LEVEL II SCOUR ANALYSIS FOR BRIDGE 86 (VERNVT01420086) on STATE ROUTE 142, crossing BROAD BROOK, VERNON, VERMONT

U.S. Geological Survey
Open-File Report 97-363

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 86 (VERNVT01420086) ON STATE ROUTE 142, CROSSING BROAD BROOK, VERNON, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure VERNVT01420086 on State Route 142 crossing Broad Brook, Vernon, 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 southeastern Vermont. The 23.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is primarily forest with the exception of the downstream left bank which is a wetland.

In the study area, Broad Brook has an incised, meandering channel with a slope of approximately 0.001 ft/ft, an average channel top width of 132 ft and an average bank height of 3 ft. The channel bed material ranges from silt to cobbles with a median grain size (D_{50}) of 80.0 mm (0.262 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 14, 1996, indicated that the reach was vertically and laterally unstable.

The State Route 142 crossing of Broad Brook is a 98-ft-long, two-lane bridge consisting of two steel-beam spans with a maximum span length of 47 feet (Vermont Agency of Transportation, written communication, March 30, 1995). The bridge is supported by vertical, concrete abutments with spill-through slopes and a concrete pier. The channel is skewed approximately 30 degrees to the opening while there is no opening-skew-to-roadway.

A scour hole 2 ft deeper than the mean thalweg depth was observed along the left bank side of the pier during the Level I assessment. There was also a scour hole 1 ft deeper than the mean thalweg depth observed along the length of the right abutment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the entire base length of the spill-through slopes. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

There was no computed contraction scour for any modelled flows. Scour at the left abutment ranged from 13.2 to 15.9 ft and at the right abutment ranged from 12.0 to 16.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 12.0 to 16.3 ft. The worst-case pier 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.

Brattleboro, VT. Quadrangle, 1:25,000, 1984

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 VERNVT01420086 ***Stream*** Broad Brook

County Windham ***Road*** VT 142 ***District*** 2

Description of Bridge

Bridge length 98 ***ft*** ***Bridge width*** 24.5 ***ft*** ***Max span length*** 47 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 08/14/96

Description of stone fill Type-2, along the entire base length of the left and right spill-through slopes.

Brief description of piers/abutments Vertical abutment walls and pier are concrete with stone spill-through slopes along the banks. There is a 2 feet deep scour hole along the left bank side of the pier and along the entire base length of the spill-through slopes.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 30

There is a moderate channel bend in the US and DS reach. A scour hole has developed in the location where the bend impacts the US LB and DS RB extending through the bridge.

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	08/14/96	0	0
Level II	08/14/96	0	0

Potential for debris High. There are cut banks and trees leaning over the channel upstream. Also debris at the pier and at the upstream end of the US RB point bar.

Describe any features near or at the bridge that may affect flow (include observation date) The upstream right bank point bar directs flow along the left bank through the bridge resulting in a significant scour hole as of 08/14/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with wide flood plains and steep valley walls on both sides.

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

Date of inspection 08/14/96

DS left: Wide flood plain.

DS right: Moderately sloped bank to a wide flood plain.

US left: Moderately sloped bank to a wide flood plain.

US right: Wide flood plain.

Description of the Channel

Average top width 132 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Gravel ***Bank material*** Organics to Cobbles

Meandering with semi-alluvial channel boundaries and a wide flood plain.

08/14/96

Vegetative co Brush and wetland.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: No

Do banks appear stable? The channel is meandering, forming cut-banks and channel scour both upstream and downstream.

date of observation.

The assessment of 08/14/96 noted flow conditions are influenced by a vegetated point bar on the right bank side of the upstream channel. In addition, some debris is caught on the point bar and pier in the upstream channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 23.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,170 ***ft³/s*** ***Q500*** 6,100 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(19.8/23.7)exp 0.7] with bridge number 5 in Guilford. Bridge number 5 crosses Broad Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 5 is 19.8 square miles. These values are within a range defined by several empirical flood frequency curves (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 278.7 feet from the USGS arbitrary survey datum to obtain the National Geodetic Vertical Datum of 1929.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X within a chiseled square on top of the US end of the left abutment (elev. 509.11 ft, arbitrary survey datum). RM2 is a nail hole in the center of a chiseled X within a chiseled square on top of the DS end of the right abutment (elev. 510.09 ft, arbitrary survey datum). RM3 is a U.S. Coast and Geodetic Survey brass disk on the US end of the left abutment of the DS railroad bridge (elev. 506.52 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT3	-914	2	Downstream rail road bridge exit section at mouth of brook (Templated from EXTEM)
FULV1	-857	1	Downstream rail road bridge full-valley section (Templated from EXIT3)
DSBRG	-857	1	Downstream rail road bridge section
RRWAY	-850	1	Railroad grade section
EXIT2	-759	2	Modelled downstream rail road bridge approach section (Templated from EXTEM)
EXTEM	-571	1	Downstream railroad bridge approach section as surveyed (Used as a template)
EXITX	-81	1	Bridge exit section
FULLV	0	2	Downstream full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road grade section
APPRO	119	2	Modelled approach section (Templated from APTEM)
ATEMP	155	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.

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 0.030 to 0.060, and overbank "n" values ranged from 0.060 to 0.080.

The water-surface elevation during the survey on August 14, 1996 was used as the starting water surface for the model at the section located at the mouth of Broad Brook (EXIT3). This elevation was the ambient backwater from Vernon dam on the Connecticut River. Although this water-surface elevation may not occur during a large flood event on Broad Brook, the extent of backwater from the Connecticut River while Broad Brook may be at peak flow is unknown. The method used follows the guidelines in HEC-18 (Richardson and others, 1995, p 26), which recommends using the lowest potential downstream water-surface elevation for scour analyses.

The surveyed approach section (ATEMP) was moved along the approach channel slope (0.0006 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 509.4 *ft*
Average low steel elevation 506.6 *ft*

100-year discharge 4,170 *ft³/s*
Water-surface elevation in bridge opening 502.2 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 482 *ft²*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 11.0 *ft/s*

Water-surface elevation at Approach section with bridge 504.1
Water-surface elevation at Approach section without bridge 503.3
Amount of backwater caused by bridge 0.8 *ft*

500-year discharge 6,100 *ft³/s*
Water-surface elevation in bridge opening 506.7 *ft*
Road overtopping? Yes *Discharge over road* 125 *ft³/s*
Area of flow in bridge opening 777 *ft²*
Average velocity in bridge opening 7.1 *ft/s*
Maximum WSPRO tube velocity at bridge 10.1 */s*

Water-surface elevation at Approach section with bridge 507.9
Water-surface elevation at Approach section without bridge 505.8
Amount of backwater caused by bridge 2.1

Incipient overtopping discharge 6,070 *ft³/s*
Water-surface elevation in bridge opening 504.6 *ft*
Area of flow in bridge opening 673 *ft²*
Average velocity in bridge opening 9.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.6 *ft/s*

Water-surface elevation at Approach section with bridge 506.8
Water-surface elevation at Approach section without bridge 505.6
Amount of backwater caused by bridge 1.2 *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 for the 100-year and incipient road-overflow model was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). 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). Thus, contraction scour for the 500-year discharge was computed using the Chang equation (Richardson and others, 1995, p. 145-146). The results of Laursen's clear water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in Appendix F. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment and extended to the vertical concrete abutment wall.

Pier scour was computed by use of the Colorado State University pier scour equation (Richardson and others, 1995, p. 36, equation 21). Variables for the Colorado State University pier scour equation include the Froude number and depth of the flow approaching the pier, pier width, and correction factors for the pier nose shape, angle of attack of flow, bed condition, and armoring by bed material. Pier scour results for both the 100-year and incipient roadway-overtopping discharges were less than the reults for the 500-year discharge. Thus, the pier scour for the 500-year event does not appear in figure 8.

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	0.0
Depth to armoring	1.1	0.2	1.0
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	13.2	15.9	13.7
Right abutment	9.3	13.1	11.6
Pier scour			
Pier 1	15.1	12.0	16.3
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:			
Left abutment	2.2	1.5	3.0
Right abutment	2.2	1.5	3.0
Piers:			
Pier 1	2.3	1.6	2.6
Pier 2	--	--	--
	--	--	--

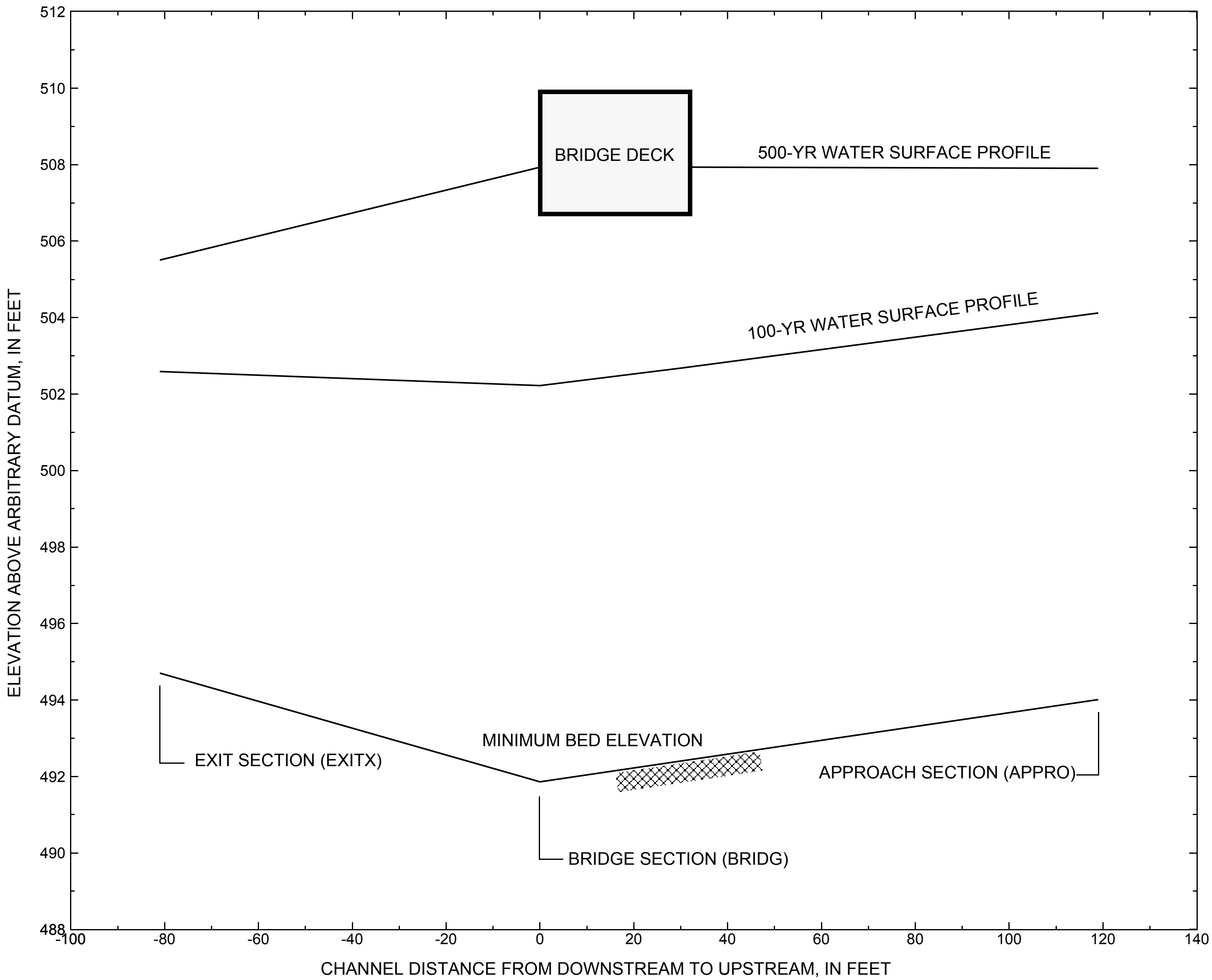

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure VERNVT01420086 on State Route 142, crossing Broad Brook, Vernon, Vermont.

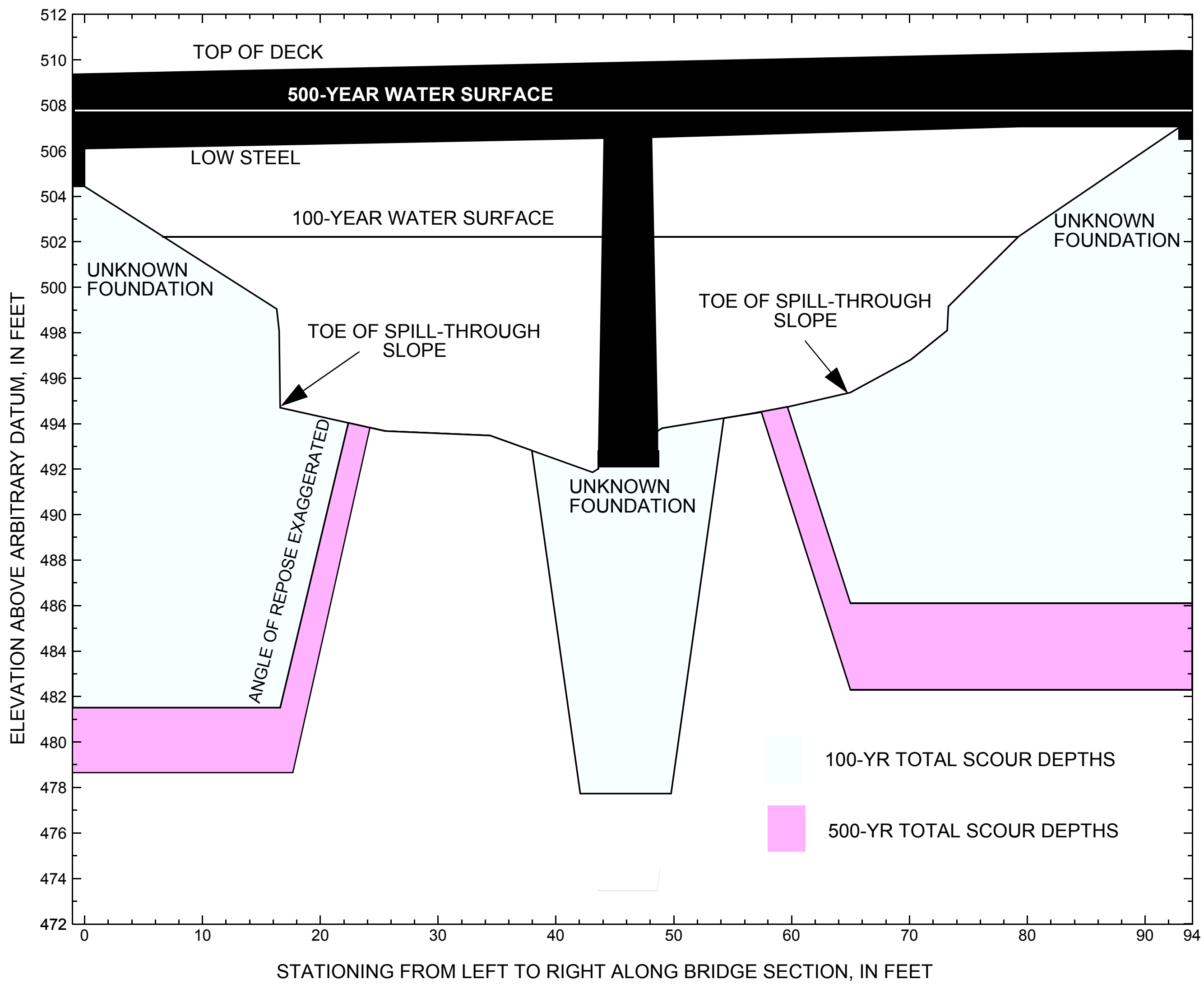

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure VERNVT01420086 on State Route 142, crossing Broad Brook, Vernon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure VERNVT01420086 on State Route 142, crossing Broad Brook, Vernon, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 4,170 cubic-feet per second											
Left abutment	0.0	--	506.1	--	504.4	0.0	--	--	--	--	--
Toe of spill-through slope	16.6	--	--	--	494.7	0.0	13.2	--	13.2	481.5	--
Pier	46.1	--	--	--	492.8	0.0	--	15.1	15.1	477.7	--
Toe of spill-through slope	65.0	--	--	--	495.4	0.0	9.3	--	9.3	486.1	--
Right abutment	93.0	--	507.1	--	507.1	0.0	--	--	--	--	--

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 VERNVT01420086 on State Route 142, crossing Broad Brook, Vernon, 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 6,100 cubic-feet per second											
Left abutment	0.0	--	506.1	--	504.4	0.0	--	--	--	--	--
Toe of spill-through slope	16.6	--	--	--	494.7	0.0	15.9	--	15.9	478.8	--
Pier	46.1	--	--	--	492.8	0.0	--	12.0	12.0	480.8	--
Toe of spill-through slope	65.0	--	--	--	495.4	0.0	13.1	--	13.1	482.3	--
Right abutment	93.0	--	507.1	--	507.1	0.0	--	--	--	--	--

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, 1984, Brattleboro, 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 vern086a.wsp
T2        Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
T3        Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4170.0   6100.0   6070.0
WS          498.33   498.33   498.33
*
XS   EXIT3   -914
GR         -147.2, 511.76   -134.4, 501.94    -29.5, 500.52    -21.7, 498.31
GR          -11.8, 496.14      0.0, 494.98     22.5, 493.49     39.6, 493.44
GR           57.9, 493.32     64.4, 496.12     79.9, 496.04    111.3, 496.55
GR          141.6, 495.66    192.8, 496.35    238.7, 496.11    260.2, 495.55
GR          268.0, 497.79    268.2, 498.35    277.0, 502.01    322.5, 502.38
GR          325.0, 510.00
N           0.080        0.045        0.060
SA                 -29.5        277.0
*
XS   FULV1   -857 * * * 0.00
*
*             SRD     LSEL    XSSKEW
BR   DSBRG   -857    502.66       0.0
GR            0.0, 502.66      0.0, 490.62      2.8, 490.30      6.3, 491.37
GR           16.6, 491.63     25.2, 491.85     33.6, 491.23     41.1, 492.30
GR           50.4, 494.02     57.1, 494.30     57.1, 498.43     57.3, 502.66
GR            0.0, 502.66
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      41.2     0.5     507.6     37.2
N           0.030
*
XR   RRWAY   -850  41.2  2
GR         -184.6, 507.51   -124.6, 507.61      0.0, 507.67     57.3, 507.59
GR          280.7, 507.51    463.2, 507.60    643.1, 507.67
*
XT   EXTEM   -571
GR         -147.2, 511.76   -134.4, 501.94    -29.5, 500.52    -21.7, 498.31
GR          -11.8, 496.14      0.0, 494.98     22.5, 493.49     39.6, 493.44
GR           57.9, 493.32     64.4, 496.12     79.9, 496.04    111.3, 496.55
GR          141.6, 495.66    192.8, 496.35    238.7, 496.11    260.2, 495.55
GR          268.0, 497.79    268.2, 498.35    277.0, 502.01    322.5, 502.38
GR          325.0, 510.00
*
AS   EXIT2   -759
GT         -0.04
N           0.080        0.045        0.060
SA                 -29.5        277.0
*
XS   EXITX   -81
GR         -137.1, 511.85   -116.9, 508.45   -113.7, 508.22   -112.4, 508.05
GR         -107.4, 507.79    -85.2, 499.79    -76.9, 498.01    -60.7, 499.17
GR          -41.0, 499.74    -33.7, 498.13    -29.8, 496.93      0.0, 498.04
GR           26.9, 497.11     54.0, 495.94     67.4, 494.70     76.2, 494.70
GR           80.7, 496.14     81.1, 498.14     84.9, 501.39    101.2, 502.75
GR          124.5, 512.97
N           0.060        0.060        0.065
```

```
SA                 -41.0        84.9
*
XS   FULLV    0 * * * 0.0004
*
*
*
*
*
*
*             SRD     LSEL    XSSKEW
BR   BRIDG    0    506.59       0.0
GR             0.0, 506.10      0.0, 504.44     16.3, 499.05     16.5, 498.08
GR            16.6, 494.71     25.5, 493.68     34.4, 493.48     43.1, 491.86
GR            49.0, 493.80     58.6, 494.61     65.0, 495.37     70.1, 496.81
GR            73.2, 498.10     73.3, 499.15     79.3, 502.24     93.0, 507.07
GR            93.0, 507.07      0.0, 506.10
*
PW           492.80,5  506.5,4
*
*          BRTYPE  BRWDTH    EMBSS   EMBELV
CD            3      25.6      2.3    509.9
N            0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY   13       24.5     1
GR          -137.1, 511.85   -116.9, 507.45    -53.7, 507.22      0.0, 509.38
GR             0.4, 510.27     46.7, 511.07     93.1, 511.20     93.4, 510.41
GR           200.7, 511.59    304.2, 511.75
*
XT   ATEMP   155
GR          -137.1, 511.85   -116.9, 507.45    -53.7, 507.22    -30.6, 504.98
GR           -21.6, 501.10     -4.1, 501.52      0.0, 498.01      0.0, 496.87
GR             4.3, 495.72     13.3, 494.03     25.0, 495.01     32.4, 496.64
GR            41.5, 496.53     47.2, 497.49     48.2, 498.01     51.2, 499.28
GR            77.9, 499.61     99.3, 498.56    121.9, 498.42    133.4, 501.10
GR           159.9, 501.70    235.7, 506.34    249.4, 506.72    259.5, 511.71
*
AS   APPRO   119
GT           -0.02
N            0.070        0.050        0.070
SA                  -4.1        133.4
*
HP 1 BRIDG   502.22 1 502.22
HP 2 BRIDG   502.22 * * 4170
HP 2 BRIDG   502.46 * * 4170
HP 1 APPRO   504.12 1 504.12
HP 2 APPRO   504.12 * * 4170
*
HP 1 BRIDG   506.66 1 506.66
HP 2 BRIDG   506.66 * * 5936
HP 2 BRIDG   507.07 * * 5936
HP 2 RDWAY   507.88 * * 125
HP 1 APPRO   507.90 1 507.90
HP 2 APPRO   507.90 * * 6100
*
HP 1 BRIDG   504.62 1 504.62
HP 2 BRIDG   504.62 * * 6070
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File vern086a.wsp
      Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
      Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
         *** RUN DATE & TIME: 03-14-97  10:50
  CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     482.   52911.    73.    80.                         7052.
 502.22          482.   52911.    73.    80.  1.00     7.    79.   7052.

  VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.22     6.7    79.3   482.1   52911.    4170.   8.65

X STA.        6.7       20.5       23.8       26.7       29.3       31.8
  A(I)           46.3       27.5       24.3       22.4       22.0
  V(I)           4.50       7.58       8.59       9.29       9.46

X STA.       31.8       34.3       36.6       38.7       40.7       42.6
  A(I)           21.2       20.3       20.3       19.4       18.9
  V(I)           9.82      10.26      10.27      10.73      11.02

X STA.       42.6       44.5       46.6       48.9       51.4       54.0
  A(I)           19.3       19.9       20.4       20.9       21.3
  V(I)          10.82      10.48      10.23      10.00       9.77

X STA.       54.0       56.9       59.8       63.2       67.2       79.3
  A(I)           22.4       22.6       24.5       27.2       41.0
  V(I)           9.32       9.24       8.49       7.67       5.09

  VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.46     6.0    79.9   499.6   55487.    4170.   8.35

X STA.        6.0       20.2       23.7       26.6       29.3       31.8
  A(I)           47.3       29.4       25.8       23.2       22.3
  V(I)           4.41       7.10       8.07       8.99       9.35

X STA.       31.8       34.2       36.5       38.7       40.7       42.6
  A(I)           22.0       21.1       20.6       20.3       19.8
  V(I)           9.46       9.90      10.14      10.25      10.52

X STA.       42.6       44.5       46.6       49.0       51.5       54.2
  A(I)           19.9       20.6       21.1       21.2       22.5
  V(I)          10.47      10.14       9.89       9.81       9.25

X STA.       54.2       57.0       59.9       63.3       67.4       79.9
  A(I)           22.7       23.4       25.4       28.2       42.9
  V(I)           9.19       8.93       8.20       7.40       4.86

  CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     119.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1      60.    2294.    25.    25.                          535.
           2     853.   84289.   138.   141.                        12056.
           3     121.    3854.    66.    66.                          930.
 504.12         1034.   90436.   228.   233.  1.20   -29.   200.  11398.

  VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     119.

       WSEL     LEW     REW    AREA        K        Q    VEL
     504.12   -28.7   199.8  1034.5   90436.    4170.   4.03

X STA.      -28.7        1.9        6.8       10.8       14.5       18.0
  A(I)           92.4       41.1       37.3       36.5       34.9
  V(I)           2.26       5.07       5.59       5.71       5.97

X STA.       18.0       21.7       25.7       30.3       35.7       41.2
  A(I)           35.4       36.4       38.9       41.4       41.2
  V(I)           5.89       5.73       5.36       5.04       5.06

X STA.       41.2       47.3       58.1       70.5       82.8       93.4
  A(I)           43.5       55.8       58.1       57.0       53.4
  V(I)           4.79       3.74       3.59       3.66       3.90

X STA.       93.4      102.3      111.0      119.6      130.4      199.8
  A(I)           48.5       49.1       48.7       53.4      131.5
  V(I)           4.30       4.25       4.28       3.90       1.59
```

```
        U.S. Geological Survey WSPRO Input File vern086a.wsp
        Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
        Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
           *** RUN DATE & TIME: 03-14-97  10:50
    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     839.   85474.    38.   156.                       22343.
   506.66          839.   85474.    38.   156.  1.00     0.    92.  22343.
    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.66     0.0    91.8   839.4   85474.    5936.   7.07
 X STA.         0.0       17.6       22.0       25.9       29.3       32.7
   A(I)             86.2       53.4       48.5       43.8       43.1
   V(I)             3.44       5.56       6.13       6.77       6.88

 X STA.        32.7       35.9       38.8       41.6       44.1       46.9
   A(I)             41.8       39.4       39.0       37.2       37.9
   V(I)             7.10       7.52       7.60       7.99       7.83

 X STA.        46.9       49.8       52.9       55.5       57.9       60.4
   A(I)             39.0       38.9       31.8       29.5       29.8
   V(I)             7.62       7.62       9.33      10.06       9.97

 X STA.        60.4       63.0       65.9       69.1       73.6       91.8
   A(I)             31.0       32.0       34.0       41.5       61.5
   V(I)             9.57       9.28       8.73       7.15       4.82
    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       507.07     0.0    93.0   847.2   74390.    5936.   7.01
 X STA.         0.0       16.7       20.7       24.1       27.2       30.0
   A(I)             76.6       47.1       41.5       39.0       36.1
   V(I)             3.88       6.30       7.16       7.61       8.23

 X STA.        30.0       32.8       35.6       38.1       40.5       42.9
   A(I)             36.3       35.8       34.6       33.6       33.6
   V(I)             8.18       8.30       8.59       8.84       8.83

 X STA.        42.9       45.2       47.8       50.5       53.4       56.5
   A(I)             33.7       35.0       35.5       36.4       37.4
   V(I)             8.81       8.47       8.36       8.16       7.93

 X STA.        56.5       59.7       63.1       67.0       72.0       93.0
   A(I)             39.0       40.0       44.9       50.8       80.5
   V(I)             7.60       7.41       6.62       5.85       3.69
    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      13.
         WSEL     LEW     REW    AREA        K        Q    VEL
       507.88  -118.9   -37.3    40.3     638.     125.   3.10
 X STA.      -118.9     -112.1     -107.4     -102.8      -98.5      -94.4
   A(I)              2.5        2.2        2.2        2.1        2.1
   V(I)             2.47       2.90       2.89       2.97       3.01

 X STA.       -94.4      -90.6      -86.8      -83.3      -79.9      -76.6
   A(I)              2.0        2.0        1.9        1.9        1.9
   V(I)             3.15       3.16       3.24       3.27       3.30

 X STA.       -76.6      -73.4      -70.3      -67.3      -64.4      -61.5
   A(I)              1.8        1.9        1.8        1.8        1.8
   V(I)             3.40       3.33       3.47       3.49       3.46

 X STA.       -61.5      -58.7      -55.9      -53.1      -49.4      -37.3
   A(I)              1.8        1.8        1.8        2.1        3.0
   V(I)             3.52       3.41       3.48       2.99       2.12
    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     119.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     239.    8247.   115.   116.                        1957.
             2    1373.  186284.   138.   141.                       24613.
             3     489.   26715.   118.   119.                        5637.
   507.90         2101.  221247.   371.   376.  1.43  -119.   252.  23689.
    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     119.
         WSEL     LEW     REW    AREA        K        Q    VEL
       507.90  -119.1   251.8  2100.8  221247.    6100.   2.90
 X STA.      -119.1       -0.3        6.7       12.1       17.0       22.1
   A(I)            269.6       83.0       70.7       67.3       68.0
   V(I)             1.13       3.67       4.31       4.53       4.48

 X STA.        22.1       27.5       33.9       40.4       47.4       57.7
   A(I)             69.7       74.5       73.8       77.1       91.6
   V(I)             4.38       4.10       4.13       3.96       3.33

 X STA.        57.7       68.4       79.4       89.6       98.9      107.9
   A(I)             90.5       92.0       88.1       85.0       84.7
   V(I)             3.37       3.31       3.46       3.59       3.60

 X STA.       107.9      116.7      126.0      143.0      171.4      251.8
   A(I)             82.6       86.7      121.2      176.0      248.4
   V(I)             3.69       3.52       2.52       1.73       1.23
```

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       U.S. Geological Survey WSPRO Input File vern086a.wsp
       Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
       Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
          *** RUN DATE & TIME: 03-14-97  10:50
    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     673.  82579.    86.    94.                       10679.
   504.62          673.  82579.    86.    94.  1.00     0.    86.  10679.


    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      504.62     0.0    86.1   673.0   82579.    6070.   9.02

X STA.        0.0       18.4       22.2       25.4       28.2       30.9
  A(I)           66.4       39.3       34.5       31.2       30.0
  V(I)           4.57       7.72       8.80       9.73      10.12

X STA.       30.9       33.5       36.0       38.4       40.6       42.7
  A(I)           28.6       28.3       27.4       27.0       26.2
  V(I)          10.62      10.74      11.07      11.23      11.57

X STA.       42.7       44.8       47.1       49.7       52.3       55.1
  A(I)           26.7       26.8       28.2       27.9       29.2
  V(I)          11.37      11.32      10.76      10.88      10.38

X STA.       55.1       58.1       61.3       64.8       69.3       86.1
  A(I)           30.6       31.5       33.6       38.7       60.8
  V(I)           9.92       9.62       9.04       7.84       4.99

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      504.80     0.0    86.6   688.5   85346.    6070.   8.82

X STA.        0.0       18.2       22.0       25.2       28.1       30.8
  A(I)           67.9       40.2       35.2       31.9       30.7
  V(I)           4.47       7.55       8.61       9.51       9.90

X STA.       30.8       33.4       36.0       38.3       40.5       42.7
  A(I)           29.2       28.9       28.0       27.2       27.2
  V(I)          10.39      10.51      10.85      11.18      11.16

X STA.       42.7       44.8       47.1       49.7       52.3       55.1
  A(I)           26.8       27.8       28.8       28.5       29.9
  V(I)          11.32      10.91      10.53      10.64      10.15

X STA.       55.1       58.2       61.4       64.9       69.4       86.6
  A(I)           31.3       32.3       34.4       39.6       62.8
  V(I)           9.70       9.40       8.83       7.67       4.83

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     119.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     146.    6699.    45.    46.                        1487.
             2    1215.  151913.   138.   141.                       20485.
             3     354.   15832.   116.   116.                        3508.
   506.75         1714.  174444.   299.   303.  1.34   -49.   250.  20130.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     119.

        WSEL     LEW     REW    AREA        K        Q    VEL
      506.75   -49.1   249.5  1714.3  174444.    6070.   3.54

X STA.      -49.1       -0.8        6.1       11.3       15.8       20.5
  A(I)          167.6       72.3       60.9       57.3       58.3
  V(I)           1.81       4.20       4.99       5.30       5.21

X STA.       20.5       25.3       30.8       37.1       43.3       51.4
  A(I)           57.5       60.8       63.8       63.6       71.8
  V(I)           5.28       4.99       4.76       4.77       4.23

X STA.       51.4       62.2       73.1       84.1       93.8      102.9
  A(I)           80.5       79.0       79.7       75.4       73.6
  V(I)           3.77       3.84       3.81       4.03       4.12

X STA.      102.9      111.6      120.2      130.7      156.6      249.5
  A(I)           71.9       71.5       78.9      141.6      228.4
  V(I)           4.22       4.24       3.85       2.14       1.33
```

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        U.S. Geological Survey WSPRO Input File vern086a.wsp
        Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
        Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
           *** RUN DATE & TIME: 03-14-97  10:50

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

EXIT3:XS   ******   -22.     781.  0.44 *****  498.77  497.49   4170.  498.33
     -914. ******   268.   49912.  1.00 ***** *******    0.57    5.34

FULV1:FV      57.   -23.     907.  0.33  0.31  499.09 *******   4170.  498.76
     -857.    57.   269.   63576.  1.00  0.00    0.00    0.46    4.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

EXIT2:AS      98.   -25.    1042.  0.25  0.34  499.43 *******   4170.  499.18
     -759.    98.   270.   79655.  1.00  0.00    0.00    0.38    4.00
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "DSBRG"     Q,CRWS =    4170.     497.56

            <<<<<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

DSBRG:BR      57.     0.     314.  3.70 *****  501.27  497.56   4170.  497.56
     -857.    57.    57.   43284.  1.35 ***** *******    1.16   13.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.861 ******  502.66 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RRWAY:RG    -850.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

EXIT2:AS      57.  -127.    1894.  0.08  0.20  501.87  497.45   4170.  501.79
     -759.    84.   277.  199432.  1.06  0.41    0.00    0.18    2.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.807  0.815   36860.    54.   111.   501.77

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

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "EXITX"     KRATIO =  0.32

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

EXITX:XS     678.   -93.     886.  0.36  0.92  502.95 *******   4170.  502.59
      -81.   678.    99.   63909.  1.06  0.14    0.01    0.40    4.71

FULLV:FV      81.   -94.     950.  0.32  0.31  503.27 *******   4170.  502.95
        0.    81.   102.   70961.  1.06  0.00    0.00    0.36    4.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     119.   -27.     856.  0.43  0.42  503.74 *******   4170.  503.31
      119.   119.   187.   69947.  1.16  0.06    0.00    0.46    4.87
         <<<<<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      81.     7.     482.  1.59  0.42  503.82  500.30   4170.  502.22
        0.    81.    79.   52960.  1.37  0.45   -0.01    0.69    8.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.854  0.091  506.59 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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      93.   -29.    1034.  0.30  0.37  504.42  500.96   4170.  504.12
      119.   100.   200.   90334.  1.20  0.24    0.02    0.37    4.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.640  0.370   56617.     2.    75.   503.91
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File vern086a.wsp
       Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
       Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
          *** RUN DATE & TIME: 03-14-97  10:50
 FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXIT3:XS    -914.   -22.   268.   4170.   49912.     781.    5.34  498.33
  FULV1:FV    -857.   -23.   269.   4170.   63576.     907.    4.60  498.76
  DSBRG:BR    -857.     0.    57.   4170.   43284.     314.   13.29  497.56
  RRWAY:RG    -850.**************      0.******************    2.00********
  EXIT2:AS    -759.  -127.   277.   4170.  199432.    1894.    2.20  501.79

   XSID:CODE   XLKQ   XRKQ       KQ
  EXIT2:AS      54.   111.   36860.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXITX:XS     -81.   -93.    99.   4170.   63909.     886.    4.71  502.59
  FULLV:FV       0.   -94.   102.   4170.   70961.     950.    4.39  502.95
  BRIDG:BR       0.     7.    79.   4170.   52960.     482.    8.64  502.22
  RDWAY:RG      13.**************      0.******************    1.00********
  APPRO:AS     119.   -29.   200.   4170.   90334.    1034.    4.03  504.12

   XSID:CODE   XLKQ   XRKQ       KQ
  APPRO:AS       2.    75.   56617.

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXIT3:XS    497.49    0.57  493.32  511.76************  0.44  498.77  498.33
  FULV1:FV  ********    0.46  493.32  511.76  0.31  0.00  0.33  499.09  498.76
  DSBRG:BR    497.56    1.16  490.30  502.66************  3.70  501.27  497.56
  RRWAY:RG  ****************  507.51  507.67**********************************
  EXIT2:AS    497.45    0.18  493.28  511.72  0.20  0.41  0.08  501.87  501.79
  EXITX:XS  ********    0.40  494.70  512.97  0.92  0.14  0.36  502.95  502.59
  FULLV:FV  ********    0.36  494.73  513.00  0.31  0.00  0.32  503.27  502.95
  BRIDG:BR    500.30    0.69  491.86  507.07  0.42  0.45  1.59  503.82  502.22
  RDWAY:RG  ****************  507.22  511.85**********************************
  APPRO:AS    500.96    0.37  494.01  511.83  0.37  0.24  0.30  504.42  504.12

       U.S. Geological Survey WSPRO Input File vern086a.wsp
       Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
       Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
          *** RUN DATE & TIME: 03-14-97  10:50

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

EXIT3:XS   ******   -22.     781.  0.95 *****  499.28  498.04   6100.  498.33
     -914. ******   268.   49912.  1.00 ***** *******    0.84    7.81

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULV1"     KRATIO =  1.63

FULV1:FV      57.   -25.    1057.  0.52  0.52  499.79 *******   6100.  499.27
     -857.    57.   270.   81549.  1.00  0.00   -0.01    0.54    5.77
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

EXIT2:AS      98.   -27.    1237.  0.38  0.43  500.22 *******   6100.  499.84
     -759.    98.   272.  105044.  1.00  0.00    0.00    0.43    4.93
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   499.14     504.27     504.40     502.66

 ===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

DSBRG:BR      57.     0.     605.  1.63 *****  504.29  499.22   6195.  502.66
     -857. ******    57.   81633.  1.00 ***** *******    0.56   10.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.457  0.091  502.66 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RRWAY:RG    -850.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

EXIT2:AS      57.  -139.    3446.  0.06  0.09  505.27  498.00   6100.  505.21
     -759.    85.   323.  448228.  1.20  0.39    0.02    0.13    1.77
```

WSPRO OUTPUT FILE (continued)

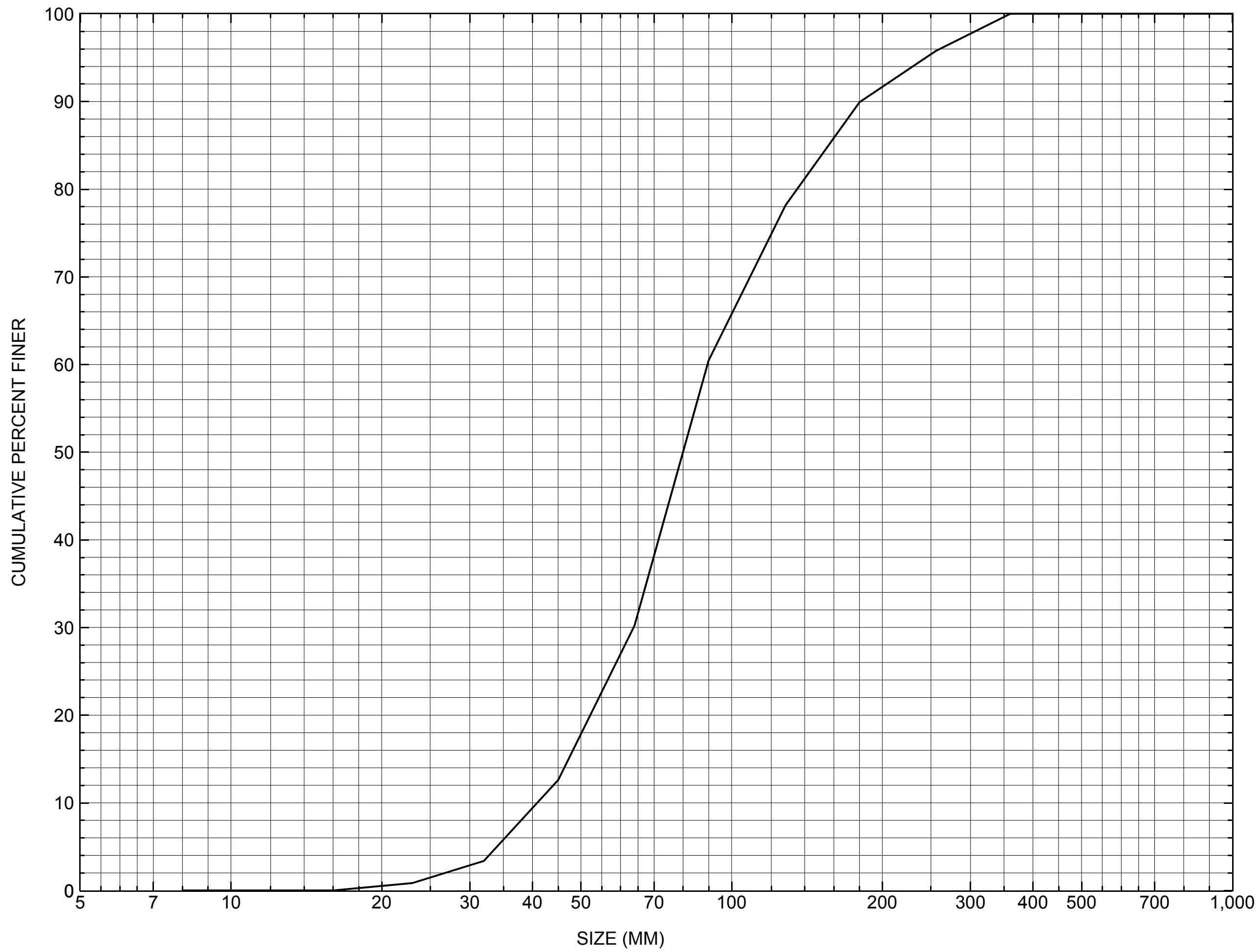
```
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "EXITX"     KRATIO =  0.31

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

EXITX:XS      678.  -101.    1473.  0.28  0.41  505.79 *******   6100.  505.50
      -81.    678.   107.  138035.  1.07  0.11    0.00    0.28    4.14

FULLV:FV       81.  -101.    1501.  0.27  0.15  505.95 *******   6100.  505.67
        0.     81.   108.  142152.  1.07  0.00    0.01    0.28    4.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      119.   -40.    1462.  0.35  0.22  506.20 *******   6100.  505.85
      119.    119.   228.  142866.  1.28  0.04    0.00    0.36    4.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   504.89     506.66     506.90     506.59

 ===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       81.     0.     777.  0.91 *****  507.57  501.92   5936.  506.66
        0. ******    92.   85486.  1.00 ***** *******    0.47    7.64

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   5.  0.405  0.074  506.59 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       13.    95.  0.07  0.19  508.02   -0.01    125.  507.88

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    125.    82.  -119.   -37.   0.7   0.5   3.6   3.1   0.6   3.1
   RT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****

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

APPRO:AS       93.  -119.    2101.  0.19  0.20  508.09  502.00   6100.  507.90
      119.    101.   252.  221248.  1.43  0.16   -0.01    0.26    2.90

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT3:XS      -914.   -22.   268.   6100.   49912.     781.    7.81  498.33
   FULV1:FV      -857.   -25.   270.   6100.   81549.    1057.    5.77  499.27
   DSBRG:BR      -857.     0.    57.   6195.   81633.     605.   10.23  502.66
   RRWAY:RG      -850.**************      0.*****************    2.00********
   EXIT2:AS      -759.  -139.   323.   6100.  448228.    3446.    1.77  505.21

    XSID:CODE   XLKQ   XRKQ       KQ
   EXIT2:AS   ***********************

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS       -81.  -101.   107.   6100.  138035.    1473.    4.14  505.50
   FULLV:FV         0.  -101.   108.   6100.  142152.    1501.    4.06  505.67
   BRIDG:BR         0.     0.    92.   5936.   85486.     777.    7.64  506.66
   RDWAY:RG        13.*******   125.    125.*********       0.    1.00  507.88
   APPRO:AS       119.  -119.   252.   6100.  221248.    2101.    2.90  507.90

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT3:XS     498.04    0.84  493.32  511.76************  0.95  499.28  498.33
   FULV1:FV   ********    0.54  493.32  511.76  0.52  0.00  0.52  499.79  499.27
   DSBRG:BR     499.22    0.56  490.30  502.66************  1.63  504.29  502.66
   RRWAY:RG   ****************  507.51  507.67********************************
   EXIT2:AS     498.00    0.13  493.28  511.72  0.09  0.39  0.06  505.27  505.21
   EXITX:XS   ********    0.28  494.70  512.97  0.41  0.11  0.28  505.79  505.50
   FULLV:FV   ********    0.28  494.73  513.00  0.15  0.00  0.27  505.95  505.67
   BRIDG:BR     501.92    0.47  491.86  507.07************  0.91  507.57  506.66
   RDWAY:RG   ****************  507.22  511.85  0.07******  0.19  508.02  507.88
   APPRO:AS     502.00    0.26  494.01  511.83  0.20  0.16  0.19  508.09  507.90
```

```
       U.S. Geological Survey WSPRO Input File vern086a.wsp
       Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
       Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
          *** RUN DATE & TIME: 03-14-97  10:50

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

EXIT3:XS   ******   -22.     781.  0.94 *****  499.27  498.04   6070.  498.33
     -914. ******   268.   49912.  1.00 ***** *******    0.83    7.77

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULV1"     KRATIO =  1.63

FULV1:FV      57.   -25.    1055.  0.52  0.52  499.78 *******   6070.  499.26
     -857.    57.   270.   81189.  1.00  0.00   -0.01    0.54    5.76
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

EXIT2:AS      98.   -27.    1234.  0.38  0.43  500.20 *******   6070.  499.83
     -759.    98.   272.  104603.  1.00  0.00    0.00    0.43    4.92
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   499.12     504.23     504.37     502.66

 ===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

DSBRG:BR      57.     0.     605.  1.50 *****  504.16  499.04   5951.  502.66
     -857. ******    57.   81633.  1.00 ***** *******    0.53    9.83

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.447  0.074  502.66 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RRWAY:RG    -850.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

EXIT2:AS      57.  -138.    3315.  0.06  0.09  504.99  498.00   6070.  504.92
     -759.    85.   323.  423950.  1.20  0.39   -0.02    0.13    1.83
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "EXITX"     KRATIO =  0.31

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

EXITX:XS     678.  -100.    1421.  0.30  0.45  505.56 *******   6070.  505.26
      -81.   678.   107.  130772.  1.07  0.12    0.00    0.30    4.27

FULLV:FV      81.  -101.    1453.  0.29  0.17  505.73 *******   6070.  505.44
        0.    81.   107.  135311.  1.07  0.00    0.01    0.29    4.18
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     119.   -38.    1406.  0.37  0.24  506.01 *******   6070.  505.64
       119.   119.   225.  135815.  1.27  0.04    0.00    0.37    4.32
          <<<<<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      81.     0.     673.  1.96  0.28  506.58  502.04   6070.  504.62
        0.    81.    86.   82653.  1.55  0.74   -0.01    0.71    9.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.804  0.080  506.59 ****** ****** ******
```

```
        U.S. Geological Survey WSPRO Input File vern086a.wsp
        Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
        Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
           *** RUN DATE & TIME: 03-14-97  10:50
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA    VEL   WSEL
   EXIT3:XS    -914.   -22.   268.   6070.   49912.     781.   7.77 498.33
   FULV1:FV    -857.   -25.   270.   6070.   81189.    1055.   5.76 499.26
   DSBRG:BR    -857.     0.    57.   5951.   81633.     605.   9.83 502.66
   RRWAY:RG    -850.**************      0.******************   2.00********
   EXIT2:AS    -759.  -138.   323.   6070.  423950.    3315.   1.83 504.92

    XSID:CODE   XLKQ   XRKQ      KQ
   EXIT2:AS  ***********************

    XSID:CODE    SRD    LEW    REW      Q        K     AREA    VEL   WSEL
   EXITX:XS     -81.  -100.   107.   6070.  130772.    1421.   4.27 505.26
   FULLV:FV       0.  -101.   107.   6070.  135311.    1453.   4.18 505.44
   BRIDG:BR       0.     0.    86.   6070.   82653.     673.   9.01 504.62
   RDWAY:RG      13.**************      0.******************   1.00********
   APPRO:AS     119.   -49.   250.   6070.  174527.    1715.   3.54 506.75

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS       4.    90.  104782.


 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File vern086a.wsp
        Hydraulic analysis for structure VERNVT01420086   Date: 16-JAN-97
        Bridge # 86 on VT 142 over Broad Brook in Vernon, VT  By MAI
           *** RUN DATE & TIME: 03-14-97  10:50
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT3:XS    498.04    0.83  493.32  511.76************  0.94  499.27  498.33
   FULV1:FV  ********    0.54  493.32  511.76  0.52  0.00  0.52  499.78  499.26
   DSBRG:BR    499.04    0.53  490.30  502.66************  1.50  504.16  502.66
   RRWAY:RG  ****************  507.51  507.67**********************************
   EXIT2:AS    498.00    0.13  493.28  511.72  0.09  0.39  0.06  504.99  504.92
   EXITX:XS  ********    0.30  494.70  512.97  0.45  0.12  0.30  505.56  505.26
   FULLV:FV  ********    0.29  494.73  513.00  0.17  0.00  0.29  505.73  505.44
   BRIDG:BR    502.04    0.71  491.86  507.07  0.28  0.74  1.96  506.58  504.62
   RDWAY:RG  ****************  507.22  511.85**********************************
   APPRO:AS    501.98    0.30  494.01  511.83  0.26  0.18  0.26  507.01  506.75
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure VERNVT01420086, in Vernon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number VERNVT01420086

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 30 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 74800

Mile marker *(I - 11; nnn.nnn)* 008300

Waterway *(I - 6)* BROAD BROOK

Road Name *(I - 7):* -

Route Number VT142

Vicinity *(I - 9)* 2.9 MI S JCT. U.S.5

Topographic Map Brattleboro

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 42491

Longitude *(i - 17; nnnnn.n)* 72328

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20010900061318

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0047

Year built *(I - 27; YYYY)* 1930

Structure length *(I - 49; nnnnnn)* 000098

Average daily traffic, ADT *(I - 29; nnnnnn)* 002463

Deck Width *(I - 52; nn.n)* 245

Year of ADT *(I - 30; YY)* 92

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 045.0

Number of spans *(I - 45; nnn)* 002

Vertical clearance from streambed (*nnn.n ft*) 010.5

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

Waterway of full opening (*nnn.n ft*^{2}) 472.5

Comments:

The structural inspection report indicates the structure is a two span, steel beam type bridge. Both concrete abutments and the wingwalls have very minor cracks and stains reported. The pier is solid concrete with very minor cracks, stains and spalls noted. There is some good stone riprap in front of both abutments. The waterway takes a moderate turn through the structure, and the majority of flow is beneath the left span. The Connecticut River is just downstream. The streambed consists of silts and sands. There is a sand point bar with vegetation growth just upstream of the pier. There are a few small logs and other debris wedged on the upstream end of the pier. There may be minor scour at the pier nose. The abutment and pier footings are not in view.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

-

Streambed material: **Silt, gravel, some 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: **This brook enters the Connecticut River just downstream from this bridge site.**

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

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

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

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

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

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

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 23.702 mi^2 Lake and pond area .012 mi^2
Watershed storage *(ST)* .05 %
Bridge site elevation 227.7 ft Headwater elevation 1732.3 ft
Main channel length 6.954 mi
10% channel length elevation 295.3 ft 85% channel length elevation 590.6 ft
Main channel slope *(S)* 56.67 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)*: - / 1930

Project Number - Minimum channel bed elevation: 188.0

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

BM#1: [spike in the root or trunk of] an 8 inch elm tree, about 30 feet right bankward of the right abutment and 45 feet right of the roadway centerline, elevation 200.0.

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 Footing bottom elevation: 186.0

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: 2

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

Briefly describe material at foundation bottom elevation or around piles:

The foundation material is a coarse sand and gravel as stated in plans

Comments:

The plans could not be found on March 30, 1995.

Cross-sectional Data

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

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

Comments: **Some cross sections are available. Orientation of the cross sections is inconsistent with any cross section data surveyed for this study and is not comparable. Data was not retrieved.**

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: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 10/10/96
Computerized by: RB Date: 10/31/96
Reviewd by: MAI Date: 03/26/97

Structure Number VERNVT01420086

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. FLYNN Date *(MM/DD/YY)* 08 / 14 / 1996

2. Highway District Number 02 Mile marker 008300

County 025 WINDHAM Town 74800 VERNON

Waterway *(I - 6)* BROAD BROOK Road Name -

Route Number VT142 Hydrologic Unit Code: 01080104

3. Descriptive comments:

Located 2.9 miles south of the junction with US 5.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 7 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 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 98 *(feet)* Span length 47 *(feet)* Bridge width 24.5 *(feet)*

Road approach to bridge:

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

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

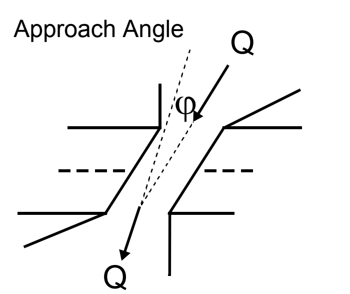
10. Embankment slope (*run / rise in feet / foot*):
US left 1.6:1 US right 3.1:1

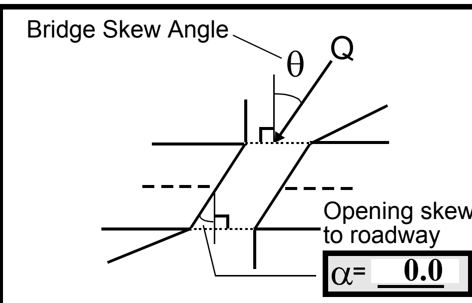
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	3	2
RBUS	0	-	3	1
RBDS	1	1	3	2
LBDS	1	1	3	1

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

Channel approach to bridge (BF):

15. Angle of approach: 20 16. Bridge skew: 30





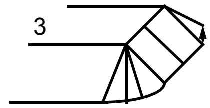
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 0 feet US *(US, UB, DS)* to 100 feet US

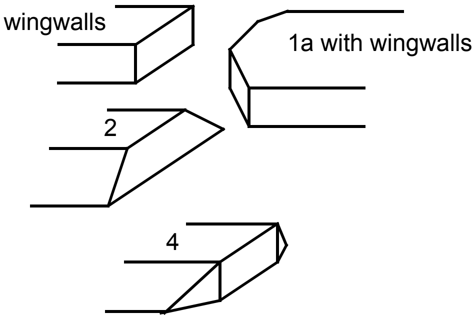
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 0 feet US *(US, UB, DS)* to 250 feet DS

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

18. Bridge Type: **3**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





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

7. Values are from the VT AOT files. Measured bridge length is 97.8 ft. and the bridge width is 24.5 ft.
4. There are some small cottages on the US right bank.
18. The bridge has spill-through slopes consisting of sand and gravel with type 2 protection along the entire base length of the toe of each slope. There is one pier in the center of the bridge.

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
132.0	**3.5**			**2.5**	**3**	**3**	**0134**	**03**	**2**	**1**

23. Bank width **40.0** 24. Channel width **15.0** 25. Thalweg depth **137.5** 29. Bed Material **3214**

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.):

29. The bed material is predominantly gravel and boulders greater than 300 ft US of the approach. There was an extensive amount of sand and silt intermixed with the gravel and cobble.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **120** 35. Mid-bar width: **50**

36. Point bar extent: **12** feet **US** (US, UB) to **210** feet **US** (US, UB, DS) positioned **50** %LB to **0** %RB

37. Material: **0234**

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

This is an old bar with vegetation and small trees. Another point bar is along the left bank from 210 ft. US to 350 ft. US. It is comprised of organics, sand, gravel and cobble. A third point bar is located on the right bank from 300 ft. US to 400 ft. US. It is comprised of gravel, sand and cobbles.

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

41. Mid-bank distance: **100** 42. Cut bank extent: **210** feet **US** (US, UB) to **0** 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.):

Tree roots are exposed and several trees are in danger of falling into the river.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **55**

47. Scour dimensions: Length **195** Width **20** Depth : **4** Position **95** %LB to **50** %RB

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

Scour is evident from 20 ft. DS to 150 ft. US. Another scour hole is evident US and adjacent to the point bar from 190 ft. US to 225 ft. US. It is 35 ft. long, 20 ft. wide, and 2 ft. deep. It is positioned from 50% LB to 25% RB.

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
122.0		4.0		2	7	7	-

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

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

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

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

3214

The protection under the bridge acts like a spill through. In front of the abutments and behind the protection are sand and gravel banks that have moderate fluvial erosion.

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

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

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

70. Debris and Ice Comments:

3

There is debris accumulation along the center pier, including an 18 in. diameter log. Debris has also accumulated US of the point bar at 210 ft. US. Ice build up is evident by scarring of the tree trunks.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	1	2	0	90.0
RABUT	1	20	90			2	1	93.0

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.):

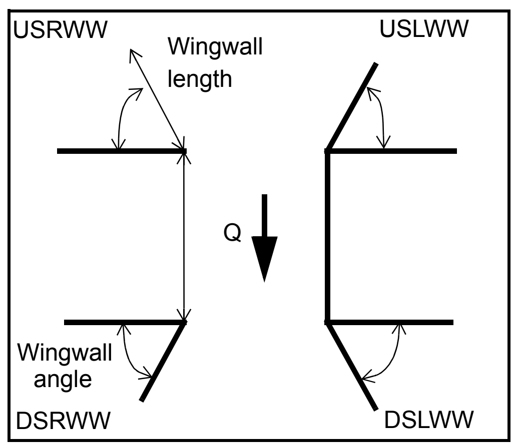
2
0
1

The abutments are protected by "spill-through" slopes at a 45 degree angle from the bed. The stone protection at the base of these banks is 4 ft. high.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						93.0	
USRWW:	N		-		-	4.5	
DSLWW:	-		-		N	26.0	
DSRWW:	-		-		-	25.5	

*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	-	-	N	-	-	-	-	-
Condition	N	-	-	-	-	-	-	-
Extent	-	-	-	-	-	0	0	2

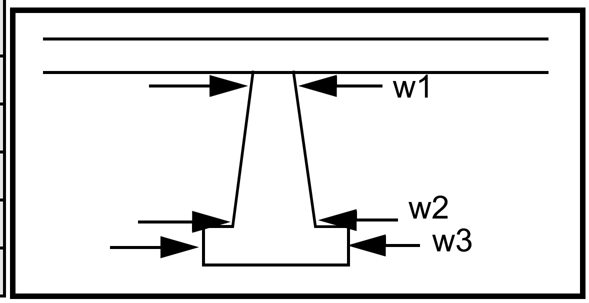
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **82.** *(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	**-**	**-**	**-**	**-**	**-**	**-**
Pier 2	**-**	**4**	**5**	**-**	**506.5**	**492.8**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The left**	**the**		**10**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**and**	**bank**		**RB**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**right**	**to**		**-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**bank**	**the**		**0**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**pro-**	**abut**		**1**	*Y- yes; N- no*
91. Attack ∠ (BF)	**tec-**	**ment**	**Y**	**2-4**	
92. Pushed	**tion**	**.**	**MC**	**0.5**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**does**		**M**	**-**	
95. Cross-members	**not**		**1**	**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**exte**		**2**	**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**nd**		**1**	**-**	
98. Exposure depth	**up**		**Y**	**-**	

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
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width (Amb) 26.5 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.):
-
-
-
-
-
-
-
-
-
-

97. Scour depth is 2 ft. adjacent to the pier on the left side and US of the pier face. The scour DS is 4 ft. deep with the footing exposed at the DS face of the pier and along the DS half of the left side of the pier. There is debris at the US face of the pier that is adding to the scouring effects toward the left side of the pier. The right side of the pier is filling in adjacent to the pier and scouring is evident at the base of the right abutment protection. The scour is 1 ft. deep and 10 ft. wide along the length of the right abutment.

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):

1
4
03

106. Point/Side bar present? 12 (Y or N. if N type ctrl-n pb) Mid-bar distance: 03 Mid-bar width: 2

Point bar extent: 2 feet 321 (US, UB, DS) to 4 feet 0 (US, UB, DS) positioned 0 %LB to - %RB

Material: -

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

There is a railroad bridge approximately 650 ft. DS of the bridge.

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

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

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

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

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

Confluence comments (eg. confluence name):

-

-

F. Geomorphic Channel Assessment

107. Stage of reach evolution -

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

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

-

NO POINT BARS

The channel splits 75 ft. DS with a large anabranched island in the center of the channel to 400 ft. DS.

Y
RB
200
0
DS
400
DS
1

109. G. Plan View Sketch

Tr

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: VERNVT01420086 Town: Vernon
Road Number: VT 142 County: Windham
Stream: Broad Brook

Initials MAI Date: 03/14/97 Checked: RHF

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	4170	6100	6070
Main Channel Area, ft2	853	1373	1215
Left overbank area, ft2	60	239	146
Right overbank area, ft2	121	489	354
Top width main channel, ft	138	138	138
Top width L overbank, ft	25	115	45
Top width R overbank, ft	66	118	116
D50 of channel, ft	0.262	0.262	0.262
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.2	9.9	9.9
y1, average depth, LOB, ft	2.4	2.1	2.1
y1, average depth, ROB, ft	1.8	4.1	4.1
Total conveyance, approach	90436	221247	174444
Conveyance, main channel	84289	186284	151913
Conveyance, LOB	2294	8247	6699
Conveyance, ROB	3854	26715	15832
Percent discrepancy, conveyance	-0.0011	0.0005	0.0005
Qm, discharge, MC, cfs	3886.6	5136.0	5110.8
Ql, discharge, LOB, cfs	105.8	227.4	226.3
Qr, discharge, ROB, cfs	177.7	736.6	732.9
Vm, mean velocity MC, ft/s	4.6	3.7	3.7
Vl, mean velocity, LOB, ft/s	1.8	1.0	0.9
Vr, mean velocity, ROB, ft/s	1.5	1.5	1.5
Vc-m, crit. velocity, MC, ft/s	9.7	10.5	10.5
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Main Channel	0	0	0

ARMORING

D90	0.594	0.594	0.594
D95	0.801	0.801	0.801

Critical grain size,Dc, ft	0.2833	0.1948	0.2783
Decimal-percent coarser than Dc	0.4317	0.7351	0.4475
Depth to armoring,ft	1.12	0.21	1.03

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	853	1373	1215
Main channel width, ft	138	138	138
y1, main channel depth, ft	6.18	9.95	8.80

Bridge Section			
(Q) total discharge, cfs	4170	6100	6070
(Q) discharge thru bridge, cfs	4170	5936	6070
Main channel conveyance	52911	85474	82579
Total conveyance	52911	85474	82579
Q2, bridge MC discharge,cfs	4170	5936	6070
Main channel area, ft2	482	777	673
Main channel width (skewed), ft	56.8	65.4	60.6
Cum. width of piers in MC, ft	4.5	4.5	4.5
W, adjusted width, ft	52.3	60.9	56.1
y_bridge (avg. depth at br.), ft	8.49	12.76	11.11
Dm, median (1.25*D50), ft	0.3275	0.3275	0.3275
y2, depth in contraction,ft	7.26	8.63	9.43
ys, scour depth (y2-ybridge), ft	-1.23	-4.13	-1.67

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)
(Richarson and others, 1995, p. 145-146)

Q, total, cfs	4170	6100	6070
Q, thru bridge, cfs	4170	5936	6070
Total Conveyance, bridge	52911	85474	82579
Main channel(MC) conveyance, bridge	52911	85474	82579
Q, thru bridge MC, cfs	4170	5936	6070
Vc, critical velocity, ft/s	9.72	10.52	10.52
Vc, critical velocity, m/s	2.96	3.21	3.21
Main channel width (skewed), ft	56.8	65.4	60.6
Cum. width of piers in MC, ft	4.5	4.5	4.5
W, adjusted width, ft	52.3	60.9	56.1
qbr, unit discharge, ft2/s	79.7	97.5	108.2
qbr, unit discharge, m2/s	7.4	9.1	10.1
Area of full opening, ft2	482.1	777.0	673.0
Hb, depth of full opening, ft	9.22	12.76	12.00
Hb, depth of full opening, m	2.81	3.89	3.66
Fr, Froude number, bridge MC	0	0.47	0

Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
Elevation of Low Steel, ft	0	506.59	0
Elevation of Bed, ft	-9.22	493.83	-12.00
Elevation of Approach, ft	0	507.9	0
Friction loss, approach, ft	0	0.2	0
Elevation of WS immediately US, ft	0.00	507.70	0.00
ya, depth immediately US, ft	9.22	13.87	12.00
ya, depth immediately US, m	2.81	4.23	3.66
Mean elevation of deck, ft	0	510.74	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.98	1.00
Ys, depth of scour, ft	N/A	-3.30	N/A

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	7.26242	8.627013	9.434768
Full valley WSEL, ft	0	505.67	0
Full valley depth, ft	9.217973	11.83862	11.99643
Ys, depth of scour (y2-yfullv), ft	N/A	-3.21161	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	4170	6100	6070	4170	6100	6070
a', abut.length blocking flow, ft	45.1	49	63.5	126.6	175	174.5
Ae, area of blocked flow ft2	226.3	375	340.3	429.1	994.5	807.2
Qe, discharge blocked abut.,cfs	947.2	756.11	1119.6	1413.7	2512.1	2375.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.19	2.02	3.29	3.29	2.53	2.94
ya, depth of f/p flow, ft	5.02	7.65	5.36	3.39	5.68	4.63
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.329	0.210	0.250	0.315	0.187	0.241
ys, scour depth, ft	13.20	15.85	13.68	13.32	16.81	16.18

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)	45.1	49	63.5	126.6	175	174.5
y1 (depth f/p flow, ft)	5.02	7.65	5.36	3.39	5.68	4.63
a'/y1	8.99	6.40	11.85	37.35	30.79	37.72
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.33	0.21	0.25	0.32	0.19	0.24
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	16.84	23.76	21.04
vertical w/ ww's	ERR	ERR	ERR	13.81	19.48	17.25
spill-through	ERR	ERR	ERR	9.26	13.07	11.57

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	Q100	Q500	Qother
Fr, Froude Number	0.69	0.47	0.71	0.69	0.47	0.71
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.49	12.76	11.11	8.49	12.76	11.11
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.50	1.74	3.46	2.50	1.74	3.46
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	2.18	1.52	3.02	2.18	1.52	3.02
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR

Pier Scour (both live-bed and clear water scour)

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	46	46	46
Area of WSPRO flow tube, ft2	19.8	33.6	26.8
Skewed width of flow tube, ft	1.9	2.4	2.1
y1, pier approach depth, ft	10.42	14.00	12.76
y1 in meters	3.176	4.267	3.890
V1, pier approach velocity, ft/s	10.5	8.8	11.3
a, pier width, ft	4.5	4.5	4.5

L, pier length, ft	26.5	26.5	26.5
Fr1, Froude number at pier	0.573	0.414	0.557
Pier attack angle, degrees	10	10	10
K1, shape factor	1	1	1
K2, attack factor	1.57	1.57	1.57
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.262	0.262	0.262
D50, m	0.079854	0.079854	0.079854
D90, ft	0.594	0.594	0.594
D90, m	0.181042	0.181042	0.181042
Vc50,critical velocity(D50),m/s	3.232	3.395	3.343
Vc90,critical velocity(D90),m/s	4.246	4.460	4.391
Vi,incipient velocity,m/s	1.793	1.883	1.854
Vr, velocity ratio	0.574	0.310	0.627
K4, armor factor	0.92	0.76	0.94
ys, scour depth (K4 applicable) ft	15.06	12.04	16.33
ys, scour depth (K4 not applied)ft	ERR	ERR	ERR

D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	1.5
V, char. aver. velocity, ft/s	12.5	10.5	13.2
D50, median stone diameter, ft	2.29	1.62	2.55