LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (ROYATH00550025) on TOWN HIGHWAY 55, crossing BROAD BROOK, ROYALTON, VERMONT

U.S. Geological Survey
Open-File Report 97-422

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

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By Ronda L. Burns and Matthew A. Weber

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Pembroke, New Hampshire

1997

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (ROYATH00550025) ON TOWN HIGHWAY 55, CROSSING BROAD BROOK, ROYALTON, VERMONT

By **Ronda L. Burns 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 ROYATH00550025 on Town Highway 55 crossing Broad Brook, Royalton, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in central Vermont. The 11.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the upstream and downstream left overbanks and forest on the upstream and downstream right overbanks.

In the study area, Broad Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 41 ft and an average bank height of 5 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 58.3 mm (0.191 ft). The geomorphic assessment at the time of the Level I site visit on April 13, 1995 indicated that the reach was laterally unstable. The stream impacts the upstream left bank where there is a cut bank.

The Town Highway 55 crossing of the Broad Brook is a 35-ft-long, two-lane bridge consisting of one 31-foot steel-beam span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 32 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening, while the opening-skew-to-roadway is zero degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the left abutment and the downstream left wingwall during the Level I assessment. The scour countermeasure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream and downstream left banks that extended to the ends of the wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). 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 0.6 to 1.5 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge which was less than the 100-year discharge. Abutment scour ranged from 3.5 to 8.9 ft. The worst-case abutment scour occurred at the incipient road-overtopping discharge for the left abutment and at the 100-year discharge for the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number ROYATH00550025 ***Stream*** Broad Brook

County Windsor ***Road*** TH55 ***District*** 4

Description of Bridge

Bridge length 35 ***ft*** ***Bridge width*** 16.1 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 04/13/95

Description of stone fill Type-2, around the upstream end of the upstream left wingwall and the downstream end of the downstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one foot deep scour hole in front of the left abutment and the downstream left wingwall.

Y 20

Is bridge skewed to flood flow according to Y ***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	04/13/95	0	0
Level II	07/10/96	0	0

Potential for debris Moderate. There are some logs caught on the downstream left bank.

None 04/13/95.

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 04/13/95

DS left: Steep channel bank to a mildly sloped overbank to the valley wall.

DS right: Moderately sloped overbank.

US left: Steep channel bank to a mildly sloped overbank to the valley wall.

US right: Moderately sloped overbank.

Description of the Channel

Average top width 41 ***ft*** ***Average depth*** 5 ***ft***

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

Sinuous with alluvial channel boundaries.

04/13/95

Vegetative co Short grass with brush along the immediate bank.

DS left: Trees and brush.

DS right: Short grass with brush along the immediate bank.

US left: Trees and brush.

US right: N

Do banks appear stable? There is a cut bank on the upstream left bank where the road embankment for TH2 is being eroded. 04/13/95

date of observation.

None. 04/13/95

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 11.6 ***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 2,130 ***ft³/s*** ***Q500*** 2,880 ***ft³/s***

The 100- and 500-year discharges are based on the median value 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 left abutment (elev. 498.85 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 498.50 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-32	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	49	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 0.035 to 0.055, and overbank "n" values ranged from 0.035 to 0.065.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0106 ft/ft which was estimated from the surveyed points downstream (Level II assessment 07/10/96).

The surveyed approach section (APPRO) was one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for this discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 498.1 *ft*

100-year discharge 2,130 *ft³/s*
Water-surface elevation in bridge opening 498.1 *ft*
Road overtopping? Y *Discharge over road* 216 *ft³/s*
Area of flow in bridge opening 207 *ft²*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 10.7 *ft/s*

Water-surface elevation at Approach section with bridge 500.4
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 2.7 *ft*

500-year discharge 2,880 *ft³/s*
Water-surface elevation in bridge opening 498.1 *ft*
Road overtopping? Y *Discharge over road* 810 *ft³/s*
Area of flow in bridge opening 206 *ft²*
Average velocity in bridge opening 10.2 *ft/s*
Maximum WSPRO tube velocity at bridge 14.1 */s*

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 498.8
Amount of backwater caused by bridge 2.4 *ft*

Incipient overtopping discharge 1,940 *ft³/s*
Water-surface elevation in bridge opening 496.4 *ft*
Area of flow in bridge opening 154 *ft²*
Average velocity in bridge opening 12.6 *ft/s*
Maximum WSPRO tube velocity at bridge 14.9 *ft/s*

Water-surface elevation at Approach section with bridge 498.5
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 0.9 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the incipient-overtopping discharge was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year and the 500-year discharges resulted in unsubmerged 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 others, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison to the Chang equation results, estimates of contraction scour for the 100- and 500-year discharges were also computed by use of the Laursen and Umbrell (Richardson and others, 1995, p. 144) scour equations and the results are presented in Appendix F. Furthermore, additional estimates of contraction scour were computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face into the equations. Contraction scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour for the incipient road-overtopping discharge and at the right abutment for the 100-year and 500-year discharges was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the left abutment for the 100-year and 500-year discharges was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.6	1.1	1.5
Depth to armoring	7.9	5.8	28.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	3.5	4.4	8.6
Right abutment	8.9	8.0	7.7
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.2	2.1	2.1
Right abutment	2.2	2.1	2.1
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

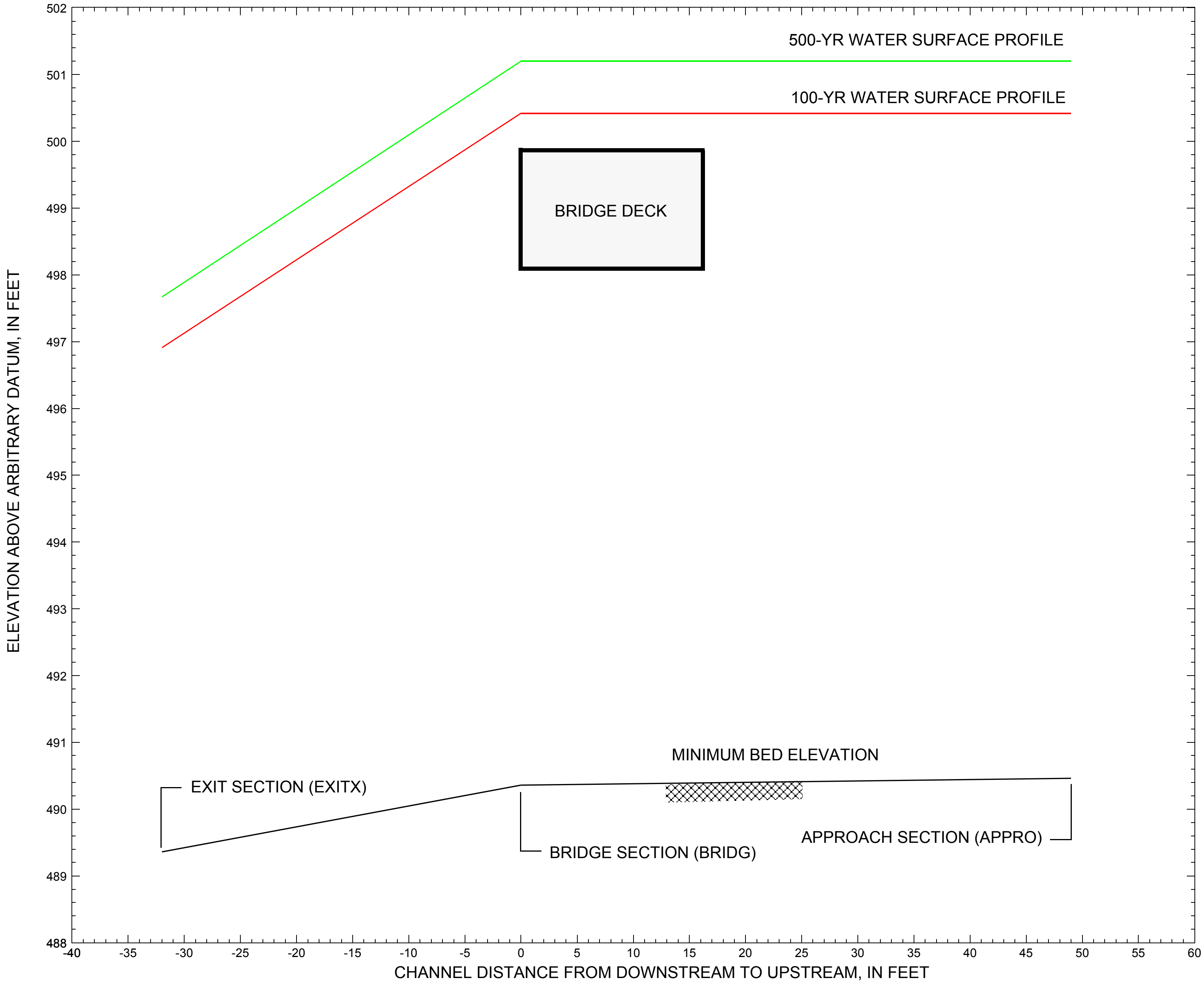

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ROYATH00550025 on Town Highway 55, crossing Broad Brook, Royalton, Vermont.

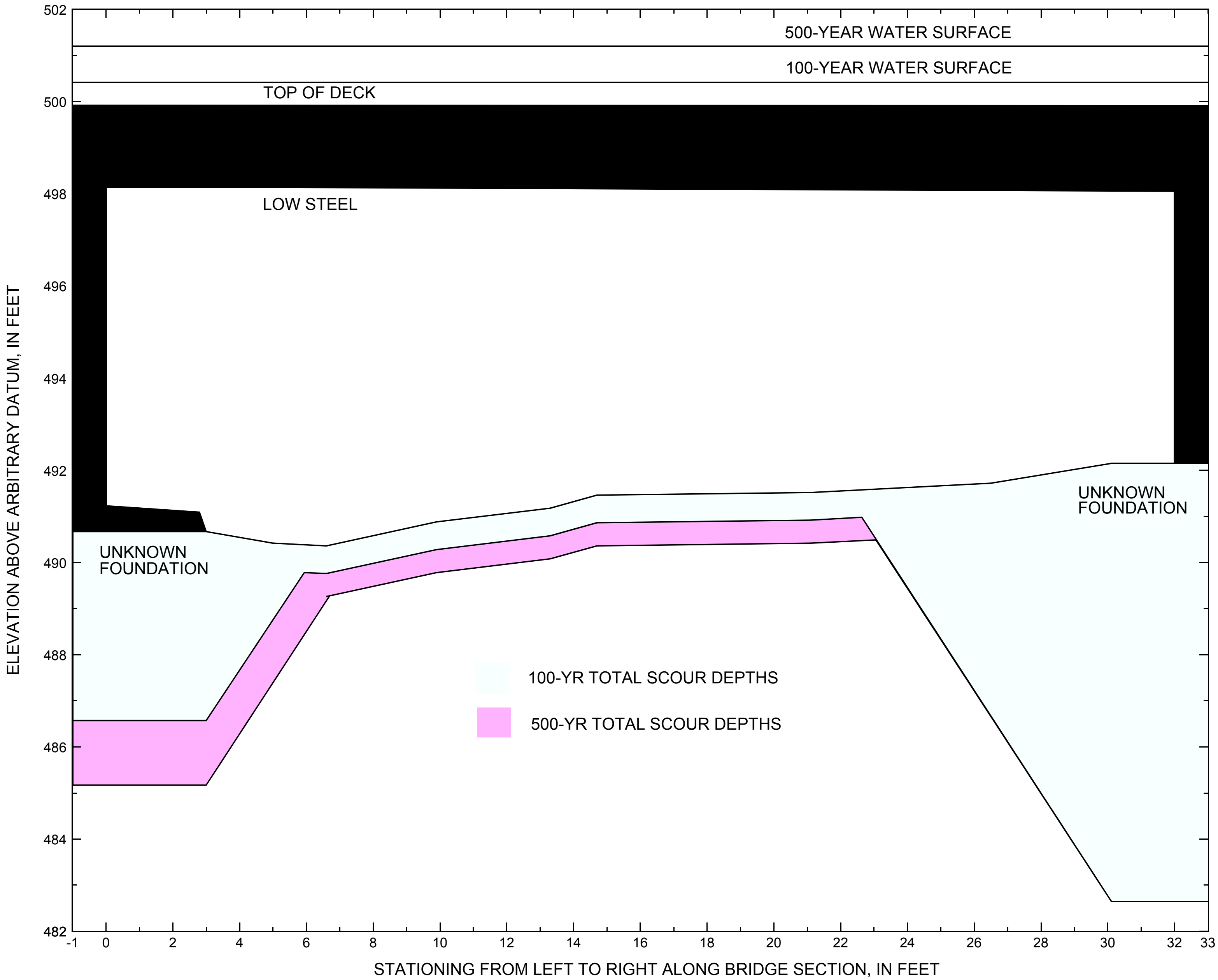

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ROYATH00550025 on Town Highway 55, crossing Broad Brook, Royalton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ROYATH00550025 on Town Highway 55, crossing Broad Brook, Royalton, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,125 cubic-feet per second											
Left abutment	0.0	--	498.1	--	490.7	0.6	3.5	--	4.1	486.6	--
Right abutment	32.0	--	498.0	--	492.2	0.6	8.9	--	9.5	482.7	--

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 ROYATH00550025 on Town Highway 55, crossing Broad Brook, Royalton, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,875 cubic-feet per second											
Left abutment	0.0	--	498.1	--	490.7	1.1	4.4	--	5.5	485.2	--
Right abutment	32.0	--	498.0	--	492.2	1.1	8.0	--	9.1	483.1	--

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File roya025.wsp
T2        Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
T3        TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                         RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2125.0   2875.0   1940.0
SK          0.0106   0.0106   0.0106
*
XS   EXITX    -32           0.
GR         -347.3, 513.11   -276.3, 504.72   -227.2, 502.93   -175.2, 502.28
GR          -80.2, 499.45    -55.5, 499.04    -47.9, 497.79    -10.0, 496.83
GR            0.0, 490.36      2.3, 489.91      6.7, 489.58      8.2, 489.36
GR           13.1, 490.02     16.5, 490.31     17.9, 490.58     23.1, 490.89
GR           33.0, 494.96     90.5, 496.01     94.5, 498.41    109.9, 500.50
GR          117.0, 500.84    197.7, 503.35
*
N           0.040        0.055        0.065
SA                 -10.0         33.0
*
*
XS   FULLV      0  * * *   0.0210
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.09       0.0
GR            0.0, 498.14      1.2, 491.59      1.6, 491.23      2.8, 491.09
GR            3.0, 490.67      5.0, 490.42      6.6, 490.36      9.9, 490.88
GR           13.3, 491.18     14.7, 491.46     21.1, 491.52     26.5, 491.72
GR           30.1, 492.15     32.0, 498.04      0.0, 498.14
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      16.7 * *     53.4      3.4
N           0.035
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      16.1     2
GR         -190.2, 503.75    -41.6, 499.96      0.0, 499.92     28.6, 499.91
GR           83.2, 500.67    197.7, 503.35    275.2, 507.65
*
*
*
*           EXPECTED SRD =   44 AT ONE BR. LENGTH BUT COMPUTED SRD =   49
*
AS   APPRO     49           0.
GR         -178.4, 510.51   -156.4, 508.75   -143.5, 502.10   -121.2, 500.48
GR          -31.5, 499.67     -8.0, 498.17      0.0, 492.15      1.6, 491.22
GR            5.3, 490.98      8.3, 490.46     12.2, 491.58     16.2, 492.17
GR           25.0, 492.72     28.8, 495.88     60.9, 498.04     67.4, 500.06
GR          197.7, 503.35
*
N           0.035        0.055        0.065
SA                  -8.0         28.8
*
HP 1 BRIDG  498.14 1 498.14
HP 2 BRIDG  498.14 * * 1914
HP 1 BRIDG  497.15 1 497.15
HP 2 RDWAY  500.42 * * 216
HP 1 APPRO  500.42 1 500.42
HP 2 APPRO  500.42 * * 2125
*
HP 1 BRIDG  498.09 1 498.09
HP 2 BRIDG  498.09 * * 2095
HP 1 BRIDG  497.89 1 497.89
HP 2 RDWAY  501.20 * * 810
HP 1 APPRO  501.20 1 501.20
HP 2 APPRO  501.20 * * 2875
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File roya025.wsp
        Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
        TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                         RLB
           *** RUN DATE & TIME: 04-16-97  15:22

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      207     17432      0     74                            0
   498.14           207     17432      0     74  1.00      0     32        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       498.14     0.0    32.0   206.9   17432.    1914.   9.25
X STA.        0.0         3.1         4.5         5.7         6.9         8.1
  A(I)            16.9        10.5         9.7         9.3         9.1
  V(I)            5.66        9.13        9.87       10.25       10.57

X STA.        8.1         9.3        10.6        11.9        13.2        14.5
  A(I)             9.1         9.1         9.0         9.1         9.4
  V(I)           10.49       10.52       10.68       10.56       10.19

X STA.       14.5        15.9        17.4        18.8        20.2        21.7
  A(I)             9.4         9.4         9.4         9.5         9.8
  V(I)           10.20       10.23       10.13       10.03        9.79

X STA.       21.7        23.2        24.8        26.4        28.2        32.0
  A(I)             9.7        10.1        10.4        11.4        16.7
  V(I)            9.84        9.50        9.23        8.43        5.72

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      177     20195     32     40                         2380
   497.15           177     20195     32     40  1.00      0     32     2380

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
         WSEL     LEW     REW    AREA         K        Q    VEL
       500.42   -59.6    65.2    47.9     807.     216.   4.51
X STA.      -59.6       -43.8       -38.9       -34.5       -30.4       -26.4
  A(I)             3.2         2.2         2.0         1.9         1.9
  V(I)            3.37        4.92        5.32        5.63        5.66

X STA.      -26.4       -22.5       -18.8       -15.1       -11.4        -7.0
  A(I)             1.8         1.8         1.8         1.8         2.2
  V(I)            5.85        5.96        6.05        6.03        4.96

X STA.       -7.0        -2.2         2.5         7.2        11.9        16.6
  A(I)             2.4         2.4         2.3         2.4         2.4
  V(I)            4.59        4.55        4.64        4.56        4.56

X STA.       16.6        21.2        25.8        30.5        37.6        65.2
  A(I)             2.3         2.3         2.4         3.1         5.3
  V(I)            4.62        4.62        4.58        3.48        2.03

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       66      2061    107    107                          297
             2      284     28185     37     40                         4475
             3      123      4896     53     53                         1059
   500.42           473     35143    196    200  1.48   -114     82     3422

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
         WSEL     LEW     REW    AREA         K        Q    VEL
       500.42  -114.6    81.7   472.8   35143.    2125.   4.49
X STA.     -114.6       -11.4        -2.3         0.5         2.5         4.2
  A(I)            59.1        32.3        20.8        18.1        16.3
  V(I)            1.80        3.28        5.10        5.87        6.54

X STA.        4.2         5.9         7.5         9.0        10.7        12.4
  A(I)            16.0        15.2        15.4        15.5        15.7
  V(I)            6.65        6.98        6.91        6.85        6.78

X STA.       12.4        14.2        16.1        18.1        20.1        22.2
  A(I)            15.7        16.2        16.0        16.6        16.4
  V(I)            6.77        6.57        6.63        6.40        6.46

X STA.       22.2        24.5        27.6        35.0        44.9        81.7
  A(I)            17.7        21.0        33.0        37.5        58.3
  V(I)            6.01        5.06        3.22        2.83        1.82
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       U.S. Geological Survey WSPRO Input File roya025.wsp
       Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
       TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                         RLB
          *** RUN DATE & TIME: 04-16-97  15:22

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      206     20438     16     58                         4209
  498.09           206     20438     16     58  1.00      0     32     4209

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA         K        Q    VEL
      498.09     0.0    32.0   206.5    20438.    2095.  10.15
X STA.         0.0         3.0         4.3         5.4         6.4         7.4
  A(I)            16.4         9.6         8.4         7.8         7.4
  V(I)            6.40       10.96       12.41       13.41       14.08

X STA.         7.4         8.4         9.4        10.4        11.5        12.6
  A(I)             7.5         7.5         7.4         7.7         7.6
  V(I)           13.90       13.88       14.14       13.52       13.70

X STA.        12.6        13.8        15.0        16.4        18.3        20.1
  A(I)             8.0         8.3         9.2        12.2        11.9
  V(I)           13.02       12.61       11.34        8.55        8.81

X STA.        20.1        21.9        23.8        25.7        27.8        32.0
  A(I)            11.9        12.5        12.5        13.1        19.3
  V(I)            8.83        8.39        8.38        8.00        5.43

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      200     24243     32     42                         2852
  497.89           200     24243     32     42  1.00      0     32     2852

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
        WSEL     LEW     REW    AREA         K        Q    VEL
      501.20   -90.2   105.8   175.0     5024.     810.   4.63
X STA.       -90.2       -58.2       -48.9       -42.5       -36.8       -31.6
  A(I)            13.1         8.7         7.3         7.0         6.5
  V(I)            3.10        4.67        5.52        5.82        6.24

X STA.       -31.6       -26.5       -21.6       -16.8       -12.0        -6.5
  A(I)             6.4         6.2         6.1         6.1         6.9
  V(I)            6.35        6.55        6.65        6.66        5.85

X STA.        -6.5        -0.3         5.9        11.9        18.1        24.2
  A(I)             7.9         7.9         7.8         7.9         7.9
  V(I)            5.12        5.10        5.21        5.12        5.14

X STA.        24.2        30.2        38.1        48.9        63.7       105.8
  A(I)             7.8         9.5        11.7        13.4        19.0
  V(I)            5.22        4.26        3.45        3.02        2.13

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      158      7945    123    123                         1016
            2      313     33092     37     40                         5170
            3      176      6587     84     84                         1446
  501.20           646     47624    244    248  1.55   -130    113     4802

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
        WSEL     LEW     REW    AREA         K        Q    VEL
      501.20  -131.1   112.6   646.5    47624.    2875.   4.45
X STA.      -131.1       -62.6       -28.9       -11.7        -2.8         0.5
  A(I)            61.3        47.3        38.6        37.1        26.5
  V(I)            2.35        3.04        3.73        3.87        5.43

X STA.         0.5         2.7         4.8         6.7         8.5        10.4
  A(I)            22.1        20.6        19.9        19.3        19.5
  V(I)            6.51        6.98        7.22        7.46        7.37

X STA.        10.4        12.4        14.6        16.8        19.1        21.6
  A(I)            19.9        20.3        20.6        20.7        21.5
  V(I)            7.22        7.09        6.98        6.93        6.69

X STA.        21.6        24.0        27.5        35.6        47.5       112.6
  A(I)            21.2        26.9        42.1        53.0        88.1
  V(I)            6.79        5.34        3.41        2.71        1.63
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        U.S. Geological Survey WSPRO Input File roya025.wsp
        Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
        TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                          RLB
           *** RUN DATE & TIME: 04-16-97  15:22

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      154     16447    31     39                         1945
   496.42           154     16447    31     39  1.00      0     31     1945

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.42     0.3    31.5   154.1   16447.    1940.  12.59
X STA.         0.3         3.3         4.7         5.9         7.1         8.2
  A(I)             13.4         8.3         7.2         6.9         6.7
  V(I)             7.23       11.65       13.49       14.03       14.56

X STA.         8.2         9.4        10.6        11.8        13.0        14.3
  A(I)              6.7         6.6         6.5         6.5         6.8
  V(I)            14.53       14.65       14.92       14.81       14.33

X STA.        14.3        15.7        17.1        18.5        19.9        21.3
  A(I)              6.9         6.9         6.9         6.8         7.1
  V(I)            14.09       14.15       14.02       14.17       13.61

X STA.        21.3        22.8        24.4        26.0        27.9        31.5
  A(I)              7.1         7.5         7.8         8.6        12.8
  V(I)            13.69       12.85       12.42       11.28        7.57

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1        1        10     5      5                            2
             2      213     17443    37     40                         2906
             3       49      1463    34     34                          341
   498.49           263     18917    75     79  1.21    -12     62     2535

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.49   -13.0    62.3   263.1   18917.    1940.   7.37
X STA.       -13.0        -1.0         1.2         2.8         4.3         5.6
  A(I)             21.3        14.0        11.8        10.8        10.4
  V(I)             4.56        6.93        8.22        9.01        9.37

X STA.         5.6         7.0         8.2         9.4        10.7        12.1
  A(I)             10.1         9.6         9.7         9.9        10.0
  V(I)             9.59       10.14        9.95        9.79        9.70

X STA.        12.1        13.6        15.1        16.8        18.5        20.2
  A(I)             10.0        10.3        10.4        10.5        10.6
  V(I)             9.72        9.44        9.30        9.23        9.12

X STA.        20.2        22.1        24.0        26.4        34.9        62.3
  A(I)             11.2        11.2        13.4        23.1        34.8
  V(I)             8.65        8.67        7.25        4.19        2.79
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       U.S. Geological Survey WSPRO Input File roya025.wsp
       Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
       TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                          RLB

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

EXITX:XS   ******    -12      313  0.94 *****  497.84  496.29    2125  496.91
       -31 ******     92    20625  1.30 ***** *******    0.79    6.80

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.96     497.15     496.96
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.41     513.78    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.41     513.78     496.96

FULLV:FV       32     -8      269  1.25  0.40  498.40  496.96    2125  497.15
         0     32     91    17330  1.29  0.16   -0.01    0.97    7.91
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.05     497.74     497.63
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.65     510.51    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.65     510.51     497.63

APPRO:AS       49     -6      211  1.83  0.88  499.56  497.63    2125  497.73
        49     49     56    14545  1.16  0.29    0.00    1.05   10.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.72     498.64     499.01     498.09
 ===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       32      0      207  1.33 *****  499.47  496.36    1914  498.14
         0 ******     32    17432  1.00 ***** *******    0.64    9.25

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.479  0.000  498.09 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    33.  0.12  0.47  500.76    0.00    216.  500.42

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    139.    74.   -60.    15.   0.5   0.4   3.7   4.4   0.8   2.8
   RT:     77.    51.    15.    65.   0.5   0.3   3.4   4.7   0.7   2.8

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

APPRO:AS       32   -113      473  0.47  0.22  500.88  497.63    2125  500.42
        49     33     82    35128  1.48  0.23    0.00    0.62    4.50

   FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -32.   -13.    92.   2125.   20625.     313.    6.80  496.91
   FULLV:FV      0.     -9.    91.   2125.   17330.     269.    7.91  497.15
   BRIDG:BR      0.      0.    32.   1914.   17432.     207.    9.25  498.14
   RDWAY:RG      8.*******   139.    216.******************    2.00  500.42
   APPRO:AS     49.  -114.    82.   2125.   35128.     473.    4.50  500.42

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    496.29    0.79  489.36  513.11************  0.94  497.84  496.91
   FULLV:FV    496.96    0.97  490.03  513.78  0.40  0.16  1.25  498.40  497.15
   BRIDG:BR    496.36    0.64  490.36  498.14************  1.33  499.47  498.14
   RDWAY:RG   ****************  499.91  507.65  0.12******  0.47  500.76  500.42
   APPRO:AS    497.63    0.62  490.46  510.51  0.22  0.23  0.47  500.88  500.42
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File roya025.wsp
        Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
        TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                          RLB

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

EXITX:XS   ******    -42      405  1.06 *****  498.72  497.06    2875  497.67
       -31 ******     93    27918  1.34 ***** *******    0.84    7.10

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.97     497.90     497.73
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   497.17     513.78    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   497.17     513.78     497.73

FULLV:FV       32    -24      348  1.40  0.40  499.30  497.73    2875  497.89
         0     32     93    23435  1.32  0.17   -0.01    0.97    8.26
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    1.19     498.33     498.80
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   497.39     510.51    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   497.39     510.51     498.80
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
            ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                 WSBEG,WSEND,CRWS =   498.80     510.51     498.80

APPRO:AS       49    -17      287  1.91 *****  500.71  498.80    2875  498.80
        49     49     63    21057  1.23 ***** *******    1.04   10.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
         WS1,WSSD,WS3,RGMIN =   501.02       0.00     497.94     499.91
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   502.86         0.      2875.
 ===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       32      0      206  1.60 *****  499.69  496.69    2095  498.09
         0 ******     32    20438  1.00 ***** *******    0.70   10.15

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.492  0.000  498.09 ****** ****** ******

   XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
  RDWAY:RG        8.    33.  0.12  0.48  501.55    0.01    810.  501.20

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:    472.   105.   -90.    15.   1.3   1.0   5.1   4.7   1.3   3.0
  RT:    338.    91.    15.   106.   1.3   0.8   4.8   4.6   1.2   3.0

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

APPRO:AS       32   -130      645  0.48  0.21  501.67  498.80    2875  501.20
        49     33    112    47527  1.55  0.00    0.01    0.60    4.46

  FIRST USER DEFINED TABLE.
   XSID:CODE     SRD    LEW     REW       Q        K     AREA     VEL    WSEL
  EXITX:XS      -32.   -43.     93.   2875.   27918.     405.    7.10  497.67
  FULLV:FV        0.   -25.     93.   2875.   23435.     348.    8.26  497.89
  BRIDG:BR        0.     0.     32.   2095.   20438.     206.   10.15  498.09
  RDWAY:RG        8.*******    472.    810.******************    2.00  501.20
  APPRO:AS       49.  -131.    112.   2875.   47527.     645.    4.46  501.20

 SECOND USER DEFINED TABLE.
   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
  EXITX:XS     497.06    0.84  489.36  513.11************  1.06  498.72  497.67
  FULLV:FV     497.73    0.97  490.03  513.78  0.40  0.17  1.40  499.30  497.89
  BRIDG:BR     496.69    0.70  490.36  498.14************  1.60  499.69  498.09
  RDWAY:RG   ****************  499.91  507.65  0.12******  0.48  501.55  501.20
  APPRO:AS     498.80    0.60  490.46  510.51  0.21  0.00  0.48  501.67  501.20
```
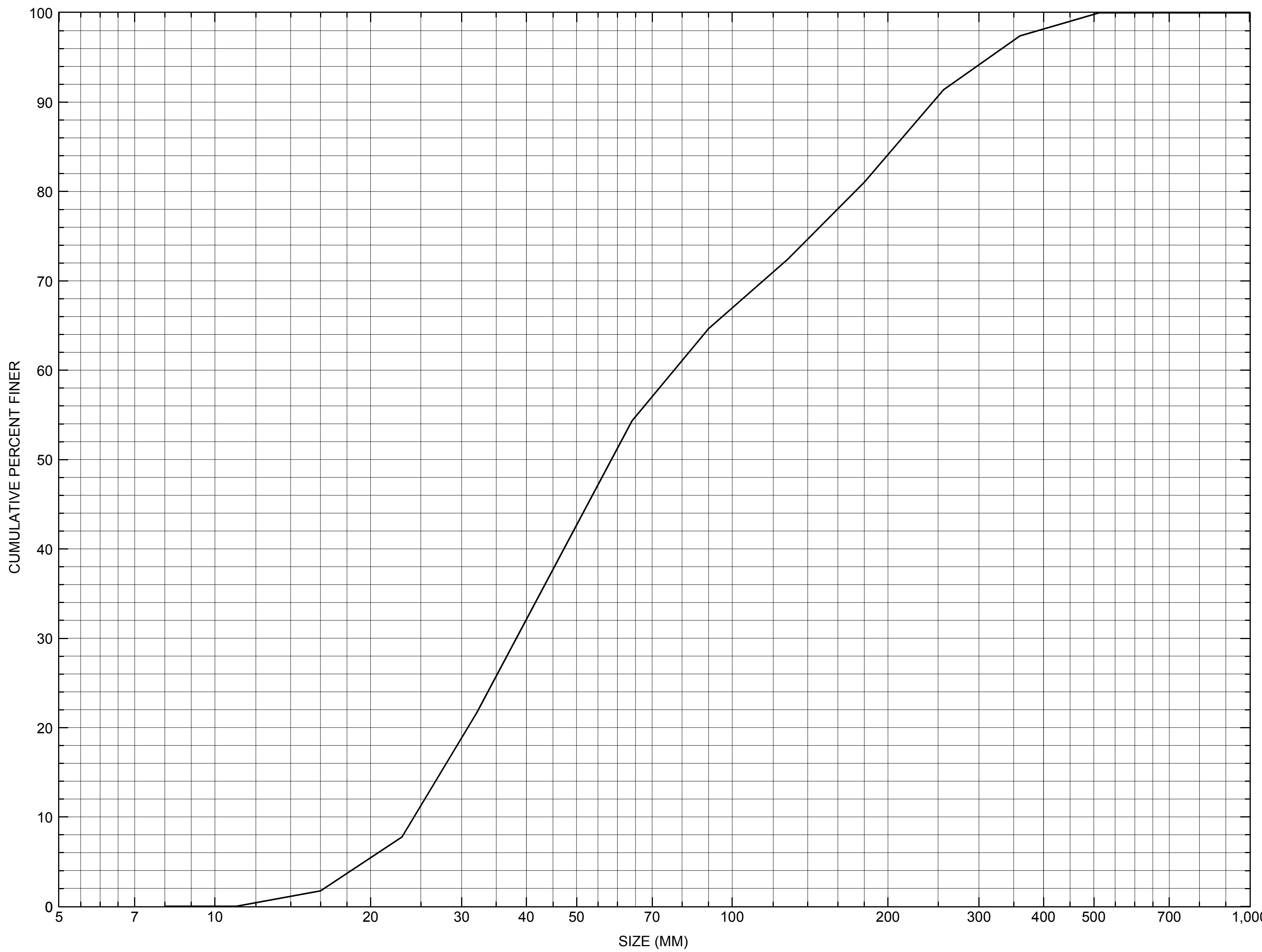

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File roya025.wsp
        Hydraulic analysis for structure ROYATH00550025   Date: 15-APR-97
        TH 55 CROSSING BROAD BROOK IN ROYALTON, VT                            RLB

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

EXITX:XS   ******     -9      289  0.91 *****  497.59  495.80    1940  496.68
       -31 ******     92    18832  1.30 ***** *******    0.80    6.70

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.00     496.91     496.47
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.18     513.78    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.18     513.78     496.47

FULLV:FV       32     -8      247  1.21  0.40  498.14  496.47    1940  496.93
         0     32     91    15839  1.26  0.15    0.00    0.99    7.86
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.01     497.56     497.29
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.43     510.51    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.43     510.51     497.29

APPRO:AS       49     -6      199  1.68  0.85  499.22  497.29    1940  497.55
        49     49     54    13639  1.14  0.23    0.00    1.01    9.75
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =    1940.     496.42

            <<<<<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       32      0      154  2.46 *****  498.88  496.42    1940  496.42
         0     32     31    16450  1.00 ***** *******    1.00   12.59

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.09 ****** ****** ******

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

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

APPRO:AS       32    -12      263  1.02  0.40  499.51  497.29    1940  498.49
        49     33     62    18905  1.21  0.23    0.02    0.77    7.38

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.483  0.054   17792.    -3.    28.   498.14

 FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.   -10.    92.   1940.   18832.     289.    6.70  496.68
   FULLV:FV       0.    -9.    91.   1940.   15839.     247.    7.86  496.93
   BRIDG:BR       0.     0.    31.   1940.   16450.     154.   12.59  496.42
   RDWAY:RG       8.**************      0.******************    2.00********
   APPRO:AS      49.   -13.    62.   1940.   18905.     263.    7.38  498.49

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.80    0.80  489.36  513.11************  0.91  497.59  496.68
   FULLV:FV    496.47    0.99  490.03  513.78  0.40  0.15  1.21  498.14  496.93
   BRIDG:BR    496.42    1.00  490.36  498.14************  2.46  498.88  496.42
   RDWAY:RG  ****************  499.91  507.65**********************************
   APPRO:AS    497.29    0.77  490.46  510.51  0.40  0.23  1.02  499.51  498.49
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ROYATH00550025, in Royalton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ROYATH00550025

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 22 / 95

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

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

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

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

Waterway *(I - 6)* BROAD BROOK

Road Name *(I - 7)*: -

Route Number TH055

Vicinity *(I - 9)* AT JCT C2 TH 2 & C3 TH55

Topographic Map South Royalton

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43461

Longitude *(i - 17; nnnnn.n)* 72317

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141600251416

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1933

Structure length *(I - 49; nnnnnn)* 000035

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

Deck Width *(I - 52; nn.n)* 161

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

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

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

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

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

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*) 006.5

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

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

Comments:

The structural inspection report of 6/22/94 indicates the structure is a steel stringer type bridge with a timber deck. The abutment walls and wingwalls are concrete which are in like new condition except for a few minor stains. The right abutment footing is reported as not in view but the left abutment footing is visible at the surface and there is some localized scouring noted at the downstream end. The top of the footing is noted as between 2 and 2.5 feet above the adjacent streambed level. Although the left abutment footing is exposed, the report indicates no undermining or settling of the abutments or wingwalls. The top surface of the footing has some surface spalling noted, but no reinforcement bar 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:

visible. The report indicated the channel makes a moderate bend into the crossing. The channel is composed of stone and gravel with some medium sized boulders. The banks are noted as fairly well protected with natural streambed material. Debris accumulation and bank erosion are noted as not evident on the report.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **11.61** mi^2 Lake and pond area **0** mi^2

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

Bridge site elevation **840** ft Headwater elevation **1958** ft

Main channel length **5.21** mi

10% channel length elevation **880** ft 85% channel length elevation **1440** ft

Main channel slope *(S)* **143.32** 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 cord to bed differences are from a sketch dated 6/22/94 that is attached to a bridge inspection report. The low cord elevations are from the 7/10/96 survey that was done for this report. This cross section is of the upstream face.**

Station	0	1.33	1.34	6.34	15.50	31.00	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low cord elevation	498.14	498.14	498.14	498.12	498.09	498.04	-	-	-	-	-
Bed elevation	491.34	491.34	489.34	489.92	491.09	491.84	-	-	-	-	-
Low cord to bed length	6.80	6.80	8.80	8.20	7.00	6.20	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/03/96**
Computerized by: **RB** Date: **10/03/96**
Reviewd by: **RB** Date: **05/13/97**

Structure Number **ROYATH00550025**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. WEBER** Date *(MM/DD/YY)* **04** / **13** / 19**95**

2. Highway District Number **04**
Mile marker **0000**
County **027**
Town **60850**
Waterway *(I - 6)* **BROAD BROOK**
Road Name **-**
Route Number **TH055**
Hydrologic Unit Code: **01080105**

3. Descriptive comments:
Located at the junction of CL2 TH2 and CL3 TH55.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** LBDS **4** 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 **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **35** *(feet)* Span length **31** *(feet)* Bridge width **16.1** *(feet)*

Road approach to bridge:

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

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

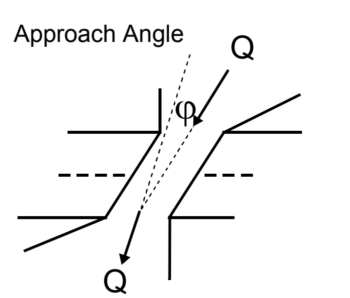
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

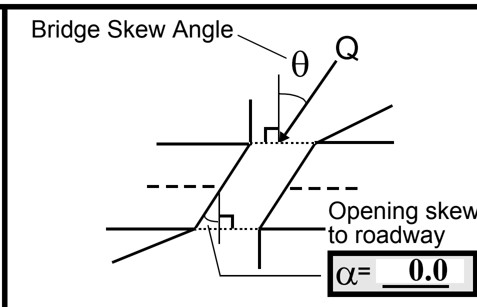
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	2	3	2
RBUS	0	-	2	1
RBDS	0	-	0	-
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **20**
16. Bridge skew: **20**





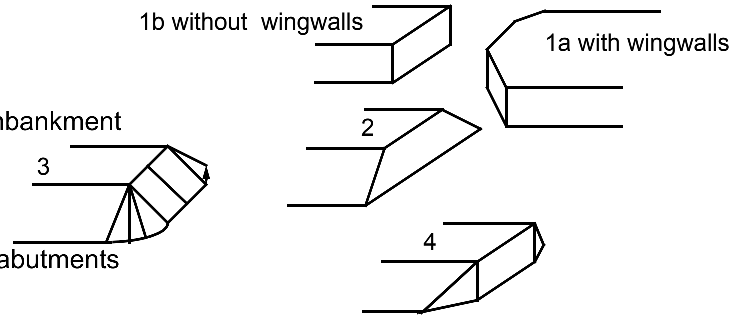
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **10** feet **UB** *(US, UB, DS)* to **35** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **70** feet **US** *(US, UB, DS)* to **120** feet **US**

*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 perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

7. Values are from the VT AOT files. Measured bridge length is 32 ft, span length is 29 ft, and the bridge width is 16 ft.
18. The US wingwalls slope down to 0.5 ft below the low chord.
4. Surface cover on the left bank is generally pasture while that on the right bank is forest. It is forest overall since the dominant watershed surface cover is forest. TH2 runs parallel to the stream along the immediate left bank.
17. The entire left bank US from 10 ft under the bridge to 120 ft US is a moderate impact zone.
11. Gravel road fill material is apparent at all road approaches down the bank.

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
33.5	6.0			3.0	1	4	3245	3245	2	1

23. Bank width **35.0** 24. Channel width **35.0** 25. Thalweg depth **37.5** 29. Bed Material **345**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** RB **-**

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

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

26. The percent vegetation cover on the US right bank is 4 though the immediate bank vegetation cover is brushy and the trees are set back.
27. Bank material is gravel, sand, cobble and boulder.
29. Bed material is gravel, cobble and boulder.
28. The US left bank is an impact zone from 70 ft US to 120 ft US.
30. Left bank protection is native boulders placed by man from the US end of the US left wingwall to 120 ft US.
A minor culvert inflow occurs 120 ft US on the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **40** 35. Mid-bar width: **3**

36. Point bar extent: **30** feet **US** (US, UB) to **90** feet **US** (US, UB, DS) positioned **85** %LB to **95** %RB

37. Material: **234**

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

Bar material is sand and gravel with some cobbles.

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

41. Mid-bank distance: **85** 42. Cut bank extent: **25** feet **US** (US, UB) to **120** feet **US** (US, UB, DS)

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

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

Road fill is slumping into the channel. There is man placed natural boulder protection on the bank. The slip failures are many small slumps rather than one large area of failure. These slumps occur along the left bank where the road embankment for TH2 is steep.

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
25.0		1.5		2	7	7	-

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

3452

63. Bed material is gravel, cobble, boulder and some sand.

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 N____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

There are some logs caught on the DS left bank but no debris is apparent US or at the bridge. Capture efficiency is moderate due to the impact at the US left end of the substructure.

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		20	90	2	2	1	2.5	90.0
RABUT	1	0	90			2	0	32.0

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

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

-

-

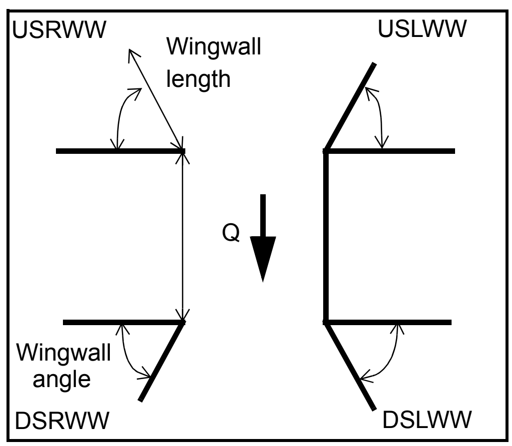
1

The left abutment footing is exposed its entire length but the maximum scour is at the DS end. Scour depth was calculated using an US average thalweg depth of 1.5 ft. There is some spalling of the left abutment footing its whole length. The spalling is most severe, 0.25 ft, on top of the footing's US end lessening the apparent exposure depth.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						32.0	
USRWW:	Y		1		2	1.0	
DSLWW:	0		0.5		Y	12.0	
DSRWW:	1		0		-	12.0	

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	-	2	Y	-	1	-	-	-
Condition	Y	1	1	-	2	-	-	-
Extent	1	2.5	0	2	0	0	0	-

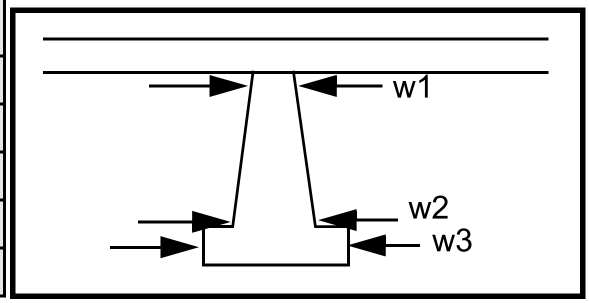
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**5.5**	**6.0**	**60.0**	**50.0**	**50.0**
Pier 2	**6.0**	**6.0**	-	**50.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e DS**	**ing is**	**0.25 ft**	**ing**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**end**	**spall**	**less.**	**had**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**of**	**ed**	**The**	**occu**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**the**	**mak-**	**expo**	**rred.**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**top**	**ing**	**sure**	**Pro-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**of**	**the**	**dept**	**tec-**	
92. Pushed	**the**	**appa**	**h is**	**tion**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**US**	**rent**	**reco**	**in all**	
95. Cross-members	**left**	**expo**	**rded**	**cases**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wing**	**sure**	**as if**	**is**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**wall**	**dept**	**no**	**man**	
98. Exposure depth	**foot-**	**h**	**spall**	**place**	

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

d native stone. There is some spalling of the DS left wingwall footing as well.

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 (Amb) - Thalweg depth (Amb) - Bed Material -

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

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

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

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

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

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

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

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

Material: _-___

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

-
-
-
-

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

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

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

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

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: _1_____

Scour dimensions: Length _4____ Width _3245_ Depth: _3245_ Positioned _1__ %LB to _1__ %RB

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

3425
2
0
1

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

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

Confluence 2: Distance _is___ Enters on _grav_ *(LB or RB)* Type _el,__ *(* ***1****- perennial;* ***2****- ephemeral)*

Confluence comments (eg. confluence name):

sand, cobble and boulder. There is moderate bank erosion on the left bank DS starting at 130 ft DS. The bed material is gravel, cobble, sand and boulder. The left bank protection is native boulders man placed from the

F. Geomorphic Channel Assessment

107. Stage of reach evolution _en__

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)*:

d of the DS left wingwall to 120 ft DS.

109. G. Plan View Sketch

N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ROYATH00550025 Town: ROYALTON
Road Number: TH 55 County: WINDSOR
Stream: BROAD BROOK

Initials RLB Date: 04/25/97 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 others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2125	2875	1940
Main Channel Area, ft2	284	313	213
Left overbank area, ft2	66	158	1
Right overbank area, ft2	123	176	49
Top width main channel, ft	37	37	37
Top width L overbank, ft	107	123	5
Top width R overbank, ft	53	84	34
D50 of channel, ft	0.191	0.191	0.191
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.7	8.5	5.8
y1, average depth, LOB, ft	0.6	1.3	0.2
y1, average depth, ROB, ft	2.3	2.1	1.4
Total conveyance, approach	35143	47624	18917
Conveyance, main channel	28185	33092	17443
Conveyance, LOB	2061	7945	10
Conveyance, ROB	4896	6587	1463
Percent discrepancy, conveyance	0.0028	0.0000	0.0053
Qm, discharge, MC, cfs	1704.3	1997.7	1788.8
Ql, discharge, LOB, cfs	124.6	479.6	1.0
Qr, discharge, ROB, cfs	296.0	397.6	150.0
Vm, mean velocity MC, ft/s	6.0	6.4	8.4
Vl, mean velocity, LOB, ft/s	1.9	3.0	1.0
Vr, mean velocity, ROB, ft/s	2.4	2.3	3.1
Vc-m, crit. velocity, MC, ft/s	9.1	9.2	8.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2125	2875	1940
(Q) discharge thru bridge, cfs	1914	2095	1940
Main channel conveyance	17432	20438	16447
Total conveyance	17432	20438	16447
Q2, bridge MC discharge,cfs	1914	2095	1940
Main channel area, ft2	207	206	154
Main channel width (normal), ft	32.0	32.0	31.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	32	32	31
y_bridge (avg. depth at br.), ft	6.47	6.44	4.97
Dm, median (1.25*D50), ft	0.23875	0.23875	0.23875
y2, depth in contraction,ft	6.21	6.71	6.46
ys, scour depth (y2-ybridge), ft	-0.26	0.28	1.49

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	2125	2875	1940
Q, thru bridge MC, cfs	1914	2095	1940
Vc, critical velocity, ft/s	9.07	9.22	8.64
Va, velocity MC approach, ft/s	6.00	6.38	8.40
Main channel width (normal), ft	32.0	32.0	31.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	32.0	32.0	31.0
qbr, unit discharge, ft2/s	59.8	65.5	62.6
Area of full opening, ft2	207.0	206.0	154.0
Hb, depth of full opening, ft	6.47	6.44	4.97
Fr, Froude number, bridge MC	0.64	0.7	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	177	200	N/A
**Hb, depth at downstream face, ft	5.53	6.25	N/A
**Fr, Froude number at DS face	0.81	0.74	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	498.09	498.09	0

Elevation of Bed, ft	491.62	491.65	-4.97
Elevation of Approach, ft	500.42	501.2	0
Friction loss, approach, ft	0.22	0.21	0.4
Elevation of WS immediately US, ft	500.20	500.99	-0.40
ya, depth immediately US, ft	8.58	9.34	4.57
Mean elevation of deck, ft	499.92	499.92	0
w, depth of overflow, ft (>=0)	0.28	1.07	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.94	1.00
**Cc, for downstream face (<=1.0)	0.893207	0.92999	ERR
Ys, scour w/Chang equation, ft	0.56	1.14	N/A
Ys, scour w/Umbrell equation, ft	0.76	1.22	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	1.85	1.39	N/A
**Ys, scour w/Umbrell equation, ft	1.69	1.41	ERR

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

y2, from Laursen's equation, ft	6.21	6.71	6.46
WSEL at downstream face, ft	497.15	497.89	0.00
Depth at downstream face, ft	5.53	6.24	4.97
Ys, depth of scour (Laursen), ft	0.68	0.48	N/A

Armoring

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1914	2095	1940
Main channel area (DS), ft2	177	200	154
Main channel width (normal), ft	32.0	32	31.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	32.0	32.0	31.0
D90, ft	0.8013	0.8013	0.8013
D95, ft	1.0305	1.0305	1.0305
Dc, critical grain size, ft	0.5998	0.5330	0.8548
Pc, Decimal percent coarser than Dc	0.185	0.216	0.083
Depth to armoring, ft	7.93	5.80	28.33

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	2125	2875	1940	2125	2875	1940
a', abut.length blocking flow, ft	114.6	131.1	13	49.7	80.6	31.3
Ae, area of blocked flow ft2	84.37	124.2	27.66	101.43	108.37	45.4

Qe, discharge blocked abut.,cfs	--	--	141.09	--	--	141.51
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.76	3.37	5.10	2.34	2.20	3.12
ya, depth of f/p flow, ft	0.74	0.95	2.13	2.04	1.34	1.45
--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	0.500	0.473	0.616	0.278	0.275	0.456
ys, scour depth, ft	8.60	10.25	8.55	8.91	7.96	7.72

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)	114.6	131.1	13	49.7	80.6	31.3
y1 (depth f/p flow, ft)	0.74	0.95	2.13	2.04	1.34	1.45
a'/y1	155.66	138.38	6.11	24.35	59.95	21.58
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.50	0.47	0.62	0.28	0.28	0.46
Ys w/ corr. factor K1/0.55:						
vertical	4.26	5.38	ERR	ERR	6.39	ERR
vertical w/ ww's	3.49	4.41	ERR	ERR	5.24	ERR
spill-through	2.34	2.96	ERR	ERR	3.51	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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.81	0.74	1	0.81	0.74	1
y, depth of flow in bridge, ft	5.53	6.25	4.97	5.53	6.25	4.97
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.12	ERR	ERR	2.12	ERR
Fr>0.8 (vertical abut.)	2.18	ERR	2.08	2.18	ERR	2.08