LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (DANVTH00010004) on TOWN HIGHWAY 1, crossing JOES BROOK, DANVILLE, VERMONT

Open-File Report 97-675

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

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (DANVTH00010004) on TOWN HIGHWAY 1, crossing JOES BROOK, DANVILLE, VERMONT

By ROBERT H. FLYNN AND ERICK M. BOEHMLER

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Pembroke, New Hampshire

1997

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Slope		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
cubic foot (ft^3)	0.02832	cubic meter (m^3)
Velocity and Flow		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

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

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 4 (DANVTH00010004) ON TOWN HIGHWAY 1, CROSSING JOES BROOK, DANVILLE, VERMONT

By **Robert H. Flynn and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure DANVTH00010004 on Town Highway 1 crossing Joes Brook, Danville, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 42.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture along the upstream and downstream left banks with trees and brush along the immediate banks. The upstream and downstream right banks are forested.

In the study area, Joes Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 68 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 80.1 mm (0.263 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 22, 1995, indicated that the reach was stable.

The Town Highway 1 crossing of Joes Brook is a 49-ft-long, two-lane bridge consisting of one 45-foot steel-beam span (Vermont Agency of Transportation, written communication, March 17, 1995). The opening length of the structure parallel to the bridge face is 45 ft.The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening and the computed opening-skew-to-roadway is 15 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. The scour hole also extends upstream and downstream of the bridge, along the right side of the channel. The scour protection measures at the site include type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left wingwall and along the entire base length of the downstream right wingwall. Type-3 stone fill (less than 48 inches diameter) is along the entire base length of the upstream right wingwall and type-5 protection (stone block wall) is along the upstream right bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. 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 was computed to be zero ft. Abutment scour ranged from 11.7 to 13.0 ft along the right abutment and from 6.6 to 9.4 ft along the left abutment. 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 and Hire equations (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.

St. Johnsbury, VT. 7.5 X 15 Minute Series Quadrangle, 1:25,000, 1983

NORTH

Figure 1. Location of study area on USGS 1:25,000 scale map.

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

LEVEL II SUMMARY

Structure Number DANVTH00010004 ***Stream*** Joes Brook

County Caledonia ***Road*** TH1 ***District*** 7

Description of Bridge

Bridge length 49 ***ft*** ***Bridge width*** 27.9 ***ft*** ***Max span length*** 45 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/22/95

Description of stone fill Type-2, along the upstream end of the upstream left wingwall and along the entire base length of the downstream right wingwall. Type-3 along the entire base length of the upstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one foot deep scour hole along the right abutment. The scour hole also extends upstream and downstream of the bridge and is approximately 2.5 ft deep at the upstream bridge face.

Y 15

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

There is a moderate channel bend in the upstream reach. A stone block wall and cut bank are located where the bend impacts the upstream right bank.

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	8/22/95	0	0
Level II	8/22/95	0	0

Potential for debris Moderate. There is some debris caught on boulders upstream and there are trees leaning over the channel at the location of the upstream cutbank.

Describe any features near or at the bridge that may affect flow (include observation date) None noted as of 8/22/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with little to no flood plain.

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

Date of inspection 8/22/95

DS left: Steep channel bank.

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

US left: Steep channel bank.

US right: Steep channel bank and overbank.

Description of the Channel

Average top width 68 ft

Average depth 5 ft

Predominant bed material Boulder / Cobble

Bank material Cobble / Boulder

Sinuous but stable with non-alluvial channel boundaries.

8/22/95

Vegetative co Pasture with trees and brush along the immediate banks.

DS left: Trees and brush.

DS right: Pasture with trees and brush along the immediate banks.

US left: Trees and brush.

US right:

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

None noted as of 8/22/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 42.5 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p _ No

-

Calculated Discharges

Q100 2,330 ***ft***^{3}***/s*** ***Q500*** 3,250 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(42.5/33.9)exp 0.67] with bridge number 35 in Danville. Bridge number 35 crosses Joes Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 35 is 33.9 square miles. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the right end of the downstream concrete curbing (elev. 485.38 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the downstream left wingwall (elev. 481.74 ft, arbitrary survey datum). RM3 is a chiseled "X" on top of the upstream right wingwall (elev. 483.73 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-49	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	73	2	Modelled Approach section (Templated from APTEM)
APTEM	80	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 0.050 to 0.075, and overbank "n" values ranged from 0.055 to 0.080.

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 0.0213 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1983).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0239 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 location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 483.0 *ft*
Average low steel elevation 479.3 *ft*

100-year discharge 2,330 *ft³/s*
Water-surface elevation in bridge opening 473.0 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 283 *ft²*
Average velocity in bridge opening 8.2 *ft/s*
Maximum WSPRO tube velocity at bridge 10.0 *ft/s*

Water-surface elevation at Approach section with bridge 474.3
Water-surface elevation at Approach section without bridge 474.1
Amount of backwater caused by bridge 0.2 *ft*

500-year discharge 3,250 *ft³/s*
Water-surface elevation in bridge opening 473.7 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 314 *ft²*
Average velocity in bridge opening 10.4 *ft/s*
Maximum WSPRO tube velocity at bridge 12.7 */s*

Water-surface elevation at Approach section with bridge 475.8
Water-surface elevation at Approach section without bridge 475.3
Amount of backwater caused by bridge 0.5 *ft*

Incipient overtopping discharge - *ft³/s*
Water-surface elevation in bridge opening - *ft*
Area of flow in bridge opening - *ft²*
Average velocity in bridge opening - *ft/s*
Maximum WSPRO tube velocity at bridge - *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20).

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	2.2	6.0	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.6	9.4	--
Right abutment	11.7	13.0	--
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	1.3	2.0	--
Right abutment	1.3	2.0	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

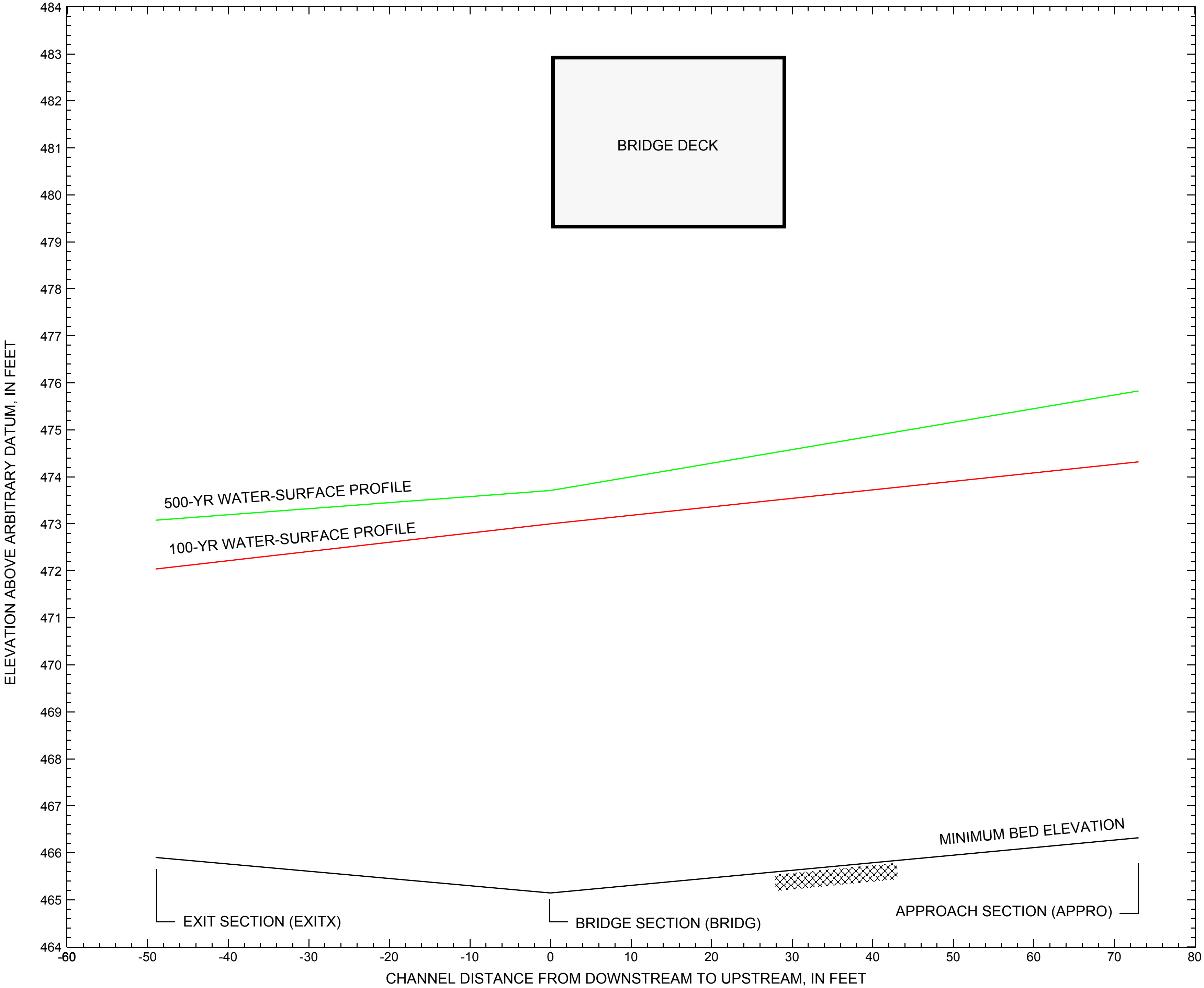

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure DANVTH00010004 on Town Highway 1, crossing Joes Brook, Danville, Vermont.

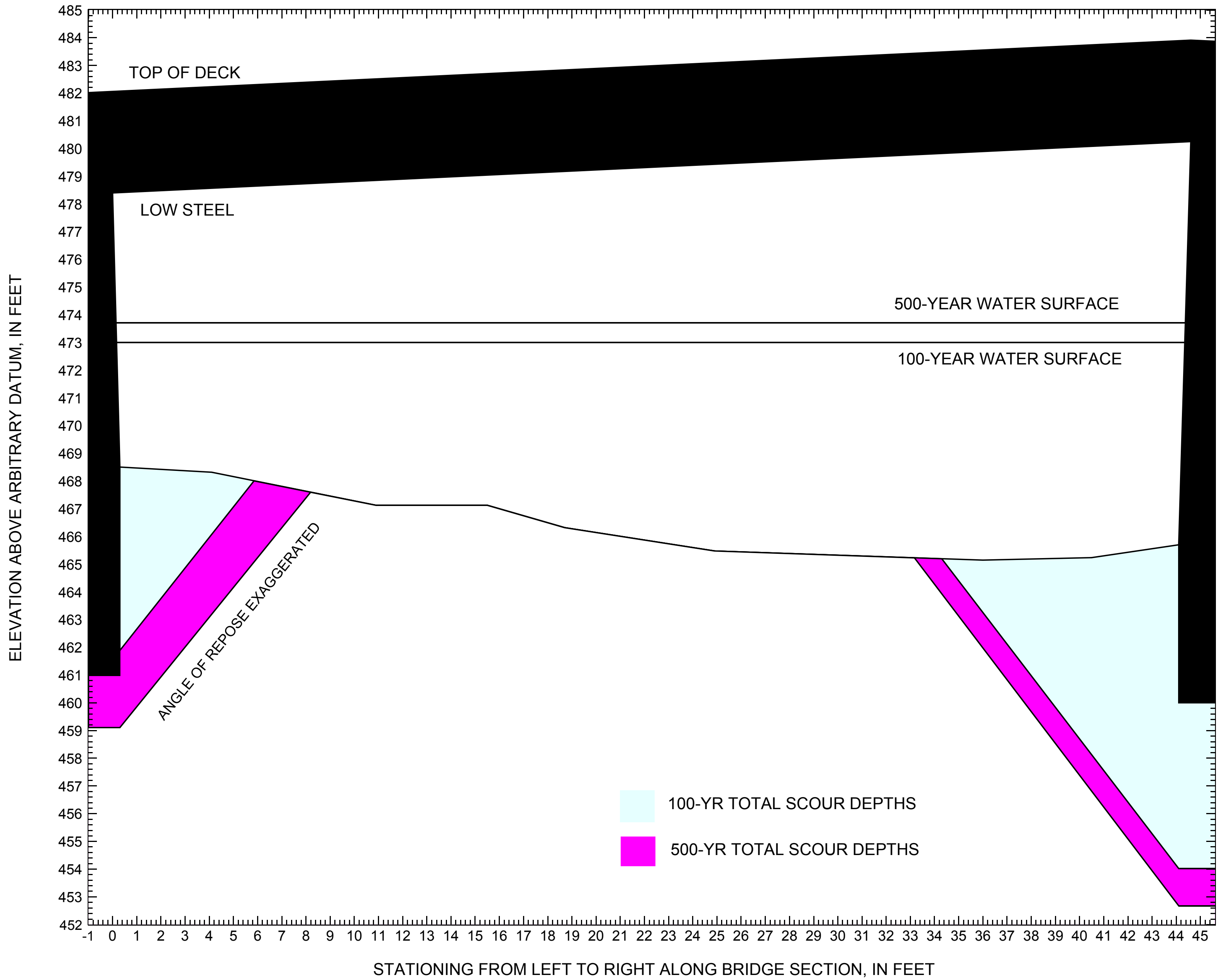

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure DANVTH00010004 on Town Highway 1, crossing Joes Brook, Danville, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure DANVTH00010004 on Town Highway 1, crossing Joes Brook, Danville, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,330 cubic-feet per second											
Left abutment	0.0	478.5	478.4	461.0	468.5	0.0	6.6	--	6.6	461.9	0.9
Right abutment	44.6	480.5	480.3	460.0	465.7	0.0	11.7	--	11.7	454.0	-6.0

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 DANVTH00010004 on Town Highway 1, crossing Joes Brook, Danville, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,250 cubic-feet per second											
Left abutment	0.0	478.5	478.4	461.0	468.5	0.0	9.4	--	9.4	459.1	-1.9
Right abutment	44.6	480.5	480.3	460.0	465.7	0.0	13.0	--	13.0	452.7	-7.3

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, 1983, St. Johnsbury, Vermont 7.5 X 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File danv004.wsp
T2        Hydraulic analysis for structure DANVTH00010004   Date: 01-AUG-97
T3        Bridge #4 over Joes Brook in Danville, VT.  RHF
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
Q           2330.0   3250.0
SK          0.0213   0.0213
*
XS   EXITX    -49          0.
GR         -251.8, 487.14
GR         -153.2, 479.43   -115.4, 478.33    -86.8, 477.59    -66.6, 473.57
GR            0.0, 472.38     13.9, 466.71     16.3, 466.19     18.2, 465.98
GR           23.0, 466.62     29.8, 466.18     34.1, 466.45     41.0, 465.90
GR           45.8, 466.23     49.5, 467.05     57.2, 470.65     70.4, 474.63
GR           90.8, 475.42    110.5, 482.22    133.5, 485.51    154.4, 491.93
GR          168.9, 492.35
*
N           0.055        0.065        0.070
SA                 0.0          70.4
*
XS   FULLV      0  * * *   0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    479.32      15.0
GR            0.0, 478.40      0.3, 468.51      4.1, 468.32     10.9, 467.13
GR           15.5, 467.13     18.7, 466.32     24.9, 465.48     36.0, 465.15
GR           40.5, 465.24     44.1, 465.70     44.6, 480.25      0.0, 478.40
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      41.2 * *     51.8      9.4
N           0.050
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     15      27.9     1
GR         -388.7, 499.70   -217.1, 485.78   -159.8, 482.36    -76.8, 480.41
GR            0.0, 482.06     49.0, 483.91    194.7, 490.13    318.3, 495.36
*
XT   APTEM     80          0.
GR         -409.9, 502.19   -406.4, 500.08   -384.8, 499.77   -344.8, 491.87
GR         -316.2, 487.07   -251.8, 487.14   -173.9, 481.52   -140.9, 476.29
GR          -92.3, 474.63      0.0, 471.50      5.4, 468.32     11.9, 467.93
GR           19.0, 467.58     24.7, 466.49     28.7, 466.56     30.1, 466.90
GR           34.6, 467.06     39.6, 467.36     40.4, 468.02     47.0, 468.43
GR           51.0, 469.61     56.3, 472.58     56.7, 474.38     65.5, 482.55
GR           69.6, 480.71     73.2, 481.80     85.3, 482.26    109.9, 484.93
GR          126.5, 495.42
*
AS   APPRO     73 * * * 0.0239
GT
N           0.055       0.075       0.080
SA                  0.0        65.5
*
HP 1 BRIDG  473.00 1 473.00
HP 2 BRIDG  473.00 * * 2330
HP 1 APPRO  474.32 1 474.32
HP 2 APPRO  474.32 * * 2330
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File danv004.wsp
        Hydraulic analysis for structure DANVTH00010004   Date: 01-AUG-97
        Bridge #4 over Joes Brook in Danville, VT.  RHF

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      283     25339     43     54                         4139
   473.00           283     25339     43     54  1.00      0     44     4139


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

         WSEL     LEW     REW    AREA         K        Q    VEL
       473.00     0.2    44.4   283.2   25339.    2330.   8.23

X STA.         0.2        5.6        8.9       11.6       14.1       16.5
  A(I)            23.9       16.7       15.0       14.4       13.8
  V(I)            4.87       6.97       7.78       8.07       8.45

X STA.        16.5       18.7       20.6       22.4       24.1       25.8
  A(I)            13.4       12.7       12.3       12.1       11.7
  V(I)            8.71       9.17       9.47       9.63       9.98

X STA.        25.8       27.4       29.0       30.5       32.1       33.7
  A(I)            11.8       11.8       11.6       11.9       11.6
  V(I)            9.90       9.84      10.01       9.79      10.03

X STA.        33.7       35.3       37.0       38.8       40.8       44.4
  A(I)            12.4       12.7       13.5       15.0       24.9
  V(I)            9.38       9.21       8.66       7.77       4.68



    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      132      4656     88     88                          913
             2      356     23069     57     61                         5062
   474.32           488     27725    145    149  1.15    -87     57     4746

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

         WSEL     LEW     REW    AREA         K        Q    VEL
       474.32   -88.1    56.8   487.8   27725.    2330.   4.78

X STA.       -88.1      -31.8      -15.2       -3.6        4.5        8.1
  A(I)            53.7       36.4       30.8       30.1       21.9
  V(I)            2.17       3.20       3.78       3.87       5.31

X STA.         8.1       11.3       14.4       17.3       20.2       22.7
  A(I)            21.0       20.0       19.9       19.7       19.1
  V(I)            5.55       5.82       5.86       5.91       6.10

X STA.        22.7       25.1       27.4       29.8       32.3       34.9
  A(I)            18.3       18.6       18.6       19.2       19.1
  V(I)            6.38       6.27       6.27       6.07       6.11

X STA.        34.9       37.6       40.6       44.1       48.0       56.8
  A(I)            20.0       21.1       22.2       24.0       34.2
  V(I)            5.83       5.52       5.24       4.85       3.41
```

WSPRO OUTPUT FILE (continued)

```
      U.S. Geological Survey WSPRO Input File danv004.wsp
      Hydraulic analysis for structure DANVTH00010004   Date: 01-AUG-97
      Bridge #4 over Joes Brook in Danville, VT.  RHF

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      313     29509     43     56                         4818
 473.71           313     29509     43     56  1.00      0     44     4818

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     473.71     0.1    44.4   313.5   29509.    3250.  10.37

X STA.        0.1        5.5        8.6       11.3       13.7       16.1
  A(I)            27.1       17.8       16.7       15.4       15.1
  V(I)            5.99       9.15       9.75      10.53      10.73

X STA.       16.1       18.3       20.2       22.0       23.8       25.4
  A(I)            14.8       14.1       13.6       13.1       13.1
  V(I)           10.99      11.55      11.95      12.38      12.43

X STA.       25.4       27.0       28.6       30.2       31.8       33.4
  A(I)            12.9       13.0       12.8       13.0       13.1
  V(I)           12.57      12.50      12.73      12.46      12.45

X STA.       33.4       35.1       36.8       38.6       40.7       44.4
  A(I)            13.7       13.9       15.3       16.6       28.3
  V(I)           11.88      11.66      10.60       9.78       5.74


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      298     13866    132    132                         2538
           2      443     32418     58     63                         6927
 475.83           741     46284    191    195  1.13   -131     58     7810

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

       WSEL     LEW     REW    AREA        K        Q    VEL
     475.83  -132.3    58.4   741.3   46284.    3250.   4.38

X STA.     -132.3      -63.4      -43.3      -29.1      -17.9       -8.3
  A(I)            81.0       54.2       46.3       41.5       38.9
  V(I)            2.01       3.00       3.51       3.92       4.18

X STA.       -8.3        0.1        6.1       10.0       13.6       17.2
  A(I)            36.4       37.8       30.6       29.5       29.2
  V(I)            4.46       4.30       5.31       5.52       5.57

X STA.       17.2       20.5       23.6       26.5       29.4       32.6
  A(I)            28.1       28.1       27.2       27.5       28.4
  V(I)            5.77       5.77       5.96       5.90       5.73

X STA.       32.6       35.7       39.2       43.3       47.8       58.4
  A(I)            28.6       30.1       32.8       34.7       50.3
  V(I)            5.69       5.39       4.95       4.68       3.23
```

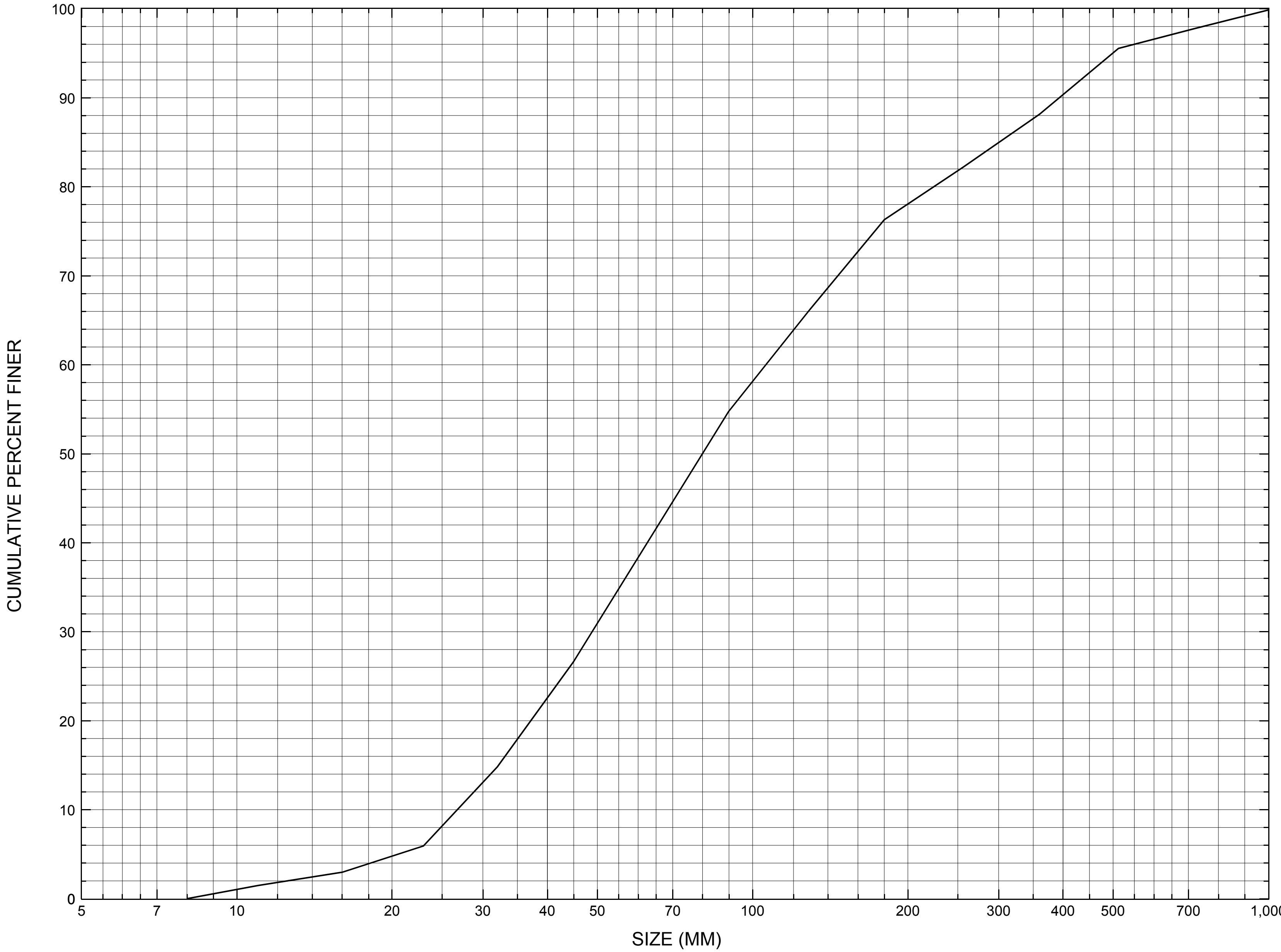
```
        U.S. Geological Survey WSPRO Input File danv004.wsp
        Hydraulic analysis for structure DANVTH00010004   Date: 01-AUG-97
        Bridge #4 over Joes Brook in Danville, VT.  RHF

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

 EXITX:XS   ******      1      267  1.19 *****  473.22  471.06    2330  472.04
       -48 ******     62    15963  1.00 ***** *******    0.74    8.73

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.47

 FULLV:FV       49    -47      365  0.69  0.71  473.93 *******    2330  473.25
         0      49     66    23453  1.08  0.00    0.00    0.66    6.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       73    -81      460  0.46  0.65  474.58 *******    2330  474.12
        73      73     57    25809  1.14  0.00   -0.01    0.53    5.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

 BRIDG:BR       49      0      283  1.05  0.82  474.05  470.89    2330  473.00
         0      49     44    25346  1.00  0.00   -0.01    0.56    8.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  479.32 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS       32    -87      488  0.41  0.33  474.73  471.86    2330  474.32
        73      34     57    27729  1.15  0.35    0.00    0.49    4.78

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.682  0.270   20249.    -2.    42.   474.00

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -49.     1.    62.   2330.   15963.     267.    8.73  472.04
   FULLV:FV       0.   -48.    66.   2330.   23453.     365.    6.39  473.25
   BRIDG:BR       0.     0.    44.   2330.   25346.     283.    8.23  473.00
   RDWAY:RG      15.**************      0.*****************     1.00********
   APPRO:AS      73.   -88.    57.   2330.   27729.     488.    4.78  474.32

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    42.   20249.

  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    471.06    0.74  465.90  492.35************  1.19  473.22  472.04
   FULLV:FV  ********    0.66  465.90  492.35  0.71  0.00  0.69  473.93  473.25
   BRIDG:BR    470.89    0.56  465.15  480.25  0.82  0.00  1.05  474.05  473.00
   RDWAY:RG  ****************  480.41  499.70********************************
   APPRO:AS    471.86    0.49  466.32  502.02  0.33  0.35  0.41  474.73  474.32
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File danv004.wsp
        Hydraulic analysis for structure DANVTH00010004   Date: 01-AUG-97
        Bridge #4 over Joes Brook in Danville, VT.  RHF

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

EXITX:XS   ******    -38      347  1.44 *****  474.53  472.11    3250  473.08
       -48 ******     65    22251  1.06 ***** *******    0.93    9.37

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.61

FULLV:FV       49    -70      534  0.66  0.65  475.17 *******    3250  474.51
         0     49     70    35810  1.15  0.00   -0.01    0.59    6.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       73   -115      638  0.46  0.56  475.72 *******    3250  475.26
        73     73     58    38451  1.14  0.00   -0.01    0.50    5.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       49      0      314  1.67  0.85  475.38  472.00    3250  473.71
         0     49     44    29526  1.00  0.01   -0.01    0.67   10.36

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  479.32 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       32   -131      742  0.34  0.29  476.17  473.09    3250  475.83
        73     35     58    46317  1.13  0.50    0.00    0.42    4.38

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.745  0.405   27518.    -5.    39.  475.61

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -49.   -39.    65.   3250.   22251.     347.    9.37  473.08
   FULLV:FV       0.   -71.    70.   3250.   35810.     534.    6.09  474.51
   BRIDG:BR       0.     0.    44.   3250.   29526.     314.   10.36  473.71
   RDWAY:RG      15.**************      0.******************    1.00********
   APPRO:AS      73.  -132.    58.   3250.   46317.     742.    4.38  475.83

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    39.   27518.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    472.11    0.93  465.90  492.35************  1.44  474.53  473.08
   FULLV:FV  ********    0.59  465.90  492.35  0.65  0.00  0.66  475.17  474.51
   BRIDG:BR    472.00    0.67  465.15  480.25  0.85  0.01  1.67  475.38  473.71
   RDWAY:RG  ****************  480.41  499.70**********************************
   APPRO:AS    473.09    0.42  466.32  502.02  0.29  0.50  0.34  476.17  475.83
  ER

  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure DANVTH00010004, in Danville, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number DANVTH00010004

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 17 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 17125

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

Waterway *(I - 6)* JOES BROOK

Road Name *(I - 7):* -

Route Number TH001

Vicinity *(I - 9)* 0.1 MI JCT TH 74 + TH 1

Topographic Map St. Johnsbury

Hydrologic Unit Code: 01080101

Latitude *(I - 16; nnnn.n)* 44227

Longitude *(i - 17; nnnnn.n)* 72056

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030300040303

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

Maximum span length *(I - 48; nnnn)* 0045

Year built *(I - 27; YYYY)* 1953

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 000300

Deck Width *(I - 52; nn.n)* 279

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 17

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

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 043.5

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

Vertical clearance from streambed (*nnn.n ft*) 012.5

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

Waterway of full opening (*nnn.n* ft^2) 544.0

Comments:

The structural inspection report of 8/30/93 indicates that the structure is a concrete T-beam type bridge. The abutment walls and wingwalls are concrete and have some minor cracks and spalls reported overall. A short section of the concrete footing is exposed at the surface on the right abutment. Some boulder stone fill was noted in front of and around the ends of the wingwalls. The report also indicates some boulder material along the banks, upstream and downstream of the bridge. The channel reportedly has scoured down approximately 3 to 4 feet along most of the base of the right abutment. The report also shows a sand and silt point bar extending along the left abutment wall.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: Gravel and boulders

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

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

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

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): -%

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: **Possibly a 3 to 4 feet drop in the channel elevation along the right abutment wall since the bridge was installed.**

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **42.477** mi^2

Lake/pond/swamp area **1.272** mi^2

Watershed storage *(ST)* **2.99** %

Bridge site elevation **837** ft

Headwater elevation **2500** ft

Main channel length **19.921** mi

10% channel length elevation **1152** ft

85% channel length elevation **2034** ft

Main channel slope *(S)* **59** 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)*: 04 / 1952

Project Number SAS 1/ 1949 Minimum channel bed elevation: 466.0

Low superstructure elevation: USLAB 478.52 DSLAB 478.52 USRAB 480.49 DSRAB 480.49

Benchmark location description:

BM#2: a spike in the root of a 24-inch elm tree located approximately 115 feet from the left abutment along the centerline of the roadway, on the left bank and approximately 20 feet in an upstream direction perpendicular to the roadway centerline on the side of the roadway, elevation 478.33

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: 460.0*

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? Y *If no, type ctrl-n bi* Number of borings taken: 5

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

Briefly describe material at foundation bottom elevation or around piles:

The right abutment is sealed into the underlying bedrock. The left abutment is set in a gravel material with some sand. The right abutment footing is "stepped" and sealed into the bedrock. The plans show step-like cuts made in the bedrock into which the concrete footing was poured. The bedrock extends along the bottom of the footing over the entire length of the right abutment and the length of the upstream wingwall. The downstream wingwall is set in a sand and fine gravel material.

Comments:

***The footing bottom elevation of the left and right abutments are 461.0 and 460.0, respectively. The footing at the upstream end of the right wingwall is shown at elevation 468.0 and steps down in two foot increments to elevation 460.0 at the roadway centerline where it remains at elevation 460.0 to the downstream end. Other points that are shown with elevations on the plans are: 1) The point on the top of the upstream right wingwall concrete on the streamward edge where the concrete slope changes from horizontal to downward, elevation 483.74, and 2) The point at the same location as in (1) but on the upstream left wingwall, elevation 481.73.**

Cross-sectional Data

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

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

Comments: **The upstream channel cross section is at stationing 0 + 92, at a distance of 8 feet from the center line of the roadway (deck). The channel baseline runs along the left bank at a skew of 83 degrees from the roadway centerline.**

Station	1.0	1.4	3.0	17.0	42.8	44.3	44.5				
Feature	LCL	BLB	footing edge	TD	footing edge	BRB	LCR				
Low chord elevation	478.5						480.5				
Bed elevation		466.5	*t463	465.9	*t468	468.0					
Low chord-bed			*b461		*b466						

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord-bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **Downstream channel cross section at stationing 1 + 10, at a distance of 10 feet from the centerline of the roadway (deck). *("t" and "b" indicate the top and bottom elevation of footing, respectively)**

Station	3.5	3.8	5.5	20.0	35.0	45.5	47.0	47.7			
Feature	LCL	BLB	footing edge			footing edge	BRB	LCR			
Low chord elevation	478.5							480.5			
Bed elevation		469.5	*t463	467.1	467.0	*t462	468.4				
Low chord-bed			*b461			*b460					

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord-bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **2/23/96**
Computerized by: **EW** Date: **2/26/96**
Reviewd by: **RF** Date: **8/19/97**

Structure Number **DANVTH00010004**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **08** / **22** / 19**95**

2. Highway District Number **07** Mile marker **-**
County **CALEDONIA 005** Town **DANVILLE 17125**
Waterway *(I - 6)* **JOE'S BROOK** Road Name **-**
Route Number **TH01** Hydrologic Unit Code: **01080101**

3. Descriptive comments:
LOCATED 0.1 MILE SOUTH OF THE INTERSECTION OF TH74 WITH TH01

B. Bridge Deck Observations

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

5. Ambient water surface... US **1** 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 **49.0** *(feet)* Span length **45.0** *(feet)* Bridge width **27.9** *(feet)*

Road approach to bridge:

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

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

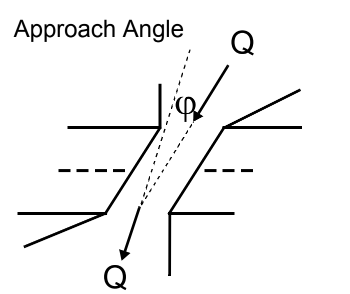
10. Embankment slope (*run / rise in feet / foot*):
US left **2.4:1** US right **-**

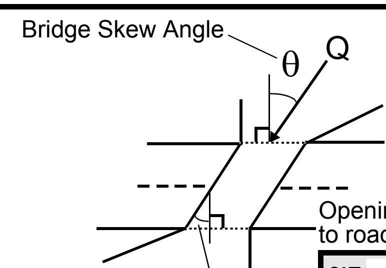
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	2	2
RBDS	0	-	0	0
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

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





Opening skew to roadway
α= **15.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **90** feet **US** *(US, UB, DS)* to **55** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **50** feet **DS** *(US, UB, DS)* to **105** feet **DS**

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

18. Bridge Type: **1A**

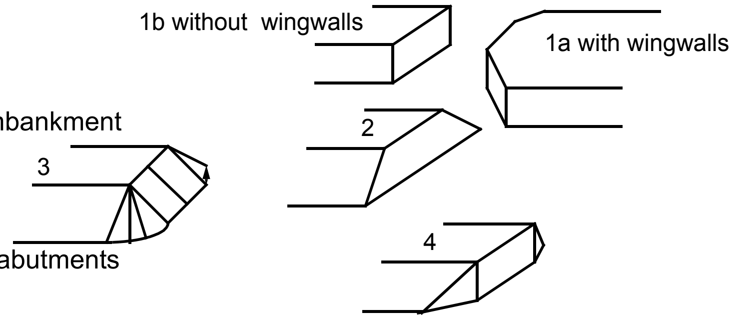
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

The embankment on road is sloped on LB side of US but near vertical on RB side US.

#4 The US and DS right banks are covered by forest for two bridge lengths.
The US left bank surface cover includes a horse corral with a strip of trees and shrubs along the immediate bank edge.
The DS left bank has a barn and a horse corral with trees along the bank.
Road overflow will occur over the left bank approach as the road dips down to the low chord elevation of the bridge.

#7 Values are from VTAOT files. Measured values: bridge length = 49.0 ft; span length = 46.0 ft; width= 27.9 ft.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
50.0	3.0			5.0	3	4	435	564	1	1

23. Bank width **30.0** 24. Channel width **15.0** 25. Thalweg depth **65.5** 29. Bed Material **546**

30 .Bank protection type: LB **0** RB **5** 31. Bank protection condition: LB **-** RB **1**

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

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

#27- Bedrock on the right bank grades into large boulders then cobble/gravel from 60 feet US to >200 feet US. LB material is fairly uniform.

#30- The RB protection is approximately 7 feet high from 35 feet US to the US face of the bridge. The material is quarried stone blocks carefully placed side by side and on top of each other to form a wall.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **30** 35. Mid-bar width: **18**

36. Point bar extent: **50** feet **US** (US, UB) to **50** feet **DS** (US, UB, DS) positioned **0** %LB to **25** %RB

37. Material: **435**

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

The side bar is discontinuous from the US to DS side and is composed of cobbles with gravel and some boulders. Under the bridge, the width of the side bar is 12 feet with a composition of sand and fine gravel. A second bar extends from about 230 feet US to 80 feet US. It is positioned 65% LB to 100% RB and is composed mainly of cobbles with gravel and a few boulders.

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

41. Mid-bank distance: **75** 42. Cut bank extent: **95** feet **US** (US, UB) to **65** feet **US** (US, UB, DS)

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

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

-

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **5.0**

47. Scour dimensions: Length **76** Width **15** Depth : **2.5** Position **50** %LB to **90** %RB

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

Bridge and bedrock constriction of flow along the right bank side of the channel with the thalweg scoured deeper here than at other locations in the channel. US and DS of bridge, the thalweg depth is between 0.5 to 1.0 feet.

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
42.0		**1.5**		**2**	**7**	**7**	**-**

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

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

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

435

The thalweg under the bridge is scoured out along RABUT side of channel for 40% of the channel width.

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

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

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

70. Debris and Ice Comments:

2

The banks and channel are stable, but there are a lot of trees on the banks. Debris and ice will most likely accumulate US at the cut bank where the stream bends along the right bank. However, debris and ice which have not accumulated at this point will be pushed under bridge and 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		-	90	0	0	0	0	90.0
RABUT	1	0	90			2	2	43.0

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

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

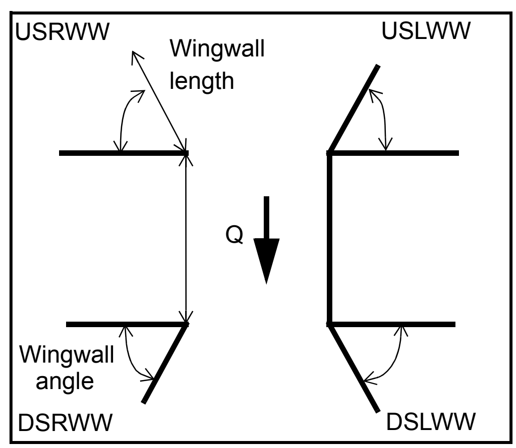
1.0
2.0
1

The RABUT footing is only exposed for 2.0 feet at the most upstream 4 ft of the footing. From 4 ft US to 10 ft US, the footing is exposed <0.5 feet above the streambed.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						43.0	
USRWW:	Y		1		0	2.0	
DSLWW:	0		0		Y	29.5	
DSRWW:	1		2		0	30.5	

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



82. **Bank / Bridge Protection**:

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

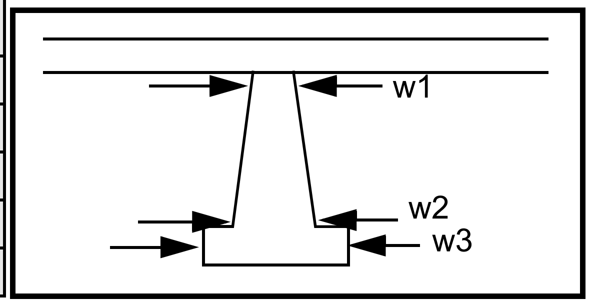
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
2
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				**45.0**	**17.5**	**60.0**
Pier 2				**12.5**	**60.0**	**16.0**
Pier 3			**-**	**30.0**	**23.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**ner of**	**end at**	**the**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**USR**	**the**	**this**	**USL**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**WW**	**RAB**	**point**	**WW**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**is**	**UT**	**due**	**may**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**expo**	**foot-**	**to**	**be**	*Y- yes; N- no*
91. Attack ∠ (BF)	**sed**	**ing.**	**the**	**cov-**	
92. Pushed	**for**	**The**	**stone**	**ered**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**2.5**	**foot-**	**fill.**	**by**	
95. Cross-members	**feet**	**ing**	**The**	**strea**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**from**	**appe**	**stone**	**m**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**the**	**ars**	**fill**	**depo**	
98. Exposure depth	**cor-**	**to**	**on**	**sits.**	

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

N

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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 3 Width 453 Depth: 453 Positioned 1 %LB to 1 %RB

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

435
0
0
-

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

Confluence 1: Distance e is Enters on wea (LB or RB) Type ther (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

ewhat rounded boulder size material on the right bank. The boulder size material is located primarily between 40 feet and 55 feet DS. Angular blocks of stone fill exist from DS end of DSRWW to about 40 feet DS.

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

-

109. G. Plan View Sketch

\- N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: DANVTH00010004 Town: Danville
Road Number: TH01 County: Caledonia
Stream: Joes Brook

Initials RHF Date: 8/15/97 Checked: EW

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	2330	3250	0
Main Channel Area, ft2	356	443	0
Left overbank area, ft2	132	298	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	57	58	0
Top width L overbank, ft	88	132	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.2628	0.2628	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.2	7.6	ERR
y1, average depth, LOB, ft	1.5	2.3	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	27725	46284	0
Conveyance, main channel	23069	32418	0
Conveyance, LOB	4656	13866	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1938.7	2276.3	ERR
Ql, discharge, LOB, cfs	391.3	973.7	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	5.4	5.1	ERR
Vl, mean velocity, LOB, ft/s	3.0	3.3	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.7	10.1	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2330	3250	N/A
Main channel area (DS), ft2	283	313	0

Main channel width (normal), ft	42.7	42.8	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	42.7	42.8	0.0
D90, ft	1.2898	1.2898	0.0000
D95, ft	1.6360	1.6360	0.0000
Dc, critical grain size, ft	0.3990	0.6055	ERR
Pc, Decimal percent coarser than Dc	0.357	0.233	0.000
Depth to armoring, ft	2.16	5.99	ERR

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2330	3250	0
(Q) discharge thru bridge, cfs	2330	3250	0
Main channel conveyance	25339	29509	0
Total conveyance	25339	29509	0
Q2, bridge MC discharge,cfs	2330	3250	ERR
Main channel area, ft2	283	313	0
Main channel width (normal), ft	42.7	42.8	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.7	42.8	0
y_bridge (avg. depth at br.), ft	6.63	7.31	ERR
Dm, median (1.25*D50), ft	0.3285	0.3285	0
y2, depth in contraction,ft	5.24	6.96	ERR
ys, scour depth (y2-ybridge), ft	-1.39	-0.35	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2330	3250	0	2330	3250	0
a', abut.length blocking flow, ft	89.1	133.2	0	13.2	14.8	0
Ae, area of blocked flow ft2	137.8	303	0	61.1	82.3	0
Qe, discharge blocked abut.,cfs	414.9	995.3	0	248	312.4	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.01	3.28	ERR	4.06	3.80	ERR
ya, depth of f/p flow, ft	1.55	2.27	ERR	4.63	5.56	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	N/A	0.82	0.82	N/A
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	N/A	105	105	N/A
K2	0.98	0.98	N/A	1.02	1.02	N/A

Fr, froude number f/p flow	0.427	0.384	ERR	0.332	0.284	ERR
ys, scour depth, ft	11.10	15.54	N/A	11.68	13.02	N/A

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)	89.1	133.2	N/A	13.2	14.8	N/A
y1 (depth f/p flow, ft)	1.55	2.27	ERR	4.63	5.56	ERR
a'/y1	57.61	58.56	ERR	2.85	2.66	ERR
Skew correction (p. 49, fig. 16)	0.95	0.95	N/A	1.03	1.03	N/A
Froude no. f/p flow	0.43	0.38	N/A	0.33	0.28	N/A
Ys w/ corr. factor K1/0.55:						
vertical	8.07	11.46	ERR	ERR	ERR	ERR
vertical w/ ww's	6.62	9.40	ERR	ERR	ERR	ERR
spill-through	4.44	6.30	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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.56	0.67	N/A	0.56	0.67	N/A
y, depth of flow in bridge, ft	6.63	7.33	N/A	6.63	7.33	N/A
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.29	2.03	0.00	1.29	2.03	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.12	1.77	0.00	1.12	1.77	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR