LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (BRNATH00660028) on TOWN HIGHWAY 66, crossing LOCUST CREEK, BARNARD, VERMONT

U.S. Geological Survey
Open-File Report 97-209

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

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By TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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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 28 (BRNATH00660028) ON TOWN HIGHWAY 66, CROSSING LOCUST CREEK, BARNARD, VERMONT

By **Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNATH00660028 on Town Highway 66 crossing the Locust Creek, Barnard, 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 Green Mountain section of the New England physiographic province in central Vermont. The 21.5-mi^2 drainage area is in a predominantly rural basin. In the vicinity of the study site, the surface cover is pasture.

In the study area, the Locust Creek has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 47 ft and an average channel depth of 5 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 72.6 mm (0.238 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 22 and 29, 1994, respectively, indicated that the reach was stable. Additional Level I data was collected on 12/15/94 and was used to update the data shown in Appendix E.

The Town Highway 66 crossing of the Locust Creek is a 41-ft-long, one-lane bridge consisting of a 39 ft steel stringer type bridge with a concrete deck (Vermont Agency of Transportation, written communication, August 24, 1994). The clear span is 36.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The upstream right wingwall is protected by stone fill. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 0 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and 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 0.3 to 2.2 ft. The worst-case contraction scour was computed at the incipient-overtopping discharge,which was less than the 100-year discharge. Abutment scour ranged from 11.1 to 14.6 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 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.

Bethel, VT. Quadrangle, 1:24,000, 1980

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 BRNATH00660028 ***Stream*** Locust Creek

County Windsor ***Road*** TH66 ***District*** 4

Description of Bridge

Bridge length 41 ***ft*** ***Bridge width*** 16 ***ft*** ***Max span length*** 39 ***ft***

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

Abutment type vertical ***Embankment type*** sloping

Stone fill on abutment? no ***Date of inspection*** 09/22/94

Description of stone fill Type-2 on US right wingwall.

Abutments and wingwalls are concrete. Both abutments are reported in good (like new) condition. The report indicates that both upstream wingwalls have some minor cracks near the top of the walls.

Y 10

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

Bridge is located on a mild bend in the channel. The right bank is impacted by flood flows.

09/22/94

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	09/29/94	0	0
Level II		-	-

Potential for debris Low

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

None on 09/22/94

Description of the Geomorphic Setting

General topography The bridge is located on Locust Creek approximately 3 miles US from the White River in a moderate-width, steep-walled valley.

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

Date of inspection 09/22/94

DS left: narrow flood plain

DS right: moderate-width flood plain

US left: narrow flood plain

US right: moderate-width flood plain

Description of the Channel

Average top width 47 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material gravel and cobbles ***Bank material*** gravel

Small channel, moderate relief valley; moderate-width flood plain, with slight sinuosity.

09/22/94

Vegetative co small trees, shrubs, and brush with pasture on overbanks

DS left: small trees, shrubs, and brush with pasture on overbanks

DS right: small trees, shrubs, and brush with pasture on overbanks

US left: small trees, shrubs, and brush with pasture on overbanks

US right: Y

Do banks appear stable? 09/22/94-- US right bank shows signs of light fluvial erosion.

date of observation.

None on 09/22/94

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 21.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None. Area is upland valley setting, with few residences.

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 3900 ***ft³/s*** ***Q500*** 4900 ***ft³/s***

Q100 and Q500 values based on drainage area relationship with Barnard bridge 35; [(21.5/24.1)(EXP)0.7]. Discharges at bridge 35 (4,200 cfs and 5,400 cfs) were selected from a range defined from applicable emperical methods (Benson, 1962; Talbot, 1887; Potter, 1957a; Potter, 1957b; Johnson and Laraway, 1971, written commun.; Johnson and Tasker, 1974; Federal Highway Administration, 1983).

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' located 2' DS of bridge deck, set in top of the intersection of left abutment and DS left wing wall (elev.499.50 feet, arbitrary survey datum). RM2 is a chiseled 'X' located 2' DS of bridge deck, set in top of the intersection of right abutment and DS right wing wall (elev.499.35 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT-	-47	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPR-	53	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 0.057, and overbank "n" values ranged from 0.035 to 0.090.

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 0.012 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1966).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.2 *ft*
Average low steel elevation 497.6 *ft*

100-year discharge 3,900 *ft³/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Y *Discharge over road* 197 *s*
Area of flow in bridge opening 364 *ft²*
Average velocity in bridge opening 10.4 *ft/s*
Maximum WSPRO tube velocity at bridge 12.0 *ft/s*

Water-surface elevation at Approach section with bridge 500.3
Water-surface elevation at Approach section without bridge 497.0
Amount of backwater caused by bridge 3.3 *t*

500-year discharge 4,900 *ft³/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Y *Discharge over road* 819
Area of flow in bridge opening 364 *ft²*
Average velocity in bridge opening 11.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.0 */s*

Water-surface elevation at Approach section with bridge 501.1
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 3.4

Incipient overtopping discharge 3,300 *ft³/s*
Water-surface elevation in bridge opening 494.2 *ft*
Area of flow in bridge opening 237 *ft²*
Average velocity in bridge opening 14.0 *ft/s*
Maximum WSPRO tube velocity at bridge 16.6 *ft/s*

Water-surface elevation at Approach section with bridge 497.8
Water-surface elevation at Approach section without bridge 496.5
Amount of backwater caused by bridge 1.3 *t*

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, 1993). 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.

The 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang presusre-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Therefore, contraction scour for the 100-year and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). For the incipient road-overflow discharge, contraction scour was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18). The results of Laursen's clear-water contraction scour for the 100-year and 500-year events were also computed and can be found in appendix F.

Scour at the left abutment was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). The Froehlich equation gives "excessively conservative estimates of scour depths" (Richardson and others, 1993, p. 48). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the right abutment was computed by use of the HIRE equation (Richardson and others, 1993, p. 50, equation 25) 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	0.3	1.0	2.2
Depth to armoring	4.9	7.4	31.1
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	13.6	14.6	11.8
Right abutment	13.2	14.1	11.1
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	2.1	2.4	2.7
Right abutment	2.1	2.4	2.7
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

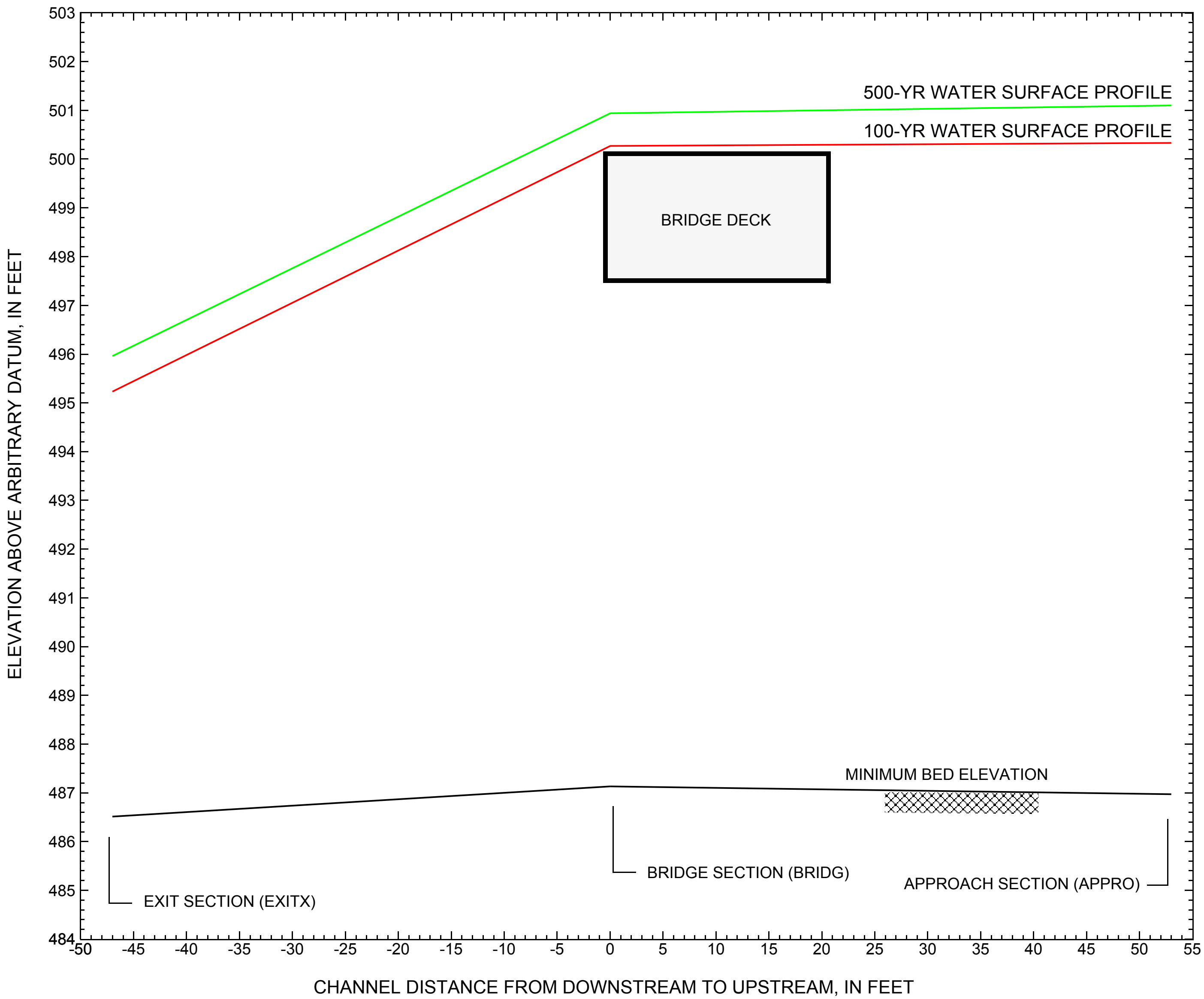

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRNATH00660028 on Town Highway 34, crossing Locust Creek, Barnard, Vermont.

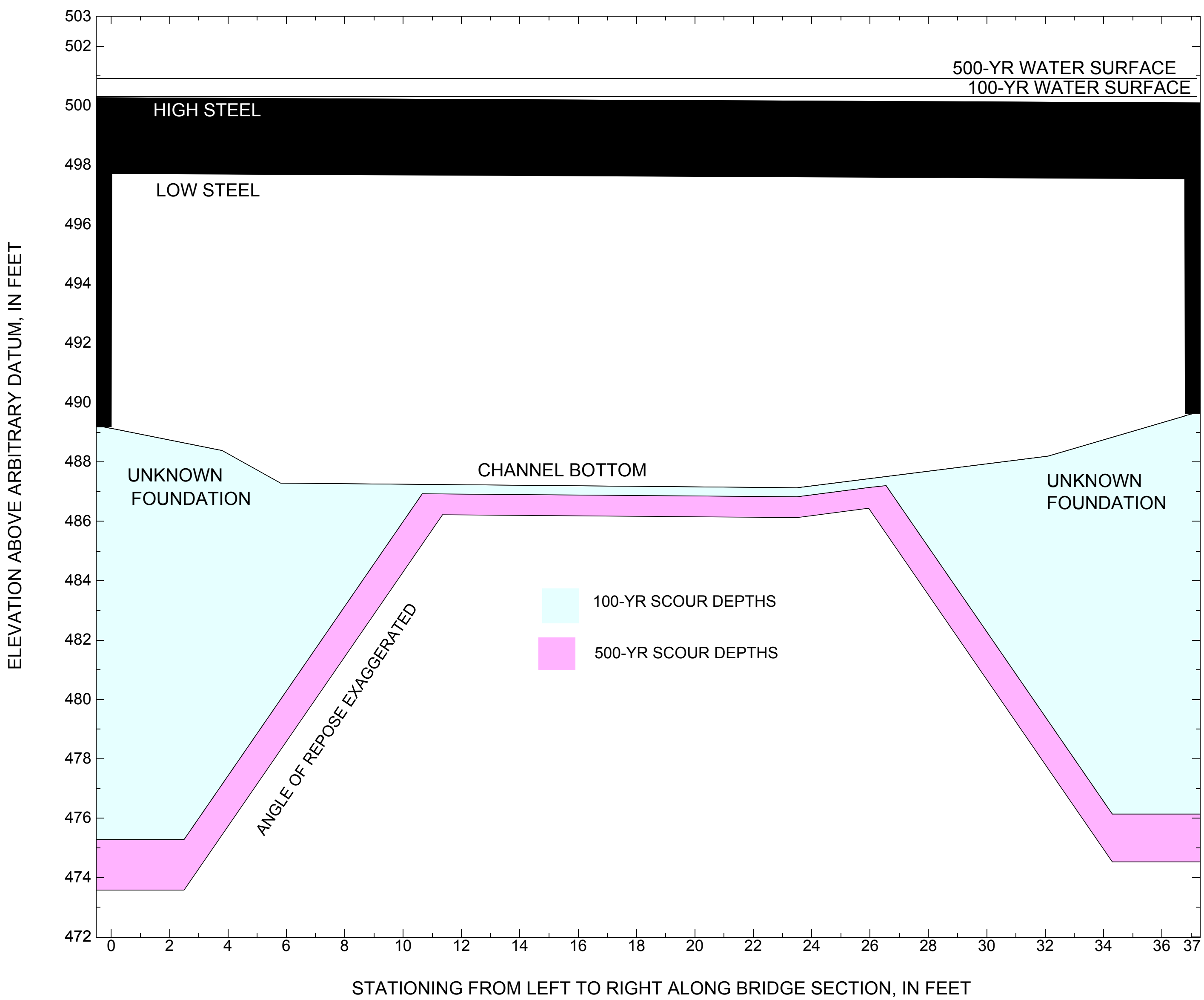

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRNATH00660028 on Town Highway 34, crossing Locust Creek, Barnard, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNATH00660028 on Town Highway 66, crossing Locust Creek, Barnard, 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 3,900 cubic-feet per second											
Left abutment	0.0	--	497.7	--	489.2	0.3	13.6	--	13.9	475.3	--
Right abutment	36.8	--	497.5	--	489.6	0.3	13.2	--	13.5	476.1	--

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 BRNATH00660028 on Town Highway 66, crossing Locust Creek, Barnard, 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 4,900 cubic-feet per second											
Left abutment	0.0	--	497.7	--	489.2	1.0	14.6	--	15.6	473.6	--
Right abutment	36.8	--	497.5	--	489.6	1.0	14.1	--	15.1	474.5	--

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, 1980, Bethel, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna028.wsp
T2        CREATED ON 13-NOV-95 FOR BRIDGE barnath0660028 USING FILE brna028.dca
T3        Hydraulic analysis of brna028  ts
Q          3900.0    4900.0    3300.0
SK         0.012     0.012     0.012
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
XS   EXIT-    -47           0.
GR          -65.9, 500.70    -55.7, 496.09    -34.2, 494.02     -8.6, 493.89
GR           -4.7, 490.90      0.0, 489.48      3.5, 488.10      5.0, 487.09
GR            7.7, 486.51     16.2, 486.53     24.1, 486.74     30.2, 488.16
GR           36.4, 490.96     39.4, 493.18     67.9, 492.64     96.0, 495.67
GR          152.4, 496.63    169.3, 503.05
N           0.070         0.057        0.09        0.035
SA                   -8.6         39.4        47.4
*
XS   FULLV      0  * * *   0.014
*
BR   BRIDG   0     497.6       0.0
GR            0.0, 497.74      0.0, 489.18      3.8, 488.39      5.8, 487.29
GR           14.3, 487.19     23.5, 487.13     32.1, 488.20     36.8, 489.63
GR           36.8, 497.51      0.0, 497.74
CD         4     20.5      4.2    500.2     52.5
N           0.045
*
XR   RDWAY     10      15.7   2
GR          -70.4, 502.48    -44.1, 500.82    -15.7, 500.39     -2.1, 500.25
GR            0.0, 500.27     17.8, 500.11     36.8, 500.10     38.5, 500.11
GR           95.1, 499.42    143.2, 499.91    217.6, 504.32    264.5, 506.18
*
AS   APPR-     53           0.
GR          -69.4, 503.83    -56.0, 498.52    -31.8, 494.51     -4.9, 492.86
GR            0.0, 491.66      7.5, 488.76      9.6, 488.27     13.5, 487.68
GR           21.3, 487.17     26.3, 486.97     33.8, 486.99     36.8, 488.77
GR           40.8, 490.91     41.7, 494.02     74.9, 493.66    110.7, 496.97
GR          186.1, 499.07    215.4, 503.28
N           0.070         0.057        0.09        0.035
SA                   -4.9         41.7        49.7
*
HP 1 BRIDG   497.74 1 497.74
HP 2 BRIDG   497.74 * * 3779
HP 2 RDWAY   500.27 * * 197
HP 1 APPR-   500.33 1 500.33
HP 2 APPR-   500.33 * * 3900
*
HP 1 BRIDG   497.74 1 497.74
HP 2 BRIDG   497.74 * * 4093
HP 2 RDWAY   500.94 * * 819
HP 1 APPR-   501.10 1 501.10
HP 2 APPR-   501.10 * * 4900
*
HP 1 BRIDG   494.15 1 494.15
HP 2 BRIDG   494.15 * * 3300
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna028.wsp
        CREATED ON 13-NOV-95 FOR BRIDGE barnath0660028 USING FILE brna028.dca
        Hydraulic analysis of brna028  ts
           *** RUN DATE & TIME: 01-11-96  10:30
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      364     30483      0     91                            0
   497.74           364     30483      0     91  1.00      0     37        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.74     0.0    36.8   364.3   30483.    3779.  10.37

X STA.        0.0        3.4        5.5        7.2        8.8       10.4
  A(I)           30.1       20.5       17.8       16.8       16.5
  V(I)           6.28       9.20      10.59      11.28      11.43

X STA.       10.4       12.0       13.5       15.0       16.5       18.0
  A(I)           16.2       16.4       15.9       15.7       15.7
  V(I)          11.67      11.53      11.91      12.05      12.05

X STA.       18.0       19.5       21.1       22.6       24.1       25.7
  A(I)           15.8       15.8       16.0       16.2       16.3
  V(I)          11.97      11.97      11.83      11.69      11.56

X STA.       25.7       27.4       29.1       31.1       33.2       36.8
  A(I)           16.9       17.1       18.6       19.8       30.3
  V(I)          11.16      11.07      10.17       9.54       6.24

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.27    -4.0   149.3    63.7    1683.     197.   3.09

X STA.       -4.0       54.6       63.5       69.9       75.2       79.6
  A(I)            9.0        3.7        3.2        3.1        2.8
  V(I)           1.09       2.69       3.08       3.22       3.53

X STA.       79.6       83.4       87.0       90.2       93.2       96.0
  A(I)            2.6        2.6        2.5        2.4        2.4
  V(I)           3.73       3.81       3.92       4.07       4.17

X STA.       96.0       98.9      102.0      105.4      108.9      112.8
  A(I)            2.4        2.5        2.6        2.6        2.7
  V(I)           4.12       4.02       3.85       3.86       3.63

X STA.      112.8      117.1      122.0      127.6      134.9      149.3
  A(I)            2.8        2.9        3.1        3.5        4.4
  V(I)           3.56       3.37       3.17       2.81       2.23

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      275     16854     56     56                         3472
             2      542     68673     47     51                        10486
             3       51      2886      8      8                          727
             4      524     52404    145    145                         5647
   500.33          1392    140818    255    261  1.18    -60    195    16978

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.33   -60.6   194.9  1391.8  140818.    3900.   2.80

X STA.      -60.6      -25.1      -10.0        0.4        6.4       11.1
  A(I)          136.7      101.2       80.0       60.4       54.8
  V(I)           1.43       1.93       2.44       3.23       3.56

X STA.       11.1       15.1       19.0       22.7       26.5       30.2
  A(I)           50.6       50.1       49.4       49.4       49.6
  V(I)           3.85       3.89       3.95       3.95       3.93

X STA.       30.2       34.0       39.2       53.4       61.4       69.8
  A(I)           51.0       61.3       96.9       52.2       54.9
  V(I)           3.82       3.18       2.01       3.73       3.55

X STA.       69.8       78.5       89.0      104.4      131.8      194.9
  A(I)           57.2       61.9       71.5       87.7      114.9
  V(I)           3.41       3.15       2.73       2.22       1.70
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     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      364     30483      0     91                            0
   497.74           364     30483      0     91  1.00      0     37        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.74     0.0    36.8   364.3   30483.    4093.  11.24

 X STA.         0.0        3.4        5.5        7.2        8.8       10.4
   A(I)            30.1       20.5       17.8       16.8       16.5
   V(I)            6.80       9.97      11.48      12.22      12.38

 X STA.        10.4       12.0       13.5       15.0       16.5       18.0
   A(I)            16.2       16.4       15.9       15.7       15.7
   V(I)           12.64      12.48      12.90      13.05      13.05

 X STA.        18.0       19.5       21.1       22.6       24.1       25.7
   A(I)            15.8       15.8       16.0       16.2       16.3
   V(I)           12.96      12.96      12.81      12.66      12.52

 X STA.        25.7       27.4       29.1       31.1       33.2       36.8
   A(I)            16.9       17.1       18.6       19.8       30.3
   V(I)           12.08      11.99      11.02      10.34       6.75

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.94   -46.0   160.6   186.9    7060.     819.   4.38

 X STA.       -46.0        6.1       25.8       45.9       55.5       62.8
   A(I)            23.7       15.7       17.1        9.5        7.9
   V(I)            1.73       2.60       2.40       4.33       5.19

 X STA.        62.8       69.2       75.1       80.5       85.4       90.1
   A(I)             7.4        7.3        7.1        6.8        6.7
   V(I)            5.50       5.63       5.81       6.03       6.15

 X STA.        90.1       94.5       98.9      103.5      108.4      113.6
   A(I)             6.6        6.6        6.7        6.9        7.1
   V(I)            6.25       6.17       6.08       5.97       5.75

 X STA.       113.6      119.3      125.4      132.4      140.2      160.6
   A(I)             7.4        7.5        8.2        8.6       12.1
   V(I)            5.50       5.43       5.02       4.75       3.39

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      319     21020     58     58                         4256
             2      578     76418     47     51                        11545
             3       57      3493      8      8                          863
             4      638     70978    151    151                         7448
   501.10          1591    171909    263    268  1.16    -62    200    20664

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.10   -62.5   200.2  1591.3  171909.    4900.   3.08

 X STA.       -62.5      -26.4      -10.7        0.2        6.8       11.6
   A(I)           155.7      116.3       91.6       71.4       61.8
   V(I)            1.57       2.11       2.67       3.43       3.96

 X STA.        11.6       16.1       20.4       24.5       28.6       32.7
   A(I)            59.7       58.9       58.0       57.9       57.9
   V(I)            4.10       4.16       4.22       4.23       4.23

 X STA.        32.7       37.8       51.8       59.8       68.1       76.4
   A(I)            66.6      112.6       58.1       60.6       61.8
   V(I)            3.68       2.18       4.22       4.04       3.96

 X STA.        76.4       86.0       98.6      117.0      144.0      200.2
   A(I)            65.6       73.5       82.4       96.4      124.6
   V(I)            3.73       3.33       2.97       2.54       1.97
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     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      236     23004     37     47                         3401
    494.15           236     23004     37     47  1.00      0     37     3401

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        494.15     0.0    36.8   236.4   23004.    3300.  13.96

 X STA.         0.0        3.8        6.0        7.7        9.3       10.8
   A(I)            20.5       13.8       11.7       10.9       10.5
   V(I)            8.06      11.94      14.12      15.13      15.77

 X STA.        10.8       12.3       13.8       15.2       16.7       18.1
   A(I)            10.5       10.4       10.0        9.9        9.9
   V(I)           15.77      15.93      16.44      16.61      16.59

 X STA.        18.1       19.5       20.9       22.4       23.8       25.4
   A(I)            10.0       10.0       10.1       10.1       10.6
   V(I)           16.50      16.48      16.27      16.39      15.61

 X STA.        25.4       27.0       28.7       30.6       32.9       36.8
   A(I)            10.7       11.3       11.9       13.4       20.2
   V(I)           15.47      14.62      13.83      12.27       8.16

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      144      6440     47     47                         1430
              2      424     45709     47     51                         7270
              3       31      1244      8      8                          341
              4      203     14734     91     91                         1721
    497.81           802     68127    193    197  1.27    -51    141     8254
1
   HP 2 APPR-   497.81 * * 3300

VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR-;  SRD =      53.

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.81   -51.7   140.9   802.1   68127.    3300.   4.11

 X STA.       -51.7      -17.3       -4.0        2.8        7.1       10.5
   A(I)            87.0       61.1       41.5       35.0       31.1
   V(I)            1.90       2.70       3.97       4.71       5.31

 X STA.        10.5       13.5       16.3       19.0       21.6       24.2
   A(I)            29.7       28.6       28.3       27.4       27.8
   V(I)            5.56       5.76       5.84       6.02       5.94

 X STA.        24.2       26.7       29.3       31.9       34.7       38.6
   A(I)            27.8       27.8       28.2       30.0       35.6
   V(I)            5.94       5.93       5.86       5.49       4.64

 X STA.        38.6       52.8       61.9       71.6       82.5      140.9
   A(I)            64.1       36.2       39.1       42.7       73.1
   V(I)            2.58       4.55       4.22       3.87       2.26
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WSPRO OUTPUT FILE (continued)

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+++ BEGINNING PROFILE CALCULATIONS --   3

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

EXIT-:XS   ******    -46      463  1.34 *****  496.57  494.81    3900  495.23
       -46 ******     92    35569  1.21 ***** *******    0.90    8.42

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.93     495.79     495.47

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.73     503.71    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.73     503.71     495.47

FULLV:FV       47    -45      450  1.41  0.58  497.21  495.47    3900  495.79
         0     47     91    34358  1.21  0.04    0.01    0.93    8.67
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR-"     KRATIO =  1.57

APPR-:AS       53    -46      652  0.69  0.44  497.64 *******    3900  496.95
        53     53    111    53923  1.24  0.00    0.00    0.58    5.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.77     499.13     499.33     497.60

 ===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       47      0      364  1.67 *****  499.41  494.62    3779  497.74
         0 ******     37    30483  1.00 ***** *******    0.58   10.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.466  0.000  497.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    37.  0.03  0.14  500.44    0.02    197.  500.27

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      7.    22.    -4.    18.   0.2   0.1   1.9   4.4   0.2   2.6
   RT:    191.   131.    18.   149.   0.9   0.5   3.4   3.1   0.6   2.8

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

APPR-:AS       33    -60     1391  0.14  0.12  500.47  495.35    3900  500.33
        53     36    195   140651  1.18  0.53    0.02    0.23    2.80

       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
   EXIT-:XS     -47.   -47.    92.   3900.   35569.     463.    8.42  495.23
   FULLV:FV       0.   -46.    91.   3900.   34358.     450.    8.67  495.79
   BRIDG:BR       0.     0.    37.   3779.   30483.     364.   10.37  497.74
   RDWAY:RG      10.*******     7.    197.       0.*********    2.00  500.27
   APPR-:AS      53.   -61.   195.   3900.  140651.    1391.    2.80  500.33


 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT-:XS    494.81    0.90  486.51  503.05************  1.34  496.57  495.23
   FULLV:FV    495.47    0.93  487.17  503.71  0.58  0.04  1.41  497.21  495.79
   BRIDG:BR    494.62    0.58  487.13  497.74************  1.67  499.41  497.74
   RDWAY:RG  ****************  499.42  506.18  0.03******  0.14  500.44  500.27
   APPR-:AS    495.35    0.23  486.97  503.83  0.12  0.53  0.14  500.47  500.33
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

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

EXIT-:XS   ******    -53      572  1.46 *****  497.42  495.49    4900  495.96
       -46 ******    113    44687  1.28 ***** *******    0.92    8.57

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.94     496.52     496.14

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =    495.46     503.71    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    495.46     503.71     496.14

FULLV:FV       47    -52      553  1.54  0.58  498.04  496.14    4900  496.51
         0     47    107    43354  1.26  0.04    0.00    0.94    8.85
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPR-”     KRATIO =  1.52

APPR-:AS       53    -50      781  0.77  0.44  498.48 *******    4900  497.70
        53     53    137    66102  1.26  0.00   -0.01    0.61    6.27
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.31       0.00     495.93     499.42

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.49     500.41     500.58     497.60

 ===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       47      0      364  1.96 *****  499.70  495.00    4093  497.74
         0 ******     37    30483  1.00 ***** *******    0.63   11.24

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.481  0.000  497.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    37.  0.03  0.17  501.24    0.00    819.  500.94

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    136.    64.   -46.    18.   0.8   0.5   3.9   4.1   0.8   2.9
   RT:    683.   142.    18.   161.   1.5   1.1   5.2   4.4   1.4   2.9

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

APPR-:AS       33    -62     1592  0.17  0.14  501.27  496.00    4900  501.10
        53     37    200   172095  1.16  0.45    0.00    0.24    3.08

       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
    EXIT-:XS     -47.   -54.   113.   4900.  44687.     572.    8.57  495.96
    FULLV:FV       0.   -53.   107.   4900.  43354.     553.    8.85  496.51
    BRIDG:BR       0.     0.    37.   4093.  30483.     364.   11.24  497.74
    RDWAY:RG      10.*******   136.    819.******************    2.00  500.94
    APPR-:AS      53.   -63.   200.   4900. 172095.    1592.    3.08  501.10

   SECOND USER DEFINED TABLE.
     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXIT-:XS    495.49    0.92  486.51  503.05************  1.46  497.42  495.96
    FULLV:FV    496.14    0.94  487.17  503.71  0.58  0.04  1.54  498.04  496.51
    BRIDG:BR    495.00    0.63  487.13  497.74************  1.96  499.70  497.74
    RDWAY:RG  ****************  499.42  506.18  0.03******  0.17  501.24  500.94
    APPR-:AS    496.00    0.24  486.97  503.83  0.14  0.45  0.17  501.27  501.10
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

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

EXIT-:XS   ******    -41      402  1.25 *****  496.02  494.29    3300  494.78
       -46 ******     88    30124  1.19 ***** *******    0.90    8.20

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.93     495.34     494.95

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.28     503.71    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.28     503.71     494.95

FULLV:FV       47    -40      388  1.33  0.59  496.65  494.95    3300  495.32
         0     47     87    28876  1.18  0.04    0.00    0.94    8.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR-"     KRATIO =  1.59

APPR-:AS       53    -43      576  0.64  0.44  497.09 *******    3300  496.45
        53     53    105    45920  1.25  0.00    0.00    0.57    5.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       47      0      237  3.13  0.74  497.28  494.04    3300  494.15
         0     47     37    23018  1.03  0.51   -0.01    0.99   13.95

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.983 ******  497.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR-:AS       33    -51      803  0.33  0.25  498.15  494.85    3300  497.81
        53     36    141    68170  1.27  0.63    0.02    0.40    4.11

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.752  0.401   40629.     5.    42.   497.72

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT-:XS     -47.   -42.    88.   3300.   30124.     402.    8.20  494.78
   FULLV:FV       0.   -41.    87.   3300.   28876.     388.    8.51  495.32
   BRIDG:BR       0.     0.    37.   3300.   23018.     237.   13.95  494.15
   RDWAY:RG      10.**************      0.******************    2.00********
   APPR-:AS      53.   -52.   141.   3300.   68170.     803.    4.11  497.81

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR-:AS       5.    42.   40629.

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT-:XS    494.29    0.90  486.51  503.05************  1.25  496.02  494.78
   FULLV:FV    494.95    0.94  487.17  503.71  0.59  0.04  1.33  496.65  495.32
   BRIDG:BR    494.04    0.99  487.13  497.74  0.74  0.51  3.13  497.28  494.15
   RDWAY:RG  ***************  499.42  506.18**********************************
   APPR-:AS    494.85    0.40  486.97  503.83  0.25  0.63  0.33  498.15  497.81
   ER
```
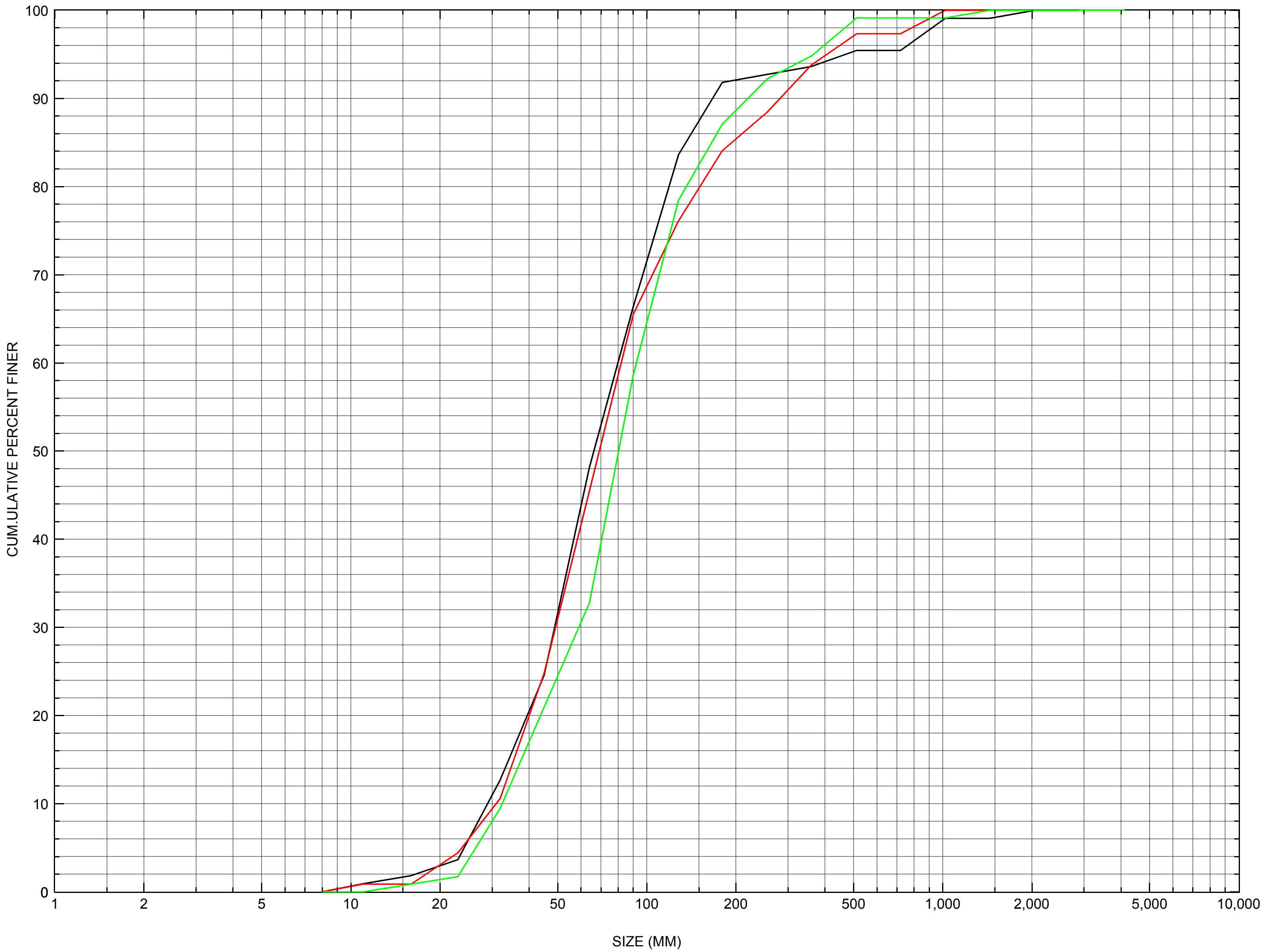

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BRNATH00660028, in Barnard, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **BRNATH00660028**

General Location Descriptive

Data collected by *(First Initial, Full last name)* **M. WEBER**

Date *(MM/DD/YY)* **02 / 08 / 95**

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

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

Town *(FIPS place code; I - 4; nnnnn)* **02725**

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

Waterway *(I - 6)* **LOCUST CREEK**

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

Route Number **TH066**

Vicinity *(I - 9)* **0.02 MI TO JCT W VT12**

Topographic Map **Bethel**

Hydrologic Unit Code: **01080105**

Latitude *(I - 16; nnnn.n)* **43469**

Longitude *(i - 17; nnnnn.n)* **72381**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10140300281403**

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

Maximum span length *(I - 48; nnnn)* **0039**

Year built *(I - 27; YYYY)* **1974**

Structure length *(I - 49; nnnnnn)* **000041**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000020**

Deck Width *(I - 52; nn.n)* **160**

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

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

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

Waterway adequacy *(I - 71; n)* **8**

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

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*) **-**

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

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

Comments:

The structural inspection report of 6/6/94 indicates the structure is a single span steel stringer type bridge with a concrete deck. The bridge provides access only for two homes. Both abutments are reported in good (like new) condition. The report indicates that both upstream wingwalls have some minor cracks near the top of the walls. The footings of the abutments and wingwalls are noted as not in view. The report notes that both abutments have some natural streambed material banked up against the walls providing protection. The streambed is composed of stone and gravel, with some small boulders. No mention is made in the report concerning point bars, debris, or the alignment of the waterway with the bridge.

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: Stone and gravel

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:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* ________ mi^2 Lake and pond area _________ mi^2

Watershed storage *(ST)* __________ %

Bridge site elevation __________ ft Headwater elevation __________ ft

Main channel length __________ mi

10% channel length elevation __________ ft 85% channel length elevation __________ ft

Main channel slope *(S)* __________ 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 NO BENCHMARK Minimum channel bed elevation: INFOR-

Low superstructure elevation: USLAB MATI DSLAB ON USRAB ___ DSRAB ___

Benchmark location description:

-
-
-

Reference Point (MSL, Arbitrary, Other): - Datum (NAD27, NAD83, Other): 4

Foundation Type: ___ (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: N

Is boring information available? - If no, type ctrl-n bi Number of borings taken: 3

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

Briefly describe material at foundation bottom elevation or around piles:

O FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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: MI Date: 01-20-95
Computerized by: MAW Date: 02-22-95
Reviewd by: JDA Date: 2-24-96

Structure Number BRNATH00660028

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* D. SONG Date *(MM/DD/YY)* 9 / 22 / 1994
2. Highway District Number 04 Mile marker 000000
County 027 (WINDSOR) Town 02725 (BARNARD)
Waterway *(I - 6)* LOCUST CREEK Road Name -
Route Number TH066 Hydrologic Unit Code: 01080105
3. Descriptive comments:
The bridge is 0.02 miles East on TH066 from the intersection with VT12. Field checking and augmenting earlier Level I data. NOTE: Additonal data were collected on 12/15/94 to supplement revisions made to this form.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 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 41 *(feet)* Span length 39 *(feet)* Bridge width 16.0 *(feet)*

Road approach to bridge:

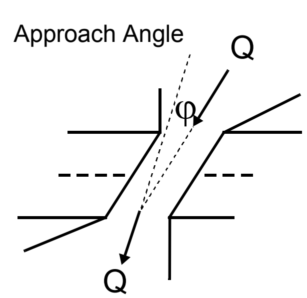
8. LB 0 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **4.3:1** US right **4.0:1**

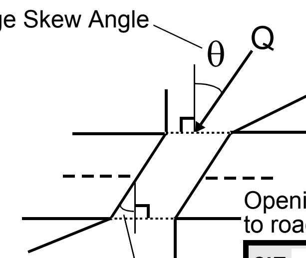
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

*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: 5 16. Bridge skew: 10





α= **0.0**

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 35 feet US *(US, UB, DS)* to 85 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 3 feet US *(US, UB, DS)* to 10 feet US

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

18. Bridge Type: 4

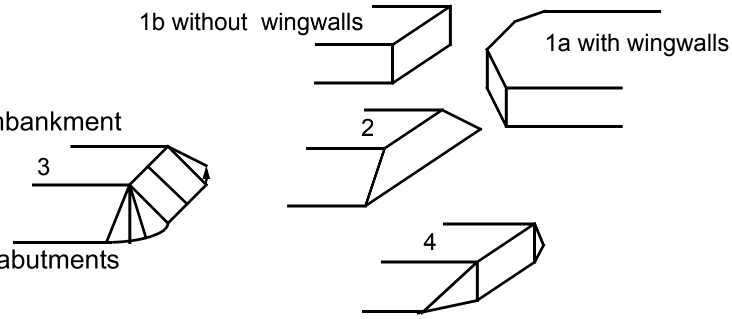
1a- Vertical abutments with wingwalls

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.)

Measured; bridge length: 41 ft, clear span length: 36.8 ft, roadway width: 15.5 ft. The surface cover on the left bank is brush and high grass. The surface cover on the right bank is brush and small trees on the immediate bank with pasture beyond. The water surface in this reach is a gentle riffle. There may be some impact at the upstream end of the left abutment at bank full flow. The right road approach overflow width is 15 ft.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
39.5	4.0			5.0	2	2	2	3	0	1

23. Bank width 20.0 24. Channel width 45.0 25. Thalweg depth 46.5 29. Bed Material 4

30 .Bank protection type: LB 0 RB 0 31. 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*

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

There are some small trees and brush on the left bank with high grass until the VT12 embankment. There are small trees on the right bank with pasture beyond. Boulders on the right bank were probably hauled from the adjacent property, they do seem to offer some protection to the upstream impact zone. The right bank material is gravel, cobble, and boulder. The left bank material is sand, gravel, and cobble. The bed material is cobble, gravel, sand and boulder. There are two small inflows, one enters 70 ft upstream on the left bank, the other enters 90 ft upstream on the right bank.

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

36. Point bar extent: - feet - (US, UB) to - feet - (US, UB, DS) positioned - %LB to - %RB

37. Material: -

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

There is a small side-bar at the base of each abutment, see under bridge comments.

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

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

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

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

The right bank is steepened on the outside of a bend but no recent cutting visible.

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
29.5		2.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

*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.):

3

There are two small side-bars present at the base of each abutment, visible at low flow. On the right is a gravel bar, and on the left is a cobble bar which redirects flow towards the center of the channel. The bed material is gravel, cobble and sand. There are some concrete chunks in the channel, possibly pieces of an older bridge.

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

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

70. Debris and Ice Comments:

1

There is no great constriction of bank full flow, the stream gradient is fairly high (0.012), there is no recent bank erosion in the upstream reach.

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		10	90	2	0	-	-	**90.0**
RABUT	1	-	90			2	0	**37.0**

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.):

-

-

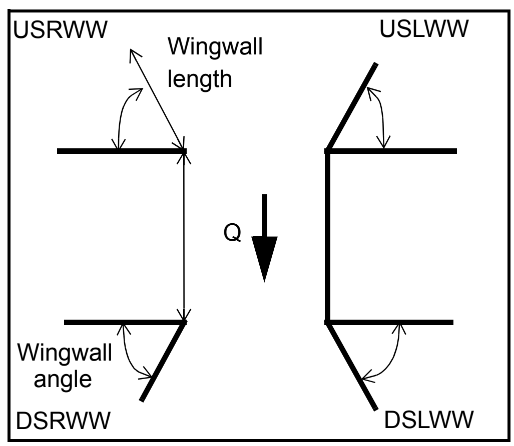
1

The upstream right wingwall is cracked on its top surface, but not badly. The overall structure is in very good condition, and there is no scour.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**37.0**	
USRWW:	Y		1		0	**1.0**	
DSLWW:	-		-		Y	**21.5**	
DSRWW:	1		0		-	**19.5**	

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



82. **Bank / Bridge Protection**:

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

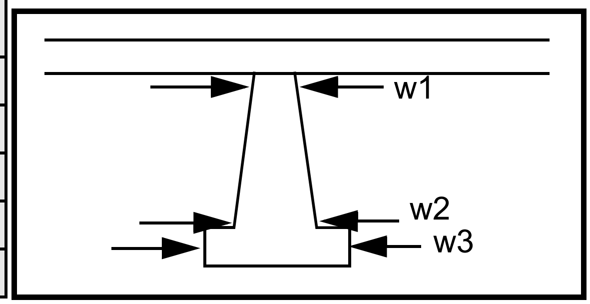
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length; **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? 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				**50.0**	**13.5**	**55.0**
Pier 2				**13.0**	**90.0**	**10.0**
Pier 3			-	**90.0**	**10.0**	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is	be	the	natu-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	light	natu-	upstr	ral or	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	cov-	ral	eam	place	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	erage	mate	left	d by	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	at the	rial.	wing	man.	*Y- yes; N- no*
91. Attack ∠ (BF)	upstr	Ther	wall;		
92. Pushed	eam	e is	it is		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	right	one	not		
95. Cross-members	wing	class	clear		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	wall,	3	whet		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	it	boul-	her it		
98. Exposure depth	may	der at	is		

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 (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 NO %LB to PIE %RB

Material: RS

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

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 2 feet 2 (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
0
0
3

Is channel scour present? 0 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length - Width - Depth: Ther Positioned e is %LB to brus %RB

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

h and small trees on the immediate banks. The bank material is cobble, sand and gravel. The bed material is gravel, cobble and sand. There is intermittent inflow from a 1 ft diameter culvert which enters 35 downstream on the left bank.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

N

-

NO DROP STRUCTURE

N

-

-

-

-

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR ANALYSIS

Structure Number: BRNATH00660028 Town: Barnard
Road Number: TH066 County: Windsor
Stream: Locust Creek

Initials TS Date: 12/07/95 Checked: SAO

Analysis of contraction scour, live-bed or clear water?

Neills Equation
Vc=11.52*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1993, p. 31, eq. 14)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3900	4900	3300
Main Channel Area, ft2	542	578	424
Left overbank area, ft2	275	319	144
Right overbank area, ft2	575	695	234
Top width main channel, ft	47	47	47
Top width L overbank, ft	56	58	47
Top width R overbank, ft	153	159	99
D50 of channel, ft	0.238	0.238	0.238
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	11.5	12.3	9.0
y1, average depth, LOB, ft	4.9	5.5	3.1
y1, average depth, ROB, ft	3.8	4.4	2.4
Total conveyance, approach	140818	171909	68127
Conveyance, main channel	68673	76418	45709
Conveyance, LOB	16854	21020	6440
Conveyance, ROB	55290	74471	15978
Percent discrepancy, conveyeance	0.00071	0	0
Qm, discharge, MC, cfs	1901.921	2178.177	2214.096
Ql, discharge, LOB, cfs	466.777	599.1426	311.9468
Qr, discharge, ROB, cfs	1531.274	2122.681	773.9575
Vm, mean velocity MC, ft/s	3.5	3.8	5.2
Vl, mean velocity, LOB, ft/s	1.7	1.9	2.2
Vr, mean velocity, ROB, ft/s	2.7	3.1	3.3
Vc-m, crit. velocity, MC, ft/s	10.7	10.8	10.3
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	0.0
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	0.0

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	0

Clear Water Contraction Scour in MAIN CHANNEL

$y2 = (Q2^2/(120*Dm^{(2/3)}*W2^2))^{(3/7)}$
ys=y2-y_bridge or ys=y2-y1
(Richardson and others, 1993, p. 35, eq. 18, 19)

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	3900	4900	3300
(Q) discharge thru bridge, cfs	3779	4093	3300
Main channel conveyance	30483	30483	23004
Total conveyance	30483	30483	23004
Q2, bridge MC discharge,cfs	3779	4093	3300
Main channel area, ft2	364	364	236
Main channel width (skewed), ft	36.8	36.8	36.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	36.8	36.8	36.8
y_bridge (avg. depth at br.), ft	9.891304	9.891304	6.413043
Dm, median (1.25*D50), ft	0.2975	0.2975	0.2975
y2, depth in contraction,ft	9.627697	10.30944	8.571729
ys, scour depth (y2-ybridge), ft	-0.26	0.42	2.16
ys, scour depth (y2-yfullv), ft	1.22	1.53	N/A

ARMORING

D90	0.749	0.749	0.749
D95	1.3	1.3	1.3
Critical grain size,Dc, ft	0.4208	0.4937	0.9122
Decimal-percent coarser than Dc	0.206	0.167	0.081
Depth to armoring,ft	4.87	7.39	31.05

Pressure Flow Scour (contraction scour for orifice flow condtions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc $Cf=1.5*Fr^{0.43}$ (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	3779	4093	0
Vc, critical velocity, ft/s	10.7	10.8	0
Vc, critical velocity, m/s	3.261201	3.291679	0
Main channel width (skewed), ft	36.8	36.8	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	36.8	36.8	0

qbr, unit discharge, ft^2/s	102.6902	111.2228	ERR
qbr, unit discharge, m^2/s	9.539302	10.33193	N/A
Area of full opening, ft^2	364	364	0
Hb, depth of full opening, ft	9.891304	9.891304	ERR
Hb, depth of full opening, m	3.014722	3.014722	N/A
Fr, Froude number MC	0.58	0.63	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	497.626	497.626	0
Elevation of Bed, ft	487.7347	487.7347	N/A
Elevation of approach WS, ft	500.33	501.1	0
HF, bridge to approach, ft	0.12	0.14	0
Elevation of WS immediately US, ft	500.21	500.96	0
ya, depth immediately US, ft	12.4753	13.2253	N/A
ya, depth immediately US, m	3.876726	4.10979	N/A
Mean elev. of deck, ft	500.1835	500.1835	0
w, depth of overflow, ft (>=0)	0.0265	0.7765	0
Cc, vert contrac correction (<=1.0)	0.943153	0.943153	ERR
Ys, depth of scour (chang), ft	0.284368	1.027825	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, 1993, p. 49, eq. 24)

	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	3900	4900	3300	3900	4900	3300
a', abut.length blocking flow, ft	60.6	62.5	51.7	158.1	163.4	104.1
Ae, area of blocked flow ft2	314.2	341	172.51	568	610.6	271.63
Qe, discharge blocked abut.,cfs	--	--	427.06	--	--	901.15
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	1.83	2.02	2.475567	2.64	3.01	3.317564
ya, depth of f/p flow, ft	5.18	5.46	3.34	3.59	3.74	2.61
--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	1	1	1	1	1
Fr, froude number f/p flow	0.14	0.15	0.24	0.23	0.25	0.36
ys, scour depth, ft	13.56	14.57	11.76	17.48	18.89	15.36

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1993, p. 50, eq. 25)

a'(abut length blocked, ft)	60.6	62.5	51.7	158.1	163.4	104.1
y1 (depth fp flow, ft)	5.18	5.46	3.34	3.59	3.74	2.61
a'/y1	11.69	11.46	15.49	44.01	43.73	39.90
Froude no. f/p flow	0.14	0.15	0.24	0.23	0.25	0.36
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	16.09	17.20	13.57
vertical w/ ww's	ERR	ERR	ERR	13.19	14.10	11.13
spill-through	ERR	ERR	ERR	8.85	9.46	7.46

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, 1993, p118-119, eq. 93,94)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.58	0.63	0.99			
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	9.9	9.9	6.4			
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.06	2.43	ERR	2.06	2.43	0
Fr>0.8 (vertical abut.)	ERR	ERR	2.67	ERR	ERR	2.67
Fr<=0.8 (spillthrough abut.)	1.80	2.12	ERR	1.80	2.12	0
Fr>0.8 (spillthrough abut.)	ERR	ERR	2.36	ERR	ERR	2.36