LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (WWINTH00370034) on TOWN HIGHWAY 37, crossing MILL BROOK, WEST WINDSOR, VERMONT

Open-File Report 98-570

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

U.S. Department of the Interior

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By ERICK M. BOEHMLER AND EMILY C. WILD

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U.S. DEPARTMENT OF THE INTERIOR
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Box 25286
Denver, CO 80225-0286

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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 34 (WWINTH00370034) ON TOWN HIGHWAY 37, CROSSING MILL BROOK, WEST WINDSOR, VERMONT

***By* Erick M. Boehmler and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WWINTH00370034 on Town Highway 37 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 16.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture except for the upstream left bank where there is mostly shrubs and brush.

In the study area, Mill Brook has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 52 ft and an average bank height of 5 ft. The channel bed material ranges from sand to cobbles with a median grain size (D_{50}) of 43.4 mm (0.142 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 laterally unstable. Point bars were observed upstream and downstream of this site. Furthermore, slip failure of the bank material was noted downstream at a cut-bank on the left side of the channel across from a point bar.

The Town Highway 37 crossing of Mill Brook is a 37-ft-long, one-lane covered bridge consisting of one 32-foot wood thru-truss span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 29.6 ft. The bridge is supported by vertical, laid-up stone abutment walls with concrete facing and laid-up stone wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. Scour protection measures at the site included type-3 (less than 48 inches diameter) and type-4 (less than 60 inches diameter) stone fill. Type-3 stone fill was observed along the upstream right bank and along the right abutments. Type-4 stone fill was observed at the upstream end of the upstream right 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 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.

There was no contraction scour predicted for any of the modeled flows. Abutment scour at the left abutment ranged from 5.7 to 7.3 ft, while that at the right abutment ranged from 11.6 to 17.7 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.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). 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 WWINTH00370034 ***Stream*** Mill Brook

County Windsor ***Road*** TH 34 ***District*** 4

Description of Bridge

Bridge length 37 ***ft*** ***Bridge width*** 12.3 ***ft*** ***Max span length*** 32 ***ft***

Alignment of bridge to road (on curve or straight) Curved, right and straight, left

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

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

Description of stone fill Type-3 along the abutments and the right bank upstream. Type-4 stone fill was observed at the upstream end of the upstream right wingwall.

Brief description of piers/abutments Abutments are laid-up stone wall with concrete facing and laid-up stone wingwalls. A 1.5 ft deep scour hole was observed along the right abutment.

Yes

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

There is a mild channel bend in the upstream reach. A scour hole has developed at the location along the bend where the flow impacts the right abutment.

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	6/5/96	0	0
Level II	6/5/96	0	0

Potential for debris Moderate. Vines and dead trees were observed along the banks upstream.

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

None were observed on 6/5/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with a narrow, slightly irregular flood plain and steep valley walls.

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

Date of inspection 6/5/96

DS left: Steep channel bank and a mildly sloped overbank.

DS right: Moderately sloped bank and mildly sloped flood plain.

US left: Moderately sloped bank and irregular overbank.

US right: Moderately sloped bank and mildly sloped flood plain.

Description of the Channel

Average top width 52 ***ft*** ***Average depth*** 5 ***ft***

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

Perennial and sinuous with semi-alluvial channel boundaries and narrow point bars.

6/5/96

Vegetative co Brush with trees and grass on the overbank.

DS left: Brush and grass with grass on the flood plain.

DS right: Trees and brush

US left: Trees and brush with grass on the flood plain.

US right:

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

Slip failure of the downstream left bank material was observed on 6/5/96 on the opposite bank from a wide, gravel point bar in the downstream reach. There was also a point bar in the upstream reach. The channel was sinuous near the site but becomes meandering further downstream.

Describe any obstructions in channel and date of observation. None were observed on 6/5/96.

Hydrology

Drainage area 16.6 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p - No

Calculated Discharges

Q100 3,500 ***ft³/s*** ***Q500*** 5,200 ***ft³/s***

The 100- and 500-year discharges are the median discharges from a range defined by flood frequency curves derived from several empirical methods (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. Add 268.67 feet to the USGS arbitrary survey datum to obtain the National Geodetic Vertical Datum of 1929.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 504.47 ft, arbitrary survey datum). RM2 is a nail 5 feet above the ground in a one foot diameter tree located on the left bank 25 feet upstream of the left abutment (elev. 501.94 ft, arbitrary survey datum). BM1 (RM7, FEMA, 1991) is a standard USGS tablet set in a bedrock outcrop about 140 feet upstream of the intersection of Town Highway 37 (Churchill Road) and State Route 44 (elev. 510.32, arbitrary survey datum).

Cross-Sections Used in WSPRO Analvsis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-30	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APTEM	47	2	Approach section as surveyed (Used as a template)
APPRO	56	1	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 0.035 to 0.045, and overbank "n" values ranged from 0.040 to 0.060.

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 0.0029 ft/ft, which was estimated from the 100-year water surface profile downstream of this site documented in the flood insurance study for the Town of West Windsor (FEMA, 1991).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0091 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 provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 504.8 *ft*
Average low steel elevation 502.4 *ft*

100-year discharge 3,500 *ft³/s*
Water-surface elevation in bridge opening 500.5 *ft*
Road overtopping? Yes *Discharge over road* 2,340 *ft³/s*
Area of flow in bridge opening 250 *ft²*
Average velocity in bridge opening 4.7 *ft/s*
Maximum WSPRO tube velocity at bridge 6.5 *ft/s*

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 500.2
Amount of backwater caused by bridge 1.0 *ft*

500-year discharge 5,200 *ft³/s*
Water-surface elevation in bridge opening 501.0 *ft*
Road overtopping? Yes *Discharge over road* 4,120 *ft³/s*
Area of flow in bridge opening 264 *ft²*
Average velocity in bridge opening 4.1 *ft/s*
Maximum WSPRO tube velocity at bridge 5.8 */s*

Water-surface elevation at Approach section with bridge 501.7
Water-surface elevation at Approach section without bridge 500.7
Amount of backwater caused by bridge 1.0 *ft*

Incipient overtopping discharge 1,460 *ft³/s*
Water-surface elevation in bridge opening 498.7 *ft*
Area of flow in bridge opening 196 *ft²*
Average velocity in bridge opening 7.4 *ft/s*
Maximum WSPRO tube velocity at bridge 10.2 *ft/s*

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 499.1
Amount of backwater caused by bridge 0.5 *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 all modeled discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (Y_o) is subtracted from the depth of flow computed by the scour equation (Y_2) to determine the depth of scour. Variables for the Laursen clear-water scour equation include the discharge through the bridge opening, the median diameter of the bed material, and the bottom width of the bridge opening.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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.

The length to depth ratio of the embankment blocking flow exceeded 25 for several modeled discharges at both abutments. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) generally is applicable when this ratio exceeds 25, the effective length of the embankment blocking flow at this site is questionable, particularly at the right abutment. Further, Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Therefore, the results from the HIRE equation were not used.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.0	0.0	0.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.5	7.3	5.7
Right abutment	15.7	17.7	11.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	0.4	0.3	1.1
Right abutment	0.4	0.3	1.1
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

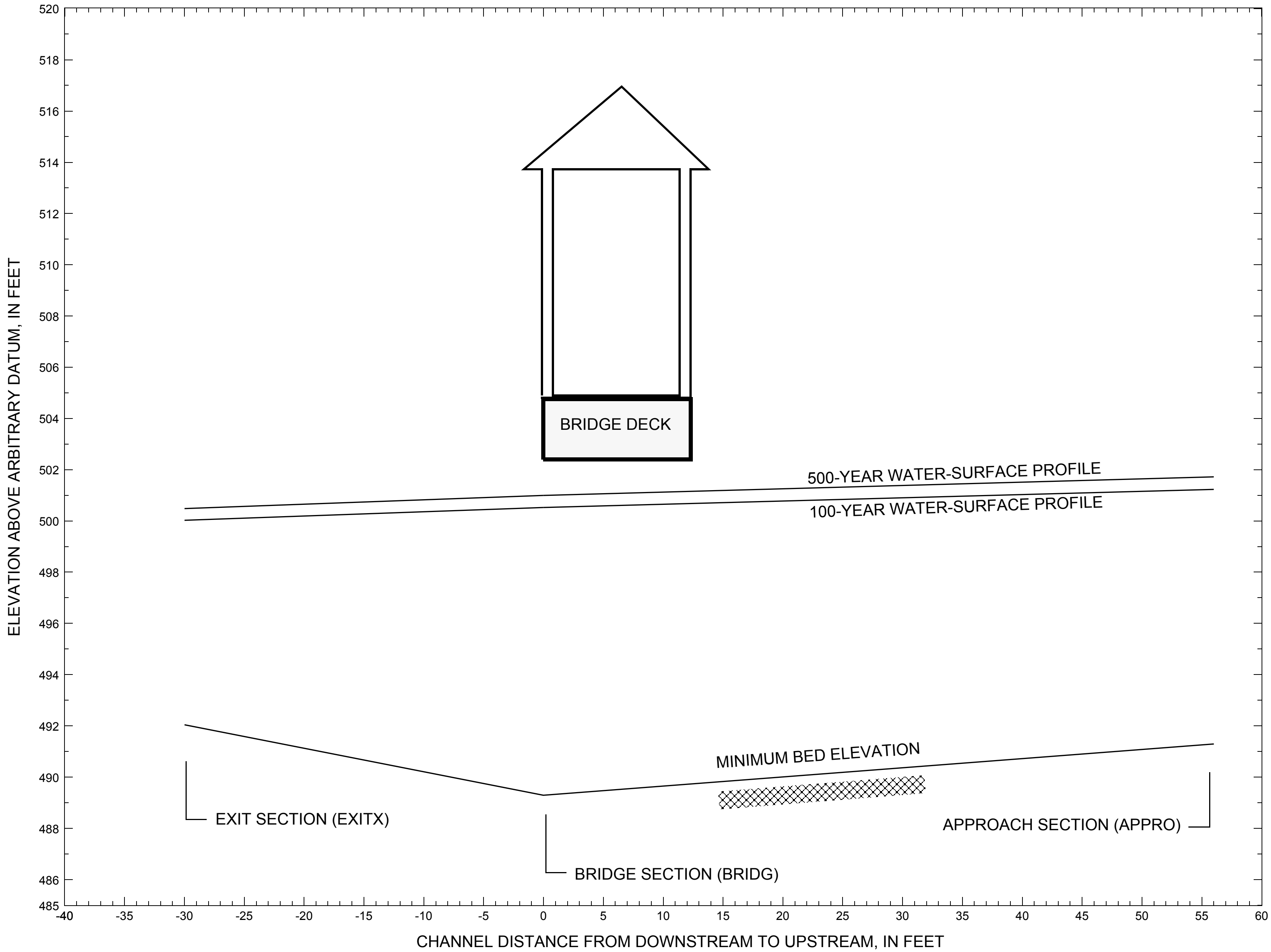

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure WWINTH00370034 on Town Highway 37, crossing Mill Brook, West Windsor, Vermont.

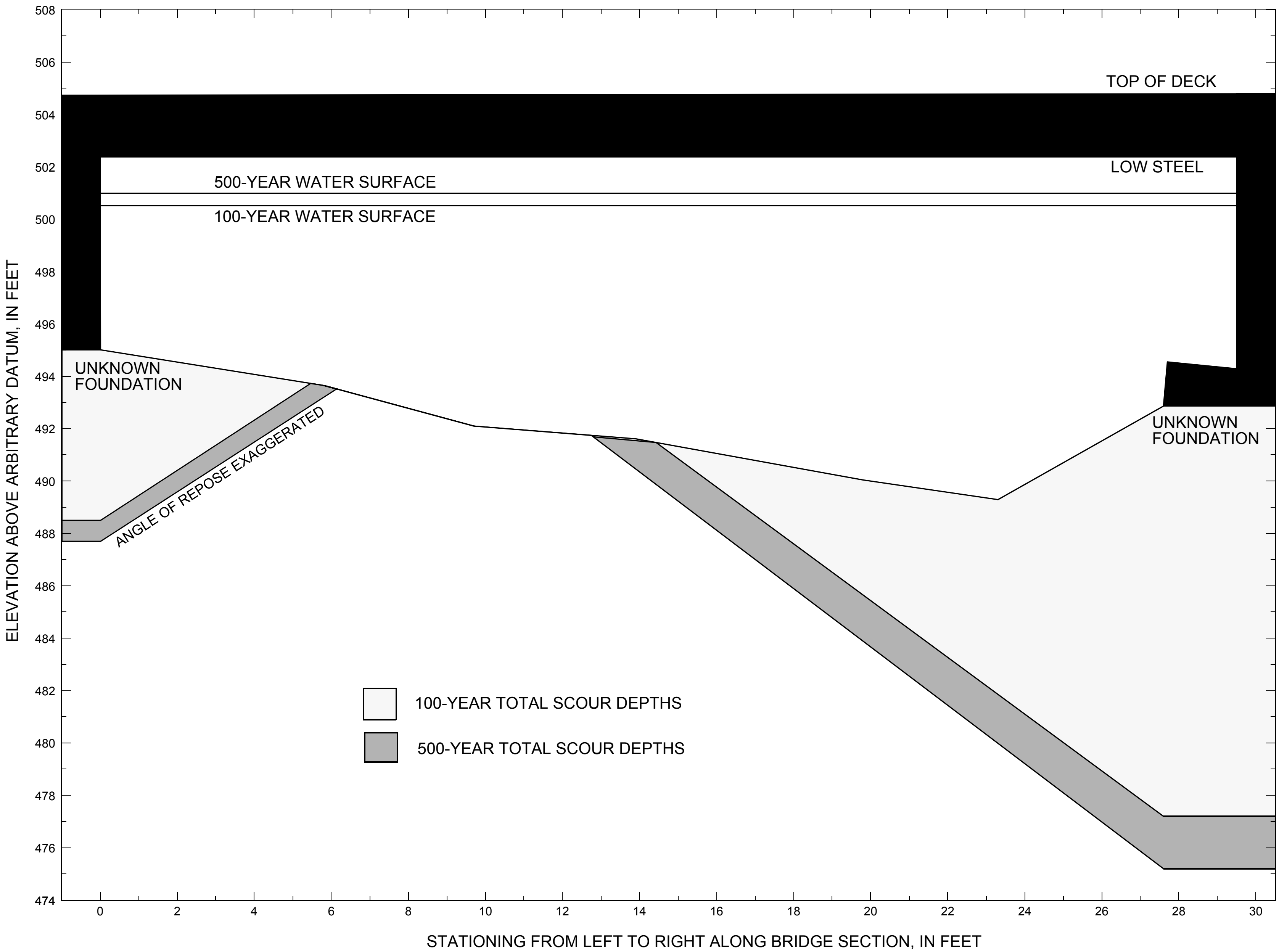

Figure 8. Scour elevations for the 100- and 500-year discharges at structure WWINTH00370034 on Town Highway 37, crossing Mill Brook, West Windsor, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WWINTH00370034 on Town Highway 37, crossing Mill Brook, West Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,500 cubic-feet per second											
Left abutment	0.0	--	502.4	--	495.0	0.0	6.5	--	6.5	488.5	--
Right abutment	29.6	--	502.4	--	492.9	0.0	15.7	--	15.7	477.2	--

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 WWINTH00370034 on Town Highway 37, crossing Mill Brook, West Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 5,200 cubic-feet per second											
Left abutment	0.0	--	502.4	--	495.0	0.0	7.3	--	7.3	487.7	--
Right abutment	29.6	--	502.4	--	492.9	0.0	17.7	--	17.7	475.2	--

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

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U.S. Geological Survey, 1972, Cavendish, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Contour Interval, 20 feet, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1         U.S. Geological Survey WSPRO Input File wwin034.wsp
T2         Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
T3         Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
*
J3          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            3500.0   5200.0   1460.0
SK           0.0029   0.0029   0.0029
*
XS    EXITX    -30
GR          -297.8, 509.16   -283.8, 503.66   -241.5, 500.83   -195.1, 499.83
GR          -161.6, 500.05   -134.3, 499.74    -37.4, 499.34      0.0, 497.70
GR             5.1, 493.27      5.9, 492.41      7.7, 492.04     15.5, 493.05
GR            22.8, 492.95     34.7, 493.13     37.7, 493.63     50.8, 498.61
GR            55.6, 499.65    582.8, 497.99    655.2, 499.25    712.8, 507.72
*
N            0.040        0.045        0.040
SA                    0.0          55.6
*
XS    FULLV      0  * * *  0.0029
*
*              SRD     LSEL    XSSKEW
BR    BRIDG      0    502.40       0.0
GR             0.0, 502.38      0.0, 495.01      5.8, 493.65      9.7, 492.10
GR            13.9, 491.61     19.8, 490.04     23.3, 489.29     27.6, 492.87
GR            27.6, 493.64     27.7, 494.55     29.5, 494.29     29.6, 502.41
GR             0.0, 502.38
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      27.4 * *      52.9      7.6
N            0.035
*
*              SRD    EMBWID   IPAVE
XR    RDWAY      9      12.3     2
GR          -270.1, 509.16   -258.9, 503.66   -216.8, 500.83   -169.8, 499.83
GR          -137.7, 500.05   -129.5, 500.17    -68.0, 500.64
GR           -42.0, 501.96      0.0, 504.73     35.9, 504.79     61.7, 503.31
GR           121.0, 500.79    395.9, 499.43    529.5, 499.72    587.1, 508.19
*
XT    APTEM     47
GR          -190.7, 510.23   -185.9, 506.20   -163.0, 506.65   -154.8, 504.71
GR          -137.4, 504.33    -77.9, 500.14    -28.3, 499.78     -7.9, 500.76
GR            -3.4, 497.67      0.0, 497.15      7.7, 493.61      9.1, 492.98
GR            17.0, 491.92     25.2, 491.21     29.0, 491.49     30.1, 493.64
GR            39.4, 498.30    288.8, 498.94    500.0, 498.94    532.6, 505.80
*            141.5, 500.43    329.4, 500.38    362.0, 507.24
*
AS    APPRO     56  * * * 0.0091
GT
N            0.060        0.045        0.040
SA                   -7.9         39.4
*
HP 1 BRIDG 500.52 1 500.52
HP 2 BRIDG 500.52 * * 1164
HP 2 RDWAY 500.97 * * 2336
HP 1 APPRO 501.23 1 501.23
HP 2 APPRO 501.23 * * 3500
*
HP 1 BRIDG 500.99 1 500.99
HP 2 BRIDG 500.99 * * 1078
HP 2 RDWAY 501.42 * * 4122
HP 1 APPRO 501.72 1 501.72
HP 2 APPRO 501.72 * * 5200
*
HP 1 BRIDG 498.71 1 498.71
HP 2 BRIDG 498.71 * * 1460
HP 1 APPRO 499.59 1 499.59
HP 2 APPRO 499.59 * * 1460
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     250.  33376.    30.    45.                         4118.
   500.52          250.  33376.    30.    45.  1.00     0.    30.   4118.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.52     0.0    29.6   249.8   33376.    1164.   4.66

X STA.         0.0         5.5         7.0         8.4         9.7        10.9
  A(I)             33.8        10.8        10.9        10.4         9.7
  V(I)             1.72        5.40        5.36        5.62        6.00

X STA.        10.9        12.0        13.1        14.2        15.3        16.4
  A(I)             10.0         9.8         9.6        10.1         9.8
  V(I)             5.81        5.94        6.04        5.77        5.95

X STA.        16.4        17.4        18.3        19.3        20.1        21.0
  A(I)              9.8         9.5         9.5         9.2         9.3
  V(I)             5.92        6.14        6.16        6.30        6.28

X STA.        21.0        21.8        22.7        23.5        24.4        29.6
  A(I)              9.0         8.9         9.0         9.7        41.0
  V(I)             6.44        6.52        6.49        5.99        1.42

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.97  -218.9   538.0   534.6   19182.    2336.   4.37

X STA.      -218.9      -166.3      -138.6       -86.1       268.3       296.8
  A(I)             34.1        28.3        35.5        88.8        28.0
  V(I)             3.42        4.13        3.29        1.32        4.17

X STA.       296.8       319.3       338.0       355.0       370.1       379.1
  A(I)             24.9        22.5        22.0        20.7        13.0
  V(I)             4.70        5.18        5.30        5.65        9.02

X STA.       379.1       389.9       404.3       418.9       433.6       448.9
  A(I)             16.1        22.0        22.0        21.7        22.0
  V(I)             7.27        5.32        5.30        5.39        5.31

X STA.       448.9       464.6       480.4       497.0       513.8       538.0
  A(I)             22.1        21.7        22.2        21.9        25.2
  V(I)             5.29        5.37        5.26        5.33        4.63

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      84.   2082.    84.    84.                          476.
             2     319.  35505.    47.    52.                         4700.
             3    1108.  73019.   471.   471.                         9648.
   501.23         1511. 110607.   603.   607.  1.28   -92.   510.  12005.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.23   -92.2   510.5  1511.4  110607.    3500.   2.32

X STA.       -92.2         7.4        12.5        17.0        21.1        25.2
  A(I)            147.8        41.9        39.6        39.1        40.1
  V(I)             1.18        4.18        4.42        4.47        4.36

X STA.        25.2        30.1        44.8        71.8       100.4       129.1
  A(I)             46.3        63.5        75.6        78.2        76.0
  V(I)             3.78        2.76        2.32        2.24        2.30

X STA.       129.1       159.1       191.0       225.7       262.7       301.9
  A(I)             77.3        79.8        83.8        86.1        87.3
  V(I)             2.26        2.19        2.09        2.03        2.00

X STA.       301.9       341.8       382.3       421.1       461.3       510.5
  A(I)             88.0        89.5        85.6        88.8        97.0
  V(I)             1.99        1.95        2.04        1.97        1.80
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     264.  36029.    30.    46.                        4467.
   500.99          264.  36029.    30.    46.  1.00     0.    30.   4467.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.99     0.0    29.6   263.7   36029.    1078.   4.09

X STA.         0.0        5.5        7.0        8.4        9.6       10.8
  A(I)            36.2       11.4       11.1       10.9       10.2
  V(I)            1.49       4.72       4.84       4.95       5.28

X STA.        10.8       11.9       13.0       14.1       15.2       16.3
  A(I)            10.3       10.4       10.4       10.2       10.5
  V(I)            5.22       5.21       5.18       5.30       5.15

X STA.        16.3       17.3       18.2       19.2       20.1       20.9
  A(I)            10.4       10.0       10.0        9.7        9.5
  V(I)            5.20       5.39       5.41       5.54       5.67

X STA.        20.9       21.8       22.6       23.4       24.3       29.6
  A(I)             9.5        9.3        9.4       10.2       44.1
  V(I)            5.70       5.77       5.74       5.26       1.22

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.42  -225.6   541.1   801.6   36252.    4122.   5.14

X STA.      -225.6     -171.4     -145.8     -110.7      171.7      228.3
  A(I)            51.4       38.7       44.2       89.3       57.8
  V(I)            4.01       5.33       4.67       2.31       3.57

X STA.       228.3      264.3      292.6      316.6      338.1      352.8
  A(I)            45.0       39.9       36.9       35.5       25.6
  V(I)            4.58       5.16       5.59       5.81       8.06

X STA.       352.8      368.1      386.5      403.6      420.5      438.2
  A(I)            27.7       35.0       33.7       33.1       33.9
  V(I)            7.43       5.89       6.12       6.23       6.08

X STA.       438.2      455.9      473.9      493.0      512.4      541.1
  A(I)            33.3       33.1       34.5       34.0       39.3
  V(I)            6.19       6.23       5.97       6.07       5.25

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     127.   3932.    91.    91.                         851.
             2     342.  39909.    47.    52.                        5221.
             3    1340.  99819.   473.   474.                       12790.
   501.72         1809. 143661.   612.   617.  1.22   -99.   513.  16011.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.72   -99.2   512.8  1809.0  143661.    5200.   2.87

X STA.       -99.2        5.9       12.3       17.6       22.6       27.5
  A(I)           187.1       53.8       50.2       49.7       50.7
  V(I)            1.39       4.83       5.18       5.23       5.13

X STA.        27.5       37.0       63.0       91.0      119.2      148.3
  A(I)            68.1       87.9       90.6       89.3       90.0
  V(I)            3.82       2.96       2.87       2.91       2.89

X STA.       148.3      178.3      210.2      243.8      279.7      316.5
  A(I)            90.6       93.9       95.9       99.5       99.4
  V(I)            2.87       2.77       2.71       2.61       2.61

X STA.       316.5      353.4      390.3      427.4      464.4      512.8
  A(I)            99.5       99.5      100.0      100.0      113.3
  V(I)            2.61       2.61       2.60       2.60       2.29
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     196.   23617.    30.    41.                        2870.
   498.71          196.   23617.    30.    41.  1.00     0.    30.   2870.

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.71     0.0    29.6   196.2   23617.    1460.   7.44

X STA.         0.0         5.7         7.5         8.9        10.2        11.4
  A(I)            25.0         9.3         8.8         8.5         7.8
  V(I)            2.92        7.81        8.27        8.60        9.30

X STA.        11.4        12.5        13.7        14.8        15.8        16.9
  A(I)             7.9         8.0         7.8         8.0         7.8
  V(I)            9.22        9.10        9.34        9.12        9.37

X STA.        16.9        17.8        18.7        19.6        20.5        21.3
  A(I)             7.8         7.5         7.5         7.4         7.2
  V(I)            9.38        9.69        9.68        9.87       10.08

X STA.        21.3        22.1        22.9        23.6        24.5        29.6
  A(I)             7.2         7.1         7.2         7.9        30.2
  V(I)           10.11       10.21       10.20        9.26        2.41

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     243.   23155.    45.    50.                        3178.
             3     342.   10417.   463.   463.                        1669.
   499.59          585.   33572.   509.   513.  1.99    -6.   503.   2519.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.59    -6.1   502.7   584.7   33572.    1460.   2.50

X STA.        -6.1         7.9        10.3        12.4        14.4        16.3
  A(I)            42.6        15.5        14.2        14.1        14.1
  V(I)            1.71        4.70        5.16        5.19        5.16

X STA.        16.3        18.1        19.9        21.6        23.4        25.1
  A(I)            13.5        14.0        13.8        14.1        13.9
  V(I)            5.40        5.23        5.30        5.18        5.25

X STA.        25.1        26.6        28.3        31.2        46.5        82.3
  A(I)            13.0        13.6        19.2        35.4        41.0
  V(I)            5.61        5.35        3.79        2.06        1.78

X STA.        82.3       124.1       176.0       249.8       375.8       502.7
  A(I)            43.7        48.0        56.2        73.6        71.3
  V(I)            1.67        1.52        1.30        0.99        1.02
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

EXITX:XS   ******  -204.    1152.  0.26 *****  500.27  499.70   3500.  500.02
      -30. ******   660.   64963.  1.80 ***** *******    0.62    3.04

FULLV:FV      30.  -204.    1156.  0.26  0.09  500.36 *******   3500.  500.11
        0.    30.   660.   65197.  1.80  0.00    0.00    0.62    3.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      56.   -78.     930.  0.35  0.18  500.59 *******   3500.  500.24
       56.    56.   506.   57668.  1.58  0.05    0.00    0.65    3.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.94       0.00     499.67     499.43

 ===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      30.     0.     250.  0.35  0.36  500.87  495.70   1164.  500.52
        0.    30.    30.   33390.  1.03  0.24    0.00    0.29    4.66

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.985 ******  502.40 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    44.  0.04  0.11  501.28    0.00   2336.  500.97

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    443.   157.  -219.   -61.   1.1   0.7   4.3   4.2   1.0   2.9
   RT:   1893.   421.   117.   538.   1.5   1.0   5.1   4.4   1.3   2.9

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

APPRO:AS      29.   -92.    1512.  0.11  0.43  501.34  499.94   3500.  501.23
       56.    62.   510.  110669.  1.28  0.03    0.01    0.29    2.31

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.949  0.936    7035.    33.    63. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -30.  -204.   660.   3500.   64963.    1152.    3.04  500.02
   FULLV:FV        0.  -204.   660.   3500.   65197.    1156.    3.03  500.11
   BRIDG:BR        0.     0.    30.   1164.   33390.     250.    4.66  500.52
   RDWAY:RG        9.*******   443.   2336.******************    2.00  500.97
   APPRO:AS       56.   -92.   510.   3500.  110669.    1512.    2.31  501.23

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      33.    63.    7035.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    499.70     0.62  492.04  509.16************  0.26  500.27  500.02
   FULLV:FV  ********     0.62  492.13  509.25  0.09  0.00  0.26  500.36  500.11
   BRIDG:BR    495.70     0.29  489.29  502.41  0.36  0.24  0.35  500.87  500.52
   RDWAY:RG  ****************  499.43  509.16  0.04******  0.11  501.28  500.97
   APPRO:AS    499.94     0.29  491.29  510.31  0.43  0.03  0.11  501.34  501.23
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

EXITX:XS   ******  -225.    1563.  0.26 *****  500.74  500.04   5200.  500.48
      -30. ******   664.   96487.  1.51 ***** *******    0.54    3.33

FULLV:FV      30.  -226.    1565.  0.26  0.09  500.83 *******   5200.  500.57
        0.    30.   664.   96683.  1.51  0.00    0.00    0.54    3.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      56.   -85.    1189.  0.42  0.20  501.11 *******   5200.  500.69
       56.    56.   508.   79189.  1.40  0.08    0.00    0.64    4.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   507.35       0.00     501.95     499.43

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===225 NO ENERGY BALANCE IN 15 ITERATIONS.
                    FLOW,Q =    4       779.
              WS1,WSSD,WS3 =   501.64       0.00     501.02

 ===235 CONTINUE FLOW CLASS 4 COMPUTATIONS.
                    ITER,QRD =    5      4421.
              WS,WSMIN,WSMAX =   501.81     501.47     502.15

            <<<<<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      30.     0.     264.  0.27  0.40  501.26  495.53   1078.  500.99
        0.    30.    30.   36012.  1.05  0.12    0.00    0.25    4.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.977 ******  502.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    44.  0.06  0.16  501.82    0.00   4122.  501.42

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    895.   173.  -226.   -53.   1.6   1.0   5.4   4.9   1.4   3.0
   RT:   3227.   435.   106.   541.   2.0   1.4   6.1   5.2   1.8   3.0

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

APPRO:AS      29.   -99.    1812.  0.16  0.59  501.88  500.32   5200.  501.72
       56.    68.   513.  143975.  1.21  0.02   -0.02    0.32    2.87

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.950  0.947    7737.    79.    109. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.  -225.   664.   5200.   96487.    1563.    3.33  500.48
   FULLV:FV       0.  -226.   664.   5200.   96683.    1565.    3.32  500.57
   BRIDG:BR       0.     0.    30.   1078.   36012.     264.    4.09  500.99
   RDWAY:RG       9.*******   895.   4122.*****************    2.00  501.42
   APPRO:AS      56.   -99.   513.   5200.  143975.    1812.    2.87  501.72

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      79.   109.    7737.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    500.04    0.54  492.04  509.16************  0.26  500.74  500.48
   FULLV:FV  ********    0.54  492.13  509.25  0.09  0.00  0.26  500.83  500.57
   BRIDG:BR    495.53    0.25  489.29  502.41  0.40  0.12  0.27  501.26  500.99
   RDWAY:RG  ****************  499.43  509.16  0.06******  0.16  501.82  501.42
   APPRO:AS    500.32    0.32  491.29  510.31  0.59  0.02  0.16  501.88  501.72
```
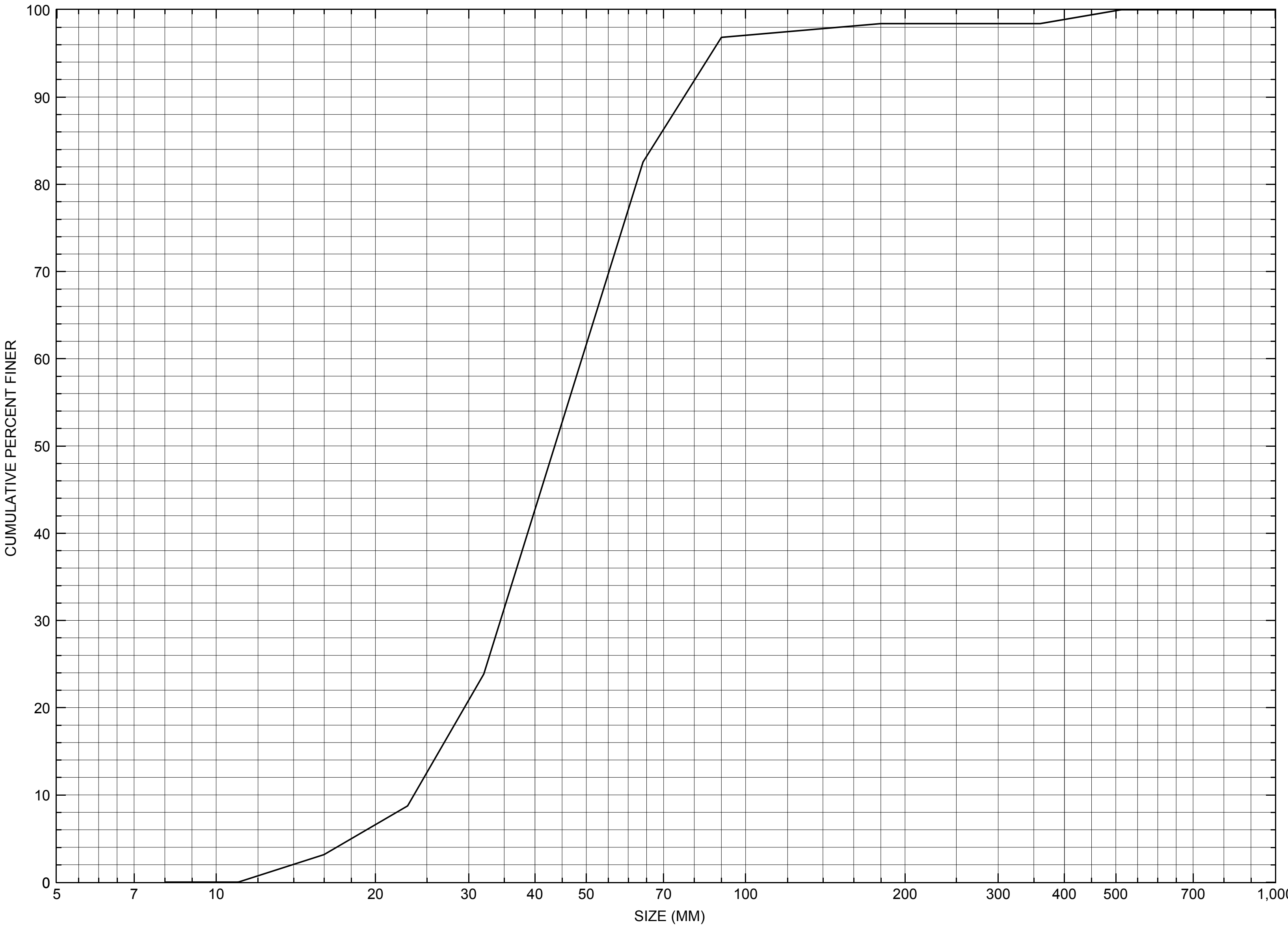

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wwin034.wsp
        Hydraulic analysis for structure WWINTH00370034   Date: 04-NOV-97
        Town Highway 37 crossing Mill Brook, West Windsor, Vermont      EMB
           *** RUN DATE & TIME: 06-29-98  13:23

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

EXITX:XS   ******   -28.     436.  0.32 *****  499.25  496.71   1460.  498.93
      -30. ******   637.   27087.  1.82 ***** *******    0.80    3.35

FULLV:FV      30.   -28.     440.  0.31  0.09  499.34 *******   1460.  499.03
        0.    30.   638.   27267.  1.83  0.00    0.01    0.79    3.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.19     499.14     497.02

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.53     510.31    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.53     510.31     497.02

APPRO:AS      56.    -5.     352.  0.50  0.20  499.63  497.02   1460.  499.13
       56.    56.   501.   22265.  1.88  0.09    0.00    1.20    4.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.59       0.00     498.71     499.43

 ===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      30.     0.     196.  0.86  0.10  499.57  496.31   1460.  498.71
        0.    30.    30.   23624.  1.00  0.22    0.00    0.51    7.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  502.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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      29.    -6.     585.  0.19  0.11  499.78  497.02   1460.  499.59
       56.    40.   503.   33571.  1.99  0.10    0.01    0.58    2.50

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.942  0.303   23260.     4.     34. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.   -28.   637.   1460.   27087.     436.    3.35  498.93
   FULLV:FV       0.   -28.   638.   1460.   27267.     440.    3.31  499.03
   BRIDG:BR       0.     0.    30.   1460.   23624.     196.    7.44  498.71
   RDWAY:RG       9.**************      0.       0.       0.    2.00********
   APPRO:AS      56.    -6.   503.   1460.   33571.     585.    2.50  499.59

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       4.    34.   23260.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    496.71    0.80  492.04  509.16************  0.32  499.25  498.93
   FULLV:FV  ********    0.79  492.13  509.25  0.09  0.00  0.31  499.34  499.03
   BRIDG:BR    496.31    0.51  489.29  502.41  0.10  0.22  0.86  499.57  498.71
   RDWAY:RG  ****************  499.43  509.16  0.08******  0.20  499.69********
   APPRO:AS    497.02    0.58  491.29  510.31  0.11  0.10  0.19  499.78  499.59
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WWINTH00370034, in West Windsor, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WWINTH00370034

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 TH037

Vicinity *(I - 9)* 0.06 MI TO JCT W VT44

Topographic Map Cavendish

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 43277

Longitude *(i - 17; nnnnn.n)* 72293

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142200341422

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

Maximum span length *(I - 48; nnnn)* 0032

Year built *(I - 27; YYYY)* 1890

Structure length *(I - 49; nnnnnn)* 000037

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

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

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

Channel & Protection *(I - 61; n)* 8

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*) 011.5

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 creosote treated timber, thru-truss type covered bridge. The abutments are constructed of "laid-up" stone walls with concrete facing, while the four wingwalls are "laid-up" stone. The concrete reportedly is in "like new" condition. The foundation type recorded for the abutments is an unknown foundation. Hence, the report indicates no footing exposure or undermining is evident. The abutment walls are protected well with riprap. The report mentions that no problems with channel scour, bank erosion, or debris accumulation are evident. The waterway makes a moderate bend into the crossing. The streambed material is **(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:

noted as consisting of stone and gravel with a few boulders. A shallow sand point bar has developed along the left abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.58** mi^2

Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **779** ft

Headwater elevation **2290** ft

Main channel length **8.57** mi

10% channel length elevation **800** ft

85% channel length elevation **1720** ft

Main channel slope *(S)* **143.13** 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	30.5	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low chord elevation	770.9	770.9	770.9	770.9	770.9	770.9	-	-	-	-	-
Bed elevation	763.8	761.6	760.0	759.7	759.6	760.3	-	-	-	-	-
Low chord to bed	7.1	9.3	10.9	11.2	11.3	10.6	-	-	-	-	-

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: **JRD** Date: **5/28/97**
Computerized by: **ECW** Date: **6/97**
Reviewd by: **EMB** Date: **9/1/98**

Structure Number **WWINTH00370034**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. Burns** Date *(MM/DD/YY)* **06** / **05** / 19**96**

2. Highway District Number **04** Mile marker **0**

County **Windsor (027)** Town **West Windsor (83050)**

Waterway *(I - 6)* **Mill Brook** Road Name **-**

Route Number **TH 37** Hydrologic Unit Code: **01080104**

3. Descriptive comments:

This structure is located six hundredths of a mile from a junction with State Route 44. The structure is a covered bridge with concrete faced abutments and laid up stone wingwalls.

B. Bridge Deck Observations

4. Surface cover... LBUS **5** 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 **37** *(feet)* Span length **32** *(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)*

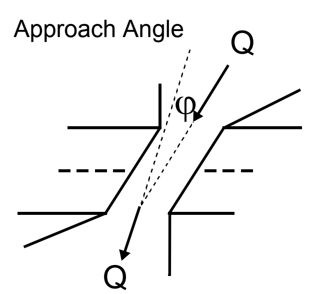
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

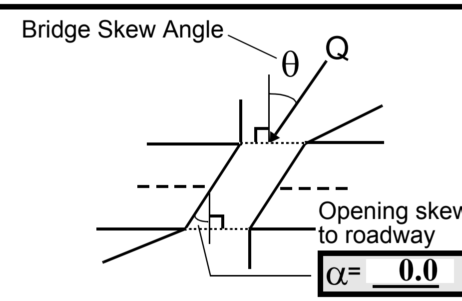
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **55** 16. Bridge skew: **10**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **18** feet **US** *(US, UB, DS)* to **49** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **30** feet **DS** *(US, UB, DS)* to **50** feet **DS**

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

18. Bridge Type: 1a

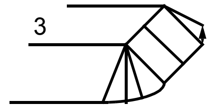
1a- Vertical abutments with wingwalls

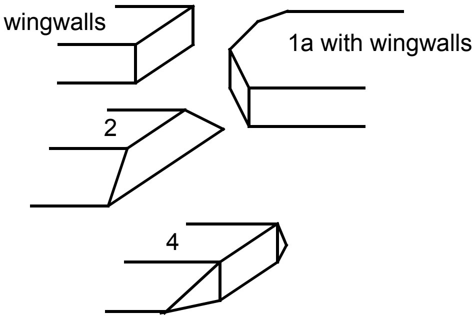
1b- Vertical abutments without wingwalls

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.)

4. The upstream left bank surface cover includes shrubs, brush, a barn and a dirt road entering the stream. The upstream right bank has trees along the bank, and a continuation of the road from the left bank into the pasture. The downstream left bank has trees along the bank and a house with a lawn beyond two bridge lengths. The downstream right bank has shrubs along the bank and a dirt road paralleling the stream through the pasture.

7. The measured bridge length is 38 feet, the span length is 30.5 feet, and the width is 12.4 feet.

8. The left road approach slopes down from the bridge and back up towards state route 44.

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
39.5	7.0			4.5	2	3	23	23	1	0

23. Bank width 25.0 24. Channel width 25.0 25. Thalweg depth 47.5 29. Bed Material 32

30 .Bank protection type: LB 0 RB 3 31. Bank protection condition: LB - RB 1

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

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

30. The right bank protection extends from fifty seven feet upstream to the upstream right wing wall. The dirt road crosses the stream one hundred and ten feet upstream of the structure.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **27** 35. Mid-bar width: **5**

36. Point bar extent: **36** feet **US** (US, UB) to **6** feet **DS** (US, UB, DS) positioned **0** %LB to **15** %RB

37. Material: **2**

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

The point bar is vegetated except for the portion under the bridge.

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: **4**

47. Scour dimensions: Length **72** Width **11** Depth : **2.5** Position **60** %LB to **100** %RB

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

The scour hole extends from 40 feet upstream to 20 feet downstream. The scour depth is based on a 1.5 foot average thalweg depth measured elsewhere in the upstream reach.

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
22.5		**2.5**		**2**	**7**	**7**	**-**

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

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

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

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

23

-

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

70. Debris and Ice Comments:

2

67. The vine and dead trees along the banks contribute to the debris potential.

68. The bend in the upstream reach increases the capture efficiency.

69. Trees on the upstream right bank have ice scaring.

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		-	90	2	0	-	-	90.0
RABUT	1	10	90			2	1	29.5

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.):

1.5

0

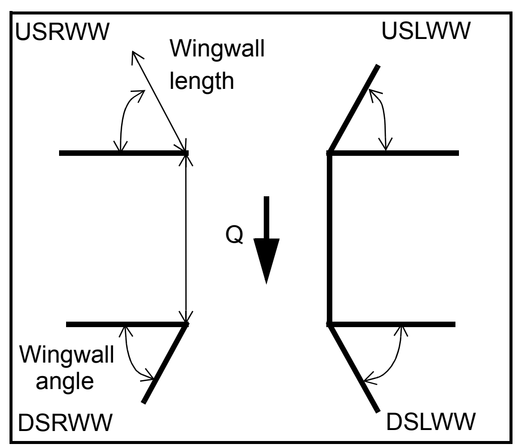
1

74. The scour condition noted along the right abutment is a result of the scour hole explained in the upstream channel assessment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						29.5	
USRWW:	Y		2		0	3.5	
DSLWW:	-		-		Y	17.5	
DSRWW:	2		1		2.5	17.5	

*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	0	Y	1.5	-	1	-	1
Condition	Y	-	2	0	-	2	-	1
Extent	2	-	1	0	4	-	3	-

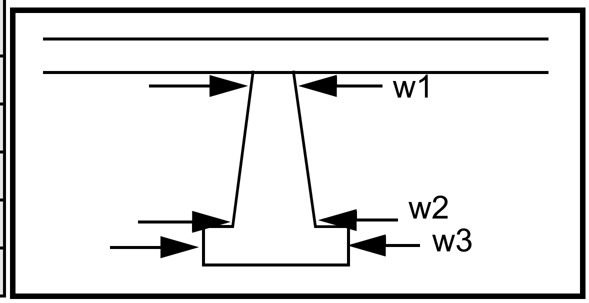
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **80.** *(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				**55.0**	**13.0**	**50.0**
Pier 2				**12.5**	**50.0**	**12.5**
Pier 3			-	**55.0**	**12.5**	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**describ**	**left**	**was**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**scou**	**ed in**	**abut**	**foun**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**r**	**the**	**ment**	**d by**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**hole**	**upst**	**pro-**	**prob**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**at**	**ream**	**tec-**	**ing**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**chan**	**tion**	**with**	
92. Pushed	**right**	**nel**	**is**	**a**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**wing**	**asses**	**cov-**	**rang**	
95. Cross-members	**walls**	**smen**	**ered**	**e**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**is the**	**t.**	**in**	**pole.**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**same**	**82.**	**sand,**		
98. Exposure depth	**one**	**The**	**and**		

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

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.):

-
-
NO PIERS

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

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

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

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

1
1
23
23

Is channel scour present? **2** (Y or if N type ctrl-n cs) Mid-scour distance: **1**

Scour dimensions: Length **342** Width **0** Depth: **0** Positioned - %LB to - %RB

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

There is a large tree, 30 feet downstream on the left bank that is being undermined, up to 1 foot horizontally.

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

Y

60

16

30

DS

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:	WWINTH00370034	Town:	West Windsor
Road Number:	TH 37	County:	Windsor
Stream:	Mill Brook		

Initials EMB   Date: 7/17/98 Checked: ECW

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 Davis, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3500	5200	1460
Main Channel Area, ft2	319	342	243
Left overbank area, ft2	84	127	0
Right overbank area, ft2	1108	1340	342
Top width main channel, ft	47	47	45
Top width L overbank, ft	84	91	0
Top width R overbank, ft	471	473	463
D50 of channel, ft	0.142	0.142	0.142
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.8	7.3	5.4
y1, average depth, LOB, ft	1.0	1.4	ERR
y1, average depth, ROB, ft	2.4	2.8	0.7
Total conveyance, approach	110607	143661	33572
Conveyance, main channel	35505	39909	23155
Conveyance, LOB	2082	3932	0
Conveyance, ROB	73019	99819	10417
Percent discrepancy, conveyance	0.0009	0.0007	0.0000
Qm, discharge, MC, cfs	1123.5	1444.6	1007.0
Ql, discharge, LOB, cfs	65.9	142.3	0.0
Qr, discharge, ROB, cfs	2310.6	3613.1	453.0
Vm, mean velocity MC, ft/s	3.5	4.2	4.1
Vl, mean velocity, LOB, ft/s	0.8	1.1	ERR
Vr, mean velocity, ROB, ft/s	2.1	2.7	1.3
Vc-m, crit. velocity, MC, ft/s	8.0	8.1	7.7
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

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	1164	1078	1460
Main channel area (DS), ft2	249.8	263.7	196.2
Main channel width (normal), ft	29.6	29.6	29.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.6	29.6	29.6
D90, ft	0.2509	0.2509	0.2509
D95, ft	0.2827	0.2827	0.2827
Dc, critical grain size, ft	0.0605	0.0457	0.1675
Pc, Decimal percent coarser than Dc	0.947	0.980	0.363
Depth to armoring, ft	0.01	0.00	0.88

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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3500	5200	1460
(Q) discharge thru bridge, cfs	1164	1078	1460
Main channel conveyance	33376	36029	23617
Total conveyance	33376	36029	23617
Q2, bridge MC discharge,cfs	1164	1078	1460
Main channel area, ft2	250	264	196
Main channel width (normal), ft	29.6	29.6	29.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.6	29.6	29.6
y_bridge (avg. depth at br.), ft	8.44	8.91	6.63
Dm, median (1.25*D50), ft	0.1775	0.1775	0.1775
y2, depth in contraction,ft	4.72	4.42	5.73
ys, scour depth (y2-ybridge), ft	-3.72	-4.49	-0.90

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3500	5200	1460	3500	5200	1460
a', abut.length blocking flow, ft	92.2	99.2	6.1	480.9	483.2	473.1
Ae, area of blocked flow ft2	121.1	143.2	18.6	737	776.6	379.8
Qe, discharge blocked abut.,cfs	--	--	31.8	--	--	551.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.18	1.39	1.71	2.13	2.74	1.45
ya, depth of f/p flow, ft	1.31	1.44	3.05	1.53	1.61	0.80
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	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	0.171	0.184	0.173	0.241	0.283	0.285
ys, scour depth, ft	**6.49**	**7.34**	**5.67**	**15.72**	**17.72**	**11.61**

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	92.2	99.2	6.1	480.9	483.2	473.1
y1 (depth f/p flow, ft)	1.31	1.44	3.05	1.53	1.61	0.80
a'/y1	70.20	68.72	2.00	313.79	300.65	589.32
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.17	0.18	0.17	0.24	0.28	0.29
Ys w/ corr. factor K1/0.55:						
vertical	5.33	6.01	ERR	6.97	7.71	3.86
vertical w/ ww's	4.37	4.92	ERR	5.71	6.32	3.17
spill-through	2.93	3.30	ERR	3.83	4.24	2.12

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.29	0.25	0.51	0.29	0.25	0.51
y, depth of flow in bridge, ft	8.44	8.91	6.63	8.44	8.91	6.63
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.44	0.34	1.07	0.44	0.34	1.07
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR