LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (WWINTH00300033) on TOWN HIGHWAY 30, crossing MILL BROOK, WEST WINDSOR, VERMONT

Open-File Report 98-256

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (WWINTH00300033) on TOWN HIGHWAY 30, crossing MILL BROOK, WEST WINDSOR, VERMONT

By EMILY C. WILD and ROBERT H. FLYNN

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (WWINTH00300033) ON TOWN HIGHWAY 30, CROSSING MILL BROOK, WEST WINDSOR, VERMONT

By **Emily C. Wild and Robert H. Flynn**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WWINTH00300033 on Town Highway 30 crossing Mill Brook, West Windsor, Vermont (Figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, 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 24.9-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 of the bridge while the immediate banks have dense woody vegetation. Downstream of the bridge is forested.

In the study area, Mill Brook has an incised, sinuous channel with a slope of approximately 0.004 ft/ft, an average channel top width of 58 ft and an average bank height of 5 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 65.7 mm (0.215 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 5, 1996, indicated that the reach was stable.

The Town Highway 30 crossing of the Mill Brook is a 46-ft-long, one-lane covered bridge consisting of a 40-foot wood-beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 36.3 ft. The bridge is supported by vertical, concrete capped laid-up stone abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream right bank, the upstream right wingwall, the right abutment and the 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 Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was analyzed since it had the potential of being the 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 0.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.0 to 16.0 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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 WWINTH00300033 ***Stream*** Mill Brook

County Windsor ***Road*** TH30 ***District*** 4

Description of Bridge

Bridge length 46 ***ft*** ***Bridge width*** 12.3 ***ft*** ***Max span length*** 40 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/5/96

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

Brief description of piers/abutments Abutments and wingwalls are laid-up stone with concrete caps.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 10

A mild channel bend is present within the upstream reach and within the downstream reach. 6/5/96

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	0	0	6/5/96
Level II	0	0	Moder

Potential for debris ate.

Describe any features near or at the bridge that may affect flow (include observation date) None, 6/5/96.

Description of the Geomorphic Setting

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

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

Date of inspection 6/5/96

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Moderately sloped overbank

US right: Moderately sloped overbank

Description of the Channel

Average top width 58 *ft* ***Average depth*** 5 *ft*

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

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

6/5/96

Vegetative co Forest.

DS left: Forest.

DS right: Pasture with a few trees.

US left: Pasture with a few trees.

US right:

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

The channel banks were noted as laterally unstable during the June 5, 1996 site assessment.

Describe any obstructions in channel and date of observation. None, 6/5/96.

Hydrology

Drainage area 24.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,750 ***ft³/s*** ***Q500*** 6,490 ***ft³/s***

The 100-year and 500-year discharges are the median values taken from empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None.

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. 502.85 ft, arbitrary survey datum). RM2 is a nail in tree, three feet from the tree base, located approximately 50 feet downstream of the bridge on the right bank (elev. 502.02 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-49	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	55	2	Modelled Approach section (Templated from APTEM)
APTEM	62	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 0.055 to 0.060, and overbank "n" values ranged from 0.045 to 0.065.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0042 ft/ft, which was estimated from the 100-year discharge water-surface profile slope downstream of the bridge in the Flood Insurance Study for West Windsor, VT (Federal Emergency Management Agency, 1981).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0048 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 506.0 ***ft***
Average low steel elevation 503.8 ***ft***

100-year discharge 4,750 ***ft³/s***
Water-surface elevation in bridge opening 503.8 ***ft***
Road overtopping? Y ***Discharge over road*** 1,729 ***ft³/s***
Area of flow in bridge opening 354 ***ft²***
Average velocity in bridge opening 8.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.0 ***ft/s***

Water-surface elevation at Approach section with bridge 505.4
Water-surface elevation at Approach section without bridge 503.2
Amount of backwater caused by bridge 2.2 ***ft***

500-year discharge 6,490 ***ft³/s***
Water-surface elevation in bridge opening 503.8 ***ft***
Road overtopping? Y ***Discharge over road*** 3,220 ***ft³/s***
Area of flow in bridge opening 354 ***ft²***
Average velocity in bridge opening 9.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.3 ***ft/s***

Water-surface elevation at Approach section with bridge 506.2
Water-surface elevation at Approach section without bridge 504.2
Amount of backwater caused by bridge 2.0 ***ft***

Incipient overtopping discharge 2,250 ***ft³/s***
Water-surface elevation in bridge opening 500.9 ***ft***
Area of flow in bridge opening 252 ***ft²***
Average velocity in bridge opening 8.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.0 ***ft/s***

Water-surface elevation at Approach section with bridge 502.5
Water-surface elevation at Approach section without bridge 501.4
Amount of backwater caused by bridge 1.1 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year discharge resulted in unsubmerged orifice flow, and the 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the discharges resulting in orifice flow was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Abutment scour was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.1	0.0
Depth to armoring	1.7 2.1	2.0	--
Left overbank	--	--	--
Right overbank	--	--	13.8

Local scour:			
Abutment scour	16.0	6.2	9.8
Left abutment	10.7–	6.0-	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.6
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.8	1.6	1.6
Left abutment	1.8	1.6	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

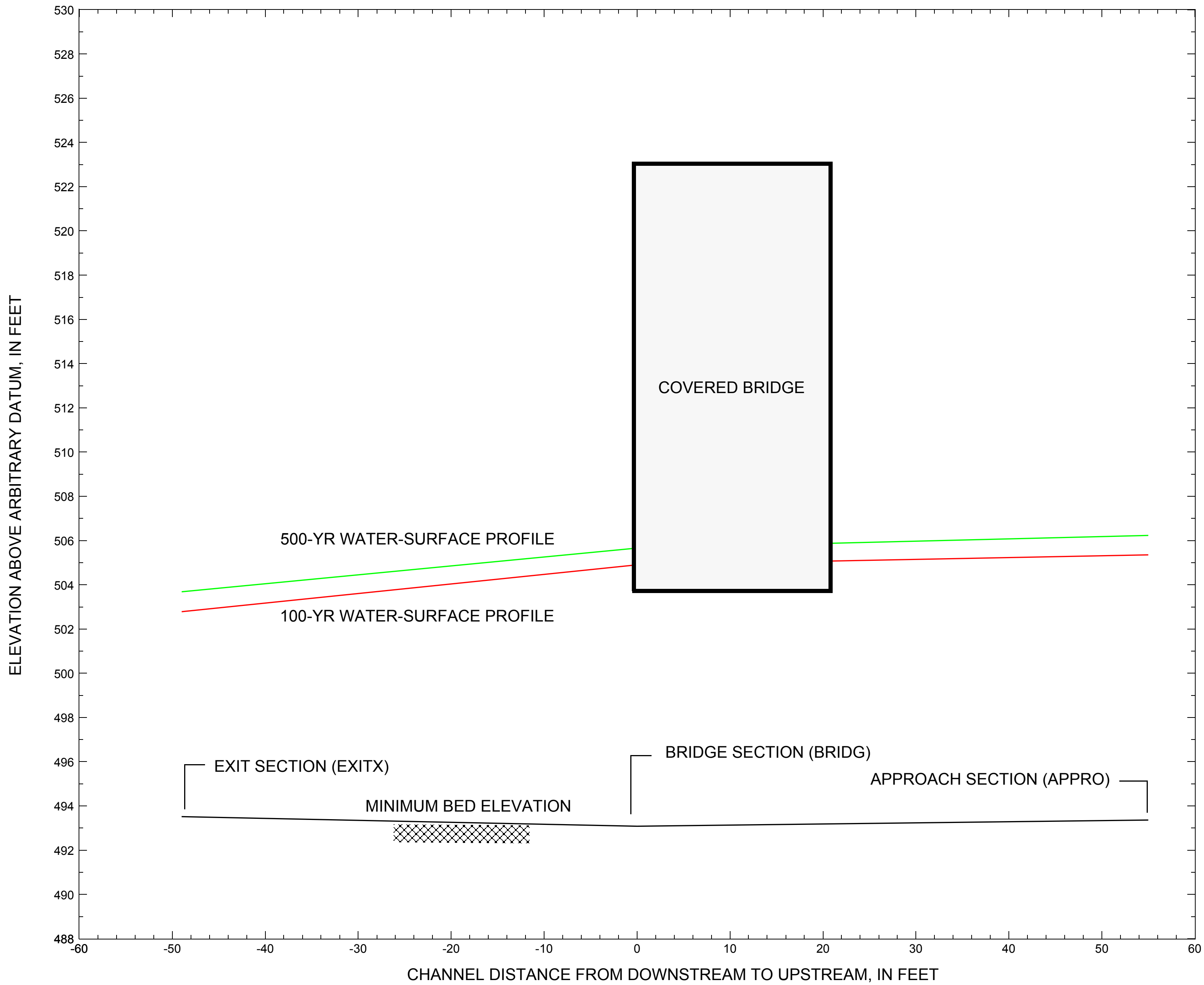

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WWINTH00300033 on Town Highway 30, crossing Mill Brook, West Windsor, Vermont.

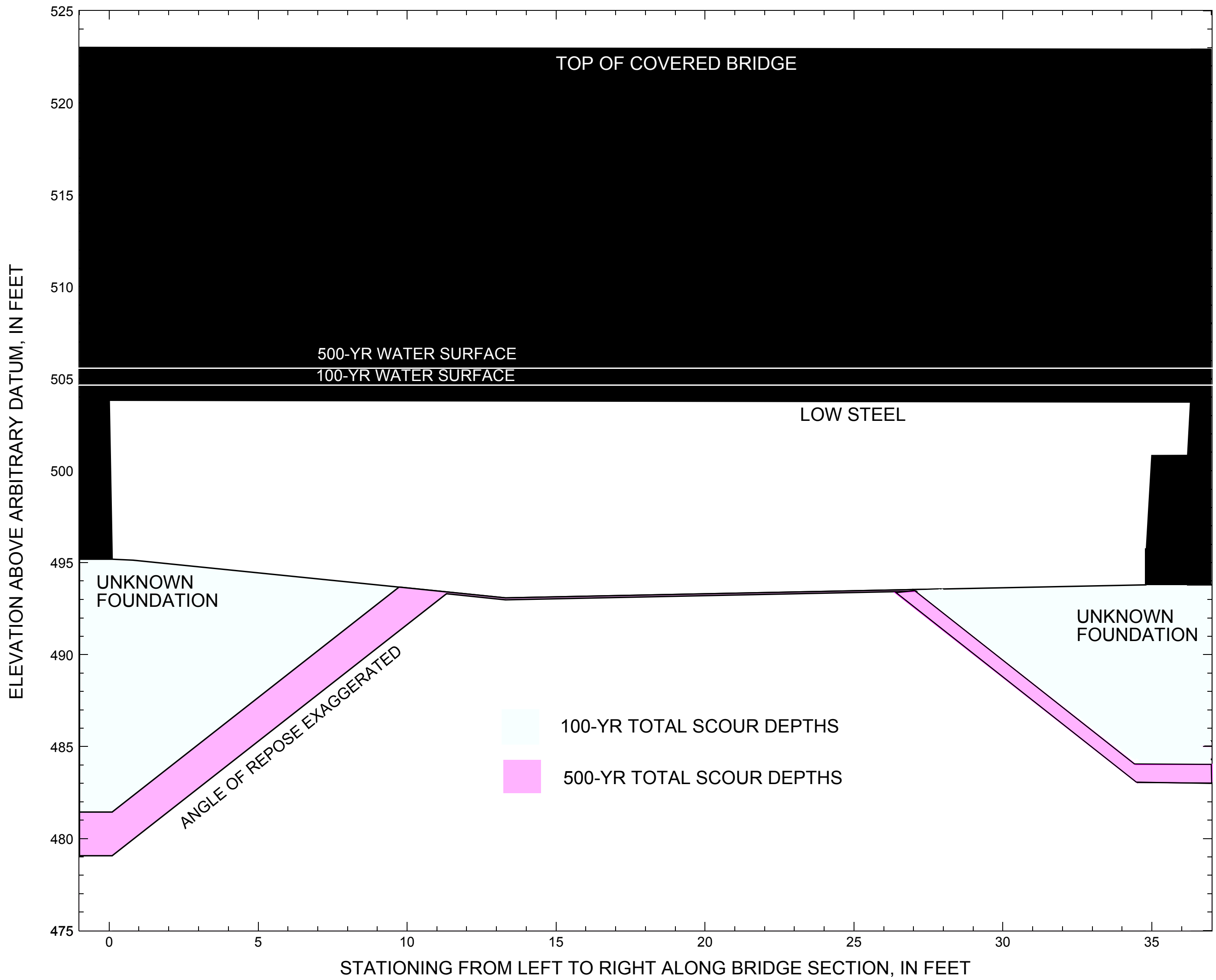

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WWINTH00300033 on Town Highway 30, crossing Mill Brook, West Windsor, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure WWINTH00300033 on Town Highway 30, crossing Mill Brook, West Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	FEMA minimum low-chord elevation, sea level (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 4,750 cubic-feet per second											
Left abutment	0.0	721.9	503.8	--	495.2	0.0	13.8	--	13.8	481.4	--
Right abutment	36.3	721.8	503.7	--	493.8	0.0	9.8	--	9.8	484.0	--

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-yr discharge at structure WWINTH00300033 on Town Highway 30, crossing Mill Brook, West Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	FEMA minimum low-chord elevation, sea level (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 6,490 cubic-feet per second											
Left abutment	0.0	721.9	503.8	--	495.2	0.1	16.0	--	16.1	479.1	--
Right abutment	36.3	721.8	503.7	--	493.8	0.1	10.7	--	10.8	483.0	--

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, 1991, Flood Insurance Study, Town of West Windsor, Windsor County, Vermont: Washington, D.C., June 17, 1991.

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. Geological Survey, 1929, Claremont, New Hampshire 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:62,500.

U.S. Geological Survey, 1929, Ludlow, Vermont 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:62.500.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wwin033.wsp
T2        Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
T3        TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4750.0   6490.0   2250.0
SK          0.0042   0.0042   0.0042
*
XS   EXITX    -49           0.
GR         -360.9, 519.80   -307.7, 509.85   -184.7, 505.41    -88.7, 503.63
GR          -69.0, 498.51      0.0, 499.53     10.4, 495.11     14.3, 494.30
GR           26.8, 493.95     36.8, 493.52     44.0, 494.08     47.0, 495.10
GR           62.1, 498.93     88.8, 500.87    120.1, 500.39    196.4, 500.59
GR          238.3, 504.33    294.8, 509.13
*
N           0.065        0.055        0.065
SA                   0.0         88.8
*
XS   FULLV      0  * * *   0.0006
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    503.78       0.0
GR            0.0, 503.83      0.1, 495.19      0.8, 495.14     13.3, 493.08
GR           34.8, 493.80     34.8, 495.14     35.0, 500.82     36.2, 500.83
GR           36.3, 503.73      0.0, 503.83
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD            1      20.8 * *     61.3      4.6
N           0.060
*
*            SRD    EMBWID   IPAVE
XR   RDWAY      8      12.3     2
GR         -259.1, 508.10   -214.4, 507.39   -196.4, 507.48   -164.7, 507.55
GR         -101.0, 503.27    -62.6, 503.32    -21.2, 505.76      0.0, 506.02
GR            0.0, 523.02     44.1, 522.91     44.1, 505.91     61.7, 505.82
GR          112.9, 502.55    134.6, 502.38    182.0, 503.77    224.3, 505.93
GR          245.1, 513.28
*
*
XT   APTEM     62           0.
GR         -335.6, 518.72   -301.7, 510.14   -272.2, 508.80   -247.3, 507.42
GR         -239.2, 501.89    -30.0, 500.48    -13.5, 500.02      0.0, 495.23
GR            2.5, 494.55     20.0, 493.83     25.6, 493.39     29.3, 494.30
GR           31.5, 495.20     33.1, 495.46     40.6, 499.88    153.9, 502.25
GR          205.2, 515.05
*
AS   APPRO     55    * * * 0.0048
GT
N           0.045        0.055        0.045
SA                 -13.5         40.6
*
HP 1 BRIDG 503.83 1 503.83
HP 2 BRIDG 503.83 * * 2996
HP 1 BRIDG 503.02 1 503.02
HP 2 RDWAY 504.91 * * 1729
HP 1 APPRO 505.35 1 505.35
HP 2 APPRO 505.35 * * 4750
*
HP 1 BRIDG 503.83 1 503.83
HP 2 BRIDG 503.83 * * 3375
HP 2 RDWAY 505.66 * * 3220
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File wwin033.wsp
       Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
       TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
          *** RUN DATE & TIME: 11-04-97  11:27
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      354     21804      0     91                            0
  503.83           354     21804      0     91  1.00      0     36        0

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA         K        Q    VEL
      503.83     0.0    36.3   354.5   21804.    2996.   8.45

X STA.        0.0        3.3        5.5        7.3        9.0       10.6
  A(I)            29.0       19.9       17.5       16.6       16.0
  V(I)            5.16       7.54       8.55       9.04       9.34

X STA.       10.6       12.1       13.5       14.9       16.4       17.8
  A(I)            15.8       15.1       15.3       15.1       15.0
  V(I)            9.47       9.90       9.78       9.94       9.99

X STA.       17.8       19.2       20.7       22.1       23.6       25.2
  A(I)            15.2       15.1       15.2       15.7       15.8
  V(I)            9.85       9.90       9.84       9.56       9.49

X STA.       25.2       26.7       28.4       30.1       32.1       36.3
  A(I)            16.2       16.9       17.6       19.7       31.7
  V(I)            9.27       8.85       8.50       7.60       4.73

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      327     27262     36     53                         5570
  503.02           327     27262     36     53  1.00      0     36     5570

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
        WSEL     LEW     REW    AREA         K        Q    VEL
      504.91  -125.4   204.3   299.8    8807.    1729.   5.77

X STA.     -125.4     -100.2      -90.8      -81.6      -72.6      -63.2
  A(I)            21.4       15.3       14.9       14.5       14.9
  V(I)            4.04       5.63       5.80       5.98       5.80

X STA.      -63.2       85.9      101.5      108.6      113.8      118.6
  A(I)            25.6       17.7       13.2       11.8       11.4
  V(I)            3.37       4.90       6.57       7.34       7.59

X STA.      118.6      123.2      127.9      132.4      137.0      142.0
  A(I)            11.2       11.4       11.3       11.5       12.0
  V(I)            7.69       7.58       7.65       7.49       7.19

X STA.      142.0      147.7      154.3      162.5      173.2      204.3
  A(I)            12.7       13.4       15.1       16.6       23.9
  V(I)            6.82       6.44       5.73       5.21       3.61

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      972     83662    231    232                        11318
            2      533     64384     54     57                         9489
            3      509     42685    126    126                         5808
  505.35          2014    190731    411    415  1.09   -243    166    24266

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
        WSEL     LEW     REW    AREA         K        Q    VEL
      505.35  -244.3   166.5  2013.8  190731.    4750.   2.36

X STA.     -244.3     -205.0     -174.5     -145.7     -119.3      -94.4
  A(I)           132.2      117.0      115.9      111.0      109.2
  V(I)            1.80       2.03       2.05       2.14       2.17

X STA.      -94.4      -71.3      -49.3      -28.1       -9.0        1.0
  A(I)           105.1      103.5      102.8      102.9       87.2
  V(I)            2.26       2.29       2.31       2.31       2.72

X STA.        1.0        7.8       14.2       20.4       26.3       33.4
  A(I)            73.9       71.4       71.1       70.1       76.7
  V(I)            3.21       3.32       3.34       3.39       3.10

X STA.       33.4       49.3       68.9       91.5      119.3      166.5
  A(I)           101.6      100.5      105.8      115.0      140.7
  V(I)            2.34       2.36       2.24       2.07       1.69
```

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       U.S. Geological Survey WSPRO Input File wwin033.wsp
       Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
       TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
          *** RUN DATE & TIME: 11-04-97  11:27
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      354     21804      0     91                            0
  503.83           354     21804      0     91  1.00      0     36        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      503.83     0.0    36.3   354.5   21804.    3375.   9.52

 X STA.        0.0        3.3        5.5        7.3        9.0       10.6
   A(I)            29.0       19.9       17.5       16.6       16.0
   V(I)            5.81       8.49       9.63      10.18      10.53

 X STA.       10.6       12.1       13.5       14.9       16.4       17.8
   A(I)            15.8       15.1       15.3       15.1       15.0
   V(I)           10.67      11.15      11.01      11.20      11.25

 X STA.       17.8       19.2       20.7       22.1       23.6       25.2
   A(I)            15.2       15.1       15.2       15.7       15.8
   V(I)           11.10      11.16      11.08      10.77      10.70

 X STA.       25.2       26.7       28.4       30.1       32.1       36.3
   A(I)            16.2       16.9       17.6       19.7       31.7
   V(I)           10.44       9.97       9.57       8.56       5.32

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

        WSEL     LEW     REW    AREA        K        Q    VEL
      505.66  -136.6   219.0   482.3   16928.    3220.   6.68

 X STA.     -136.6     -104.3      -94.0      -84.3      -75.0      -65.6
   A(I)            35.0       24.1       23.2       22.0       22.1
   V(I)            4.59       6.69       6.95       7.33       7.28

 X STA.      -65.6      -54.7       86.3       99.7      107.7      114.0
   A(I)            23.6       45.4       24.7       20.3       18.6
   V(I)            6.82       3.54       6.53       7.95       8.67

 X STA.      114.0      119.7      125.5      131.1      136.8      142.9
   A(I)            18.1       18.3       18.1       18.6       19.1
   V(I)            8.91       8.79       8.87       8.66       8.44

 X STA.      142.9      149.9      157.8      167.6      180.0      219.0
   A(I)            20.6       21.4       24.2       26.4       38.8
   V(I)            7.82       7.53       6.65       6.10       4.15

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1     1176    114367    232    233                        15015
            2      580     74255     54     57                        10788
            3      621     58395    129    130                         7725
  506.23          2377    247017    416    420  1.06   -245    170    31414

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

        WSEL     LEW     REW    AREA        K        Q    VEL
      506.23  -245.6   170.0  2377.4  247017.    6490.   2.73

 X STA.     -245.6     -208.6     -179.6     -153.3     -127.4     -103.5
   A(I)           151.1      135.6      127.9      130.6      124.5
   V(I)            2.15       2.39       2.54       2.48       2.61

 X STA.     -103.5      -80.6      -58.6      -38.0      -18.0       -2.5
   A(I)           122.8      121.2      116.7      117.3      118.2
   V(I)            2.64       2.68       2.78       2.77       2.75

 X STA.       -2.5        5.8       13.1       20.1       27.1       35.9
   A(I)            93.4       87.5       87.0       87.8       98.3
   V(I)            3.47       3.71       3.73       3.70       3.30

 X STA.       35.9       53.7       74.0       96.5      124.2      170.0
   A(I)           118.2      119.9      122.2      136.5      160.9
   V(I)            2.75       2.71       2.66       2.38       2.02
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        U.S. Geological Survey WSPRO Input File wwin033.wsp
        Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
        TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
           *** RUN DATE & TIME: 11-04-97  11:27

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      252     18603     36     49                         3765
   500.94           252     18603     36     49  1.00      0     36     3765

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.94     0.0    36.2   251.6   18603.    2250.   8.94

 X STA.         0.0        3.8        5.9        7.8        9.4       11.0
  A(I)             22.1       14.1       12.5       11.8       11.1
  V(I)             5.09       7.99       9.01       9.53      10.10

 X STA.        11.0       12.4       13.7       15.0       16.4       17.7
  A(I)             10.8       10.4       10.5       10.3       10.2
  V(I)            10.43      10.84      10.73      10.92      10.98

 X STA.        17.7       19.0       20.4       21.8       23.2       24.7
  A(I)             10.2       10.5       10.4       10.7       11.0
  V(I)            10.98      10.70      10.81      10.52      10.21

 X STA.        24.7       26.2       27.8       29.5       31.5       36.2
  A(I)             11.4       12.0       12.5       14.5       24.4
  V(I)             9.90       9.39       8.97       7.74       4.60

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      325     13649    227    227                         2205
             2      380     36608     54     57                         5708
             3      169      7239    115    115                         1163
   502.52           873     57496    395    398  1.52   -239    155     5983

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.52  -240.2   155.1   873.2   57496.    2250.   2.58

 X STA.      -240.2     -147.5      -97.6      -61.5      -31.6       -9.0
  A(I)             89.5       72.4       62.7       58.8       56.3
  V(I)             1.26       1.55       1.79       1.91       2.00

 X STA.        -9.0       -1.9        2.2        5.7        9.0       12.2
  A(I)             38.5       29.9       28.4       27.1       26.7
  V(I)             2.92       3.76       3.96       4.16       4.22

 X STA.        12.2       15.3       18.3       21.3       24.2       27.1
  A(I)             26.3       25.8       26.0       25.4       26.2
  V(I)             4.28       4.35       4.32       4.42       4.29

 X STA.        27.1       30.5       35.2       51.3       78.1      155.1
  A(I)             28.6       32.4       50.8       58.0       83.3
  V(I)             3.94       3.47       2.21       1.94       1.35
```

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        U.S. Geological Survey WSPRO Input File wwin033.wsp
        Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
        TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
           *** RUN DATE & TIME: 11-04-97  11:27

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

EXITX:XS   ******    -84     1102  0.39 *****  503.17  501.17    4750  502.78
       -48 ******    221    73262  1.35 ***** *******    0.47    4.31

FULLV:FV       49    -85     1168  0.34  0.19  503.36 *******    4750  503.02
         0     49    223    79250  1.34  0.00    0.01    0.43    4.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       55   -240     1147  0.35  0.19  503.56 *******    4750  503.21
        55     55    158    82565  1.33  0.00    0.01    0.50    4.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   507.13       0.00     502.12     502.38

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   503.09     504.92     505.09     503.78

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR       49      0      354  1.11 *****  504.94  499.87    2996  503.83
         0 ******     36    21804  1.00 ***** *******    0.48    8.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.417  0.000  503.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    43.  0.03  0.09  505.42   -0.01   1729.  504.91

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    577.     90.  -125.   -36.   1.6   1.2   5.8   5.6   1.7   3.0
   RT:   1152.    128.    76.   204.   2.5   1.5   6.6   5.9   2.0   3.1

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

APPRO:AS       34   -243     2015  0.09  0.17  505.45  502.32    4750  505.35
        55     48    166   190862  1.09  0.31   -0.01    0.20    2.36

       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
   EXITX:XS     -49.   -85.   221.   4750.   73262.    1102.    4.31  502.78
   FULLV:FV       0.   -86.   223.   4750.   79250.    1168.    4.07  503.02
   BRIDG:BR       0.     0.    36.   2996.   21804.     354.    8.45  503.83
   RDWAY:RG       8.*******   577.   1729.******************    2.00  504.91
   APPRO:AS      55.  -244.   166.   4750.  190862.    2015.    2.36  505.35

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    501.17    0.47  493.52  519.80************  0.39  503.17  502.78
   FULLV:FV  ********    0.43  493.55  519.83  0.19  0.00  0.34  503.36  503.02
   BRIDG:BR    499.87    0.48  493.08  503.83************  1.11  504.94  503.83
   RDWAY:RG  ****************  502.38  523.02  0.03******  0.09  505.42  504.91
   APPRO:AS    502.32    0.20  493.36  518.69  0.17  0.31  0.09  505.45  505.35
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        U.S. Geological Survey WSPRO Input File wwin033.wsp
        Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
        TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
           *** RUN DATE & TIME: 11-04-97  11:27

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

EXITX:XS   ******    -91     1387  0.45 *****  504.13  501.80    6490  503.68
       -48 ******    231   100088  1.32 ***** *******    0.46    4.68

FULLV:FV       49   -102     1455  0.42  0.20  504.34 *******    6490  503.92
         0     49    233   105424  1.34  0.00    0.01    0.44    4.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       55   -242     1539  0.32  0.17  504.51 *******    6490  504.18
        55     55    162   126511  1.17  0.00    0.00    0.41    4.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   503.92     503.78

            <<<<<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       49      0      354  1.41 *****  505.24  500.37    3375  503.83
         0 ******     36    21804  1.00 ***** *******    0.54    9.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  503.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    43.  0.03  0.12  506.32    0.02   3220.  505.66

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1169.   114.  -137.   -23.   2.4   1.6   6.9   6.5   2.2   3.1
   RT:   2051.   155.    64.   219.   3.3   2.0   7.6   6.8   2.6   3.1

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

APPRO:AS       34   -245     2376  0.12  0.23  506.35  502.77    6490  506.23
        55     52    170   246850  1.06  0.31    0.02    0.21    2.73

       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
   EXITX:XS     -49.   -92.   231.   6490.  100088.    1387.    4.68  503.68
   FULLV:FV       0.  -103.   233.   6490.  105424.    1455.    4.46  503.92
   BRIDG:BR       0.     0.    36.   3375.   21804.     354.    9.52  503.83
   RDWAY:RG       8.******* 1169.   3220.******************    2.00  505.66
   APPRO:AS      55.  -246.   170.   6490.  246850.    2376.    2.73  506.23

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL     WSEL
   EXITX:XS     501.80    0.46  493.52  519.80************  0.45  504.13  503.68
   FULLV:FV   ********    0.44  493.55  519.83  0.20  0.00  0.42  504.34  503.92
   BRIDG:BR     500.37    0.54  493.08  503.83************  1.41  505.24  503.83
   RDWAY:RG   ****************  502.38  523.02  0.03******  0.12  506.32  505.66
   APPRO:AS     502.77    0.21  493.36  518.69  0.23  0.31  0.12  506.35  506.23
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        U.S. Geological Survey WSPRO Input File wwin033.wsp
        Hydraulic analysis for structure WWINTH00300033   Date: 31-OCT-97
        TH 30 CROSSING MILL BROOK, WEST WINDSOR, VERMONT                ECW
           *** RUN DATE & TIME: 11-04-97  11:27

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

 EXITX:XS   ******    -78      610  0.29 *****  501.39  498.77    2250  501.10
       -48 ******    202    34699  1.36 ***** *******    0.51    3.69

 FULLV:FV       49    -79      668  0.24  0.19  501.58 *******    2250  501.34
         0     49    204    38547  1.38  0.00    0.00    0.45    3.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81    501.41     499.18

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   500.84     518.69    0.50

  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   500.84     518.69     499.18

 APPRO:AS       55   -173      469  0.53  0.23  501.95  499.18    2250  501.42
        55     55    116    31231  1.49  0.15    0.00    0.81    4.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.52       0.00     500.94     502.38

  ===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       49      0      252  1.24  0.38  502.18  498.79    2250  500.94
         0     49     36    18597  1.00  0.41    0.00    0.60    8.95

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   4.  1.000 ******  503.78 ****** ****** ******

     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

 APPRO:AS       34   -239      872  0.16  0.19  502.67  499.18    2250  502.52
        55     39    155    57364  1.52  0.30    0.00    0.38    2.58

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.875  0.434   32388.    -2.    34. ********

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
    EXITX:XS     -49.   -79.   202.   2250.   34699.     610.    3.69  501.10
    FULLV:FV       0.   -80.   204.   2250.   38547.     668.    3.37  501.34
    BRIDG:BR       0.     0.    36.   2250.   18597.     252.    8.95  500.94
    RDWAY:RG       8.**************      0.       0.       0.    2.00********
    APPRO:AS      55.  -240.   155.   2250.   57364.     872.    2.58  502.52

     XSID:CODE   XLKQ   XRKQ      KQ
    APPRO:AS      -2.    34.   32388.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS    498.77    0.51  493.52  519.80************  0.29  501.39  501.10
    FULLV:FV  ********    0.45  493.55  519.83  0.19  0.00  0.24  501.58  501.34
    BRIDG:BR    498.79    0.60  493.08  503.83  0.38  0.41  1.24  502.18  500.94
    RDWAY:RG  ****************  502.38  523.02  0.07******  0.16  502.60********
    APPRO:AS    499.18    0.38  493.36  518.69  0.19  0.30  0.16  502.67  502.52
   ER

NORMAL  END  OF  WSPRO  EXECUTION.
```
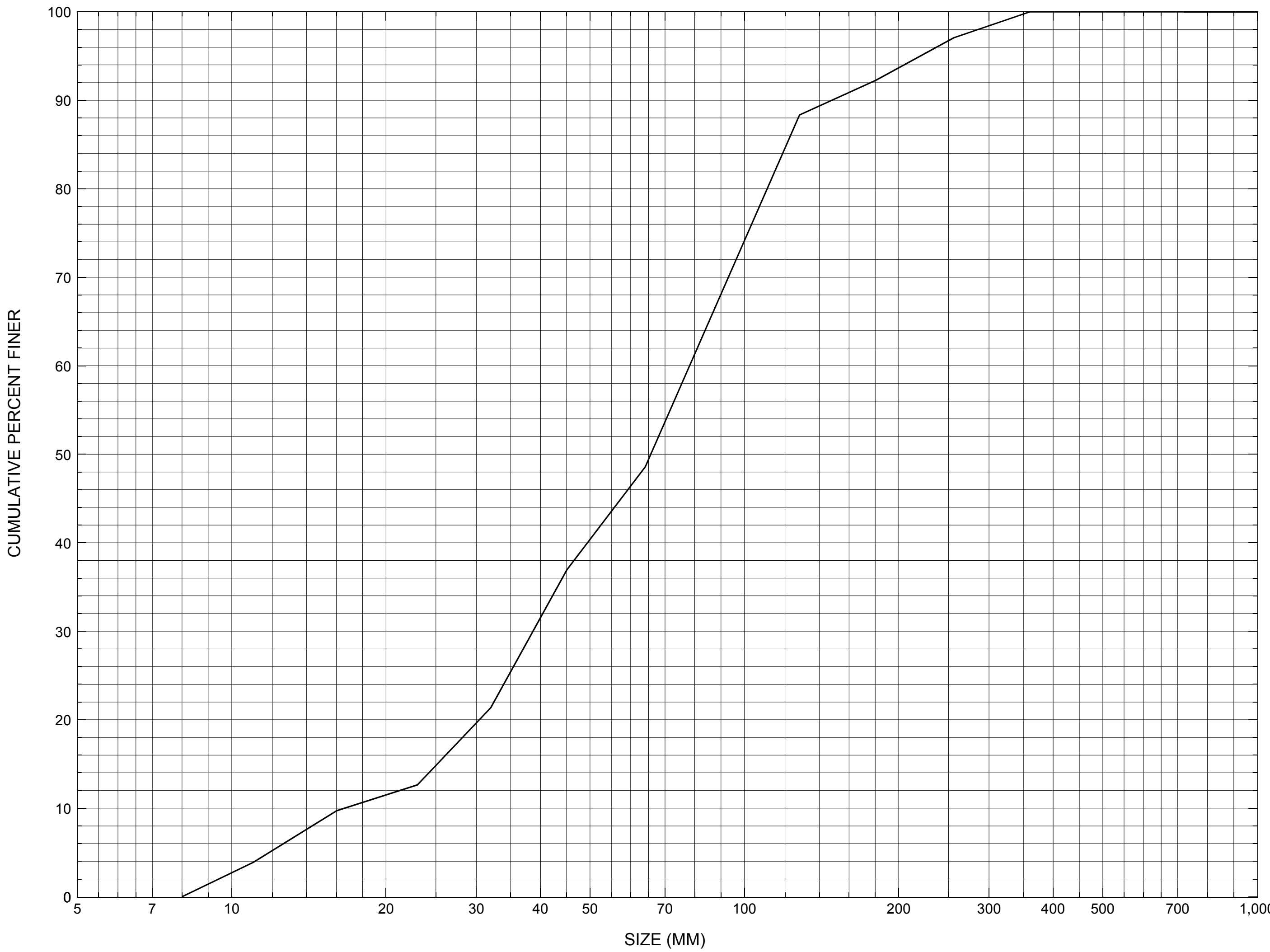

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WWINTH00300033, in West Windsor, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WWINTH00300033

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)* 83050

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

Waterway *(I - 6)* MILL BROOK

Road Name *(I - 7)*: -

Route Number TH030

Vicinity *(I - 9)* 0.35 MI TO JCT W VT44

Topographic Map Mt.Ascutney

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 43273

Longitude *(i - 17; nnnnn.n)* 72310

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142200331422

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

Maximum span length *(I - 48; nnnn)* 0040

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

Structure length *(I - 49; nnnnnn)* 000046

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

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

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 712

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*) 010.5

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

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

Comments:

The structural inspection report of 11/1/93 indicates the structure is a pressure treated, timber, thru-arch type covered bridge. The abutment walls are constructed of “laid-up” stone with concrete caps, of which the concrete is noted in “like new” condition. The report mentions there are some random areas on the right abutment where voids are evident between some of the stones in the wall. However, the report indicates no significant displacement is evident. The foundation is unknown, and therefore no exposure or undermining of the abutment walls could be reported. Channel scour, bank erosion, and debris accumulation problems are indicated as not evident in this report. **(Continued, page 33)**

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} (*ft³/ 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 (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
The report mentions that there is not much stone fill protection at this site. The waterway makes a slight to moderate bend into the crossing. The streambed material is noted as consisting of stone and gravel with some sand and boulders.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **24.85** mi^2 Lake/pond/swamp area **0.03** mi^2
Watershed storage *(ST)* **0.1** %
Bridge site elevation **725** ft Headwater elevation **3093** ft
Main channel length **10.53** mi
10% channel length elevation **781** ft 85% channel length elevation **1520** ft
Main channel slope *(S)* **93.56** 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:

Station	0	6	12	18	24	30	36	-	-	-	-
Feature	LAB	-	-	-	-	-	RAB	-	-	-	-
Low chord elevation	721.90	721.88	721.87	721.85	721.83	721.82	721.80	-	-	-	-
Bed elevation	713.20	712.10	711.00	710.80	710.50	711.00	712.40	-	-	-	-
Low chord to bed	8.70	9.78	10.87	11.05	11.33	10.82	9.40	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **11/20/96**
Computerized by: **RB** Date: **1/21/97**
Reviewd by: **EW** Date: **12/4/97**

Structure Number **WWINTH00300033**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. FLYNN** Date *(MM/DD/YY)* **06** / **05** / 19**96**
2. Highway District Number **04** Mile marker **0000**
County **WINDSOR (027)** Town **WEST WINDSOR (83050)**
Waterway *(I - 6)* **MILL BROOK** Road Name **Ely Road**
Route Number **TH030** Hydrologic Unit Code: **01080104**
3. Descriptive comments:
The bridge is located 0.35 miles from the junction with VT 44. This is a covered bridge with concrete capped laid-up stone abutments.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **6** RBDS **6** Overall **5**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US **1** UB **1** DS **1** *(**1**- pool; **2**- riffle)*
6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length **46** *(feet)* Span length **40** *(feet)* Bridge width **12.3** *(feet)*

Road approach to bridge:

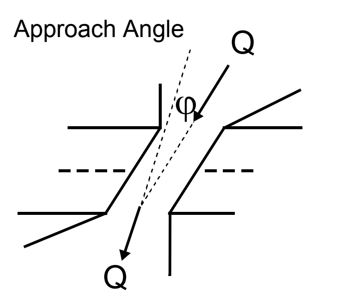
8. LB **1** RB **1** *(**0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **2** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

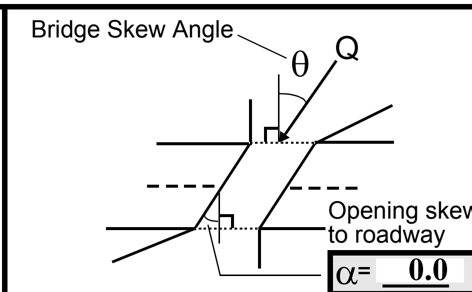
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	2	2
RBUS	2	2	1	2
RBDS	2	2	2	1
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **10**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **40** feet **US** *(US, UB, DS)* to **60** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **20** feet **DS** *(US, UB, DS)* to **80** feet **DS**

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

18. Bridge Type: **1a**

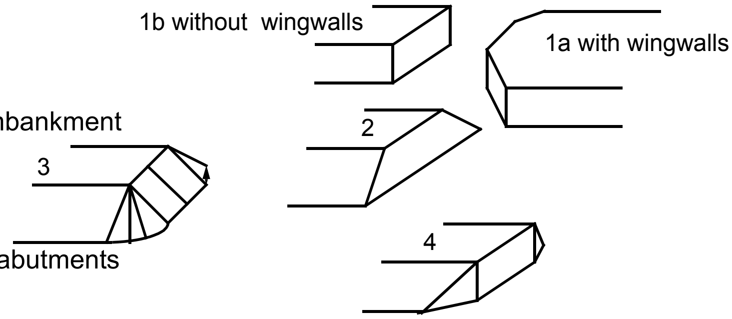
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

5. The US riffle ends approximately at the approach section at 45 ft US. The riffle begins again DS at the exit section, about 40 ft DS.
4. There are shrubs along the left bank DS and along both banks US.
18. There are only two wingwalls, on the US right and DS left. They are constructed of laid-up stone.
On the left bank US, there is a gully formation in the embankment where sand is eroding near the abutment.

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
50.0	5.0			4.5	1	1	243	425	0	1

23. Bank width **20.0** 24. Channel width **30.0** 25. Thalweg depth **54.0** 29. Bed Material **4231**

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

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

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

30. The right bank protection extends from the bridge abutment to 40 ft US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **25** 35. Mid-bar width: **15**

36. Point bar extent: **0** feet **US** (US, UB) to **50** feet **US** (US, UB, DS) positioned **0** %LB to **20** %RB

37. Material: **21**

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: **45** 42. Cut bank extent: **35** feet **US** (US, UB) to **60** 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.):

Moderate erosion with cobbles and some debris on the cut bank.

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

47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
33.0		2.0		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.):

2543

-

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 **2** ____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

-

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		30	90	2	0	-	-	90.0
RABUT	2	-	90			2	0	36.5

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.):

-

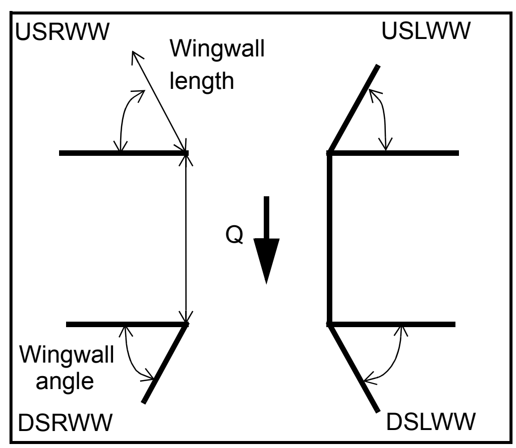
-

2

The left abutment is laid-up stone with a concrete cap. The stone is 6 ft high with a 1.5 ft concrete cap on top. Voids are evident between the stones in the wall, about 1 in to 2 in, length and width. There is a foot of sand along the bottom of the abutment. The right abutment is also constructed of 6 ft of laid-up stone with a 2 ft high concrete cap on top. Larger voids are evident between stones in the wall about 1 in to 4 in, length and width. The channel bottom is covered in cobbles and boulders which is underlain by sand.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						36.5	
USRWW:	N		-		-	2.0	
DSLWW:	-		-		Y	17.0	
DSRWW:	2		0		-	16.5	



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	-	0	N	-	-	2	-	2
Condition	Y	-	-	-	-	1	-	1
Extent	2	-	-	-	2	0	2	-

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

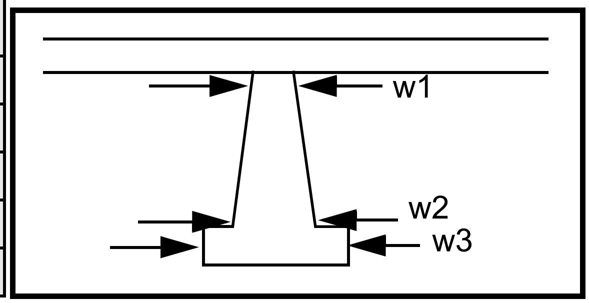
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
2
1
-
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**-**		**9.5**	**-**	**60.0**	**75.0**
Pier 2	**8.0**	**-**	**-**	**-**	**-**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e pro-**	**DS left**	**h are**	**nd US**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tec-**	**con-**	**from**	**alon**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tion**	**sists**	**1 ft**	**g the**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**for**	**of**	**to 2**	**base**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**smal**	**ft**	**of**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wing**	**ler**	**abov**	**the**	
92. Pushed	**walls**	**cob-**	**e the**	**wing**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**on**	**bles**	**chan**	**wall**	
95. Cross-members	**the**	**to**	**nel**	**to**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**US**	**boul-**	**bed**	**the**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**right**	**ders**	**and**	**bank**	
98. Exposure depth	**and**	**whic**	**exte**	**. It**	

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

is the same along the right abutment also.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -____

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

-
-
-
-

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

Cut bank extent: RS____ 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: 3______

Scour dimensions: Length 4_____ Width 245____ Depth: 245___ Positioned 1____ %LB to 0____ %RB

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

4213
0
0
-

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

\- N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WWINTH00300033 Town: WEST WINDSOR
Road Number: TH 30 County: WINDSOR
Stream: MILL BROOK

Initials ECW Date: 12/3/97 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	4750	6490	2250
Main Channel Area, ft2	533	580	380
Left overbank area, ft2	972	1176	325
Right overbank area, ft2	509	621	169
Top width main channel, ft	54	54	54
Top width L overbank, ft	231	232	227
Top width R overbank, ft	126	129	115
D50 of channel, ft	0.215	0.215	0.215
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.9	10.7	7.0
y1, average depth, LOB, ft	4.2	5.1	1.4
y1, average depth, ROB, ft	4.0	4.8	1.5
Total conveyance, approach	190731	247017	57496
Conveyance, main channel	64384	74255	36608
Conveyance, LOB	83662	114367	13649
Conveyance, ROB	42685	58395	7239
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1603.4	1950.9	1432.6
Ql, discharge, LOB, cfs	2083.5	3004.8	534.1
Qr, discharge, ROB, cfs	1063.0	1534.2	283.3
Vm, mean velocity MC, ft/s	3.0	3.4	3.8
Vl, mean velocity, LOB, ft/s	2.1	2.6	1.6
Vr, mean velocity, ROB, ft/s	2.1	2.5	1.7
Vc-m, crit. velocity, MC, ft/s	9.8	10.0	9.3
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)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	4750	6490	2250
(Q) discharge thru bridge, cfs	2996	3375	2250
Main channel conveyance	21804	21804	18603
Total conveyance	21804	21804	18603
Q2, bridge MC discharge,cfs	2996	3375	2250
Main channel area, ft2	354	354	252
Main channel width (normal), ft	36.3	36.3	36.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	36.3	36.3	36.2
y_bridge (avg. depth at br.), ft	9.75	9.75	6.96
Dm, median (1.25*D50), ft	0.26875	0.26875	0.26875
y2, depth in contraction,ft	7.92	8.77	6.21
ys, scour depth (y2-ybridge), ft	-1.84	-0.99	-0.75

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	2996	3375	2250
Main channel area (DS), ft2	327	354	252
Main channel width (normal), ft	36.3	36.3	36.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	36.3	36.3	36.2
D90, ft	0.4854	0.4854	0.4854
D95, ft	0.7218	0.7218	0.7218
Dc, critical grain size, ft	0.2880	0.3029	0.3014
Pc, Decimal percent coarser than Dc	0.335	0.306	0.309
Depth to armoring, ft	1.72	2.06	2.03

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	4750	6490	2250
Q, thru bridge MC, cfs	2996	3375	2250
Vc, critical velocity, ft/s	9.84	9.98	9.30
Va, velocity MC approach, ft/s	3.01	3.36	3.77
Main channel width (normal), ft	36.3	36.3	36.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	36.3	36.3	36.2
qbr, unit discharge, ft2/s	82.5	93.0	62.2
Area of full opening, ft2	354.0	354.0	252.0
Hb, depth of full opening, ft	9.75	9.75	6.96
Fr, Froude number, bridge MC	0.48	0.54	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	327	N/A	N/A
**Hb, depth at downstream face, ft	9.01	N/A	N/A
**Fr, Froude number at DS face	0.54	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	503.78	503.78	0
Elevation of Bed, ft	494.03	494.03	-6.96
Elevation of Approach, ft	505.35	506.23	0
Friction loss, approach, ft	0.17	0.23	0
Elevation of WS immediately US, ft	505.18	506.00	0.00
ya, depth immediately US, ft	11.15	11.97	6.96
Mean elevation of deck, ft	522.96	522.96	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.95	1.00
**Cc, for downstream face (<=1.0)	0.947406	ERR	ERR
Ys, scour w/Chang equation, ft	-1.08	0.06	N/A
Ys, scour w/Umbrell equation, ft	-3.74	-2.90	N/A

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

**Ys, scour w/Chang equation, ft	-0.15	N/A	N/A

**Ys, scour w/Umbrell equation, ft	-2.99	N/A	ERR

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

y2, from Laursen's equation, ft	7.92	8.77	6.21
WSEL at downstream face, ft	503.02	--	--
Depth at downstream face, ft	9.01	N/A	N/A
Ys, depth of scour (Laursen), ft	-1.09	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	4750	6490	2250	4750	6490	2250
a', abut.length blocking flow, ft	244.3	245.6	240.2	130.2	133.7	118.9
Ae, area of blocked flow ft2	986.23	1126.42	392.06	377.64	411.83	188.94
Qe, discharge blocked abut.,cfs	--	--	727.13	--	--	330.51
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.18	2.58	1.85	2.10	2.47	1.75
ya, depth of f/p flow, ft	4.04	4.59	1.63	2.90	3.08	1.59
--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	0.183	0.198	0.256	0.181	0.196	0.245
ys, scour depth, ft	19.60	22.19	12.95	12.67	13.82	9.60

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)	244.3	245.6	240.2	130.2	133.7	118.9
y1 (depth f/p flow, ft)	4.04	4.59	1.63	2.90	3.08	1.59
a'/y1	60.52	53.55	147.16	44.89	43.41	74.82
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.18	0.20	0.26	0.18	0.20	0.24
Ys w/ corr. factor K1/0.55:						
vertical	16.76	19.55	7.57	12.00	13.08	7.26
vertical w/ ww's	13.75	16.03	6.21	9.84	10.73	5.95
spill-through	9.22	10.75	4.16	6.60	7.20	3.99

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	0.54	0.54	0.6	0.48	0.54	0.6
y, depth of flow in bridge, ft	9.01	9.75	6.96	9.01	9.75	6.96
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.62	1.76	1.55	1.28	1.76	1.55
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR