LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (BRNATH00800016) on TOWN HIGHWAY 80, crossing LOCUST CREEK, BARNARD, VERMONT

U.S. Geological Survey
Open-File Report 96-383

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

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By MICHAEL A. IVANOFF and MATTHEW A. WEBER

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Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

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Denver, CO 80225

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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 16 (BRNATH00800016) ON TOWN HIGHWAY 80, CROSSING LOCUST CREEK, BARNARD, VERMONT

By Michael A. Ivanoff and Matthew A. Weber

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNATH00800016 on town highway 80 crossing 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). A Level I study is included in Appendix E of this report. A Level I study 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 can be found in Appendix D.

The site is in the Green Mountain physiographic province of central Vermont in the town of Barnard. The 22.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the left banks are forested and the right banks are covered with shrub and brush. Vermont Route 12 is adjacent to the right bank.

In the study area, Locust Creek has an incised channel with a slope of approximately 0.02 ft/ft, an average channel top width of 60 ft and an average channel depth of 4 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 102 mm (0.336 ft). The geomorphic assessment at the time of the Level I and Level II site visits on September 22, 1994 and October 12, 1994, indicated that the reach was stable.

The town highway 80 crossing of Locust Creek is a 36-ft-long, one-lane bridge consisting of one 33-foot steel-beam span with timber deck (Vermont Agency of Transportation, written communication, August 23, 1994). The bridge is supported by vertical, log crib abutments with wingwalls. Type-2 stone fill (less than 36 inches diameter) protects the upstream and downstream left wingwalls and the downstream left road embankment. Type-3 stone fill (less than 48 inches diameter) protects the upstream and downstream right wingwalls. The upstream left and downstream right road embankments are not protected and road wash is eroding these areas. The channel approach to the bridge is straight with the bridge skewed zero degrees to flow; the opening-skew-to-roadway is also zero degrees. Additional details describing conditions at the site are included in the Level II Summary, Appendix D, and Appendix E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 3.7 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge, which was between the 100- and 500-year discharge. Abutment scour ranged from 17.5 to 23.2 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, 1993, p. 48). 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 BRNATH00800016 ***Stream*** Locust Creek

County Windsor ***Road*** TH080 ***District*** 04

Description of Bridge

Bridge length 36 ***ft*** ***Bridge width*** 13 ***ft*** ***Max span length*** 33 ***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 exists on the downstream left road approach and the upstream and downstream left wingwalls. Type-3 exists on upstream and downstream right wingwalls.

Abutments and wingwalls consist of log cribbing

Brief description of piers/abutments

N

Is bridge skewed to flood flow according to Level I survey? 0 ***Angle*** N

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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***
	0	0	10/12/
Level I	94	-	-
Level II	Low		

Potential for debris

None evident on 9/22/94 or 10/12/94.

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

Description of the Geomorphic Setting

General topography The bridge is over a steep upland incised channel.

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

Date of inspection 09/22/94

DS left: terrace to valley wall

DS right: terrace to valley wall

US left: terrace to valley wall

US right: terrace to valley wall

Description of the Channel

Average top width 60 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material gravel and cobbles ***Bank material*** sand to boulders

Narrow, incised

channel with only slight sinuosity.

09/22/94

Vegetative co forested with residence on the terrace

DS left: shrub and brush with state route 12 and residence on the terrace

DS right: forested with residence on the terrace

US left: shrub and brush with state route 12 and residence on the terrace

US right:

Do banks appear stable? Y ***If not, describe location and type of instability and***

date of observation.

None evident on

09/22, 10/12, or 12/15 1994 respectively.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 22.0 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	*Percent of drainage area*
Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

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

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,000 ***ft³/s*** ***Q500*** 5,100 ***ft³/s***

The discharges were selected from a range of values determined from empirical methods applicable to sites having basin characteristics similar to this one (Talbot, 1887; Potter, 1957a; Potter, 1957b; Benson, 1962; Johnson and Laraway, 1971, written commuication; 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 Not applicable.

Description of reference marks used to determine USGS datum. RM1 is the top center of a concrete post marked "VT 1959 DS 035 12/ VT 1956 S 142 2" (elev. 507.24 feet, arbitrary datum). RM2 is a chiseled square on the top of a boulder, 10 feet streamward of Rt. 12, 42 feet upstream of the bridge, near top of the right bank (elev. 500.29 feet, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT-	-44	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT-)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	63	2	Modelled Approach section (Templated from ATEMP)
ATEMP	77	1	Approach section as surveyed (Used as a template)

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.060.

Normal depth at the exit section (EXIT-) 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, 1980).

The surveyed approach section (ATEMP) was moved along the approach channel slope (0.033 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the 100-year and incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 498.2 *ft*
Average low steel elevation 496.6 *ft*

100-year discharge 4,000 *ft³/s*
Water-surface elevation in bridge opening 489.9 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 243 *ft²*
Average velocity in bridge opening 16.5 *ft/s*
Maximum WSPRO tube velocity at bridge 20.8 *ft/s*

Water-surface elevation at Approach section with bridge 495.3
Water-surface elevation at Approach section without bridge 490.8
Amount of backwater caused by bridge 4.5 *ft*

500-year discharge 5,100 *ft³/s*
Water-surface elevation in bridge opening 496.8 *ft*
Road overtopping? Y *Discharge over road* 215 *ft³/s*
Area of flow in bridge opening 439 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.8 *ft/s*

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 491.8
Amount of backwater caused by bridge 7.5

Incipient overtopping discharge 4,800 *ft³/s*
Water-surface elevation in bridge opening 491.0 *ft*
Area of flow in bridge opening 275 *ft²*
Average velocity in bridge opening 17.4 *ft/s*
Maximum WSPRO tube velocity at bridge 22.3 *ft/s*

Water-surface elevation at Approach section with bridge 497.0
Water-surface elevation at Approach section without bridge 491.5
Amount of backwater caused by bridge 5.5 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 500-year discharge 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). Therefore, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18) for the 100-year and incipient road over-flow discharges. For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). 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.

In this case, the incipient road-overflow discharge model resulted in the worst case contraction scour and the worst case total scour. Furthermore, because contraction scour and total scour depths were greater for the 100-year event than the 500-year event, figure 7 does not show the 500-year scour depths.

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	2.9	0.0	3.7
Depth to armoring	49.0	2.4	62.5
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	19.5	23.2	21.8
Right abutment	17.5	18.9	19.4
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	3.5	2.3	4.0
Right abutment	3.5	2.3	4.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

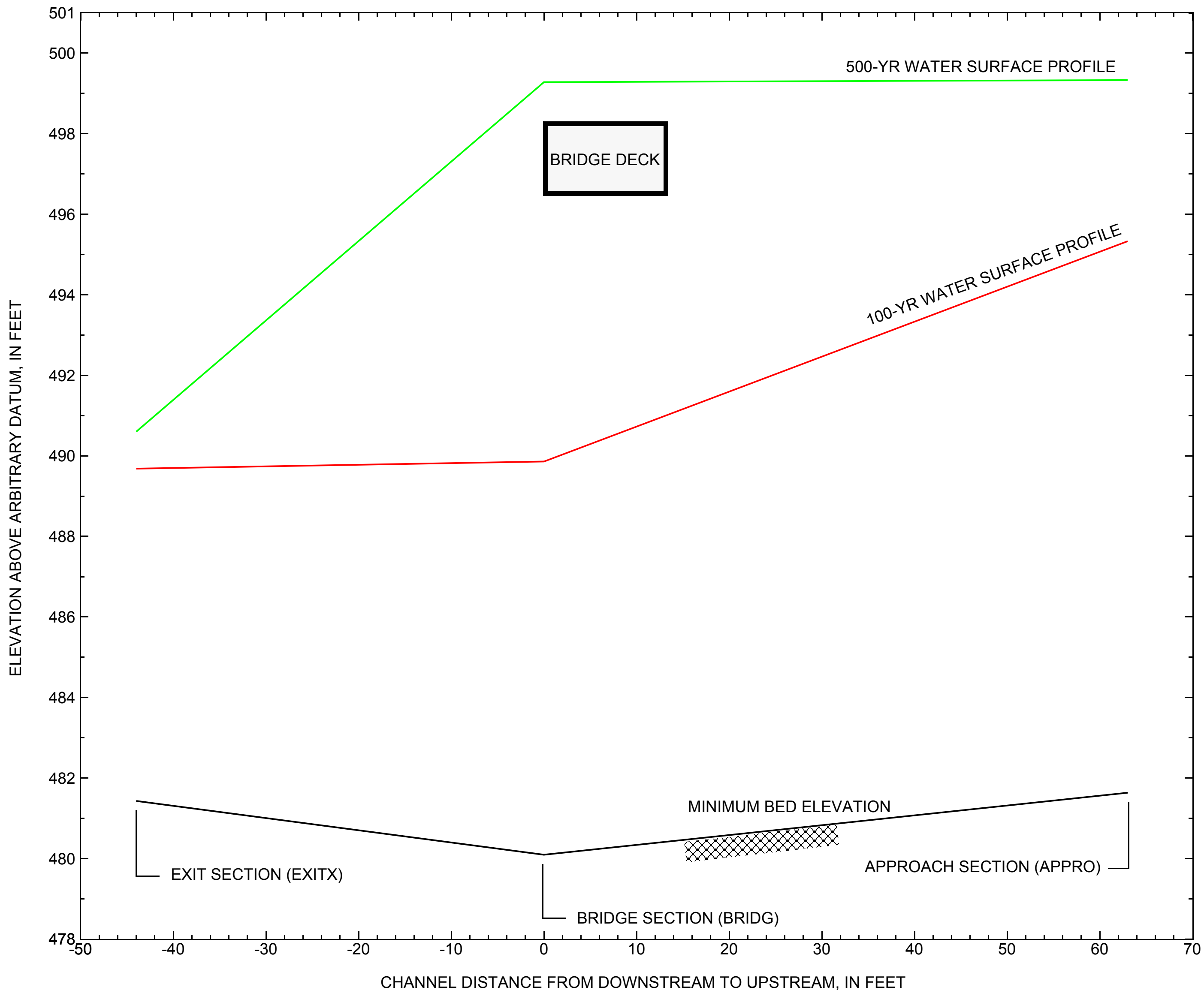

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRNATH00800016 on town highway 80, crossing Locust Creek, Barnard, Vermont.

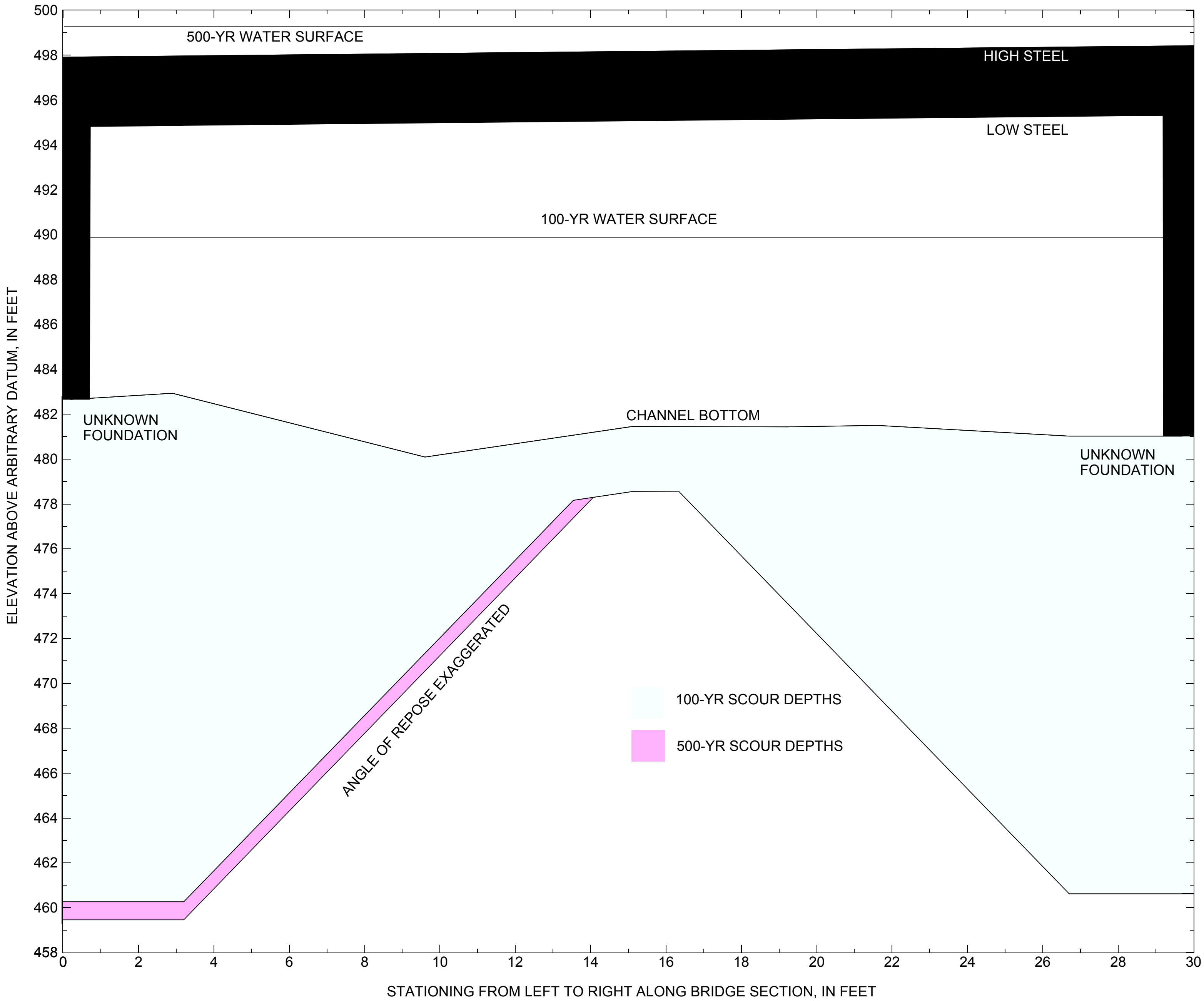

Figure 8. Scour elevations for the 100-year discharge at structure BRNATH00800016 on town highway 80, crossing Locust Creek, Barnard, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNATH00800016 on Town Highway 80, 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 4,000 cubic-feet per second											
Left abutment	0.0	--	496.4	--	482.7	2.9	19.5	--	22.4	460.3	--
Right abutment	29.2	--	496.8	--	481.0	2.9	17.5	--	20.4	460.6	--

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 BRNATH00800016 on Town Highway 80, 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 5,100 cubic-feet per second											
Left abutment	0.0	--	496.4	--	482.7	0.0	23.2	--	23.2	459.5	--
Right abutment	29.2	--	496.8	--	481.0	0.0	18.9	--	18.9	462.1	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna016.wsp
T2        CREATED ON 13-NOV-95 FOR BRIDGE BRNATH00800016 USING FILE brna016.dca
T3        Hydraulic analysis of Barnard 016 by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          4000.0   4800.0  5100.0
SK         0.012    0.012   0.012
*
XS   EXIT-    -44           0.
GR          -59.1, 499.76    -39.3, 489.26    -20.0, 485.90     -4.7, 484.37
GR            0.0, 482.40      0.1, 482.42     14.5, 481.51     20.7, 481.43
GR           37.0, 482.09     37.3, 482.59     38.7, 483.53     47.4, 486.40
GR           53.4, 492.17     74.6, 498.74
N           0.060
*
XS   FULLV      0  * * *   0.005
*
BR   BRIDG   0     496.7
GR            0.0, 496.41      0.7, 482.66      2.9, 482.93      5.1, 482.07
GR            5.3, 480.63      7.8, 480.28      9.6, 480.09     12.1, 480.49
GR           15.1, 481.45     19.2, 481.43     21.6, 481.50     24.4, 481.09
GR           26.7, 481.02     27.1, 482.75     28.3, 482.79     29.2, 483.24
GR           29.2, 496.82      0.0, 496.41
N            0.055
CD         1   34.1 * * 55  10.4
*
XR   RDWAY     10      12.9   2
GR          -81.7, 503.08    -66.5, 500.87    -45.7, 500.48    -28.9, 499.98
GR          -17.9, 499.22     -3.3, 498.17      0.0, 497.91     29.7, 498.42
GR           38.3, 499.00     51.3, 499.62     61.5, 499.60     72.3, 500.74
GR           98.9, 502.30    102.5, 501.97    106.6, 500.59    113.2, 502.70
*
XT   ATEMP     77           0.
GR          -48.7, 504.82    -31.8, 491.30    -20.8, 489.59    -15.4, 487.66
GR            0.0, 483.52      0.0, 483.52      5.1, 482.91     11.2, 482.48
GR           15.1, 483.04     19.3, 482.87     25.4, 482.09     30.4, 483.69
GR           37.7, 486.40     48.6, 491.96     53.9, 498.28     72.7, 502.82
*
AS   APPRO    63
GT            -0.46
N           0.060
*
HP 1 BRIDG  489.86 1 489.86
HP 2 BRIDG  489.86 * * 4000
HP 1 APPRO  495.33 1 495.33
HP 2 APPRO  495.33 * * 4000
*
HP 1 BRIDG  496.82 1 496.82
HP 2 BRIDG  496.82 * * 4868
HP 2 RDWAY  499.28 * * 215
HP 1 APPRO  499.33 1 499.33
HP 2 APPRO  499.33 * * 5100
*
HP 1 BRIDG  490.97 1 490.97
HP 2 BRIDG  490.97 * * 4800
HP 1 APPRO  496.96 1 496.96
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna016.wsp
        CREATED ON 13-NOV-95 FOR BRIDGE BRNATH00800016 USING FILE brna016.dca
        Hydraulic analysis of Barnard 016 by MAI
           *** RUN DATE & TIME: 11-30-95  08:38
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      243.   20122.    29.    45.                      4002.
   489.86           243.   20122.    29.    45.  1.00     0.    29.   4002.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       489.86     0.3    29.2   243.0   20122.    4000.  16.46

X STA.         0.3        3.8        5.8        7.0        8.2        9.3
  A(I)            23.0       16.2       11.8       11.1       10.2
  V(I)            8.69      12.34      16.89      17.94      19.52

X STA.         9.3       10.3       11.3       12.3       13.4       14.5
  A(I)            10.0        9.8        9.6        9.6        9.8
  V(I)           20.08      20.44      20.75      20.82      20.33

X STA.        14.5       15.7       16.8       18.0       19.2       20.4
  A(I)             9.8        9.8        9.9       10.2       10.1
  V(I)           20.34      20.45      20.19      19.52      19.78

X STA.        20.4       21.7       23.0       24.4       26.0       29.2
  A(I)            10.9       11.0       12.1       13.8       24.2
  V(I)           18.42      18.20      16.56      14.50       8.28

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      818.   84892.    89.    96.                     14060.
   495.33           818.   84892.    89.    96.  1.00   -37.    52.  14060.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.33   -37.4    51.8   818.2   84892.    4000.   4.89

X STA.       -37.4      -20.8      -13.7       -8.7       -4.7       -1.4
  A(I)            71.7       52.8       45.8       41.8       38.6
  V(I)            2.79       3.79       4.37       4.78       5.19

X STA.        -1.4        1.6        4.4        7.1        9.6       12.2
  A(I)            36.9       35.3       34.3       33.2       33.6
  V(I)            5.42       5.66       5.83       6.02       5.95

X STA.        12.2       14.7       17.3       19.9       22.5       25.0
  A(I)            33.5       33.0       33.7       33.4       33.8
  V(I)            5.96       6.05       5.93       5.98       5.92

X STA.        25.0       27.7       30.6       34.2       38.8       51.8
  A(I)            35.6       36.9       41.1       44.9       68.2
  V(I)            5.61       5.42       4.87       4.45       2.93

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      439.   34692.     0.    88.                         0.
   496.82           439.   34692.     0.    88.  1.00     0.    29.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.82     0.0    29.2   439.2   34692.    4868.  11.08

X STA.         0.0        3.4        5.2        6.6        7.9        9.1
  A(I)            41.5       26.2       22.4       20.3       19.1
  V(I)            5.87       9.28      10.87      11.97      12.77

X STA.         9.1       10.2       11.3       12.4       13.5       14.7
  A(I)            18.8       17.7       18.0       17.8       17.9
  V(I)           12.97      13.76      13.55      13.69      13.57

X STA.        14.7       15.9       17.1       18.3       19.4       20.7
  A(I)            18.0       18.0       18.2       18.1       18.9
  V(I)           13.54      13.54      13.36      13.45      12.88

X STA.        20.7       21.9       23.3       24.6       26.3       29.2
  A(I)            18.9       20.6       21.2       25.5       42.2
  V(I)           12.86      11.82      11.50       9.54       5.76
```

```
   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.
         WSEL     LEW     REW    AREA        K       Q    VEL
       499.28   -18.8    44.2    51.5    1118.    215.   4.17

X STA.       -18.8       -7.8       -4.5       -2.3       -0.5        1.1
  A(I)           4.3        3.0        2.5        2.3        2.2
  V(I)          2.50       3.64       4.29       4.72       4.95

X STA.         1.1        2.7        4.3        5.9        7.6        9.3
  A(I)           2.1        2.1        2.1        2.1        2.1
  V(I)          5.15       5.14       5.24       5.13       5.09

X STA.         9.3       11.1       12.9       14.9       17.0       19.2
  A(I)           2.1        2.2        2.2        2.3        2.4
  V(I)          5.10       4.92       4.81       4.73       4.50

X STA.        19.2       21.7       24.4       27.3       31.0       44.2
  A(I)           2.5        2.6        2.7        3.1        4.7
  V(I)          4.37       4.07       3.92       3.44       2.29

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1196.  144030.   103.   112.                       23164.
   499.33         1196.  144030.   103.   112.  1.00   -42.    60.  23164.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.
         WSEL     LEW     REW    AREA        K       Q    VEL
       499.33   -42.4    60.2  1195.6  144030.   5100.   4.27

X STA.       -42.4      -25.5      -18.4      -13.0       -8.6       -4.7
  A(I)         101.6       72.2       64.6       58.5       55.8
  V(I)          2.51       3.53       3.95       4.36       4.57

X STA.        -4.7       -1.3        1.8        4.7        7.6       10.4
  A(I)          52.9       50.5       49.2       48.5       47.6
  V(I)          4.82       5.05       5.19       5.26       5.36

X STA.        10.4       13.2       16.0       19.0       21.8       24.7
  A(I)          48.5       47.5       49.8       48.9       49.7
  V(I)          5.26       5.37       5.12       5.22       5.13

X STA.        24.7       27.6       31.0       35.1       40.5       60.2
  A(I)          51.7       55.7       61.3       71.8      109.5
  V(I)          4.93       4.58       4.16       3.55       2.33

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     275.   23965.    29.    48.                        4815.
   490.97          275.   23965.    29.    48.  1.00     0.    29.   4815.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K       Q    VEL
       490.97     0.3    29.2   275.1   23965.   4800.  17.45

X STA.         0.3        3.7        5.7        7.0        8.2        9.3
  A(I)          26.6       18.1       13.7       12.5       11.8
  V(I)          9.04      13.30      17.47      19.17      20.41

X STA.         9.3       10.3       11.3       12.4       13.4       14.5
  A(I)          11.1       10.9       10.8       11.0       10.9
  V(I)         21.60      21.95      22.26      21.91      21.99

X STA.        14.5       15.7       16.9       18.0       19.2       20.4
  A(I)          11.1       11.0       11.1       11.1       11.5
  V(I)         21.71      21.79      21.53      21.68      20.79

X STA.        20.4       21.7       23.0       24.4       26.0       29.2
  A(I)          12.2       12.7       13.5       16.0       27.7
  V(I)         19.73      18.96      17.74      15.05       8.68

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     966.  108492.    93.   101.                       17714.
   496.96          966.  108492.    93.   101.  1.00   -39.    53.  17714.
```

```
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =       63.
         WSEL      LEW      REW    AREA         K        Q    VEL
       496.96    -39.4     53.2   966.4  108492.    4800.   4.97

X STA.       -39.4      -23.1      -15.6      -10.5       -6.3       -2.6
  A(I)            82.7       62.8       53.1       49.4       46.2
  V(I)            2.90       3.82       4.52       4.86       5.19

X STA.        -2.6        0.6        3.5        6.3        9.0       11.7
  A(I)            43.3       41.7       40.6       39.3       39.8
  V(I)            5.54       5.76       5.92       6.11       6.03

X STA.        11.7       14.4       17.1       19.8       22.5       25.1
  A(I)            39.6       38.9       39.6       40.0       39.8
  V(I)            6.06       6.17       6.06       6.00       6.04

X STA.        25.1       27.9       31.1       34.8       39.9       53.2
  A(I)            41.8       44.7       47.4       56.2       79.5
  V(I)            5.74       5.37       5.06       4.27       3.02

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna016.wsp
        CREATED ON 13-NOV-95 FOR BRIDGE BRNATH00800016 USING FILE brna016.dca
        Hydraulic analysis of Barnard 016 by MAI
           *** RUN DATE & TIME: 11-30-95  08:38

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

EXIT-:XS   ******   -40.     490.  1.04 *****  490.72  488.00   4000.  489.68
      -44. ******    51.   36511.  1.00 ***** *******    0.62    8.17

FULLV:FV      44.   -41.     525.  0.90  0.47  491.19 *******   4000.  490.29
        0.    44.    51.   40601.  1.00  0.00    0.00    0.56    7.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.   -32.     438.  1.29  0.75  492.13 *******   4000.  490.83
       63.    63.    47.   33262.  1.00  0.20    0.00    0.68    9.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     4000.      489.86

            <<<<<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      44.     0.     243.  4.22 *****  494.07  489.86   4000.  489.86
        0.    44.    29.   20113.  1.00 ***** *******    1.00   16.46

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.70 ****** ****** ******

    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

APPRO:AS      29.   -37.     819.  0.37  0.29  495.71  489.17   4000.  495.33
       63.    30.    52.   84960.  1.00  1.35    0.00    0.28    4.89

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.635  0.397   51208.     0.    29.   495.22

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

```
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT-:XS     -44.   -40.    51.   4000.   36511.     490.    8.17  489.68
   FULLV:FV       0.   -41.    51.   4000.   40601.     525.    7.62  490.29
   BRIDG:BR       0.     0.    29.   4000.   20113.     243.   16.46  489.86
   RDWAY:RG      10.**************      0.*****************    2.00********
   APPRO:AS      63.   -37.    52.   4000.   84960.     819.    4.89  495.33

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT-:XS    488.00    0.62  481.43  499.76************  1.04  490.72  489.68
   FULLV:FV  ********    0.56  481.65  499.98  0.47  0.00  0.90  491.19  490.29
   BRIDG:BR    489.86    1.00  480.09  496.82************  4.22  494.07  489.86
   RDWAY:RG  ***************  497.91  503.08*********************************
   APPRO:AS    489.17    0.28  481.63  504.36  0.29  1.35  0.37  495.71  495.33




        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna016.wsp
        CREATED ON 13-NOV-95 FOR BRIDGE BRNATH00800016 USING FILE brna016.dca
        Hydraulic analysis of Barnard 016 by MAI
           *** RUN DATE & TIME: 11-30-95  08:38

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

EXIT-:XS   ******   -42.     574.  1.23 *****  491.82  488.81   5100.  490.60
      -44. ******    52.   46547.  1.00 ***** *******    0.63    8.88

FULLV:FV      44.   -43.     612.  1.08  0.48  492.30 *******   5100.  491.22
        0.    44.    52.   51264.  1.00  0.00    0.00    0.58    8.33
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.   -33.     512.  1.54  0.76  493.29 *******   5100.  491.75
       63.    63.    49.   41974.  1.00  0.23    0.00    0.70    9.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   491.35     497.29     497.56     496.70

 ===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      44.     0.     439.  1.91 *****  498.73  491.05   4868.  496.82
        0. ******    29.   34692.  1.00 ***** *******    0.50   11.08

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.431 ******  496.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    50.  0.06  0.28  499.55    0.00    215.  499.28

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    130.    33.   -19.    15.   1.4   0.9   4.9   4.2   1.2   3.0
   RT:     84.    30.    15.    44.   1.1   0.7   4.4   4.1   1.0   3.0

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

APPRO:AS      29.   -42.    1196.  0.28  0.15  499.62  490.21   5100.  499.33
       63.    31.    60.  144079.  1.00  1.39    0.00    0.22    4.26

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT-:XS     -44.   -42.    52.   5100.   46547.     574.    8.88  490.60
   FULLV:FV       0.   -43.    52.   5100.   51264.     612.    8.33  491.22
   BRIDG:BR       0.     0.    29.   4868.   34692.     439.   11.08  496.82
   RDWAY:RG      10.*******   130.    215.*****************    2.00  499.28
   APPRO:AS      63.   -42.    60.   5100.  144079.    1196.    4.26  499.33
```

```
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT-:XS    488.81    0.63  481.43  499.76************  1.23  491.82  490.60
   FULLV:FV  ********    0.58  481.65  499.98  0.48  0.00  1.08  492.30  491.22
   BRIDG:BR    491.05    0.50  480.09  496.82************  1.91  498.73  496.82
   RDWAY:RG  ****************  497.91  503.08  0.06******  0.28  499.55  499.28
   APPRO:AS    490.21    0.22  481.63  504.36  0.15  1.39  0.28  499.62  499.33
```

```
         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brna016.wsp
         CREATED ON 13-NOV-95 FOR BRIDGE BRNATH00800016 USING FILE brna016.dca
         Hydraulic analysis of Barnard 016 by MAI
            *** RUN DATE & TIME: 11-30-95  08:38

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

EXIT-:XS   ******   -41.     552.  1.18 *****  491.53  488.59   4800.  490.36
      -44. ******    52.   43816.  1.00 ***** *******    0.63    8.70

FULLV:FV      44.   -42.     589.  1.03  0.48  492.01 *******   4800.  490.97
        0.    44.    52.   48365.  1.00  0.00    0.00    0.57    8.15
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.   -33.     493.  1.48  0.76  492.99 *******   4800.  491.51
       63.    63.    49.   39569.  1.00  0.22    0.00    0.70    9.74
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    4800.     490.97

             <<<<<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      44.     0.     275.  4.74 *****  495.70  490.97   4800.  490.97
        0.    44.    29.   23960.  1.00 ***** *******    1.00   17.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.70 ****** ****** ******

    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

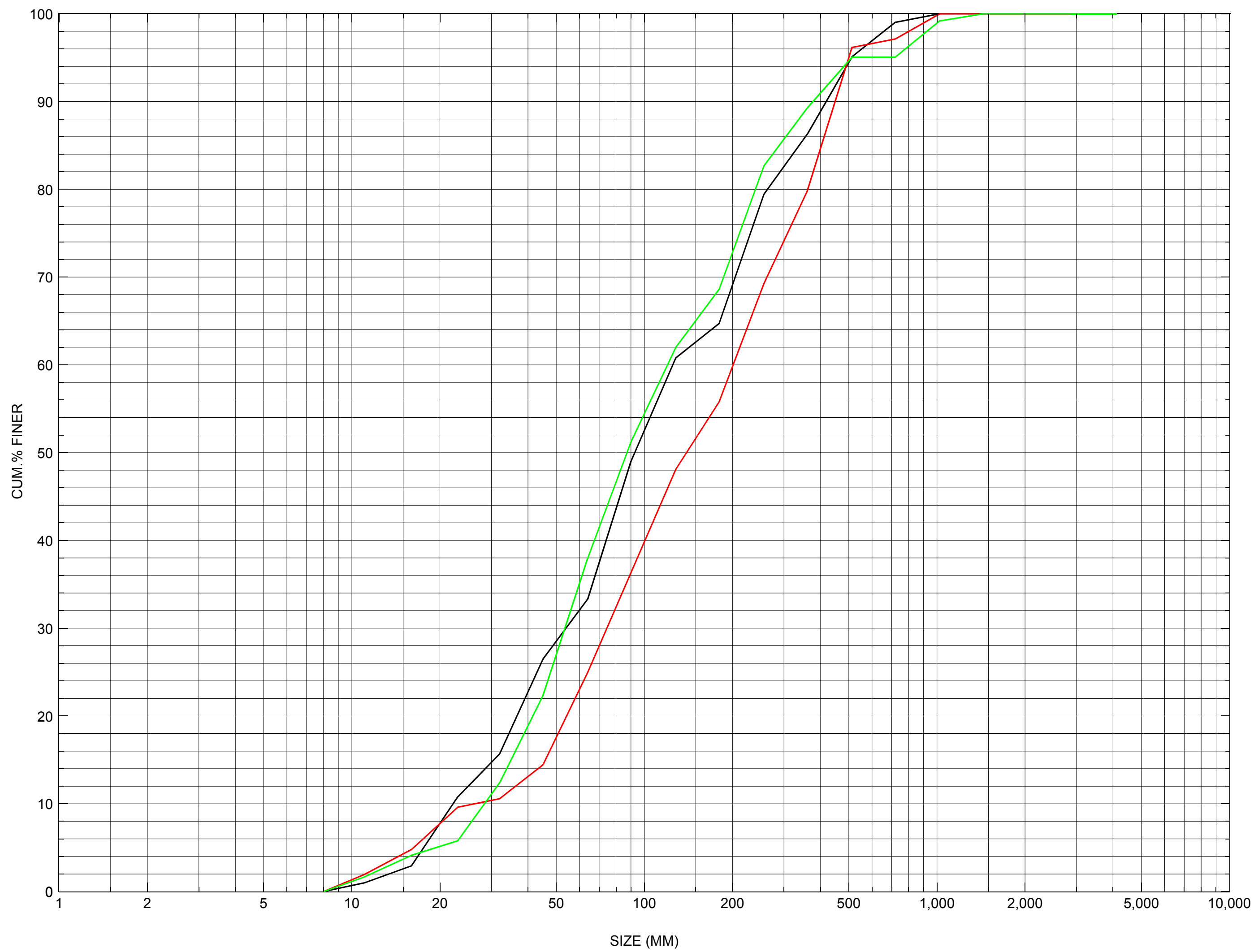
APPRO:AS      29.   -39.     966.  0.38  0.27  497.34  489.94   4800.  496.96
       63.    31.    53.  108499.  1.00  1.37    0.00    0.27    4.97

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.644  0.425   62404.     0.    28.  496.86

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

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 BRNATH00800016, in Barnard, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNATH00800016

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 23 / 94

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 TH080

Vicinity *(I - 9)* 0.01 MI TO JCT W VT12

Topographic Map Bethel

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43472

Longitude *(i - 17; nnnnn.n)* 72385

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140300161403

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

Maximum span length *(I - 48; nnnn)* 0033

Year built *(I - 27; YYYY)* 1971

Structure length *(I - 49; nnnnnn)* 000036

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

Deck Width *(I - 52; nn.n)* 129

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)* P

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 033.0

Number of spans *(I - 45; nnn)* 001

Vertical clearance from streambed (*nnn.n ft*) 015.0

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

Waterway of full opening (*nnn.n* ft^2) 495.0

Comments:

Structural inspection report of 6/6/94 indicates some random heavy rotting of timber at bridge seat with no severe timber displacement. The upstream right wingwall leans forward 18 inches at top and has rotten logs. The left abutment has a free poured concrete footing. The report noted only minor channel scour and no embankment erosion. No apparent settlement or undermining. No drift/vegetation is indicated. Channel alignment is straight through the crossing. Stone fill and boulders along the banks.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **22.2**

Terrain character: **Hilly to mountainous, mostly forested**

Stream character & type: -

Streambed material: **GRAVEL TO COBBLE**

Discharge Data *(cfs)*: $Q_{2.33}$ **800** Q_{10} **1700** Q_{25} **2300**

Q_{50} **2750** Q_{100} **3300** 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)* : **LIGHT** Debris *(Heavy, Moderate, Light)*: **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*)	**734.7**	**736.9**	**738.2**	**739.2**	**740.3**
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*): **Y** *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): **0.1** Town: **BARNARD** Year Built: **1959**

Highway No. : **VT12** Structure No. : **27** Structure Type: **CONC. WF BEAM**

Clear span (*ft*): **86** Clear Height (*ft*): **14** Full Waterway (*ft^2*): -

Downstream distance (*miles*): **0.5** Town: **Barnard** Year Built: **-**

Highway No. : **TH68** Structure No. : **35** Structure Type: **Bridge**

Clear span (*ft*): **30** Clear Height (*ft*): **10** Full Waterway (ft^2): **-**

Comments:

Design flow is Q25. The upstream bridge full waterway is noted as 900 square feet.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **22.02** mi^2

Lake and pond area **0.18** mi^2

Watershed storage *(ST)* **0.8** %

Bridge site elevation **720** ft

Headwater elevation **2836** ft

Main channel length **10.24** mi

10% channel length elevation **790** ft

85% channel length elevation **1810** ft

Main channel slope *(S)* **132.81** ft / mi

Watershed Precipitation Data

Average site precipitation ___________ in

Average headwater precipitation ___________ in

Maximum 2yr-24hr precipitation event *(I24,2)* **2.5** 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? ______ *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? 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: MAI Date: 1/12/95
Computerized by: MAI Date: 1/12/95
Reviewd by: SAO Date: 1/19/96

Structure Number BRNATH00800016

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. WEBER Date *(MM/DD/YY)* 09 / 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 TH080 Hydrologic Unit Code: 01080105

3. Descriptive comments:

The bridge is 0.01 miles West from the intersection of VT12 and TH080. Additional information for this form was collected 12/15/94 by S. Olson.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 5 LBDS 6 RBDS 5 Overall 5
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 2 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 36 *(feet)* Span length 33 *(feet)* Bridge width 12.9 *(feet)*

Road approach to bridge:

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

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

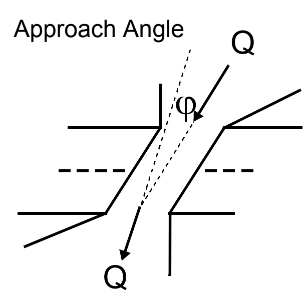
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

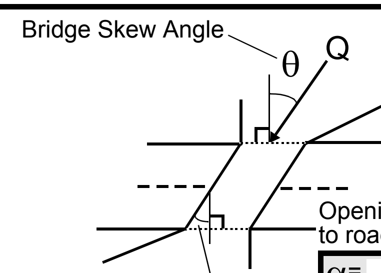
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	3
RBUS	0	-	0	0
RBDS	0	-	2	1
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 0





Opening skew to roadway
α= 0.0

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

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

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

18. Level II Bridge Type: **1a**

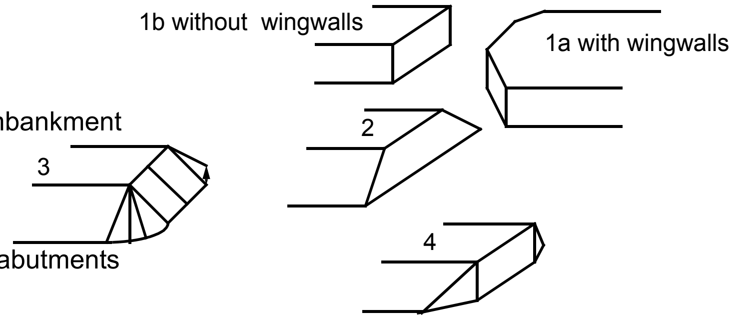
1a- Vertical abutments with wingwalls

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.)

Measured; bridge length: 36 ft, span length: 31 ft, roadway width: 13 ft. On the left bank upstream are large trees, a gravel road, a house, and a lawn high on the overbank. On the right bank upstream are small trees on a steep bank, VT 12 parallels the right bank and is within two bridge lengths, the road embankment is grass. On the left bank downstream are some large trees, but mostly small trees about 80 ft high. The right bank downstream surface cover is equivalent to that on the right bank upstream. The right road approach is unpaved for about 20 ft until in intersects VT12. There has been a failure of the left bank upstream wingwall.

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
57.5	**4.0**			**4.5**	**3**	**2**	**5**	**5**	**0**	**0**

23. Bank width **15.0**   24. Channel width **20.0**   25. Thalweg depth **53.0**   29. Bed Material **4**

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

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

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

There are small and large trees on the left bank upstream except near the bridge which is shrubland. There are small trees on the right bank upstream. The left bank material is boulder, cobble and gravel, with some surficial sand. The right bank material is boulder, cobble, and gravel. The bed material is mainly cobble with some gravel and boulder. There is an old drywall on the left bank at bank full level from the upstream left wingwall to 80 ft high. The wall is up to 5 ft high but is slumped to the extent that here it is counted only as class 2 protection. There is also a drywall on the right bank upstream 92 ft upstream to about 200 ft upstream, and is up to 10 ft high. There does not appear to be an impact zone in this area, it may have been built to stabilize the VT 12 embankment. There is also boulder protection on the right bank 20 to 50 ft upstream.

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.):

NO POINT BARS

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.):

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
30.0		1.0		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.):

4

The under bridge bed material is mostly cobble with gravel and sand, occasional boulder. The upstream reach has more boulders than under bridge, but the D50 is probably in the cobble range for them both.

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 are no trees falling into the channel, the deck is fairly high, the bank full constriction under the bridge is not too great. Paraphrased from a resident: ice flow is in small pieces with no blockage upstream, most ice forms in the pool downstream.

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		**0**	**90**	**2**	**0**	**-**	**-**	**90.0**
RABUT	**4**	**0**	**90**			**2**	**1**	**29.5**

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

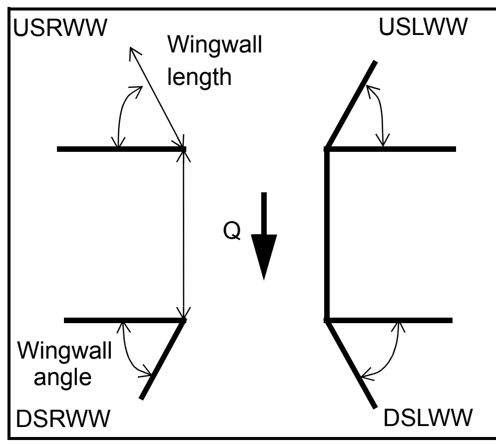
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1
0
4

There is a free-poured concrete footing on the right abutment which is undermined by a maximum of 1.8 ft, however the abutment continues deeper than this and does not seem to be undermined. Under the junction of the upstream right wingwall and the right abutment there may be some undermining, the rangepole strikes wood but it is set back 0.5 ft. The abutments and wingwalls are stone filled log cribwork. Some logs of the right abutment under the deck are crushed. Some logs of both abutments appear to be rotting. See photos 11 and 12. The water is 2 feet deep at the junction of the upstream right wingwall and right abutment, and the average thalweg depth upstream and downstream was about 1 ft, so scour depth was estimated at 1 ft.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**29.5**	
USRWW:	**Y**		**4**		**0**	**1.5**	
DSLWW:	**-**		**-**		**Y**	**18.5**	
DSRWW:	**4**		**1**		**1**	**20.0**	



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

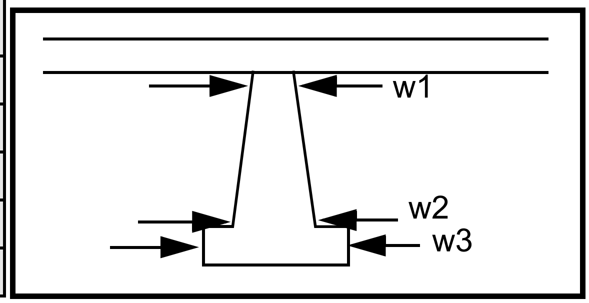
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
4
3
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				55.0	17.5	55.0
Pier 2				19.0	30.0	24.0
Pier 3			-	30.0	21.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is	altho	pro-	dow	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	good	ugh	tec-	nstre	**1**- Solid pier, **2**- column, **3**- bent
88. Material	cov-	there	tion.	am	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	erag	may	Ther	left	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	e at	have	e is	wing	Y- yes; N- no
91. Attack ∠ (BF)	the	been	spar	wall,	
92. Pushed	dow	some	se	there	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	nstre	unde	pro-	is	
95. Cross-members	am	rmin	tec-	more	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	right	ing	tion	rip	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	wing	of	at	rap	
98. Exposure depth	wall	the	the	at	

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

the end of the wingwall to prevent road wash. There are two large probably naturally placed boulders in the channel near the left abutment. The upstream left wingwall has failed.

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: 3

Scour dimensions: Length 2 Width 2 Depth: 2 Positioned 0 %LB to 0 %RB

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

3
0
2
-

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? On

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

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

Confluence comments (eg. confluence name):

d is at least 0.5 ft deep, but deeper material is probably analogous to the bed material, which is gravel cobble and sand. There is sparse native protection on the right bank along the right edge of water. There is intermit-

F. Geomorphic Channel Assessment

107. Stage of reach evolution ten

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)*:

t inflow from a 1.5 ft diameter culvert on the right bank downstream 30 ft from the bridge.

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: BRNATH00800016 Town: Barnard
Road Number: TH 80 County: Windsor
Stream: Locust Creek

Initials MAI Date: 11/20/95 Checked:

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	4000	5100	4800
Main Channel Area, ft2	818	1196	966
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	89.2	102.6	92.6
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.336	0.336	0.336
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	9.2	11.7	10.4
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	84892	144079	108492
Conveyance, main channel	84892	144079	108492
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0	0	0
Qm, discharge, MC, cfs	4000	5100	4800
Ql, discharge, LOB, cfs	0	0	0
Qr, discharge, ROB, cfs	0	0	0
Vm, mean velocity MC, ft/s	4.9	4.3	5.0
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	11.6	12.1	11.8
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

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/(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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	818	1196	966
Main channel width, ft	89.2	102.6	92.6
y1, main channel depth, ft	9.170404	11.65692	10.43197
Bridge Section			
(Q) total discharge, cfs	4000	5100	4800
(Q) discharge thru bridge, cfs	4000	4868	4800
Main channel conveyance	20122	34692	23965
Total conveyance	20122	34692	23965
Q2, bridge MC discharge,cfs	4000	4868	4800
Main channel area, ft2	243	439	275
Main channel width (skewed), ft	28.9	29.2	28.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.9	29.2	28.9
y_bridge (avg. depth at br.), ft	8.408304	15.03425	9.515571
Dm, median (1.25*D50), ft	0.42	0.42	0.42
y2, depth in contraction,ft	11.26801	13.21628	13.17398
ys, scour depth (y2-ybridge), ft	2.86	-1.82	3.66
ys, scour depth (y2-y1), ft	2.10	1.56	2.74
ys, scour depth (y2-yfullv), ft	N/A	3.58	N/A
ARMORING			
D90	1.39	1.39	1.39
D95	1.66	1.66	1.66
Critical grain size,Dc, ft	1.4763	0.5201	1.5685
Decimal-percent coarser than Dc	0.08	0.39	0.07
Depth to armoring,ft	49.00	2.44	62.52

Pressure Flow Scour (contraction scour for orifice flow conditions)

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	0	4868	0
Vc, critical velocity, ft/s	0	12.1	0
Vc, critical velocity, m/s	0	3.6879	0
Main channel width (skewed), ft	0	29.2	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	29.2	0
qbr, unit discharge, ft^2/s	ERR	166.7123	ERR
qbr, unit discharge, m^2/s	N/A	15.48657	N/A
Area of full opening, ft^2	0	439	0
Hb, depth of full opening, ft	ERR	15.03425	ERR
Hb, depth of full opening, m	N/A	4.582215	N/A
Fr, Froude number MC	1	0.5	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
Elevation of Low Steel, ft	0	496.617	0
Elevation of Bed, ft	N/A	481.5828	N/A
Elevation of approach WS, ft	0	499.33	0
HF, bridge to approach, ft	0	0.15	0
Elevation of WS immediately US, ft	0	499.18	0
ya, depth immediately US, ft	N/A	17.59725	N/A
ya, depth immediately US, m	N/A	5.46838	N/A
Mean elev. of deck, ft	0	498.163	0
w, depth of overflow, ft (>=0)	0	1.017	0
Cc, vert contrac correction (<=1.0)	ERR	0.976214	ERR
Ys, depth of scour (chang), ft	N/A	-0.92066	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4000	5100	4800	4000	5100	4800
a', abut.length blocking flow, ft	37.7	42.4	39.7	22.6	31	24
Ae, area of blocked flow ft2	271.61	413.99	333.44	172.01	265.88	209.64
Qe, discharge blocked abut.,cfs	1113.33	--	1417.5	696.55	--	862.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	4.099002	3.84	4.25114	4.049474	3.31	4.114196
ya, depth of f/p flow, ft	7.20	9.76	8.40	7.61	8.58	8.74
--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	0.27	0.22	0.26	0.26	0.20	0.25
ys, scour depth, ft	19.47	23.20	21.76	17.53	18.94	19.39

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)	37.7	42.4	39.7	22.6	31	24
y1 (depth fp flow, ft)	7.20	9.76	8.40	7.61	8.58	8.74
a'/y1	5.23	4.34	4.73	2.97	3.61	2.75
Froude no. f/p flow	0.27	0.22	0.26	0.26	0.20	0.25
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	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, 1993, p118-119, eq. 93,94)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	0.5	1			
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.4	15	9.5			
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.32	ERR	0.00	0.00	0
Fr>0.8 (vertical abut.)	3.51	ERR	3.97	ERR	ERR	ERR