LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (BRNATH00290034) on TOWN HIGHWAY 29, crossing LOCUST CREEK, BARNARD, VERMONT

U.S. Geological Survey
Open-File Report 96-642

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
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CONTENTS

FIGURES

TABLES

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 34 (BRNATH00290034) ON TOWN HIGHWAY 29, 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 BRNATH00290034 on Town Highway 29 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). 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 11.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest, except for pasture on the downstream right overbank.

In the study area, Locust Creek has an incised, generally straight channel with a slope of approximately 0.03 ft/ft, an average channel top width of 64 ft and an average channel depth of 7 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 89.3 mm (0.293 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 13, 1994 and December 16, 1994, indicated that the reach was stable.

The Town Highway 29 crossing of Locust Creek is a 37-ft-long, one-lane bridge consisting of one 32-foot concrete span (Vermont Agency of Transportation, written communication, August 23, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 25 degrees.

There was no observable scour protection measure at the site. 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 0.0 to 2.0 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Abutment scour ranged from 11.7 to 16.9 ft. The worst-case abutment scour occurred at the incipient-overtopping 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
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number BRNATH00290034 *Stream* Locust Creek

County Windsor *Road* TH 29 *District* 4

Description of Bridge

Bridge length 37 *ft* *Bridge width* 14.8 *ft* *Max span length* 32 *ft*

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

Abutment type Vertical, concrete *Embankment type* Sloping

Stone fill on abutment? No *Date of inspection* 10/13/94

Description of stone fill None

Brief description of piers/abutments Abutments and wingwalls are concrete. The top of the right abutment footing, downstream end is exposed, level with the bed material.

Is bridge skewed to flood flow according to No *survey?* Y *Angle* 25

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

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	10/13/94	0	0
Level II	10/13/94	0	0

Potential for debris Moderate. The upstream reach is forested with some trees leaning into the channel.

Describe any features near or at the bridge that may affect flow (include observation date) The stream flow impacts the right abutment with the top of the footing exposed at the downstream end. 10/13/94

Description of the Geomorphic Setting

General topography The channel has a flat to slightly irregular floodplain with steep valley walls on both sides.

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

Date of inspection 10/13/94 & 12/16/94

DS left: Steep valley wall

DS right: Moderately sloping channel bank to a narrow terrace

US left: Steep channel bank to floodplain

US right: Steep valley wall

Description of the Channel

Average top width 64 ft ***Average depth*** 7 ft

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

Straight, perennial stream with semi-alluvial channel boundaries.

10/13/94 & 12/16/96

Vegetative co Trees

DS left: Trees and brush

DS right: Trees

US left: Trees.

US right:

Do banks appear stable? Yes ***If not, describe location and type of instability and date of observation.*** -

The assessment of 10/13/94 and 12/16/96 noted a side bar under the bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 11.5 ***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:***

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

-

Calculated Discharges

Q100 2,350 ***ft³/s*** ***Q500*** 3,050 ***ft³/s***

The 100-year discharge is from the VTAOT database (VTAOT, written communication, May 4, 1995). The 500-year discharge was extrapolated and compared to other empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Subtract 3 feet from USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X in a chiseled square on top of the upstream end of the right abutment (elev. 500.02 ft, arbitrary survey datum). RM2 is a chiseled X in a chiseled square on top of the downstream end of the left abutment (elev. 501.31ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-62	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	48	2	Modelled Approach section (Templated from ATEMP)
ATEMP	107	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 0.035 to 0.064, and overbank "n" values ranged from 0.045 to 0.05.

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 0.0305 ft/ft which was determined from thalweg points downstream of the bridge.

The surveyed approach section (ATEMP) was moved along the approach channel slope (0.035 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 501.0 *ft*
Average low steel elevation 498.9 *ft*

100-year discharge 2,350 *ft³/s*
Water-surface elevation in bridge opening 494.2 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 168 *ft²*
Average velocity in bridge opening 14.0 *ft/s*
Maximum WSPRO tube velocity at bridge 17.1 *ft/s*

Water-surface elevation at Approach section with bridge 497.5 *ft*
Water-surface elevation at Approach section without bridge 496.0 *ft*
Amount of backwater caused by bridge 1.5 *ft*

500-year discharge 3,050 *ft³/s*
Water-surface elevation in bridge opening 499.0 *ft*
Road overtopping? Yes *Discharge over road* 378 *ft³/s*
Area of flow in bridge opening 288 *ft²*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 13.3 *ft/s*

Water-surface elevation at Approach section with bridge 500.8 *ft*
Water-surface elevation at Approach section without bridge 496.9 *ft*
Amount of backwater caused by bridge 3.9 *ft*

Incipient overtopping discharge 2,970 *ft³/s*
Water-surface elevation in bridge opening 495.5 *ft*
Area of flow in bridge opening 197 *ft²*
Average velocity in bridge opening 15.1 *ft/s*
Maximum WSPRO tube velocity at bridge 18.7 *ft/s*

Water-surface elevation at Approach section with bridge 499.0 *ft*
Water-surface elevation at Approach section without bridge 496.8 *ft*
Amount of backwater caused by bridge 2.2 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 100-year and incipient road overtopping discharge. 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 and Richarson and others, 1995, p. 145-146). The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F. In this case, the incipient road-overflow model resulted in the worst case contraction scour with a scour depth of 2.9 ft. The incipient road-overflow model also resulted in the worst case total scour with a depth at 19.8 at the right abutment.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.3 0.0	2.0	35.9 1.4
Depth to armoring	45.1	--	--
Left overbank	--	--	--
Right overbank	--	11.7	14.1

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	13.3	15.1	16.5
Left abutment	16.9	--	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.5	1.9
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	3.0	2.5	1.9
Left abutment	3.0	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

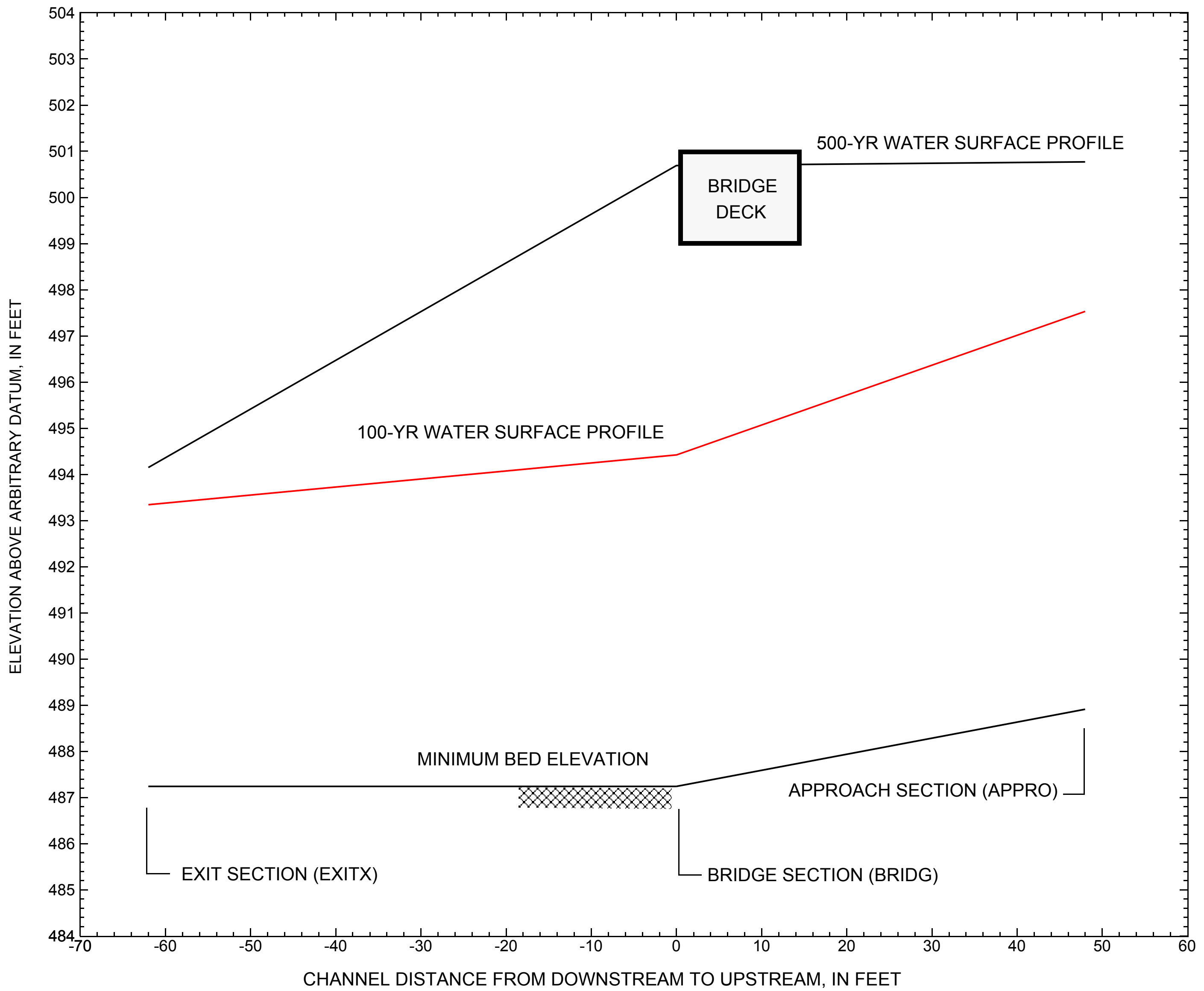

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRNATH00290034 on Town Highway 34, crossing Locust Creek, Barnard, Vermont.

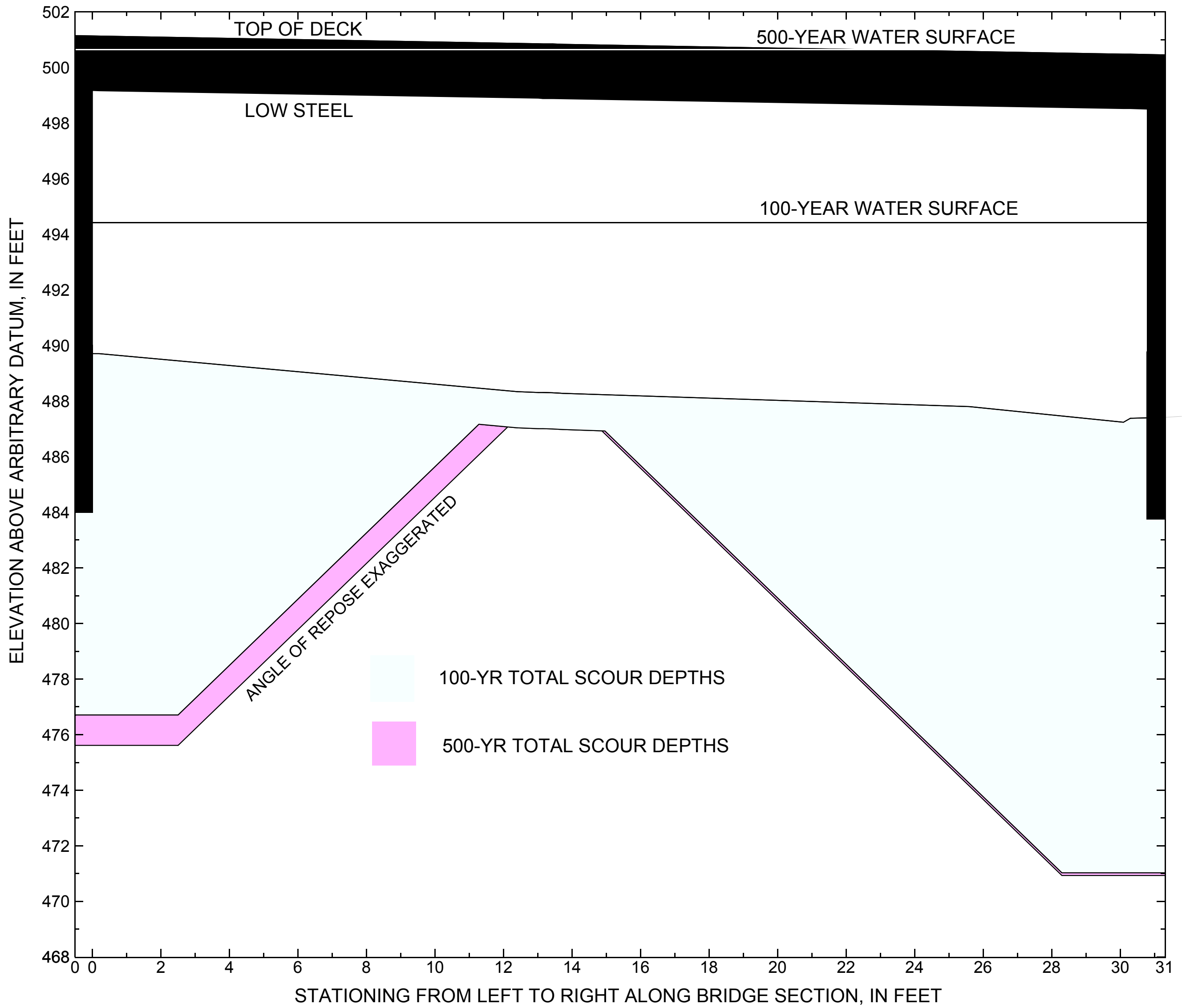

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRNATH00290034 on Town Highway 29, crossing Locust Creek, Barnard, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNATH00290034 on Town Highway 29, 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 2,350 cubic-feet per second											
Left abutment	0.0	496.5	499.5	484	489.7	1.3	11.7	--	13.0	476.7	-7
Right abutment	30.8	495.2	498.2	484	487.4	1.3	15.1	--	16.4	471.0	-13

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 BRNATH00290034 on Town Highway 29, 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 3,050 cubic-feet per second											
Left abutment	0.0	496.5	499.5	484	489.7	0.0	14.1	--	14.1	475.6	-8
Right abutment	30.8	495.2	498.2	484	487.4	0.0	16.5	--	16.5	470.9	-13

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, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brna034.wsp
T2        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
T3        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
Q           2350.0   3050.0   2970.0
SK           0.0305   0.0305   0.0305
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -62
GR          -57.6, 511.34    -34.2, 499.62    -12.7, 498.14     -4.1, 494.80
GR            0.0, 489.88     10.0, 488.29     19.3, 487.42     23.9, 487.51
GR           28.3, 487.24     31.1, 487.49     33.7, 488.39     61.4, 495.28
GR           79.5, 496.53     91.6, 497.64    104.0, 497.07    131.3, 510.60
SA             -12.7     61.4
N           0.05   0.064   0.045
*
XS   FULLV      0  * * *   0.0135
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    498.87      25.0
GR            0.0, 499.50      0.2, 489.71      5.3, 489.18     12.4, 488.34
GR           19.7, 488.03     25.6, 487.80     30.1, 487.24     30.3, 487.38
GR           30.8, 487.43     30.8, 489.18     30.8, 498.18      0.0, 499.50
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      25.7 * *     51.1     10.2
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      14.8      2
GR         -173.5, 506.21    -93.6, 503.99    -31.9, 502.41     -1.7, 501.44
GR            0.0, 501.35     16.5, 500.62     31.7, 500.26     34.2, 500.25
GR           68.0, 499.41     90.7, 498.73    106.6, 505.05
*
XT   ATEMP    107
GR          -20.5, 506.97    -11.0, 499.06     -3.0, 492.06      0.0, 491.82
GR            4.5, 491.25     10.1, 491.15     18.6, 491.59     26.2, 491.61
GR           29.7, 490.97     34.7, 491.94     36.6, 492.19     43.3, 495.05
GR           43.9, 496.96     73.2, 516.14
*
AS   APPRO    48
GT           -2.06
N                0.060
*
HP 1 BRIDG   494.42 1 494.42
HP 2 BRIDG   494.42 * * 2350
HP 1 APPRO   497.53 1 497.53
HP 2 APPRO   497.53 * * 2350
*
HP 1 BRIDG   498.96 1 498.96
HP 2 BRIDG   498.96 * * 2680
HP 2 RDWAY   500.69 * * 378
HP 1 APPRO   500.77 1 500.77
HP 2 APPRO   500.77 * * 3050
*
HP 1 BRIDG   495.46 1 495.46
HP 2 BRIDG   495.46 * * 2970
```

APPENDIX B:

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File brna034.wsp
      Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
      Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
         *** RUN DATE & TIME: 05-17-96  10:49
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      168     18786     28     40                         2348
 494.42           168     18786     28     40  1.00      0     31     2348

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

       WSEL     LEW     REW    AREA         K        Q    VEL
     494.42     0.1    30.8   168.3   18786.    2350.  13.97

X STA.        0.1        3.5        5.6        7.3        8.9       10.4
  A(I)            14.8        9.7        8.5        7.8        7.7
  V(I)            7.96      12.10      13.76      14.99      15.20

X STA.       10.4       11.7       13.0       14.3       15.6       16.8
  A(I)             7.4        7.2        7.2        6.9        7.0
  V(I)           15.86      16.42      16.41      17.05      16.90

X STA.       16.8       18.0       19.2       20.4       21.6       22.8
  A(I)             6.9        7.0        6.9        7.0        7.2
  V(I)           16.99      16.85      17.11      16.72      16.28

X STA.       22.8       24.1       25.4       26.8       28.3       30.8
  A(I)             7.4        7.6        8.5        9.5       16.1
  V(I)           15.82      15.48      13.85      12.38       7.29

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      401     33319     60     65                         5897
 497.53           401     33319     60     65  1.00    -11     48     5897

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

       WSEL     LEW     REW    AREA         K        Q    VEL
     497.53   -11.6    47.9   400.6   33319.    2350.   5.87

X STA.      -11.6       -2.8        0.1        2.5        4.8        6.9
  A(I)            33.8       22.3       19.2       19.0       17.6
  V(I)            3.47       5.27       6.11       6.17       6.69

X STA.        6.9        9.0       11.0       13.1       15.2       17.3
  A(I)            17.7       16.9       17.2       17.4       17.1
  V(I)            6.62       6.95       6.84       6.77       6.86

X STA.       17.3       19.5       21.7       23.9       26.1       28.2
  A(I)            17.5       17.4       17.6       17.4       17.7
  V(I)            6.73       6.75       6.68       6.73       6.62

X STA.       28.2       30.4       32.7       35.3       38.5       47.9
  A(I)            18.2       18.8       20.2       23.2       34.3
  V(I)            6.44       6.24       5.82       5.06       3.43
```

```
        U.S. Geological Survey WSPRO Input File brna034.wsp
        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
           *** RUN DATE & TIME: 05-17-96  10:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      288     33331     11     64                         8225
   498.96           288     33331     11     64  1.00      0     31     8225

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.96     0.0    30.8   288.3   33331.    2680.   9.30

X STA.        0.0        3.0        4.6        6.0        7.3        8.5
  A(I)            24.8       14.2       12.3       11.3       10.7
  V(I)            5.41       9.45      10.87      11.86      12.51

X STA.        8.5        9.6       10.7       11.7       12.9       14.3
  A(I)            10.5       10.3       10.1       10.9       13.2
  V(I)           12.76      13.05      13.29      12.24      10.12

X STA.       14.3       15.7       17.0       18.5       19.9       21.4
  A(I)            13.4       13.4       13.6       14.0       14.2
  V(I)            9.98       9.99       9.87       9.55       9.43

X STA.       21.4       22.9       24.4       26.1       27.9       30.8
  A(I)            14.2       14.9       16.0       17.6       28.6
  V(I)            9.41       9.00       8.38       7.62       4.68

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.69    14.9    95.6    75.6    2495.     378.   5.00

X STA.       14.9       44.6       53.5       59.8       63.5       66.3
  A(I)            10.9        7.2        6.3        4.1        3.4
  V(I)            1.74       2.62       3.01       4.59       5.64

X STA.       66.3       68.8       71.2       73.3       75.3       77.2
  A(I)             3.3        3.2        3.0        2.9        2.9
  V(I)            5.81       5.99       6.21       6.47       6.63

X STA.       77.2       79.0       80.7       82.2       83.8       85.3
  A(I)             2.8        2.7        2.7        2.7        2.6
  V(I)            6.68       6.89       7.13       7.08       7.19

X STA.       85.3       86.7       88.1       89.5       91.0       95.6
  A(I)             2.6        2.6        2.7        2.9        4.2
  V(I)            7.17       7.21       7.11       6.46       4.47

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      608     60195     68     76                        10284
   500.77           608     60195     68     76  1.00    -15     53    10284

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.77   -15.5    52.9   607.9   60195.    3050.   5.02

X STA.      -15.5       -4.3       -1.1        1.7        4.2        6.5
  A(I)            53.5       34.3       30.5       28.2       26.6
  V(I)            2.85       4.44       5.00       5.42       5.73

X STA.        6.5        8.7       10.9       13.1       15.3       17.5
  A(I)            26.1       24.9       26.0       25.0       25.6
  V(I)            5.83       6.13       5.87       6.09       5.96

X STA.       17.5       19.8       22.1       24.4       26.7       29.0
  A(I)            25.5       25.5       25.8       26.1       26.9
  V(I)            5.98       5.99       5.92       5.84       5.67

X STA.       29.0       31.3       33.8       36.7       40.3       52.9
  A(I)            26.5       28.8       30.7       35.9       55.6
  V(I)            5.76       5.30       4.96       4.25       2.74
```

```
        U.S. Geological Survey WSPRO Input File brna034.wsp
        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
           *** RUN DATE & TIME: 05-17-96  10:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      197     23654     28     42                         2978
   495.46           197     23654     28     42  1.00      0     31     2978

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.46     0.1    30.8   197.2   23654.    2970.  15.06

X STA.         0.1        3.5        5.5        7.2        8.7       10.2
  A(I)            17.9       11.4        9.7        9.1        9.0
  V(I)            8.28      12.98      15.27      16.24      16.56

X STA.        10.2       11.5       12.8       14.1       15.3       16.5
  A(I)             8.4        8.4        8.0        8.1        7.9
  V(I)           17.68      17.68      18.45      18.25      18.70

X STA.        16.5       17.7       18.9       20.1       21.3       22.6
  A(I)             8.0        8.1        8.0        8.1        8.4
  V(I)           18.45      18.32      18.63      18.22      17.76

X STA.        22.6       23.8       25.1       26.5       28.1       30.8
  A(I)             8.6        9.1        9.8       11.3       19.6
  V(I)           17.27      16.41      15.12      13.12       7.56

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      493     44795     64     70                         7787
   499.03           493     44795     64     70  1.00    -12     50     7787

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.03   -13.4    50.2   493.0   44795.    2970.   6.02

X STA.       -13.4       -3.4       -0.4        2.1        4.5        6.7
  A(I)            42.8       27.4       24.2       23.1       21.8
  V(I)            3.47       5.43       6.15       6.43       6.81

X STA.         6.7        8.9       11.0       13.1       15.3       17.4
  A(I)            21.4       20.4       21.3       20.8       20.5
  V(I)            6.93       7.28       6.98       7.15       7.23

X STA.        17.4       19.6       21.8       24.1       26.3       28.6
  A(I)            21.2       21.1       21.4       21.2       22.1
  V(I)            7.01       7.03       6.95       7.01       6.71

X STA.        28.6       30.8       33.2       35.9       39.3       50.2
  A(I)            22.0       23.3       24.6       28.9       43.6
  V(I)            6.74       6.37       6.04       5.13       3.41
```

```
        U.S. Geological Survey WSPRO Input File brna034.wsp
        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
           *** RUN DATE & TIME: 05-17-96  10:49

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

EXITX:XS   ******     -2      232  1.59 *****  494.94  492.96    2350  493.34
       -61 ******     54    13452  1.00 ***** *******    0.88   10.13

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.42

FULLV:FV       62     -3      298  0.97  1.33  496.26 *******    2350  495.30
         0     62     58    19139  1.00  0.00    0.00    0.63    7.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       48     -9      311  0.89  0.60  496.86 *******    2350  495.97
        48     48     46    23099  1.00  0.00   -0.01    0.56    7.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    2350.      494.42

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

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

BRIDG:BR       62      0      168  3.03 *****  497.45  494.42    2350  494.42
         0     62     31    18780  1.00 ***** *******    1.00   13.97

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.87 ****** ****** ******

    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       22    -11      401  0.54  0.21  498.07  493.99    2350  497.53
        48     24     48    33319  1.00  0.40    0.02    0.40    5.87

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.445  0.239   25271.     1.    31.   497.36

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -62.    -3.    54.   2350.   13452.     232.   10.13  493.34
   FULLV:FV       0.    -4.    58.   2350.   19139.     298.    7.88  495.30
   BRIDG:BR       0.     0.    31.   2350.   18780.     168.   13.97  494.42
   RDWAY:RG      10.**************      0.******************    2.00********
   APPRO:AS      48.   -12.    48.   2350.   33319.     401.    5.87  497.53

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    31.   25271.
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.96    0.88  487.24  511.34************  1.59  494.94  493.34
   FULLV:FV  ********    0.63  488.08  512.18  1.33  0.00  0.97  496.26  495.30
   BRIDG:BR    494.42    1.00  487.24  499.50************  3.03  497.45  494.42
   RDWAY:RG  ****************  498.73  506.21**********************************
   APPRO:AS    493.99    0.40  488.91  514.08  0.21  0.40  0.54  498.07  497.53
```

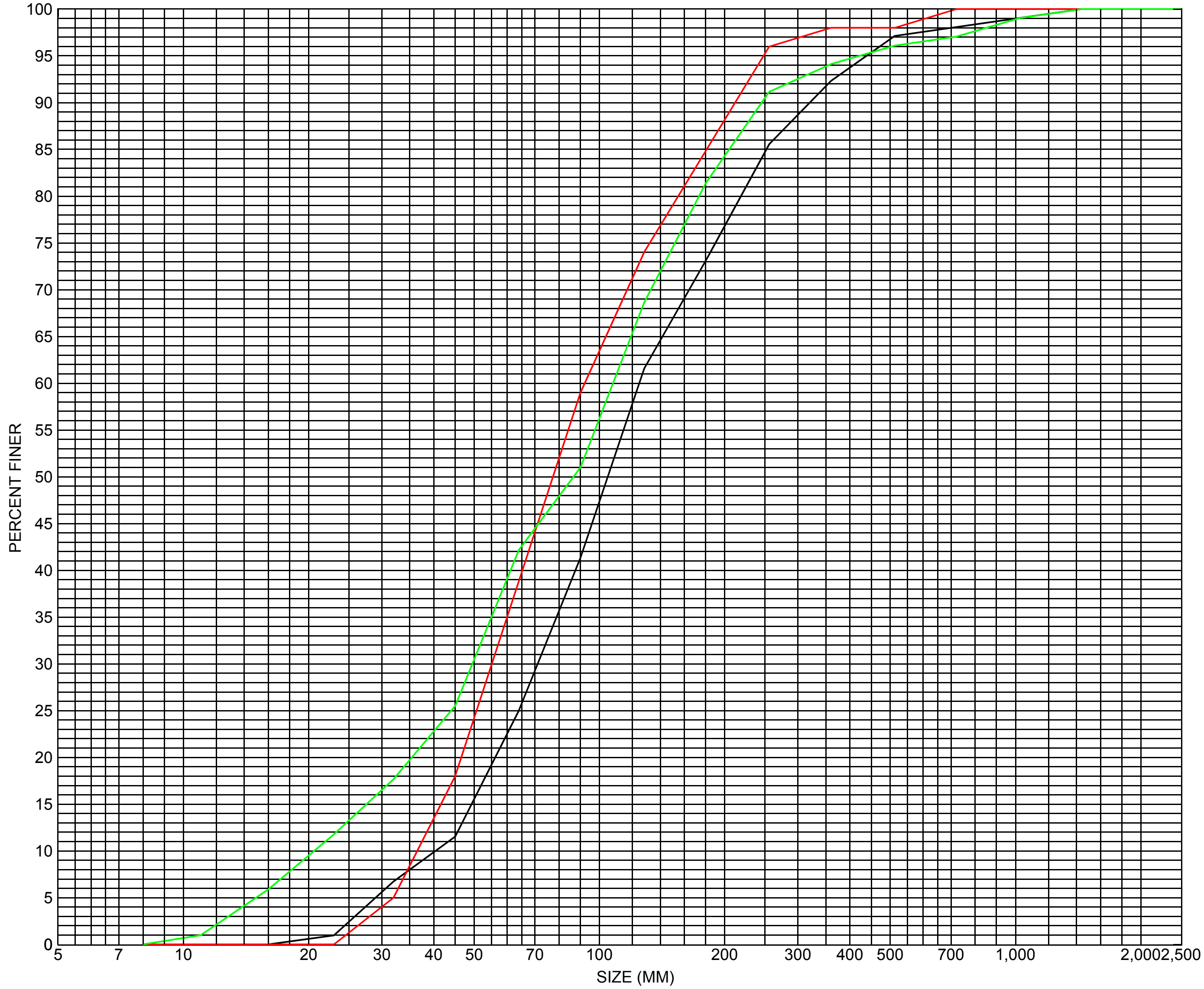
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File brna034.wsp
        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
           *** RUN DATE & TIME: 05-17-96  10:49

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

EXITX:XS   ******     -3      279  1.86 *****  496.01  493.77    3050  494.15
       -61 ******     57    17447  1.00 ***** *******    0.90   10.93

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.40

FULLV:FV       62     -5      356  1.14  1.35  497.34 *******    3050  496.20
         0     62     63    24427  1.00  0.00   -0.02    0.66    8.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       48    -10      362  1.10  0.63  497.98 *******    3050  496.88
        48     48     47    28832  1.00  0.00    0.00    0.59    8.42
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.21       0.00     495.58     498.73

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.55     498.96     499.16     498.87

 ===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       62      0      288  1.34 *****  500.30  494.98    2680  498.96
         0 ******     31    33344  1.00 ***** *******    0.54    9.30

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.442 ******  498.87 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       10.    33.  0.09  0.39  501.08    0.00    378.  500.69

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     1.     1.    15.    16.   0.1   0.0   2.6  23.7   0.4   2.7
   RT:   377.    79.    16.    96.   2.0   0.9   5.3   5.0   1.3   3.1

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

APPRO:AS       22    -15      608  0.39  0.10  501.16  494.79    3050  500.77
        48     24     53    60207  1.00  0.41    0.00    0.30    5.02

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -62.    -4.    57.   3050.   17447.     279.   10.93  494.15
   FULLV:FV        0.    -6.    63.   3050.   24427.     356.    8.56  496.20
   BRIDG:BR        0.     0.    31.   2680.   33344.     288.    9.30  498.96
   RDWAY:RG       10.*******     1.    378.       0.       0.    2.00  500.69
   APPRO:AS       48.   -16.    53.   3050.   60207.     608.    5.02  500.77

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS     493.77    0.90  487.24  511.34************  1.86  496.01  494.15
   FULLV:FV   ********    0.66  488.08  512.18  1.35  0.00  1.14  497.34  496.20
   BRIDG:BR     494.98    0.54  487.24  499.50************  1.34  500.30  498.96
   RDWAY:RG   ****************  498.73  506.21  0.09******  0.39  501.08  500.69
   APPRO:AS     494.79    0.30  488.91  514.08  0.10  0.41  0.39  501.16  500.77
```

```
        U.S. Geological Survey WSPRO Input File brna034.wsp
        Hydraulic analysis for structure BRNATH00290034   Date: 29-APR-96
        Hydraulic Analysis for Bridge 34 over Locust Creek by MAI
           *** RUN DATE & TIME: 05-17-96  10:49

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

EXITX:XS   ******     -2      274  1.83 *****  495.89  493.69    2970  494.06
       -61 ******     57    16991  1.00 ***** *******    0.89   10.84

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.41

FULLV:FV       62     -4      351  1.11  1.35  497.24 *******    2970  496.13
         0     62     62    23899  1.00  0.00    0.00    0.65    8.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       48    -10      357  1.07  0.63  497.87 *******    2970  496.79
        48     48     47    28278  1.00  0.00    0.00    0.59    8.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.03       0.00     495.46     498.73

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =     2970.      495.46

            <<<<<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       62      0      197  3.52 *****  498.99  495.46    2970  495.46
         0     62     31    23674  1.00 ***** *******    1.00   15.05

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  498.87 ****** ****** ******

    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       22    -12      493  0.56  0.20  499.59  494.70    2970  499.03
        48     24     50    44763  1.00  0.40    0.00    0.38    6.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.466  0.250   33537.     1.    32. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -62.    -3.    57.   2970.   16991.     274.   10.84  494.06
   FULLV:FV       0.    -5.    62.   2970.   23899.     351.    8.45  496.13
   BRIDG:BR       0.     0.    31.   2970.   23674.     197.   15.05  495.46
   RDWAY:RG      10.**************      0.       0.       0.    2.00********
   APPRO:AS      48.   -13.    50.   2970.   44763.     493.    6.03  499.03

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    32.   33537.
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.69    0.89  487.24  511.34************  1.83  495.89  494.06
   FULLV:FV  ********    0.65  488.08  512.18  1.35  0.00  1.11  497.24  496.13
   BRIDG:BR    495.46    1.00  487.24  499.50************  3.52  498.99  495.46
   RDWAY:RG  ****************  498.73  506.21  0.15******  0.57  499.43********
   APPRO:AS    494.70    0.38  488.91  514.08  0.20  0.40  0.56  499.59  499.03
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for three pebble count transects near the channel approach section of structure BRNATH00290034, in Barnard, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNATH00290034

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 TH029

Vicinity *(I - 9)* 0.3 MI TO JCT W VT12

Topographic Map Bethel

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43453

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

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140300341403

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

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

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

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

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

Deck Width *(I - 52; nn.n)* 148

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

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 19

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 030.0

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

Vertical clearance from streambed (*nnn.n ft*) 008.0

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

Waterway of full opening (*nnn.n ft*^{2}) 240.0

Comments:

Structural inspection report of 5/25/94 indicates that the abutment concrete is in “like new” condition. The upstream left wingwall is indicated as having cracks. No undermining or settlement are reported. Report noted minor channel scour and slight exposure at downstream end of the right abutment. Very minor embankment erosion is reported. No noted debris or channel bars. Channel makes a slight turn into the bridge crossing. Stone fill is reported in fair condition.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 11.6

Terrain character: Mountainous

Stream character & type: -

Streambed material: Stone and gravel with some moderate size boulders.

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 1200 Q_{25} 1650

Q_{50} 2000 Q_{100} 2350 Q_{500} -

Record flood date *(MM / DD / YY)*: - / - / - Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 11.5

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*))	-	-	7.0	8.1	9.1
Velocity (*ft / sec*)	-	-	11.5	-	-

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*): - Town: Barnard Year Built: -

Highway No. : - Structure No. : 26 Structure Type: Bridge

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

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

Highway No. : - Structure No. : **25** Structure Type: **Bridge**

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **11.48** mi^2 Lake and pond area **0.02** mi^2

Watershed storage *(ST)* **0.2** %

Bridge site elevation **920** ft Headwater elevation **2836** ft

Main channel length **7.34** mi

10% channel length elevation **9.90** ft 85% channel length elevation **1940** ft

Main channel slope *(S)* **172.57** 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 05 / 1974

Project Number **DSR 4B-13** Minimum channel bed elevation: **485.0**

Low superstructure elevation: USLAB **496.15** DSLAB **496.15** USRAB **495.04** DSRAB **495.04**

Benchmark location description:
BM#1, spike in a 4 inch maple, 18 feet from right bank road approach (side of roadway is not clear), elevation 500.00 feet.

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

Foundation Type: **1** (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness **2.0** Footing bottom elevation: **481.00**

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: _______

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
Some hydraulic information is printed on the plans: Q10 = 1200, Q25 = 1650, high water =7.0 feet; Q50 = 2000, high water = 8.1 feet; Q100 = 2350, high water = 9.1 feet, drainage area = 11.6 square miles, outlet velocity at Q25 = 11.0 feet / second.

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: _______ Date: __________

Computerized by: _______ Date: __________

Reviewd by: _______ Date: __________

Structure Number **BRNATH00290034**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M**. **WEBER** Date *(MM/DD/YY)* **12** / **16** / 19**94**

2. Highway District Number **04** Mile marker **000000**

County **027 (WINDSOR)** Town **02725 (BARNARD)**

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

Route Number **TH029** Hydrologic Unit Code: **01080105**

3. Descriptive comments:

The bridge is located about 0.3 mile southwest of the intersection of town highway 29 with State Route 12. Field checking and augmenting earlier Level I forms.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **5** Overall **6**

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **1** 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 **37** *(feet)* Span length **32** *(feet)* Bridge width **14.8** *(feet)*

Road approach to bridge:

8. LB **2** 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 **-:1** US right **-:1**

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

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

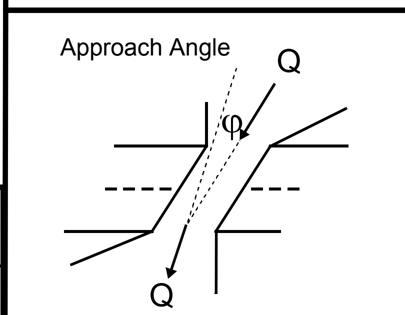
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

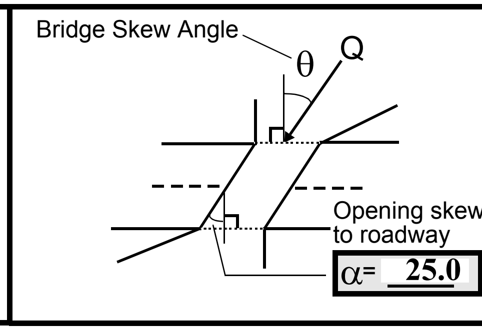
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **25**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **RB** *(LB, RB)* Severity **1**

Range? **8** feet **US** *(US, UB, DS)* to **10** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*

Where? **LB** *(LB, RB)* Severity **1**

Range? **45** feet **DS** *(US, UB, DS)* to **100** feet **DS**

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

18. Bridge Type: **1a**

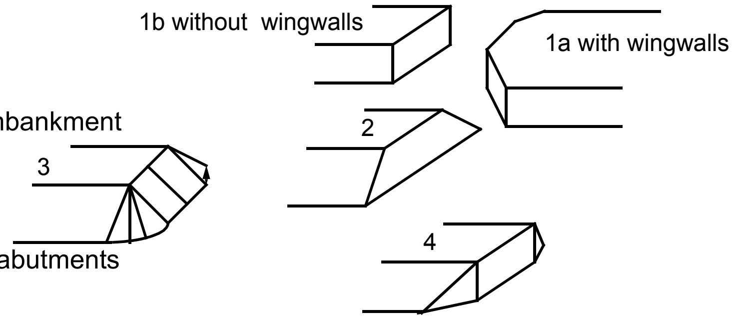
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

4. There is shrub and brushland near the bridge on the right bank downstream and gravel roadway bisects the area but forested beyond.
7. Values are from VTAOT database. Measured dimensions are: bridge length: 36.5 ft, span length: 32 ft, roadway width: 15 ft.
10. Road embankments cited as not significant on the Survey Log Notes.
11. There is no road approach protection apparent or detected using a rangepole to probe through snow on the road approaches. Old photos from previous assessments justify the no protection designation.

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
88.5	**7.0**			**5.0**	**4**	**4**	**4**	**4**	**1**	**1**

23. Bank width **40.0** 24. Channel width **35.0** 25. Thalweg depth **55.0** 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.):

27. The bank material is cobble, boulder and gravel.
29. The bed material is cobble, gravel, and boulder.
30. The right and left banks have native boulder and cobble protection.

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.):

There is light fluvial erosion on the left bank.

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
34.5		0.5		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

The downstream end of the right abutment footing is exposed.

63. The bed material is gravel, cobble, sand, silt and clay.

65. **Debris and Ice** Is there debris accumulation? ____ *(Y or N)* 66. Where? N____ *(1- Upstream; 2- At bridge; 3- Both)*

67. Debris Potential -____ *(1- Low; 2- Moderate; 3- High)* 68. Capture Efficiency 2____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

There is a high stream slope with trees along the upstream banks.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT	-	90	2	0	-	-	1	90.0
RABUT	10	90	2			2	1	31.0

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.):

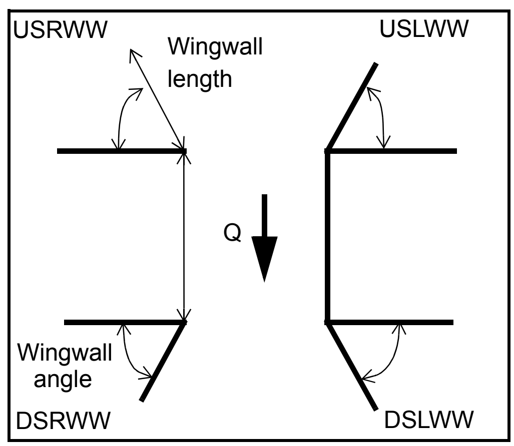
0

1

The Top of the right abutment footing is exposed at the downstream end. However, the bed elevation is flush with the footing so exposure depth is zero. The scour depth is 1 ft since the water depth at the downstream right end of the bridge face is about 1 ft deeper than the thalweg depth upstream and downstream. The thalweg depths under the bridge are almost 0.5 ft deeper than upstream or downstream which may indicate some remnant contraction scour.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:					Y	25.5	
USRWW:	1		0		-	1.0	
DSLWW:	-		Y		1	19.5	
DSRWW:	0		-		-	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	Y	-	1	0	-	-	-	-
Condition	1	-	2	0	0	0	0	-
Extent	0	Y	1	-	-	-	-	-

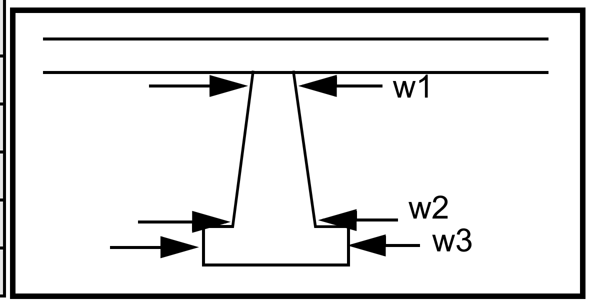
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
0
-
-
0
-
-
There is no protection besides fluvially deposited cobbles and boulders at the upstream wingwalls.

Piers:

84. Are there piers? _____ *(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				**10.0**	**21.0**	**90.0**
Pier 2	**8.0**			**90.0**	**13.0**	**35.0**
Pier 3		-	-	**15.5**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**N**	-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	-	-	-	-	
98. Exposure depth	-	-	-	-	

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

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
-	-			-	**NO**	**PIE**	**RS**			

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.):

3
2
3
3
3
0
4
0
0
-
-
The bank material is gravel, boulder and sand.
The bed material is cobble gravel and boulder.
There are large boulders scattered on the right bank downstream that appear fluvially deposited and provide

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

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

105. Drop structure comments (eg. downstream scour depth):
bank and road embankment protection.

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 **N** *(US, UB, DS)* positioned **-** %LB to **NO** %RB

Material: **DR**

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

OP STRUCTURE

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

Cut bank extent: **40** feet **20** *(US, UB, DS)* to **14** feet **UB** *(US, UB, DS)*

Bank damage: **48** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
30
3

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

Scour dimensions: Length **side** Width **bar** Depth: **here** Positioned **is** %LB to **loca** %RB

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

ted in a position where gravel has aggraded from an intermittent confluence entering at this location on the bank. The side bar material is gravel and cobble.

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

Confluence 1: Distance **66** Enters on **45** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **100** Enters on **DS** *(LB or RB)* Type **2** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

A large slip failure (landslide) on the outside of the channel bend.

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
-
-
-
-
-
-
There may be some contraction scour under the bridge since the thalweg depths at the upstream and downstream faces are almost 0.5 ft deeper than the thalweg depths upstream and downstream.

Y

109. G. Plan View Sketch

- 1

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BRNATH00290034 Town: Barnard
Road Number: TH 29 County: Windsor
Stream: Locust Creek

Initials MAI Date: 4/30/96 Checked: EMB

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

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2350	3050	2970
Main Channel Area, ft2	400.6	607.9	493
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	59.5	68.4	63.6
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.293	0.293	0.293
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.7	8.9	7.8
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	33319	60195	44795
Conveyance, main channel	33319	60195	44795
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyeance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	2350.0	3050.0	2970.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	5.9	5.0	6.0
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	10.2	10.7	10.5
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/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	400.6	607.9	493
Main channel width, ft	59.5	68.4	63.6
y1, main channel depth, ft	6.73	8.89	7.75

Bridge Section			
(Q) total discharge, cfs	2350	3050	2970
(Q) discharge thru bridge, cfs	2350	2680	2970
Main channel conveyance	18786	33331	23654
Total conveyance	18786	33331	23654
Q2, bridge MC discharge,cfs	2350	2680	2970
Main channel area, ft2	168	288	197
Main channel width (skewed), ft	27.8	27.9	27.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	27.8	27.9	27.8
y_bridge (avg. depth at br.), ft	6.05	10.33	7.09
Dm, median (1.25*D50), ft	0.36625	0.36625	0.36625
y2, depth in contraction,ft	7.40	8.25	9.04
ys, scour depth (y2-ybridge), ft	1.34	-2.08	1.95
ys, scour depth (y2-yfullv), ft	--	0.56	--

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	2680	0
Vc, critical velocity, ft/s	0	10.72	0
Vc, critical velocity, m/s	0	3.267297	0
Main channel width (skewed), ft	0	27.9	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	27.9	0
qbr, unit discharge, ft^2/s	ERR	96.05735	ERR
qbr, unit discharge, m^2/s	N/A	8.923149	N/A
Area of full opening, ft^2	0	288.3	0
Hb, depth of full opening, ft	ERR	10.33333	ERR
Hb, depth of full opening, m	N/A	3.149446	N/A
Fr, Froude number MC	1	0.54	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5

Elevation of Low Steel, ft	0	498.84	0
Elevation of Bed, ft	N/A	488.5067	N/A
Elevation of approach WS, ft	0	500.77	0
HF, bridge to approach, ft	0	0.1	0
Elevation of WS immediately US, ft	0	500.67	0
ya, depth immediately US, ft	N/A	12.16333	N/A
ya, depth immediately US, m	N/A	3.77978	N/A
Mean elev. of deck, ft	0	500.81	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.960161	ERR
Ys, depth of scour (chang), ft	N/A	-1.00097	N/A

ARMORING

D90	0.818	0.818	0.818
D95	1.223	1.223	1.223
Critical grain size,Dc, ft	0.9694	0.3434	1.0525
Decimal-percent coarser than Dc	0.075	0.421	0.0655
Depth to armoring,ft	35.87	1.42	45.05

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2350	3050	2970	2350	3050	2970
a', abut.length blocking flow, ft	12.2	16.1	14	17.7	22.7	20
Ae, area of blocked flow ft2	60.1	106.3	79.9	98.2	151.19	126.4
Qe, discharge blocked abut.,cfs	259.5	397.6	356.4	480.7	--	634.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	4.32	3.74	4.46	4.90	4.17	5.02
ya, depth of f/p flow, ft	4.93	6.60	5.71	5.55	6.66	6.32
--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	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.343	0.257	0.329	0.366	0.274	0.352
ys, scour depth, ft	11.68	14.14	13.31	15.06	16.50	16.86

HIRE equation (a'/ya > 25)

ys = 4*Fr^0.33*y1*K/0.55

(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	12.2	16.1	14	17.7	22.7	20
y1 (depth f/p flow, ft)	4.93	6.60	5.71	5.55	6.66	6.32
a'/y1	2.48	2.44	2.45	3.19	3.41	3.16
Skew correction	0.92	0.92	0.92	1.08	1.08	1.08
Froude no. f/p flow	0.34	0.26	0.33	0.37	0.27	0.35
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, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	0.54	1	1	0.54	1
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.05	10.33	7.09	6.05	10.33	7.09
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.86	ERR	ERR	1.86	ERR
Fr>0.8 (vertical abut.)	2.53	ERR	2.96	2.53	ERR	2.96