LEVEL II SCOUR ANALYSIS FOR BRIDGE 27 (READTH00380027) on TOWN HIGHWAY 38, crossing the NORTH BRANCH BLACK RIVER, READING, VERMONT

Open-File Report 98-379

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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By MICHAEL A. IVANOFF AND MATTHEW A. WEBER

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Pembroke, New Hampshire

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

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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 27 (READTH00380027) ON TOWN HIGHWAY 38, CROSSING THE NORTH BRANCH BLACK RIVER, READING, VERMONT

By **Michael A. Ivanoff and Matthew A. Weber**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure READTH00380027 on Town Highway 38 crossing the North Branch Black River, Reading, 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 eastern Vermont. The 9.08-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the North Branch Black River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 66 ft and an average bank height of 8 ft. The channel bed material ranges from gravel to cobble with a median grain size (D_{50}) of 66.9 mm (0.220 ft). The geomorphic assessment at the time of the Level I site visit on March 29, 1995 and the Level II site visit on October 12, 1995, indicated that the reach was laterally unstable with moderate to severe fluvial bank erosion.

The Town Highway 38 crossing of the North Branch Black River is a 36-ft-long, two-lane bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, March 9, 1995). The opening length of the structure parallel to the bridge face is 26.5 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was observed along the left abutment and the downstream left wingwall during the Level I assessment. The footing was undermined along the left abutment and the downstream left wingwall. The scour protection measures at the site include type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall and along the entire base length of the upstream left wingwall and type-1 stone fill (less than 12 inches diameter) along the upstream left and right banks and the downstream left and right banks. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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.

Contraction scour for all modelled flows ranged from 0.0 to 3.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.9 to 17.4 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.

Cavendish, VT. Quadrangle, 1:24,000, 1972
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 READTH00380027 ***Stream*** North Branch Black River

County Windsor ***Road*** TH 38 ***District*** 4

Description of Bridge

Bridge length 36.0 ***ft*** ***Bridge width*** 14.0 ***ft*** ***Max span length*** 35.0 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 3/29/95

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

Abutments and wingwalls are concrete. There is a two ft deep scour hole in front of the left abutment and downstream left wingwall. The left abutment and downstream left wingwall footing is undermined 1.0 ft.

Yes 45

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

There is a mild channel bend in the upstream reach.

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	3/29/95	0	0
Level II	10/12/95	0	0

Potential for debris Moderate. The banks are well vegetated.

None as of 3/29/95.

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

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 3/29/95

DS left: Steep channel bank to an irregular overbank.

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

US left: Steep channel bank to an overbank.

US right: Steep channel bank to an irregular overbank.

Description of the Channel

Average top width 66 ***ft*** ***Average depth*** 8 ***ft***

Predominant bed material Gravel/Cobbles ***Bank material*** Gravel/Cobbles

Sinuous, neither braided nor anabranched with semi-alluvial channel boundaries.

3/29/95

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Trees and brush.

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

There is moderate to severe fluvial erosion along the upstream and downstream banks.

None as of 3/29/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 9.08 ***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***: None.

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 2,300 ***ft³/s*** ***Q500*** 3,400 ***ft³/s***

The 100- and 500-year discharges were extrapolated from the values obtained from the VTAOT database for this site. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.90 ft, arbitrary survey datum). RM2 is a nail 5 ft high on an oak tree 125 ft upstream and 10 ft left bankward of the left abutment (elev. 504.75 ft, arbitrary survey datum). RM3 is a chiseled X on top of the downstream end of the left abutment (elev. 496.24 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITA	-147	3	Exit section(overbanks added from EXITX)
EXITX	-31	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	48	1	Approach section

[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 0.045 to 0.065, and overbank "n" values ranged from 0.040 to 0.070.

Critical depth at the downstream exit section (EXITA) was assumed as the starting water surface. Normal depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990), and resulted in a supercritical solution. Because normal depth was within 0.2 ft of critical depth, the critical water surface was assumed to be a satisfactory starting water surface. The slope used was 0.030 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1972).

The approach section (APPRO) was surveyed 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 499.8 ***ft***
Average low steel elevation 498.0 ***ft***

100-year discharge 2,300 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 209 ***ft³/s***
Area of flow in bridge opening 203 ***ft²***
Average velocity in bridge opening 10.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 20.8 ***ft/s***

Water-surface elevation at Approach section with bridge 501.3
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 4.4 ***ft***

500-year discharge 3,400 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 710 ***ft³/s***
Area of flow in bridge opening 204 ***ft²***
Average velocity in bridge opening 13.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.8 ***/s***

Water-surface elevation at Approach section with bridge 502.3
Water-surface elevation at Approach section without bridge 498.0
Amount of backwater caused by bridge 4.3 ***ft***

Incipient overtopping discharge 1,740 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Area of flow in bridge opening 204 ***ft²***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.5 ***ft/s***

Water-surface elevation at Approach section with bridge 499.8
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 3.7 ***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.

At this site, each modeled discharge resulted in orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and 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 also was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, for those discharges resulting in unsubmerged orifice flow, the 100-year and incipient road-overtopping discharges, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these alternative computations are provided in appendix F.

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 all modelled discharges at the left abutment and for the 100-year and 500-year discharges at the right abutment. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) is applicable generally when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Since the equation was developed from U.S. Army Corps. of Engineers' data for spur dikes in the Mississippi River, the HIRE equation was not adopted for the narrow, incised, upland valley at this site.

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	1.4	3.7	0.0
Depth to armoring	37.2	28.1	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	14.6	17.4	11.3
Right abutment	6.9	9.5	8.7
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	2.5	3.1	2.2
Right abutment	2.5	3.1	2.2
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

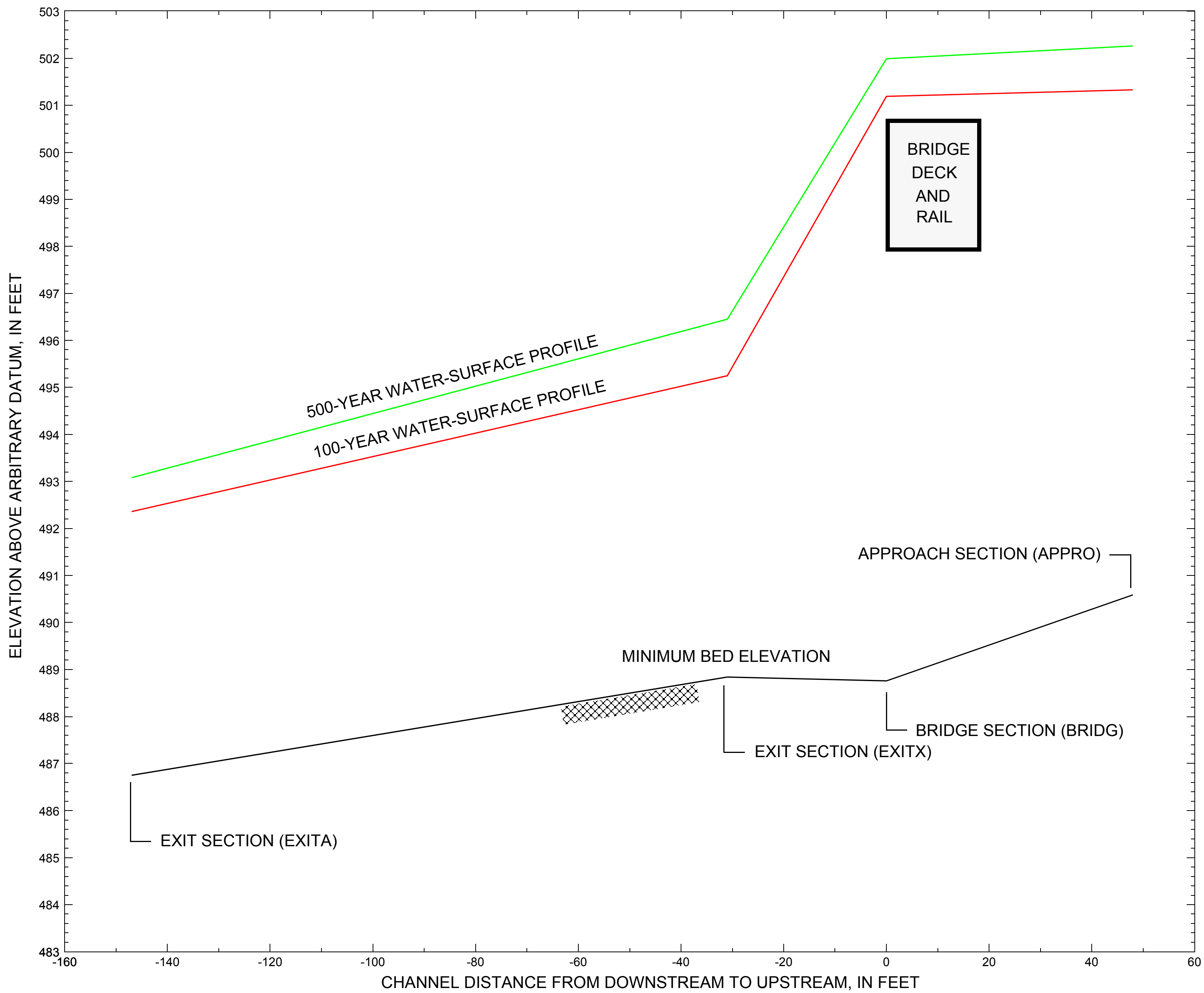

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure READTH00380027 on Town Highway 38, crossing the North Branch Black River, Reading, Vermont.

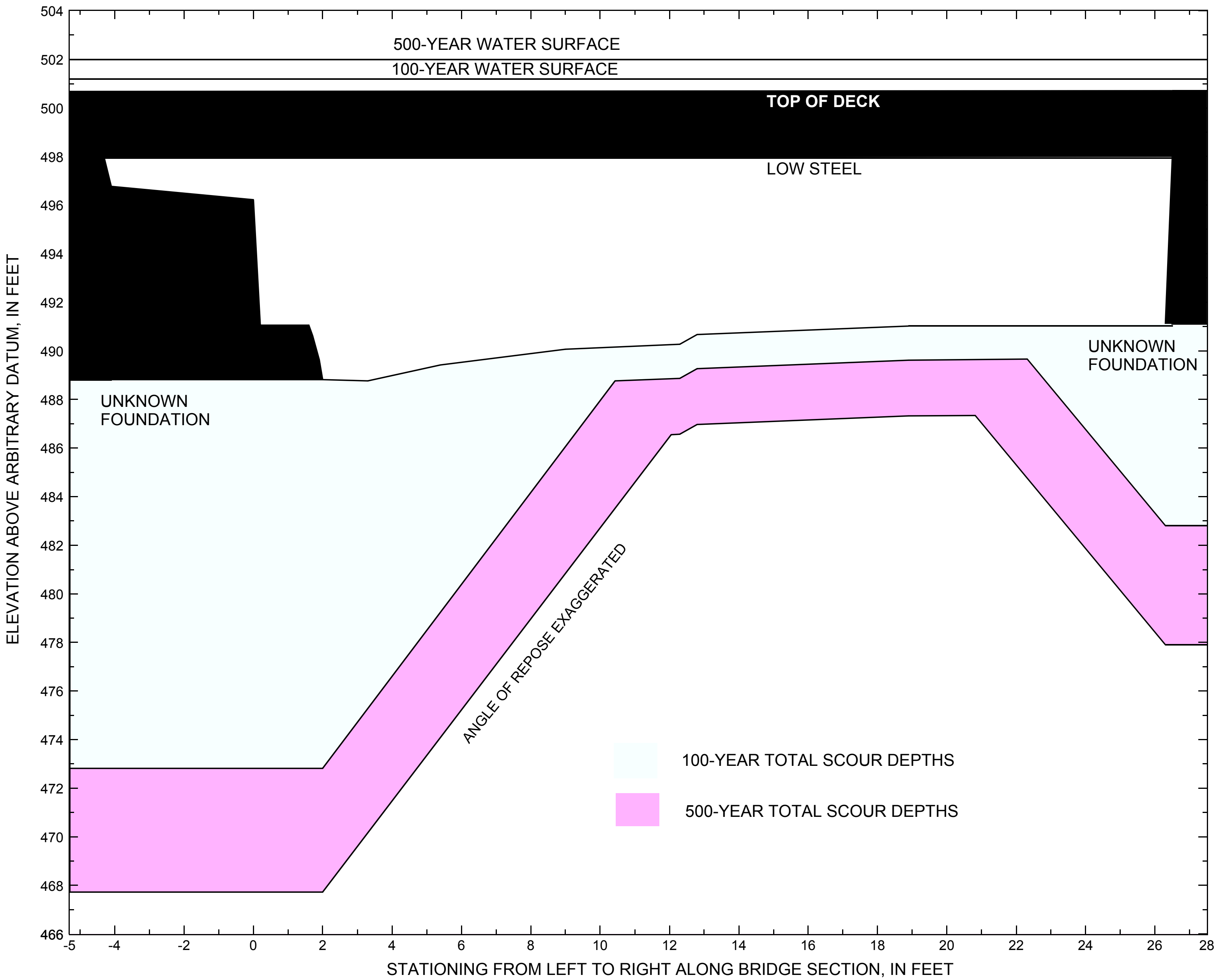

Figure 8. Scour elevations for the 100- and 500-year discharges at structure READTH00380027 on Town Highway 38, crossing the North Branch Black River, Reading, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure READTH00380027 on Town Highway 38, crossing the North Branch Black River, Reading, 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 2,300 cubic-feet per second											
Left abutment	0.0	--	497.9	--	488.8	1.4	14.6	--	16.0	472.8	--
Right abutment	26.5	--	498.0	--	491.1	1.4	6.9	--	8.3	482.8	--

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 READTH00380027 on Town Highway 38, crossing the North Branch Black River, Reading, 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 3,400 cubic-feet per second											
Left abutment	0.0	--	497.9	--	488.8	3.7	17.4	--	21.1	467.7	--
Right abutment	26.5	--	498.0	--	491.1	3.7	9.5	--	13.2	477.9	--

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, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File read027.wsp
T2        Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
T3        Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2300.0   3400.0   1740.0
SK          0.030    0.030    0.030
*
XS   EXITA    -147
GR         -102.4, 504.23    -49.4, 500.07    -22.1, 501.42
GR            0.0, 491.80      5.9, 487.65      7.4, 487.19     12.3, 487.00
GR           17.0, 486.82     24.7, 486.75     28.9, 487.63     32.2, 487.61
GR           38.3, 490.11     49.4, 490.11     54.2, 490.92     61.3, 489.83
GR          102.2, 492.18    115.8, 498.97
*
N            0.070       0.065        0.055
SA                 -22.1       38.3
*
XS   EXITX    -31
GR         -102.4, 507.54    -49.4, 503.38    -22.1, 504.73      0.0, 495.11
GR            6.5, 491.26     12.3, 490.14     13.2, 489.76     21.4, 489.27
GR           27.1, 488.84     35.6, 489.83     38.3, 490.10     43.3, 491.35
GR           49.4, 495.13     54.2, 495.94     61.3, 494.85    102.2, 497.20
GR          115.8, 503.99    145.5, 505.52    235.3, 517.23    262.4, 528.47
N           0.065       0.055
SA                  49.4
*
XS   FULLV      0  * * *   0.00
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.95       5.0
GR           -4.3, 497.93     -4.1, 496.77      0.0, 496.22      0.2, 491.06
GR            1.6, 491.06      1.7, 490.66      1.9, 489.63      2.0, 488.82
GR            3.3, 488.76      5.4, 489.42      9.0, 490.07     12.3, 490.27
GR           12.8, 490.67     18.9, 491.02     26.3, 491.11     26.5, 497.89
GR           26.5, 497.98     -4.3, 497.93
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      22.3 * *     38.0      5.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      14.0     2
GR         -141.3, 508.39    -49.5, 502.38    -11.2, 499.97     -7.8, 499.77
GR           -7.7, 500.67      0.0, 500.68     26.4, 500.71     27.4, 500.71
GR           27.5, 499.89     74.4, 501.92
GR          115.8, 503.99    145.5, 505.52    235.3, 517.23    262.4, 528.47
*
*    At the incipient discharge, flow remains within the approach channel.
AS   APPRO     48
GR         -115.5, 510.72   -102.9, 498.99    -30.2, 498.74    -21.9, 499.09
GR          -16.4, 498.45     -7.8, 493.06      0.0, 492.13      7.9, 491.59
GR            9.8, 491.07     12.6, 490.83     15.4, 490.59     18.1, 490.80
GR           20.9, 491.52     28.2, 492.29     36.8, 499.02     39.2, 500.27
GR           66.0, 500.80    157.6, 500.99    185.5, 509.51    223.8, 526.19
*           90.6, 498.42
N           0.040       0.055        0.055
SA                  -21.9        39.2
*
HP 1 BRIDG 497.95 1 497.95
HP 2 BRIDG 497.95 * * 2092
HP 1 BRIDG 496.56 1 496.56
HP 2 RDWAY 501.19 * * 209
HP 1 APPRO 501.33 1 501.33
HP 2 APPRO 501.33 * * 2300
*
HP 1 BRIDG 497.98 1 497.98
HP 2 BRIDG 497.98 * * 2689
HP 2 RDWAY 501.99 * * 710
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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U.S. Geological Survey WSPRO Input File read027.wsp
Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
   *** RUN DATE & TIME: 06-12-98  09:10

 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     203.   15569.    18.    58.                        3834.
497.95          203.   15569.    18.    58.  1.00    -4.    27.   3834.

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    497.95    -4.3    26.5   203.3   15569.    2092.  10.29

X STA.       -4.3        5.6        6.7        7.8        8.7        9.5
  A(I)            51.2        9.3        9.4        7.0        6.5
  V(I)            2.04      11.20      11.08      14.98      16.19

X STA.        9.5       10.4       11.2       12.1       13.0       13.7
  A(I)             6.5        6.5        6.7        7.1        5.0
  V(I)           16.06      16.09      15.71      14.68      20.78

X STA.       13.7       14.6       15.7       16.8       18.0       19.1
  A(I)             6.3        8.1        7.7        7.9        7.7
  V(I)           16.49      12.93      13.54      13.28      13.63

X STA.       19.1       20.2       21.3       22.4       23.5       26.5
  A(I)             7.7        7.5        7.7        7.3       20.1
  V(I)           13.66      13.92      13.62      14.33       5.20

 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     161.   13205.    29.    41.                        2159.
496.56          161.   13205.    29.    41.  1.00    -3.    26.   2159.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

      WSEL     LEW     REW    AREA        K        Q    VEL
    501.19   -30.6    57.5    53.5     898.     209.   3.90

X STA.      -30.6      -18.2      -15.6      -13.5      -11.8      -10.1
  A(I)             4.9        2.2        2.1        2.0        2.0
  V(I)            2.15       4.80       4.95       5.18       5.22

X STA.      -10.1       -8.7       -4.9        1.4        7.7       14.2
  A(I)             2.0        2.7        3.2        3.2        3.2
  V(I)            5.35       3.82       3.25       3.28       3.22

X STA.       14.2       20.7       27.4       29.2       31.0       32.9
  A(I)             3.2        3.2        2.3        2.1        2.1
  V(I)            3.29       3.24       4.55       5.07       4.97

X STA.       32.9       35.0       37.3       40.2       44.0       57.5
  A(I)             2.2        2.2        2.3        2.6        4.0
  V(I)            4.85       4.81       4.52       4.07       2.63

 CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     202.   13480.    84.    84.                        1785.
          2     462.   45914.    61.    66.                        7200.
          3      61.    1065.   120.   120.                         249.
501.33          725.   60459.   264.   270.  1.22  -105.   159.   6162.

 VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

      WSEL     LEW     REW    AREA        K        Q    VEL
    501.33  -105.4   158.7   725.1   60459.    2300.   3.17

X STA.     -105.4      -83.7      -64.9      -47.3      -30.3       -9.1
  A(I)            48.4       46.0       44.1       43.4       72.0
  V(I)            2.37       2.50       2.61       2.65       1.60

X STA.       -9.1       -5.6       -2.5        0.3        3.1        5.6
  A(I)            28.8       26.8       26.0       25.4       24.3
  V(I)            3.99       4.30       4.42       4.53       4.73

X STA.        5.6        8.3       10.8       13.2       15.6       17.8
  A(I)            25.4       25.8       25.4       24.8       24.4
  V(I)            4.53       4.46       4.52       4.64       4.72

X STA.       17.8       20.2       22.9       25.5       28.4      158.7
  A(I)            24.7       25.6       25.0       26.0      112.8
  V(I)            4.66       4.49       4.60       4.41       1.02
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      U.S. Geological Survey WSPRO Input File read027.wsp
      Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
      Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
         *** RUN DATE & TIME: 06-12-98  09:10

  CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     204.  12974.     0.    76.                           0.
 497.98          204.  12974.     0.    76.  1.00    -4.    27.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.98    -4.3    26.5   203.6   12974.    2689.  13.21

X STA.        -4.3        3.5        4.3        5.2        6.2        7.1
  A(I)             33.1        7.7        7.6        8.0        7.9
  V(I)             4.06      17.43      17.78      16.91      16.92

X STA.         7.1        8.1        9.1       10.2       11.2       12.3
  A(I)              7.9        8.2        8.1        8.3        8.2
  V(I)            17.07      16.36      16.51      16.25      16.38

X STA.        12.3       13.5       14.7       15.9       17.2       18.4
  A(I)              8.8        8.7        8.7        8.7        8.7
  V(I)            15.20      15.50      15.46      15.41      15.50

X STA.        18.4       19.7       20.9       22.2       23.5       26.5
  A(I)              8.8        8.6        8.8        8.7       20.1
  V(I)            15.30      15.61      15.27      15.44       6.71

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.99   -43.3    75.8   136.5    3572.     710.   5.20

X STA.       -43.3      -20.6      -16.8      -13.7      -11.1       -8.6
  A(I)             16.2        5.9        5.4        5.1        5.2
  V(I)             2.19       5.98       6.60       6.90       6.87

X STA.        -8.6       -4.0        0.9        5.9       11.0       15.7
  A(I)              6.8        6.5        6.5        6.6        6.2
  V(I)             5.24       5.47       5.46       5.38       5.75

X STA.        15.7       20.5       25.6       29.4       32.2       35.3
  A(I)              6.2        6.6        6.3        5.5        5.6
  V(I)             5.73       5.41       5.66       6.40       6.36

X STA.        35.3       38.6       42.4       47.2       53.0       75.8
  A(I)              5.6        5.9        6.5        6.5       11.4
  V(I)             6.36       5.98       5.48       5.43       3.11

  CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     280.  22990.    85.    86.                        2897.
           2     518.  55715.    61.    66.                        8569.
           3     174.   5943.   123.   123.                        1176.
 502.26          973.  84648.   268.   274.  1.26  -106.   162.   9380.

  VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.26  -106.4   161.8   972.7   84648.    3400.   3.50

X STA.      -106.4      -86.9      -71.9      -57.0      -42.6      -28.6
  A(I)             58.4       50.2       50.8       49.7       48.9
  V(I)             2.91       3.38       3.35       3.42       3.48

X STA.       -28.6      -10.0       -5.6       -2.1        1.3        4.5
  A(I)             78.6       39.3       34.2       33.9       32.7
  V(I)             2.16       4.32       4.97       5.01       5.21

X STA.         4.5        7.6       10.7       13.6       16.4       19.2
  A(I)             33.1       34.5       32.5       32.4       32.3
  V(I)             5.14       4.93       5.23       5.24       5.27

X STA.        19.2       22.3       25.5       29.0       63.4      161.8
  A(I)             33.1       33.3       35.5       97.8      131.5
  V(I)             5.13       5.10       4.79       1.74       1.29
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        U.S. Geological Survey WSPRO Input File read027.wsp
        Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
        Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 06-12-98  09:10

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     204.  12974.     0.    76.                           0.
  497.98           204.  12974.     0.    76.  1.00    -4.    27.       0.

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

         WSEL     LEW     REW    AREA        K        Q     VEL
       497.98    -4.3    26.5   203.6   12974.    1740.   8.55

X STA.        -4.3         3.5        4.3         5.2         6.2        7.1
  A(I)             33.1        7.7         7.6         8.0         7.9
  V(I)             2.63       11.28       11.51       10.94       10.95

X STA.         7.1         8.1         9.1        10.2        11.2       12.3
  A(I)              7.9         8.2         8.1         8.3         8.2
  V(I)            11.04       10.59       10.68       10.52       10.60

X STA.        12.3        13.5        14.7        15.9        17.2       18.4
  A(I)              8.8         8.7         8.7         8.7         8.7
  V(I)             9.83       10.03       10.01        9.97       10.03

X STA.        18.4        19.7        20.9        22.2        23.5       26.5
  A(I)              8.8         8.6         8.8         8.7        20.1
  V(I)             9.90       10.10        9.88        9.99        4.34

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     136.  10661.    26.    37.                        1753.
  495.62           136.  10661.    26.    37.  1.00     0.    26.    1753.

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      78.   2812.    82.    82.                         433.
             2     370.  32088.    60.    65.                        5206.
  499.83           448.  34900.   142.   147.  1.16  -104.    38.    4199.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      48.

         WSEL     LEW     REW    AREA        K        Q     VEL
       499.83  -103.8    38.4   448.3   34900.    1740.   3.88

X STA.      -103.8       -50.4       -7.2        -4.7        -2.3       -0.1
  A(I)             49.2       73.7        17.4        17.6        16.7
  V(I)             1.77        1.18        5.00        4.94        5.20

X STA.        -0.1         2.0         4.2         6.2         8.2       10.0
  A(I)             16.6       16.8        16.2        16.5        15.7
  V(I)             5.25        5.19        5.36        5.27        5.54

X STA.        10.0        11.8        13.7        15.4        17.2       18.9
  A(I)             16.1       16.4        16.3        15.9        16.0
  V(I)             5.41        5.31        5.35        5.49        5.44

X STA.        18.9        20.8        22.8        24.9        27.1       38.4
  A(I)             16.3       16.4        16.8        16.6        45.2
  V(I)             5.34        5.29        5.19        5.25        1.93
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File read027.wsp
        Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
        Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 06-12-98  09:10

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITA":  USED WSI = CRWS.
                         WSI,CRWS =    492.20     492.36

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

EXITA:XS   ******    -1.     279.  1.19 *****  493.55  492.36   2300.  492.36
     -147. ******   103.   14380.  1.13 ***** *******    0.94    8.24

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.92     495.25     494.70
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.86     528.47    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.86     528.47     494.70

EXITX:XS     116.      0.     228.  1.60  3.09  496.85  494.70   2300.  495.25
      -31.   116.     68.   13795.  1.01  0.20    0.00    0.92   10.07

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.55

FULLV:FV      31.     -3.     332.  0.83  0.56  497.39 *******   2300.  496.56
        0.    31.     91.   21379.  1.12  0.00   -0.01    0.69    6.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.92     496.84     496.58
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.06     526.19    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.06     526.19     496.58
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.69

APPRO:AS      48.    -14.     210.  1.86  0.81  498.71  496.58   2300.  496.85
       48.    48.     34.   14674.  1.00  0.51    0.00    0.92   10.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =    500.16       0.00     496.90     499.77
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   504.02          0.       2300.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      31.     -4.     203.  1.65 *****  499.60  496.34   2092.  497.95
        0. ******     27.   15569.  1.00 ***** *******    0.71   10.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.495  0.000  497.95 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF    VHD      EGL      ERR       Q    WSEL
   RDWAY:RG        9.    34.  0.05  0.19  501.47     0.00     209.  501.19

             Q    WLEN     LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    105.     43.    -31.     12.   1.4   0.6   4.1   4.0   0.9   2.9
   RT:    104.     45.     12.     57.   1.3   0.6   3.9   3.9   0.9   2.8

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

APPRO:AS      26.  -105.     725.  0.19  0.14  501.52  496.58   2300.  501.33
       48.    27.    159.   60421.  1.22  0.00    0.00    0.37    3.17

       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
   EXITA:XS     -147.    -1.   103.   2300.   14380.      279.    8.24  492.36
   EXITX:XS      -31.     0.    68.   2300.   13795.      228.   10.07  495.25
   FULLV:FV        0.    -3.    91.   2300.   21379.      332.    6.93  496.56
   BRIDG:BR        0.    -4.    27.   2092.   15569.      203.   10.29  497.95
   RDWAY:RG        9.*******   105.    209.******************    2.00  501.19
   APPRO:AS       48.  -105.   159.   2300.   60421.      725.    3.17  501.33

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITA:XS     492.36    0.94  486.75  504.23************  1.19  493.55  492.36
   EXITX:XS     494.70    0.92  488.84  528.47  3.09  0.20  1.60  496.85  495.25
   FULLV:FV   ********    0.69  488.84  528.47  0.56  0.00  0.83  497.39  496.56
   BRIDG:BR     496.34    0.71  488.76  497.98************  1.65  499.60  497.95
   RDWAY:RG   ****************  499.77  528.47  0.05******  0.19  501.47  501.19
   APPRO:AS     496.58    0.37  490.59  526.19  0.14  0.00  0.19  501.52  501.33
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File read027.wsp
        Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
        Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 06-12-98  09:10

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITA":  USED WSI = CRWS.
                             WSI,CRWS =   493.00     493.08

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

EXITA:XS   ******    -3.     356.  1.52 *****  494.60  493.08   3400.  493.08
     -147. ******   104.   20303.  1.07 ***** *******    0.96    9.56

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.13      496.21     496.45
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.58     528.47    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.58     528.47     496.45
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                  WSBEG,WSEND,CRWS =   496.45     528.47     496.45

EXITX:XS     116.    -3.     322.  1.93 *****  498.38  496.45   3400.  496.45
      -31.   116.    89.   20653.  1.11 ***** *******    1.05   10.55

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.66

FULLV:FV      31.    -7.     487.  0.84  0.51  498.88 *******   3400.  498.04
        0.    31.   104.   34240.  1.12  0.00   -0.01    0.62    6.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.00      497.95     497.93
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.54     526.19    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.54     526.19     497.93
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.60

APPRO:AS      48.   -16.     266.  2.55  0.79  500.52  497.93   3400.  497.97
       48.    48.    35.   20605.  1.00  0.85    0.00    0.99   12.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   498.04     497.95

            <<<<<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      31.    -4.     204.  2.71 *****  500.69  497.53   2689.  497.98
        0. ******    27.   12974.  1.00 ***** *******    0.91   13.21

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    34.  0.06  0.24  502.44    0.00    710.  501.99

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    345.    56.   -43.    12.   2.2   1.2   5.7   5.2   1.6   3.0
   RT:    365.    64.    12.    76.   2.1   1.1   5.5   5.2   1.6   2.9

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

APPRO:AS      26.  -106.     972.  0.24  0.22  502.49  497.93   3400.  502.26
       48.    27.   162.   84526.  1.26  0.00    0.00    0.36    3.50

       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
   EXITA:XS    -147.    -3.   104.   3400.   20303.     356.    9.56  493.08
   EXITX:XS     -31.    -3.    89.   3400.   20653.     322.   10.55  496.45
   FULLV:FV       0.    -7.   104.   3400.   34240.     487.    6.98  498.04
   BRIDG:BR       0.    -4.    27.   2689.   12974.     204.   13.21  497.98
   RDWAY:RG       9.*******   345.    710.******************    2.00  501.99
   APPRO:AS      48.  -106.   162.   3400.   84526.     972.    3.50  502.26

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

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITA:XS     493.08    0.96  486.75  504.23************  1.52  494.60  493.08
   EXITX:XS     496.45    1.05  488.84  528.47************  1.93  498.38  496.45
   FULLV:FV   ********    0.62  488.84  528.47  0.51  0.00  0.84  498.88  498.04
   BRIDG:BR     497.53    0.91  488.76  497.98************  2.71  500.69  497.98
   RDWAY:RG   ****************  499.77  528.47  0.06******  0.24  502.44  501.99
   APPRO:AS     497.93    0.36  490.59  526.19  0.22  0.00  0.24  502.49  502.26
```
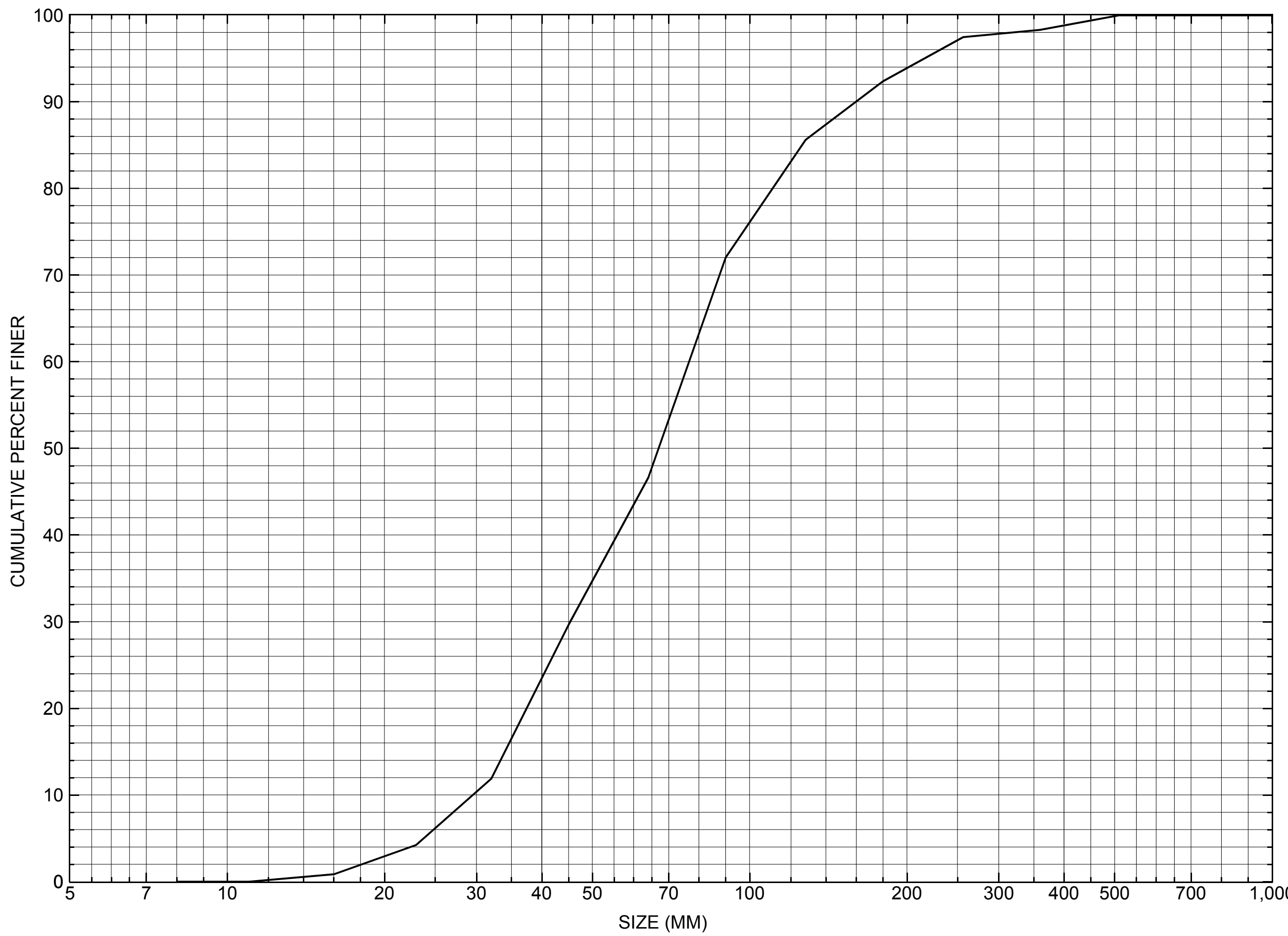

```
        U.S. Geological Survey WSPRO Input File read027.wsp
        Hydraulic analysis for structure READTH00380027   Date: 04-NOV-97
        Bridge 27 on Town Highway 38 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 06-12-98  09:10

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITA":  USED WSI = CRWS.
                          WSI,CRWS =   491.67     491.77

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

EXITA:XS   ******     0.     220.  1.13 *****  492.90  491.77   1740.  491.77
     -147. ******    95.   10602.  1.17 ***** *******    0.99    7.90

EXITX:XS     116.     1.     198.  1.20  2.93  495.87 *******   1740.  494.67
      -31.   116.    49.   11313.  1.00  0.03    0.00    0.76    8.79

FULLV:FV      31.    -1.     253.  0.77  0.53  496.39 *******   1740.  495.62
        0.    31.    75.   15650.  1.04  0.00   -0.01    0.66    6.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.91     496.06     495.81
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.12     526.19     0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.12     526.19     495.81

APPRO:AS      48.   -13.     173.  1.57  0.84  497.63  495.81   1740.  496.06
       48.    48.    33.   11040.  1.00  0.40    0.00    0.91   10.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.59     498.23     498.55     497.95
 ===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      31.    -4.     204.  1.14 *****  499.12  495.59   1742.  497.98
        0. ******    27.   12974.  1.00 ***** *******    0.59    8.56

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.465  0.000  497.95 ****** ****** ******

    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      26.  -104.     448.  0.27  0.18  500.10  495.81   1740.  499.83
       48.    26.    38.   34841.  1.16  0.60    0.00    0.42    3.89

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.74
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITA:XS     -147.     0.    95.   1740.   10602.     220.    7.90  491.77
   EXITX:XS      -31.     1.    49.   1740.   11313.     198.    8.79  494.67
   FULLV:FV        0.    -1.    75.   1740.   15650.     253.    6.88  495.62
   BRIDG:BR        0.    -4.    27.   1742.   12974.     204.    8.56  497.98
   RDWAY:RG        9.**************      0.       0.       0.    2.00********
   APPRO:AS       48.  -104.    38.   1740.   34841.     448.    3.89  499.83

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS      FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXITA:XS     491.77    0.99  486.75  504.23************  1.13  492.90  491.77
   EXITX:XS   ********    0.76  488.84  528.47  2.93  0.03  1.20  495.87  494.67
   FULLV:FV   ********    0.66  488.84  528.47  0.53  0.00  0.77  496.39  495.62
   BRIDG:BR     495.59    0.59  488.76  497.98************  1.14  499.12  497.98
   RDWAY:RG   ****************  499.77  528.47************  0.27  500.01********
   APPRO:AS     495.81    0.42  490.59  526.19  0.18  0.60  0.27  500.10  499.83
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure READTH00380027, in Reading, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number READTH00380027

General Location Descriptive

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

Date (MM/DD/YY) 03 / 09 / 95

Highway District Number (I - 2; nn) 04

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

Town (FIPS place code; I - 4; nnnnn) 58375

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

Waterway (I - 6) North Branch Black River

Road Name (I - 7): -

Route Number TH038

Vicinity (I - 9) 0.03 miles to jct with TH 1

Topographic Map Cavendish

Hydrologic Unit Code: 01080106

Latitude (I - 16; nnnn.n) 43282

Longitude (i - 17; nnnnn.n) 72342

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10141400271414

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0035

Year built (I - 27; YYYY) 1974

Structure length (I - 49; nnnnnn) 000036

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

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

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 4

Opening skew to Roadway (I - 34; nn) 10

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) P

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

Structure type (I - 43; nnn) 302

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) -

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 8.0

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

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

Comments:

The structural inspection report of 9/10/93 indicates the structure is a steel stringer type bridge with a timber deck. The right abutment is concrete. The right abutment is in good condition with no exposure of the footing or cracking of the concrete noted. The report indicated that nearly 3 years ago the left abutment stone wall was faced with concrete and a concrete subfooting was constructed. The subfooting is undermined 1 ft by an adjacent scour hole. The concrete facing and subfooting show no signs of settling. The waterway makes a sharp turn through the structure and impacts the left abutment. There is some heavy stream bank erosion just upstream from the left abutment. The report indicates that scour is likely to continue along the left abutment with the current channel alignment.

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: Stone and gravel with some random boulders.

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:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 9.08 mi^2
Lake/pond/swamp area 0.09 mi^2
Watershed storage *(ST)* 1.0 %
Bridge site elevation 1103 ft
Headwater elevation 2478 ft
Main channel length 4.16 mi
10% channel length elevation 1240 ft
85% channel length elevation 1780 ft
Main channel slope *(S)* 173.24 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*)? **VTAOT**

Comments: **The station and low chord to bed differences are taken from a sketch dated 9/10/93 of the upstream face that was attached to a bridge inspection report. The low chord elevation is an average of the coordinates surveyed during the level 2 assessment on 10/12/95.**

Station	0	1.50	1.51	17.50	35.00	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.95	497.95	497.95	497.95	497.95	-	-	-	-	-	-
Bed elevation	491.05	491.05	488.82	490.62	490.95	-	-	-	-	-	-
Low chord to bed	6.90	6.90	9.13	7.33	7	-	-	-	-	-	-

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: EW Date: 6/96
Computerized by: EW Date: 6/96
Reviewd by: MAL Date: 1/30/98

Structure Number READTH00380027

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. WEBER Date *(MM/DD/YY)* 03 / 29 / 1995

2. Highway District Number 04 Mile marker 000000

County WINDSOR (027) Town READING (58375)

Waterway *(I - 6)* N. BRANCH BLACK RIVER Road Name ARCHER ROAD

Route Number THO38 Hydrologic Unit Code: 01080106

3. Descriptive comments:

The bridge is located 0.03 miles from the junction with VT 100. A passerby said the old bridge went out in 1967.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 5 LBDS 6 RBDS 6 Overall 6
*(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 36 *(feet)* Span length 35 *(feet)* Bridge width 14.0 *(feet)*

Road approach to bridge:

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

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

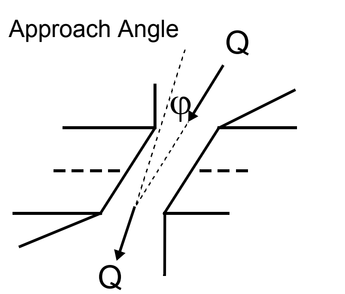
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

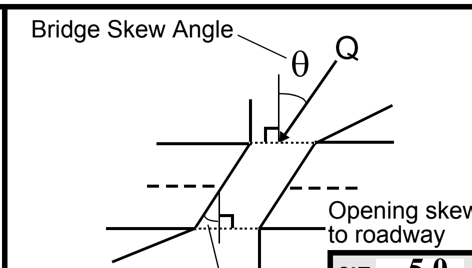
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	1	1	0	0
RBDS	2	1	0	0
LBDS	1	1	0	0

*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: 40 16. Bridge skew: 50





α= 5.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 3
Range? 80 feet US *(US, UB, DS)* to 130 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 10 feet US *(US, UB, DS)* to 0 feet DS

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

18. Bridge Type: **1a**

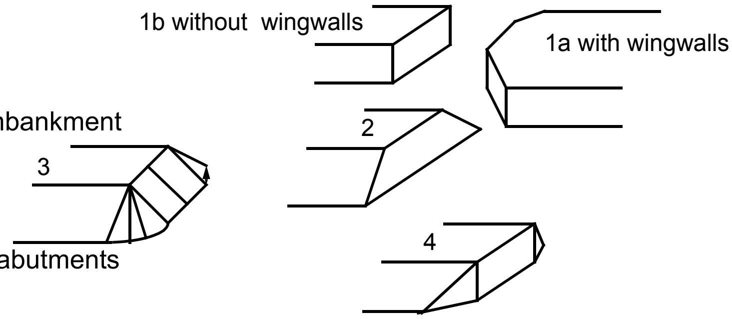
1a- Vertical abutments with wingwalls

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 LBUS is a sparsely wooded forest. The RBUS has grass adjacent to the stream and a road with brushland and forest beyond. The LBDS is a forest except for an area 10-20 feet DS. The RBDS surface cover is the same as the LBDS

#7: Values are from VTAOT. During site visit, the measured bridge length was 36.5 feet, the span length was 31 feet, and the bridge width was 14.0 feet.

#11: The USRB has the most extensive road approach protection coverage.

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
32.0	6.0			8.0	3	3	3	4	1	3

23. Bank width **25.0** 24. Channel width **35.0** 25. Thalweg depth **58.5** 29. Bed Material **3**

30 .Bank protection type: LB **1** RB **1** 31. Bank protection condition: LB **1** 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.):

#26: The right bank vegetation cover is less dense upstream of bridge.

#27: The right bank material from the upstream bridge face to 100 feet US is cobble, gravel and boulder. In the area of 120 feet US, the right bank material is clay with gravel. The left bank material is gravel and sand with some boulders.

#28: On the left bank, there is light fluvial erosion just US of the bridge and just DS of the US point bar. The US reach is characterized by lateral instability, another point bar/cut bank combination exists just US of the cut bank and point bar visible from the bridge.

#29: The bed material is composed of gravel, cobble, sand and scattered boulders.

#30: The left bank protection extends from 0 to 25 feet US and is placed native cobble and boulder. Some bank erosion has occurred despite the protection.

33. Point/Side bar present? Y (*Y or N. if N type ctrl-n pb*) 34. Mid-bar distance: 150 35. Mid-bar width: 33

36. Point bar extent: 250 feet US (*US, UB*) to 30 feet US (*US, UB, DS*) positioned 0 %LB to 60 %RB

37. Material: 1

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

The point bar material is silt, sand, gravel, cobble and some boulders. There is brushy vegetation growing on the bar.

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: 100 42. Cut bank extent: 180 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.):

-

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
36.0		1.0		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.):

345

#63 The bed material is gravel, cobble, sand and scattered boulders.

There is a gap in the DS lower end of the left abutment stonework where culvert flow would enter the stream. A culvert passes under the left road approach and drains the US left overbank. There is no flow through the culvert at this time.

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

Lateral migration US may cause trees to be undercut and fall into the channel. The bridge will not constrict bank full flow.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**40**	**90**	**2**	**3**	**2**	**3**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**30.5**

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.):

-

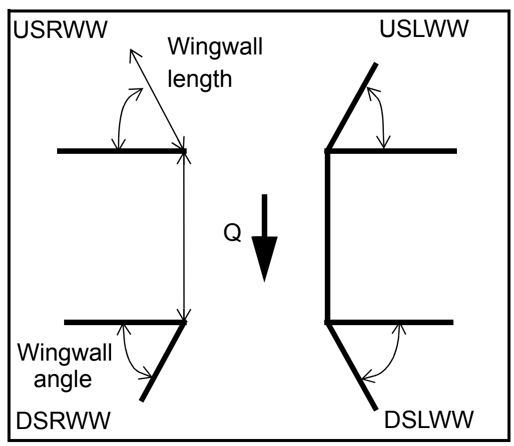
-

1

The left abutment footing is exposed 3 feet above the channel bottom almost its entire length, though at the US end, the exposure depth is 1.5 feet. As noted in historical form, the left abutment is a stonewall which was faced with concrete and an additional subfooting. The undermined penetration is 1 foot.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**30.5**	
USRWW:	**Y**		**1**		**0**	**2.0**	
DSLWW:	**-**		**-**		**Y**	**19.0**	
DSRWW:	**1**		**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	**-**	**3**	**Y**	**-**	**1**	**1**	**-**	**-**
Condition	**Y**	**2**	**1**	**-**	**1**	**2**	**-**	**-**
Extent	**1**	**2**	**0**	**2**	**2**	**0**	**0**	**-**

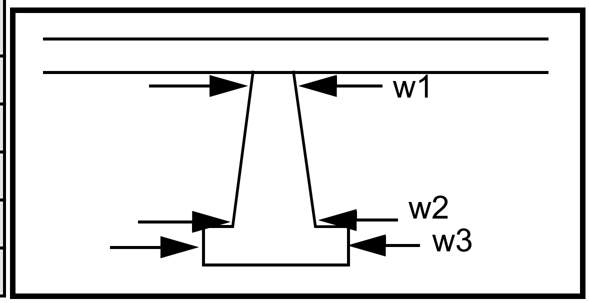
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **Co** (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		**4.0**		**35.0**	**40.0**	**10.5**
Pier 2		**5.0**	**8.0**	**80.0**	**105.0**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**verage**	**; the**	**Type-2**	**UT are**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**at**	**pro-**	**stone**	**not**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**the**	**tec-**	**s**	**con-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**upst**	**tion**	**that**	**sid-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**ream**	**exte**	**are**	**ered**	*Y- yes; N- no*
91. Attack ∠ (BF)	**end**	**nds**	**part**	**as**	
92. Pushed	**of**	**US**	**of**	**pro-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**the**	**as**	**the**	**tec-**	
95. Cross-members	**USR**	**bank**	**old**	**tion.**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**WW**	**pro-**	**dry**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**is**	**tec-**	**wall**		
98. Exposure depth	**light**	**tion.**	**LAB**		

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: __4__ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

4
3
3
3

Is channel scour present? __2__ *(Y or if N type ctrl-n cs)* Mid-scour distance: __3__

Scour dimensions: Length __1__ Width __1__ Depth: __1__ Positioned __1__ %LB to __The__ %RB

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

re is an area on both banks 10-20 feet DS that is cleared of trees. The bank material is gravel, sand, cobble and boulder. Along the cut area of the left bank, the sand is washed away. At 250 feet DS on the LB, there exists clay with gravel which is exposed, similar to the upstream right bank material. Bed material is gravel, cobble, sand and boulder. There is natural cobble and boulder protection, but from 0 to 80 feet DS on the left

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

Confluence 1: Distance __and__ Enters on __fro__ *(LB or RB)* Type __m 0__ *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance __to 35__ Enters on __feet__ *(LB or RB)* Type __DS__ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

on the right bank the material looks as though it was placed by man. There is moderate fluvial erosion on the right bank downstream of the protection and light fluvial erosion on the left bank concurrent with the protec-

F. Geomorphic Channel Assessment

107. Stage of reach evolution __tio__

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. Severe cutting is seen on the left bank further downstream.

N

-

NO DROP STRUCTURE

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: READTH00380027 Town: Reading
Road Number: TH 38 County: Windsor
Stream: North Branch Black River

Initials: EMB Date: 6/11/98 Checked: RLB

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	2300	3400	1740
Main Channel Area, ft2	462	518	370
Left overbank area, ft2	202	280	78
Right overbank area, ft2	61	174	0
Top width main channel, ft	61	61	60
Top width L overbank, ft	84	85	82
Top width R overbank, ft	120	123	0
D50 of channel, ft	0.2197	0.2197	0.2197
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.6	8.5	6.2
y1, average depth, LOB, ft	2.4	3.3	1.0
y1, average depth, ROB, ft	0.5	1.4	ERR
Total conveyance, approach	60459	84648	34900
Conveyance, main channel	45914	55715	32088
Conveyance, LOB	13480	22990	2812
Conveyance, ROB	1065	5943	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1746.7	2237.9	1599.8
Ql, discharge, LOB, cfs	512.8	923.4	140.2
Qr, discharge, ROB, cfs	40.5	238.7	0.0
Vm, mean velocity MC, ft/s	3.8	4.3	4.3
Vl, mean velocity, LOB, ft/s	2.5	3.3	1.8
Vr, mean velocity, ROB, ft/s	0.7	1.4	ERR
Vc-m, crit. velocity, MC, ft/s	9.5	9.7	9.2
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

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	2300	3400	1740
Q, thru bridge MC, cfs	2092	2689	1740
Vc, critical velocity, ft/s	9.48	9.66	9.16
Va, velocity MC approach, ft/s	3.78	4.32	4.32
Main channel width (normal), ft	26.4	26.4	26.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.4	26.4	26.4
qbr, unit discharge, ft2/s	79.2	101.9	65.9
Area of full opening, ft2	203.3	203.6	203.6
Hb, depth of full opening, ft	7.70	7.71	7.71
Fr, Froude number, bridge MC	0.71	0.91	0.59
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	161	--	136
**Hb, depth at downstream face, ft	6.10	--	5.15
**Fr, Froude number at DS face	0.93	--	0.99
**Cf, for downstream face (<=1.0)	1.00	--	1.00
Elevation of Low Steel, ft	497.95	497.95	497.95
Elevation of Bed, ft	490.25	490.24	490.24
Elevation of Approach, ft	501.33	502.26	499.83
Friction loss, approach, ft	0.14	0.22	0.18
Elevation of WS immediately US, ft	501.19	502.04	499.65
ya, depth immediately US, ft	10.94	11.80	9.41
Mean elevation of deck, ft	500.7	500.7	500.7
w, depth of overflow, ft (>=0)	0.49	1.34	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.95
**Cc, for downstream face (<=1.0)	0.838523	0.79	0.79
Ys, scour w/Chang equation, ft	**1.36**	**3.71**	**-0.15**
Ys, scour w/Umbrell equation, ft	-0.96	-0.27	-1.12

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

**Ys, scour w/Chang equation, ft	3.87	ERR	3.96
**Ys, scour w/Umbrell equation, ft	0.64	ERR	1.44

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	7.60	9.42	6.49
WSEL at downstream face, ft	496.56	--	495.62
Depth at downstream face, ft	6.10	--	5.15
Ys, depth of scour (Laursen), ft	1.50	N/A	1.34

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	2300	3400	1740
(Q) discharge thru bridge, cfs	2092	2689	1740
Main channel conveyance	15569	12974	12974
Total conveyance	15569	12974	12974
Q2, bridge MC discharge,cfs	2092	2689	1740
Main channel area, ft2	203	204	204
Main channel width (normal), ft	26.4	26.4	26.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.4	26.4	26.4
y_bridge (avg. depth at br.), ft	7.70	7.71	7.71
Dm, median (1.25*D50), ft	0.274625	0.274625	0.274625
y2, depth in contraction,ft	7.60	9.42	6.49
ys, scour depth (y2-ybridge), ft	-0.10	1.71	-1.22

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	2092	2689	1740
Main channel area (DS), ft2	161	204	136
Main channel width (normal), ft	26.4	26.4	26.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	26.4	26.4	26.4
D90, ft	0.5241	0.5241	0.5241
D95, ft	0.7084	0.7084	0.7084
Dc, critical grain size, ft	0.6933	0.6421	0.7203
Pc, Decimal percent coarser than Dc	0.053	0.064	0.048

Depth to armoring, ft	**37.16**	**28.08**	**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	2300	3400	1740	2300	3400	1740
a', abut.length blocking flow, ft	105.4	106.4	103.8	132.3	135.4	12
Ae, area of blocked flow ft2	312.3	381.1	175.4	110.5	203.9	50.5
Qe, discharge blocked abut.,cfs	--	--	439.1	--	--	114.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.73	3.40	2.50	1.49	1.82	2.27
ya, depth of f/p flow, ft	2.96	3.58	1.69	0.84	1.51	4.21
--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.271	0.298	0.339	0.263	0.234	0.195
ys, scour depth, ft	**14.60**	**17.37**	**11.32**	**6.87**	**9.45**	**8.71**

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)	105.4	106.4	103.8	132.3	135.4	12
y1 (depth f/p flow, ft)	2.96	3.58	1.69	0.84	1.51	4.21
a'/y1	35.57	29.71	61.43	158.40	89.91	2.85
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.27	0.30	0.34	0.26	0.23	0.20
Ys w/ corr. factor K1/0.55:						
vertical	14.15	17.64	8.69	3.83	6.65	ERR
vertical w/ ww's	11.60	14.47	7.13	3.14	5.45	ERR
spill-through	7.78	9.70	4.78	2.11	3.66	ERR

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	0.93	0.91	0.99	0.93	0.91	0.99
y, depth of flow in bridge, ft	6.10	7.71	5.15	6.10	7.71	5.15
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	**2.50**	**3.14**	**2.15**	**2.50**	**3.14**	**2.15**