LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (ROYATH00920029) on TOWN HIGHWAY 92, crossing the FIRST BRANCH WHITE RIVER, ROYALTON, VERMONT

Open-File Report 97-819

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

USGS
science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (ROYATH00920029) on TOWN HIGHWAY 92, crossing the FIRST BRANCH WHITE RIVER, ROYALTON, VERMONT

By EMILY C. WILD and ROBERT E. HAMMOND

U.S. Geological Survey
Open-File Report 97-819

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, Acting Director

For additional information write to:

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

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 29 (ROYATH00920029) ON TOWN HIGHWAY 92, CROSSING THE FIRST BRANCH WHITE RIVER, ROYALTON, VERMONT

By **Emily C. Wild 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 ROYATH00920029 on Town Highway 92 crossing the First Branch White River, Royalton, 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 central Vermont. The 101-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge.

In the study area, the First Branch White River has an incised, sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 81 ft and an average bank height of 9 ft. The channel bed material ranges from sand to bedrock with a median grain size (D_{50}) of 1.18 mm (0.00347 ft). The geomorphic assessment at the time of the Level I site visit on July 23, 1996 and Level II site visit on June 2, 1995, indicated that the reach was stable.

The Town Highway 92 crossing of the First Branch White River is a 59-ft-long, one-lane bridge consisting of a 57-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 52.2 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 4.0 ft deeper than the mean thalweg depth was observed in the upstream channel during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream left and right wingwalls, the left abutment and downstream left wingwall. 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 discharge was determined and analyzed as another potential worst-case scour scenario. 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 4.1 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Left abutment scour ranged from 12.9 to 15.4 ft, where the worst-case abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 14.5 to 15.0 ft, where the worst-case abutment scour occurred 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.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number ROYATH00920029 ***Stream*** First Branch White River

County Windsor ***Road*** TH92 ***District*** 4

Description of Bridge

Bridge length 59 ***ft*** ***Bridge width*** 12.3 ***ft*** ***Max span length*** 57 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? Yes ***Date of inspection*** 7/23/96

Description of stone fill Type-2, sparsely along the upstream left and right wingwalls, the left abutment and the downstream left wingwall..

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

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

There is a mild channel bend in the upstream reach. The scour hole has developed in the upstream reach where the stream becomes constricted.

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	7/23/96	0	0
Level II	6/02/95	0	0

Potential for debris Low.

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

None, 7/23/96.

Description of the Geomorphic Setting

General topography The channel is located within a narrow, irregular flood plain with a steep valley wall on the left side.

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

Date of inspection 7/23/96

DS left: Narrow flood plain, with a verical bedrock wall.

DS right: Narrow flood plain.

US left: Moderately sloped overbank.

US right: Narrow flood plain.

Description of the Channel

Average top width 81 *ft* ***Average depth*** 9 *ft*

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

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

7/23/96

Vegetative co Pasture and VT 110.

DS left: Pasture.

DS right: Pasture with VT 110 along immediate bank.

US left: Pasture.

US right:

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

The assessment of 7/23/96 noted no obstructions in the channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 101 ***mi***^{2}

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 -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 15,000 ***ft***^{3}***/s*** ***Q500*** 22,000 ***ft***^{3}***/s***

The 100- and 500-year discharges are from the Flood Insurance Study of the Town of Royalton (Federal Emergency Management Agency, 1989). The values computed are within a range defined by several empirical flood frequency curves (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 To obtain the Federal Emergency Management Agency's datum (sea level), add 3.1 ft to USGS survey.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 498.69 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 498.40 ft, arbitrary survey datum). RM3 is a "VT" concrete post behind the downstream left wingwall (elev. 498.41 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-529	1	Exit section
EXITX	-57	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APTEM	56	1	Approach section as surveyed (Used as a template)
APPR1	69	2	Modelled Approach section (Templated from APTEM)

[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 0.033 to 0.040, and overbank "n" values ranged from 0.030 to 0.037.

Normal depth at the downstream-most exit section (EXIT2) 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 0.0013 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1981).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0011 ft/ft) to establish the modelled approach section (APPR1), 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 499.4 ***ft***
Average low steel elevation 498.4 ***ft***

100-year discharge 15,000 ***ft³/s***
Water-surface elevation in bridge opening 498.7 ***ft***
Road overtopping? Y ***Discharge over road*** 8,360 ***ft³/s***
Area of flow in bridge opening 791 ***ft²***
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.2 ***ft/s***

Water-surface elevation at Approach section with bridge 503.5
Water-surface elevation at Approach section without bridge 502.8
Amount of backwater caused by bridge 0.7 ***ft***

500-year discharge 22,000 ***ft³/s***
Water-surface elevation in bridge opening 498.7 ***ft***
Road overtopping? Y ***Discharge over road*** 16,600 ***ft³/s***
Area of flow in bridge opening 791 ***ft²***
Average velocity in bridge opening 7.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.5 ***ft/s***

Water-surface elevation at Approach section with bridge 505.8
Water-surface elevation at Approach section without bridge 505.9
Amount of backwater caused by bridge N/A ***ft***

Incipient overtopping discharge 6,980 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Area of flow in bridge opening 715 ***ft²***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.6 ***ft/s***

Water-surface elevation at Approach section with bridge 498.0
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 0.3 ***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 100-year and 500-year scour analyses are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

At this site, the 100-year and 500-year discharges resulted in submerged orifice flow, for which, contraction scour is frequently estimated by use of the Chang pressure-flow scour equation. However, the Chang equation for was derived solely with data for clear-water conditions. Under live-bed conditions, the Chang equation "may yield overly conservative results" (Richardson and others, 1995, p. 147-148). Therefore, contraction scour for the 100-year, 500-year, and incipient roadway-overtopping discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented 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*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	1.0	0.0	4.1
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.9	15.4	11.0
Right abutment	15.0	14.5	14.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.4	1.0	1.9
Right abutment	1.4	1.0	1.9
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

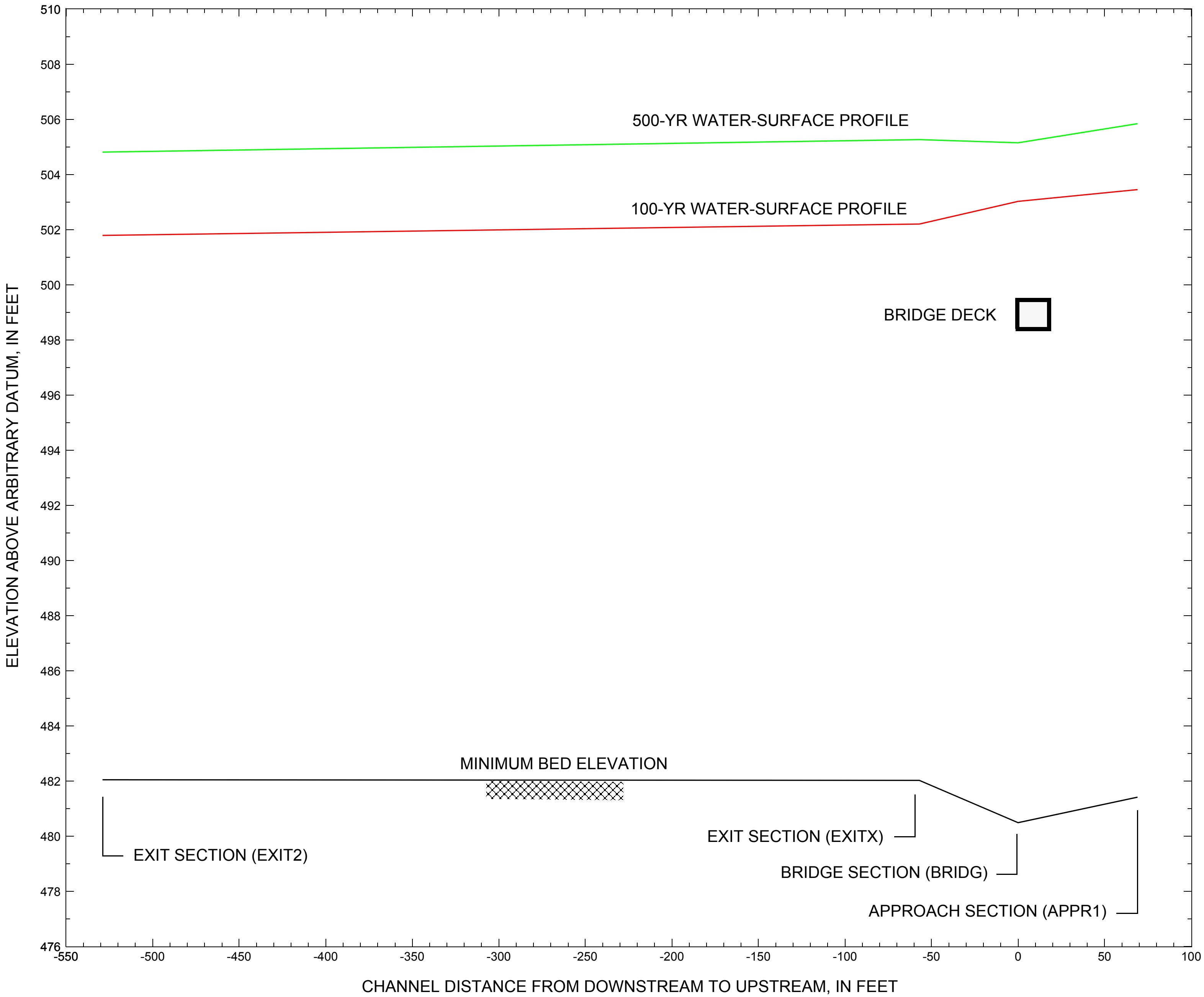


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ROYATH00920029 on Town Highway 92, crossing the First Branch White River, Royalton, Vermont.

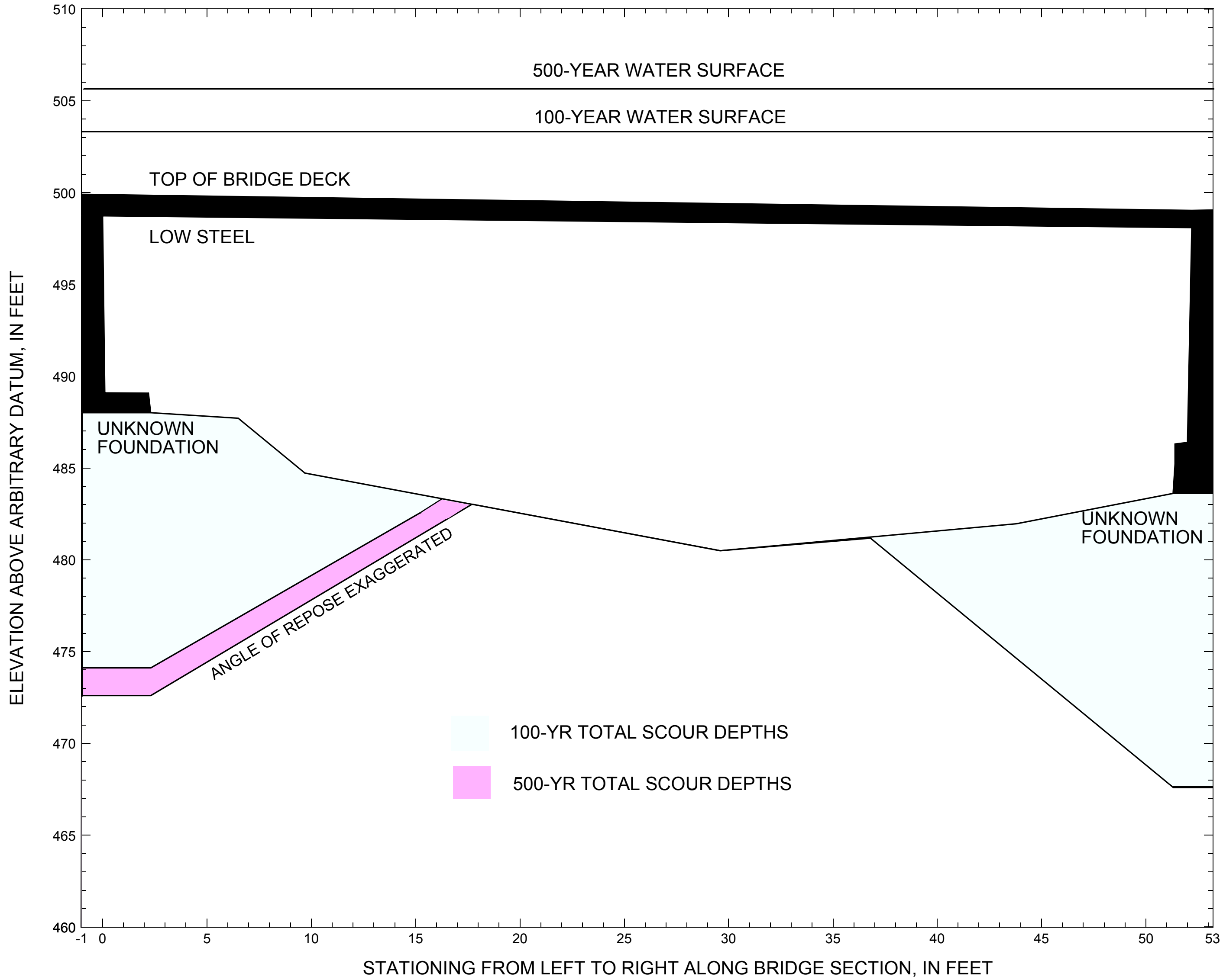


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ROYATH00920029 on Town Highway 92, crossing the First Branch White River, Royalton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ROYATH00920029 on Town Highway 92, crossing the First Branch White River, Royalton, Vermont.

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

Description	Station[1]	FEMA 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-yr. discharge is 15,000 cubic-feet per second											
Left abutment	0.0	502	498.7	--	488.0	1.0	12.9	--	13.9	474.1	--
Right abutment	52.2	501	498.1	--	483.6	1.0	15.0	--	16.0	467.6	--

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 ROYATH00920029 on Town Highway 92, crossing the First Branch White River, Royalton, Vermont.

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

Description	Station[1]	FEMA 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-yr. discharge is 22,000 cubic-feet per second											
Left abutment	0.0	502	498.7	--	488.0	0.0	15.4	--	15.4	472.6	--
Right abutment	52.2	501	498.1	--	483.6	0.0	14.5	--	14.5	469.1	--

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.

Federal Emergency Management Agency, 1989, Flood Insurance Study, Town of Royalton, Windsor County, Vermont: Washington, D.C., June 5, 1989.

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, 1981, South Royalton, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
T2        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
T3        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          15000.0  22000.0   6980.0
SK           0.0013   0.0013   0.0013
*
XS   EXIT2   -529            0.
GR         -103.1, 516.23    -60.6, 507.55    -46.3, 500.67    -13.6, 493.52
GR            0.0, 492.51     11.5, 485.31     21.0, 486.03     32.2, 485.12
GR           46.9, 483.13     54.8, 483.71     63.3, 482.04     73.0, 483.20
GR           73.2, 485.26     76.0, 490.72     99.9, 492.99    149.5, 497.88
GR          210.4, 515.90
*
N           0.035        0.040        0.035
SA                   0.0         76.0
*
XS   EXITX    -57
GR         -119.2, 506.39    -79.3, 505.28    -61.1, 502.40    -19.6, 498.25
GR            0.0, 488.46      2.9, 485.23     19.6, 483.46     33.7, 482.02
GR           53.7, 482.84     64.5, 484.60     65.0, 485.16     67.2, 488.66
GR           69.8, 492.46     78.5, 495.37    140.6, 500.47    165.8, 500.92
GR          200.0, 502.50    250.0, 502.00    375.0, 515.90
*
N           0.035        0.033        0.037
SA                 -19.6         78.5
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.41       0.0
GR            0.0, 498.73      0.1, 489.09      2.2, 489.08      2.2, 488.01
GR            6.5, 487.71      9.7, 484.72     18.9, 482.76     29.6, 480.49
GR           37.6, 481.26     43.8, 481.96     51.3, 483.61     51.4, 485.20
GR           51.6, 486.31     52.0, 486.39     52.2, 498.09      0.0, 498.73
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      31.4 * *     56.7      9.3
N           0.033
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      12.3     2
GR          -85.6, 504.32      -28.2, 501.21     0.0, 499.88     58.4, 499.03
GR          108.4, 497.96      120.8, 497.91   155.4, 498.35    203.2, 500.92
GR          250.0, 504.00
*
XT   APTEM     56            0.
GR          -71.4, 502.88    -30.0, 499.90    -19.5, 497.73    -10.5, 496.97
GR            0.0, 491.40      6.7, 485.28     12.1, 481.89     16.3, 481.41
GR           27.7, 482.20     44.3, 483.33     52.0, 483.85     54.4, 485.35
GR           58.0, 490.27     65.2, 491.41    104.8, 494.22    147.0, 495.64
GR          180.3, 497.35    221.3, 502.39    250.0, 506.00
*
AS   APPR1     69  * * 0.0011
GT
N           0.030        0.035        0.037
SA                 -10.5         58.0
*
HP 1 BRIDG 498.73 1 498.73
HP 2 BRIDG 498.73 * * 6643
HP 2 RDWAY 503.02 * * 8357
HP 1 APPR1 503.45 1 503.45
HP 2 APPR1 503.45 * * 15000
*
HP 1 BRIDG 498.73 1 498.73
HP 2 BRIDG 498.73 * * 5519
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File roya029.extra.wsp
       Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
       Town Highway 92, First Branch White River, Royalton, Vermont     ECW
          *** RUN DATE & TIME: 12-09-97  12:55
   CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      791    118428      0    131                            0
  498.73           791    118428      0    131  1.00      0     52        0

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.73     0.0    52.2   790.6  118428.    6643.  8.40

X STA.         0.0        6.5       10.4       13.2       15.8       18.3
  A(I)             66.9       49.2       40.7       39.3       37.4
  V(I)             4.96       6.75       8.16       8.46       8.87

X STA.        18.3       20.5       22.7       24.7       26.7       28.6
  A(I)             35.7       34.8       34.7       33.2       32.9
  V(I)             9.32       9.55       9.58       9.99      10.08

X STA.        28.6       30.4       32.3       34.1       36.1       38.1
  A(I)             32.9       32.6       32.7       33.4       34.2
  V(I)            10.11      10.17      10.17       9.95       9.72

X STA.        38.1       40.1       42.4       44.7       47.4       52.2
  A(I)             35.0       36.5       37.8       42.8       68.0
  V(I)             9.50       9.09       8.78       7.77       4.89

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       8.

        WSEL     LEW     REW    AREA        K        Q    VEL
      503.02   -61.6   235.1   962.0   92411.    8357.  8.69

X STA.       -61.6       -8.0        8.0       21.8       34.3       46.0
  A(I)             76.4       49.1       46.4       44.2       43.7
  V(I)             5.47       8.50       9.00       9.45       9.57

X STA.        46.0       56.9       66.8       76.1       85.3       94.3
  A(I)             42.6       40.3       39.4       41.3       41.8
  V(I)             9.82      10.36      10.62      10.11       9.99

X STA.        94.3      102.9      110.9      119.1      127.4      136.0
  A(I)             41.7       40.5       41.4       42.0       42.9
  V(I)            10.03      10.31      10.09       9.96       9.73

X STA.       136.0      145.1      155.1      167.0      183.4      235.1
  A(I)             44.4       47.3       52.1       59.0       85.6
  V(I)             9.41       8.84       8.02       7.09       4.88

   CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      189     19745     61     62                         1887
            2     1242    339655     69     76                        30008
            3     1254    189692    172    172                        19237
  503.45          2685    549092    301    310  1.30    -70    230    39833

   VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

        WSEL     LEW     REW    AREA        K        Q    VEL
      503.45   -71.4   229.7  2685.1  549092.   15000.  5.59

X STA.       -71.4       -4.4        6.3       11.9       16.3       20.4
  A(I)            237.9      142.3      110.5       95.3       90.1
  V(I)             3.15       5.27       6.78       7.87       8.32

X STA.        20.4       24.5       28.7       32.8       37.0       41.4
  A(I)             88.5       88.6       87.8       87.3       88.8
  V(I)             8.47       8.47       8.54       8.59       8.44

X STA.        41.4       45.8       50.5       56.9       68.2       81.3
  A(I)             88.7       93.0      116.1      142.1      148.7
  V(I)             8.46       8.07       6.46       5.28       5.04

X STA.        81.3       96.3      114.6      135.1      161.3      229.7
  A(I)            155.6      169.9      175.4      202.0      276.4
  V(I)             4.82       4.41       4.28       3.71       2.71
```

```
        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
           *** RUN DATE & TIME: 12-09-97  12:55
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      791    118428      0    131                            0
   498.73           791    118428      0    131  1.00      0     52        0

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.73     0.0    52.2   790.6  118428.    5519.   6.98

  X STA.        0.0        6.5       10.4       13.2       15.8       18.3
    A(I)            66.9       49.2       40.7       39.3       37.4
    V(I)            4.12       5.61       6.78       7.03       7.37

  X STA.       18.3       20.5       22.7       24.7       26.7       28.6
    A(I)            35.7       34.8       34.7       33.2       32.9
    V(I)            7.74       7.94       7.96       8.30       8.38

  X STA.       28.6       30.4       32.3       34.1       36.1       38.1
    A(I)            32.9       32.6       32.7       33.4       34.2
    V(I)            8.40       8.45       8.45       8.27       8.07

  X STA.       38.1       40.1       42.4       44.7       47.4       52.2
    A(I)            35.0       36.5       37.8       42.8       68.0
    V(I)            7.89       7.55       7.29       6.45       4.06

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.15   -85.6   250.0  1654.0  207596.   16562.  10.01

  X STA.      -85.6      -28.1       -7.8        7.4       20.9       33.6
    A(I)           137.4       89.6       79.3       74.0       71.6
    V(I)            6.03       9.25      10.44      11.20      11.57

  X STA.       33.6       45.9       57.5       68.3       78.7       89.7
    A(I)            71.9       70.2       67.3       66.8       73.6
    V(I)           11.52      11.80      12.30      12.40      11.25

  X STA.       89.7      100.4      110.4      120.4      130.7      141.4
    A(I)            73.4       71.1       72.7       73.5       75.3
    V(I)           11.28      11.64      11.39      11.27      11.00

  X STA.      141.4      152.7      165.0      180.2      200.5      250.0
    A(I)            78.1       81.5       89.3      100.1      137.3
    V(I)           10.60      10.16       9.28       8.27       6.03

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      334     49895     61     64                         4447
             2     1406    417510     69     76                        36133
             3     1687    289900    191    192                        28482
   505.84          3428    757306    320    332  1.26    -70    249    56746

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.84   -71.4   248.7  3427.5  757306.   22000.   6.42

  X STA.      -71.4      -17.6        0.5        9.2       14.5       19.2
    A(I)           273.4      190.4      163.2      125.5      115.0
    V(I)            4.02       5.78       6.74       8.77       9.56

  X STA.       19.2       24.0       28.6       33.5       38.4       43.3
    A(I)           113.2      111.4      112.8      113.9      112.2
    V(I)            9.72       9.87       9.75       9.66       9.80

  X STA.       43.3       48.5       54.2       65.3       77.7       92.2
    A(I)           115.6      123.6      179.7      172.5      188.9
    V(I)            9.52       8.90       6.12       6.38       5.82

  X STA.       92.2      108.4      126.7      147.9      173.3      248.7
    A(I)           194.6      204.0      223.6      241.2      352.7
    V(I)            5.65       5.39       4.92       4.56       3.12
```

```
        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
           *** RUN DATE & TIME: 12-09-97  12:55
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      715    144191     52     76                        15019
   496.96           715    144191     52     76  1.00      0     52    15019

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.96     0.0    52.2   714.9  144191.    6980.   9.76

X STA.         0.0         7.7        11.5        14.3        16.8        19.1
  A(I)            67.3        44.8        36.7        33.6        32.8
  V(I)            5.18        7.79        9.51       10.40       10.64

X STA.        19.1        21.3        23.3        25.2        27.0        28.8
  A(I)            31.1        30.2        29.5        28.4        28.2
  V(I)           11.22       11.57       11.81       12.30       12.39

X STA.        28.8        30.5        32.2        34.0        35.8        37.7
  A(I)            28.0        27.8        28.8        28.8        29.6
  V(I)           12.47       12.55       12.10       12.11       11.81

X STA.        37.7        39.6        41.8        44.1        46.9        52.2
  A(I)            31.1        32.8        35.3        40.3        69.9
  V(I)           11.22       10.65        9.89        8.65        4.99

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1        6       203     10     10                           26
             2      868    186929     69     76                        17531
             3      437     39940    128    128                         4591
   497.99          1311    227073    206    214  1.32    -20    186    16312

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPR1;  SRD =      69.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.99   -20.8   185.5  1310.8  227073.    6980.   5.32

X STA.       -20.8         6.1        10.9        14.3        17.3        20.2
  A(I)           102.7        66.3        55.1        49.8        47.7
  V(I)            3.40        5.27        6.33        7.01        7.31

X STA.        20.2        23.1        26.0        28.8        31.7        34.6
  A(I)            46.5        46.2        44.9        45.4        44.8
  V(I)            7.50        7.56        7.78        7.69        7.79

X STA.        34.6        37.6        40.6        43.7        46.9        50.2
  A(I)            44.9        45.7        44.9        47.6        47.2
  V(I)            7.78        7.64        7.78        7.33        7.39

X STA.        50.2        54.1        64.3        80.9       107.7       185.5
  A(I)            53.5        86.0       100.7       121.3       169.7
  V(I)            6.52        4.06        3.47        2.88        2.06
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
           *** RUN DATE & TIME: 12-09-97  12:55

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

EXIT2:XS   ******    -48     2130  0.87 *****  502.67  496.19   15000  501.79
      -528 ******    163   415728  1.13 ***** *******    0.42    7.04

EXITX:XS      472    -58     1932  1.23  0.59  503.43 *******   15000  502.20
       -56    472    252   435827  1.31  0.18    0.00    0.59    7.76

FULLV:FV       57    -59     1956  1.21  0.07  503.50 *******   15000  502.29
         0     57    253   440036  1.32  0.00    0.00    0.60    7.67
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       69    -70     2501  0.74  0.07  503.57 *******   15000  502.83
        69     69    225   501721  1.31  0.00    0.00    0.42    6.00
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   502.29     498.41

            <<<<<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       57      0      791  1.10 *****  499.83  491.21    6643  498.73
         0 ******     52   118428  1.00 ***** *******    0.38    8.40

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    57.  0.04  0.63  504.04    0.00   8357.  503.02

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1622.    90.   -62.    29.   3.6   2.2   8.5   8.3   3.2   3.2
   RT:   6735.   206.    29.   235.   5.1   3.7  10.3   8.8   4.7   3.2

===140 AT SECID “APPR1”:  END OF CROSS SECTION EXTENDED VERTICALLY.
                            WSEL,YLT,YRT =   503.45      502.9      506.0

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

APPR1:AS       38    -70     2684  0.63  0.08  504.08  497.50   15000  503.45
        69     45    230   548846  1.30  0.00    0.00    0.38    5.59

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT2:XS    -529.   -49.   163.  15000.  415728.    2130.    7.04  501.79
   EXITX:XS     -57.   -59.   252.  15000.  435827.    1932.    7.76  502.20
   FULLV:FV       0.   -60.   253.  15000.  440036.    1956.    7.67  502.29
   BRIDG:BR       0.     0.    52.   6643.  118428.     791.    8.40  498.73
   RDWAY:RG       8.*******  1622.   8357.******************    2.00  503.02
   APPR1:AS      69.   -71.   230.  15000.  548846.    2684.    5.59  503.45

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS   ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    496.19    0.42  482.04  516.23************  0.87  502.67  501.79
   EXITX:XS   ********   0.59  482.02  515.90  0.59  0.18  1.23  503.43  502.20
   FULLV:FV   ********   0.60  482.02  515.90  0.07  0.00  1.21  503.50  502.29
   BRIDG:BR    491.21    0.38  480.49  498.73************  1.10  499.83  498.73
   RDWAY:RG   ****************  497.91  504.32  0.04******  0.63  504.04  503.02
   APPR1:AS    497.50    0.38  481.41  506.00  0.08  0.00  0.63  504.08  503.45
```

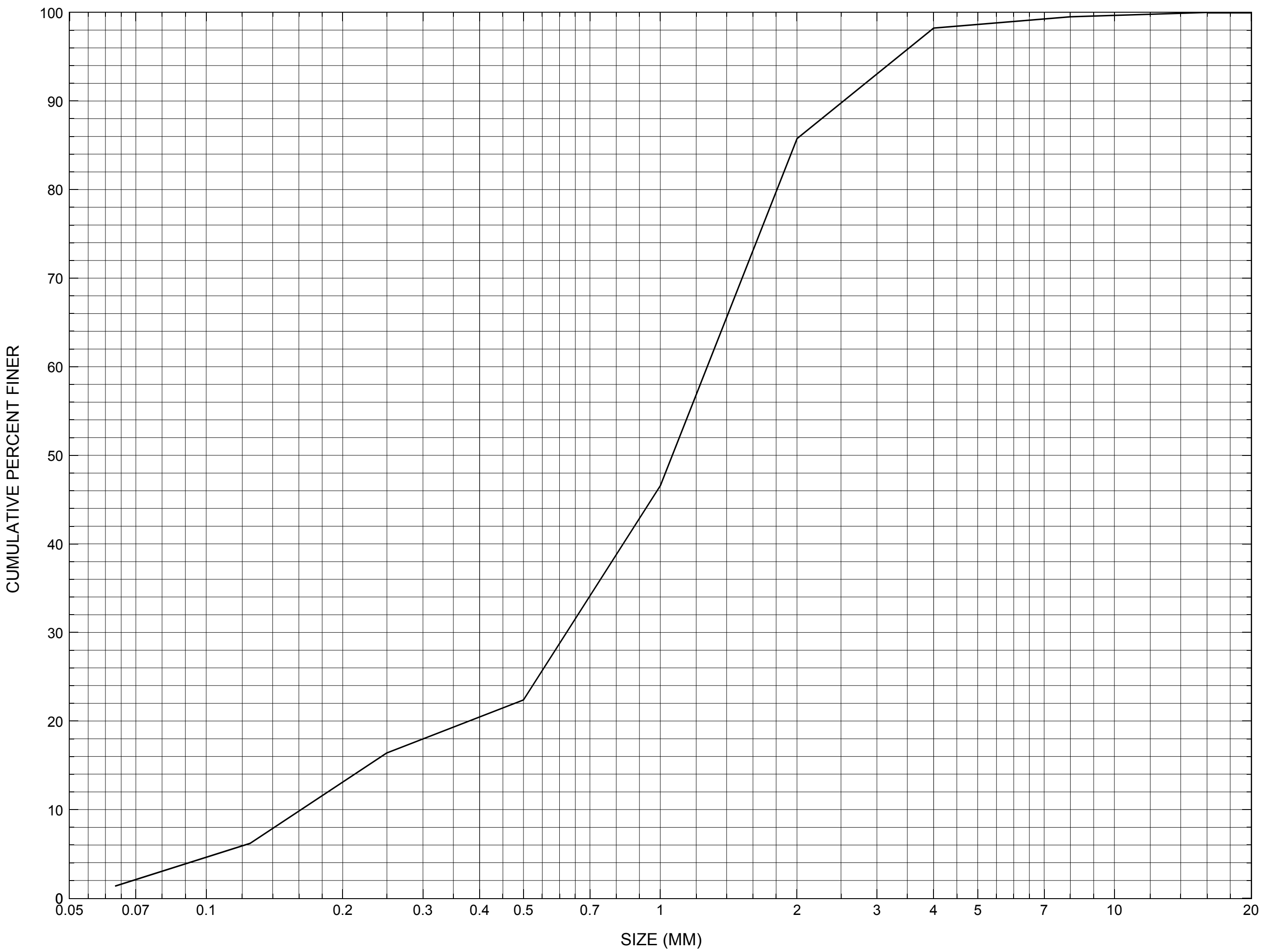
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
           *** RUN DATE & TIME: 12-09-97  12:55

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

EXIT2:XS   ******    -54     2792  1.06 *****  505.87  498.73   22000  504.81
      -528 ******    173   609926  1.10 ***** *******    0.42    7.88

EXITX:XS      472    -78     2952  1.27  0.56  506.53 *******   22000  505.26
       -56    472    279   669957  1.47  0.10    0.00    0.56    7.45

FULLV:FV       57    -81     2990  1.24  0.06  506.61 *******   22000  505.37
         0     57    280   679062  1.48  0.00    0.02    0.55    7.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===140 AT SECID "APPR1":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   505.87     502.88     506.00

APPR1:AS       69    -70     3436  0.80  0.06  506.67 *******   22000  505.87
        69     69    249   759867  1.26  0.00   -0.01    0.39    6.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   505.37     498.41

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =   16562.     15504.    1.07

            <<<<<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       57      0      791  0.76 *****  499.49  490.27    5519  498.73
         0 ******     52   118428  1.00 ***** *******    0.32    6.98

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    57.  0.05  0.81  506.60    0.00  16562.  505.15

             Q    WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   4158.   114.   -86.     29.   5.7   3.7  10.6   9.8   5.2   3.1
   RT:  12404.   221.    29.    250.   7.2   5.6  12.0  10.1   7.0   3.0

===140 AT SECID "APPR1":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   505.84      502.9      506.0

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

APPR1:AS       38    -70     3428  0.81  0.10  506.65  499.63   22000  505.84
        69     47    249   757471  1.26  0.00    0.00    0.39    6.42

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

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT2:XS    -529.   -55.   173.  22000.  609926.    2792.    7.88  504.81
   EXITX:XS     -57.   -79.   279.  22000.  669957.    2952.    7.45  505.26
   FULLV:FV       0.   -82.   280.  22000.  679062.    2990.    7.36  505.37
   BRIDG:BR       0.     0.    52.   5519.  118428.     791.    6.98  498.73
   RDWAY:RG       8.******* 4158.  16562.*****************    2.00  505.15
   APPR1:AS      69.   -71.   249.  22000.  757471.    3428.    6.42  505.84

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT2:XS    498.73    0.42  482.04  516.23************  1.06  505.87  504.81
   EXITX:XS  ********    0.56  482.02  515.90  0.56  0.10  1.27  506.53  505.26
   FULLV:FV  ********    0.55  482.02  515.90  0.06  0.00  1.24  506.61  505.37
   BRIDG:BR    490.27    0.32  480.49  498.73************  0.76  499.49  498.73
   RDWAY:RG  ****************  497.91  504.32  0.05******  0.81  506.60  505.15
   APPR1:AS    499.63    0.39  481.41  506.00  0.10  0.00  0.81  506.65  505.84
```

```
        U.S. Geological Survey WSPRO Input File roya029.extra.wsp
        Hydraulic analysis for structure ROYATH00920029   Date: 05-SEP-97
        Town Highway 92, First Branch White River, Royalton, Vermont     ECW
           *** RUN DATE & TIME: 12-09-97  12:55

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

EXIT2:XS   ******    -29     1203  0.61 *****  497.64  491.39    6980  497.03
      -528 ******    141   193540  1.17 ***** *******    0.42    5.80

EXITX:XS      472    -17     1100  0.65  0.52  498.18 *******    6980  497.53
       -56    472    105   228716  1.04  0.02    0.00    0.38    6.34

FULLV:FV       57    -17     1109  0.64  0.05  498.24 *******    6980  497.60
         0     57    106   231095  1.04  0.00    0.01    0.38    6.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       69    -18     1249  0.64  0.07  498.33 *******    6980  497.69
        69     69    183   214305  1.32  0.00    0.02    0.46    5.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   497.99       0.00     496.96     497.91

 ===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       57      0      715  1.48  0.08  498.44  491.47    6980  496.96
         0     57     52   144139  1.00  0.18    0.00    0.47    9.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  498.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       38    -20     1311  0.58  0.06  498.57  491.45    6980  497.99
        69     41    186   227097  1.32  0.07    0.00    0.43    5.32

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.742  0.166  189234.     6.    58. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT2:XS    -529.   -30.   141.   6980.  193540.    1203.    5.80  497.03
   EXITX:XS     -57.   -18.   105.   6980.  228716.    1100.    6.34  497.53
   FULLV:FV       0.   -18.   106.   6980.  231095.    1109.    6.29  497.60
   BRIDG:BR       0.     0.    52.   6980.  144139.     715.    9.77  496.96
   RDWAY:RG       8.**************      0.        0.       0.    2.00********
   APPR1:AS      69.   -21.   186.   6980.  227097.    1311.    5.32  497.99

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       6.    58.  189234.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    491.39    0.42  482.04  516.23************  0.61  497.64  497.03
   EXITX:XS  ********    0.38  482.02  515.90  0.52  0.02  0.65  498.18  497.53
   FULLV:FV  ********    0.38  482.02  515.90  0.05  0.00  0.64  498.24  497.60
   BRIDG:BR    491.47    0.47  480.49  498.73  0.08  0.18  1.48  498.44  496.96
   RDWAY:RG  ****************  497.91  504.32  0.05******  0.59  498.51********
   APPR1:AS    491.45    0.43  481.41  506.00  0.06  0.07  0.58  498.57  497.99
  ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a sieve analysis in the channel approach of structure ROYATH00920029, in Royalton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **ROYATH00920029**

General Location Descriptive

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

Date *(MM/DD/YY)* **03 / 23 / 95**

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

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

Town *(FIPS place code; I - 4; nnnnn)* **60850**

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

Waterway *(I - 6)* **FIRST BRANCH WHITE RIVER**

Road Name *(I - 7):* **-**

Route Number **TH092**

Vicinity *(I - 9)* **@ JCT W VT110**

Topographic Map **South Royalton**

Hydrologic Unit Code: **01080105**

Latitude *(I - 16; nnnn.n)* **43509**

Longitude *(i - 17; nnnnn.n)* **72308**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10141600291416**

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

Maximum span length *(I - 48; nnnn)* **0057**

Year built *(I - 27; YYYY)* **1919**

Structure length *(I - 49; nnnnnn)* **000059**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000010**

Deck Width *(I - 52; nn.n)* **123**

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

Channel & Protection *(I - 61; n)* **7**

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

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

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

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

Structure type *(I - 43; nnn)* **303**

Year Reconstructed *(I - 106)* **0000**

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

Clear span (*nnn.n ft*) **-**

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

Vertical clearance from streambed (*nnn.n ft*) **16.0**

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

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

Comments:

The structural inspection report of 6/24/94 indicates the structure is a single span, steel stringer type bridge with an asphalt filled corrugated metal deck. Both abutment walls are concrete, which is very clean overall except for some minor spalling on the older right abutment. Both abutment footings are reported as exposed. The right abutment footing has some minor spalling noted. However, no undermining or settling is evident. There is bedrock which outcrops at the base of the left abutment. The waterway is noted as making a moderate bend into the crossing with the left abutment side on the outside of the channel bend. The left abutment is noted as having good stone fill protection placed **(Continued, page 33)**

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*): 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:

along its front. Channel scour, bank erosion, and debris accumulation are reported as not evident. While the footings are exposed, the report indicates the foundation type of the abutments is unknown. The left abutment probably is doweled or sealed into the bedrock.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **101.41** mi^2 Lake/pond/swamp area **.09** mi^2

Watershed storage *(ST)* **.89** %

Bridge site elevation **490** ft Headwater elevation **1700** ft

Main channel length **21.27** mi

10% channel length elevation **500** ft 85% channel length elevation **1160** ft

Main channel slope *(S)* **41.4** 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
-
-
-

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

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

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

Comments:
NO PLANS.

Cross-sectional Data

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

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

Comments: The station and elevation measurements are in feet.
-
-

Station	1000	1009	1210	1035	1055	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low cord elevation	502	501.8	501.6	501.4	501	-	-	-	-	-	-
Bed elevation	493	488	484	484	490	-	-	-	-	-	-
Low cord to bed length	9	13.8	17.6	17.4	11	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 10/16/96
Computerized by: EW Date: 10/17/96
Reviewd by: EW Date: 9/24/97

Structure Number ROYATH00920029

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 7 / 23 / 1996

2. Highway District Number 04 Mile marker 000000

County WINDSOR (027) Town ROYALTON (60850)

Waterway *(I - 6)* FIRST BRANCH WHITE RIVER Road Name -

Route Number TH092 Hydrologic Unit Code: 01080105

3. Descriptive comments:

The bridge is located 50 feet from junction with VT110.

B. Bridge Deck Observations

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

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

7. Bridge length 59 *(feet)* Span length 57 *(feet)* Bridge width 12.3 *(feet)*

Road approach to bridge:

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

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

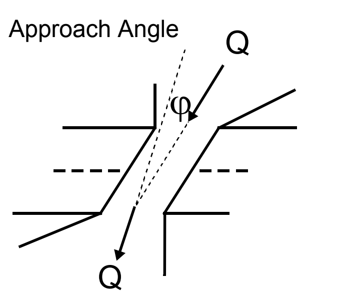
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

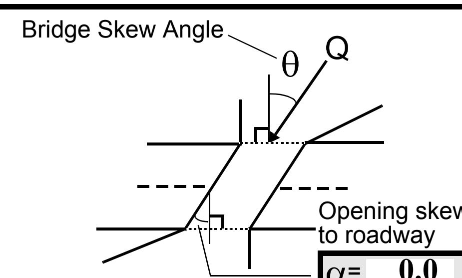
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	0
RBUS	0	-	2	0
RBDS	0	-	2	0
LBDS	0	-	2	0

*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: 10 16. Bridge skew: 20





α= 0.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 500 feet US *(US, UB, DS)* to 0 feet DS

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

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

18. Bridge Type: **1a**

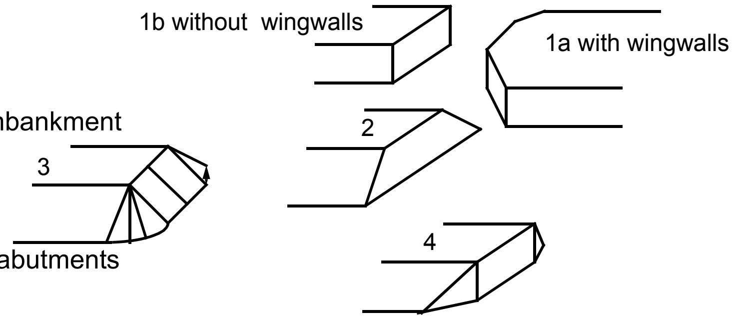
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#7: Values are from the VTAOT database. The measured bridge length = 58.5 feet; bridge span = 54.7 feet; and bridge width = 12 feet within the steel curb.

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
43.5	**15.0**			**5.0**	**1**	**1**	**5**	**432**	**1**	**1**

23. Bank width **35.0** 24. Channel width **55.0** 25. Thalweg depth **68.5** 29. Bed Material **2**

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.):

#30: Left bank road protection for Vermont 110 extends from bridge to at least 500 feet upstream. Boulders are sparce along the bank.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 250 35. Mid-bar width: 15

36. Point bar extent: 500 feet US (US, UB) to 5 feet US (US, UB, DS) positioned 80 %LB to 100 %RB

37. Material: 2

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

Point bar.

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

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

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

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

NO CUT BANKS

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 15

47. Scour dimensions: Length 65 Width 15 Depth : 4 Position 40 %LB to 70 %RB

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

The average thalweg near bridge is 4 feet.
The scour hole extends from 70 feet upstream to 5 feet upstream.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
42.5		4.0		2	7	7	-

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

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

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

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

621

-

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

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

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

70. Debris and Ice Comments:

1

-

<u>Abutments</u>	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76.Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**0**	**-**	**-**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**3**	**52.0**

Pushed: LB or RB *Toe Location (Loc.): **0**- even, **1-** set back, **2-** protrudes*
*Scour cond.: **0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**-undermined footing; **4**- piling exposed; **5**- settled; **6**- failed*
Materials: ***1***- Concrete; ***2***- Stone masonry or drywall; ***3***- steel or metal; ***4***- wood

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

0

3

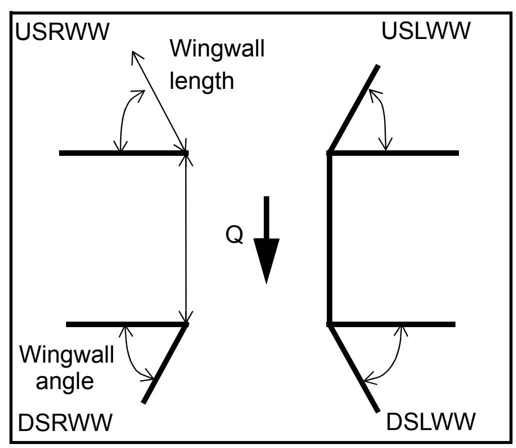
1

#74: The RABUT footing can be penetrated 2 feet at the downstream end, and 1.5 feet in the middle of the abutment. The upstream end of the footing can not be penetrated.

80. <u>Wingwalls</u>:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**52.0**	
USRWW:	**Y**		**1**		**0**	**4.5**	
DSLWW:	**-**		**-**		**Y**	**18.5**	
DSRWW:	**1**		**0**		**-**	**15.0**	

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



82. <u>Bank / Bridge Protection</u>:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**1**	**1**	**1**	**-**
Condition	**Y**	**-**	**1**	**-**	**1**	**1**	**1**	**-**
Extent	**1**	**-**	**0**	**2**	**2**	**2**	**0**	**-**

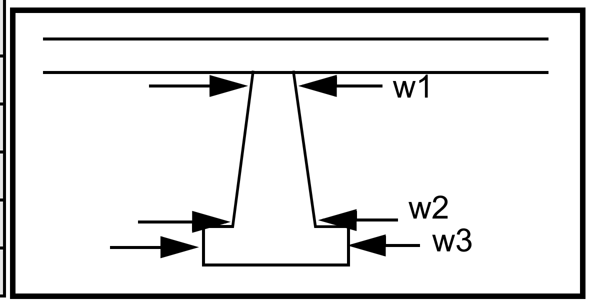
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**70.0**	**19.0**	**40.0**
Pier 2				**17.0**	**60.0**	**10.0**
Pier 3			-	**40.0**	**13.0**	-
Pier 4	-	-	-	-	-	-



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

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
-	-			-	-	NO	PIE	RS		

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.):

1
2
5
2
2
1
2
0
0
-
-
There are some naturally placed boulders along the left bank.

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 **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

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

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

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

-
-
-
-

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

Scour dimensions: Length **T** Width **BAR** Depth: **S** Positioned ____ %LB to ____ %RB

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

Y
LB
45

Are there major confluences? **0** *(Y or if N type ctrl-n mc)* How many? **DS**

Confluence 1: Distance **70** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

N

F. Geomorphic Channel Assessment

107. Stage of reach evolution **-**

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

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

-
-
-
-
-

NO CHANNEL SCOUR

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: ROYATH00920029 Town: ROYALTON
Road Number: TOWN HIGHWAY 92 County: WINDSOR
Stream: FIRST BRANCH WHITE RIVER

Initials ECW Date: 9/19/97 Checked: MAI

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	15000	22000	6980
Main Channel Area, ft2	1242	1406	868
Left overbank area, ft2	189	334	6
Right overbank area, ft2	1254	1687	437
Top width main channel, ft	69	69	69
Top width L overbank, ft	61	61	10
Top width R overbank, ft	172	191	128
D50 of channel, ft	0.003486	0.003486	0.003486
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	18.0	20.4	12.6
y1, average depth, LOB, ft	3.1	5.5	0.6
y1, average depth, ROB, ft	7.3	8.8	3.4
Total conveyance, approach	549092	757306	227073
Conveyance, main channel	339655	417510	186929
Conveyance, LOB	19745	49895	203
Conveyance, ROB	189692	289900	39940
Percent discrepancy, conveyance	0.0000	0.0001	0.0004
Qm, discharge, MC, cfs	9278.6	12128.8	5746.0
Ql, discharge, LOB, cfs	539.4	1449.5	6.2
Qr, discharge, ROB, cfs	5182.0	8421.7	1227.7
Vm, mean velocity MC, ft/s	7.5	8.6	6.6
Vl, mean velocity, LOB, ft/s	2.9	4.3	1.0
Vr, mean velocity, ROB, ft/s	4.1	5.0	2.8
Vc-m, crit. velocity, MC, ft/s	2.8	2.8	2.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Live-Bed Contraction Scour

Laursen’s Live Bed Contraction Scour

y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)

ys=y2-y_bridge

(Richardson and others, 1995, p. 30, eq. 17 and 18)

Characteristic	Approach 100 yr	Approach 500 yr	Approach Other Q	Bridge 100 yr	Bridge 500 yr	Bridge Other Q
Q1, discharge, cfs	15000	22000	6980	6643	5519	6980
Total conveyance	549092	757306	227073	118428	118428	144191
Main channel conveyance	339655	417510	186929	118428	118428	144191
Main channel discharge	9279	12129	5746	6643	5519	6980
Area - main channel, ft2	1242	1406	868	791	791	715
(W1) channel width, ft	69	69	69	52.2	52.2	52.2
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	69	69	69	52.2	52.2	52.2
D50, ft	0.003486	0.003486	0.003486			
w, fall velocity, ft/s (p. 32)	0.45826	0.45826	0.45826			
y, ave. depth flow, ft	18.00	20.38	12.58	15.15	15.15	13.70
S1, slope EGL	0.001	0.00087	0.0013			
P, wetted perimeter, MC, ft	76	76	76			
R, hydraulic Radius, ft	16.342	18.500	11.421			
V*, shear velocity, ft/s	0.725	0.720	0.691			
V*/w	1.583	1.571	1.509			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.64	0.64	0.64			
y2,depth in contraction, ft	16.16	12.40	17.77			
ys, scour depth, ft (y2-y_bridge)	1.01	-2.75	4.07			

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	15000	22000	6980
Q, thru bridge MC, cfs	6643	5519	6980
Vc, critical velocity, ft/s	2.75	2.81	2.59
Va, velocity MC approach, ft/s	7.47	8.63	6.62
Main channel width (normal), ft	52.2	52.2	52.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	52.2	52.2	52.2
qbr, unit discharge, ft2/s	127.3	105.7	133.7
Area of full opening, ft2	791.0	791.0	715.0
Hb, depth of full opening, ft	15.15	15.15	13.70
Fr, Froude number, bridge MC	0.38	0.32	0
Cf, Fr correction factor (<=1.0)	0.99	0.92	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	498.41	498.41	0
Elevation of Bed, ft	483.26	483.26	-13.70
Elevation of Approach, ft	503.45	505.84	0
Friction loss, approach, ft	0.08	0.1	0
Elevation of WS immediately US, ft	503.37	505.74	0.00
ya, depth immediately US, ft	20.11	22.48	13.70
Mean elevation of deck, ft	499.46	499.46	0
w, depth of overflow, ft (>=0)	3.91	6.28	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.98	1.00
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	32.36	26.48	N/A
Ys, scour w/Umbrell equation, ft	20.38	24.86	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	6643	5519	6980
Main channel area (DS), ft2	791	791	715
Main channel width (normal), ft	52.2	52.2	52.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	52.2	52.2	52.2
D90, ft	0.0083	0.0083	0.0083
D95, ft	0.0110	0.0110	0.0110
Dc, critical grain size, ft	0.0711	0.0490	0.0980
Pc, Decimal percent coarser than Dc	0.000	0.000	0.000
Depth to armoring, ft	N/A	N/A	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	15000	22000	6980	15000	22000	6980
a', abut.length blocking flow, ft	71.4	71.4	20.8	177.5	196.5	133.3
Ae, area of blocked flow ft2	195.47	244.78	79.4	686.23	712.11	503.3
Qe, discharge blocked abut.,cfs	--	--	269.86	--	--	1566.03
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.57	4.73	3.40	4.28	5.10	3.11
ya, depth of f/p flow, ft	2.74	3.43	3.82	3.87	3.62	3.78
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	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	0.309	0.329	0.307	0.273	0.297	0.282
ys, scour depth, ft	**12.86**	**15.38**	**10.98**	20.76	21.53	18.81

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)	71.4	71.4	20.8	177.5	196.5	133.3
y1 (depth f/p flow, ft)	2.74	3.43	3.82	3.87	3.62	3.78
a'/y1	26.08	20.83	5.45	45.91	54.22	35.30
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.31	0.33	0.31	0.27	0.30	0.28
Ys w/ corr. factor K1/0.55:						
vertical	13.51	ERR	ERR	18.32	17.66	18.08
vertical w/ ww's	11.08	ERR	ERR	**15.02**	**14.48**	**14.83**
spill-through	7.43	ERR	ERR	10.08	9.71	9.95

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	0.38	0.32	0.47	0.38	0.32	0.47
y, depth of flow in bridge, ft	15.15	15.15	13.70	15.15	15.15	13.70
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.35	0.96	1.87	1.35	0.96	1.87
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR