LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (BURKTH00130033) on TOWN HIGHWAY 13, crossing ROUNDY BROOK, BURKE, VERMONT

U.S. Geological Survey
Open-File Report 98-005

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

U.S. Department of the Interior
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LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (BURKTH00130033) on TOWN HIGHWAY 13, crossing ROUNDY BROOK, BURKE, VERMONT

By ROBERT H. FLYNN AND JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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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 33 (BURKTH00130033) ON TOWN HIGHWAY 13, CROSSING ROUNDY BROOK, BURKE, VERMONT

By **Robert H. Flynn and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BURKTH00130033 on Town Highway 13 crossing Roundy Brook, Burke, 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 7.85-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover upstream and downstream of the bridge is forest.

In the study area, Roundy Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 45 ft and an average bank height of 3 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 99.0 mm (0.325 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 8, 1995, indicated that the reach was stable.

The Town Highway 13 crossing of Roundy Brook is a 30-ft-long, narrow two-lane bridge consisting of one 26-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 24.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 60 degrees to the opening while the opening-skew-to-roadway is 35 degrees.

A scour hole approximately 1.0 ft deeper than the mean thalweg depth was observed along the left abutment and upstream left wingwall during the Level I assessment. In addition, there are two other scour holes, approximately 0.5 ft deeper than the mean thalweg depth, which are located at the upstream end of the downstream left wingwall and at the downstream end of the upstream right wingwall. The scour protection measures at the site include type-1 stone fill (less than 12 inches diameter) along the upstream banks and type-2 stone fill (less than 36 inches diameter) along the downstream left bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.4 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 1.7 to 7.0 ft along the right abutment and from 9.6 to 11.7 ft along the left abutment. The worst-case abutment scour occurred at the 100-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 Davis, 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.

West Burke, VT. 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 BURKTH00130033 ***Stream*** Roundy Brook

County Caledonia ***Road*** TH13 ***District*** 7

Description of Bridge

Bridge length 30 ***ft*** ***Bridge width*** 19.5 ***ft*** ***Max span length*** 26 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/08/95

Description of stone fill -

Abutments and wingwalls are concrete. There is an approximately one foot deep scour hole in front of the LABUT and USLWW.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 60

There is a moderate channel bend in the upstream and downstream reaches. Scour holes have developed in the locations where the bend impacts the LABUT and wingwalls.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/08/95	0	0
Level II	8/08/95	0	0

Potential for debris Moderate. The channel is laterally unstable and sinuous with tree cover and cut-banks evident along the upstream and downstream banks.

Describe any features near or at the bridge that may affect flow (include observation date)

Point bars along the RABUT and upstream left bank constrict the channel at lower flows. Observed on 8/08/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with no flood plain and steep valley walls on both sides.

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

Date of inspection 8/08/95

DS left: Steep channel bank and valley wall.

DS right: Steep channel bank and valley wall.

US left: Steep channel bank and valley wall.

US right: Steep channel bank and valley wall.

Description of the Channel

Average top width 45 ***ft*** ***Average depth*** 3 ***ft***

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

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

8/08/95

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Yes

Do banks appear stable? Impact zones and cut-banks exist along the upstream left bank and the downstream right bank but, the stream is considered to be stable due to the steep valley walls and large bed and bank material which includes bedrock outcrops in many areas along the reach.

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

The assessment of 8/08/95 noted low flow conditions are influenced by point bars along the right abutment and along the upstream left bank. In addition, some debris is caught on boulders in the upstream channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.85 ***mi²***

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 -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,490 ***ft³/s*** ***Q500*** 2,100 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(7.8/8.1) exp 0.67] with bridge number 10 in Burke. Bridge number 10 crosses Roundy Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 10 is 8.1 square miles. These values were selected due to their central tendency when compared to other discharge frequency curves which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the right end of the downstream concrete bridge curb (elev. 501.63 ft, arbitrary survey datum). RM2 is a chiseled X on top of the left end of the downstream concrete bridge curb (elev. 500.99 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-21	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	46	2	Modelled Approach section (Templated from APTEM)
APTEM	63	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 0.045 to 0.060, and overbank "n" values ranged from 0.040 to 0.070.

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 0.0164 ft/ft, which was estimated from surveyed downstream thalweg points.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0619 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 501.2 *ft*
Average low steel elevation 497.6 *ft*

100-year discharge 1,490 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 424 *ft³/s*
Area of flow in bridge opening 97 *ft²*
Average velocity in bridge opening 11.0 *ft/s*
Maximum WSPRO tube velocity at bridge 12.7 *ft/s*

Water-surface elevation at Approach section with bridge 501.4
Water-surface elevation at Approach section without bridge 499.2
Amount of backwater caused by bridge 2.2 *ft*

500-year discharge 2,100 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 1,050 *ft³/s*
Area of flow in bridge opening 97 *ft²*
Average velocity in bridge opening 10.9 *ft/s*
Maximum WSPRO tube velocity at bridge 12.6 */s*

Water-surface elevation at Approach section with bridge 502.0
Water-surface elevation at Approach section without bridge 499.9
Amount of backwater caused by bridge 2.1 *ft*

Incipient overtopping discharge 770 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Area of flow in bridge opening 97 *ft²*
Average velocity in bridge opening 8.0 *ft/s*
Maximum WSPRO tube velocity at bridge 9.2 *ft/s*

Water-surface elevation at Approach section with bridge 499.5
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 2.0 *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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the 100- and 500-year scour analysis are presented in Tables 1 and 2 and the scour depths are presented graphically in Figure 8.

At this site, the 100- and 500-year discharges resulted in submerged orifice flow, while the incipient roadway-overtopping discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and presented in Appendix F. Furthermore, for the discharge resulting in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution are provided in Appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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 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	1.2	0.0
Depth to armoring	9.3	8.3	3.6
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	11.7	11.5	9.6
Right abutment	7.0	1.7	5.7
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	2.0	2.0	1.6
Right abutment	2.0	2.0	1.6
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

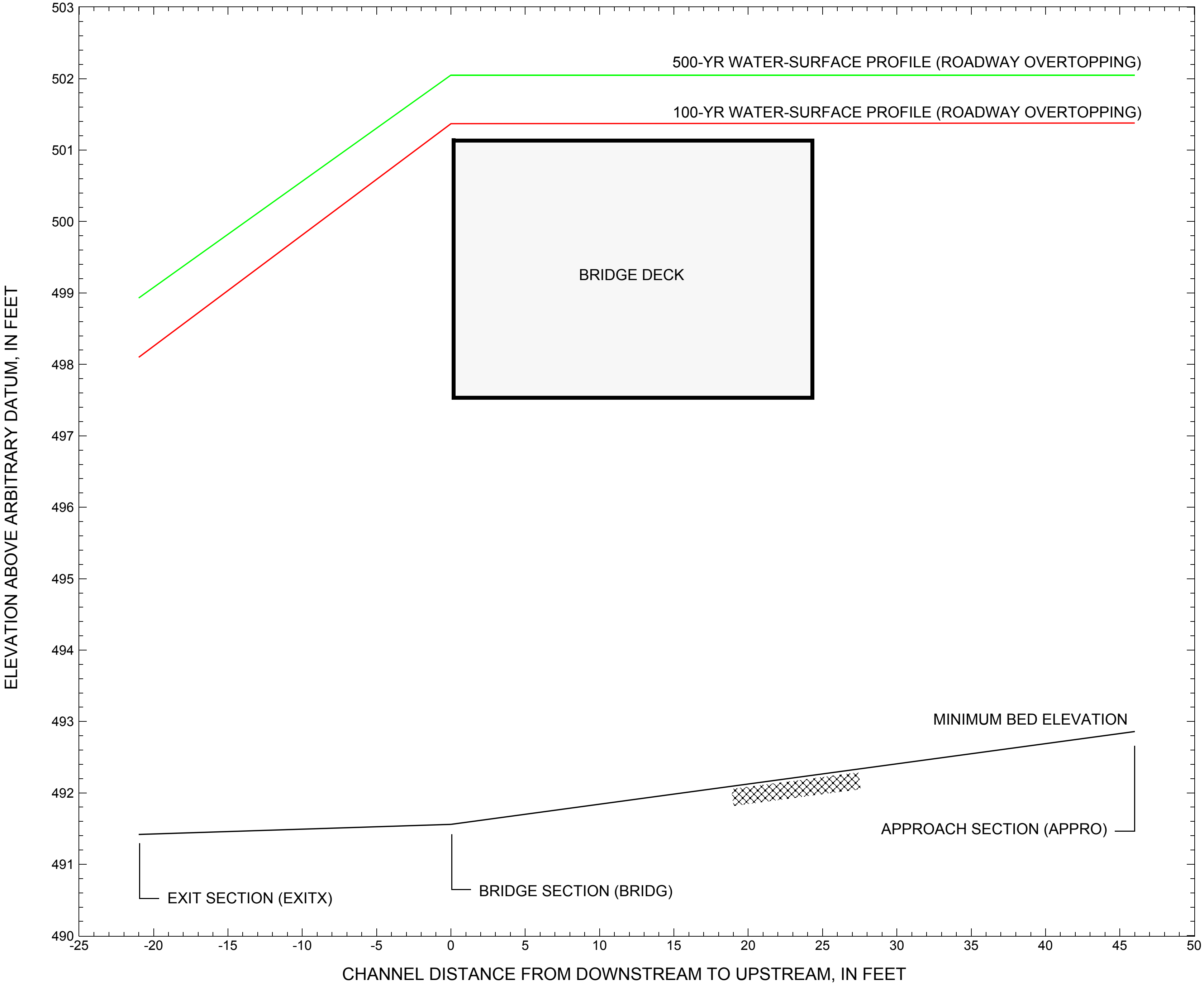

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BURKTH00130033 on Town Highway 13, crossing Roundy Brook, Burke, Vermont.

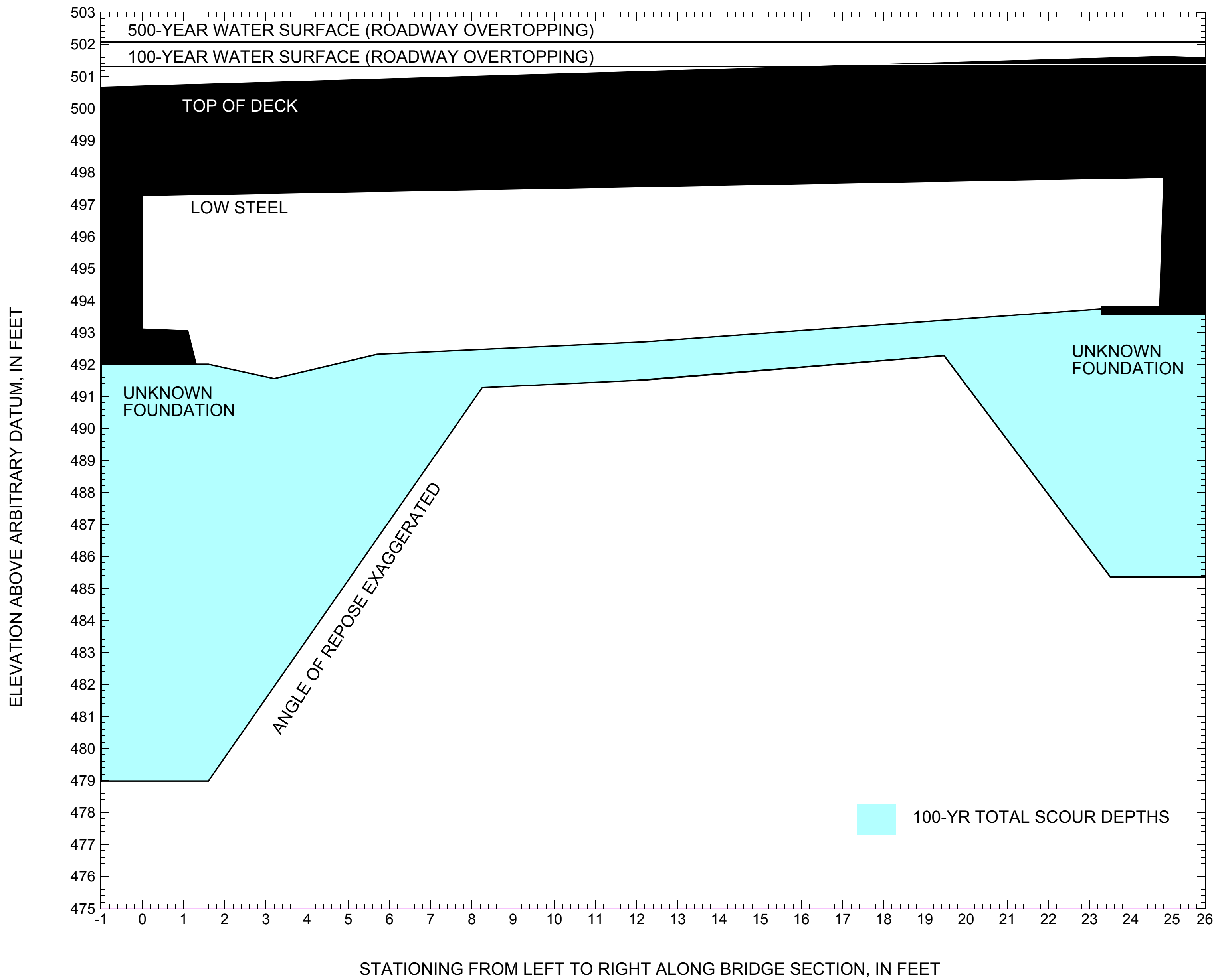

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BURKTH00130033 on Town Highway 13, crossing Roundy Brook, Burke, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BURKTH00130033 on Town Highway 13, crossing Roundy Brook, Burke, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,490 cubic-feet per second											
Left abutment	0.0	-	497.3	-	492.0	1.4	11.7	--	13.1	478.9	-
Right abutment	24.8	-	497.8	-	493.8	1.4	7.0	--	8.4	485.4	-

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 BURKTH00130033 on Town Highway 13, crossing Roundy Brook, Burke, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,100 cubic-feet per second											
Left abutment	0.0	-	497.3	-	492.0	1.2	11.5	--	12.7	479.3	-
Right abutment	24.8	-	497.8	-	493.8	1.2	1.7	--	2.9	490.9	-

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 Terrain: 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 Emergency Management Agency, 1979, Flood Insurance Study, Town of Burke, Caledonia County, Vermont: Washington, D.C., December 1979.

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

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

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.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 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.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 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. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 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, 1988, West Burke, 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

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T1        U.S. Geological Survey WSPRO Input File burk033.wsp
T2        Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
T3        Bridge #33 over Roundy Brook in Burke, Vt.  RHF
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
Q           1490.0   2100.0    770.0
SK          0.0164   0.0164    0.0164
*
XS   EXITX    -21           0.
GR          -63.1, 508.40    -52.9, 500.52    -40.0, 498.61    -29.5, 498.39
GR          -18.0, 497.46     -9.5, 497.39     -4.5, 494.87      0.0, 492.92
GR            5.2, 491.42      8.2, 491.58     15.0, 492.09     17.4, 492.83
GR           24.0, 496.07     27.8, 497.86     44.6, 498.61     60.5, 505.67
*
N           0.040        0.055        0.070
SA                 -9.5         27.8
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.56      35.0
GR            0.0, 497.28      0.0, 493.10      1.1, 493.05      1.6, 492.01
GR            3.2, 491.56      5.7, 492.32     12.2, 492.71     24.7, 493.76
GR           24.8, 497.85      0.0, 497.28
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD          1      33.5 * *     62.9      4.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      19.5     2
GR          -63.1, 508.40    -52.9, 500.52    -45.7, 500.04    -28.0, 499.32
GR          -12.7, 499.46     -6.5, 500.16     -6.0, 500.70     -5.9, 501.07
GR           33.0, 501.73     33.6, 501.63     40.3, 500.59     79.4, 503.10
GR           96.0, 502.90
**
XT   APTEM     63
GR          -37.5, 510.00    -23.8, 508.95     -7.5, 499.88     -3.8, 496.00
GR            0.0, 495.15      2.0, 494.34      7.2, 493.91     10.6, 494.53
GR           13.7, 494.04     18.8, 494.72     20.8, 495.23     23.2, 495.92
GR           25.4, 499.90     28.5, 502.41     43.0, 503.10     59.6, 502.90
GR           65.0, 506.00
*
AS   APPRO     46 * * * 0.0619
GT
N           0.070        0.060        0.040
SA                 -23.8        28.5
*
HP 1 BRIDG  497.85 1 497.85
HP 2 BRIDG  497.85 * * 1065
HP 2 RDWAY  501.37 * * 424
HP 1 APPRO  501.38 1 501.38
HP 2 APPRO  501.38 * * 1490
*
HP 1 BRIDG  497.85 1 497.85
HP 2 BRIDG  497.85 * * 1049
HP 2 RDWAY  502.05 * * 1051
HP 1 APPRO  502.05 1 502.05
HP 2 APPRO  502.05 * * 2100
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
        U.S. Geological Survey WSPRO Input File burk033.wsp
        Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
        Bridge #33 over Roundy Brook in Burke, Vt.  RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       97      4971      0     50                      3899352
   497.85            97      4971      0     50  1.00      0     25  3899352

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.85     0.0    24.8    96.6    4971.    1065.  11.03

X STA.        0.0        2.1        3.2        4.2        5.2        6.2
  A(I)            7.9        5.0        4.6        4.3        4.3
  V(I)           6.73      10.62      11.56      12.25      12.41

X STA.        6.2        7.2        8.3        9.3       10.3       11.4
  A(I)            4.3        4.3        4.2        4.2        4.2
  V(I)          12.41      12.44      12.74      12.54      12.64

X STA.       11.4       12.5       13.5       14.7       15.8       17.0
  A(I)            4.3        4.3        4.4        4.5        4.5
  V(I)          12.38      12.53      12.13      11.94      11.87

X STA.       17.0       18.3       19.6       20.9       22.5       24.8
  A(I)            4.6        4.8        4.8        5.5        7.7
  V(I)          11.62      11.14      11.11       9.74       6.94


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.37   -54.0    11.8    81.4    3950.     424.   5.21

X STA.      -54.0      -47.6      -44.0      -41.0      -38.4      -36.0
  A(I)            5.9        4.7        4.4        4.1        4.0
  V(I)           3.57       4.47       4.85       5.20       5.27



X STA.      -36.0      -33.9      -31.8      -30.0      -28.2      -26.6
  A(I)            3.8        3.7        3.6        3.5        3.4
  V(I)           5.62       5.67       5.93       6.10       6.18

X STA.      -26.6      -24.9      -23.2      -21.5      -19.8      -18.1
  A(I)            3.4        3.4        3.4        3.4        3.4
  V(I)           6.20       6.24       6.22       6.32       6.25

X STA.      -18.1      -16.3      -14.5      -12.7      -10.8       11.8
  A(I)            3.4        3.5        3.4        3.6        9.4
  V(I)           6.16       6.13       6.20       5.95       2.27


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           2      247     18569     41     47                         3450
             3        0         0      0      0                            0
   501.38           247     18569     41     47  1.00    -11     29     3430

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.38   -12.1    29.0   246.6   18569.    1490.   6.04

X STA.      -12.1       -3.6       -1.5        0.3        1.9        3.2
  A(I)           23.5       14.6       12.7       12.0       11.2
  V(I)           3.17       5.10       5.88       6.23       6.68

X STA.        3.2        4.5        5.7        6.9        8.1        9.3
  A(I)           10.6       10.2        9.9       10.0       10.1
  V(I)           7.03       7.31       7.49       7.42       7.38

X STA.        9.3       10.6       11.9       13.1       14.3       15.6
  A(I)           10.1       10.1       10.1       10.0       10.4
  V(I)           7.35       7.37       7.36       7.42       7.15

X STA.       15.6       16.9       18.3       19.9       21.9       29.0
  A(I)           11.0       11.1       12.3       14.1       22.6
  V(I)           6.78       6.73       6.04       5.29       3.30
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WSPRO OUTPUT FILE (continued)

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         U.S. Geological Survey WSPRO Input File burk033.wsp
         Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
         Bridge #33 over Roundy Brook in Burke, Vt.  RHF

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       97      4971      0     50                      3899352
    497.85            97      4971      0     50  1.00      0     25  3899352

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.85     0.0    24.8    96.6    4971.    1049.  10.86

 X STA.        0.0        2.1        3.2        4.2        5.2        6.2
   A(I)            7.9        5.0        4.6        4.3        4.3
   V(I)           6.62      10.46      11.39      12.07      12.23

 X STA.        6.2        7.2        8.3        9.3       10.3       11.4
   A(I)            4.3        4.3        4.2        4.2        4.2
   V(I)          12.22      12.25      12.55      12.35      12.45

 X STA.       11.4       12.5       13.5       14.7       15.8       17.0
   A(I)            4.3        4.3        4.4        4.5        4.5
   V(I)          12.19      12.34      11.95      11.76      11.69

 X STA.       17.0       18.3       19.6       20.9       22.5       24.8
   A(I)            4.6        4.8        4.8        5.5        7.7
   V(I)          11.45      10.97      10.94       9.60       6.83


     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

          WSEL     LEW     REW    AREA        K        Q    VEL
        502.05   -54.9    63.0   160.1    7882.    1051.   6.56

 X STA.      -54.9      -48.3      -44.7      -41.5      -38.7      -36.0
   A(I)            9.2        7.1        6.7        6.4        6.3
   V(I)           5.71       7.36       7.86       8.24       8.34

 X STA.      -36.0      -33.5      -31.2      -29.1      -27.0      -24.9
   A(I)            6.0        5.8        5.7        5.6        5.6
   V(I)           8.70       9.03       9.18       9.35       9.37

 X STA.      -24.9      -22.9      -20.8      -18.7      -16.6      -14.4
   A(I)            5.6        5.5        5.5        5.7        5.6
   V(I)           9.47       9.53       9.49       9.24       9.42

 X STA.      -14.4      -12.3       -9.8       -0.4       35.5       63.0
   A(I)            5.6        6.0       12.9       21.5       21.8
   V(I)           9.31       8.80       4.08       2.45       2.41

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              2      274     21735     42     48                         3986
              3        7        90     31     32                           18
    502.05           281     21825     73     80  1.04    -12     60     3067

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

          WSEL     LEW     REW    AREA        K        Q    VEL
        502.05   -13.3    60.0   281.0   21825.    2100.   7.47

 X STA.      -13.3       -4.0       -1.7        0.1        1.7        3.1
   A(I)           26.8       17.0       14.3       13.4       12.2
   V(I)           3.92       6.19       7.35       7.83       8.57

 X STA.        3.1        4.5        5.8        7.0        8.2        9.5
   A(I)           12.0       11.7       11.2       11.2       11.3
   V(I)           8.78       9.00       9.41       9.35       9.29

 X STA.        9.5       10.8       12.1       13.3       14.6       15.9
   A(I)           11.2       11.3       11.3       11.1       11.5
   V(I)           9.35       9.30       9.31       9.45       9.13

 X STA.       15.9       17.3       18.8       20.4       22.4       60.0
   A(I)           12.1       12.6       13.2       15.5       30.1
   V(I)           8.64       8.33       7.93       6.76       3.49
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         U.S. Geological Survey WSPRO Input File burk033.wsp
         Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
         Bridge #33 over Roundy Brook in Burke, Vt.  RHF

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

      WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
              1       97      4971     0     50                      3899352
    497.85            97      4971     0     50  1.00      0     25  3899352

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.85     0.0    24.8    96.6    4971.     770.   7.97

 X STA.        0.0        2.1        3.2        4.2        5.2        6.2
  A(I)             7.9        5.0        4.6        4.3        4.3
  V(I)            4.86       7.68       8.36       8.86       8.98

 X STA.        6.2        7.2        8.3        9.3       10.3       11.4
  A(I)             4.3        4.3        4.2        4.2        4.2
  V(I)            8.97       9.00       9.21       9.06       9.14

 X STA.       11.4       12.5       13.5       14.7       15.8       17.0
  A(I)             4.3        4.3        4.4        4.5        4.5
  V(I)            8.95       9.06       8.77       8.63       8.58

 X STA.       17.0       18.3       19.6       20.9       22.5       24.8
  A(I)             4.6        4.8        4.8        5.5        7.7
  V(I)            8.40       8.06       8.03       7.04       5.02


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

      WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
              1       84      5739    20     28                          968
    496.94            84      5739    20     28  1.00      0     25      968


     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

      WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
              2      176     11715    35     40                         2235
    499.50           176     11715    35     40  1.00     -8     26     2235

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

          WSEL     LEW     REW    AREA        K        Q    VEL
        499.50    -8.7    26.2   175.6   11715.     770.   4.38

 X STA.       -8.7       -2.6       -0.5        1.1        2.5        3.7
  A(I)            15.6       10.5        9.0        8.3        7.9
  V(I)            2.46       3.68       4.25       4.62       4.88

 X STA.        3.7        4.9        6.0        7.2        8.3        9.4
  A(I)             7.7        7.3        7.3        7.3        7.3
  V(I)            4.98       5.25       5.26       5.25       5.26

 X STA.        9.4       10.7       11.9       13.0       14.2       15.4
  A(I)             7.5        7.5        7.3        7.4        7.7
  V(I)            5.14       5.14       5.29       5.18       4.99

 X STA.       15.4       16.6       18.0       19.5       21.4       26.2
  A(I)             7.7        8.3        8.7       10.1       15.1
  V(I)            5.02       4.65       4.43       3.82       2.55
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File burk033.wsp
        Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
        Bridge #33 over Roundy Brook in Burke, Vt.  RHF

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

EXITX:XS   ******    -25      173  1.22 *****  499.32  497.34    1490  498.10
       -20 ******     33    11626  1.06 ***** *******    0.91    8.61

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.81    498.73     497.34
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   497.60     508.40    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   497.60     508.40     497.34

FULLV:FV       21    -40      221  0.82  0.26  499.58  497.34    1490  498.76
         0     21     45    15276  1.17  0.00    0.00    0.80    6.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.70

APPRO:AS       46     -7      164  1.29  0.63  500.44 *******    1490  499.15
        46     46     26    10649  1.00  0.23    0.00    0.73    9.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =   498.76     497.56

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

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

BRIDG:BR       21      0       97  1.89 *****  499.74  497.22    1065  497.85
         0 ******     25     4971  1.00 ***** *******    0.99   11.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.56 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    27.  0.17  0.57  501.78    0.00    424.  501.37

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    424.    48.   -54.    -6.   2.0   1.6   6.5   5.4   2.0   3.0
   RT:      0.    11.    11.    23.   0.2   0.1   3.0  11.3   0.5   2.7

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

APPRO:AS       13    -11      247  0.57  0.23  501.95  498.12    1490  501.38
        46     13     29    18561  1.00  0.00    0.00    0.43    6.04

        U.S. Geological Survey WSPRO Input File burk033.wsp
        Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
        Bridge #33 over Roundy Brook in Burke, Vt.  RHF
           *** RUN DATE & TIME: 09-30-97  14:03

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -21.   -26.    33.   1490.   11626.     173.    8.61  498.10
   FULLV:FV       0.   -41.    45.   1490.   15276.     221.    6.73  498.76
   BRIDG:BR       0.     0.    25.   1065.    4971.      97.   11.03  497.85
   RDWAY:RG      13.*******   424.    424.*********       0.    2.00  501.37
   APPRO:AS      46.   -12.    29.   1490.   18561.     247.    6.04  501.38

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    497.34    0.91  491.42  508.40************  1.22  499.32  498.10
   FULLV:FV    497.34    0.80  491.42  508.40  0.26  0.00  0.82  499.58  498.76
   BRIDG:BR    497.22    0.99  491.56  497.85************  1.89  499.74  497.85
   RDWAY:RG  ***************  499.32  510.00  0.17******  0.57  501.78  501.37
   APPRO:AS    498.12    0.43  492.86  508.95  0.23  0.00  0.57  501.95  501.38
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WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File burk033.wsp
       Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
       Bridge #33 over Roundy Brook in Burke, Vt.  RHF

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

EXITX:XS   ******    -41      235  1.46 *****  500.39  498.92    2100  498.93
       -20 ******     45    16393  1.18 ***** *******    1.04    8.92

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.42

FULLV:FV       21    -47      315  0.83  0.24  500.62 *******    2100  499.79
         0     21     47    23359  1.20  0.00    0.00    0.71    6.68
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85     499.91     499.27
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   499.29     508.95    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   499.29     508.95     499.27
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.56

APPRO:AS       46     -8      191  1.89  0.66  501.81  499.27    2100  499.92
        46     46     27    13105  1.00  0.53    0.00    0.85   11.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   499.79     497.56
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    1051.      1028.    1.02

            <<<<<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       21      0       97  1.84 *****  499.69  497.18    1049  497.85
         0 ******     25     4971  1.00 ***** *******    0.97   10.87

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.56 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    27.  0.24  0.90  502.71    0.00   1051.  502.05

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    824.    66.   -55.    11.   2.7   1.9   7.3   6.5   2.6   3.0
   RT:    227.    52.    11.    63.   1.5   0.7   5.0   6.6   1.3   2.9

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

APPRO:AS       13    -12      281  0.90  0.30  502.95  499.27    2100  502.05
        46     13     60    21844  1.04  0.00    0.00    0.68    7.47

       U.S. Geological Survey WSPRO Input File burk033.wsp
       Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
       Bridge #33 over Roundy Brook in Burke, Vt.  RHF

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -21.   -42.    45.   2100.   16393.     235.    8.92  498.93
   FULLV:FV       0.   -48.    47.   2100.   23359.     315.    6.68  499.79
   BRIDG:BR       0.     0.    25.   1049.    4971.      97.   10.87  497.85
   RDWAY:RG      13.*******   824.   1051.*********       0.    2.00  502.05
   APPRO:AS      46.   -13.    60.   2100.   21844.     281.    7.47  502.05

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD     EGL    WSEL
   EXITX:XS    498.92    1.04  491.42  508.40************  1.46  500.39  498.93
   FULLV:FV  ********    0.71  491.42  508.40   0.24   0.00  0.83  500.62  499.79
   BRIDG:BR    497.18    0.97  491.56  497.85************  1.84  499.69  497.85
   RDWAY:RG  ****************  499.32  508.40   0.24******  0.90  502.71  502.05
   APPRO:AS    499.27    0.68  492.86  508.95   0.30   0.00  0.90  502.95  502.05
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 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V042094            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File burk033.wsp
         Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
         Bridge #33 over Roundy Brook in Burke, Vt.  RHF
            *** RUN DATE & TIME: 09-12-97  14:30

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

 EXITX:XS   ******     -7      105  0.83 *****  497.28  495.68     770  496.44
       -20 ******     25     6008  1.00 ***** *******    0.72    7.32

 FULLV:FV       21     -8      122  0.62  0.28  497.56 *******     770  496.94
         0     21     26     7360  1.00  0.00    0.01    0.59    6.32
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       46     -5      110  0.76  0.62  498.25 *******     770  497.50
        46     46     25     6004  1.00  0.07    0.00    0.65    6.97
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   496.37     498.68     498.86     497.56
  ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

 BRIDG:BR       21      0       97  0.99 *****  498.84  496.35     769  497.85
         0 ******     25     4971  1.00 ***** *******    0.71    7.96

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.493  0.000  497.56 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS       13     -8      176  0.30  0.13  499.80  496.53     770  499.50
        46     13     26    11717  1.00  0.94    0.00    0.34    4.38

         U.S. Geological Survey WSPRO Input File burk033.wsp
         Hydraulic analysis for structure BURKTH00130033   Date: 15-AUG-97
         Bridge #33 over Roundy Brook in Burke, Vt.  RHF

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -21.    -8.    25.    770.    6008.     105.    7.32  496.44
    FULLV:FV       0.    -9.    26.    770.    7360.     122.    6.32  496.94
    BRIDG:BR       0.     0.    25.    769.    4971.      97.    7.96  497.85
    RDWAY:RG      13.**************      0.       0.       0.    2.00********
    APPRO:AS      46.    -9.    26.    770.   11717.     176.    4.38  499.50

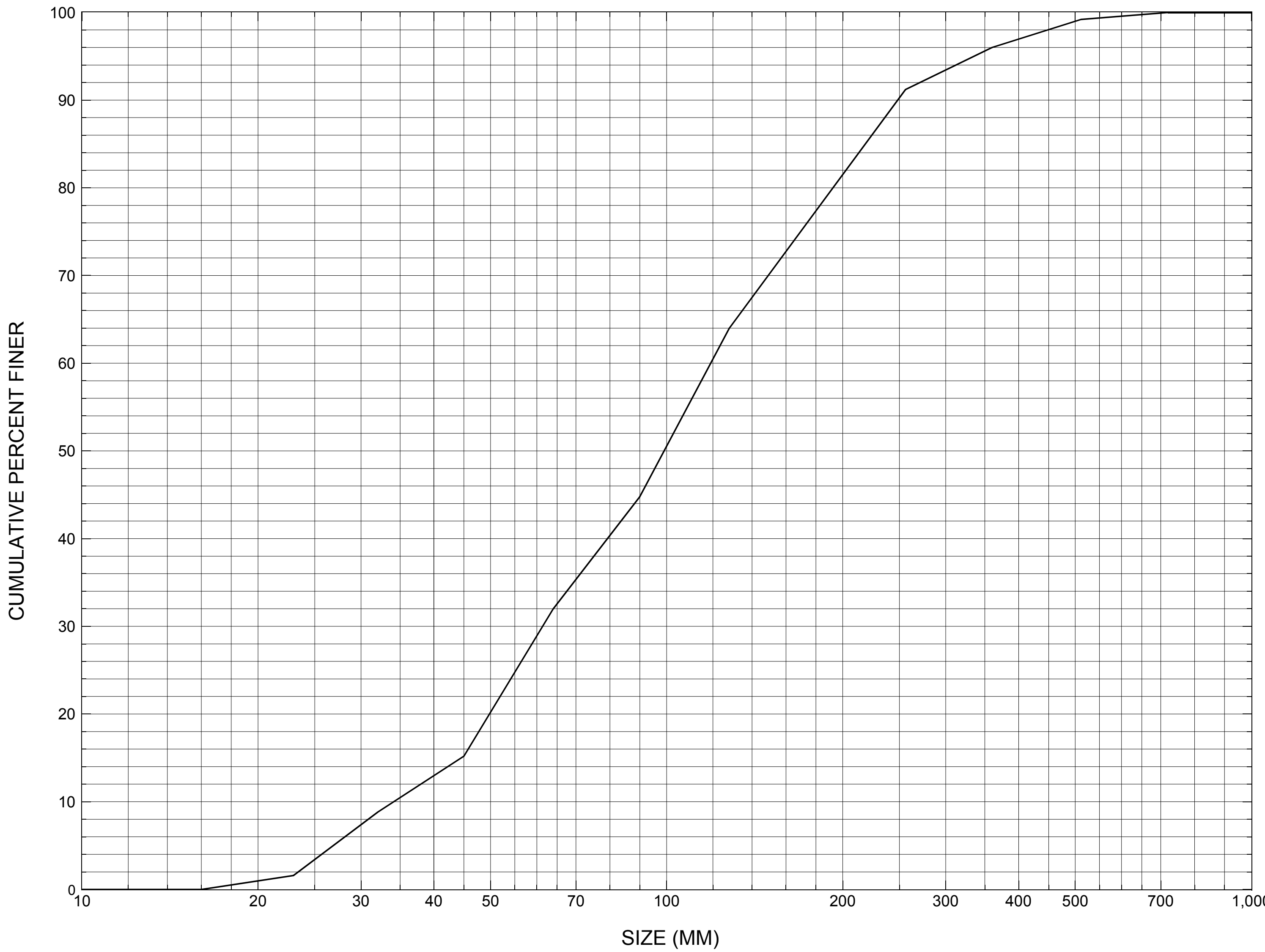
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS    495.68    0.72  491.42  508.40************  0.83  497.28  496.44
    FULLV:FV  ********    0.59  491.42  508.40  0.28  0.00  0.62  497.56  496.94
    BRIDG:BR    496.35    0.71  491.56  497.85************  0.99  498.84  497.85
    RDWAY:RG  ****************  499.32  508.40************  0.30  499.68********
    APPRO:AS    496.53    0.34  492.86  508.95  0.13  0.94  0.30  499.80  499.50
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BURKTH00130033, in Burke, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BURKTH00130033

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 24 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 10450

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

Waterway *(I - 6)* ROUNDY BROOK

Road Name *(I - 7):* -

Route Number TH013

Vicinity *(I - 9)* 0.6 MI JCT TH 13 + TH 29

Topographic Map West Burke

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44377

Longitude *(i - 17; nnnnn.n)* 71566

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030200330302

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000030

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 195

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

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

Opening skew to Roadway *(I - 34; nn)* 35

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 022.9

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

Vertical clearance from streambed (*nnn.n ft*) 004.8

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

Waterway of full opening (*nnn.n ft*^{2}) 110.0

Comments:

The structural inspection report of 10/31/94 indicates that the structure is a steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete and reportedly have a few fine cracks, small leaks and spalls overall. The left abutment and its upstream wingwall have a couple of deeper spalls along the base of the wall. The left abutment footing is exposed and its concrete is spalled with small voided areas along the bottom at its upstream end. The right abutment has a 1/8” vertical crack just left of the centerline of the roadway. A small section of the right abutment footing is noted as exposed along the upstream end and along the upstream wingwall. A low, coarse gravel point bar **(Continued, page 33)**

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: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

is reported in front of the right abutment and blocks half of the channel. Bedrock is noted as outcropped in the upstream channel. Boulders (riprap) also are evident along the up- and downstream banks. The report indicates the channel has a poor alignment with the bridge opening, flowing around a 90 degree bend in order to proceed through the bridge. Debris accumulation is reported as minor.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **7.85** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1040** ft Headwater elevation **2215** ft

Main channel length **8.86** mi

10% channel length elevation **1170** ft 85% channel length elevation **1790** ft

Main channel slope *(S)* **93.29** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number ________________________ Minimum channel bed elevation: ________

Low superstructure elevation: USLAB _______ DSLAB ________ USRAB _______ DSRAB _______

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **This cross section is along the upstream face. The low chord elevations are from the survey log completed for this report on 8/8/95. The low chord to bed length data is from the sketch attached to an bridge inspection report dated 10/31/94. The sketch was completed on 10/28/92.**

Station	0	2	13.3	22.9	-	-	-	-	-	-	-
Feature	LAB	-	-	RAB	-	-	-	-	-	-	-
Low chord elevation	497.3	497.3	497.6	497.8	-	-	-	-	-	-	-
Bed elevation	493.5	492.1	493.3	493.9	-	-	-	-	-	-	-
Low chord-bed	3.8	5.2	4.3	3.9	-	-	-	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/1/96**
Computerized by: **RB** Date: **3/4/96**
Reviewd by: **RHF** Date: **10/1/97**

Structure Number **BURKTH00130033**

A. General Location Descriptive

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

2. Highway District Number **07** Mile marker **0000**

County **005** Town **10450**

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

Route Number **TH013** Hydrologic Unit Code: **01080102**

3. Descriptive comments:
This concrete slab bridge is located just DS of bedrock outcrops on a severe bend in the channel. The slab is supported by steel I-beams. The year "1928" is shown in the raised concrete on the US left bank guard rail post. This bridge is located 0.6 mile from the junction of TH013 and TH029.

B. Bridge Deck Observations

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

5. Ambient water surface... US **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 **30** *(feet)* Span length **26** *(feet)* Bridge width **19.5** *(feet)*

Road approach to bridge:

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

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

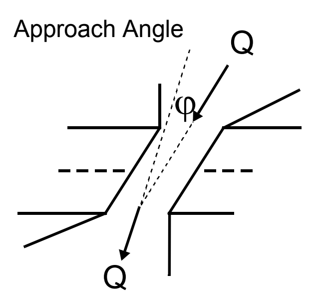
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

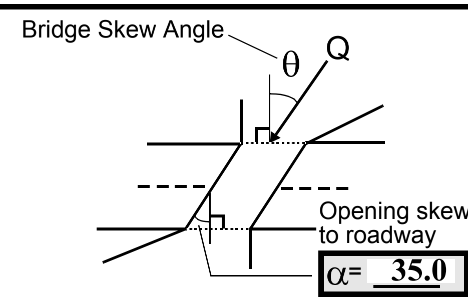
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	2	4	1	3
RBDS	0	-	0	0
LBDS	1	3	3	2

*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: **30** 16. Bridge skew: **60**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **20** feet **US** *(US, UB, DS)* to **45** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **0** feet **UB** *(US, UB, DS)* to **15** feet **US**

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

18. Bridge Type: **1a**

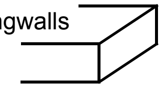
1a- Vertical abutments with wingwalls

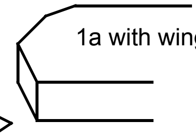
1b- Vertical abutments without wingwalls

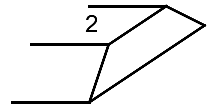
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face

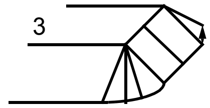
3- Spill through abutments

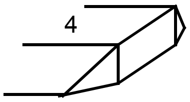
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.











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

7. Values are from the VT AOT. Measured bridge length is 30 feet, span length is 26 feet and bridge width is 20 feet.

17. Channel impact zone 1 on the US right bank has a small impact angle but is causing extensive cut-bank damage at the location of the right road embankment.
Channel impact zone 2 impacts the US left bank and has a severe impact angle at the location of the US left wingwall and left abutment.

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
31.0	**4.0**			**4.0**	**3**	**2**	**543**	**543**	**2**	**2**

23. Bank width **40.0** 24. Channel width **60.0** 25. Thalweg depth **52.5** 29. Bed Material **456**

30 .Bank protection type: LB **1** RB **1** 31. Bank protection condition: LB **2** RB **4**

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 bedrock provides a good control for potential channel scour upstream. The upstream channel bed also contains some sand and gravel especially in the vicinity of the point bar.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **40** 35. Mid-bar width: **6**

36. Point bar extent: **35** feet **US** (US, UB) to **78** feet **US** (US, UB, DS) positioned **0** %LB to **20** %RB

37. Material: **632**

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

The point bar is underlain by beds of shist dipping towards the left bank and upstream which help to hold the fine bar material in place. There are also cobbles and boulders on the point bar.

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

41. Mid-bank distance: **20** 42. Cut bank extent: **0** feet **US** (US, UB) to **30** feet **US** (US, UB, DS)

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

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

The cutbank begins at the US end of the US left wingwall. There is an additional cut bank on the right bank starting at 27 feet US (at the US end of the US right wingwall) and ending at 47 feet US. It has block failure and is cutting into the right road embankment.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **10** Width **3** Depth : **1** Position **0** %LB to **10** %RB

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

The scour is along the left abutment and US left wingwall footings with the maximum scour depth being at the US bridge face.

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
27.0		1.0		2	7	7	-

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

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

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

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

345

There is also a lot of sand on the point bar located under the bridge and this is discussed in the DS channel assessment.

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

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

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

70. Debris and Ice Comments:

2

The debris potential is moderate due to the large number of trees along the banks. The capture efficiency is moderate because of a low opening height and a sharp skew angle. The ice blockage potential is moderate for the same reasons.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**30**	**90**	**2**	**2**	**1.0**	**1.5**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**20.5**

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.):

-

-

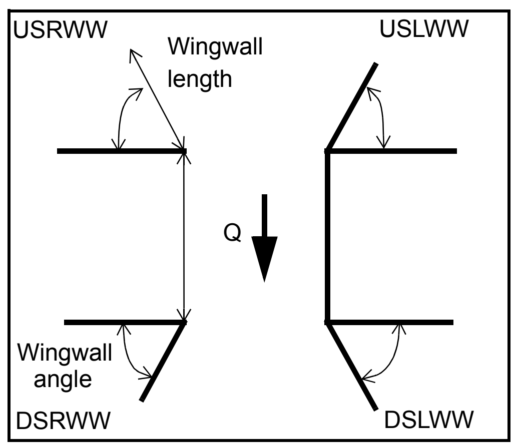
1

There is a void between the bottom of the left abutment wall and the top of the left abutment footing.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**20.5**	
USRWW:	**Y**		**1**		**2**	**2.0**	
DSLWW:	**1.0**		**1.5**		**Y**	**25.5**	
DSRWW:	**1**		**2**		**0.5**	**25.0**	

*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	**1**	**2**	**Y**	**-**	**-**	**-**	**-**	**-**
Condition	**Y**	**0.5**	**1**	**-**	**-**	**-**	**-**	**-**
Extent	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**

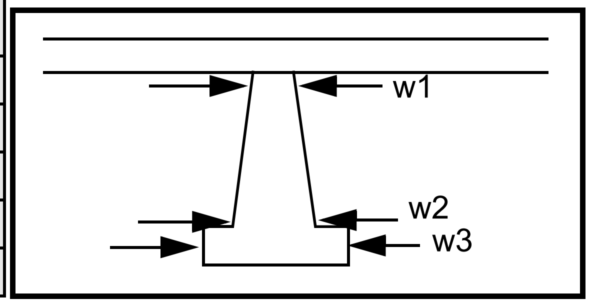
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
0
-
-
0
-
-
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	110.0			13.0	20.0	14.5
Pier 2				30.0	10.0	85.0
Pier 3		-	-	10.5	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
-
-
NO PIERS

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):

2
3
543

106. Point/Side bar present? 54 *(Y or N. if N type ctrl-n pb)* Mid-bar distance: 3 Mid-bar width: 1

Point bar extent: 2 feet 465 *(US, UB, DS)* to 2 feet 0 *(US, UB, DS)* positioned 3 %LB to - %RB

Material: At

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

45 feet DS, on the right bank, there is a currently dry minor inflow channel created by road gulley wash. The left bank protection extends from the DS end of the DS left wingwall to 40 feet DS. It has been eroded by channel and road wash with erosion becoming more severe towards the wingwall. The bank and bed also contain some interstitial sand.

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

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

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

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

N

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

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

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

RE

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

Confluence 1: Distance Y Enters on 0 *(LB or RB)* Type 9 *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance 0 Enters on US *(LB or RB)* Type 5 *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

DS
60

F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

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)*:

324

This point bar is noted in the historical form.

Y

RB

45

20

DS

80

DS

1

- T

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: BURKTH00130033 Town: Burke
Road Number: TH 13 County: Caledonia
Stream: Roundy Brook

Initials RHF Date: 9/12/97 Checked: SAO

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	1490	2100	770
Main Channel Area, ft2	247	274	175.6
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	7	0
Top width main channel, ft	41	42	35
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	31	0
D50 of channel, ft	0.32483	0.32483	0.32483
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	6.5	5.0
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	0.2	ERR
Total conveyance, approach	18569	21825	11715
Conveyance, main channel	18569	21735	11715
Conveyance, LOB	0	0	0
Conveyance, ROB	0	90	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1490.0	2091.3	770.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	8.7	0.0
Vm, mean velocity MC, ft/s	6.0	7.6	4.4
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	1.2	ERR
Vc-m, crit. velocity, MC, ft/s	10.4	10.5	10.1
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1065	1049	770
Main channel area (DS), ft2	97	97	84

Main channel width (normal), ft	20.3	20.3	20.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	20.3	20.3	20.3
D90, ft	0.8142	0.8142	0.8142
D95, ft	1.1001	1.1001	1.1001
Dc, critical grain size, ft	0.6661	0.6462	0.4972
Pc, Decimal percent coarser than Dc	0.178	0.189	0.293
Depth to armoring, ft	**9.26**	**8.31**	**3.61**

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	1490	2100	770
(Q) discharge thru bridge, cfs	1065	1049	770
Main channel conveyance	4971	4971	4971
Total conveyance	4971	4971	4971
Q2, bridge MC discharge,cfs	1065	1049	770
Main channel area, ft2	97	97	97
Main channel width (normal), ft	20.3	20.3	20.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.3	20.3	20.3
y_bridge (avg. depth at br.), ft	4.78	4.78	4.78
Dm, median (1.25*D50), ft	0.406038	0.406038	0.406038
y2, depth in contraction,ft	4.77	4.71	3.61
ys, scour depth (y2-ybridge), ft	-0.01	-0.07	-1.17

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc

Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)

Umbrell pressure flow equation

(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031

(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1490	2100	770
Q, thru bridge MC, cfs	1065	1049	770
Vc, critical velocity, ft/s	10.39	10.53	10.08
Va, velocity MC approach, ft/s	6.03	7.63	4.38
Main channel width (normal), ft	20.3	20.3	20.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.3	20.3	20.3
qbr, unit discharge, ft2/s	52.5	51.7	37.9
Area of full opening, ft2	97.0	97.0	97.0
Hb, depth of full opening, ft	4.78	4.78	4.78
Fr, Froude number, bridge MC	0.99	0.97	0.71
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	84
**Hb, depth at downstream face, ft	N/A	N/A	4.14
**Fr, Froude number at DS face	ERR	ERR	0.79
**Cf, for downstream face (<=1.0)	N/A	N/A	1.00
Elevation of Low Steel, ft	497.56	497.56	497.56
Elevation of Bed, ft	492.78	492.78	492.78
Elevation of Approach, ft	501.38	502.05	499.5
Friction loss, approach, ft	0.23	0.3	0.13
Elevation of WS immediately US, ft	501.15	501.75	499.37
ya, depth immediately US, ft	8.37	8.97	6.59
Mean elevation of deck, ft	501.16	501.16	501.16

w, depth of overflow, ft (>=0)	0.00	0.59	0.00
Cc, vert contrac correction (<=1.0)	0.82	0.82	0.92
**Cc, for downstream face (<=1.0)	ERR	ERR	0.872505
Ys, scour w/Chang equation, ft	**1.35**	**1.19**	**-0.68**
Ys, scour w/Umbrell equation, ft	1.86	3.03	-0.38

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

**Ys, scour w/Chang equation, ft	N/A	N/A	0.17
**Ys, scour w/Umbrell equation, ft	N/A	N/A	0.26

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

y2, from Laursen's equation, ft	4.77	4.71	3.61
WSEL at downstream face, ft	--	--	496.94
Depth at downstream face, ft	N/A	N/A	4.14
Ys, depth of scour (Laursen), ft	N/A	N/A	-0.52

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1490	2100	770	1490	2100	770
a', abut.length blocking flow, ft	14.3	15.5	10.9	6.5	37.5	3.7
Ae, area of blocked flow ft2	57.51	52.73	41.62	20.69	3.13	11.64
Qe, discharge blocked abut.,cfs	-	-	145.75	-	-	29.68

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	4.82	6.03	3.50	3.30	3.49	2.55
ya, depth of f/p flow, ft	4.02	3.40	3.82	3.18	0.08	3.15

--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	125	55	55	55
K2	1.04	1.04	1.04	0.94	0.94	0.94
Fr, froude number f/p flow	0.397	0.480	0.316	0.326	0.687	0.253
ys, scour depth, ft	**11.69**	**11.51**	**9.58**	**7.00**	**1.69**	**5.69**

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

a'(abut length blocked, ft)	14.3	15.5	10.9	6.5	37.5	3.7
y1 (depth f/p flow, ft)	4.02	3.40	3.82	3.18	0.08	3.15
a'/y1	3.56	4.56	2.85	2.04	449.28	1.18
Skew correction (p. 49, fig. 16)	1.08	1.08	1.08	0.87	0.87	0.87
Froude no. f/p flow	0.40	0.48	0.32	0.33	0.69	0.25
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	0.46	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	0.38	ERR
spill-through	ERR	ERR	ERR	ERR	0.26	ERR

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.99	0.97	0.79	0.99	0.97	0.79
y, depth of flow in bridge, ft	4.76	4.76	4.14	4.76	4.76	4.14
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	**1.60**	ERR	ERR	**1.60**
Fr>0.8 (vertical abut.)	**1.98**	**1.97**	ERR	**1.98**	**1.97**	ERR