LEVEL II SCOUR ANALYSIS FOR BRIDGE 59 (STRATH00030059) on TOWN HIGHWAY 3, crossing ABBOTT BROOK, STRAFFORD, VERMONT

Open-File Report 98-261

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 59 (STRATH00030059) on TOWN HIGHWAY 3, crossing ABBOTT BROOK, STRAFFORD, VERMONT

By RONDA L. BURNS and JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

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

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 59 (STRATH00030059) ON TOWN HIGHWAY 3, CROSSING ABBOTT BROOK, STRAFFORD, VERMONT

By **Ronda L. Burns 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 STRATH00030059 on Town Highway 3 crossing Abbott Brook, Strafford, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 8.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Abbott Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 36 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 126 mm (0.413 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 29, 1996, indicated that the reach was stable.

The Town Highway 3 crossing of Abbott Brook is a 28-ft-long, two-lane bridge consisting of one 24-foot concrete slab span (Vermont Agency of Transportation, written communication, March 9, 1995). The opening length of the structure parallel to the bridge face is 23.3 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 40 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the upstream right wingwall and right abutment during the Level I assessment. The only scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) along the upstream and downstream left and right banks. 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 0.4 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 5.7 to 7.4 ft. Right abutment scour ranged from 11.9 to 16.0 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number STRATH00030059 ***Stream*** Abbott Brook

County Orange ***Road*** TH 3 ***District*** 4

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 30.8 ***ft*** ***Max span length*** 24 ***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*** 7/29/96

Description of stone fill There is no stone fill at the bridge, but there is type-3 stone fill along the upstream and downstream left and right banks.

Abutments and wingwalls are concrete. There is a one foot deep scour hole in front of the upstream right wingwall and along the right abutment.

Yes

Is bridge skewed to flood flow according to There ***survey?*** 10 ***Angle*** Yes

is a severe channel bend in the upstream reach. The scour hole has developed where the flow impacts the upstream right wingwall and right abutment.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	7/29/96	0	0
Level II	7/29/96	0	0

Potential for debris Moderate. There are many trees on the banks.

Describe any features near or at the bridge that may affect flow (include observation date) There was a point bar in front of the upstream left wingwall as of 7/29/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 7/29/96

DS left: Steep channel bank to a mildly sloped overbank

DS right: Steep road embankment to Town Highway 3

US left: Steep road embankment to Town Highway 3

US right: Steep valley wall

Description of the Channel

Average top width 36 *ft* ***Average depth*** 5 *ft*

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

Sinuous but stable
with non-alluvial channel boundaries and narrow point bars.

7/29/96

Vegetative co Trees

DS left: Trees and brush

DS right: Trees and brush

US left: Trees

US right:

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

None as of 7/29/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.2 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,800 ***ft³/s*** ***Q500*** 2,800 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (written communication, May 1995) for this site. These values were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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 0.3 ft from the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 501.09 ft, arbitrary survey datum). RM2 is a chiseled X on top of the concrete curb at the downstream right corner of the bridge deck (elev. 500.50 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	-24	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	58	2	Modelled Approach section (Templated from APTEM)
APTEM	66	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 0.065, and overbank "n" values ranged from 0.040 to 0.080.

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 0.0186 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0677 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 provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.7 ***ft***
Average low steel elevation 498.4 ***ft***

100-year discharge 1,800 ***ft³/s***
Water-surface elevation in bridge opening 498.4 ***ft***
Road overtopping? Yes ***Discharge over road*** 631 ***ft³/s***
Area of flow in bridge opening 120 ***ft²***
Average velocity in bridge opening 9.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***ft/s***

Water-surface elevation at Approach section with bridge 501.6
Water-surface elevation at Approach section without bridge 498.6
Amount of backwater caused by bridge 3.0 ***ft***

500-year discharge 2,800 ***ft³/s***
Water-surface elevation in bridge opening 498.5 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,471 ***ft³/s***
Area of flow in bridge opening 121 ***ft²***
Average velocity in bridge opening 11.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.2 ***ft/s***

Water-surface elevation at Approach section with bridge 502.4
Water-surface elevation at Approach section without bridge 499.9
Amount of backwater caused by bridge 2.5 ***ft***

Incipient overtopping discharge 1,000 ***ft³/s***
Water-surface elevation in bridge opening 498.5 ***ft***
Area of flow in bridge opening 121 ***ft²***
Average velocity in bridge opening 8.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.1 ***ft/s***

Water-surface elevation at Approach section with bridge 500.2
Water-surface elevation at Approach section without bridge 496.7
Amount of backwater caused by bridge 3.5 ***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 scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

At this site, the 100-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow and the 500-year discharge resulted in submerged 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 streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was 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). Results from these computations are presented in appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions 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-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.4	0.0
Depth to armoring	5.0	6.5	17.3
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	5.7	7.4	6.2
Right abutment	15.2	16.0	11.9
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.2	2.7	1.9
Right abutment	2.2	2.7	1.9
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

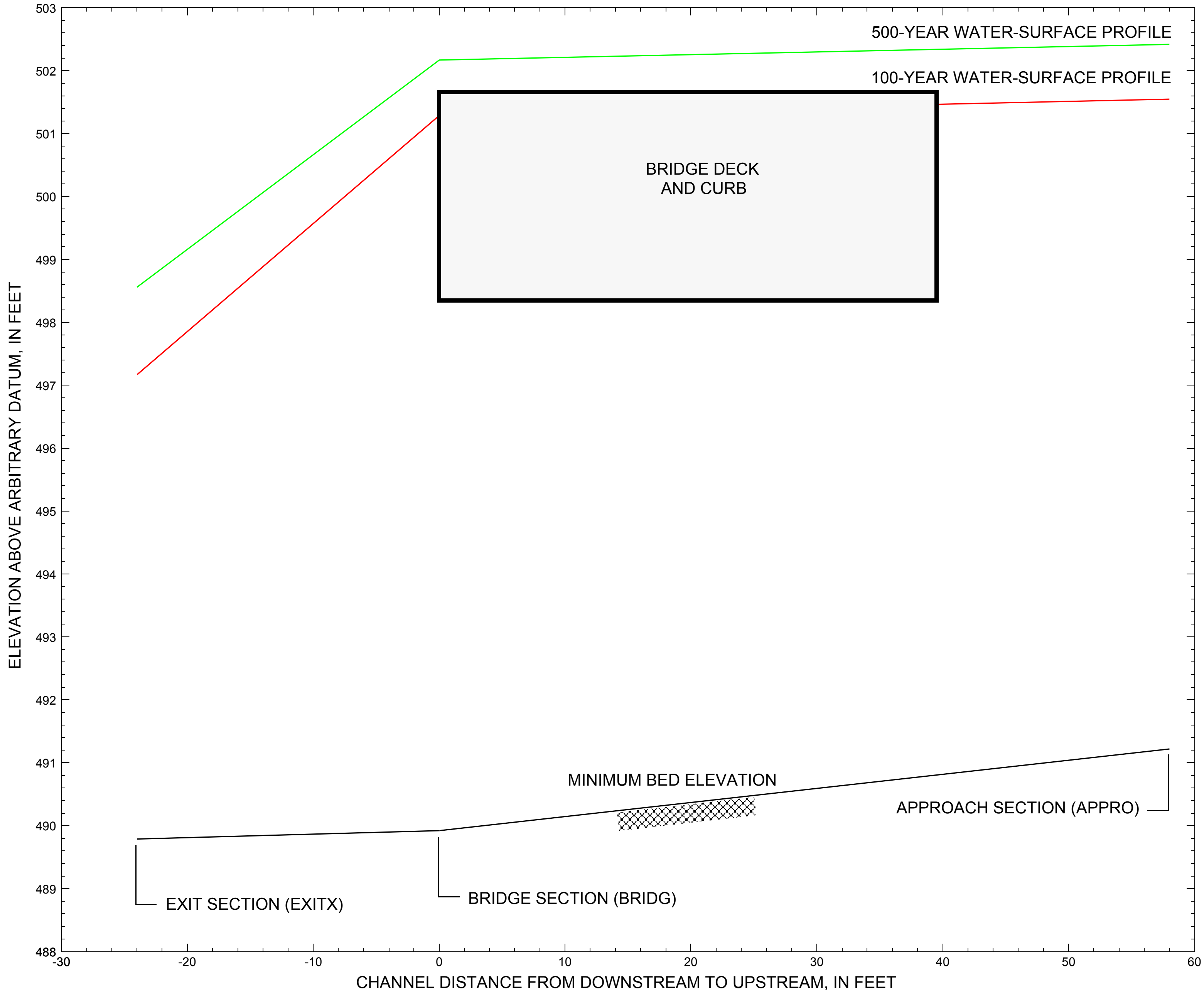

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure STRATH00030059 on Town Highway 3, crossing Abbott Brook, Strafford, Vermont.

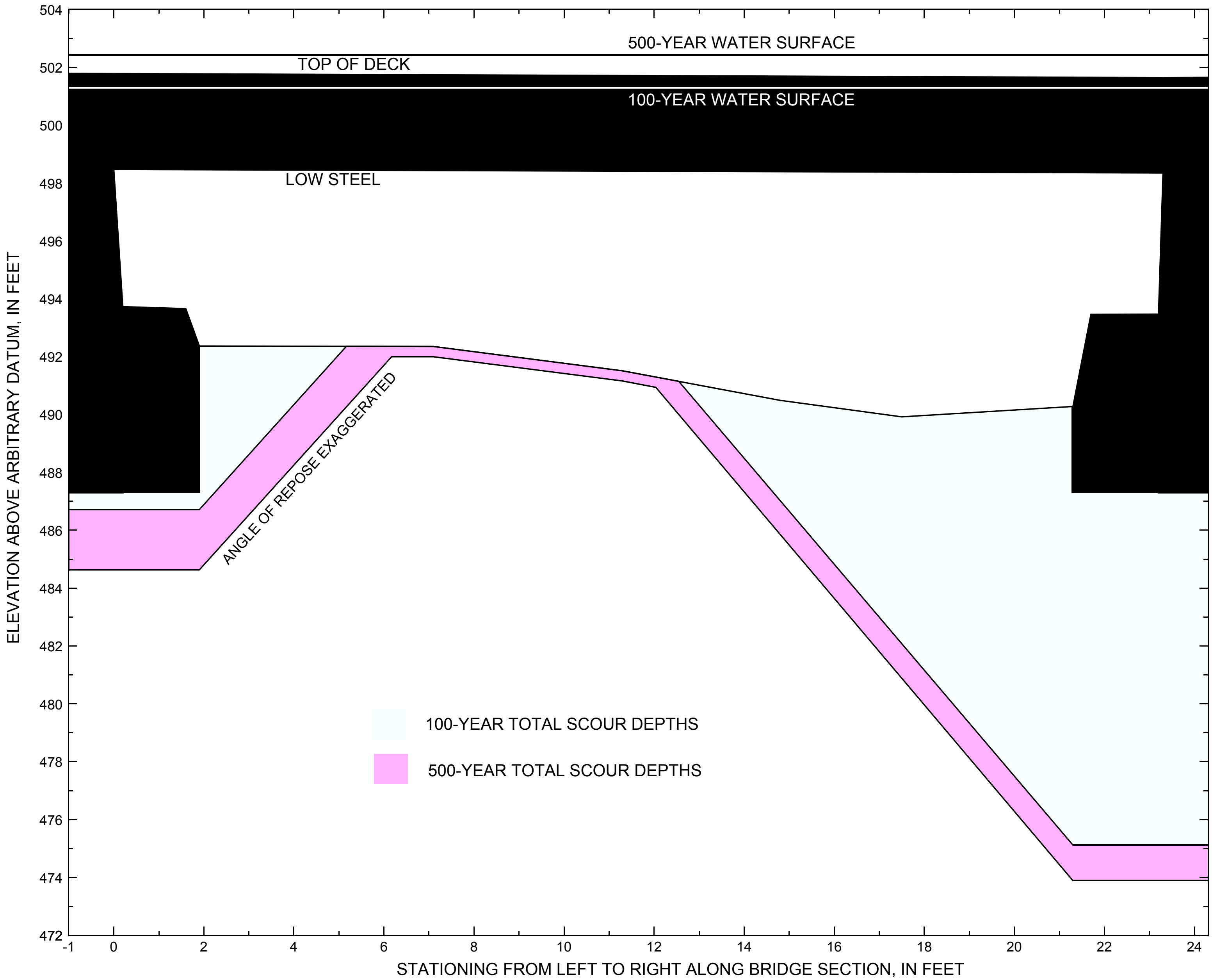

Figure 8. Scour elevations for the 100- and 500-year discharges at structure STRATH00030059 on Town Highway 3, crossing Abbott Brook, Strafford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure STRATH00030059 on Town Highway 3, crossing Abbott Brook, Strafford, 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-year discharge is 1,800 cubic-feet per second											
Left abutment	0.0	497.7	498.5	487.3	492.4	0.0	5.7	--	5.7	486.7	-0.6
Right abutment	23.3	497.7	498.4	487.3	490.3	0.0	15.2	--	15.2	475.1	-12.2

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 STRATH00030059 on Town Highway 3, crossing Abbott Brook, Strafford, 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-year discharge is 2,800 cubic-feet per second											
Left abutment	0.0	497.7	498.5	487.3	492.4	0.4	7.4	--	7.8	484.6	-2.7
Right abutment	23.3	497.7	498.4	487.3	490.3	0.4	16.0	--	16.4	473.9	-13.4

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 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. Geological Survey, 1981, South Strafford, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File stra059.wsp
T2        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
T3        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1800.0   2800.0  1000.0
SK          0.0186   0.0186  0.0186
*
XS   EXITX    -24           0.
GR        -116.5, 504.00    -96.5, 498.33    -75.8, 498.14    -23.9, 498.14
GR          -6.8, 494.78      0.0, 491.00      5.1, 490.51      9.6, 489.88
GR          14.7, 489.79     18.7, 491.07     24.4, 493.57     30.4, 497.74
GR          45.9, 498.79     86.7, 498.49     95.1, 498.49    116.4, 508.48
*
N           0.080        0.060        0.040
SA                 -23.9         30.4
*
XS   FULLV      0  * * *   0.0020
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.41      40.0
GR           0.0, 498.47      0.2, 493.73      1.6, 493.66      1.9, 492.37
GR           7.1, 492.35     11.3, 491.51     14.8, 490.49     17.5, 489.92
GR          21.3, 490.28     21.7, 493.46     23.2, 493.47
GR          23.3, 498.35      0.0, 498.47
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      49.1 * *     76.2      0.7
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     20      30.8     1
GR        -162.1, 505.84   -149.1, 503.60    -37.7, 502.33    -20.1, 501.63
GR          -3.4, 501.26     -3.0, 501.81      0.0, 501.78     22.1, 501.64
GR          24.0, 501.53     24.0, 500.79     74.3, 499.91    102.2, 498.79
GR         126.3, 509.25
*
*    For the incipient road-overtopping model, a wall was placed on the right
*    road approach at the intersection of the approach and roadway cross sections,
*    station 55.0.
*
XT   APTEM     66           0.
GR        -162.1, 505.84   -149.1, 503.60    -37.7, 502.33     -4.1, 500.58
GR           0.0, 495.26      4.8, 493.19      7.7, 492.76     12.2, 491.95
GR          19.2, 491.76     25.9, 492.89     31.0, 495.72     50.2, 498.43
GR          66.8, 504.74     85.7, 506.66    106.5, 515.70
*
AS   APPRO     58 * * * 0.0677
GT
N           0.040        0.065        0.080
SA                  -4.1         31.0
*
HP 1 BRIDG  498.41 1 498.41
HP 2 BRIDG  498.41 * * 1170
HP 1 BRIDG  497.81 1 497.81
HP 2 RDWAY  501.29 * * 631
HP 1 APPRO  501.55 1 501.55
HP 2 APPRO  501.55 * * 1800
*
HP 1 BRIDG  498.47 1 498.47
HP 2 BRIDG  498.47 * * 1379
HP 2 RDWAY  502.17 * * 1471
HP 1 APPRO  502.42 1 502.42
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File stra059.wsp
       Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
       TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
          *** RUN DATE & TIME: 04-09-98  10:05

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     120.   8227.     9.    40.                        2505.
  498.41          120.   8227.     9.    40.  1.00     0.    23.   2505.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.41     0.0    23.3   120.2    8227.    1170.   9.73

X STA.        0.0         3.5         4.4         5.3         6.3         7.2
  A(I)            13.9         4.3         4.3         4.4         4.5
  V(I)            4.22       13.62       13.49       13.44       13.02

X STA.        7.2         8.2         9.1        10.0        10.9        11.6
  A(I)             4.4         4.5         4.5         4.6         4.0
  V(I)           13.26       12.96       12.96       12.69       14.47

X STA.       11.6        12.5        13.4        14.3        15.1        15.9
  A(I)             4.5         5.3         5.2         5.1         5.0
  V(I)           13.04       11.12       11.27       11.49       11.78

X STA.       15.9        16.7        17.5        18.2        19.0        23.3
  A(I)             5.0         4.8         4.8         4.8        22.4
  V(I)           11.69       12.11       12.15       12.29        2.61

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     110.   8558.    18.    30.                        1547.
  497.81          110.   8558.    18.    30.  1.00     0.    23.   1547.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.29    -4.8   108.0   108.6    4819.     631.   5.81

X STA.       -4.8        44.4        53.5        60.0        65.4        70.1
  A(I)            13.9         8.5         7.0         6.3         5.9
  V(I)            2.28        3.72        4.49        4.97        5.31

X STA.       70.1        74.3        77.9        80.9        83.6        85.1
  A(I)             5.7         5.1         4.8         4.6         2.7
  V(I)            5.56        6.14        6.51        6.91       11.74

X STA.       85.1        86.8        89.2        91.4        93.5        95.5
  A(I)             3.0         4.6         4.6         4.4         4.3
  V(I)           10.39        6.81        6.87        7.10        7.41

X STA.       95.5        97.4        99.2       100.9       102.5       108.0
  A(I)             4.4         4.1         4.2         4.0         6.4
  V(I)            7.24        7.67        7.58        7.85        4.91

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      22.    677.    29.    29.                         108.
            2     302.  27048.    35.    39.                        5025.
            3     114.   5202.    29.    30.                        1286.
  501.55          438.  32928.    93.    98.  1.23   -33.    60.   4867.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.55   -33.1    59.8   437.8   32928.    1800.   4.11

X STA.      -33.1         3.0         5.1         6.9         8.7        10.3
  A(I)            61.2        18.0        16.9        16.1        16.1
  V(I)            1.47        5.00        5.34        5.60        5.59

X STA.       10.3        11.9        13.4        14.9        16.5        17.9
  A(I)            16.0        15.2        15.4        15.5        15.1
  V(I)            5.64        5.91        5.83        5.79        5.95

X STA.       17.9        19.4        21.0        22.6        24.3        26.1
  A(I)            15.4        16.2        16.0        16.4        16.7
  V(I)            5.83        5.56        5.62        5.50        5.39

X STA.       26.1        28.4        31.7        36.2        41.8        59.8
  A(I)            19.0        22.7        27.2        29.3        53.2
  V(I)            4.74        3.96        3.30        3.07        1.69
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        U.S. Geological Survey WSPRO Input File stra059.wsp
        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
           *** RUN DATE & TIME: 04-09-98  10:05

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     121.    7225.     0.    49.                           0.
   498.47          121.    7225.     0.    49.  1.00     0.    23.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.47     0.0    23.3   120.5    7225.    1379.  11.44

X STA.         0.0         3.7         4.8         6.0         7.1         8.2
  A(I)             15.2         5.3         5.2         5.3         5.3
  V(I)             4.54       13.11       13.21       13.07       13.06

X STA.         8.2         9.2        10.3        11.2        12.1        13.0
  A(I)              5.1         5.1         5.0         5.1         4.9
  V(I)            13.57       13.56       13.86       13.64       14.00

X STA.        13.0        13.9        14.7        15.5        16.2        17.0
  A(I)              4.9         4.8         4.8         4.7         4.7
  V(I)            13.95       14.40       14.42       14.79       14.74

X STA.        17.0        17.7        18.4        19.1        19.8        23.3
  A(I)              4.6         4.6         4.5         4.5        17.1
  V(I)            15.12       15.06       15.20       15.23        4.03

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.17   -33.7   110.0   211.8   11547.    1471.   6.94

X STA.       -33.7        28.5        37.3        44.2        50.4        55.9
  A(I)             34.8        13.6        11.6        11.0        10.5
  V(I)             2.11        5.43        6.35        6.72        7.03

X STA.        55.9        61.0        65.7        70.1        74.2        77.6
  A(I)             10.1         9.7         9.4         9.2         8.0
  V(I)             7.29        7.61        7.81        8.01        9.24

X STA.        77.6        80.8        84.1        87.2        90.0        92.7
  A(I)              7.7         8.7         8.3         8.0         8.0
  V(I)             9.50        8.47        8.83        9.25        9.21

X STA.        92.7        95.3        97.7       100.1       102.3       110.0
  A(I)              7.8         7.7         7.7         7.4        12.9
  V(I)             9.45        9.60        9.57        9.95        5.70

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      68.    2122.    89.    89.                         338.
             2     332.   31760.    35.    39.                        5806.
             3     140.    6957.    31.    32.                        1686.
   502.42          541.   40839.   155.   160.  1.33   -93.    62.   4971.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.42   -93.1    62.1   540.6   40839.    2800.   5.18

X STA.       -93.1         0.8         3.5         5.6         7.5         9.4
  A(I)             95.0        23.3        20.8        18.8        19.2
  V(I)             1.47        6.01        6.74        7.43        7.28

X STA.         9.4        11.1        12.8        14.4        16.1        17.7
  A(I)             18.6        18.4        18.0        17.9        17.9
  V(I)             7.52        7.59        7.78        7.84        7.81

X STA.        17.7        19.3        21.0        22.7        24.6        26.5
  A(I)             18.0        19.0        18.8        19.2        20.0
  V(I)             7.76        7.38        7.46        7.30        7.01

X STA.        26.5        29.0        32.8        37.4        43.0        62.1
  A(I)             22.5        27.7        30.8        33.6        63.2
  V(I)             6.24        5.05        4.54        4.17        2.22
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        U.S. Geological Survey WSPRO Input File stra059.wsp
        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
           *** RUN DATE & TIME: 04-09-98  09:44

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      121.    7225.     0.    49.                          0.
   498.47           121.    7225.     0.    49.  1.00     0.    23.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.47     0.0    23.3   120.5    7225.    1000.   8.30

 X STA.        0.0        3.7        4.8        6.0        7.1        8.2
  A(I)            15.2        5.3        5.2        5.3        5.3
  V(I)            3.29       9.50       9.58       9.48       9.47

 X STA.        8.2        9.2       10.3       11.2       12.1       13.0
  A(I)             5.1        5.1        5.0        5.1        4.9
  V(I)            9.84       9.83      10.05       9.89      10.15

 X STA.       13.0       13.9       14.7       15.5       16.2       17.0
  A(I)             4.9        4.8        4.8        4.7        4.7
  V(I)           10.12      10.44      10.46      10.73      10.69

 X STA.       17.0       17.7       18.4       19.1       19.8       23.3
  A(I)             4.6        4.6        4.5        4.5       17.1
  V(I)           10.97      10.92      11.02      11.05       2.92

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       81.    5591.    18.    27.                        989.
   496.21            81.    5591.    18.    27.  1.00     0.    23.    989.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1        0.       3.     4.     4.                          1.
             2      256.   20537.    35.    39.                       3922.
             3       78.    3050.    25.    26.                        782.
   500.24           335.   23590.    64.    69.  1.17    -8.    56.   4008.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.24    -8.0    56.4   334.8   23590.    1000.   2.99

 X STA.       -8.0        4.6        6.3        8.0        9.5       11.0
  A(I)            42.3       13.1       13.2       12.6       12.7
  V(I)            1.18       3.82       3.78       3.96       3.95

 X STA.       11.0       12.4       13.8       15.2       16.5       17.8
  A(I)            12.1       12.4       12.0       12.1       11.8
  V(I)            4.13       4.03       4.15       4.12       4.23

 X STA.       17.8       19.2       20.6       22.1       23.6       25.2
  A(I)            12.1       12.8       12.6       12.9       13.2
  V(I)            4.12       3.91       3.96       3.87       3.80

 X STA.       25.2       27.0       29.5       33.7       39.2       56.4
  A(I)            13.8       16.2       21.4       23.6       41.6
  V(I)            3.61       3.09       2.33       2.11       1.20
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File stra059.wsp
        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
           *** RUN DATE & TIME: 04-09-98  10:05

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

EXITX:XS   ******   -19.     209.  1.15 *****  498.32  496.11   1800.  497.17
      -24. ******    30.   13192.  1.00 ***** *******    0.73    8.60

FULLV:FV      24.   -22.     239.  0.88  0.38  498.69 *******   1800.  497.81
        0.    24.    31.   15670.  1.00  0.00   -0.01    0.62    7.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.    -3.     237.  1.04  0.81  499.59 *******   1800.  498.55
       58.    58.    52.   14893.  1.16  0.08    0.01    0.69    7.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.65       0.00     498.36     498.79

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   503.03         0.      1800.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      24.     0.     120.  1.47 *****  499.88  496.75   1170.  498.41
        0. ******    23.    8227.  1.00 ***** *******    0.76    9.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.497  0.000  498.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    27.  0.08  0.32  501.79    0.00    631.  501.29

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      2.     1.     -5.    -3.   0.0   0.0   3.3  71.5   0.5   3.0
   RT:    629.    84.     24.   108.   2.5   1.3   6.3   5.8   1.8   3.1

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

APPRO:AS       9.   -33.     438.  0.32  0.09  501.87  497.23   1800.  501.55
       58.    11.    60.   32931.  1.23  0.00    0.00    0.37    4.11

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -24.   -19.    30.   1800.   13192.     209.    8.60  497.17
   FULLV:FV       0.   -22.    31.   1800.   15670.     239.    7.53  497.81
   BRIDG:BR       0.     0.    23.   1170.    8227.     120.    9.73  498.41
   RDWAY:RG      20.*******     2.    631.       0.*********    1.00  501.29
   APPRO:AS      58.   -33.    60.   1800.   32931.     438.    4.11  501.55

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN     YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     496.11    0.73  489.79  508.48************  1.15  498.32  497.17
   FULLV:FV  ********    0.62  489.84  508.53  0.38  0.00  0.88  498.69  497.81
   BRIDG:BR     496.75    0.76  489.92  498.47************  1.47  499.88  498.41
   RDWAY:RG  ****************  498.79  509.25  0.08******  0.32  501.79  501.29
   APPRO:AS     497.23    0.37  491.22  515.16  0.09  0.00  0.32  501.87  501.55
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        U.S. Geological Survey WSPRO Input File stra059.wsp
        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
           *** RUN DATE & TIME: 04-09-98  10:05

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

EXITX:XS   ******   -97.     317.  1.46 *****  500.02  497.64   2800.  498.56
      -24. ******    95.   20520.  1.20 ***** *******    1.20    8.85

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.57

FULLV:FV      24.  -101.     513.  0.66  0.28  500.29 *******   2800.  499.63
        0.    24.    97.   32303.  1.42  0.00   -0.01    0.71    5.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.67

APPRO:AS      58.    -4.     313.  1.45  0.65  501.33 *******   2800.  499.88
       58.    58.    55.   21520.  1.16  0.40   -0.01    0.74    8.95
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   499.63     498.41

            <<<<<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      24.     0.     121.  2.04 *****  500.51  497.36   1379.  498.47
        0. ******    23.    7225.  1.00 ***** *******    0.89   11.45

     TYPE PPCD FLOW      C    P/A     LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.41 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       20.    27.  0.13  0.55  502.85    0.02   1471.  502.17

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     180.    47.   -34.    13.   0.9   0.5   5.0   7.9   1.2   3.1
   RT:    1290.    97.    13.   110.   3.4   2.0   7.6   6.8   2.6   3.1

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

APPRO:AS       9.   -93.     541.  0.55  0.16  502.98  498.75   2800.  502.42
       58.    11.    62.   40877.  1.33  0.00    0.02    0.56    5.17

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA     VEL    WSEL
   EXITX:XS      -24.   -97.     95.   2800.   20520.      317.     8.85  498.56
   FULLV:FV        0.  -101.     97.   2800.   32303.      513.     5.46  499.63
   BRIDG:BR        0.     0.     23.   1379.    7225.      121.    11.45  498.47
   RDWAY:RG       20.*******    180.   1471.        0.*********     1.00  502.17
   APPRO:AS       58.   -93.     62.   2800.   40877.      541.     5.17  502.42

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL     WSEL
   EXITX:XS     497.64    1.20  489.79  508.48************  1.46  500.02  498.56
   FULLV:FV   ********    0.71  489.84  508.53  0.28  0.00  0.66  500.29  499.63
   BRIDG:BR     497.36    0.89  489.92  498.47************  2.04  500.51  498.47
   RDWAY:RG   ****************  498.79  509.25  0.13******  0.55  502.85  502.17
   APPRO:AS     498.75    0.56  491.22  515.16  0.16  0.00  0.55  502.98  502.42
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        U.S. Geological Survey WSPRO Input File stra059.wsp
        Hydraulic analysis for structure STRATH00030059   Date: 07-APR-98
        TH 3 (MILLER POND ROAD) CROSSING ABBOTT BROOK IN STRAFFORD, VT     RLB
           *** RUN DATE & TIME: 04-09-98  09:44

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

EXITX:XS   ******   -10.     131.  0.90 *****  496.25  494.41   1000.  495.34
      -24. ******    27.    7328.  1.00 ***** *******    0.71    7.61

FULLV:FV      24.   -12.     152.  0.67  0.37  496.61 *******   1000.  495.94
        0.    24.    28.    8827.  1.00  0.00   -0.01    0.59    6.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.    -2.     145.  0.80  0.83  497.51 *******   1000.  496.71
       58.    58.    42.    7885.  1.07  0.06    0.00    0.69    6.91
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.25     499.91     500.00     498.41

 ===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      24.     0.     121.  1.05 *****  499.52  496.21    988.  498.47
        0. ******    23.    7225.  1.00 ***** *******    0.64    8.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.481  0.000  498.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<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       9.    -8.     335.  0.16  0.06  500.40  495.59   1000.  500.24
       58.    11.    56.   23602.  1.17  1.53   -0.01    0.25    2.99

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   500.19

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -24.   -10.    27.   1000.    7328.     131.    7.61  495.34
   FULLV:FV       0.   -12.    28.   1000.    8827.     152.    6.56  495.94
   BRIDG:BR       0.     0.    23.    988.    7225.     121.    8.20  498.47
   RDWAY:RG      20.**************      0.       0.       0.    1.00********
   APPRO:AS      58.    -8.    56.   1000.   23602.     335.    2.99  500.24

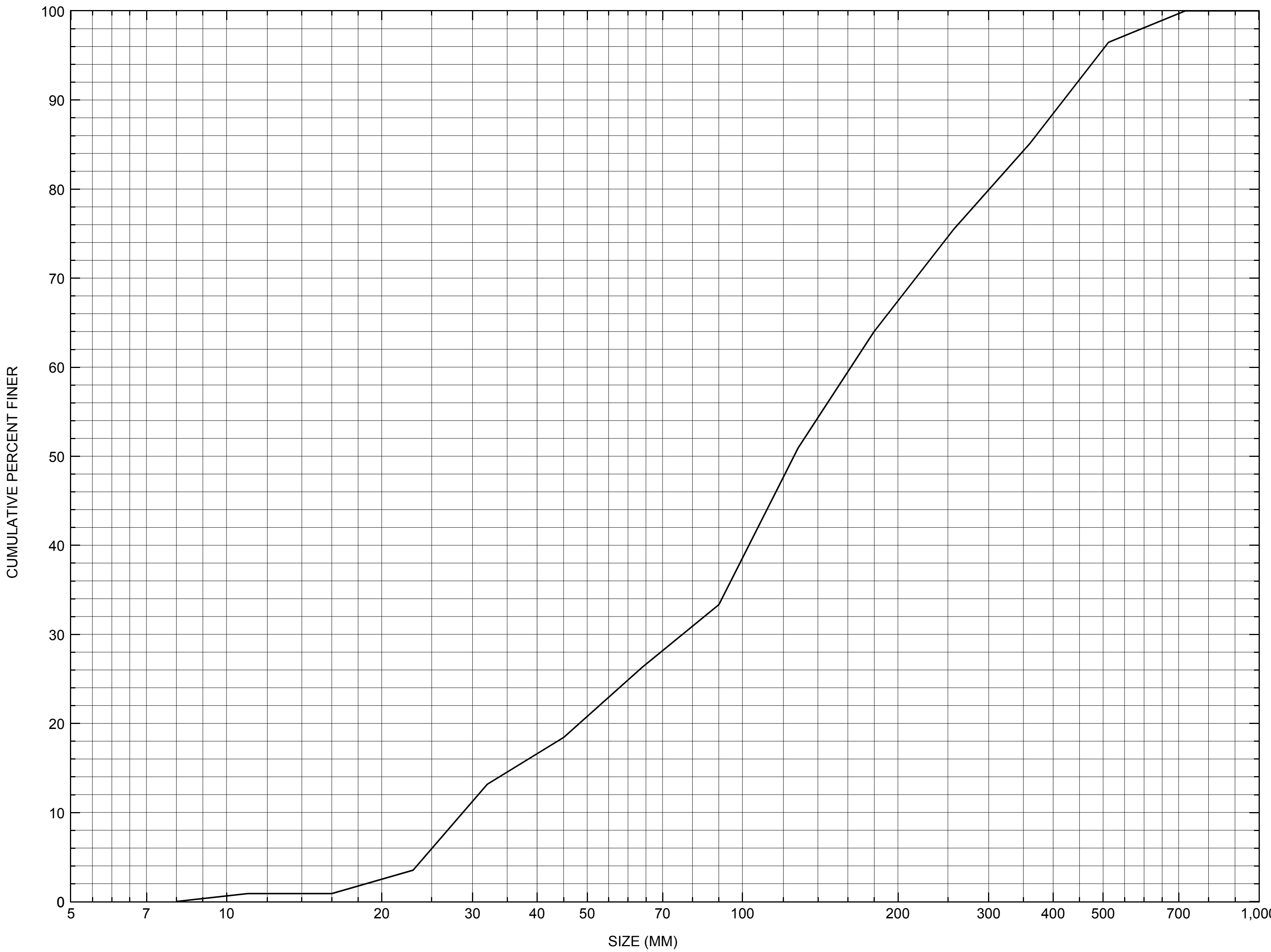
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS   ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.41    0.71  489.79  508.48************  0.90  496.25  495.34
   FULLV:FV   ********   0.59  489.84  508.53  0.37  0.00  0.67  496.61  495.94
   BRIDG:BR    496.21    0.64  489.92  498.47************  1.05  499.52  498.47
   RDWAY:RG   ****************  500.20  509.25************  0.16  500.36********
   APPRO:AS    495.59    0.25  491.22  515.16  0.06  1.53  0.16  500.40  500.24
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure STRATH00030059, in Strafford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number STRATH00030059

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 09 / 95

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

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 70675

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

Waterway *(I - 6)* ABBOTT BROOK

Road Name *(I - 7)*: -

Route Number TH003

Vicinity *(I - 9)* 0.8 MI TO JCT W CL3 TH28

Topographic Map South Strafford

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 43509

Longitude *(i - 17; nnnnn.n)* 72190

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10091000590910

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

Maximum span length *(I - 48; nnnn)* 0024

Year built *(I - 27; YYYY)* 1976

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 308

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

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 40

Waterway adequacy *(I - 71; n)* 5

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*) 17.1

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

Vertical clearance from streambed (*nnn.n ft*) 6.0

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

Waterway of full opening (*nnn.n ft*^{2}) 103.0

Comments:

The structural inspection report of 5/27/94 indicates the structure is a concrete slab type bridge. Both abutments are concrete. The walls have newer concrete on the downstream ends of both abutments. Also the downstream wingwalls have newer concrete than the upstream ones. The older parts of both abutment walls have minor cracks. Both abutment walls have newer concrete subfootings which are not undermined. The right abutment has a vertical crack near the upstream face. There is no displacement of the wall indicated along the crack. There is a retaining wall that extends upstream from the upstream end of the left abutment. The waterway makes a sharp bend into the structure. **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 8.3

Terrain character: Mountainous

Stream character & type: An upland stream

Streambed material: Stone and gravel with a few moderately sized boulders.

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 775 Q_{25} 1100

Q_{50} 1450 Q_{100} 1800 Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 9.5

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*)	-	498.3	500.3	501.3	502.0
Velocity (*ft / sec*)	-	-	9.5	-	-

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:

The banks are well protected with stone fill. The streambed material consists of mainly stone and gravel with a few moderately sized boulders. Some settlement may have resulted in the cracking visible through the right abutment. The report indicates only very minor channel bank erosion.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.20** mi^2
Lake/pond/swamp area **0.10** mi^2
Watershed storage *(ST)* **1** %
Bridge site elevation **840** ft
Headwater elevation **1940** ft
Main channel length **5.43** mi
10% channel length elevation **900** ft
85% channel length elevation **1530** ft
Main channel slope *(S)* **154.69** 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)*: 08 / 1975

Project Number SRS 2302(34) Minimum channel bed elevation: 491.0

Low superstructure elevation: USLAB N/A DSLAB 497.69 USRAB 498.38 DSRAB 497.70

Benchmark location description:

BM#1, At top of concrete at corner where the upstream right wingwall meets the right abutment, elevation 500.00

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 1.5 Footing bottom elevation: 487.0

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 available.

Comments:

A note on the plans indicates the bridge was built as designed. These plans were for the deck widening and the lowering of the abutment footings. The original structure was built in 1929. Note that the top of the footings were to be buried by about 3 feet upon reconstruction. Other elevation points: 1. the streamward top of the downstream end of the right wingwall where the slope begins to decline, elevation 500.0; 2. at the same location as described above on the downstream left wingwall, elevation 500.1.

Cross-sectional Data

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

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

Comments: **There are some channel sections available on the plans to be retrieved when necessary. No reproducible bridge face cross-sections.**

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

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 10/11/96
Computerized by: EW Date: 10/11/96
Reviewd by: RB Date: 4/17/98

Structure Number STRATH00030059

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 29 / 1996

2. Highway District Number 04 Mile marker 000000

County ORANGE (017) Town STRAFFORD (70675)

Waterway *(I - 6)* ABBOTT BROOK Road Name MILLER POND ROAD

Route Number TH3 Hydrologic Unit Code: 01080103

3. Descriptive comments:

The bridge is located 0.8 miles to the junction with Town Highway 28.

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 1 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 24 *(feet)* Bridge width 30.8 *(feet)*

Road approach to bridge:

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

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

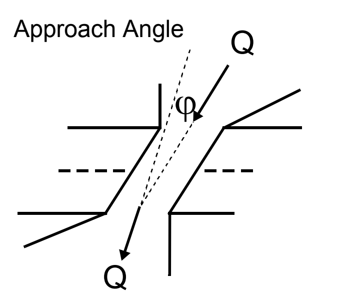
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

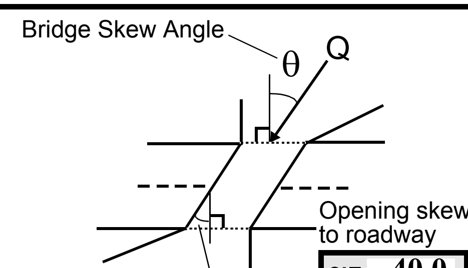
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	1	1
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	0	-	2	2

*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: 0 16. Bridge skew: 10





α= 40.0

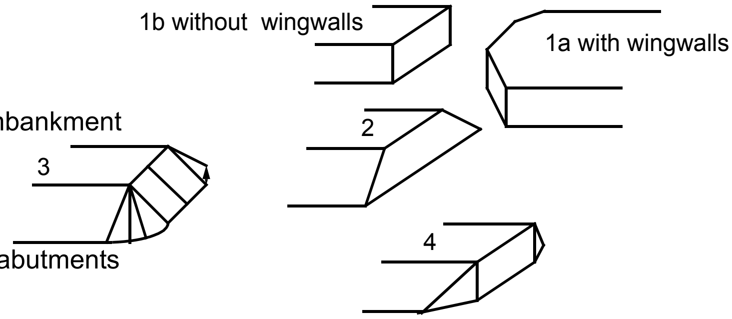
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 3
Range? 55 feet US *(US, UB, DS)* to 0 feet US

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. 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.)

Town Highway 3 crosses the upstream left overbank.

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
27.0	**7.5**			**3.0**	**3**	**3**	**543**	**543**	**2**	**2**

23. Bank width **40.0** 24. Channel width **25.0** 25. Thalweg depth **35.0** 29. Bed Material **543**

30 .Bank protection type: LB **3** RB **3** 31. Bank protection condition: LB **2** RB **2**

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 left bank protection extends from 230 feet upstream to 10 feet upstream (the upstream end of the upstream left wingwall). It consists of a stone wall that is eroding from 80 feet upstream to 40 feet upstream.

The right bank protection extends from 35 feet upstream to 10 feet upstream (the upstream end of the upstream right wingwall).

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **10** 35. Mid-bar width: **15**
36. Point bar extent: **15** feet **US** (US, UB) to **10** feet **UB** (US, UB, DS) positioned **0** %LB to **30** %RB
37. Material: **345**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This is a point bar.

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **RB** (LB or RB)
41. Mid-bank distance: **50** 42. Cut bank extent: **245** feet **US** (US, UB) to **35** feet **DS** (US, UB, DS)
43. Bank damage: **2** (1- eroded and/or creep; 2- slip failure; 3- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
The bank is cut beyond the left bank protection.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0 UB**
47. Scour dimensions: Length **45** Width **10** Depth : **1** Position **50** %LB to **100** %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
The scour depth is based on a 1 foot thalweg depth.

49. Are there major confluences? **Y** (Y or if N type ctrl-n mc) 50. How many? **1**
51. Confluence 1: Distance **105** 52. Enters on **RB** (LB or RB) 53. Type **1** (1- perennial; 2- ephemeral)
Confluence 2: Distance _____ Enters on _____ (LB or RB) Type _____ (1- perennial; 2- ephemeral)
54. Confluence comments (eg. confluence name):
-

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
21.0		1.5		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.):
453
-

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 Y___ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

-

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		-	90	2	2	0	4	90.0
RABUT	1	15	90			2	3	18.0

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

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

1

3

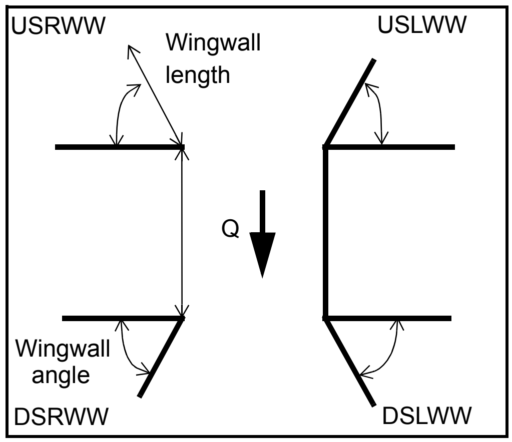
1

The left abutment can be penetrated 1 foot under the footing.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						18.0	
USRWW:	Y		1		2	1.5	
DSLWW:	0		2		Y	39.0	
DSRWW:	1		3		1	40.5	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	3	1	Y	-	-	-	-	-
Condition	Y	0	1	0.1	-	-	-	-
Extent	1	0	2	0	0	0	0	-

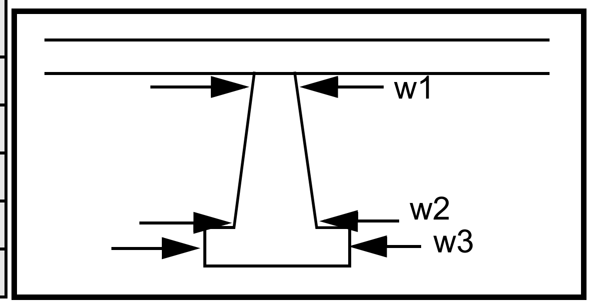
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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		**8.5**		**40.0**	**110.0**	**14.0**
Pier 2		**8.5**		**70.0**	**50.0**	**11.0**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**foot**	**ing.**	**ing;**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**upst**	**hori-**		**the**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ream**	**zon-**	**The**	**con-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**right**	**tally**	**dow**	**crete**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wing**	**unde**	**nstre**	**wall,**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wall**	**r the**	**am**	**how-**	
92. Pushed	**can**	**upst**	**left**	**ever,**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**also**	**ream**	**wing**	**is**	
95. Cross-members	**be**	**end**	**wall**	**unde**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**pen-**	**of**	**has**	**rmin**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**etrat**	**the**	**no**	**ed**	
98. Exposure depth	**ed 1**	**foot-**	**foot-**	**and**	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
can be penetrated 0.3 feet.

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 - 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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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.):

-
-
-
NO PIERS

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.):

4
3
543

Is channel scour present? **453** (Y or if N type ctrl-n cs) Mid-scour distance: **2**

Scour dimensions: Length **2** Width **435** Depth: **3** Positioned **3** %LB to **3** %RB

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

1

Left bank protection extends from the end of the wingwall at 10 feet downstream to 55 feet downstream.

Right bank protection extends from the end of the wingwall at 20 feet downstream to 62 feet downstream.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N
-
NO DROP STRUCTURE

Y
135
20
110

109. G. Plan View Sketch

- D

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: STRATH00030059 Town: STRAFFORD
Road Number: TH 3 County: ORANGE
Stream: ABBOTT BROOK

Initials RLB Date: 4/14/98 Checked: ECW

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1800	2800	1000
Main Channel Area, ft2	302	332	256
Left overbank area, ft2	22	68	0
Right overbank area, ft2	114	140	78
Top width main channel, ft	35	35	35
Top width L overbank, ft	29	89	0
Top width R overbank, ft	29	31	25
D50 of channel, ft	0.4126	0.4126	0.4126
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.6	9.5	7.3
y1, average depth, LOB, ft	0.8	0.8	ERR
y1, average depth, ROB, ft	3.9	4.5	3.1
Total conveyance, approach	32928	40839	23590
Conveyance, main channel	27048	31760	20537
Conveyance, LOB	677	2122	0
Conveyance, ROB	5202	6957	3050
Percent discrepancy, conveyance	0.0030	0.0000	0.0127
Qm, discharge, MC, cfs	1478.6	2177.5	870.6
Ql, discharge, LOB, cfs	37.0	145.5	0.0
Qr, discharge, ROB, cfs	284.4	477.0	129.3
Vm, mean velocity MC, ft/s	4.9	6.6	3.4
Vl, mean velocity, LOB, ft/s	1.7	2.1	ERR
Vr, mean velocity, ROB, ft/s	2.5	3.4	1.7
Vc-m, crit. velocity, MC, ft/s	12.0	12.1	11.6
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

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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1800	2800	1000
(Q) discharge thru bridge, cfs	1170	1379	1000
Main channel conveyance	8227	7225	7225
Total conveyance	8227	7225	7225
Q2, bridge MC discharge,cfs	1170	1379	1000
Main channel area, ft2	120	121	121
Main channel width (normal), ft	17.8	17.8	17.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	17.8	17.8	17.8
y_bridge (avg. depth at br.), ft	6.75	6.77	6.77
Dm, median (1.25*D50), ft	0.51575	0.51575	0.51575
y2, depth in contraction,ft	5.41	6.22	4.72
ys, scour depth (y2-ybridge), ft	-1.35	-0.55	-2.04

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 Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1800	2800	1000
Q, thru bridge MC, cfs	1170	1379	1000
Vc, critical velocity, ft/s	11.95	12.14	11.63
Va, velocity MC approach, ft/s	4.90	6.56	3.40
Main channel width (normal), ft	17.8	17.8	17.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	17.8	17.8	17.8
qbr, unit discharge, ft2/s	65.7	77.5	56.2
Area of full opening, ft2	120.2	120.5	120.5
Hb, depth of full opening, ft	6.75	6.77	6.77
Fr, Froude number, bridge MC	0.76	0.89	0.64
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	110	N/A	81
**Hb, depth at downstream face, ft	6.18	N/A	4.55
**Fr, Froude number at DS face	0.75	ERR	1.02
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	498.41	498.41	498.41

Elevation of Bed, ft	491.66	491.64	491.64
Elevation of Approach, ft	501.55	502.42	500.24
Friction loss, approach, ft	0.09	0.16	0.06
Elevation of WS immediately US, ft	501.46	502.26	500.18
ya, depth immediately US, ft	9.80	10.62	8.54
Mean elevation of deck, ft	501.71	501.71	501.71
w, depth of overflow, ft (>=0)	0.00	0.55	0.00
Cc, vert contrac correction (<=1.0)	0.90	0.90	0.94
**Cc, for downstream face (<=1.0)	0.87391	ERR	0.79
Ys, scour w/Chang equation, ft	**-0.67**	**0.35**	**-1.64**
Ys, scour w/Umbrell equation, ft	-0.45	1.05	-2.29

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

**Ys, scour w/Chang equation, ft	0.11	N/A	1.57
**Ys, scour w/Umbrell equation, ft	0.13	N/A	-0.07

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	5.41	6.22	4.72
WSEL at downstream face, ft	497.81	--	496.21
Depth at downstream face, ft	6.18	N/A	4.55
Ys, depth of scour (Laursen), ft	-0.77	N/A	0.17

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	1170	1379	1000
Main channel area (DS), ft2	110	120.5	81
Main channel width (normal), ft	17.8	17.8	17.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	17.8	17.8	17.8
D90, ft	1.3746	1.3746	1.3746
D95, ft	1.6042	1.6042	1.6042
Dc, critical grain size, ft	0.7110	0.7869	1.1227
Pc, Decimal percent coarser than Dc	0.300	0.267	0.163
Depth to armoring, ft	4.98	6.48	17.29

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	1800	2800	1000	1800	2800	1000
a', abut.length blocking flow, ft	35.9	95.9	5.7	39.2	41.5	31.2
Ae, area of blocked flow ft2	59.5	93.41	21.25	183.31	178.29	96.3

Qe, discharge blocked abut.,cfs	--	--	37.01	--	--	350

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

Ve, (Qe/Ae), ft/s	1.47	2.17	1.74	3.63	4.80	3.63
ya, depth of f/p flow, ft	1.66	0.97	3.73	4.68	4.30	3.09

--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	50	50	50	130	130	130
K2	0.93	0.93	0.93	1.05	1.05	1.05
Fr, froude number f/p flow	0.199	0.354	0.159	0.280	0.351	0.365
ys, scour depth, ft	**5.66**	**7.39**	**6.24**	**15.16**	**16.04**	**11.89**

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

a'(abut length blocked, ft)	35.9	95.9	5.7	39.2	41.5	31.2
y1 (depth f/p flow, ft)	1.66	0.97	3.73	4.68	4.30	3.09
a'/y1	21.66	98.46	1.53	8.38	9.66	10.11
Skew correction (p. 49, fig. 16)	0.83	0.83	0.83	1.09	1.09	1.09
Froude no. f/p flow	0.20	0.35	0.16	0.28	0.35	0.36
Ys w/ corr. factor K1/0.55:						
vertical	ERR	4.19	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	3.43	ERR	ERR	ERR	ERR
spill-through	ERR	2.30	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.75	0.89	1.00	0.75	0.89	1.00
y, depth of flow in bridge, ft	6.18	6.77	4.55	6.18	6.77	4.55
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.15	ERR	ERR	2.15	ERR	ERR
Fr>0.8 (vertical abut.)	ERR	2.74	1.90	ERR	2.74	1.90