of LABUT footing at 8 feet upstream to 23 feet upstream.

Along the right bank, beginning at 45 feet upstream, an old mill building extends to 150 feet upstream. Also at 45 feet upstream, the downstream nose of an island comprised of boulders and sand begins which forms a penstock for the old mill. The bank on the bankward side is formed by stones and concrete that are the foundation of the building. There is a stone dam at 250 feet upstream. All measurements were made from the right side of the channel.

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	RB	57 Angle (BF) LB	RB	61. Material (BF) LB	RB	62. Erosion (BF) LB	RB
40.5		**1.5**		**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.):

542

63: Sand is along RABUT and boulders (placed protection) are along LABUT at base of footing.

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? **2** ____ (Y or N) Ice Blockage Potential **Y** ____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

67: Not many large trees, but small to medium size trees line the upstream banks.

68/ 69: Small bridge opening.

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		25	90	2	2	-	4	90.0
RABUT	2, 1	0	90			2	2	25.0

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.):

-
2.5
2, 1
71/ 73: Upstream end of left abutment protrudes into the channel more than the downstream end of left abutment. Downstream end of left abutment also acts as bank to 26 feet downstream.

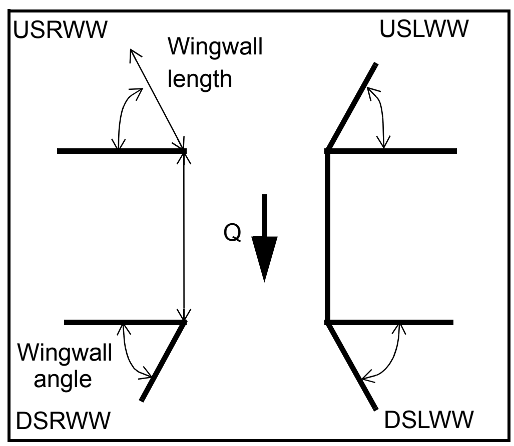
76: The RABUT footing is exposed 2 feet at upstream and downstream ends of footing, and exposure depth is 2.5 feet at the center area of footing.

77: Both abutments are comprised of laid-up stone walls with new concrete footings. Bags filled with concrete

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	are		betw		een	25.0	
USRWW:	the		brid		ge	3.0	
DSLWW:	seats		and		the	21.5	
DSRWW:	bot-		tom		of	22.0	

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	the	steel	at	of	e	both	ts.	-
Condition	brid	bea	the	the	wall	abut		-
Extent	ge	ms,	top	ston	s on	men	N	-

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

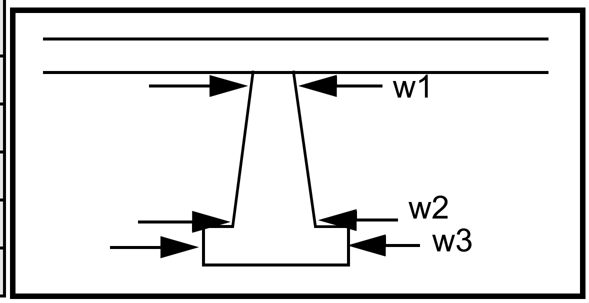
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
Y
2
0
-
-
N
-
-
-
-

Piers:

84. Are there piers? **N** (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	-			-	35.0	18.5
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	-	1	-	there	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	-	0	-	are 5	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	-	-	-	large	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	-	-	-	(2.5	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	-	-	80:	ft	*Y- yes; N- no*
91. Attack ∠ (BF)	-	-	Alon	diam	
92. Pushed	-	-	g the	eter)	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	2	-	upst	boul-	
95. Cross-members	1	-	ream	ders	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	1	-	left	stack	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	2	-	bank	ed	
98. Exposure depth	1	-	,	roug	

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

hly at an angle back from the upstream end of the abutment wall. These 5 boulders extend to 8 feet upstream from the upstream end of the bridge deck. The LABUT extends to 26 feet downstream with no change in angle.

The DSRWW does not exist, but there are stacked cut stones extending back from the RABUT wall at a 90 degree angle, beginning approximately 6 feet from the face of the abutment wall.

82: Right bank protection extends from 4 feet upstream (end of concrete footing) to 38 feet upstream.

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length 2 Width 2 Depth: 5 Positioned 52 %LB to 0 %RB

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

1
45
2
2

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? 1

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

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

Confluence comments (eg. confluence name):

r is type 3 for both banks beyond one bridge length, while it is type-2 within one bridge length.

F. Geomorphic Channel Assessment

107. Stage of reach evolution Th

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)*:

e left bank protection is an extension of the left abutment wall to 26 feet downstream. Beyond that, the left bank is comprised of naturally occurring boulders.

The right bank protection consists of stone block with concrete between and extends from the downstream end of the footing to 18 feet downstream. This block is set in the channel, one foot higher than the current water level. It is approximately 1.5 feet high.

There are a couple of large boulders placed at the right side of the channel at 35 feet downstream. Beyond the boulders, the channel cuts into the right bank to form an eddy area of approximately 20 feet in diameter. It is a small island with trees in the center of eddy area.

N

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: CABOTH00410037 Town: Cabot
Road Number: TH041 County: Washington
Stream: Winooski River

Initials RHF Date: 07/21/97 Checked: LKS
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	other Q
Total discharge, cfs	3000	4100	2430	2570
Main Channel Area, ft2	697	741	579	601
Left overbank area, ft2	276	351	148	166
Right overbank area, ft2	328	402	136	172
Top width main channel, ft	60	60	60	60
Top width L overbank, ft	91	112	48	53
Top width R overbank, ft	100	101	96	97
D50 of channel, ft	0.21177	0.21177	0.21177	0.21177
D50 left overbank, ft	--	--	--	--
D50 right overbank, ft	--	--	--	--
y1, average depth, MC, ft	11.6	12.4	9.7	10.0
y1, average depth, LOB, ft	3.0	3.1	3.1	3.1
y1, average depth, ROB, ft	3.3	4.0	1.4	1.8
Total conveyance, approach	99171	116333	62519	68542
Conveyance, main channel	74064	82109	54396	57922
Conveyance, LOB	7179	9296	3849	4363
Conveyance, ROB	17928	24928	4275	6257
Percent discrepancy, conveyance	0.0000	0.0000	-0.0016	0.0000
Qm, discharge, MC, cfs	2240.5	2893.8	2114.3	2171.8
Ql, discharge, LOB, cfs	217.2	327.6	149.6	163.6
Qr, discharge, ROB, cfs	542.3	878.6	166.2	234.6
Vm, mean velocity MC, ft/s	3.2	3.9	3.7	3.6
Vl, mean velocity, LOB, ft/s	0.8	0.9	1.0	1.0
Vr, mean velocity, ROB, ft/s	1.7	2.2	1.2	1.4
Vc-m, crit. velocity, MC, ft/s	10.1	10.2	9.7	9.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?				
Main Channel	0	0	0	0
Left Overbank	N/A	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A	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	Other Q
Q, discharge thru bridge MC, cfs	2457	2740	2430	2554
Main channel area (DS), ft2	218	245	169	172

Main channel width (normal), ft	25.1	25.1	24.1	24.2
Cum. width of piers, ft	0.0	0.0	0.0	0.0
Adj. main channel width, ft	25.1	25.1	24.1	24.2
D90, ft	0.7347	0.7347	0.7347	0.7347
D95, ft	1.1070	1.1070	1.1070	1.1070
Dc, critical grain size, ft	0.5183	0.4872	0.9210	0.9767
Pc, Decimal percent coarser than Dc	0.142	0.150	0.073	0.065
Depth to armoring, ft	9.39	8.30	35.24	41.87

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

Bridge Section	Q100	Q500	Other Q	Other Q
(Q) total discharge, cfs	3000	4100	2430	2570
(Q) discharge thru bridge, cfs	2457	2740	2430	2554
Main channel conveyance	19832	19832	13954	14376
Total conveyance	19832	19832	13954	14376
Q2, bridge MC discharge,cfs	2457	2740	2430	2554
Main channel area, ft2	270	270	169	172
Main channel width (normal), ft	25.1	25.1	24.1	24.2
Cum. width of piers in MC, ft	0.0	0.0	0.0	0.0
W, adjusted width, ft	25.1	25.1	24.1	24.2
y_bridge (avg. depth at br.), ft	10.76	10.76	7.01	7.11
Dm, median (1.25*D50), ft	0.264713	0.264713	0.264713	0.264713
y2, depth in contraction,ft	9.20	10.10	9.44	9.81
ys, scour depth (y2-ybridge), ft	-1.56	-0.65	2.43	2.71

Pressure Flow Scour (contraction scour for orifice flow conditions)
Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	3000	4100	2430
Q, thru bridge MC, cfs	2457	2740	2430
Vc, critical velocity, ft/s	10.06	10.16	9.75
Va, velocity MC approach, ft/s	3.21	3.91	3.65
Main channel width (normal), ft	25.1	25.1	24.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.1	25.1	24.1
qbr, unit discharge, ft2/s	97.9	109.2	100.8
Area of full opening, ft2	270.0	270.0	169.0
Hb, depth of full opening, ft	10.76	10.76	7.01
Fr, Froude number, bridge MC	0.5	0.55	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	218	245	N/A
**Hb, depth at downstream face, ft	8.69	9.76	N/A
**Fr, Froude number at DS face	0.67	0.63	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	498.83	498.83	0
Elevation of Bed, ft	488.07	488.07	-7.01
Elevation of Approach, ft	500.6	501.34	0
Friction loss, approach, ft	0.11	0.15	0
Elevation of WS immediately US, ft	500.49	501.19	0.00
ya, depth immediately US, ft	12.42	13.12	7.01
Mean elevation of deck, ft	500.25	500.25	0

w, depth of overflow, ft (>=0)	0.24	0.94	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.97	1.00
**Cc, for downstream face (<=1.0)	0.913795	0.945432	ERR
Ys, scour w/Chang equation, ft	-0.72	0.32	N/A
Ys, scour w/Umbrell equation, ft	-3.96	-2.99	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	1.97	1.61	N/A
**Ys, scour w/Umbrell equation, ft	-1.89	-2.00	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	9.20	10.10	9.44
WSEL at downstream face, ft	496.75	497.84	--
Depth at downstream face, ft	8.69	9.76	N/A
Ys, depth of scour (Laursen), ft	0.52	0.34	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	3000	4100	2430	3000	4100	2430
a', abut.length blocking flow, ft	90.9	112.6	48.7	134.2	135.6	130.9
Ae, area of blocked flow ft2	274.91	310.81	156.01	626.14	644.91	470.86
Qe, discharge blocked abut.,cfs	__	__	192.22	__	__	1375.55
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.92	1.06	1.23	2.49	3.04	2.92
ya, depth of f/p flow, ft	3.02	2.76	3.20	4.67	4.76	3.60
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.092	0.105	0.121	0.189	0.218	0.271
ys, scour depth, ft	10.08	10.72	9.81	17.68	19.17	17.44

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)	90.9	112.6	48.7	134.2	135.6	130.9
y1 (depth f/p flow, ft)	3.02	2.76	3.20	4.67	4.76	3.60
a'/y1	30.06	40.79	15.20	28.76	28.51	36.39
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.09	0.11	0.12	0.19	0.22	0.27
Ys w/ corr. factor K1/0.55:						
vertical	10.34	9.86	ERR	18.60	19.88	16.16
vertical w/ ww's	8.48	8.08	ERR	15.25	16.30	13.25
spill-through	5.69	5.42	ERR	10.23	10.93	8.89

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.67	0.63	0.97	0.67	0.63	0.97
y, depth of flow in bridge, ft	8.69	9.76	7.01	8.69	9.76	7.01
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.41	2.39	ERR	2.41	2.39	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.91	ERR	ERR	2.91
Fr<=0.8 (spillthrough abut.)	2.10	2.09	ERR	2.10	2.09	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	2.57	ERR	ERR	2.57