LEVEL II SCOUR ANALYSIS FOR BRIDGE 11 (BELVTH00080011) on TOWN HIGHWAY 8, crossing the NORTH BRANCH LAMOILLE RIVER, BELVIDERE, VERMONT

U.S. Geological Survey
Open-File Report 98-278

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

U.S. Department of the Interior
U.S. Geological Survey

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By ERICK M. BOEHMLER AND JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

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

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 11 (BELVTH00080011) ON TOWN HIGHWAY 8, CROSSING THE NORTH BRANCH LAMOILLE RIVER, BELVIDERE, VERMONT

By **Erick M. Boehmler and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BELVTH00080011 on Town Highway 8 crossing the North Branch Lamoille River, Belvidere, 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 23.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of short grass, a few houses, and gravel driveways except for the right overbank downstream, which is forest.

In the study area, the North Branch Lamoille River has an incised, sinuous channel with a slope of approximately 0.04 ft/ft, an average channel top width of 72 feet and an average bank height of 9 ft. The predominant channel bed materials are cobbles and boulders with a median grain size (D_{50}) of 172 mm (0.566 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 27, 1995, indicated that the reach was stable.

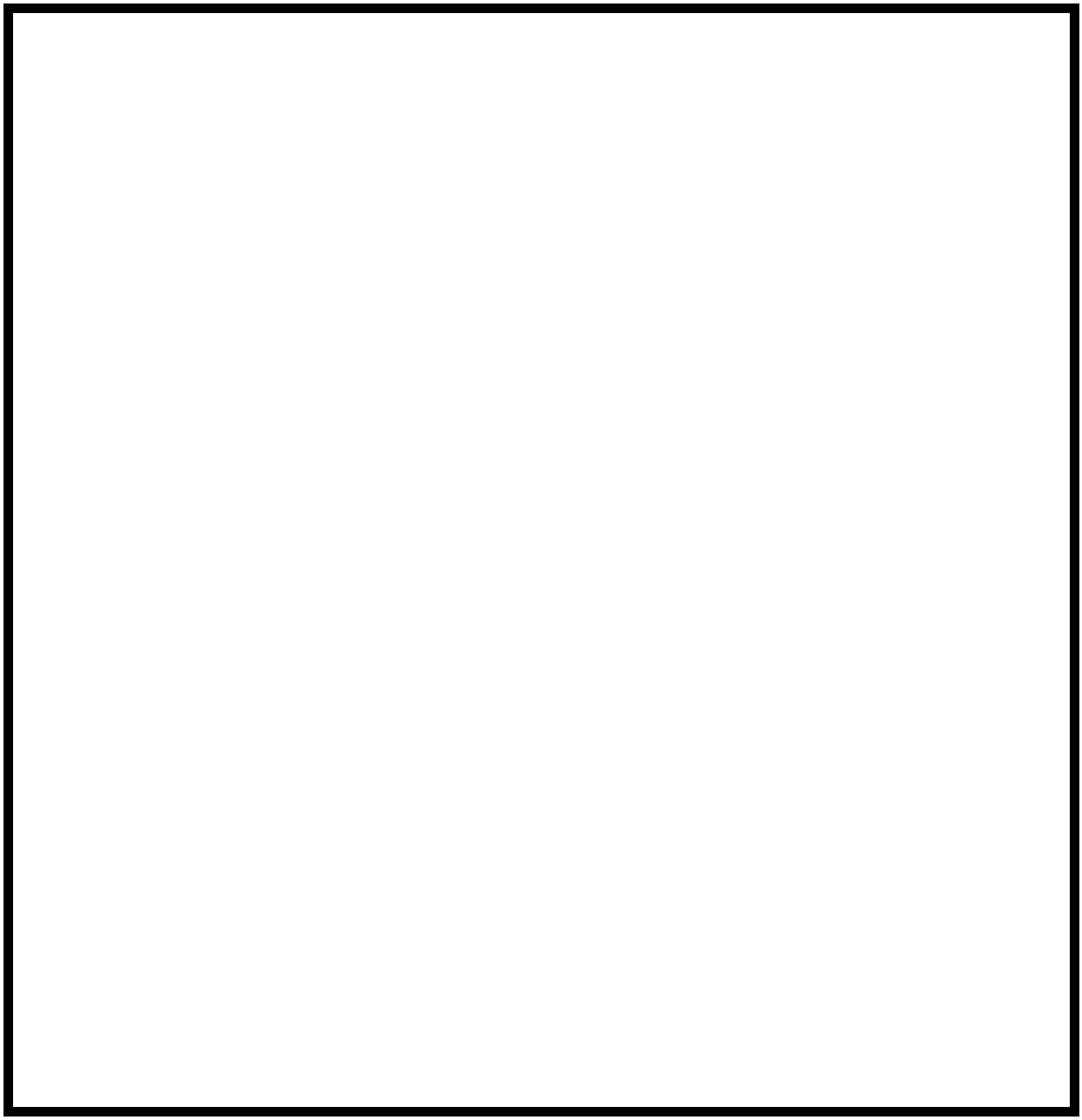
The Town Highway 8 crossing of the North Branch Lamoille River is a 40-ft-long, one-lane bridge consisting of one 37-foot steel-beam span (Vermont Agency of Transportation, written communication, March 7, 1995). The bridge is supported by vertical, concrete abutments with wingwalls on the left abutment. The channel is skewed approximately 35 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) along the right abutment wall and type-3 stone fill along the left abutment, the upstream and downstream left wingwalls and the upstream right roadway embankment. 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.

Contraction scour for all modelled flows ranged from 0.6 to 0.9 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.9 to 22.2 feet. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.



Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number BELVTH00080011 ***Stream*** North Branch Lamoille River

County Lamoille ***Road*** TH 8 ***District*** 8

Description of Bridge

Bridge length 40 ***ft*** ***Bridge width*** 12.6 ***ft*** ***Max span length*** 37 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/27/95

Description of stone fill Type-3 on the right roadway embankment upstream, the left abutment and its wingwalls.Type-2 along the right abutment.

Abutments and wingwalls are "laid-up" stone walls.

Brief description of facing (if any) The stone has a concrete facing on the left abutment and its wingwalls.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 35

There is a mild channel bend in the upstream reach. High flows primarily impact the right roadway embankment and the left abutment.

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	6/27/95	0	0
Level II	6/27/95	0	0

Potential for debris Low. Although there is significant vegetation cover on the banks, the channel is stable.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 6/27/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with narrow, irregular overbanks and steep valley walls on both sides.

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

Date of inspection 6/27/95

DS left: Steep channel bank to a narrow overbank.

DS right: Steep channel bank and the valley wall.

US left: Steep channel bank and a narrow overbank.

US right: Moderately sloping channel bank and valley wall.

Description of the Channel

Average top width 72 ***ft*** ***Average depth*** 9 ***ft***

Predominant bed material Cobbles / Boulders ***Bank material*** Cobbles / Boulders

Perennial but flashy and sinuous but stable with non-alluvial channel boundaries.

Vegetative co Trees, shrubs, and brush with short grass on the overbank. 6/27/95

DS left: Trees

DS right: Trees with short grass on the overbank.

US left: Trees.

US right: Trees.

Do banks appear stable? Yes

If not, describe location and type of instability and date of observation.

Describe any obstructions in channel and date of observation. The assessment of 6/27/95 noted up to 50% of the channel width immediately downstream of the bridge was occupied by very large boulders on the left side.

Hydrology

Drainage area 23.4 ***mi^2***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area ***mi^2***

Is there a lake/p No

Calculated Discharges

Q100 3,650 ***ft^3/s*** ***Q500*** 5,400 ***ft^3/s***

The 100- and 500-year discharges are based on the flood frequency curve computed by use of the New England Hills and Lowlands empirical relationship (Potter, 1957). The resulting curve was within a range of flood frequency curves computed by use of several other empirical relationships. (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is an orange painted nail hole in the top of the upstream end of the right abutment concrete cap (elev. 499.71 feet, arbitrary survey datum). RM2 is an orange painted nail hole in the top of the downstream end of the left abutment concrete cap (elev. 499.64 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-29	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	49	2	Modelled Approach section (Templated from APTEM)
APTEM	60	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.065, and overbank "n" values ranged from 0.035 to 0.055.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0357 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0536 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.3 *ft*
Average low steel elevation 498.1 *ft*

100-year discharge 3,650 *ft³/s*
Water-surface elevation in bridge opening 493.7 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 234 *ft²*
Average velocity in bridge opening 15.6 *ft/s*
Maximum WSPRO tube velocity at bridge 20.8 *ft/s*

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 493.8
Amount of backwater caused by bridge 4.6 *ft*

500-year discharge 5,400 *ft³/s*
Water-surface elevation in bridge opening 498.1 *ft*
Road overtopping? Yes *Discharge over road* 1050 *ft³/s*
Area of flow in bridge opening 373 *ft²*
Average velocity in bridge opening 11.7 *ft/s*
Maximum WSPRO tube velocity at bridge 16.3 *ft/s*

Water-surface elevation at Approach section with bridge 501.7
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 6.1 *ft*

Incipient overtopping discharge 3,670 *ft³/s*
Water-surface elevation in bridge opening 493.7 *ft*
Area of flow in bridge opening 235 *ft²*
Average velocity in bridge opening 15.6 *ft/s*
Maximum WSPRO tube velocity at bridge 20.7 *ft/s*

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 493.8
Amount of backwater caused by bridge 4.6 *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 overtopping discharges were computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, 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, for the 500-year discharge contraction scour was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour for the 500-year event also were computed by use of Laursen's clear-water scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and are presented in appendix F. Furthermore, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the scour equations. Contraction scour results with respect to these substitutions also are provided in appendix F.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.6	0.9	0.6
Depth to armoring	35	114	35
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	6.9	13.8	7.1
Left abutment	20.7	22.2	20.7
Right abutment	--	--	--
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:	3.2	3.6	3.2
Left abutment	3.2	3.6	3.2
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

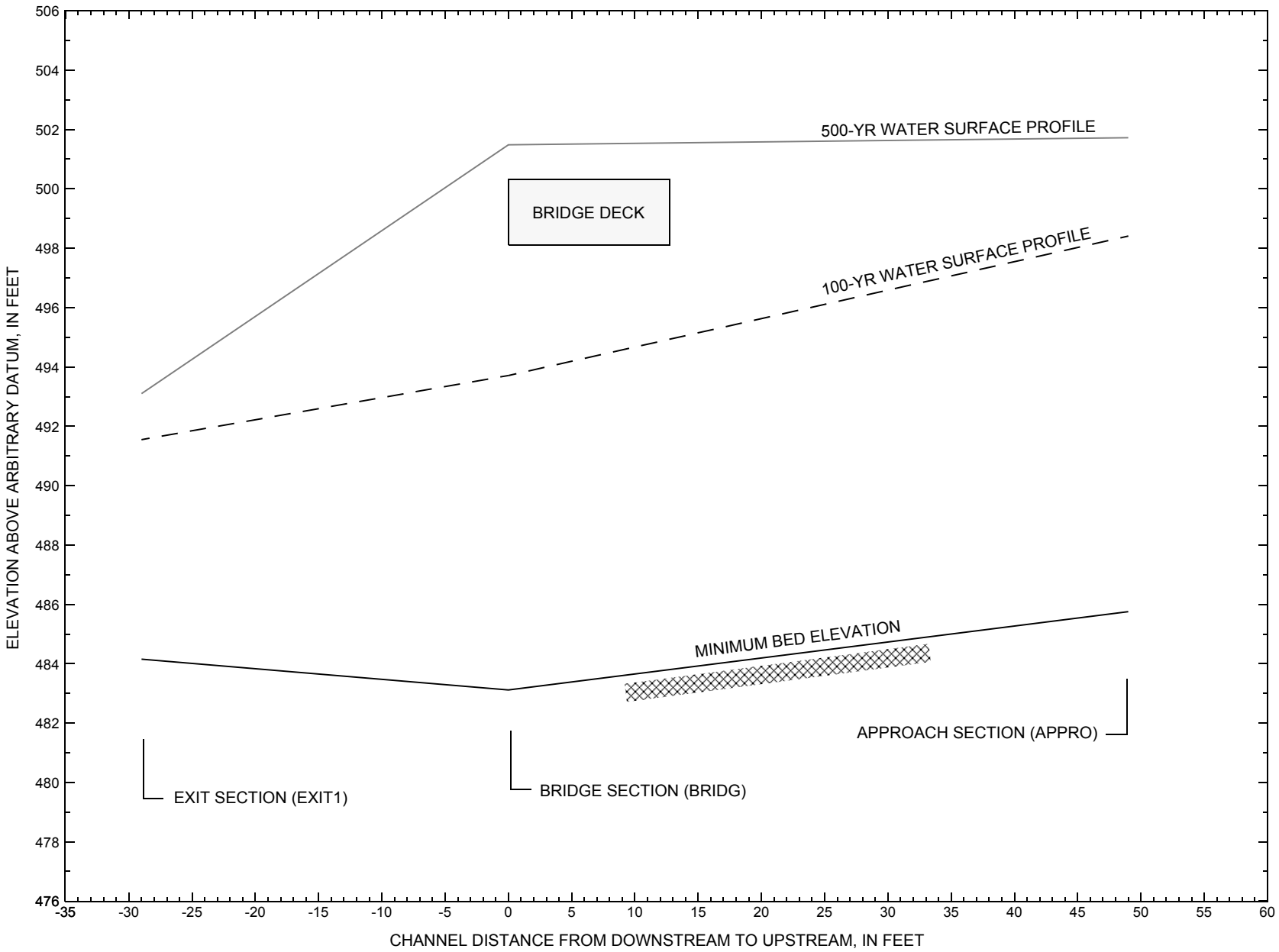


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BELVTH00080011 on Town Highway 8, crossing the North Branch Lamoille River, Belvidere, Vermont.

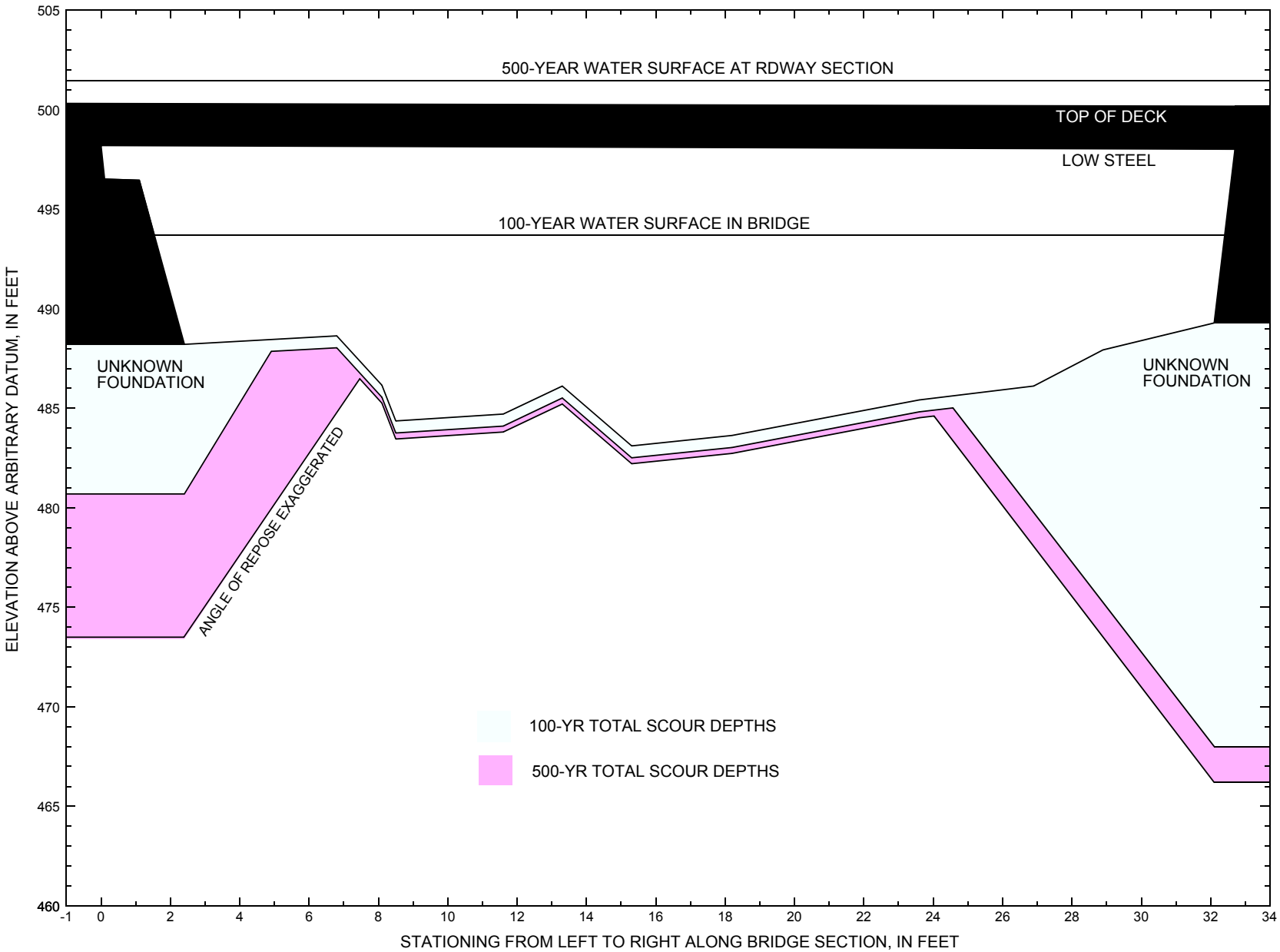


Figure 8. Scour elevations for the 100- and 500-year discharges at structure BELVTH00080011 on Town Highway 8, crossing the North Branch Lamoille River, Belvidere, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BELVTH00080011 on Town Highway 8, crossing the North Branch Lamoille River, Belvidere, 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-year discharge is 3,650 cubic-feet per second											
Left abutment	0.0	--	498.2	--	488.2	0.6	6.9	--	7.5	480.7	--
Right abutment	32.7	--	498.0	--	489.3	0.6	20.7	--	21.3	468.0	--

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 BELVTH00080011 on Town Highway 8, crossing the North Branch Lamoille River, Belvidere, 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-year discharge is 5,400 cubic-feet per second											
Left abutment	0.0	--	498.2	--	488.2	0.9	13.8	--	14.7	473.5	--
Right abutment	32.7	--	498.0	--	489.3	0.9	22.2	--	23.1	466.2	--

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, 1986, Cold Hollow Mountains, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial photographs, 1980; Contour interval, 6 meters; Scale 1:24,000.

U.S. Geological Survey, 1986, Johnson, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial photographs, 1981; Contour interval, 6 meters; Scale, 1:24,000

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File belv011.wsp
T2        Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
T3        Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3650.0   5400.0   3670.0
SK          0.0357   0.0357   0.0357
*
XS   EXIT1    -29
GR         -166.2, 512.06   -101.0, 501.99    -13.1, 499.32     -6.0, 493.59
GR            0.0, 488.58     13.1, 486.16     28.9, 484.15     38.0, 484.89
GR           42.5, 486.14     52.7, 488.94     54.0, 491.77     63.4, 496.03
GR           73.1, 496.31    152.4, 507.15
*
N           0.035        0.065        0.055
SA                -13.1         63.4
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL
BR   BRIDG     0    498.11
GR            0.0, 498.20      0.1, 496.52      1.1, 496.46      2.4, 488.21
GR            6.8, 488.64      8.1, 486.16      8.5, 484.36     11.6, 484.71
GR           13.3, 486.11     15.3, 483.11     18.2, 483.63     23.6, 485.42
GR           26.9, 486.12     28.9, 487.93     32.1, 489.29     32.7, 498.02
GR            0.0, 498.20
*
*         BRTYPE  BRWDTH
CD           1      18.0
N           0.065
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      12.6     2
GR         -319.1, 527.30   -172.6, 509.13    -81.7, 500.22    -44.3, 499.31
GR            0.0, 500.32     32.8, 500.18    218.1, 514.08
*
XT   APTEM     60
GR         -148.0, 508.53   -129.3, 498.95   -120.9, 497.82   -117.2, 498.79
GR          -94.9, 498.99    -87.9, 498.70    -72.5, 497.93    -13.8, 496.36
GR           -3.3, 493.35      0.0, 488.72     10.1, 487.80     21.8, 486.34
GR           31.6, 486.46     34.5, 487.82     39.6, 490.25     52.2, 492.61
GR           63.2, 500.61
*
AS   APPRO     49  * * *  0.0536
GT
N           0.040        0.055
SA                -13.8
*
HP 1 BRIDG 493.71 1 493.71
HP 2 BRIDG 493.71 * * 3650
HP 1 APPRO 498.41 1 498.41
HP 2 APPRO 498.41 * * 3650
*
HP 1 BRIDG 498.11 1 498.11
HP 2 BRIDG 498.11 * * 4348
HP 2 BRIDG 495.11 * * 4348
HP 2 RDWAY 501.48 * * 1050
HP 1 APPRO 501.72 1 501.72
HP 2 APPRO 501.72 * * 5400
*
HP 1 BRIDG 493.74 1 493.74
HP 2 BRIDG 493.74 * * 3670
HP 1 APPRO 498.45 1 498.45
HP 2 APPRO 498.45 * * 3670
*
EX   ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File belv011.wsp
Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
   *** RUN DATE & TIME: 06-09-97  14:03

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      234     15840     31     46                         3659
493.71           234     15840     31     46  1.00      2     32     3659

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    493.71     1.5    32.4   234.1   15840.    3650.  15.59

X STA.         1.5        5.8        8.7        9.9       11.1       12.3
  A(I)            20.7       18.0       11.8       10.8       10.5
  V(I)            8.83      10.12      15.49      16.89      17.43

X STA.        12.3       13.8       15.1       16.0       16.9       17.7
  A(I)            11.8       12.3        9.4        8.9        8.8
  V(I)           15.44      14.86      19.35      20.51      20.81

X STA.        17.7       18.6       19.5       20.5       21.5       22.6
  A(I)             8.9        8.9        9.2        9.1        9.7
  V(I)           20.57      20.50      19.83      19.96      18.81

X STA.        22.6       23.7       25.0       26.5       28.4       32.4
  A(I)             9.9       10.5       11.3       13.6       20.1
  V(I)           18.35      17.45      16.21      13.43       9.09

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      131      5274    116    116                          788
          2      650     70650     75     81                        10874
498.41           781     75924    190    197  1.17   -128     61     8278

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

      WSEL     LEW     REW    AREA        K        Q    VEL
    498.41  -129.4    61.0   780.7   75924.    3650.   4.68

X STA.      -129.4      -25.3       -4.6        1.5        4.7        7.7
  A(I)           102.2       65.0       48.4       34.3       32.5
  V(I)            1.79       2.81       3.77       5.32       5.61

X STA.         7.7       10.5       13.1       15.7       18.1       20.4
  A(I)            31.3       29.8       29.8       28.7       28.5
  V(I)            5.83       6.11       6.12       6.37       6.41

X STA.        20.4       22.6       24.8       27.1       29.4       31.8
  A(I)            28.0       28.1       28.4       29.3       29.6
  V(I)            6.51       6.49       6.43       6.23       6.17

X STA.        31.8       34.5       37.9       42.2       47.7       61.0
  A(I)            32.7       34.8       38.2       42.1       59.0
  V(I)            5.59       5.25       4.78       4.33       3.09
```

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      373     25535     16     72                          10106
   498.11           373     25535     16     72  1.00      0     33    10106

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.11     0.0    32.7   372.9   25535.    4348.  11.66

X STA.         0.0        4.8        6.7        8.6        9.7       10.7
  A(I)            32.5       18.6       21.5       15.1       13.8
  V(I)            6.70      11.69      10.12      14.36      15.77

X STA.        10.7       11.8       12.9       14.1       15.2       16.1
  A(I)            14.0       14.2       15.2       15.1       13.3
  V(I)           15.54      15.36      14.30      14.41      16.34

X STA.        16.1       17.1       18.2       19.3       20.6       21.9
  A(I)            14.9       16.1       16.4       17.0       17.7
  V(I)           14.60      13.47      13.27      12.76      12.29

X STA.        21.9       23.3       24.8       26.5       28.6       32.7
  A(I)            18.3       19.3       20.4       23.8       35.7
  V(I)           11.88      11.25      10.67       9.14       6.08

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.11     1.3    32.5   277.6   20220.    4348.  15.67

X STA.         1.3        5.6        8.2        9.7       10.9       12.1
  A(I)            25.3       19.1       15.6       12.8       12.5
  V(I)            8.60      11.35      13.93      17.00      17.37

X STA.        12.1       13.5       14.9       15.9       16.8       17.7
  A(I)            13.0       14.5       11.5       10.6       10.4
  V(I)           16.66      15.03      18.93      20.59      20.87

X STA.        17.7       18.6       19.5       20.5       21.6       22.6
  A(I)            10.5       10.5       10.9       10.9       11.1
  V(I)           20.79      20.66      19.92      19.98      19.61

X STA.        22.6       23.8       25.1       26.6       28.5       32.5
  A(I)            11.8       12.2       13.5       16.0       24.9
  V(I)           18.35      17.83      16.11      13.61       8.73

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.48   -94.6    50.1   197.6    9108.    1050.   5.31

X STA.       -94.6      -77.8      -71.3      -65.8      -61.0      -56.8
  A(I)            13.2        9.4        8.6        8.2        7.7
  V(I)            3.99       5.58       6.12       6.41       6.80

X STA.       -56.8      -52.9      -49.3      -46.0      -42.8      -39.7
  A(I)             7.4        7.1        6.9        6.8        6.7
  V(I)            7.08       7.34       7.57       7.69       7.88

X STA.       -39.7      -36.2      -32.7      -28.8      -24.7      -20.1
  A(I)             7.0        6.9        7.3        7.2        7.7
  V(I)            7.55       7.62       7.21       7.24       6.85

X STA.       -20.1      -15.0       -4.9        9.7       24.2       50.1
  A(I)             8.0       13.9       17.5       17.8       22.3
  V(I)            6.59       3.77       3.00       2.95       2.35

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      524     51261    122    123                           6161
           2      903    117944     77     85                          17549
   501.72          1427    169205    199    208  1.05   -135     63    21140

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.72  -135.9    63.2  1427.1  169205.    5400.   3.78

X STA.      -135.9     -103.7      -76.9      -57.6      -41.6      -27.2
  A(I)           105.4       96.9       86.6       80.3       77.5
  V(I)            2.56       2.79       3.12       3.36       3.48

X STA.       -27.2      -14.4       -2.5        3.0        7.1       11.0
  A(I)            73.9       89.3       70.3       57.9       55.8
  V(I)            3.65       3.02       3.84       4.66       4.84

X STA.        11.0       14.7       18.2       21.6       24.9       28.3
  A(I)            55.2       53.4       53.4       54.0       54.0
  V(I)            4.89       5.06       5.06       5.00       5.00

X STA.        28.3       31.9       36.1       41.4       48.1       63.2
  A(I)            57.2       60.6       67.2       74.0      104.1
  V(I)            4.72       4.45       4.02       3.65       2.59
```

WSPRO OUTPUT FILE (continued)

```
U.S. Geological Survey WSPRO Input File belv011.wsp
Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
   *** RUN DATE & TIME: 06-09-97  14:03

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      235     15930     31     46                         3680
493.74           235     15930     31     46  1.00      2     32     3680

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    493.74     1.5    32.4   235.0   15930.    3670.  15.61

X STA.         1.5        5.8        8.7        9.9       11.1       12.3
  A(I)            20.8       18.1       11.8       10.8       10.5
  V(I)            8.83      10.13      15.52      16.92      17.46

X STA.        12.3       13.8       15.1       16.0       16.8       17.7
  A(I)            11.9       12.2        9.5        9.0        8.8
  V(I)           15.46      15.09      19.29      20.43      20.74

X STA.        17.7       18.6       19.5       20.5       21.5       22.6
  A(I)             8.9        9.2        9.0        9.4        9.6
  V(I)           20.71      20.00      20.34      19.62      19.19

X STA.        22.6       23.7       25.0       26.5       28.4       32.4
  A(I)            10.0       10.5       11.3       13.6       20.2
  V(I)           18.38      17.48      16.23      13.45       9.08

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      135      5586    116    116                          830
          2      653     71153     75     81                        10945
498.45           788     76739    191    197  1.17   -128     61     8395

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      49.

      WSEL     LEW     REW    AREA        K        Q    VEL
    498.45  -129.5    61.0   788.3   76739.    3670.   4.66

X STA.      -129.5      -26.5       -5.0        1.1        4.5        7.5
  A(I)           103.3       66.8       47.3       35.5       32.8
  V(I)            1.78       2.75       3.88       5.16       5.60

X STA.         7.5       10.3       13.0       15.5       18.0       20.2
  A(I)            31.6       30.1       30.1       29.3       28.2
  V(I)            5.81       6.10       6.10       6.25       6.50

X STA.        20.2       22.5       24.7       27.0       29.4       31.7
  A(I)            28.4       28.5       28.7       29.7       30.0
  V(I)            6.47       6.45       6.39       6.19       6.13

X STA.        31.7       34.5       37.9       42.2       47.7       61.0
  A(I)            32.3       35.9       37.7       42.5       59.6
  V(I)            5.68       5.11       4.86       4.31       3.08
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File belv011.wsp
        Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
        Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
           *** RUN DATE & TIME: 06-09-97  14:03

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

EXIT1:XS   ******     -3      295  2.38 *****  493.94  491.43    3650  491.55
       -28 ******     54    19302  1.00 ***** *******    0.96   12.38

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.55

FULLV:FV       29     -5      400  1.30  0.67  494.60 *******    3650  493.30
         0     29     57    29903  1.00  0.00   -0.01    0.64    9.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85     493.83     493.17

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.80     507.94    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.80     507.94     493.17

APPRO:AS       49     -6      328  1.92  0.84  495.75  493.17    3650  493.83
        49     49     55    25897  1.00  0.31    0.00    0.85   11.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3650.     493.71

           <<<<<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       29      2      234  3.78 *****  497.49  493.71    3650  493.71
         0     29     32    15848  1.00 ***** *******    1.00   15.58

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.11 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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       31   -128      780  0.40  0.36  498.81  493.17    3650  498.41
        49     33     61    75836  1.17  0.95    0.00    0.44    4.68

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.501  0.324   51332.     6.    36.   498.32

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -29.    -4.    54.   3650.   19302.     295.   12.38  491.55
   FULLV:FV       0.    -6.    57.   3650.   29903.     400.    9.13  493.30
   BRIDG:BR       0.     2.    32.   3650.   15848.     234.   15.58  493.71
   RDWAY:RG       8.**************      0.****************    2.00********
   APPRO:AS      49.  -129.    61.   3650.   75836.     780.    4.68  498.41

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    36.   51332.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.43    0.96  484.15  512.06************  2.38  493.94  491.55
   FULLV:FV  ********    0.64  484.15  512.06  0.67  0.00  1.30  494.60  493.30
   BRIDG:BR    493.71    1.00  483.11  498.20************  3.78  497.49  493.71
   RDWAY:RG  ***************  499.31  527.30**********************************
   APPRO:AS    493.17    0.44  485.75  507.94  0.36  0.95  0.40  498.81  498.41
```

WSPRO OUTPUT FILE (continued)

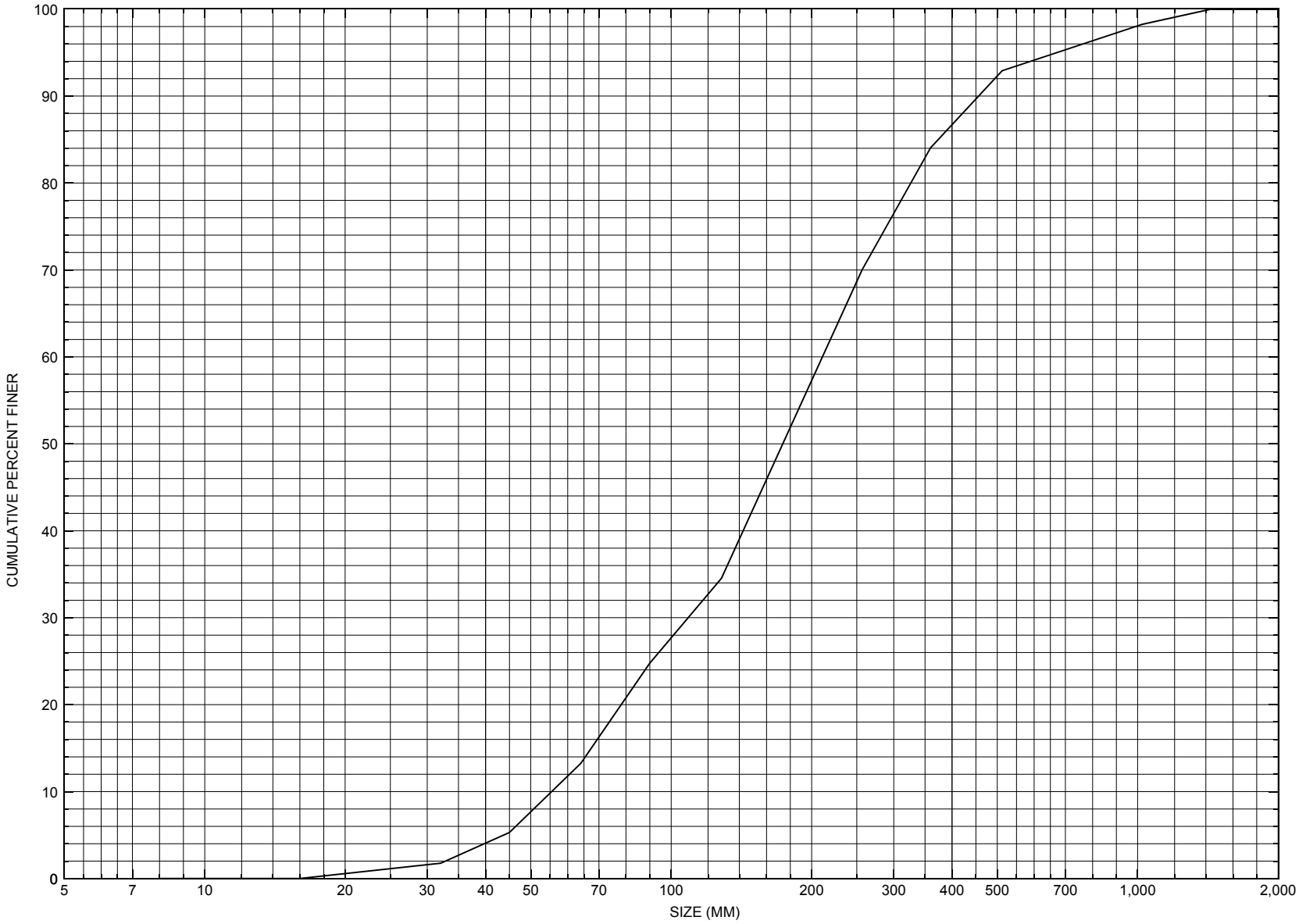
```
        U.S. Geological Survey WSPRO Input File belv011.wsp
        Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
        Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
           *** RUN DATE & TIME: 06-09-97  14:03

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

EXIT1:XS   ******     -4      387  3.03 *****  496.12  493.04    5400  493.10
       -28 ******     57    28557  1.00 ***** *******    0.99   13.95

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.52

FULLV:FV       29     -7      520  1.68  0.68  496.79 *******    5400  495.11
         0     29     61    43280  1.00  0.00   -0.02    0.67   10.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     495.66     494.83
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.61     507.94    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.61     507.94     494.83

APPRO:AS       49    -12      449  2.25  0.83  497.90  494.83    5400  495.65
        49     49     57    39850  1.00  0.28    0.00    0.84   12.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.54       0.00     496.01     499.31
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   504.91         0.      5400.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       29      0      373  2.11 *****  500.22  494.67    4348  498.11
         0 ******     33    25535  1.00 ***** *******    0.61   11.66

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.475 ******  498.11 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    36.  0.04  0.23  501.92    0.00   1050.  501.48

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    895.   112.   -95.    18.   2.2   1.5   6.2   5.3   1.9   3.0
   RT:    155.    32.    18.    50.   1.3   0.9   5.2   5.1   1.4   3.0

===140 AT SECID "APPRO":  END OF CROSS SECTION EXTENDED VERTICALLY.
                              WSEL,YLT,YRT =   501.72      507.9      500.0

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

APPRO:AS       31   -135     1427  0.23  0.18  501.95  494.83    5400  501.72
        49     33     63   169191  1.05  0.00    0.00    0.26    3.78

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -29.    -5.    57.   5400.   28557.     387.   13.95  493.10
   FULLV:FV       0.    -8.    61.   5400.   43280.     520.   10.39  495.11
   BRIDG:BR       0.     0.    33.   4348.   25535.     373.   11.66  498.11
   RDWAY:RG       8.*******   895.   1050.*****************    2.00  501.48
   APPRO:AS      49.  -136.    63.   5400.  169191.    1427.    3.78  501.72

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    493.04    0.99  484.15  512.06************  3.03  496.12  493.10
   FULLV:FV  ********    0.67  484.15  512.06  0.68  0.00  1.68  496.79  495.11
   BRIDG:BR    494.67    0.61  483.11  498.20************  2.11  500.22  498.11
   RDWAY:RG  ****************  499.31  527.30  0.04******  0.23  501.92  501.48
   APPRO:AS    494.83    0.26  485.75  507.94  0.18  0.00  0.23  501.95  501.72
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File belv011.wsp
        Hydraulic analysis for structure BELVTH00080011   Date: 22-MAY-97
        Town Highway 8 over the North Branch Lamoille River, Belvidere, VT  EB
           *** RUN DATE & TIME: 06-09-97  14:03

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

EXIT1:XS   ******     -3      296  2.39 *****  493.96  491.45    3670  491.57
       -28 ******     54    19407  1.00 ***** *******    0.96   12.40

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.55

FULLV:FV       29     -5      401  1.30  0.67  494.62 *******    3670  493.32
         0     29     57    30054  1.00  0.00   -0.01    0.64    9.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85     493.85     493.21

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.82     507.94    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.82     507.94     493.21

APPRO:AS       49     -6      330  1.93  0.84  495.78  493.21    3670  493.85
        49     49     55    26052  1.00  0.31    0.00    0.85   11.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3670.     493.74

           <<<<<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       29      2      235  3.79 *****  497.53  493.74    3670  493.74
         0     29     32    15939  1.00 ***** *******    1.00   15.61

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.11 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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       31   -128      788  0.40  0.36  498.84  493.21    3670  498.45
        49     33     61    76701  1.17  0.95    0.00    0.44    4.66

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.502  0.327   51646.     6.    36.   498.36

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -29.    -4.    54.   3670.   19407.     296.   12.40  491.57
   FULLV:FV       0.    -6.    57.   3670.   30054.     401.    9.15  493.32
   BRIDG:BR       0.     2.    32.   3670.   15939.     235.   15.61  493.74
   RDWAY:RG       8.**************      0.****************    2.00********
   APPRO:AS      49.  -129.    61.   3670.   76701.     788.    4.66  498.45

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    36.   51646.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.45    0.96  484.15  512.06************  2.39  493.96  491.57
   FULLV:FV  ********    0.64  484.15  512.06  0.67  0.00  1.30  494.62  493.32
   BRIDG:BR    493.74    1.00  483.11  498.20************  3.79  497.53  493.74
   RDWAY:RG  ***************  499.31  527.30**********************************
   APPRO:AS    493.21    0.44  485.75  507.94  0.36  0.95  0.40  498.84  498.45
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BELVTH00080011, in Belvidere, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BELVTH00080011

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 015

Town *(FIPS place code; I - 4; nnnnn)* 04375

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

Waterway *(I - 6)* North Branch Lamoille River

Road Name *(I - 7)*: -

Route Number TH 8

Vicinity *(I - 9)* 0.05 MI JCT TH 8 + VT109

Topographic Map Cold Hollow Mountains

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44451

Longitude *(i - 17; nnnnn.n)* 72411

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10080100110801

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

Maximum span length *(I - 48; nnnn)* 0037

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000040

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

Deck Width *(I - 52; nn.n)* 126

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 5

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

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

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

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

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

Year Reconstructed *(I - 106)* 1958

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 12.6

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

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

Comments:

The structural inspection report of 6/21/93 indicates the structure is a steel stringer type bridge with a concrete deck. The abutments are "laid-up" stone with concrete caps. The wingwalls are also "laid-up" stone. The left abutment, the downstream left wingwall and a portion of the upstream left wingwall all have concrete facings. Boulder material along the base of the left abutment has been encased in the concrete facing. The right abutment has some free-poured concrete along its bottom. A few boulders under the right abutment have slid out from underneath creating voids, above which several stones of the abutment are cracked or broken. A few large boulders are present in front of both **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ 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 (*ft²*): -

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

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

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

Comments:

abutment walls and all of the wingwalls. Additional riprap protection is noted along the up- and downstream banks.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **23.41** mi^2 Lake/pond/swamp area **0.71** mi^2

Watershed storage *(ST)* **3.0** %

Bridge site elevation **925** ft Headwater elevation **2999** ft

Main channel length **10** mi

10% channel length elevation **1014** ft 85% channel length elevation **1844** ft

Main channel slope *(S)* **110.67** 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? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / -

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness _____ Footing bottom elevation: _____

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

If 3: Footing bottom elevation: -

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

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

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

Comments:
-

Cross-sectional Data

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

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

Comments: **The low cord elevations and the bed elevations were retrieved from the FEMA cross sections.**

Station	200	200.1	205	213	221	227	228	233	233.1	-	-
Feature	LB								RB	-	-
Low cord elevation	895.3	904.8	904.8	904.8	904.8	904.8	904.8	904.8	895.9	-	-
Bed elevation	895.3	895.3	893.6	892.4	891.6	892.6	893.6	895.9	895.9	-	-
Low cord to bed length	0	9.5	11.2	12.4	13.2	12.2	11.2	8.9	0	-	-

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: 03/15/96
Computerized by: RB Date: 03/18/96
Reviewd by: EMB Date: 5/23/97

Structure Number BELVTH00080011

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 06 / 27 / 1995

2. Highway District Number 08
Mile marker 0000
County LAMOILLE (015)
Town BELVIDERE (04375)
Waterway *(I - 6)* North Branch Lamoille River
Road Name -
Route Number TH 8
Hydrologic Unit Code: 02010005

3. Descriptive comments:
This site is located about 0.05 mile from the intersection of TH08 with VT 109. The left abutment is cemented over. The right abutment is stone.

B. Bridge Deck Observations

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

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

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

7. Bridge length 40 *(feet)* Span length 37 *(feet)* Bridge width 12.6 *(feet)*

Road approach to bridge:

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

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

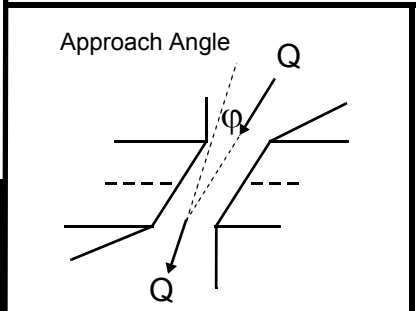
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

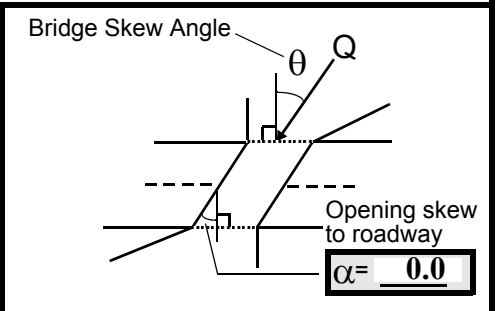
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	3	1	0	-
RBDS	0	-	2	1
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 35 16. Bridge skew: 35





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 14 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 100 feet DS *(US, UB, DS)* to 145 feet DS

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

18. Bridge Type: **1b/1a**

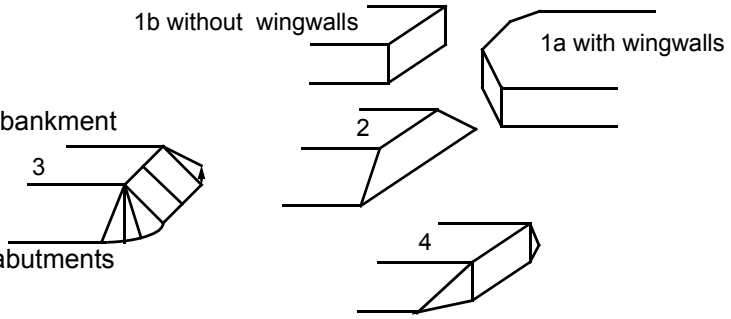
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The right abutment has no wingwalls and is made of stone with a concrete bridge seat. The left abutment has a concrete cap and angled wingwalls.
Each of the US left bank, US right bank, and DS left bank has a house, a gravel driveway, and a lawn yard. The house on the US right bank sits very high on the bank. The immediate banks have trees and shrubs. There is an additional moderate channel impact on the right road approach embankment from 0 to 30 feet upstream.

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
47.0	4.5			13.0	3	4	432	543	0	1

23. Bank width **55.0** 24. Channel width **25.0** 25. Thalweg depth **66.5** 29. Bed Material **543**

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

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

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

There is a minor inflow flowing along the US left road approach and down along the wingwall.

33. Point/Side bar present? Y *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: 100 35. Mid-bar width: 20

36. Point bar extent: 40 feet US *(US, UB)* to 215 feet US *(US, UB, DS)* positioned 60 %LB to 100 %RB

37. Material: 453

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

Point bar grades to smaller particles going DS.

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

41. Mid-bank distance: 132 42. Cut bank extent: 85 feet US *(US, UB)* to 180 feet US *(US, UB, DS)*

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

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

-

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR

49. Are there major confluences? N *(Y or if N type ctrl-n mc)* 50. How many? -

51. Confluence 1: Distance - 52. Enters on - *(LB or RB)* 53. Type - *(**1**- perennial; **2**- ephemeral)*

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB _____ *(**1**- natural bank; **2**- abutment; **3**- artificial levee)*

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
34.5		1.5		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.):

5

There is some free-poured concrete covering and protecting the streambed at the bottom of the right abutment wall, particularly at the upstream end.

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

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

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

70. Debris and Ice Comments:

2

The bridge and boulders constrict the channel as much as 50% in width but the high gradient, straight alignment and the high bridge deck should reduce ice blockage.

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		30	90	2	0	-	-	90.0
RABUT	2	-	90			2	0	32.5

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

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

-

-

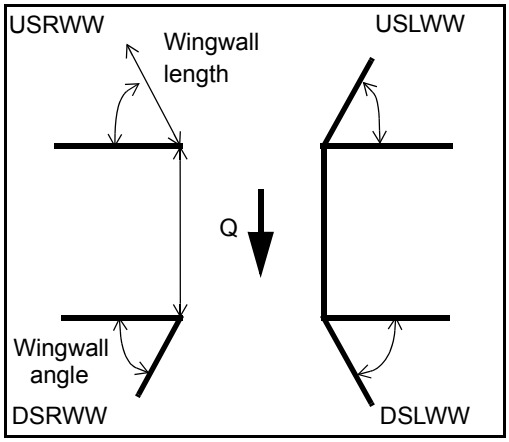
2

The abutments are not parallel. They are each angled inward towards the DS end relative to the bridge deck a few degrees creating a greater DS constriction.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						32.5	
USRWW:	Y		12		0	3.0	
DSLWW:	-		-		N	16.5	
DSRWW:	-		-		-	15.0	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	N	-	1	-	1	2
Condition	Y	-	-	-	1	-	1	1
Extent	1	-	-	3	-	3	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*

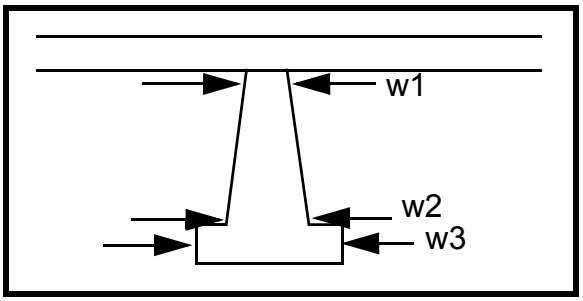
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
3
1
1
-
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		5.0	-	60.0	-	30.0
Pier 2		-	-	12.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e abut-	there-	as		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	ment	fore	oppo		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	walls	the	sed		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	are	pro-	to	N	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	mold	tec-	stone	-	*Y- yes; N- no*
91. Attack ∠ (BF)	ed	tion	fill.	-	
92. Pushed	into	may		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	the	be		-	
95. Cross-members	pro-	nativ		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	tec-	e		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	tion	boul-		-	
98. Exposure depth	and	ders		-	

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) - Thalweg depth (Amb) - Bed Material -

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-

NO PIERS

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

Point bar extent: _____ feet ____ *(US, UB, DS)* to _____ feet 3___ *(US, UB, DS)* positioned 4___ %LB to 543 %RB

Material: 432

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

-
-
543
-

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

Cut bank extent: Ther feet e is *(US, UB, DS)* to bed- feet roc *(US, UB, DS)*

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

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

on the left bank from 100-145 feet DS. There are tree roots exposed on both banks.

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

Scour dimensions: Length _____ Width _____ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

Confluence 1: Distance NO Enters on DR *(LB or RB)* Type OP *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

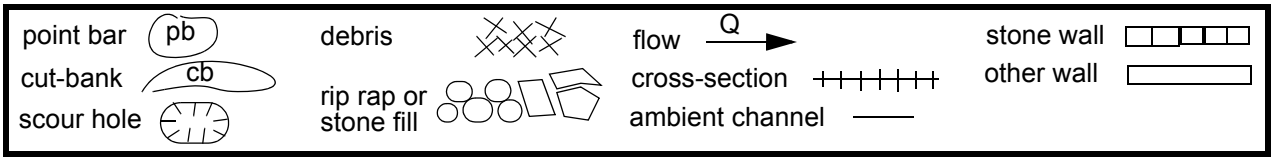
__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

Y
165
27
85
DS
230
DS
40
100
543

109. G. Plan View Sketch

- T



APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BELVTH00080011 Town: Belvidere
Road Number: TH 8 County: Lamoille
Stream: North Branch Lamoille River

Initials EMB Date: 6/9/97 Checked: SAO 6/12/97

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	3650	5400	3670
Main Channel Area, ft2	650	903	653
Left overbank area, ft2	131	524	135
Right overbank area, ft2	0	0	0
Top width main channel, ft	75	77	75
Top width L overbank, ft	116	122	116
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.5659	0.5659	0.5659
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.7	11.7	8.7
y1, average depth, LOB, ft	1.1	4.3	1.2
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	75924	169205	76739
Conveyance, main channel	70650	117944	71153
Conveyance, LOB	5274	51261	5586
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3396.5	3764.1	3402.9
Ql, discharge, LOB, cfs	253.5	1635.9	267.1
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	5.2	4.2	5.2
Vl, mean velocity, LOB, ft/s	1.9	3.1	2.0
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	13.3	14.0	13.3
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

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

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	3650	5400	3670
Main channel area (DS), ft2	234	278	235
Main channel width (normal), ft	30.9	32.7	30.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	30.9	32.7	30.9
D90, ft	1.4950	1.4950	1.4950
D95, ft	2.1940	2.1940	2.1940
Dc, critical grain size, ft	1.4420	2.1160	1.4425
Pc, Decimal percent coarser than Dc	0.109	0.053	0.109
Depth to armoring, ft	35.36	113.88	35.37

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3650	5400	3670
(Q) discharge thru bridge, cfs	3650	5400	3670
Main channel conveyance	15840	25535	15930
Total conveyance	15840	25535	15930
Q2, bridge MC discharge,cfs	3650	5400	3670
Main channel area, ft2	234	373	235
Main channel width (normal), ft	30.9	32.7	30.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.9	32.7	30.9
y_bridge (avg. depth at br.), ft	7.57	11.41	7.61
Dm, median (1.25*D50), ft	0.707375	0.707375	0.707375
y2, depth in contraction,ft	8.16	10.88	8.20
ys, scour depth (y2-ybridge), ft	0.59	-0.53	0.60

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc Cf=1.5*Fr^0.43 (<=1) Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	3650	5400	3670
Q, thru bridge MC, cfs	3650	5400	3670
Vc, critical velocity, ft/s	13.29	13.98	13.30
Va, velocity MC approach, ft/s	5.23	4.17	5.21
Main channel width (normal), ft	30.9	32.7	30.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.9	32.7	30.9
qbr, unit discharge, ft2/s	118.1	165.1	118.8
Area of full opening, ft2	234.0	373.0	235.0
Hb, depth of full opening, ft	7.57	11.41	7.61
Fr, Froude number, bridge MC	0	0.61	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	278	N/A
**Hb, depth at downstream face, ft	N/A	8.50	N/A
**Fr, Froude number at DS face	ERR	1.17	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	498.11	0
Elevation of Bed, ft	-7.57	486.70	-7.61
Elevation of Approach, ft	0	501.72	0
Friction loss, approach, ft	0	0.18	0
Elevation of WS immediately US, ft	0.00	501.54	0.00
ya, depth immediately US, ft	7.57	14.84	7.61
Mean elevation of deck, ft	0	500.25	0
w, depth of overflow, ft (>=0)	0.00	1.29	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	1	ERR
Ys, scour w/Chang equation, ft	N/A	0.93	N/A
Ys, scour w/Umbrell equation, ft	N/A	-3.94	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	N/A	3.31	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-1.04	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen
equation results and the estimated downstream bridge face properties
can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	8.16	10.88	8.20
WSEL at downstream face, ft	--	495.11	--
Depth at downstream face, ft	N/A	8.50	N/A
Ys, depth of scour (Laursen), ft	N/A	2.38	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	3650	5400	3670	3650	5400	3670
a', abut.length blocking flow, ft	130.9	135.9	131	28.6	30.5	28.6
Ae, area of blocked flow ft2	215.6	496	221.6	199.5	279.4	199.9
Qe, discharge blocked abut.,cfs	547.5	--	572.1	871.9	--	871.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.54	3.14	2.58	4.37	3.49	4.36
ya, depth of f/p flow, ft	1.65	3.65	1.69	6.98	9.16	6.99
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--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	0.349	0.254	0.350	0.292	0.198	0.291
ys, scour depth, ft	12.23	17.60	12.46	20.67	22.15	20.67

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)	130.9	135.9	131	28.6	30.5	28.6
y1 (depth f/p flow, ft)	1.65	3.65	1.69	6.98	9.16	6.99
a'/y1	79.48	37.24	77.44	4.10	3.33	4.09
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.35	0.25	0.35	0.29	0.20	0.29
Ys w/ corr. factor K1/0.55:						
vertical	8.46	16.89	8.70	ERR	ERR	ERR
vertical w/ ww's	6.94	13.85	7.13	ERR	ERR	ERR
spill-through	4.65	9.29	4.78	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	1	1	1	1
y, depth of flow in bridge, ft	7.57	8.50	7.61	7.57	8.50	7.61
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	3.17	3.55	3.18	3.17	3.55	3.18