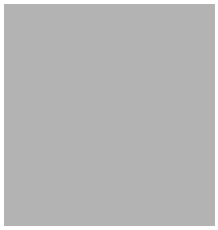
LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (WODSTH00990049) on TOWN HIGHWAY 99, crossing GULF BROOK, WOODSTOCK, VERMONT

U.S. Geological Survey
Open-File Report 96-639

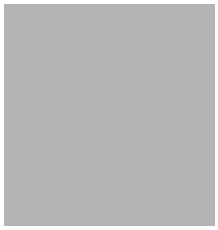


Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (WODSTH00990049) on TOWN HIGHWAY 99, crossing GULF BROOK, WOODSTOCK, VERMONT

By SCOTT A. OLSON and ROBERT E. HAMMOND

U.S. Geological Survey
Open-File Report 96-639



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

Pembroke, New Hampshire

1996

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

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

For additional information
write to:

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

Copies of this report may be
purchased from:

U.S. Geological Survey
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 49 (WODSTH00990049) ON TOWN HIGHWAY 99, CROSSING GULF BROOK, WOODSTOCK, VERMONT

By **Scott A. Olson and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WODSTH00990049 on Town Highway 99 crossing the Gulf Brook, Woodstock, 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 east-central Vermont. The 16.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the primary surface cover is pasture except for upstream right of the bridge which is cover by trees and brush. The immediate banks throughout the reach have scattered woody vegetation.

In the study area, the Gulf Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 91 ft and an average channel depth of 6 ft. The channel bed materials range from sand to cobble with a median grain size (D_{50}) of 85.3 mm (0.280 ft). The geomorphic assessment at the time of the Level I site visits on September 15, 1994 and December 14, 1994, indicated that the reach was stable.

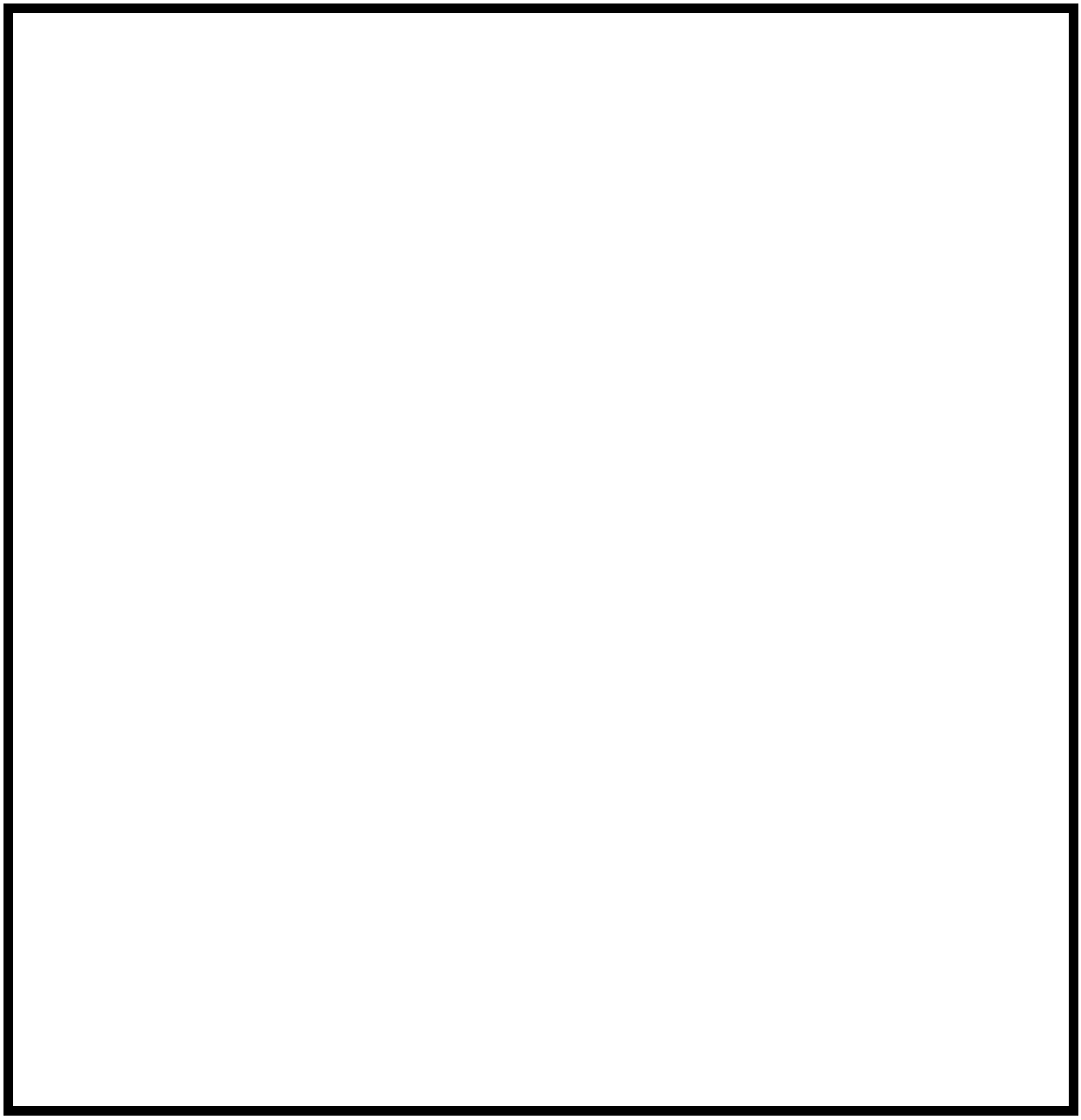
The Town Highway 99 crossing of the Gulf Brook is a 56-ft-long, one-lane bridge consisting of one 55-foot steel-beam span (Vermont Agency of Transportation, written communication, April 4, 1995). The bridge is supported by vertical, concrete abutments with a spill-through slope constructed of large quarried stone. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

Erosion at the right abutment has undermined the toe of the spill-through slope by nearly a foot. Material has been removed from under the stone spill-through slope so that 0.5 feet of horizontal penetration was possible at the time of the visits. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 0.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour at the left abutment ranged from 3.1 to 10.3 ft. with the worst-case occurring at the 500-year discharge. Abutment scour at the right abutment ranged from 6.4 to 10.4 ft. with the worst-case occurring at the 100-year discharge.Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). 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.

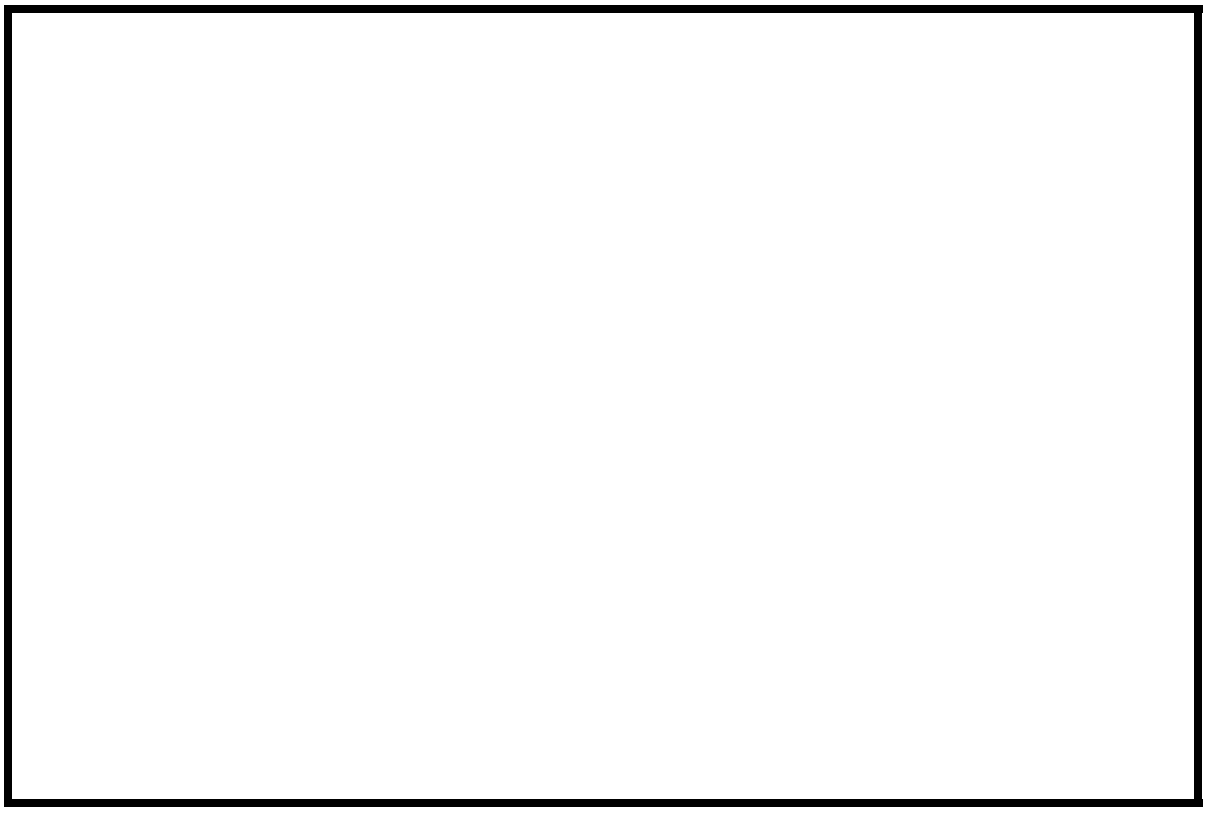


Woodstock North, VT. Quadrangle, 1:24,000, 1966

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 WODSTH00990049 ***Stream*** Gulf Brook

County Windsor ***Road*** TH99 ***District*** 4

Description of Bridge

Bridge length 56 ***ft*** ***Bridge width*** 14.0 ***ft*** ***Max span length*** 55 ***ft***

Alignment of bridge to road (on curve or straight) Straight

Abutment type Spill-through ***Embankment type*** sloping

Stone fill on abutment? Yes ***Date of inspection*** 9/15/94 and 12/14/94

Description of stone fill 3 ft by 3 ft by 2 ft quarried stone block are used for the face of the abutment spill-through slope.

Concrete abutment with stone spill-through slopes along the abutment face. Toe of spill-through slope on right abutment is experiencing undermining.

Is bridge skewed to flood flow according to Y ***survey?*** Yes ***Angle*** 20

Mild bend in the reach. Landowner report that the channel was moved and straightened upstream of the bridge after the 1973 flood.

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	9/15/94 and 12/14/94	0	0
Level II	9/15/94	0	0

Potential for debris Low.

Describe any features near or at the bridge that may affect flow (include observation date) The right abutment protrudes out into the channel about ten feet.

Description of the Geomorphic Setting

General topography The channel is located within a wide, irregular flood plain with steep valley walls on both sides.

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

Date of inspection 9/15/94 and 12/14/94

DS left: Flood plain to moderately sloped valley wall.

DS right: Flood plain to moderately sloped valley wall.

US left: Flood plain to moderately sloped valley wall.

US right: Flood plain to moderately sloped valley wall.

Description of the Channel

Average top width 91 ft ***Average depth*** 6 ft

Predominant bed material Cobbles ***Bank material*** Sand

Channel Slightly sinuous and stable with alluvial to semi-alluvial channel boundaries.

Vegetative co 11/08/94

DS left: Grass with a few trees on immediate bank. VT Route 12 parallels bank

DS right: Grass with a few trees on immediate bank.

US left: Grass with a few trees on immediate bank. VT Route 12 parallels bank

US right: Trees and brush with grass on far overbank.

Do banks appear stable? Y

~~***If not, describe location and type of instability and date of observation.***~~

None. September 15, 1994 and December 14, 1994.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 16.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
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 5,130 ***ft³/s*** ***Q500*** 8,400 ***ft³/s***

The 100- and 500-year discharges were interpolated between flood frequency estimates at two locations on Gulf Brook in the Flood Insurance Study for the Town of Woodstock (Federal Emergency Management Agency, 1979). The discharges were within a ranged defined by several empirical methods for estimating flood discharges (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 Subtract 4280.0 from USGS survey to obtain VTAOT plans' datum (+/-0.2 ft).

Description of reference marks used to determine USGS datum. RM1 is a chiseled square on top of the downstream end of the left abutment (elev. 5001.00 ft, arbitrary survey datum). RM2 is a chiseled square on top of the upstream end of the right abutment (elev. 5000.33 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-117	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRDGE	0	1	Bridge section
RDWY	7	1	Road Grade section
APPRO	67	2	Modelled Approach section (Templated from APTEM)
APTEM	95	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 0.053 to 0.055, and overbank "n" values ranged from 0.036 to 0.110.

Normal depth at the exit section (EXIT1) 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 determined from the 100-year water surface profile downstream of the bridge in the Flood Insurance Study for the Town of Woodstock (Federal Emergency Management Agency, 1979).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.016 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 5000.9 *ft*
Average low steel elevation 4998.4 *ft*

100-year discharge 5,130 *ft³/s*
Water-surface elevation in bridge opening 4998.4 *ft*
Road overtopping? Y *Discharge over road* 2,610 *ft³/s*
Area of flow in bridge opening 271 *ft²*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 12.3 *ft/s*

Water-surface elevation at Approach section with bridge 5001.9
Water-surface elevation at Approach section without bridge 5000.1
Amount of backwater caused by bridge 1.8 *ft*

500-year discharge 8,400 *ft³/s*
Water-surface elevation in bridge opening 4998.7 *ft*
Road overtopping? Y *Discharge over road* 5,500 *ft³/s*
Area of flow in bridge opening 275 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.6 *ft/s*

Water-surface elevation at Approach section with bridge 5003.0
Water-surface elevation at Approach section without bridge 5001.5
Amount of backwater caused by bridge 1.5

Incipient overtopping discharge 1,540 *ft³/s*
Water-surface elevation in bridge opening 4996.6 *ft*
Area of flow in bridge opening 180 *ft²*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 11.0 *ft/s*

Water-surface elevation at Approach section with bridge 4998.3
Water-surface elevation at Approach section without bridge 4997.4
Amount of backwater caused by bridge 0.9 *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 100- and 500-year event was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). For the 100- and 500-year discharges, there was orifice flow at the bridge. 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). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for these discharges were also computed and can be found in appendix F. Contraction scour for the incipient roadway-overtopping discharges was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20).

Abutment scour 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.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the variables for the abutment scour equations applied were computed including the width of the spill-through embankments. The total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment, as shown in figure 8.

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	0.2	0.9	0.0
Depth to armoring	4.5	10.1	4.4
Left overbank	--	--	--
Right overbank			
Local scour:			
Abutment scour	8.2	10.3	3.1
Left abutment	10.4	10.3	6.4
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.5	1.8	1.2
Left abutment	1.5	1.8	1.2
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

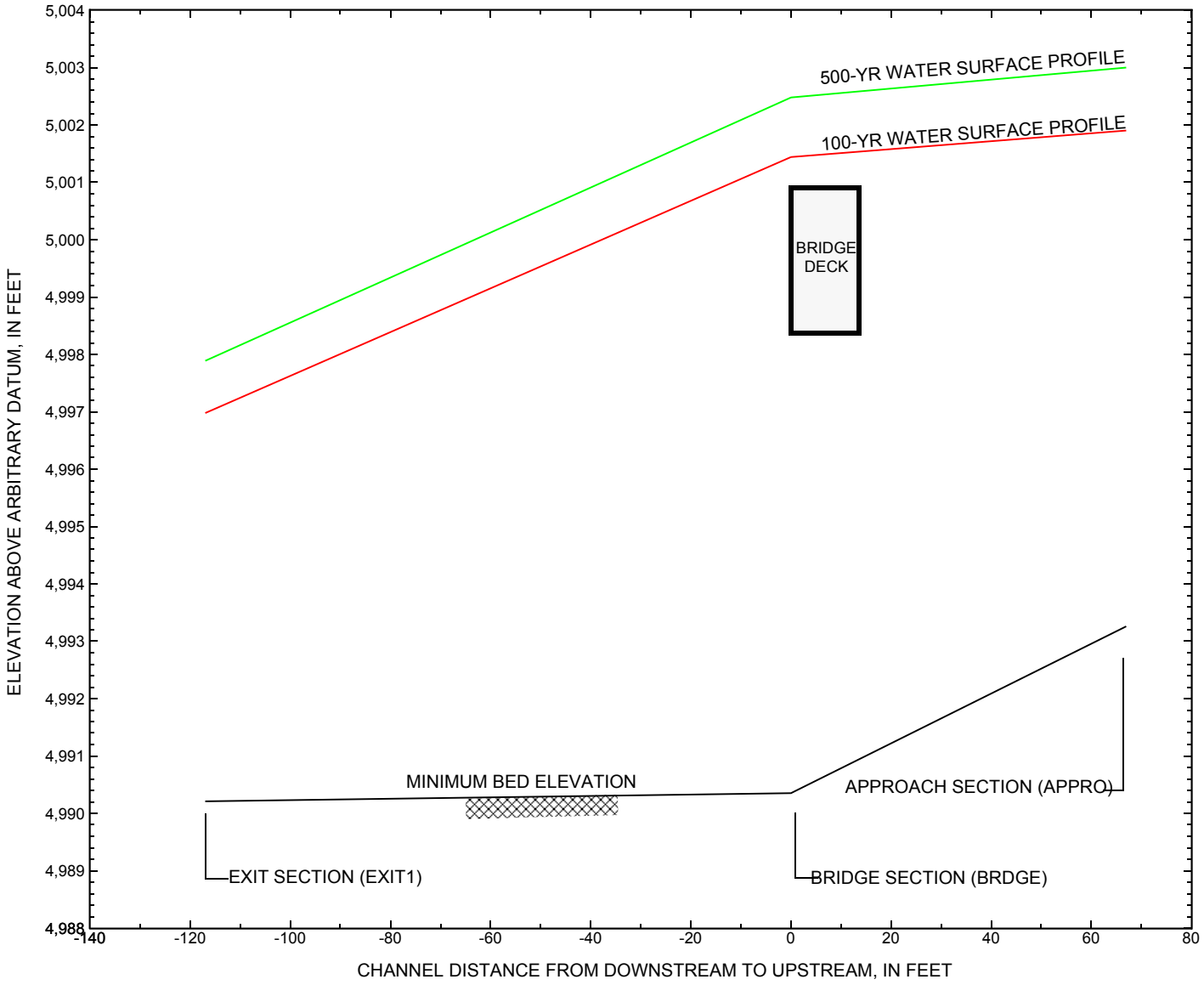


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WODSTH00990049 on Town Highway 99, crossing Gulf Brook, Woodstock, Vermont.

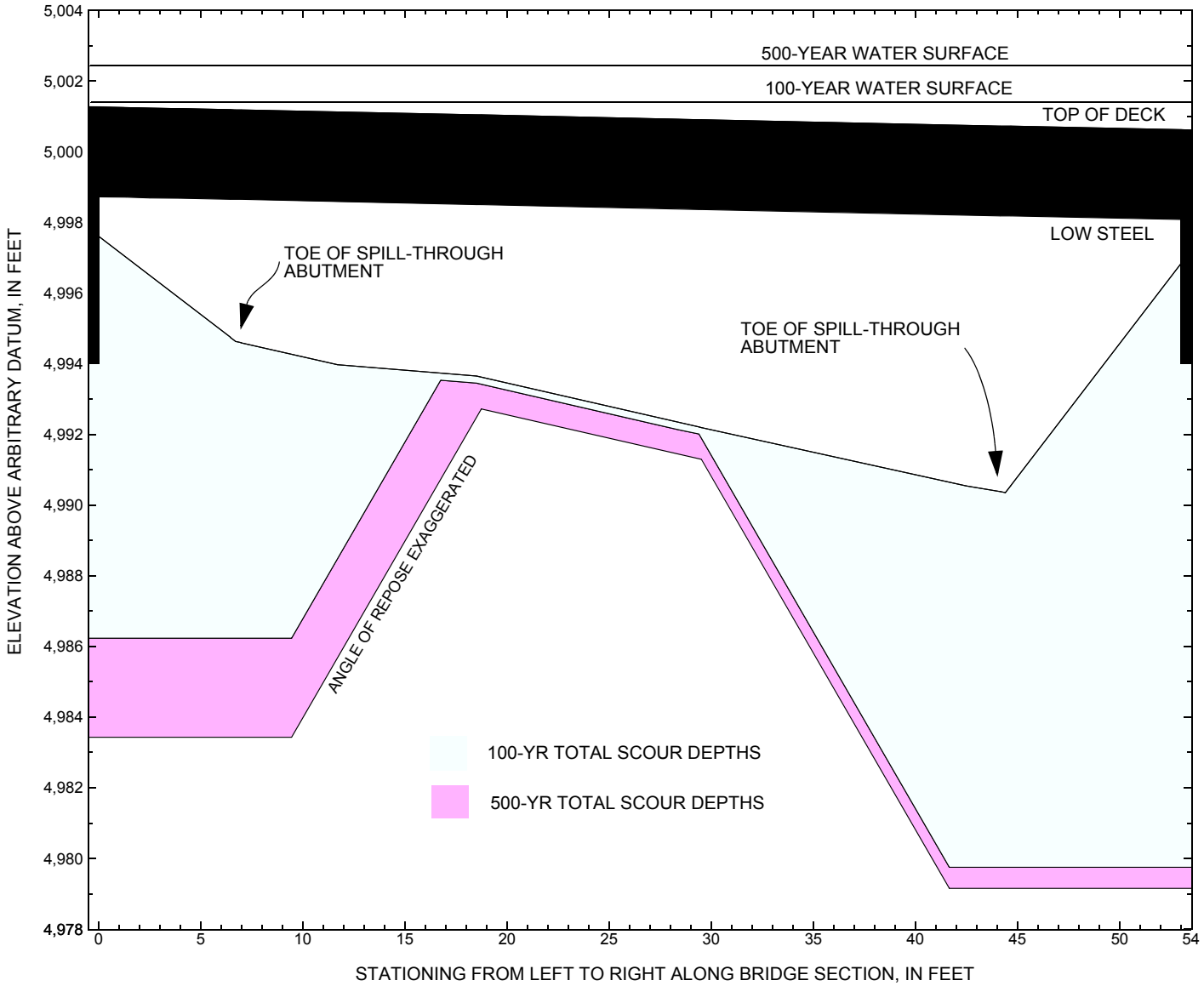


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WODSTH00990049 on Town Highway 99, crossing Gulf Brook, Woodstock, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WODSTH00990049 on Town Highway 99, crossing Gulf Brook, Woodstock, Vermont.

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

Description	Station[1]	VTAOT bridge seat 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 5,130 cubic-feet per second											
Left abutment	0.0	718.6	4998.7	4994	--	--	--	--	--	--	--
Left abutmnet toe	6.7	--	--	--	4994.6	0.2	8.2	--	8.4	4986.2	-8
Right abutment toe	44.4	--	--	--	4990.4	0.2	10.4	--	10.6	4979.8	-14
Right abutment	53.0	718.1	4998.1	4994	--	--	--	--	--	--	--

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 WODSTH00990049 on Town Highway 99, crossing Gulf Brook, Woodstock, Vermont.

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

Description	Station[1]	VTAOT bridge seat 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 8,400 cubic-feet per second											
Left abutment	0.0	718.6	4998.7	4994	--	--	--	--	--	--	--
Left abutment toe	6.7	--	--	--	4994.6	0.9	10.3	--	11.2	4983.4	-11
Right abutment toe	44.4	--	--	--	4990.4	0.9	10.3	--	11.2	4979.2	-15
Right abutment	53.0	718.1	4998.1	4994	--	--	--	--	--	--	--

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 Emergency Management Agency, 1979, Flood Insurance Study, Town of Woodstock, Windsor County, Vermont: Washington, D.C., September 1979.

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

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

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1966, Woodstock North, 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 wods049.wsp
T2        Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
T3        HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5130 8400 1540
SK          0.0104 0.0104 0.0104
*
XS   EXIT1  -117
GR         -217.8,5002.00    -55.6,4999.33    -28.0,5001.41      0.0,5000.13
GR            9.6,4998.43     21.6,4991.02     22.1,4990.60     28.2,4990.23
GR           36.4,4990.21     41.2,4990.46     43.2,4991.03     43.8,4991.42
GR           80.9,4995.82    305.4,4993.97    305.4,5005
N             0.039  0.055  0.085  0.036
SA                0  43.8       80.9
*
XS   FULLV   0 * * * 0.0104
*
BR   BRDGE   0 4998.4
GR            0.0,4998.73      0.0,4997.60      6.7,4994.63     11.7,4993.97
GR           18.5,4993.65     28.4,4992.33     36.5,4991.32     42.5,4990.54
GR           44.4,4990.35     53.0,4996.83     53.0,4998.07      0.0,4998.73
N            0.053
CD           3 14.3 1 5000.9
*
XR   RDWY    7 14 2
GR          -90.6,5004.73    -38.9,5002.20    -14.8,5001.00      0.0,5001.34
GR           56.4,5000.54    165.2,5000.65    243.8,4999.01    292.5,4998.16
GR          292.5,5005
*
XT   APTEM   95
GR         -557.5,5010.35   -387.3,5005.64   -259.7,5007.73    -90.6,5004.73
GR          -61.4,5003.02    -47.7,5000.97      0.0,4999.31      4.3,4996.78
GR           11.3,4996.39     17.3,4994.58     18.5,4994.15     28.5,4993.83
GR           35.4,4993.71     46.9,4993.78     48.4,4994.51     56.2,4996.30
GR          101.1,4998.14    111.4,5001.22    294.8,4996.56    294.8,5008
*
AS   APPRO   67
GT            -0.45
N             0.038   0.055       0.110
SA                 0         56.2
*
HP 1 BRDGE    4998.40 1 4998.40
HP 2 BRDGE    4998.40 * * 2560
HP 2 RDWY     5001.44 * * 2607
HP 1 APPRO    5001.90 1 5001.90
HP 2 APPRO    5001.90 * * 5130
*
HP 1 BRDGE    4998.73 1 4998.73
HP 2 BRDGE    4998.73 * * 3054
HP 2 RDWY     5002.48 * * 5499
HP 1 APPRO    5003.00 1 5003.00
HP 2 APPRO    5003.00 * * 8400
*
HP 1 BRDGE    4996.58 1 4996.58
HP 2 BRDGE    4996.58 * * 1540
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wods049.wsp
        Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
        HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     271.   16531.    27.    85.                        4911.
  4998.40          271.   16531.    27.    85.  1.00     0.    53.   4911.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
      4998.40     0.0    53.0   270.8   16531.    2560.   9.45
X STA.          0.0         7.5        10.7        13.4        15.9        18.3
  A(I)              18.5        12.9        11.9        11.5        11.1
  V(I)              6.92        9.93       10.76       11.09       11.56

X STA.         18.3        20.5        22.6        24.5        26.3        28.8
  A(I)              10.8        10.7        10.5        10.4        14.5
  V(I)             11.86       11.98       12.14       12.28        8.83

X STA.         28.8        31.0        33.2        35.2        37.1        39.0
  A(I)              14.1        13.8        13.4        13.3        13.4
  V(I)              9.06        9.28        9.55        9.64        9.58

X STA.         39.0        40.8        42.5        44.4        46.7        53.0
  A(I)              13.1        13.4        14.1        16.1        23.3
  V(I)              9.79        9.55        9.05        7.96        5.50

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWY ;  SRD =       7.
         WSEL     LEW     REW    AREA        K        Q    VEL
      5001.44   -23.6   292.5   391.6   19577.    2607.   6.66
X STA.        -23.6        84.1       115.9       153.7       186.4       202.9
  A(I)              58.7        27.2        31.1        30.6        23.2
  V(I)              2.22        4.79        4.20        4.26        5.62

X STA.        202.9       215.1       224.7       233.1       240.4       246.7
  A(I)              20.7        18.6        17.9        16.5        15.4
  V(I)              6.29        6.99        7.29        7.91        8.44

X STA.        246.7       252.6       257.9       263.0       267.7       272.1
  A(I)              14.8        14.0        13.8        13.1        12.9
  V(I)              8.79        9.29        9.42        9.97       10.12

X STA.        272.1       276.3       280.2       284.0       287.8       292.5
  A(I)              12.3        11.9        11.7        11.9        15.3
  V(I)             10.59       10.96       11.12       10.94        8.49

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     112.    6862.    57.    57.                         889.
             2     418.   42416.    56.    58.                        6466.
             3     892.   28622.   239.   245.                        9794.
  5001.90         1422.   77900.   352.   360.  2.11   -57.   295.  11181.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
         WSEL     LEW     REW    AREA        K        Q    VEL
      5001.90   -56.9   294.8  1422.1   77900.    5130.   3.61
X STA.        -56.9       -14.8         3.7        12.0        17.8        22.3
  A(I)              70.6        56.4        47.7        40.9        37.2
  V(I)              3.63        4.54        5.38        6.27        6.89

X STA.         22.3        26.7        30.8        34.9        38.9        42.9
  A(I)              36.5        35.2        35.1        34.8        34.7
  V(I)              7.02        7.28        7.31        7.37        7.39

X STA.         42.9        47.0        52.0        61.6        79.7       104.1
  A(I)              34.6        38.4        59.7        98.8       110.6
  V(I)              7.42        6.69        4.30        2.60        2.32

X STA.        104.1       199.5       232.0       255.2       275.1       294.8
  A(I)             214.3       122.8       104.2       100.5       109.0
  V(I)              1.20        2.09        2.46        2.55        2.35
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wods049.wsp
        Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
        HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     275.   14130.     0.   111.                          0.
  4998.73          275.   14130.     0.   111.  1.00     0.    53.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
      4998.73     0.0    53.0   275.1   14130.    3054.  11.10
X STA.          0.0         7.9        11.7        14.9        18.0        21.0
  A(I)              22.1        16.6        15.3        14.7        14.8
  V(I)              6.90        9.21       10.00       10.37       10.35

X STA.         21.0        23.6        25.9        28.1        30.2        32.1
  A(I)              13.8        13.0        13.0        12.5        12.2
  V(I)             11.06       11.73       11.71       12.22       12.55

X STA.         32.1        33.9        35.6        37.3        38.8        40.4
  A(I)              11.9        11.5        11.5        11.3        11.4
  V(I)             12.85       13.28       13.28       13.52       13.39

X STA.         40.4        41.9        43.4        45.0        47.1        53.0
  A(I)              11.2        11.5        12.5        13.9        20.5
  V(I)             13.64       13.27       12.26       11.02        7.44

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWY ;  SRD =       7.
         WSEL     LEW     REW    AREA        K        Q    VEL
      5002.48   -44.6   292.5   731.3   48814.    5499.   7.52
X STA.        -44.6        21.6        66.6        95.4       115.9       137.5
  A(I)              69.3        78.7        55.2        38.7        40.4
  V(I)              3.97        3.49        4.98        7.10        6.81

X STA.        137.5       160.1       181.3       196.5       209.3       220.2
  A(I)              41.8        41.4        35.4        33.5        31.4
  V(I)              6.58        6.64        7.77        8.21        8.77

X STA.        220.2       229.9       238.5       246.5       253.8       260.8
  A(I)              29.8        28.0        27.5        26.3        25.8
  V(I)              9.21        9.83       10.00       10.45       10.65

X STA.        260.8       267.2       273.4       279.5       285.3       292.5
  A(I)              24.5        24.5        24.3        24.2        30.6
  V(I)             11.20       11.21       11.32       11.35        8.97

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     179.   13309.    69.    69.                         1645.
             2     480.   53383.    56.    58.                         7953.
             3    1155.   43856.   239.   246.                        14418.
  5003.00         1814.  110548.   364.   373.  1.94   -69.   295.  16497.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
         WSEL     LEW     REW    AREA        K        Q    VEL
      5003.00   -68.7   294.8  1814.0  110548.    8400.   4.63
X STA.        -68.7       -24.2        -6.0         7.0        14.8        20.3
  A(I)              89.5        65.7        65.3        56.9        49.1
  V(I)              4.69        6.39        6.43        7.38        8.55

X STA.         20.3        25.4        30.2        34.9        39.6        44.2
  A(I)              47.6        45.9        45.8        45.5        45.3
  V(I)              8.82        9.14        9.17        9.24        9.27

X STA.         44.2        49.2        55.7        72.7        93.4       156.6
  A(I)              47.1        51.5       115.9       125.5       207.7
  V(I)              8.91        8.16        3.62        3.35        2.02

X STA.        156.6       200.5       229.5       253.1       273.8       294.8
  A(I)             173.0       140.7       130.9       125.7       139.4
  V(I)              2.43        2.98        3.21        3.34        3.01
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File wods049.wsp
       Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
       HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     180.   11404.    50.    53.                        1929.
  4996.58          180.   11404.    50.    53.  1.00     2.    53.   1929.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDGE;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
      4996.58     2.3    52.7   179.9   11404.    1540.   8.56
X STA.          2.3       11.6       15.9       19.7       22.8       25.4
  A(I)             15.5       11.6       11.0       10.1        9.5
  V(I)             4.97       6.61       6.98       7.60       8.14

X STA.         25.4       27.6       29.6       31.4       33.0       34.6
  A(I)              8.9        8.4        8.1        7.8        7.7
  V(I)             8.65       9.19       9.49       9.85      10.06

X STA.         34.6       36.0       37.4       38.7       39.9       41.2
  A(I)              7.4        7.2        7.2        7.1        7.0
  V(I)            10.45      10.75      10.70      10.87      11.01

X STA.         41.2       42.3       43.6       44.8       46.6       52.7
  A(I)              7.0        7.5        7.6        9.4       13.9
  V(I)            10.95      10.29      10.10       8.21       5.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     214.   14113.    55.    56.                        2394.
             3     160.    2431.   132.   134.                         998.
  4998.27          374.   16544.   187.   191.  1.91     1.   295.   2171.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.
         WSEL     LEW     REW    AREA        K        Q    VEL
      4998.27     1.0   294.8   373.9   16544.    1540.   4.12
X STA.          1.0       12.7       17.3       20.3       22.9       25.4
  A(I)             21.8       15.9       13.3       12.3       12.1
  V(I)             3.54       4.86       5.78       6.26       6.39

X STA.         25.4       27.8       30.1       32.4       34.6       36.7
  A(I)             11.5       11.2       11.2       10.8       10.8
  V(I)             6.70       6.85       6.87       7.14       7.10

X STA.         36.7       38.9       41.1       43.2       45.5       47.8
  A(I)             10.8       10.8       10.9       11.0       11.4
  V(I)             7.12       7.13       7.07       7.00       6.78

X STA.         47.8       50.9       55.8       76.2      271.6      294.8
  A(I)             12.4       15.1       41.1       76.3       43.3
  V(I)             6.20       5.09       1.87       1.01       1.78
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File wods049.wsp
       Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
       HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******    12.     767.  0.77 ***** 4997.75 4996.66   5130. 4996.98
     -117. ******   305.   50257.  1.11 ***** *******    0.77    6.69

FULLV:FV     117.    12.     771.  0.76  1.21 4998.97 *******   5130. 4998.21
        0.   117.   305.   50775.  1.11  0.00    0.02    0.76    6.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  4997.71    5009.90    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  4997.71    5009.90    5000.11

 ===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 =  5000.11    5009.90    5000.11

APPRO:AS      67.   -36.     815.  1.43 ***** 5001.54 5000.11   5130. 5000.11
       67.    67.   295.   38397.  2.32 ***** *******    1.03    6.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =  5008.05       0.00    4998.43    4998.16

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =  5003.06         1.      5129.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===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

BRDGE:BR     117.     0.     271.  1.39 ***** 4999.79 4997.36   2560. 4998.40
        0. ******    53.   16531.  1.00 ***** *******    0.74    9.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   5.  0.496  0.000 4998.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY :RG       7.    53.  0.23  0.43 5002.10    0.01   2607. 5001.44

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    141.    54.   -24.    31.   0.5   0.3   4.1   8.9   0.9   2.8
   RT:   2466.   262.    31.   293.   3.3   1.4   6.7   6.5   2.1   3.1

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

APPRO:AS      53.   -57.    1423.  0.43  0.83 5002.33 5000.11   5130. 5001.90
       67.    73.   295.   78007.  2.11  0.00    0.01    0.46    3.60

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS    -117.    12.   305.   5130.   50257.     767.    6.69 4996.98
   FULLV:FV       0.    12.   305.   5130.   50775.     771.    6.65 4998.21
   BRDGE:BR       0.     0.    53.   2560.   16531.     271.    9.45 4998.40
   RDWY :RG       7.*******   141.   2607.       0.*********    2.00 5001.44
   APPRO:AS      67.   -57.   295.   5130.   78007.    1423.    3.60 5001.90

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS   4996.66     0.77 4990.21 5005.00************  0.77 4997.75 4996.98
   FULLV:FV  ********     0.76 4991.43 5006.22  1.21  0.00  0.76 4998.97 4998.21
   BRDGE:BR   4997.36     0.74 4990.35 4998.73************  1.39 4999.79 4998.40
   RDWY :RG  ********************* 4998.16 5005.00  0.23******  0.43 5002.10 5001.44
   APPRO:AS   5000.11     0.46 4993.26 5009.90  0.83  0.00  0.43 5002.33 5001.90
```

WSPRO OUTPUT FILE (continued)

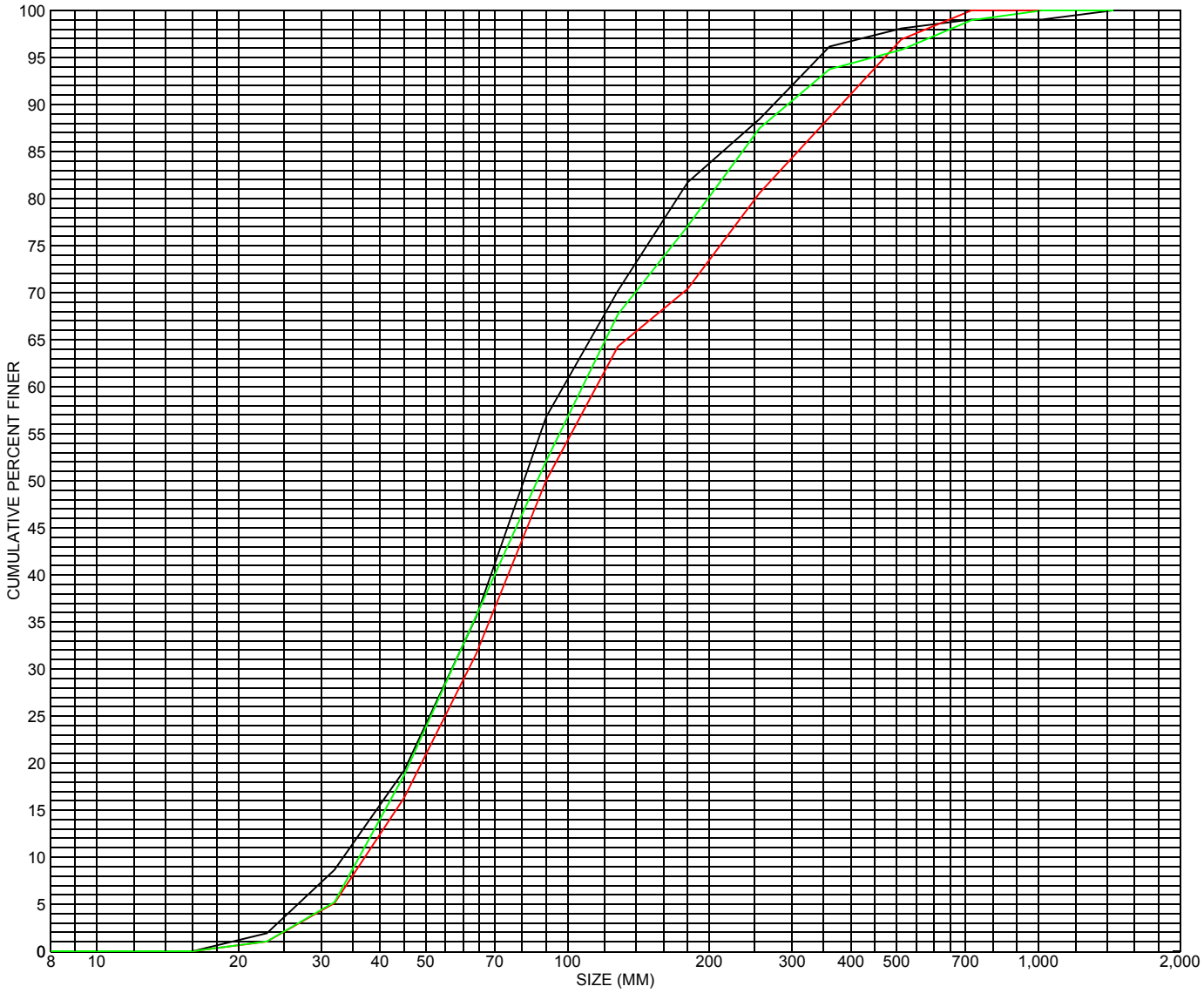
```
       U.S. Geological Survey WSPRO Input File wods049.wsp
       Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
       HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO
          *** RUN DATE & TIME: 06-11-96  08:21

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

EXIT1:XS   ******    10.    1036.  1.11 ***** 4999.00 4997.42   8400. 4997.89
     -117. ******   305.   82331.  1.09 ***** *******    0.79    8.11

FULLV:FV     117.    10.    1041.  1.10  1.21 5000.22 *******   8400. 4999.13
        0.   117.   305.   82955.  1.09  0.00    0.01    0.79    8.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  4998.63    5009.90    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  4998.63    5009.90    5001.45

 ===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 =  5001.45    5009.90    5001.45

APPRO:AS      67.   -54.    1264.  1.51 ***** 5002.96 5001.45   8400. 5001.45
       67.    67.   295.   65975.  2.20 ***** *******    0.91    6.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =  4999.13    4998.40

            <<<<<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

BRDGE:BR     117.     0.     275.  1.92 ***** 5000.65 4997.91   3054. 4998.73
        0. ******    53.   14130.  1.00 ***** *******    0.86   11.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   6.  0.800  0.000 4998.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY :RG       7.    53.  0.31  0.65 5003.34    0.02   5499. 5002.48

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    627.    77.   -45.    32.   1.6   1.1   6.2   7.4   2.0   3.0
   RT:   4872.   260.    32.   293.   4.3   2.5   8.4   7.6   3.3   3.1

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

APPRO:AS      53.   -69.    1813.  0.65  1.53 5003.65 5001.45   8400. 5003.00
       67.    75.   295.  110470.  1.94  0.00    0.02    0.51    4.63

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS    -117.    10.   305.   8400.   82331.    1036.    8.11 4997.89
   FULLV:FV       0.    10.   305.   8400.   82955.    1041.    8.07 4999.13
   BRDGE:BR       0.     0.    53.   3054.   14130.     275.   11.10 4998.73
   RDWY :RG       7.******   627.   5499.******************    2.00 5002.48
   APPRO:AS      67.   -69.   295.   8400.  110470.    1813.    4.63 5003.00

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS   4997.42    0.79 4990.21 5005.00************  1.11 4999.00 4997.89
   FULLV:FV  ********    0.79 4991.43 5006.22  1.21  0.00  1.10 5000.22 4999.13
   BRDGE:BR   4997.91    0.86 4990.35 4998.73************  1.92 5000.65 4998.73
   RDWY :RG  ********** 4998.16 5005.00  0.31******  0.65 5003.34 5002.48
   APPRO:AS   5001.45    0.51 4993.26 5009.90  1.53  0.00  0.65 5003.65 5003.00
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File wods049.wsp
       Hydraulic analysis for structure WODSTH00990049   Date: 10-JUN-96
       HYDRAULIC ANALYSIS OF WODS049 OVER GULF BROOK     SAO
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******    14.     325.  0.53 ***** 4995.96 4995.35   1540. 4995.43
     -117. ******   305.   15093.  1.52 ***** *******    0.89    4.74

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88    4996.66    4996.57
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  4994.93    5006.22    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  4994.93    5006.22    4996.57

FULLV:FV     117.    14.     329.  0.52  1.20 4997.18 4996.57   1540. 4996.66
        0.   117.   305.   15314.  1.51  0.00    0.02    0.87    4.68
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.16    4997.40    4997.40
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  4996.16    5009.90    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  4996.16    5009.90    4997.40
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.66

APPRO:AS      67.     2.     229.  1.08  1.02 4998.49 4997.40   1540. 4997.40
       67.    67.   295.   10177.  1.55  0.28    0.00    1.16    6.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =  4998.26       0.00    4996.58    4998.16
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =  5001.48         1.      1539.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.10    4998.90    4999.21
 ===270 REJECTED 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

BRDGE:BR     117.     2.     180.  1.15  1.61 4997.73 4990.55   1540. 4996.58
        0.   117.    53.   11427.  1.01  0.17    0.00    0.80    8.55

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.994 ****** 4998.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWY :RG       7.        <<<<<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      53.     1.     374.  0.50  0.73 4998.77 4997.40   1540. 4998.27
       67.    58.   295.   16544.  1.91  0.31    0.01    0.71    4.12

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.827  0.150   13988.     3.    53.  4997.81
                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS    -117.    14.   305.   1540.   15093.     325.    4.74 4995.43
   FULLV:FV       0.    14.   305.   1540.   15314.     329.    4.68 4996.66
   BRDGE:BR       0.     2.    53.   1540.   11427.     180.    8.55 4996.58
   RDWY :RG       7.**************      0.       0.*********    2.00********
   APPRO:AS      67.     1.   295.   1540.   16544.     374.    4.12 4998.27
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    53.   13988.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS   4995.35    0.89 4990.21 5005.00************  0.53 4995.96 4995.43
   FULLV:FV   4996.57    0.87 4991.43 5006.22  1.20  0.00  0.52 4997.18 4996.66
   BRDGE:BR   4990.55    0.80 4990.35 4998.73  1.61  0.17  1.15 4997.73 4996.58
   RDWY :RG  *************** 4998.16 5005.00************  0.24 4999.27********
   APPRO:AS   4997.40    0.71 4993.26 5009.90  0.73  0.31  0.50 4998.77 4998.27
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for three pebble count transects in the channel approach of structure WODSTH00990049, in Woodstock, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WODSTH00990049

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 04 / 95

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 85975

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

Waterway *(I - 6)* GULF BROOK

Road Name *(I - 7):* -

Route Number TH099

Vicinity *(I - 9)* 0.05 MI JCT TH 99 + VT12

Topographic Map Woodstock.North

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43388

Longitude *(i - 17; nnnnn.n)* 72322

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142400491424

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

Maximum span length *(I - 48; nnnn)* 0055

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

Structure length *(I - 49; nnnnnn)* 000056

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

Deck Width *(I - 52; nn.n)* 140

Year of ADT *(I - 30; YY)* 90

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 1968

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:

The structural inspection report of 08/19/94 indicates the structure is a steel stringer type bridge with a timber deck. The right road approach has a crushed stone wearing surface. The route VT 12 intersects on the left approach. The concrete abutment walls have very minor stains reported. There is good stone block riprap placed along both abutments. The footings reportedly are not in view. The waterway takes a slight turn through the structure with the majority of the flow proceeding along the right abutment side of the channel. There is a shallow gravel point bar along the left abutment. The streambed consists of stone and gravel.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.77** mi^2 Lake and pond area **0.04** mi^2

Watershed storage *(ST)* **0.2** %

Bridge site elevation **720** ft Headwater elevation **2697** ft

Main channel length **8.4** mi

10% channel length elevation **790** ft 85% channel length elevation **1899** ft

Main channel slope *(S)* **176.0** ft / mi

Watershed Precipitation Data

Average site precipitation _____ in Average headwater precipitation _____ in

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

Average seasonal snowfall *(Sn)* _____ ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / 1954

Project Number T 12 / 1954 Minimum channel bed elevation: 712.0

Low superstructure elevation: USLAB 718.6 DSLAB 718.6 USRAB 718.06 DSRAB 718.06

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: 714.*

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

If 3: Footing bottom elevation: _____

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
***The footing bottom elevations are 714.10 and 713.56 for the left and right abutments respectively.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MAI Date: 2/15/95
Computerized by: MAI Date: 2/21/95
Reviewd by: SAO Date: 11/1/96

Structure Number WODSTH00990049

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 09 / 15 / 1994

2. Highway District Number 4
County WINDSOR
Waterway *(I - 6)* GULF STREAM
Route Number TH099
Mile marker 0
Town WOODSTOCK
Road Name -
Hydrologic Unit Code: 01080106

3. Descriptive comments:
LOCATED 0.05 MILES FROM JUNCTION OF TOWN HIGHWAY 99 AND STATE HIGHWAY 12.
-
SITE REVISITED ON 12/14/94 BY M. WEBER TO SUPPLEMENT DATA COLLECTED ON 9/15/94.
-

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 2 UB 1 DS 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 56 *(feet)* Span length 55 *(feet)* Bridge width 14 *(feet)*

Road approach to bridge:

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

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

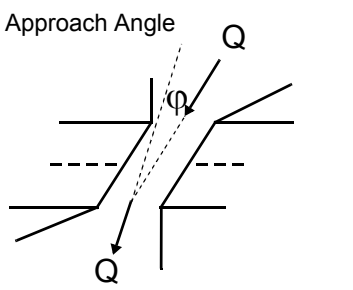
10. Embankment slope (*run / rise in feet / foot*):
US left 4:1 US right -

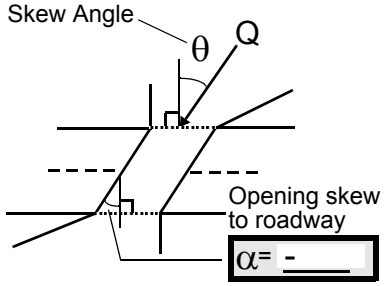
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	1	2
RBDS	0	-	1	2
LBDS	0	-	0	-

*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: 20 16. Bridge skew: 20





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 35 feet US *(US, UB, DS)* to 70 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: **3**

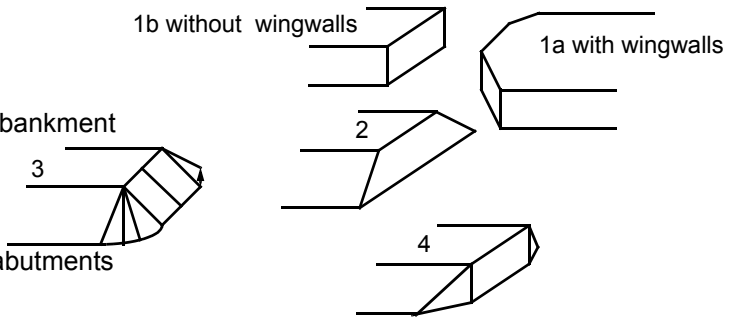
1a- Vertical abutments with wingwalls

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.)

LARGE QUARRIED STONE ON SPILL-THROUGH SLOPE OF BOTH ABUTMENTS. VERMONT ROUTE 12 IS PARALLEL TO LEFT BANK OF GULF STREAM IN THE VICINITY OF THE BRIDGE.

C. Upstream Channel Assessment

	21. Bank height (BF)		22. Bank angle (BF)		26. % Veg. cover (BF)		27. Bank material (BF)		28. Bank erosion (BF)	
20. SRD	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
81.0	**5.0**			**7.5**	**2**	**3**	**23**	**23**	**0**	**1**

23. Bank width **15.0** 24. Channel width **5.0** 25. Thalweg depth **111.5** 29. Bed Material **345**

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

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

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

RIGHT ABUTMENT PROTUDES INTO CHANNEL NEARLY 10 FEET.

33. Point/Side bar present? Y *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: 50 35. Mid-bar width: 25

36. Point bar extent: 250 feet US *(US, UB)* to 55 feet DS *(US, UB, DS)* positioned 0 %LB to 25 %RB

37. Material: 23

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

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

41. Mid-bank distance: 20 42. Cut bank extent: 55 feet US *(US, UB)* to 15 feet US *(US, UB, DS)*

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

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

45. Is channel scour present? Y *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: 25

47. Scour dimensions: Length 43 Width 9 Depth : 1.3 Position 75 %LB to 100 %RB

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

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):

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
28.5		1.0		2	7	7	-

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) - 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.):

324

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 N ___ *(**1**- Low; **2**- Moderate; **3**- High)*

70. Debris and Ice Comments:

1

RIFFLES US AND DS, SOME CONSTRICTION UNDER THE BRIDGE AND A RELATIVELY LOW LOW CHORD RESULTS IN A MODERATE CAPTURE EFFICIENCY.

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		--	40	2	0	-	-	-
RABUT	1,2	20	40			2	1	53.0

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

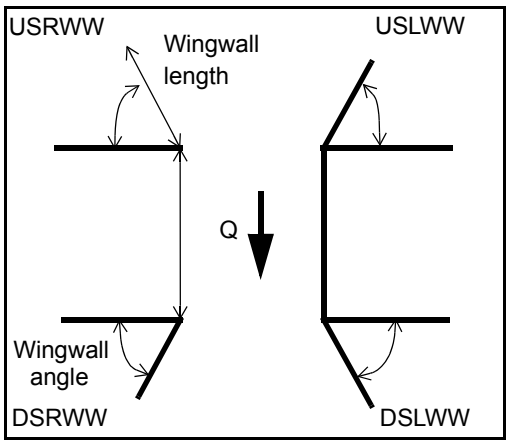
1,2

76. SCOUR AT BASE OF RIGHT ABUTMENT. TOE OF SPILL-THROUGH SLOPE OF LARGE QUARRIED STONE (3FTX3FTX2FT) IS UNDERMINED IN SOME LOCATIONS. UNDERMINING IS LESS THAN A FOOT. HORIZONTAL PENETRATION UNDER THE STONE IS O.5 FT. THERE IS NO APPARENT MOVEMENT OF THE STONE SPILL-THROUGH SLOPE.

77. ABUTMENTS ARE CONCRETE WITH A STONE SPILL-THROUGH SLOPE.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						30.0	
USRWW:	N		-		-	3.5	
DSLWW:	-		-		N	14.0	
DSRWW:	-		-			14.5	



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

82. Bank / Bridge Protection:

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

*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

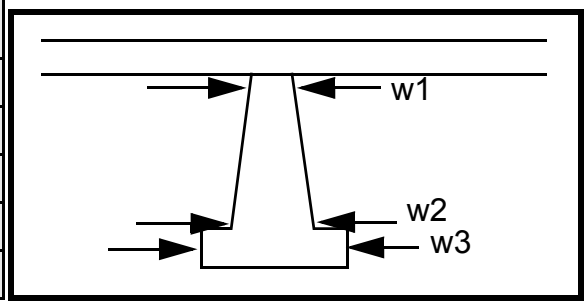
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
-
-
-
-
-
-

Piers:

84. Are there piers? **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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4
86. Location (BF)	**E**	**THR**	**ABU**	
87. Type	**QUA**	**OU**	**TM**	
88. Material	**RRI**	**GH**	**ENT**	
89. Shape	**ED**	**SLO**	**PRO**	
90. Inclined?	**STO**	**PE**	**TEC**	**N**
91. Attack ∠ (BF)	**NE**	**IS**	**TIO**	-
92. Pushed	**USE**	**ALS**	**N.**	-
93. Length (feet)	-	-	-	-
94. # of piles	**D**	**O**		-
95. Cross-members	**FOR**	**CON**		-
96. Scour Condition	**THE**	**SID-**		-
97. Scour depth	**SPIL**	**ERE**		-
98. Exposure depth	**L-**	**D AS**		-

LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP

***1**- Solid pier, **2**- column, **3**- bent*

***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*

***1**- Round; **2**- Square; **3**- Pointed*

Y- yes; N- no

LB or RB

***0**- none; **1**- laterals; **2**- diagonals; **3**- both*

***0**- not evident; **1**- evident (comment);*
***2**- footing exposed; **3**- piling exposed;*
***4**- undermined footing; **5**- settled; **6**- failed*

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

-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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):

-

NO PIERS

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 **1** %LB to **1** %RB

Material: **213**

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

213
0
2
324

Is a cut-bank present? **0** *(Y or if N type ctrl-n cb)* Where? **2** *(LB or RB)* Mid-bank distance: **-**

Cut bank extent: **1** feet ____ *(US, UB, DS)* to _____ feet ____ *(US, UB, DS)*

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

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

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

Scour dimensions: Length _____ Width _____ Depth: _____ Positioned ____ %LB to ____ %RB

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

N
-
NO DROP STRUCTURE

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

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

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

Confluence comments (eg. confluence name):

-
-

F. Geomorphic Channel Assessment

107. Stage of reach evolution **-**

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

-

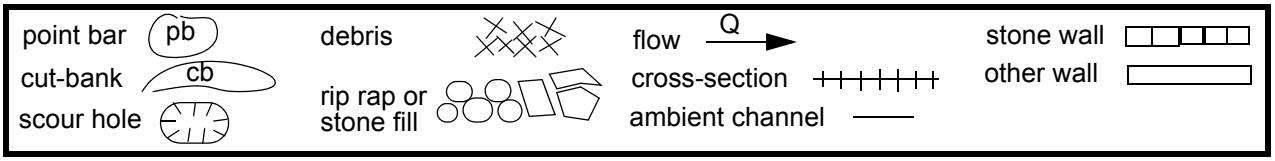
-

-

POINT BAR IN UPSTREAM SECTION DATA EXTENDS DOWNSTREAM.

Y
RB
25
25
DS
75

109. G. Plan View Sketch



APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WODSTH00990049 Town: Woodstock
Road Number: TH099 County: Windsor
Stream: Gulf Brook

Initials SAO Date: 6/11/96 Checked: MAI 09/09/96

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5130	8400	1540
Main Channel Area, ft2	418	480	214
Left overbank area, ft2	112	179	0
Right overbank area, ft2	892	1155	160
Top width main channel, ft	56	56	55
Top width L overbank, ft	57	69	0
Top width R overbank, ft	239	239	132
D50 of channel, ft	0.280	0.280	0.280
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	8.6	3.9
y1, average depth, LOB, ft	2.0	2.6	ERR
y1, average depth, ROB, ft	3.7	4.8	1.2
Total conveyance, approach	77900	110548	16544
Conveyance, main channel	42416	53383	14113
Conveyance, LOB	6862	13309	0
Conveyance, ROB	28622	43856	2431
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	2793.2	4056.3	1313.7
Ql, discharge, LOB, cfs	451.9	1011.3	0.0
Qr, discharge, ROB, cfs	1884.9	3332.4	226.3
Vm, mean velocity MC, ft/s	6.7	8.5	6.1
Vl, mean velocity, LOB, ft/s	4.0	5.6	ERR
Vr, mean velocity, ROB, ft/s	2.1	2.9	1.4
Vc-m, crit. velocity, MC, ft/s	10.25	10.49	9.20
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

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	418	480	214
Main channel width, ft	56	56	55
y1, main channel depth, ft	7.46	8.57	3.89
Bridge Section			
(Q) total discharge, cfs	5130	8400	1540
(Q) discharge thru bridge, cfs	2560	3054	1540
Main channel conveyance	16531	14130	11404
Total conveyance	16531	14130	11404
Q2, bridge MC discharge,cfs	2560	3054	1540
Main channel area, ft2	271	275	180
Main channel width (skewed), ft	53.0	53.0	50.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	53	53	50.4
y_bridge (avg. depth at br.), ft	5.11	5.19	3.57
Dm, median (1.25*D50), ft	0.35	0.35	0.35
y2, depth in contraction,ft	4.64	5.39	3.13
ys, scour depth (y2-ybridge), ft	-0.48	0.21	-0.44
ys, scour depth (y2-yfullv), ft	-0.28	N/A	N/A

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)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	2560	3054	0
Vc, critical velocity, ft/s	10.25	10.49	0
Vc, critical velocity, m/s	3.124048	3.197196	0
Main channel width (skewed), ft	53	53	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	53	53	0
qbr, unit discharge, ft^2/s	48.30189	57.62264	ERR
qbr, unit discharge, m^2/s	4.486954	5.352796	N/A
Area of full opening, ft^2	270.8	275.1	0
Hb, depth of full opening, ft	5.109434	5.190566	ERR
Hb, depth of full opening, m	1.557279	1.582007	N/A
Fr, Froude number MC	0.74	0.86	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	4998.4	4998.4	0

Elevation of Bed, ft	4993.291	4993.209	N/A
Elevation of approach WS, ft	5001.9	5003	0
HF, bridge to approach, ft	0.83	1.53	0
Elevation of WS immediately US, ft	5001.07	5001.47	0
ya, depth immediately US, ft	7.779434	8.260566	N/A
ya, depth immediately US, m	2.417475	2.566988	N/A
Mean elev. of deck, ft	5000.94	5000.94	0
w, depth of overflow, ft (>=0)	0.13	0.53	0
Cc, vert contrac correction (<=1.0)	0.893899	0.895562	ERR
Ys, depth of scour (chang), ft	0.162281	0.943124	N/A

ARMORING			
D90	1.031	1.031	1.031
D95	1.413	1.413	1.413
Critical grain size,Dc, ft	0.5343	0.7333	0.5262
Decimal-percent coarser than Dc	0.262	0.179	0.266
Depth to armoring,ft	4.52	10.09	4.36

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	5130	8400	1540	5130	8400	1540
a', abut.length blocking flow, ft	56.9	68.7	1.3	58.4	58.4	242.1
Ae, area of blocked flow ft2	101.9	136.9	2.42	238.5	212.5	170.3
Qe, discharge blocked abut.,cfs	--	--	8.56	--	--	279.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.99	5.58	3.54	2.73	3.52	1.64
ya, depth of f/p flow, ft	1.79	1.99	1.86	4.08	3.64	0.70
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.493	0.598	0.457	0.220	0.264	0.345
ys, scour depth, ft	8.22	10.32	3.10	10.44	10.29	6.36
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)	56.9	68.7	1.3	58.4	58.4	242.1
y1 (depth f/p flow, ft)	1.79	1.99	1.86	4.08	3.64	0.70
a'/y1	31.77	34.48	0.70	14.30	16.05	344.17
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.49	0.60	0.46	0.22	0.26	0.35
Ys w/ corr. factor K1/0.55:						
vertical	10.31	12.23	ERR	ERR	ERR	3.60
vertical w/ ww's	8.46	10.03	ERR	ERR	ERR	2.95

spill-through	5.67	6.73	ERR	ERR	ERR	1.98

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.74	0.86	0.8	0.74	0.86	0.8
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.11	5.19	3.57	5.11	5.19	3.57
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.73	ERR	1.41	1.73	ERR	1.412422
Fr>0.8 (vertical abut.)	ERR	2.08	ERR	ERR	2.08	ERR
Fr<=0.8 (spillthrough abut.)	1.51	ERR	1.23	1.51	ERR	1.232407
Fr>0.8 (spillthrough abut.)	ERR	1.84	ERR	ERR	1.84	ERR