LEVEL II SCOUR ANALYSIS FOR BRIDGE 9 (BLOOVT01020009) on STATE ROUTE 102, crossing the NULHEGAN RIVER, BLOOMFIELD, VERMONT

U.S. Geological Survey
Open-File Report 97-389

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

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By JOSEPH D. AYOTTE

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 9 (BLOOVT01020009) ON STATE ROUTE 102, CROSSING THE NULHEGAN RIVER, BLOOMFIELD, VERMONT

By **Joseph D. Ayotte**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BLOOVT01020009 on State Route 102 crossing the Nulhegan River, Bloomfield, 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 White Mountain section of the New England physiographic province in northeastern Vermont. The 144-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest except for the downstream right bank area which is shrub and brush land. The Nulhegan River flows into the Connecticut River 210 feet downstream of this bridge.

In the study area, the Nulhegan River has an incised, sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 164 ft and an average channel depth of 5 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 152 mm (0.498 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 6, 1995, indicated that the reach was laterally unstable. This was due to numerous point bars and side bars indicating an unstable thalweg.

The State Route 102 crossing of the Nulhegan River is a 134-ft-long, two-lane bridge consisting of one 130-foot steel-truss span (Vermont Agency of Transportation, written communication, August 4, 1994). The field measured clear span was 131.6 ft. The bridge is supported by vertical, concrete abutments with rip-rapped spill-through slopes. The channel is skewed approximately 25 degrees to the opening while the measured opening-skew-to-roadway is 5 degrees.

A scour hole 3.5 ft deeper than the mean thalweg depth was observed 250 ft upstream during the Level I assessment. It was noted that the scour was localized on the right bank side and due to the presence of an old abutment. Scour countermeasures include the type-3 stone-fill (less than 48 inches diameter) which forms the spill-through slopes of the abutments. Additional details describing conditions at the site are included in the Level II Summary and Appendices
D and E.

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

Computed contraction scour for all modelled flows was zero ft. Abutment scour ranged from 4.5 to 5.0 ft at the left abutment and 9.6 to 11.4 ft at the right abutment. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich 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.

Bloomfield, VT.-N.H. Quadrangle, 1:24,000, 1988

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 BLOOVT01020009 ***Stream*** Nulhegan River

County Essex ***Road*** VT 102 ***District*** 9

Description of Bridge

Bridge length 134 ***ft*** ***Bridge width*** 24.4 ***ft*** ***Max span length*** 130 ***ft***

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

Abutment type spill-through ***Embankment type*** sloping

Stone fill on abutment? Yes ***Date of inspection*** 07/06/95

There are spill-through slopes at each abutment consisting of type-3 stone-fill.

Abutments are vertical concrete with rip-rapped spill-through slopes.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 25

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	07/06/95	0	0
Level II	07/06/95	0	0

Potential for debris Moderate, but it is noted that the capture efficiency of the bridge is low.

Describe any features near or at the bridge that may affect flow (include observation date) July 6, 1995. The confluence with the Connecticut River is 210 ft downstream.

Description of the Geomorphic Setting

General topography The channel is located within a 1000 foot-wide, moderate relief valley at the confluence with the Connecticut River with moderate valley walls.

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

Date of inspection 07/06/95

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Moderately sloped overbank

US right: Steep bank to over bank

Description of the Channel

Average top width 164 ***ft*** ***Average depth*** 5 ***ft***

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

Sinuous with semi-alluvial to alluvial channel boundaries and a moderately wide flood plain.

Vegetative co 07/06/95

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right: Shrubs and brush

Do banks appear stable? N

On 07/06/95, moderate fluvial erosion was noted along the downstream right bank. Bank cutting is occurring along the left bank from 71 ft upstream of the bridge to 145 ft downstream.

date of observation.

Describe any obstructions in channel and date of observation. The assessment of 07/06/95 noted large cobble point bars in the US and DS reaches as well as under the bridge.

Hydrology

Drainage area 144 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

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

Is there a lake/p No

Calculated Discharges

Q100 8,330 ***ft***^{3}***/s*** ***Q500*** 10,700 ***ft***^{3}***/s***

The 100- and 500-year discharges were the median of several empirical methods for estimating flood frequencies (Benson, 1962; Johnson and Tasker, 1974; Potter, 1957a&b; Talbot, 1887) applicable to this site.The flood frequency curves developed for this site were graphically extrapolated to the 500-year return period.

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 Add 1.0 ft to USGS datum to obtain VTAOT datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 195.96 ft, VTAOT survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 195.87 ft, VTAOT survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-90	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	155	2	Modelled Approach section (Templated from APTEM)
APTEM	175	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 0.040 to 0.060, and overbank "n" values ranged from 0.040 to 0.080.

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 0.005 ft/ft, which was estimated from surveyed channel thalweg points between the bridge and the exit sections. This slope matched the channel slope upstream of the bridge measured from the topographical map (USGS, 1988).

Using normal depth as the starting water-surface ignores the effects of backwater from the Connecticut River, 210 ft downstream. However, due to the difference in drainage areas at the confluence and the significant storage in the Connecticut River basin, the extent of backwater from the Connecticut River while the Nulhegan River is at a peak discharge is unknown. Thus, normal depth is appropriate.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.011 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 195.5 *ft*
Average low steel elevation 191.0 *ft*

100-year discharge 8,330 *ft³/s*
Water-surface elevation in bridge opening 187.9 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 746 *ft²*
Average velocity in bridge opening 11.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.4 *ft/s*

Water-surface elevation at Approach section with bridge 190.2
Water-surface elevation at Approach section without bridge 189.6
Amount of backwater caused by bridge 0.6 *ft*

500-year discharge 10,700 *ft³/s*
Water-surface elevation in bridge opening 188.3 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 791 *ft²*
Average velocity in bridge opening 13.5 *ft/s*
Maximum WSPRO tube velocity at bridge 16.2 */s*

Water-surface elevation at Approach section with bridge 191.6
Water-surface elevation at Approach section without bridge 190.3
Amount of backwater caused by bridge 1.3

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). In this case, computed contraction scour was zero feet for both of the modelled discharges.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	4.3	16.5	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	4.5	5.0	--
Right abutment	9.6	11.4	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.3	2.7	--
Right abutment	2.3	2.7	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

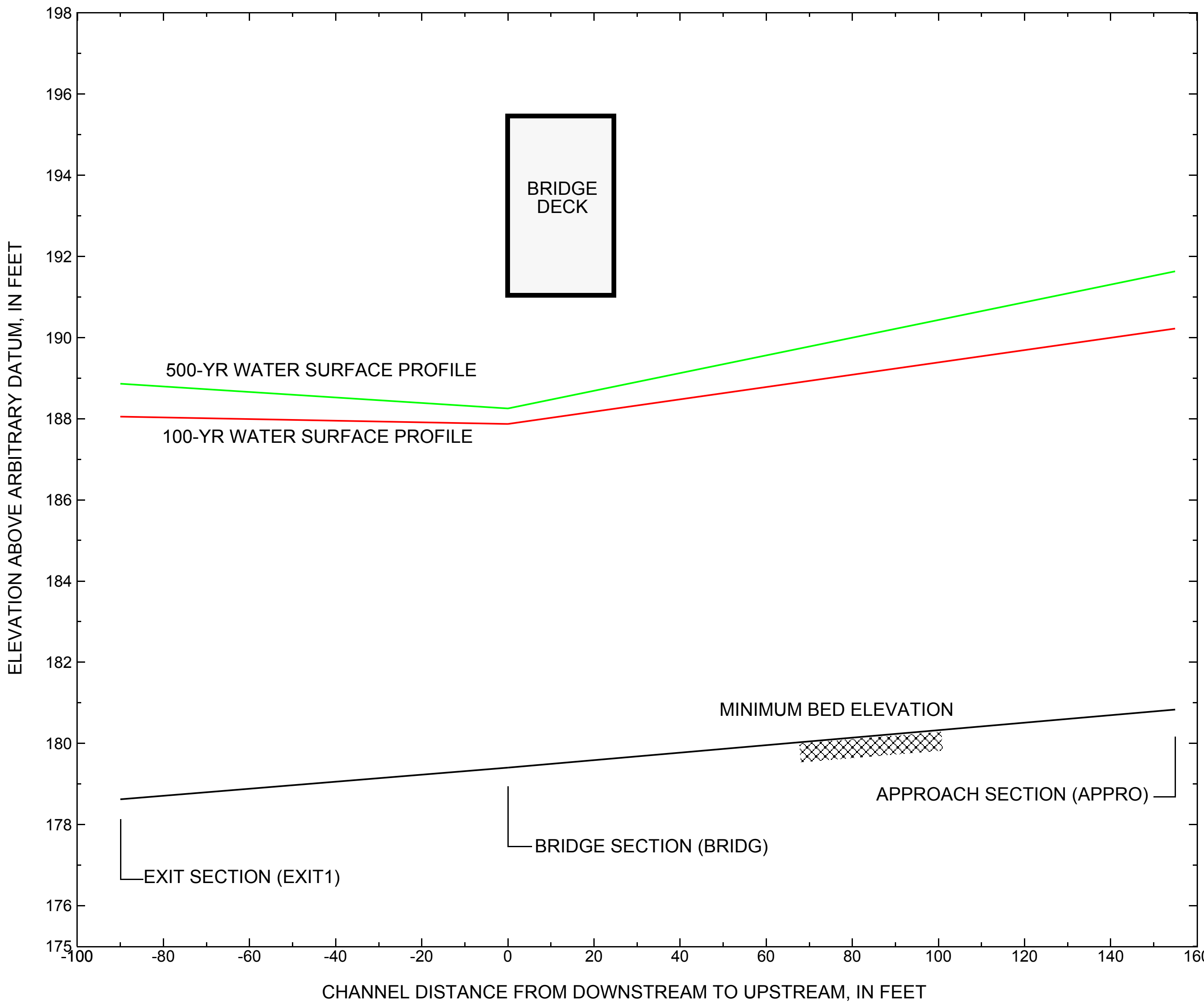

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BLOOVT01020009 on State Route 102, crossing the Nulhegan River, Bloomfield, Vermont.

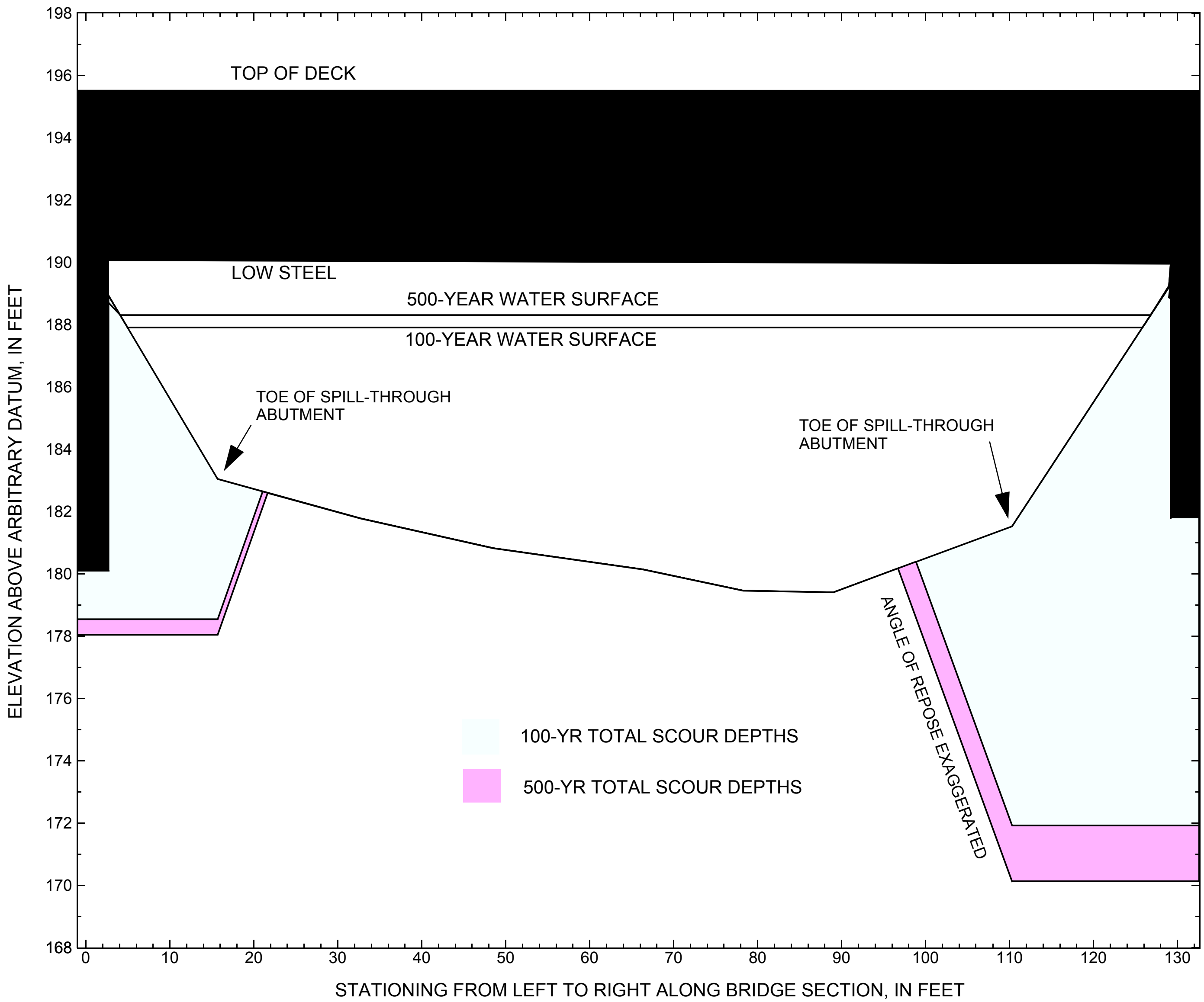

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BLOOVT01020009 on State Route 102, crossing the Nulhegan River, Bloomfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BLOOVT01020009 on State Route 102, crossing the Nulhegan River, Bloomfield, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT bridge seat 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 8,330 cubic-feet per second											
Left abutment	0.0	191.1	190.1	180.1	--	--	--	--	--	--	-1.6
Toe of spill-thru	15.7	--	--	--	183.0	0.0	4.5	--	4.5	178.5	-1.6
Toe of spill-thru	110.3	--	--	--	181.5	0.0	9.6	--	9.6	171.9	-9.9
Right abutment	131.6	191.1	190.0	181.8	--	--	--	--	--	--	-9.9

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 BLOOVT01020009 on State Route 102, crossing the Nulhegan River, Bloomfield, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT bridge seat 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 10,700 cubic-feet per second											
Left abutment	0.0	191.1	190.1	180.1	--	--	--	--	--	--	-2.1
Toe of spill-thru	15.7	--	--	--	183.0	0.0	5.0	--	5.0	178.0	-2.1
Toe of spill-thru	110.3	--	--	--	181.5	0.0	11.4	--	11.4	170.1	-11.7
Right abutment	131.6	191.1	190.0	181.8	--	--	--	--	--	--	-11.7

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, 1988, Bloomfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File bloo009.wsp
T2        Hydraulic analysis for structure BLOOVT01020009   Date: 11-APR-96
T3        Bloomfield Br 9, crossing Nulhegan R., VT Rte 102          JDA
Q           8330.0  10700.0
SK          0.005   0.005
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXIT1    -90           0.
GR         -200.0, 188.48    -41.9, 187.16     -6.1, 183.38     11.7, 181.36
GR           42.1, 180.84     45.0, 180.71     59.0, 180.29     76.7, 179.64
GR           86.0, 178.88     99.0, 178.62    109.7, 180.68    114.0, 182.20
GR          118.7, 186.09    167.9, 188.08    194.0, 193.57    356.2, 192.88
GR          449.6, 194.72    559.7, 198.85
N           0.040        0.045        0.040
SA                -41.9        118.7
*
*
XS   FULLV      0  * * *   0.005
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    190.98       5.0
GR            0.0, 191.08      0.0, 190.07      1.7, 190.12      2.6, 190.10
GR            2.7, 188.93     15.7, 183.04     32.7, 181.77     48.5, 180.82
GR           66.4, 180.13     78.3, 179.45     89.0, 179.40    103.3, 180.83
GR          110.3, 181.52    129.0, 189.20    129.2, 189.94    129.9, 189.96
GR          131.6, 189.95    131.6, 190.88      0.0, 191.08
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      23.6      2.2    195.5
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      24.4     1
GR         -584.9, 209.54   -568.3, 201.56   -355.1, 198.68   -289.1, 194.00
GR         -244.5, 193.03   -190.7, 192.14   -149.7, 193.92   -138.6, 196.98
GR         -105.6, 197.44    -49.3, 197.63      1.1, 197.67    133.0, 197.54
GR          143.1, 197.87    143.4, 195.40    180.4, 195.66    183.0, 196.90
GR          237.1, 206.02    297.2, 214.24
*
*
XT   APTEM    175
GR         -323.5, 199.31   -258.2, 195.80   -194.9, 192.72    -13.1, 189.48
GR            8.9, 186.27     12.0, 183.43     30.4, 181.86     52.7, 181.13
GR           69.6, 181.05    107.1, 183.19    111.5, 185.29    131.2, 186.84
GR          178.0, 208.02
*
AS   APPRO    155  * * * 0.011
GT
N           0.080        0.060
SA                -13.1
*
HP 1 BRIDG    187.87 1 187.87
HP 2 BRIDG    187.87 * * 8330
HP 1 APPRO    190.22 1 190.22
HP 2 APPRO    190.22 * * 8330
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File bloo009.wsp
        Hydraulic analysis for structure BLOOVT01020009   Date: 11-APR-96
        Bloomfield Br 9, crossing Nulhegan R., VT Rte 102          JDA

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     745.   92408.   120.   123.                      10531.
   187.87          745.   92408.   120.   123.  1.00     5.   126.  10531.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       187.87     5.0   125.8   745.4   92408.    8330.  11.17
X STA.         5.0        22.1       30.0       36.5       42.3       47.6
  A(I)             58.1        44.2       39.4       37.7       35.8
  V(I)             7.16        9.43      10.57      11.05      11.63

X STA.        47.6        52.6       57.3       61.9       66.2       70.4
  A(I)             35.3        34.4       34.2       32.8       32.6
  V(I)            11.80       12.12      12.17      12.70      12.78

X STA.        70.4        74.4       78.1       81.9       85.6       89.4
  A(I)             32.3        31.2       31.9       31.1       32.0
  V(I)            12.90       13.37      13.06      13.38      13.00

X STA.        89.4        93.5       97.9      102.9      108.9      125.8
  A(I)             33.3        34.3       36.2       40.7       58.0
  V(I)            12.50       12.15      11.51      10.23       7.18

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      26.     295.    54.    54.                        102.
             2    1014.   88130.   152.   155.                      14859.
   190.22         1040.   88425.   206.   209.  1.04   -67.   139.  12997.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
         WSEL     LEW     REW    AREA        K        Q    VEL
       190.22   -67.0   139.2  1040.3   88425.    8330.   8.01
X STA.       -67.0        13.2       21.2       27.6       33.1       38.4
  A(I)            107.9        59.8       51.5       47.2       46.6
  V(I)             3.86        6.97       8.09       8.83       8.95

X STA.        38.4        43.4       48.2       52.9       57.5       62.1
  A(I)             44.5        43.7       43.0       42.9       43.0
  V(I)             9.36        9.53       9.69       9.72       9.70

X STA.        62.1        66.6       71.1       75.8       80.8       86.2
  A(I)             42.3        42.3       43.4       44.3       46.1
  V(I)             9.85        9.84       9.60       9.41       9.03

X STA.        86.2        91.7       97.9      104.9      115.1      139.2
  A(I)             46.1        49.0       53.3       61.1       82.7
  V(I)             9.04        8.51       7.82       6.82       5.04
```

```
        U.S. Geological Survey WSPRO Input File bloo009.wsp
        Hydraulic analysis for structure BLOOVT01020009   Date: 11-APR-96
        Bloomfield Br 9, crossing Nulhegan R., VT Rte 102          JDA

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1     791.  101065.   122.   125.                        11438.
   188.25          791.  101065.   122.   125.  1.00     4.   127.  11438.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       188.25     4.2   126.7   791.5  101065.   10700.  13.52
X STA.          4.2        21.7        29.3        36.0        41.8        47.1
  A(I)             62.4        44.8        43.1        40.1        38.0
  V(I)             8.58       11.95       12.40       13.36       14.09

X STA.         47.1        52.2        56.9        61.5        65.9        70.1
  A(I)             37.4        36.4        35.4        35.6        34.3
  V(I)            14.31       14.70       15.12       15.02       15.61

X STA.         70.1        74.1        78.0        81.9        85.6        89.6
  A(I)             33.7        33.6        33.8        33.0        34.8
  V(I)            15.86       15.94       15.82       16.20       15.37

X STA.         89.6        93.6        98.1       103.1       109.2       126.7
  A(I)             34.6        36.4        38.5        43.5        62.2
  V(I)            15.48       14.68       13.89       12.31        8.60

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1     158.    3286.   133.   133.                          973.
             2    1231.  119962.   155.   158.                        19670.
   191.63         1389.  123248.   288.   291.  1.17  -146.   142.  15959.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
         WSEL     LEW     REW    AREA        K        Q    VEL
       191.63  -146.1   142.3  1388.9  123248.   10700.   7.70
X STA.       -146.1         2.3        15.0        22.5        28.7        34.5
  A(I)            211.5        81.1        67.0        59.6        58.3
  V(I)             2.53        6.60        7.99        8.98        9.18

X STA.         34.5        40.0        45.2        50.4        55.4        60.4
  A(I)             55.8        54.7        55.0        53.3        53.4
  V(I)             9.59        9.78        9.72       10.05       10.01

X STA.         60.4        65.4        70.4        75.4        80.8        86.6
  A(I)             53.7        53.8        53.5        56.0        57.2
  V(I)             9.96        9.94        9.99        9.55        9.35

X STA.         86.6        92.6        99.3       106.7       118.0       142.3
  A(I)             58.3        62.2        66.0        77.5       100.9
  V(I)             9.17        8.61        8.11        6.90        5.30
```

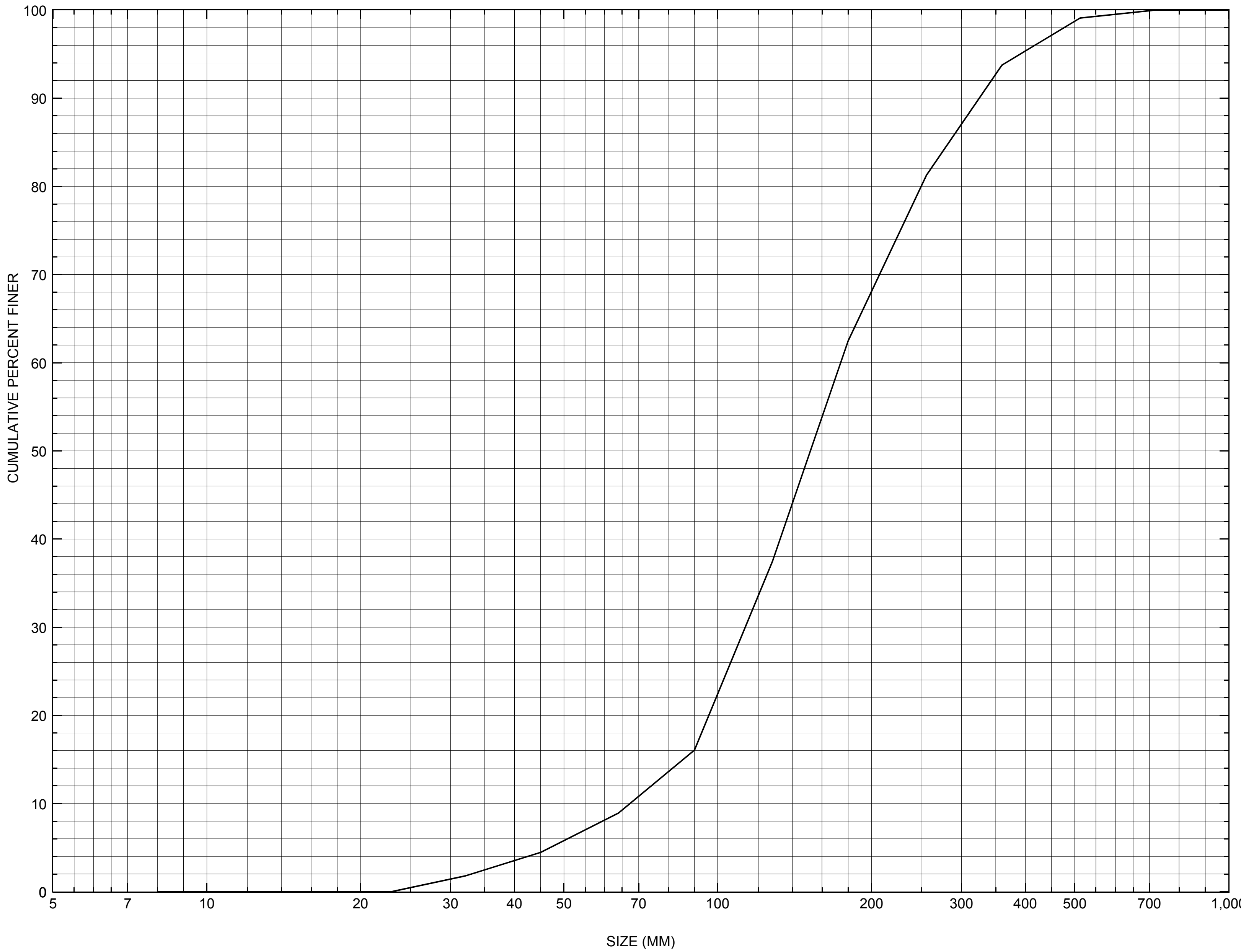
```
        U.S. Geological Survey WSPRO Input File bloo009.wsp
        Hydraulic analysis for structure BLOOVT01020009   Date: 11-APR-96
        Bloomfield Br 9, crossing Nulhegan R., VT Rte 102          JDA

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

EXIT1:XS   ******  -149.    1116.  0.96 *****  189.02  185.91   8330.  188.05
      -90. ******   167.  117785.  1.11 ***** *******    0.74    7.46

FULLV:FV      90.  -150.    1120.  0.96  0.45  189.47 *******   8330.  188.51
        0.    90.   167.  118168.  1.12  0.00    0.01    0.74    7.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.63

APPRO:AS     155.   -30.     918.  1.29  1.22  190.85 *******   8330.  189.57
      155.   155.   138.   74765.  1.01  0.16    0.00    0.69    9.08
         <<<<<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      90.     5.     746.  1.94  0.60  189.81  186.89   8330.  187.87
        0.    90.   126.   92518.  1.00  0.20   -0.01    0.79   11.17

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  190.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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     131.   -67.    1041.  1.04  1.17  191.26  187.85   8330.  190.22
      155.   133.   139.   88491.  1.04  0.28   -0.01    0.64    8.00

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.263  0.000   89107.    -3.   118.   189.07

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

   FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT1:XS      -90.  -149.   167.   8330.  117785.    1116.    7.46  188.05
   FULLV:FV        0.  -150.   167.   8330.  118168.    1120.    7.44  188.51
   BRIDG:BR        0.     5.   126.   8330.   92518.     746.   11.17  187.87
   RDWAY:RG       12.**************       0.******************    1.00********
   APPRO:AS      155.   -67.   139.   8330.   88491.    1041.    8.00  190.22

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.   118.   89107.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    185.91    0.74  178.62  198.85************  0.96  189.02  188.05
   FULLV:FV  ********    0.74  179.07  199.30  0.45  0.00  0.96  189.47  188.51
   BRIDG:BR    186.89    0.79  179.40  191.08  0.60  0.20  1.94  189.81  187.87
   RDWAY:RG  ****************  192.14  214.24**********************************
   APPRO:AS    187.85    0.64  180.83  207.80  1.17  0.28  1.04  191.26  190.22
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File bloo009.wsp
       Hydraulic analysis for structure BLOOVT01020009   Date: 11-APR-96
       Bloomfield Br 9, crossing Nulhegan R., VT Rte 102          JDA

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

EXIT1:XS   ******  -200.    1403.  1.09 *****  189.94  186.89  10700.  188.86
      -90. ******   172.  151189.  1.20 ***** *******    0.76    7.63

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                            WSEL,YLT,YRT =   189.32     188.93     199.30

FULLV:FV      90.  -200.    1408.  1.08  0.45  190.40 *******  10700.  189.32
        0.    90.   172.  151866.  1.20  0.00    0.01    0.75    7.60
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     190.32     188.81

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   188.82     207.80    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   188.82     207.80     188.81

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.60

APPRO:AS     155.   -72.    1060.  1.66  1.29  191.98  188.81  10700.  190.31
      155.   155.   139.   90488.  1.05  0.29   -0.01    0.81   10.10
        <<<<<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      90.     4.     791.  2.90  0.67  191.15  187.95  10700.  188.25
        0.    90.   127.  101040.  1.02  0.52   -0.01    0.95   13.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.991 ******  190.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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     131.  -146.    1390.  1.08  1.22  192.72  188.81  10700.  191.63
      155.   133.   142.  123330.  1.18  0.36    0.02    0.67    7.70

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.403  0.040  117866.    -3.   119.   190.64

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -90.  -200.   172.  10700.  151189.    1403.    7.63  188.86
   FULLV:FV       0.  -200.   172.  10700.  151866.    1408.    7.60  189.32
   BRIDG:BR       0.     4.   127.  10700.  101040.     791.   13.52  188.25
   RDWAY:RG      12.**************      0.*****************    1.00********
   APPRO:AS     155.  -146.   142.  10700.  123330.    1390.    7.70  191.63

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.   119.  117866.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS     186.89    0.76  178.62  198.85************  1.09  189.94  188.86
   FULLV:FV   ********    0.75  179.07  199.30  0.45  0.00  1.08  190.40  189.32
   BRIDG:BR     187.95    0.95  179.40  191.08  0.67  0.52  2.90  191.15  188.25
   RDWAY:RG   ****************  192.14  214.24*********************************
   APPRO:AS     188.81    0.67  180.83  207.80  1.22  0.36  1.08  192.72  191.63
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BLOOVT01020009, in Bloomfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BLOOVT01020009

General Location Descriptive

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

Date (MM/DD/YY) 08 / 04 / 94

Highway District Number (I - 2; nn) 09

County (FIPS county code; I - 3; nnn) 009

Town (FIPS place code; I - 4; nnnnn) 06325

Mile marker (I - 11; nnn.nnn) 000170

Waterway (I - 6) NULHEGAN RIVER

Road Name (I - 7): -

Route Number VT102

Vicinity (I - 9) 0.2 MI S JCT. VT.105

Topographic Map Bloomfield

Hydrologic Unit Code: 01080101

Latitude (I - 16; nnnn.n) 44451

Longitude (i - 17; nnnnn.n) 71379

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 20027100090503

Maintenance responsibility (I - 21; nn) 01

Maximum span length (I - 48; nnnn) 0130

Year built (I - 27; YYYY) 1937

Structure length (I - 49; nnnnnn) 000134

Average daily traffic, ADT (I - 29; nnnnnn) 000360

Deck Width (I - 52; nn.n) 244

Year of ADT (I - 30; YY) 92

Channel & Protection (I - 61; n) 8

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

Waterway adequacy (I - 71; n) 7

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 310

Year Reconstructed (I - 106) 0000

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) 010.0

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

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

Comments:

The bridge in the photos supplied with the bridge record looks much newer than 1937, renovation/reconstruction suspected. The existing structure is a steel truss type bridge. Structural inspection report of 10/21/93 indicated asphalt cracking over end joints and extensive rust on steel girders. The right abutment stem has heavy spalling and cracks in the floor beam. The stone fill at abutments is in good shape.

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: Boulders, coarse gravel, cobbles

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) : Light Debris (Heavy, Moderate, Light): Light

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

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

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

Watershed storage area (in percent): - %

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

Clear span (ft): - Clear Height (ft): - Full Waterway (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)* **143.61** mi^2

Lake and pond area **8.06** mi^2

Watershed storage *(ST)* **5.6** %

Bridge site elevation **900** ft

Headwater elevation **2948** ft

Main channel length **21.23** mi

10% channel length elevation **940** ft

85% channel length elevation **1300** ft

Main channel slope *(S)* **22.61** ft / mi

Watershed Precipitation Data

Average site precipitation __________ in

Average headwater precipitation __________ in

Maximum 2yr-24hr precipitation event *(I24,2)* ________ in

Average seasonal snowfall *(Sn)* _________ ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 05 / 1937

Project Number 231 - L Minimum channel bed elevation: 181.0

Low superstructure elevation: USLAB 191.08 DSLAB 191.08 USRAB 191.08 DSRAB 191.08

Benchmark location description:
BM, wash boring on top of stone at end of downstream left wingwall, elevation 192.40.

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 2.3 Footing bottom elevation: 182.*

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:
COARSE GRAVEL AND BOULDERS.

Comments:
***The left abutment bottom of footing is shown at elevation 181.08 and that of the right abutment is shown at elevation 182.83.**

Cross-sectional Data

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

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

Comments: **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: MAI Date: 10/24/95
Computerized by: MAI Date: 10/24/95
Reviewd by: JDA Date: 01/08/97

Structure Number BLOOVT01020009

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. Boehmler   Date *(MM/DD/YY)* 07 / 06 / 1995

2. Highway District Number 09   Mile marker 000170

County Essex (009)   Town Bloomfield (06325)

Waterway *(I - 6)* Nulhegan River   Road Name -

Route Number VT 102   Hydrologic Unit Code: 01080101

3. Descriptive comments:
Located 0.2 miles south of the junction with state route 105. Jim Degnan assisted with the following assessment.

B. Bridge Deck Observations

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

5. Ambient water surface... US 2   UB 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 134.0 *(feet)*   Span length 130.0 *(feet)*   Bridge width 24.4 *(feet)*

Road approach to bridge:

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

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

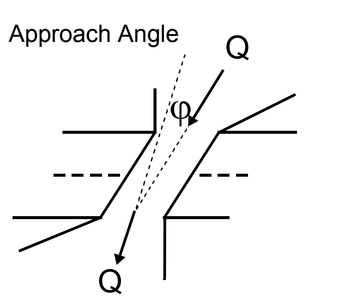
10. Embankment slope (*run / rise in feet / foot*):
US left 2.2:1   US right --

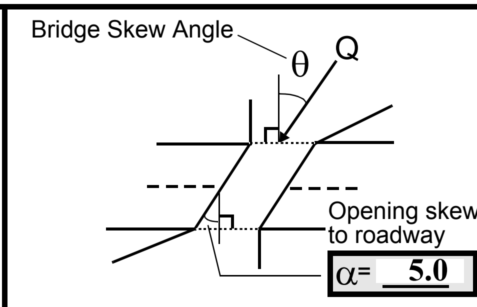
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: 5   16. Bridge skew: 25





17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? RB *(LB, RB)*   Severity 1
Range? 52 feet US *(US, UB, DS)* to 35 feet DS

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

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

18. Bridge Type: **3/1b**

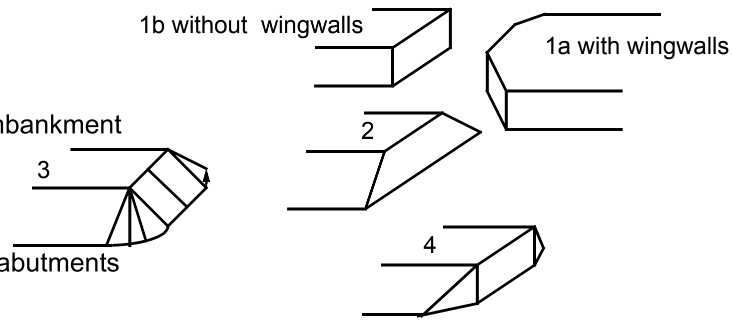
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The predominant surface cover is forest except for on the downstream right bank which has some shrubs along the immediate bank and sparse trees and grass on the overbank.

7. Measured bridge dimensions matched the historical values.

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
152.5	**6.0**			**3.5**	**4**	**4**	**3245**	**3245**	**1**	**1**

23. Bank width **40.0**   24. Channel width **25.0**   25. Thalweg depth **168.5**   29. Bed Material **435**

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

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

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

27. Bank material consists of gravel, sand, cobble, and some boulders.

29. Bed material consists of cobble, gravel, and boulders.

30. Left bank protection extends 70 to 220 feet upstream. The protection appears to be native material pushed up on the bank and served as protection for a previous structure. There is a pile of stone fill similar to that on the left bank across the channel from a remnant left abutment wall.

A scour hole has developed just DS from the stone fill pile on the right bank.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 265 35. Mid-bar width: 85

36. Point bar extent: 400 feet US (US, UB) to 100 feet US (US, UB, DS) positioned 95 %LB to 65 %RB

37. Material: 345

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

Point bar consisting of gravel, cobble, and boulders. The US end is more cobble boulder grading down to gravel with some sand at the very highest part of the bar. Shrubs, brush, and small trees are growing in the sandy part of the bar.

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: 35 42. Cut bank extent: 71 feet US (US, UB) to 145 feet DS (US, UB, DS)

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

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

Bed material at the toe of riprap along the right abutment has eroded primarily at the DS end. A couple of the stones have slumped. This cut bank extends under the bridge with the stones protecting the bank.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 250

47. Scour dimensions: Length 105 Width 45 Depth : 3.5 Position 70 %LB to 95 %RB

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

This localized scour hole is on the right bank side just DS of the old abutment location. Ambient depth of the channel is 1.0 feet.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
95.0		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.):

435

Bed material consists of cobble, gravel, and boulders.

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

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

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

70. Debris and Ice Comments:

1

Lots of trees on the banks upstream with potential for bank instability and erosion. The bridge opening will accommodate debris flow.

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**	**45**	**0**	**0**	**0**	**0**	**90.0**
RABUT	**1**	**25**	**35**			**2**	**0**	**129.0**

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

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

0

0

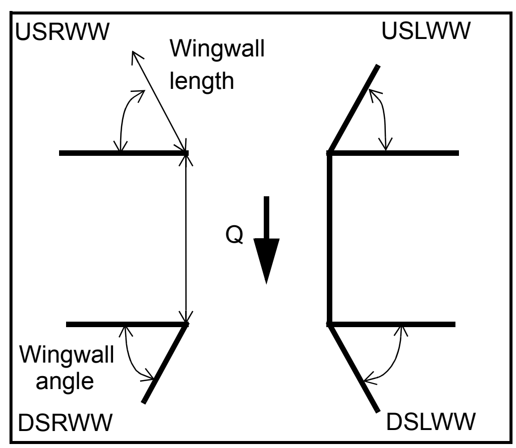
1

The concrete abutments are visible at the top of the riprapped spill-through slopes.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**95.0**	
USRWW:	**N**		**-**		**-**	**1.5**	
DSLWW:	**-**		**-**		**N**	**23.5**	
DSRWW:	**-**		**-**		**-**	**23.5**	

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**	**-**	**-**	**-**	**1**	**1**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**1**	**1**
Extent	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**-**

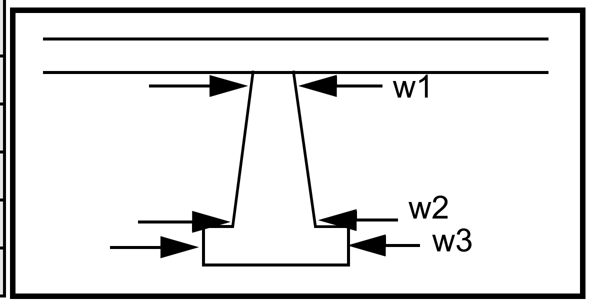
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

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



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

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

4
1
345
345
0
2
435
0
3
-
2
Right bank protection has eroded and slipped down the bank extending 35 feet DS.
Bank material consists of gravel, cobble, and boulders.

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

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

105. Drop structure comments (eg. downstream scour depth):
material consists of cobble, gravel, and boulders.

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

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

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **0** feet **50** *(US, UB, DS)* to **79** feet **US** *(US, UB, DS)*

Bank damage: **210** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
30
435

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

Scour dimensions: Length **wid-** Width **est** Depth: **poin** Positioned **t on** %LB to **the** %RB

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

bar is at the DS bridge face. There is a little vegetation on the bar occupying less than 5% of the area. The bar ends at the confluence with the Connecticut River. The bar consist mostly of cobble and boulders.

N

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

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

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

Confluence comments (eg. confluence name):

CUT BANKS

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N
-
-
-
-
-
-
NO CHANNEL SCOUR

Y

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	BLOOVT01020009	Town:	Bloomfield
Road Number:	VT102	County:	Essex
Stream:	Nulhegan River		

Initials JDA Date: 1/8/97 Checked: EMB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	8330	10700	0
Main Channel Area, ft2	1014	1231	0
Left overbank area, ft2	26	158	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	152	155	0
Top width L overbank, ft	54	133	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.498	0.498	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.7	7.9	ERR
y1, average depth, LOB, ft	0.5	1.2	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	88425	123248	0
Conveyance, main channel	88130	119962	0
Conveyance, LOB	295	3286	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	8302.2	10414.7	ERR
Ql, discharge, LOB, cfs	27.8	285.3	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	8.2	8.5	ERR
Vl, mean velocity, LOB, ft/s	1.1	1.8	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	12.2	12.6	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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	8330	10700	0
(Q) discharge thru bridge, cfs	8330	10700	0
Main channel conveyance	92408	101065	0
Total conveyance	92408	101065	0
Q2, bridge MC discharge,cfs	8330	10700	ERR
Main channel area, ft2	745	791	0
Main channel width (normal), ft	107.3	108.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	107.3	108.1	0
y_bridge (avg. depth at br.), ft	6.94	7.32	ERR
Dm, median (1.25*D50), ft	0.6225	0.6225	0
y2, depth in contraction,ft	5.91	7.28	ERR
ys, scour depth (y2-ybridge), ft	-1.03	-0.04	N/A

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	8330	10700	N/A
Main channel area (DS), ft2	745	791	0
Main channel width (normal), ft	107.3	108.1	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	107.3	108.1	0.0
D90, ft	1.0663	1.0663	0.0000
D95, ft	1.2823	1.2823	0.0000
Dc, critical grain size, ft	0.6584	0.9410	ERR
Pc, Decimal percent coarser than Dc	0.317	0.146	0.000
Depth to armoring, ft	4.26	16.51	ERR

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)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	8330	10700	0	8330	10700	0
a', abut.length blocking flow, ft	76.2	154.9	0	22.7	25.4	0
Ae, area of blocked flow ft2	102.5	253	0	77.9	108.4	0
Qe, discharge blocked abut.,cfs	395.7	808.8	0	392.3	587.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.86	3.20	ERR	5.04	5.42	ERR
ya, depth of f/p flow, ft	1.35	1.63	ERR	3.43	4.27	ERR
--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.587	0.441	ERR	0.479	0.462	ERR
ys, scour depth, ft	8.28	10.46	N/A	9.55	11.38	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
a'(abut length blocked, ft)	76.2	154.9	0	22.7	25.4	0
y1 (depth f/p flow, ft)	1.35	1.63	ERR	3.43	4.27	ERR
a'/y1	56.65	94.84	ERR	6.61	5.95	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.59	0.44	N/A	0.48	0.46	N/A
Ys w/ corr. factor K1/0.55:						
vertical	8.20	9.07	ERR	ERR	ERR	ERR
vertical w/ ww's	6.73	7.43	ERR	ERR	ERR	ERR
spill-through	4.51	4.99	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.79	0.95	0	0.79	0.95	0
y, depth of flow in bridge, ft	6.94	7.32	0.00	6.94	7.32	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	2.34	ERR	0.00	2.34	ERR	0.00
Fr>0.8 (spillthrough abut.)	ERR	2.67	ERR	ERR	2.67	ERR