LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (BRNATH00470032) on TOWN HIGHWAY 47, crossing LOCUST CREEK, BARNARD, VERMONT

U.S. Geological Survey
Open-File Report 96-409

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (BRNATH00470032) on TOWN HIGHWAY 47, crossing LOCUST CREEK, BARNARD, VERMONT

By Erick M. Boehmler

U.S. Geological Survey
Open-File Report 96-409

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

Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Federal Center
Denver, CO 80225

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (BRNATH00470032) ON TOWN HIGHWAY 47, CROSSING LOCUST CREEK, BARNARD, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNATH00470032 on town highway 47 crossing Locust Creek, Barnard, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province of central Vermont in the town of Barnard. The 6.26-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have dense woody vegetation coverage except for the upstream right bank, which is grass and brush covered.

In the study area, Locust Creek has an incised, sinuous channel with a slope of approximately 0.029 ft/ft, an average channel top width of 44 ft., and an average channel depth of 5 ft. The predominant channel bed material is gravel and cobbles (D_{50} is 91.7 mm or 0.301 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 12, 1994, indicated that the reach was stable.

The town highway 47 crossing of Locust Creek is a 28-ft-long, one-lane bridge consisting of one 25-foot span concrete slab superstructure (Vermont Agency of Transportation, written commun., August 23, 1994). The bridge is supported by vertical, concrete abutments with concrete wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 35 degrees.

The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) on the banks upstream, the upstream wingwalls, the downstream right wingwall, and the downstream right bank. The downstream left wingwall and left bank are protected with type-3 stone fill (less than 48 inches diameter). 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, 1993).
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 these computed results follow.

Contraction scour for all modelled flows ranged from 1.4 to 2.2 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.3 to 15.0 feet. The worst-case abutment scour also 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 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, 1993, 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.

Delectable Mountain, 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 BRNATH00470032 ***Stream*** Locust Creek

County Windsor ***Road*** TH 47 ***District*** 04

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 15.2 ***ft*** ***Max span length*** 25 ***ft***

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

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 10/12/94

Description of stone fill Type-2, on the upstream banks, the upstream wingwalls, the downstream right wingwall, and the downstream right bank. Type-3 on the downstream left wingwall and the downstream left bank. Abutments are not protected.

Abutments and wingwalls are concrete.

Y 10

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

There is a mild channel bend in the upstream reach.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	10/12/94	0	0
Level II	10/12/94	--	--

Potential for debris Moderate. Local residents indicate floating debris is common during floods. There is significant tree cover on the banks upstream.

Describe any features near or at the bridge that may affect flow (include observation date) There is a large bedrock outcrop that makes up the channel bed beyond 100 feet US. Local residents indicate during past floods the flow has eroded the overburden material on the right side forming a channel that flows around the outcrop. 10/12/94.

Description of the Geomorphic Setting

General topography The channel is located within a 150 foot-wide valley, with narrow irregular flood plains and steep to moderately sloping valley walls on both sides.

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

Date of inspection 10/12/94

DS left: Steep channel bank to a narrow, irregular flood plain.

DS right: Steep channel bank to moderately sloping valley wall.

US left: Steep channel bank to steep valley wall

US right: Steep channel bank to moderately sloped, irregular, narrow flood plain.

Description of the Channel

Average top width 44 ***ft*** ***Average depth*** 5 ***ft***

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

Sinuous but stable with semi-alluvial to non-alluvial channel boundaries and a narrow flood plain.

10/12/94

Vegetative co[...] Trees and brush

DS left: Trees

DS right: Forest

US left: Grass and brush with a few trees.

US right: Y

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

The assessment of 10/12/94 noted a bedrock outcrop on the channel bed upstream. Local residents indicated flood flows have eroded a channel around the right bank side of the outcrop in the past. Additionally, floating debris is common during floods.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 6.26 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,575 ***ft³/s*** ***Q500*** 2,100 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates from the VTAOT database. The database estimates were selected when compared to those estimates derived from a drainage area relationship [(6.3/11.5)exp 0.67] with bridge number 34 in Barnard and several empirical methods (Potter, 1957a&b; Johnson and Tasker, 1974; Benson, 1962; FHWA, 1983; Talbot, 1887). Bridge number 34 crosses Locust Creek downstream of this site and has a 100-yr. discharge estimate of 2,350 from the VTAOT database.

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

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

Datum tie between USGS survey and VTAOT plans Subtract 11 feet from USGS survey to obtain VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum.

RM1 is a chiseled "X" on top of the US end of the left abutment (elev. 503.15 ft, arbitrary datum). RM2 is a chiseled "X" on top of the DS end of the right abutment (elev. 503.40 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-44	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	43	2	Modelled Approach section (Templated from APTEM)
APTEM	75	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). Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

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

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the User's manual for WSPRO (Shearman, 1990). The slope used was 0.0291 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1966).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0292 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the modeled 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, the results suggest that the water surface profile passes through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satifactory solutions.

Although the upstream channel is skewed to the bridge opening, flow was assumed to align with the abutment walls when passing through the bridge.

Bridge Hydraulics Summary

Average bridge embankment elevation 503.4 *ft*
Average low steel elevation 501.7 *ft*

100-year discharge 1,575 *ft³/s*
Water-surface elevation in bridge opening 496.6 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 116 *ft²*
Average velocity in bridge opening 13.6 *ft/s*
Maximum WSPRO tube velocity at bridge 17.2 *ft/s*

Water-surface elevation at Approach section with bridge 499.7 *ft*
Water-surface elevation at Approach section without bridge 497.3 *ft*
Amount of backwater caused by bridge 2.4 *ft*

500-year discharge 2,100 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 140 *ft²*
Average velocity in bridge opening 15.0 *ft/s*
Maximum WSPRO tube velocity at bridge 19.4 *ft/s*

Water-surface elevation at Approach section with bridge 501.6 *ft*
Water-surface elevation at Approach section without bridge 498.3 *ft*
Amount of backwater caused by bridge 3.3 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). 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, 1993, p. 35, equation 18) for the 100-year, 500-year discharges. For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The large armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Abutment scour for each abutment at all modelled discharges was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.4	2.2	--
Depth to armoring	40.3	66.0	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.3	13.2	--
Right abutment	12.9	15.0	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:			
Left abutment	2.4	2.9	--
Right abutment	2.4	2.9	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

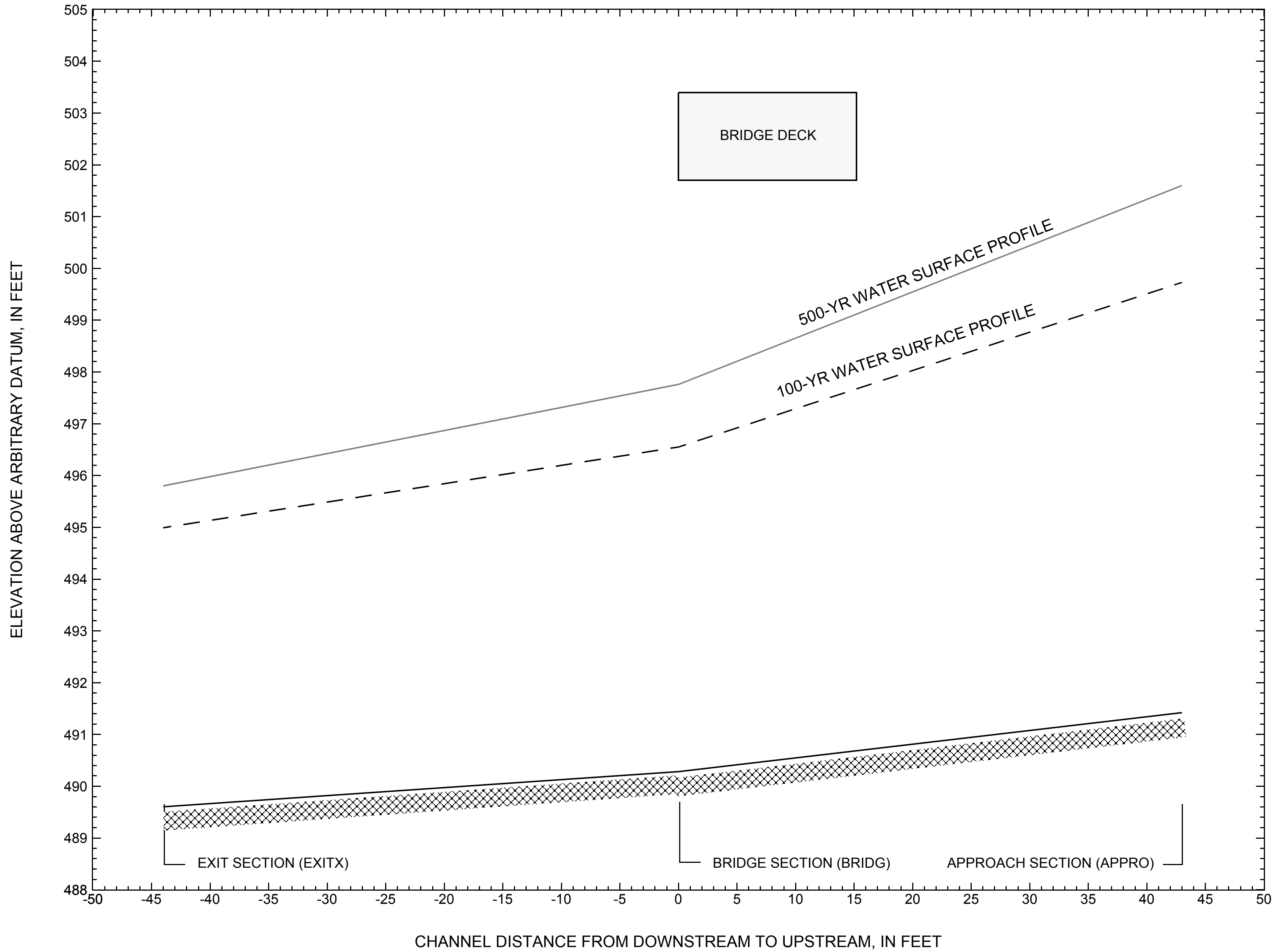


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRNATH00470032 on town highway 47, crossing Locust Creek, Barnard, Vermont.

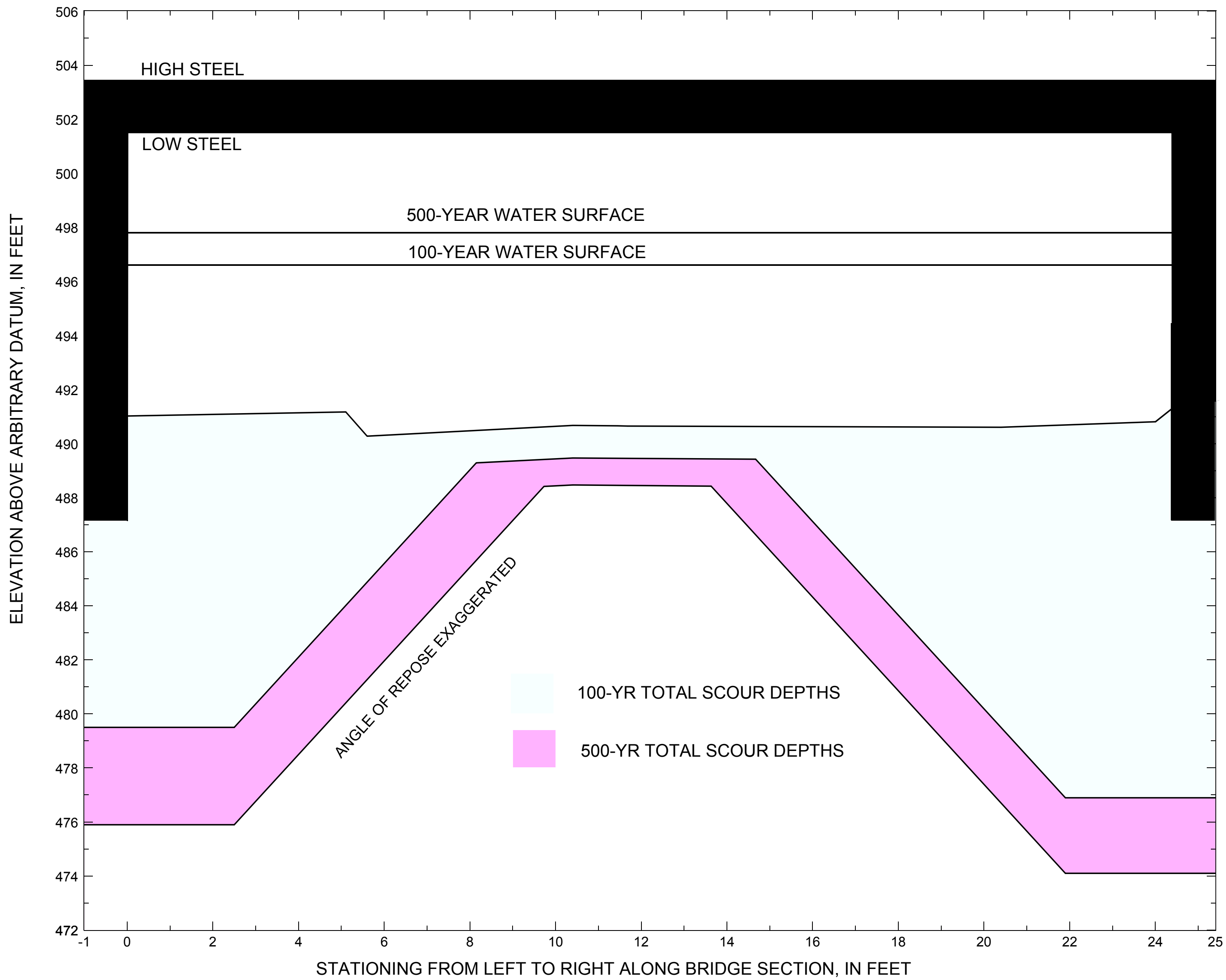


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRNATH00470032 on town highway 47, crossing Locust Creek, Barnard, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNATH00470032 on Town Highway 47, crossing Locust Creek, Barnard, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,575 cubic-feet per second											
Left abutment	0.0	490.4	501.5	487	491.0	1.4	10.3	--	11.7	479.3	-8
Right abutment	24.4	490.8	501.9	487	491.3	1.4	13.2	--	14.6	476.7	-10

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 BRNATH00470032 on Town Highway 47, crossing Locust Creek, Barnard, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,100 cubic-feet per second											
Left abutment	0.0	490.4	501.5	487	491.0	2.2	12.9	--	15.1	475.9	-11
Right abutment	24.4	490.8	501.9	487	491.3	2.2	15.0	--	17.2	473.2	-14

1. Measured along the face of the most constricting side of the bridge.

2. Arbitrary datum for this study.

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M.A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terraine, U.S. Geological Survey Water-supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 131 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1966, Delectable Mountain, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial Photographs, 1964; Photoinspected 1983, Scale 1:24,000, Contour Interval, 20 feet.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brna032.wsp
T2        Hydraulic analysis for structure BRNATH00470032   Date: 31-JAN-96
T3        Town Highway 47 crossing of Locust Creek, Barnard, VT             EMB
Q          1575.0,   2100.0
SK          0.0291,   0.0291
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -44           0.
GR         -113.6, 501.89   -101.2, 500.02    -92.2, 500.90    -67.7, 501.44
GR          -58.5, 501.79    -42.7, 500.53    -29.9, 500.05    -15.1, 497.24
GR           -7.5, 494.14      0.0, 490.27      4.6, 490.33      7.4, 490.41
GR           10.2, 489.78     14.9, 489.60     17.9, 490.58     22.4, 490.58
GR           29.8, 494.44     35.9, 499.66     43.5, 506.90     43.7, 507.23
*
N           0.055
*
*
XS   FULLV      0  * * *   0.0173
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0     501.7      35.0
GR            0.0, 501.51      0.2, 491.05      5.1, 491.17      5.6, 490.28
GR           10.4, 490.67     16.3, 490.60     20.4, 490.61     24.0, 490.81
GR           24.3, 491.27     24.4, 501.88      0.0, 501.51
*
*                   BRTYPE  BRWDTH  EMBSS  EMBELV   WWANGL
*         CD           4      23.2    2.2   503.2     52.9
*         Average end of wingwall elevation only 1.5 feet below low cord.
*         Hence, bridge modeled as type 1.
*         BRTYPE  BRWDTH        WWANGL  WWWID
CD           1      32.7   *  *   52.9    7.2
N           0.035
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      15.2     2
GR          -42.2, 504.00    -42.1, 502.82      0.0, 503.21     25.9, 503.65
GR          111.8, 508.07    173.4, 512.08    224.0, 515.06
BP          0.75
*           Changed: -97.2, 501.28
*
*
XT   APTEM     75
GR          -42.7, 516.25    -33.0, 508.31    -23.8, 503.95    -17.6, 499.91
GR           -8.0, 498.59      0.0, 493.62      0.0, 493.60      1.0, 492.67
GR            3.9, 492.76      9.7, 492.35     17.9, 492.44     22.8, 492.72
GR           24.6, 493.42     24.6, 493.42     30.0, 495.25     35.9, 497.60
GR           39.5, 502.82     80.3, 508.05    108.4, 512.09
*
AS   APPRO    43  *  *  *  0.0292
GT
N           0.055
*
HP 1 BRIDG   496.55 1 496.55
HP 2 BRIDG   496.55 * * 1575
HP 1 APPRO   499.73 1 499.73
HP 2 APPRO   499.73 * * 1575
*
HP 1 BRIDG   497.76 1 497.76
HP 2 BRIDG   497.76 * * 2100
HP 1 APPRO   501.60 1 501.60
HP 2 APPRO   501.60 * * 2100
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: 02-07-96  08:47

   T1        U.S. Geological Survey WSPRO Input File brna032.wsp
   T2        Hydraulic analysis for structure BRNATH00470032   Date: 31-JAN-96
   T3        Town Highway 47 crossing of Locust Creek, Barnard, VT             EMB
   Q          1575.0,   2100.0
 *** Q-DATA FOR SEC-ID, ISEQ =           1
   SK          0.0291,   0.0291
   *
   J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
   *

HP 1 496.55 1 496.55
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      116     11731     20     31                         1582
    496.55           116     11731     20     31  1.00      0     24     1582
1
   HP 2 BRIDG   496.55 * * 1575
     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

          WSEL     LEW     REW    AREA        K        Q    VEL
        496.55     0.1    24.3   115.6   11731.    1575.  13.63

 X STA.         0.1        2.7        4.1        5.6        6.6        7.6
   A(I)             11.3        6.5        6.7        5.2        5.1
   V(I)             6.98      12.14      11.78      15.05      15.47

 X STA.         7.6        8.6        9.6       10.6       11.5       12.5
   A(I)              4.9        4.8        4.7        4.7        4.7
   V(I)            16.02      16.55      16.64      16.89      16.86

 X STA.        12.5       13.5       14.4       15.4       16.4       17.3
   A(I)              4.6        4.6        4.7        4.8        4.8
   V(I)            17.17      17.13      16.90      16.31      16.49

 X STA.        17.3       18.4       19.4       20.6       21.9       24.3
   A(I)              5.0        5.3        5.7        6.4       11.2
   V(I)            15.71      14.92      13.81      12.30       7.02
1
   HP 1 APPRO   499.73 1 499.73
     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      312     24931     57     61                         4143
    499.73           312     24931     57     61  1.00    -18     38     4143
1
   HP 2 APPRO   499.73 * * 1575
     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

          WSEL     LEW     REW    AREA        K        Q    VEL
        499.73   -18.8    38.0   311.6   24931.    1575.   5.05

 X STA.       -18.8       -2.8        0.4        2.5        4.4        6.2
   A(I)             33.0       20.4       16.9       15.0       14.5
   V(I)             2.39       3.86       4.66       5.24       5.43

 X STA.         6.2        7.9        9.5       11.1       12.6       14.1
   A(I)             13.7       13.1       12.8       12.8       12.4
   V(I)             5.74       6.01       6.17       6.16       6.37

 X STA.        14.1       15.6       17.1       18.6       20.1       21.7
   A(I)             12.4       12.4       12.5       12.5       12.7
   V(I)             6.36       6.37       6.31       6.29       6.19

 X STA.        21.7       23.4       25.3       27.6       30.7       38.0
   A(I)             13.3       14.2       15.0       17.8       24.4
   V(I)             5.94       5.55       5.25       4.44       3.22
1
   *
```

WSPRO OUTPUT FILE (continued)

```
   HP 1 BRIDG   497.76 1 497.76
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      140     15301     20     34                         2099
    497.76           140     15301     20     34  1.00      0     24     2099
1
   HP 2 BRIDG   497.76 * * 2100
     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.76     0.1    24.4   139.6   15301.    2100.  15.04

 X STA.         0.1        2.7        4.2        5.6        6.7        7.7
   A(I)            13.9        8.3        7.9        6.3        6.0
   V(I)            7.53      12.66      13.36      16.58      17.53

 X STA.         7.7        8.7        9.6       10.6       11.5       12.5
   A(I)             5.9        5.6        5.6        5.6        5.4
   V(I)           17.77      18.76      18.81      18.79      19.36

 X STA.        12.5       13.4       14.3       15.3       16.2       17.2
   A(I)             5.5        5.5        5.5        5.7        5.7
   V(I)           19.26      19.23      18.98      18.32      18.52

 X STA.        17.2       18.2       19.3       20.5       21.8       24.4
   A(I)             6.0        6.3        7.0        7.9       14.2
   V(I)           17.64      16.75      15.02      13.28       7.41
1
   HP 1 APPRO   501.60 1 501.60
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      422     38901     61     67                         6295
    501.60           422     38901     61     67  1.00    -21     39     6295
1
   HP 2 APPRO   501.60 * * 2100
     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

          WSEL     LEW     REW    AREA        K        Q    VEL
        501.60   -21.6    39.3   421.7   38901.    2100.   4.98

 X STA.       -21.6       -7.1       -2.3        0.5        2.7        4.7
   A(I)            40.4       28.7       24.1       21.1       19.2
   V(I)            2.60       3.66       4.35       4.98       5.48

 X STA.         4.7        6.5        8.3       10.0       11.7       13.4
   A(I)            18.5       17.7       17.7       16.9       16.9
   V(I)            5.68       5.95       5.94       6.20       6.21

 X STA.        13.4       15.0       16.7       18.3       20.1       21.8
   A(I)            16.9       16.9       16.5       17.3       17.4
   V(I)            6.20       6.21       6.37       6.07       6.05

 X STA.        21.8       23.7       25.8       28.2       31.5       39.3
   A(I)            18.1       19.4       20.2       23.8       34.0
   V(I)            5.82       5.41       5.19       4.41       3.09
1
   EX

 +++ BEGINNING PROFILE CALCULATIONS --   2

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

 EXITX:XS   ******     -9      148  1.76 *****  496.75  494.92    1575  494.99
        -43 ******     30     9224  1.00 ***** *******    0.97   10.63

 FULLV:FV       44    -11      180  1.18  0.97  497.72 *******    1575  496.53
          0     44     31    12196  1.00  0.00    0.00    0.75    8.73
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       43     -6      189  1.08  0.68  498.40 *******    1575  497.32
         43     43     36    12956  1.00  0.00    0.01    0.71    8.35
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
```

WSPRO OUTPUT FILE (continued)

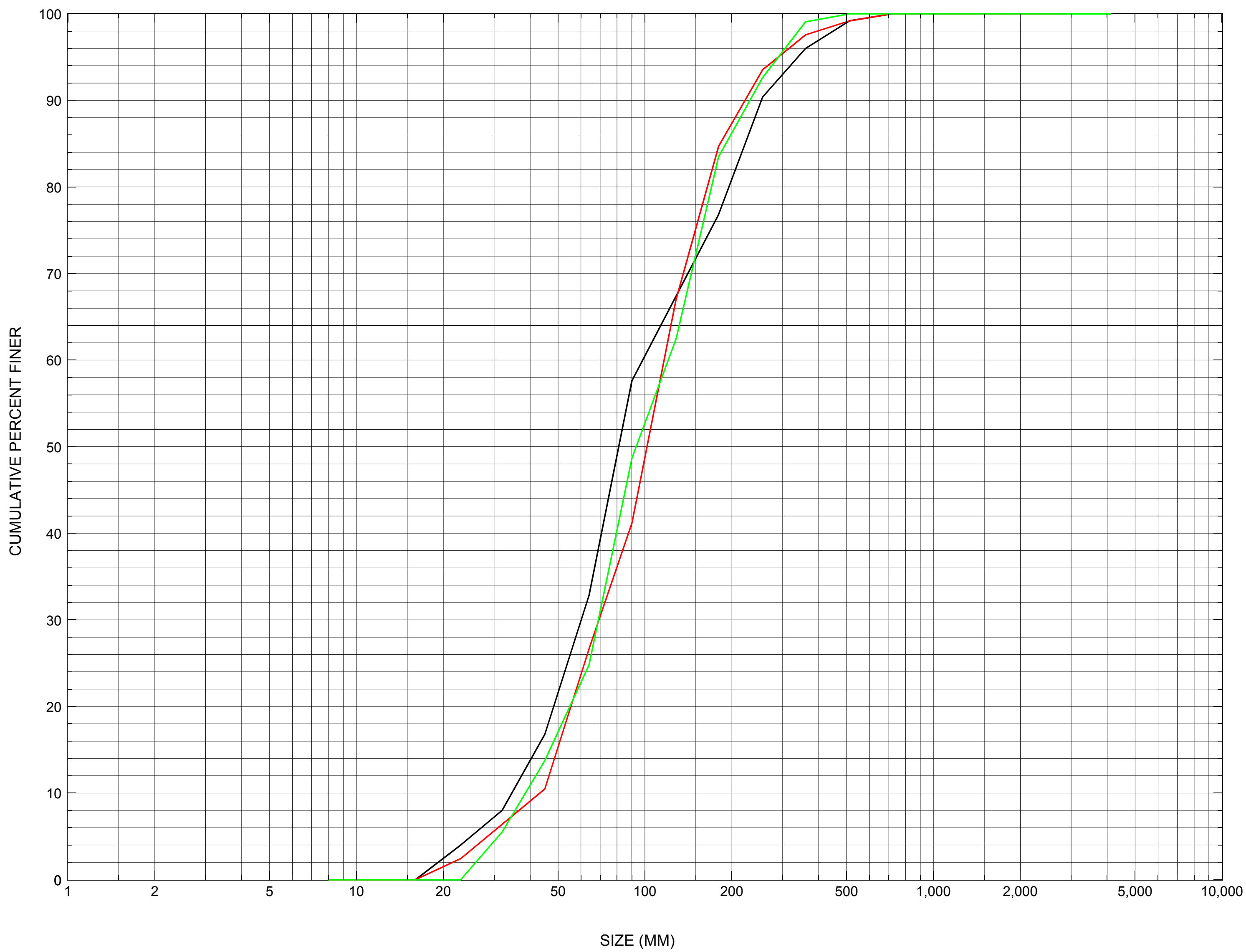
```
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1575.     496.55

           <<<<<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       44      0      116  2.89 *****  499.44  496.55    1575  496.55
         0     44     24    11725  1.00 ***** *******    1.00   13.63

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  501.70 ****** ****** ******

    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       10    -18      311  0.40  0.10  500.13  496.32    1575  499.73
        43     12     38    24915  1.00  0.59    0.01    0.38    5.06

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.446  0.147   21170.     1.    25.   499.62

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
 FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -44.   -10.    30.   1575.    9224.     148.   10.63  494.99
   FULLV:FV       0.   -12.    31.   1575.   12196.     180.    8.73  496.53
   BRIDG:BR       0.     0.    24.   1575.   11725.     116.   13.63  496.55
   RDWAY:RG      12.**************      0.*****************     2.00********
   APPRO:AS      43.   -19.    38.   1575.   24915.     311.    5.06  499.73

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    25.   21170.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.92    0.97  489.60  507.23************  1.76  496.75  494.99
   FULLV:FV  ********    0.75  490.36  507.99  0.97  0.00  1.18  497.72  496.53
   BRIDG:BR    496.55    1.00  490.28  501.88************  2.89  499.44  496.55
   RDWAY:RG  ****************  502.82  515.06**********************************
   APPRO:AS    496.32    0.38  491.42  515.32  0.10  0.59  0.40  500.13  499.73

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

EXITX:XS   ******    -11      182  2.08 *****  497.88  495.78    2100  495.80
       -43 ******     31    12306  1.00 ***** *******    0.99   11.56

FULLV:FV       44    -13      221  1.41  0.98  498.85 *******    2100  497.44
         0     44     32    16169  1.00  0.00   -0.01    0.77    9.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       43    -11      232  1.27  0.70  499.54 *******    2100  498.27
        43     43     37    16862  1.00  0.00    0.00    0.73    9.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2100.     497.76

           <<<<<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       44      0      140  3.52 *****  501.28  497.76    2100  497.76
         0     44     24    15297  1.00 ***** *******    1.00   15.04

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  501.70 ****** ****** ******
```

WSPRO OUTPUT FILE (continued)

```
     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       10    -21      421  0.39  0.09  501.98  497.15    2100  501.60
        43      12     39    38870  1.00  0.62    0.00    0.33    4.98

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.509  0.231   29874.     2.    26.   501.51

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -44.   -12.    31.   2100.   12306.     182.   11.56  495.80
    FULLV:FV       0.   -14.    32.   2100.   16169.     221.    9.52  497.44
    BRIDG:BR       0.     0.    24.   2100.   15297.     140.   15.04  497.76
    RDWAY:RG      12.**************      0.*****************    2.00********
    APPRO:AS      43.   -22.    39.   2100.   38870.     421.    4.98  501.60

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       2.    26.   29874.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    495.78    0.99  489.60  507.23************  2.08  497.88  495.80
    FULLV:FV  ********    0.77  490.36  507.99  0.98  0.00  1.41  498.85  497.44
    BRIDG:BR    497.76    1.00  490.28  501.88************  3.52  501.28  497.76
    RDWAY:RG  ****************  502.82  515.06**********************************
    APPRO:AS    497.15    0.33  491.42  515.32  0.09  0.62  0.39  501.98  501.60
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BRNATH00470032, in Barnard, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNATH00470032

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 23 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 02725

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

Waterway *(I - 6)* Locust Creek

Road Name *(I - 7):* -

Route Number TH047

Vicinity *(I - 9)* 0.85 MI TO JCT W CL3 TH5

Topographic Map Delectable.Mtn

Hydrologic Unit Code: 0180105

Latitude *(I - 16; nnnn.n)* 43434

Longitude *(i - 17; nnnnn.n)* 72386

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140300321403

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1977

Structure length *(I - 49; nnnnnn)* 000028

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

Deck Width *(I - 52; nn.n)* 152

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 45

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 020.0

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

Vertical clearance from streambed (*nnn.n ft*) 011.0

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

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

Comments:

Structural inspection report of 5/23/94 indicates that the abutment and wingwall concrete is in like new condition. Footings were reported as not exposed at the surface and no undermining or settlement apparent. Report indicated no channel scour or embankment erosion. No debris or in-channel bars are noted. Riprap and channel alignment with the bridge is not reported.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 6.3

Terrain character: Mountainous

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 700 Q_{25} 1000
Q_{50} 1300 Q_{100} 1575 Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 14.7

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*)	-	5.2	6.5	7.8	9.0
Velocity (*ft / sec*)	-	-	14.7	-	-

Long term stream bed changes: -

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

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

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

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

Highway No. : TH47 Structure No. : 33 Structure Type: Bridge

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

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

Highway No. : TH47 Structure No. : 36 Structure Type: Bridge

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 6.26 mi^2 Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1190 ft Headwater elevation 2836 ft

Main channel length 4.86 mi

10% channel length elevation 1260 ft 85% channel length elevation 2040 ft

Main channel slope *(S)* 213.99 ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **04** / **1977**

Project Number **DSR 0022** Minimum channel bed elevation: **480.2**

Low superstructure elevation: USLAB **490.43** DSLAB **490.30** USRAB **490.77** DSRAB **490.73**

Benchmark location description:

BM#1, S.I.R. (spike in root) of 6 inch maple located on left side of right bank road approach going away from the bridge, stationing 12 + 30, 22 feet right, elevation 500.00. BM#2, S.I.T. of 24 inch poplar about 30 feet of right side of left bank road approach going away from bridge, stationing 14 + 36, 54 feet right, elevation 491.61.

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 **2.1** Footing bottom elevation: **476.0**

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

If 3: Footing bottom elevation: **-**

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

Some hydraulic info was on plans: Q10=700, high water=5.2 feet,Q25=1000, high water=6.5 feet, Q50=1300, high water=7.8 feet, Q100=1575, high water=9.0 feet.

Cross-sectional Data

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

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

Comments: **Sections available were not comparable.**

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: **1/26/95**

Computerized by: **MAI** Date: **2/22/96**

Reviewd by: **EMB** Date: **3/20/96**

Structure Number **BRNATH00470032**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **10** / **12** / 19**94**

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

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

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

Route Number **TH047** Hydrologic Unit Code: **01080105**

3. Descriptive comments:

The bridge is 0.90 miles South of TH47 intersection with West road. West road on the topographic map is TH5.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **5** RBDS **4** 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 **28** *(feet)* Span length **25** *(feet)* Bridge width **15.2** *(feet)*

Road approach to bridge:

8. LB **0** 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 **-:1** US right **-:1**

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

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

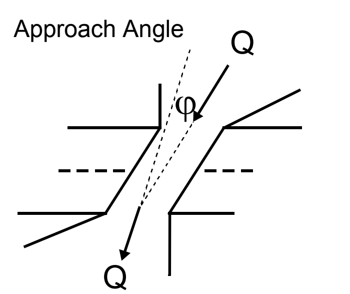
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

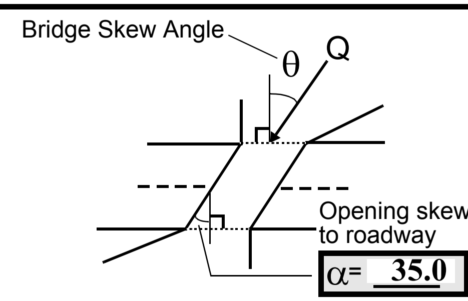
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **10**





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

Where? **LB** *(LB, RB)* Severity **0**

Range? **50** feet **US** *(US, UB, DS)* to **75** feet **US**

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. Level II Bridge Type: **1A**

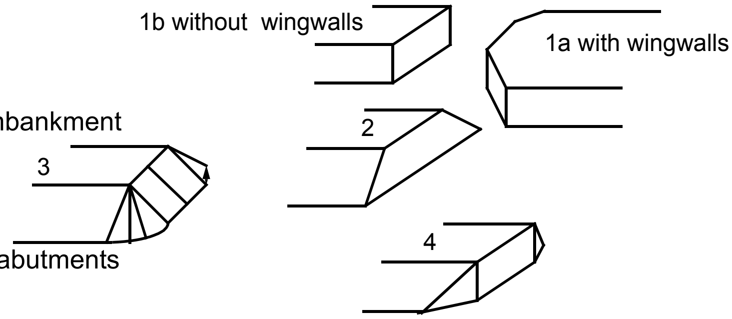
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The road embankments upstream were not measured. The right bank downstream surface cover is mainly lawn with a couple cabins and a 20 ft wide stretch of trees on the immediate bank. The left bank downstream has mainly weeds and grass and very small (young) aspen and pin cherry up on the bank with maples right along the edge of the channel and bank. The upstream right bank has mainly brush and some shrubs nearest the bridge and mostly trees further upstream with a small gravel road pullout just beyond a stand of trees. The left bank upstream is virtually all forest. A small road drainage ditch runs down along the downstream side of the right bank road approach but is grown in with grasses and no visible erosion is taking place. Measured; bridge length: 28 ft, span length: 25 ft, roadway width: 15 ft. Values reported for item #7 are from VTAOT files.

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
57.0	**5.0**			**4.0**	**3**	**3**	**4**	**4**	**1**	**1**

23. Bank width **30.0** 24. Channel width **20.0** 25. Thalweg depth **44.0** 29. Bed Material **4**

30 .Bank protection type: LB **2** RB **2** 31. Bank protection condition: LB **1** RB **1**

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

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

The bank material is mainly cobble with some boulders, coarse gravel and sand. The bed material is cobble, boulder and gravel. The left bank protection extends from the end of the upstream left wingwall to 65 ft upstream while that on the right bank extends from the end of the upstream right wingwall to 35 ft upstream.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

There are small areas of bank cutting visible mainly on the left bank upstream beyond 2 bridge lengths. These cuts are in the part of the channel where bedrock outcrops and is the bed material from 100 ft upstream to greater than 250 ft upstream.

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.):

A small scour hole (pool) has developed in the channel 100 ft upstream to 80 ft upstream just downstream of the contact between the bedrock exposure and alluvium.

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
24.5		1.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

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

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

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

3

There is some cobble and boulder under the bridge but the bed material is mainly coarse to fine gravel, and medium to coarse sand.

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

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

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

70. Debris and Ice Comments:

1

A local resident said the ice doesn't tend to block the channel or accumulate at the bridge. He also noted lots of debris flows with flood events and pointed out a large area upstream where bedrock is present on the bed and high flows have carved a channel bend in the bank perhaps to flow around the bedrock. This is a high gradient stream and the bridge span is approximately 80% of the upstream bank full width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	19.5

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.):

-

-

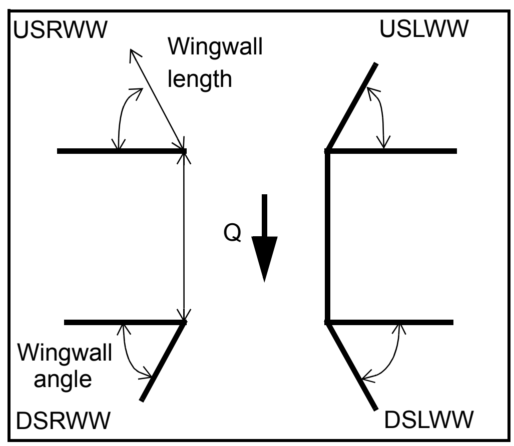
1

The abutments are in good condition, like new concrete, no cracks, the footings are not detectable with the rangepole beneath the bed material at the base of the abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						19.5	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	23.0	
DSRWW:	1		0		-	23.0	

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	Y	-	1	1	-	-
Condition	Y	-	1	-	1	1	-	-
Extent	1	-	0	2	2	0	0	-

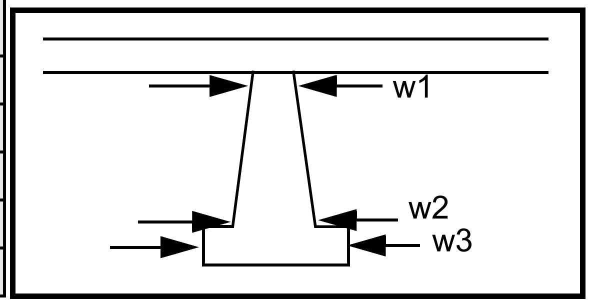
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
1
1
2
1
1

Piers:

84. Are there piers? **A** *(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		9.0		70.0	35.0	15.0
Pier 2				30.0	17.5	70.0
Pier 3	8.5	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	local	flow	and	of	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	resi-	over-	flow	the	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	dent	topp	ed	brid	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	men-	ed	dow	ge,	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	tione	the	n the	reen-	*Y- yes; N- no*
91. Attack ∠ (BF)	d	right	road	ter-	
92. Pushed	that	bank	to	ing	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	in	abou	the	the	
95. Cross-members	the	t 250	dow	main	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	flood	ft	nstre	chan	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	of	upst	am	nel	
98. Exposure depth	1973	ream	side	just	

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

downstream of the downstream right wingwall. Fill material is presently in the location where the road wash occurred, see photo 16.

N

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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):
-
-
-
-
-
-

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

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

Material: -_____

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

-
-
-
-

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

Cut bank extent: **RS**___ feet ____ *(US, UB, DS)* to _____ feet ____ *(US, UB, DS)*

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

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

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: **3**______

Scour dimensions: Length **4**_____ Width **4**_____ Depth: **5**_____ Positioned **0**____ %LB to **2**____ %RB

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

4
3
2
1

Are there major confluences? **2**____ *(Y or if N type ctrl-n mc)* How many? **The**____

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

Confluence 2: Distance **exten**____ Enters on **t is**____ *(LB or RB)* Type **full**____ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

bank length to at least 56 ft downstream (2 bridge lengths). Most of it appears placed but native material. The right bank downstream appears slumped but not cut directly by the channel. One has to go 200 ft downstream

F. Geomorphic Channel Assessment

107. Stage of reach evolution **to**____

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)*:

find natural bank material. The bed material is cobbles, boulders, and gravel.

N

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: BRNATH00470032 Town: Barnard
Road Number: TH07 County: Windsor
Stream: Locust Creek

Initials EMB Date: 2/7/96 Checked: SAO Date: 3/20/96

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

Neills Equation
Vc=11.52*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1993, p. 31, eq. 14)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1575	2100	0
Main Channel Area, ft2	311.6	421.7	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	56.8	60.9	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.301	0.301	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.5	6.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	24931	38901	0
Conveyance, main channel	24931	38901	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0	0	ERR
Qm, discharge, MC, cfs	1575	2100	ERR
Ql, discharge, LOB, cfs	0	0	ERR
Qr, discharge, ROB, cfs	0	0	ERR
Vm, mean velocity MC, ft/s	5.1	5.0	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.3	10.7	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	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/(120*Dm^(2/3)*W2^2))^(3/7)
ys=y2-y_bridge or ys=y2-y1
(Richardson and others, 1993, p. 35, eq. 18, 19)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	311.6	421.7	0
Main channel width, ft	56.8	60.9	0
y1, main channel depth, ft	5.485915	6.924466	ERR
Bridge Section			
(Q) total discharge, cfs	1575	2100	0
(Q) discharge thru bridge, cfs	1575	2100	0
Main channel conveyance	11731	15301	0
Total conveyance	11731	15301	0
Q2, bridge MC discharge,cfs	1575	2100	ERR
Main channel area, ft2	116	140	0
Main channel width (skewed), ft	19.8	20.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.8	20	0
y_bridge (avg. depth at br.), ft	5.838384	6.98	ERR
Dm, median (1.25*D50), ft	0.37625	0.37625	0
y2, depth in contraction,ft	7.23292	9.176197	ERR
ys, scour depth (y2-ybridge), ft	1.39	2.20	N/A
ys, scour depth (y2-y1), ft	1.75	2.25	N/A

ARMORING

D90	0.781	0.781	
D95	1.007	1.007	
Critical grain size,Dc, ft	0.918818	1.036535	ERR
Decimal-percent coarser than Dc	0.064	0.045	
Depth to armoring,ft	40.31316	65.99273	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1993, p. 49, eq. 24)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1575	2100	0	1575	2100	0
a', abut.length blocking flow, ft	21	23.8	0	15.9	17.1	0
Ae, area of blocked flow ft2	67.9	109.5	0	81.6	111.7	0
Qe, discharge blocked abut.,cfs	225	396	0	375	503	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.313697	3.616438	ERR	4.595588	4.503133	ERR
ya, depth of f/p flow, ft	3.23	4.60	ERR	5.13	6.53	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	125	125	0	55	55	0
K2	1.043631	1.043631	0	0.937984	0.937984	0
Fr, froude number f/p flow	0.32	0.30	ERR	0.36	0.31	ERR
ys, scour depth, ft	10.30	13.24	N/A	12.91	14.98	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1993, p. 50, eq. 25)

a'(abut length blocked, ft)	21	23.8	0	15.9	17.1	0
y1 (depth fp flow, ft)	3.23	4.60	ERR	5.13	6.53	ERR
a'/y1	6.49	5.17	ERR	3.10	2.62	ERR
Froude no. f/p flow	0.32	0.30	N/A	0.36	0.31	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1993, p118-119, eq. 93,94)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.8	7		5.8	7	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	2.43	2.93	ERR	2.43	2.93	ERR