LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (CORITH00500034) on TOWN HIGHWAY 50, crossing the SOUTH BRANCH WAITS RIVER, CORINTH, VERMONT

Open-File Report 97-671

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (CORITH00500034) on TOWN HIGHWAY 50, crossing the SOUTH BRANCH WAITS RIVER, CORINTH, VERMONT

By MICHAEL A. IVANOFF

U.S. Geological Survey
Open-File Report 97-671

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

For additional information
write to:

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

Copies of this report may be
purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

Introduction and Summary of Results	1
Level II summary	7
Description of Bridge	7
Description of the Geomorphic Setting.....	8
Description of the Channel.....	8
Hydrology.....	9
Calculated Discharges	9
Description of the Water-Surface Profile Model (WSPRO) Analysis	10
Cross-Sections Used in WSPRO Analysis.....	10
Data and Assumptions Used in WSPRO Model	11
Bridge Hydraulics Summary.....	12
Scour Analysis Summary	13
Special Conditions or Assumptions Made in Scour Analysis.....	13
Scour Results.....	14
Riprap Sizing.....	14
References.....	18
Appendixes:	
A. WSPRO input file.....	19
B. WSPRO output file.....	22
C. Bed-material particle-size distribution	30
D. Historical data form.....	32
E. Level I data form.....	38
F. Scour computations.....	48

FIGURES

1. Map showing location of study area on USGS 1:24,000 scale map	3
2. Map showing location of study area on Vermont Agency of Transportation town highway map	4
3. Structure CORITH00500034 viewed from upstream (September 5, 1995)	5
4. Downstream channel viewed from structure CORITH00500034 (September 5, 1995).....	5
5. Upstream channel viewed from structure CORITH00500034 (September 5, 1995).....	6
6. Structure CORITH00500034 viewed from downstream (September 5, 1995).	6
7. Water-surface profiles for the 100- and 500-year discharges at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont.....	15
8. Scour elevations for the 100- and 500-year discharges at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont.....	16

TABLES

1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont	17
2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont	17

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	VT AOT	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 34 (CORITH00500034) ON TOWN HIGHWAY 50, CROSSING THE SOUTH BRANCH WAITS RIVER, CORINTH, VERMONT

By Michael A. Ivanoff

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CORITH00500034 on Town Highway 50 crossing the South Branch Waits River, Corinth, 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 New England Upland section of the New England physiographic province in central Vermont. The 35.9-mi² drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge while the immediate banks have dense woody vegetation.

In the study area, the South Branch Waits River has an incised, meandering channel with a slope of approximately 0.005 ft/ft, an average channel top width of 63 ft and an average bank height of 6 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 23.7 mm (0.078 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 5, 1995, indicated that the reach was stable.

The Town Highway 50 crossing of the South Branch Waits River is a 56-ft-long, one-lane bridge consisting of one 54-foot steel thru-truss span (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 51.5 ft. The bridge is supported by vertical, concrete abutments with no wingwalls. Stone fill and bank material in front of the abutments create spill-through embankments. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 2.5 ft deeper than the mean thalweg depth was observed along the left bank through the bridge during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left and right banks extending from upstream to downstream through the bridge. The stone fill under the bridge creates spill-through embankments. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as other 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 3.0 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 2.4 to 6.3 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 and HIRE equations (abutment scour) give “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 CORITH00500034 **Stream** South Branch Waits River
County Orange **Road** TH 50 **District** 7

Description of Bridge

Bridge length 56 **ft** **Bridge width** 11.7 **ft** **Max span length** 54 **ft**
Alignment of bridge to road (on curve or straight) Curve on right, Straight on left
Abutment type Vertical, concrete **Embankment type** Sloping
Stone fill on abutment? Yes **Date of inspection** 9/5/95

Description of stone fill Type-2, along the left and right banks extending from upstream to downstream through the bridge. Stone fill under the bridge creates spill-through embankments. Abutments are concrete. There is a two and a half foot deep scour hole along the left bank through the bridge.

Yes

30 Yes

Is bridge skewed to flood flow according to There ' survey? **Angle**
is a mild channel bend in the upstream reach. The scour hole has developed in the location, where the bend impacts the left bank.

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	<u>9/5/95</u>	<u>0</u>	<u>0</u>
Level II	<u>9/5/95</u>	<u>0</u>	<u>0</u>

Potential for debris Moderate. There is some debris caught on boulders and trees are leaning over the channel upstream.

None noted as of 9/5/95.

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

Description of the Geomorphic Setting

General topography The channel is located within a low relief valley with narrow flood plains.
9/5/95

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

Date of inspection Steep channel

DS left: bank to a narrow flood plain.

DS right: Steep channel bank to a narrow flood plain

US left: Steep channel bank to a narrow flood plain.

US right: Steep channel bank to a narrow flood plain.

Description of the Channel

Average top width	<u>63</u>	Average depth	<u>6</u>
	<u>Sand / Gravel</u>		<u>Silt/Gravel</u>
Predominant bed material		Bank material	<u>Meandering but</u>
<u>stable with semi-alluvial channel boundaries and narrow flood plains.</u>			

9/5/95

Vegetative cover A few trees and brush with pasture on the flood plain.

DS left: A few trees and brush with pasture on the flood plain.

DS right: Trees and brush with pasture on the flood plain.

US left: Trees and brush with pasture on the flood plain.

US right: Yes

Do banks appear stable? - Yes, no serious erosion and type of instability was

date of observation.

None noted during the

assessment of 9/5/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 35.9 **mi²**

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	Percent of drainage area
<u>New England/New England Upland</u>	<u>100</u>

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- **mi²** No

Is there a lake/p -

Calculated Discharges	
<u>5,450</u>	<u>8,200</u>
Q100	Q500
ft³/s	ft³/s

The 100- and 500-year discharges are based on a drainage area relationship $[(35.9/16.2)\exp 0.67]$ with bridge number 20 in Corinth. Bridge number 20 crosses Cooksville Brook a tributary to the South Branch Waits River upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 20 is 16.2 square miles. The drainage area adjusted discharge values are within a range defined by several empirical flood frequency curves (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 downstream end of the right abutment (elev. 502.62 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 502.60 ft, arbitrary survey datum). RM3 is a nail in the streamward post marking trail 25W located 215 ft bankward from the right abutment along TH 50 and 215 feet along the trail upstream (elev. 506.78 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

¹ <i>Cross-section</i>	<i>Section Reference Distance (SRD) in feet</i>	² <i>Cross-section development</i>	<i>Comments</i>
EXITX	-51	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	75	1	Approach section

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.

² Cross-section development: (1) survey at SRD, (2) shift of survey data to SRD, (3) modification of survey data, (4) composite bridge section, (5) other.

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 0.030 to 0.046, and overbank "n" values ranged from 0.030 to 0.032.

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 0.0048 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1973).

The approach section (APPRO) was surveyed 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.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for the discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 506.1 *ft*
Average low steel elevation 502.7 *ft*

100-year discharge 5,450 *ft³/s*
Water-surface elevation in bridge opening 502.7 *ft*
Road overtopping? Yes *Discharge over road* 3,074 *ft³/s*
Area of flow in bridge opening 358 *ft²*
Average velocity in bridge opening 6.4 *ft/s*
Maximum WSPRO tube velocity at bridge 8.0 *ft/s*

Water-surface elevation at Approach section with bridge 503.6
Water-surface elevation at Approach section without bridge 501.1
Amount of backwater caused by bridge 2.5 *ft*

500-year discharge 8,200 *ft³/s*
Water-surface elevation in bridge opening 502.7 *ft*
Road overtopping? Yes *Discharge over road* 5,440 *ft³/s*
Area of flow in bridge opening 358 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 504.2
Water-surface elevation at Approach section without bridge 501.6
Amount of backwater caused by bridge 2.6 *ft*

Incipient overtopping discharge 1,830 *ft³/s*
Water-surface elevation in bridge opening 498.2 *ft*
Area of flow in bridge opening 156 *ft²*
Average velocity in bridge opening 11.7 *ft/s*
Maximum WSPRO tube velocity at bridge 14.7 *ft/s*

Water-surface elevation at Approach section with bridge 501.6
Water-surface elevation at Approach section without bridge 499.3
Amount of backwater caused by bridge 2.3 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient road-overtopping was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 100-year and 500-year discharges 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). 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 and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and 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 HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths computed at the toe of each embankment were applied for the entire spill-through embankment as shown in figure 8.

Scour Results

<i>Contraction scour:</i>	<i>100-yr discharge</i>	<i>500-yr discharge</i>	<i>Incipient overtopping discharge</i>
	<i>(Scour depths in feet)</i>		

Main channel

<i>Live-bed scour</i>	--	--	--
	<u>0.0</u>	<u>1.7</u>	<u>3.0</u>
<i>Clear-water scour</i>	6.7 ⁻	N/A ⁻	5.6 ⁻
<i>Depth to armoring</i>	-- ⁻	-- ⁻	-- ⁻
<i>Left overbank</i>	-- ⁻	-- ⁻	-- ⁻
<i>Right overbank</i>	<u> </u>	<u> </u>	<u> </u>

Local scour:

<i>Abutment scour</i>	5.7	6.3	4.1
<i>Left abutment</i>	<u>4.0</u>	<u>5.2</u>	<u>2.4</u>
<i>Right abutment</i>	<u> </u>	<u> </u>	<u> </u>
<i>Pier scour</i>	--	--	--
<i>Pier 1</i>	<u> </u>	<u> </u>	<u> </u>
<i>Pier 2</i>	<u> </u>	<u> </u>	<u> </u>
<i>Pier 3</i>	<u> </u>	<u> </u>	<u> </u>

Riprap Sizing

	<i>100-yr discharge</i>	<i>500-yr discharge</i>	<i>Incipient overtopping discharge</i>
	<i>(D₅₀ in feet)</i>		
<i>Abutments:</i>	1.2	1.5	2.0
<i>Left abutment</i>	<u>1.2</u>	<u>1.5</u>	<u>2.0</u>
<i>Right abutment</i>	-- ⁻	-- ⁻	-- ⁻
<i>Piers:</i>	--	--	--
<i>Pier 1</i>	-- ⁻	-- ⁻	-- ⁻
<i>Pier 2</i>	<u> </u>	<u> </u>	<u> </u>

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont.

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, 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 5,450 cubic-feet per second											
Left abutment	0.0	--	502.7	--	501.2	0.0	--	--	--	--	--
Toe of left embankment	14.0	--	--	--	493.6	0.0	5.7	--	5.7	487.9	--
Toe of right embankment	38.5	--	--	--	493.6	0.0	4.0	--	4.0	489.6	--
Right abutment	51.5	--	502.7	--	500.4	0.0	--	--	--	--	--

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

2. Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CORITH00500034 on Town Highway 50, crossing the South Branch Waits River, Corinth, 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 8,200 cubic-feet per second											
Left abutment	0.0	--	502.7	--	501.2	1.7	--	--	--	--	--
Toe of left embankment	14.0	--	--	--	493.6	1.7	6.3	--	8.0	485.6	--
Toe of right embankment	38.5	--	--	--	493.6	1.7	5.2	--	6.9	486.7	--
Right abutment	51.5	--	502.7	--	500.4	1.7	--	--	--	--	--

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. 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, 1973, East Corinth, 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 cori034.wsp
T2      Hydraulic analysis for structure CORITH00500034   Date: 06-AUG-97
T3      Bridge 34 on Town Highway 50 over South Branch Waits River by MAI
*
J3      6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q        5450.0      8200.0      1830.0
SK        0.0048      0.0048      0.0048
WS        500.55      501.05      499.12
*
XS      EXITX      -51
GR        -684.6, 509.03      -598.0, 503.05      -554.9, 500.70      -552.4, 499.30
GR        -362.2, 499.13      -6.8, 500.40      0.0, 496.94      1.3, 493.86
GR         1.9, 493.61      4.4, 492.07      6.8, 491.91      9.7, 492.36
GR         11.6, 491.96      16.8, 491.99      19.4, 492.10      23.1, 492.17
GR         29.0, 492.30      32.3, 492.73      39.1, 493.01      44.0, 492.54
GR         44.1, 493.60      46.2, 497.88      49.7, 499.15      99.8, 498.61
GR        231.0, 500.47      298.0, 504.53      342.5, 504.94      363.4, 505.87
GR        381.3, 505.79      403.1, 506.62      411.7, 509.53
N         0.030      0.046      0.032
SA        -6.8      49.7
*
XS      FULLV      0 * * * 0.0000
*
*          SRD      LSEL      XSSKEW
BR      BRIDG      0      502.67      15.0
GR        0.0, 502.67      0.1, 501.15      10.6, 495.99      12.2, 494.08
GR        14.0, 493.63      18.4, 493.18      20.8, 492.45      26.6, 491.80
GR        33.7, 493.30      38.5, 493.63      40.1, 495.87      46.1, 499.47
GR        51.3, 500.40      51.5, 502.68      0.0, 502.67
*
*          BRTYPE  BRWDTH  EMBSS  EMBELV
CD        3          19.8    1.9    503.8
N         0.030
*
*          SRD      EMBWID  IPAVE
XR      RDWAY      10      11.7    2
GR        -688.7, 509.06      -619.6, 503.13      -562.6, 502.38      -361.8, 501.62
GR        -195.1, 501.89      -39.3, 503.06      -6.4, 503.81      -6.3, 506.25
GR         61.8, 505.94      61.9, 503.69      129.2, 503.97      237.5, 504.16
GR        320.6, 505.00      381.6, 506.02      437.4, 506.92
*
AS      APPRO      75
GR        -696.7, 508.40      -683.2, 505.92      -528.0, 500.17      -471.8, 499.84
GR        -221.5, 499.10      -115.1, 500.52      -25.4, 501.33      -14.2, 501.15
GR         0.0, 495.87      1.5, 494.21      3.3, 493.62      6.1, 492.81
GR         13.0, 492.88      25.6, 493.63      28.4, 493.65      37.8, 492.98
GR         40.9, 492.99      42.3, 493.67      44.7, 494.80      47.5, 497.57
GR         55.7, 499.90      101.8, 500.86      193.5, 501.90      293.2, 503.26
GR        350.9, 504.51      423.6, 507.30      463.9, 511.44
N         0.030      0.046      0.030
SA         0.0      69.9
*
HP 1 BRIDG      502.68 1 502.68
HP 2 BRIDG      502.68 * * 2273
HP 1 BRIDG      500.99 1 500.99
HP 2 RDWAY      503.27 * * 3074

```

WSPRO INPUT FILE (continued)

HP	1	APPRO	503.56	1	503.56
HP	2	APPRO	503.56	*	* 5450
*					
HP	1	BRIDG	502.68	1	502.68
HP	2	BRIDG	502.68	*	* 2790
HP	1	BRIDG	501.42	1	501.42
HP	2	RDWAY	503.80	*	* 5440
HP	1	APPRO	504.18	1	504.18
HP	2	APPRO	504.18	*	* 8200
*					
HP	1	BRIDG	498.24	1	498.24
HP	2	BRIDG	498.24	*	* 1830
HP	1	APPRO	501.65	1	501.65
HP	2	APPRO	501.65	*	* 1830
*					
EX					
ER					

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

U.S. Geological Survey WSPRO Input File cori034.wsp

Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97

Bridge 34 on Town Highway 50 over South Branch Waits River by MAI

*** RUN DATE & TIME: 08-18-97 12:23

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	358	39489	0	108				19645822
502.68		358	39489	0	108	1.00	0	52	19645822

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

WSEL	LEW	REW	AREA	K	Q	VEL
502.68	0.0	51.5	357.6	39489.	2273.	6.36
X STA.	0.0	8.7	12.1		14.2	16.1
A(I)		30.4	22.3		17.7	17.0
V(I)		3.74	5.10		6.43	6.68
X STA.	17.9	19.5	21.1		22.6	24.0
A(I)		15.5	15.1		14.7	14.2
V(I)		7.34	7.55		7.74	7.98
X STA.	25.4	26.7	28.1		29.6	31.1
A(I)		14.3	14.6		14.6	14.9
V(I)		7.97	7.81		7.79	7.63
X STA.	32.8	34.6	36.5		38.5	41.9
A(I)		16.0	17.1		18.1	22.8
V(I)		7.10	6.66		6.27	4.99

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	274	39920	49	55				3670
500.99		274	39920	49	55	1.00	0	51	3670

VELOCITY DISTRIBUTION: ISEQ = 4; SECID = RDWAY; SRD = 10.

WSEL	LEW	REW	AREA	K	Q	VEL
503.27	-621.2	-30.1	661.9	35443.	3074.	4.64
X STA.	-621.2	-541.0	-504.2		-474.6	-449.2
A(I)		49.6	38.4		34.5	32.3
V(I)		3.10	4.01		4.46	4.75
X STA.	-426.7	-406.1	-387.5		-369.8	-352.9
A(I)		29.6	28.2		28.1	27.7
V(I)		5.19	5.44		5.48	5.55
X STA.	-336.1	-318.8	-301.0		-282.7	-263.3
A(I)		27.5	27.9		28.2	29.1
V(I)		5.59	5.52		5.45	5.28
X STA.	-243.0	-221.5	-199.0		-172.9	-135.3
A(I)		30.9	31.6		34.2	40.4
V(I)		4.97	4.87		4.49	3.81

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 75.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	2112	237282	620	621				22123
	2	567	72085	70	73				9152
	3	396	27729	237	237				2908
503.56		3075	337096	927	930	1.06	-619	307	30857

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 75.

WSEL	LEW	REW	AREA	K	Q	VEL
------	-----	-----	------	---	---	-----

WSPRO OUTPUT FILE (continued)

503.56 -619.5 307.0 3074.6 337096. 5450. 1.77

X STA.	-619.5	-509.7	-466.2	-426.7	-390.4	-355.5
A(I)	218.0	157.8	149.9	141.8	140.2	
V(I)	1.25	1.73	1.82	1.92	1.94	
X STA.	-355.5	-322.7	-290.6	-260.2	-230.2	-200.1
A(I)	134.8	135.0	130.8	131.9	130.9	
V(I)	2.02	2.02	2.08	2.07	2.08	
X STA.	-200.1	-164.7	-120.5	-58.7	-1.1	10.8
A(I)	139.5	150.4	173.9	168.3	118.1	
V(I)	1.95	1.81	1.57	1.62	2.31	
X STA.	10.8	21.9	33.7	49.3	112.9	307.0
A(I)	115.8	119.2	143.0	205.0	270.4	
V(I)	2.35	2.29	1.91	1.33	1.01	

U.S. Geological Survey WSPRO Input File cori034.wsp

Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97

Bridge 34 on Town Highway 50 over South Branch Waits River by MAI

*** RUN DATE & TIME: 08-18-97 12:23

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	358	39489	0	108				19645822
502.68		358	39489	0	108	1.00	0	52	19645822

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

	WSEL	LEW	REW	AREA	K	Q	VEL
	502.68	0.0	51.5	357.6	39489.	2790.	7.80
X STA.	0.0	8.7	12.1	14.2	16.1	17.9	
A(I)	30.4	22.3	17.7	17.0	16.0		
V(I)	4.59	6.26	7.89	8.19	8.71		
X STA.	17.9	19.5	21.1	22.6	24.0	25.4	
A(I)	15.5	15.1	14.7	14.2	14.5		
V(I)	9.01	9.26	9.49	9.79	9.65		
X STA.	25.4	26.7	28.1	29.6	31.1	32.8	
A(I)	14.3	14.6	14.6	14.9	15.9		
V(I)	9.78	9.58	9.56	9.37	8.79		
X STA.	32.8	34.6	36.5	38.5	41.9	51.5	
A(I)	16.0	17.1	18.1	22.8	32.1		
V(I)	8.71	8.17	7.70	6.13	4.35		

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	295	44645	50	56				4090
501.42		295	44645	50	56	1.00	0	51	4090

VELOCITY DISTRIBUTION: ISEQ = 4; SECID = RDWAY; SRD = 10.

	WSEL	LEW	REW	AREA	K	Q	VEL
	503.80	-627.4	88.3	984.4	66345.	5440.	5.53
X STA.	-627.4	-559.1	-522.5	-491.9	-464.5	-439.4	
A(I)	67.2	55.0	49.9	47.7	46.2		
V(I)	4.05	4.94	5.45	5.70	5.89		
X STA.	-439.4	-416.3	-395.0	-374.7	-355.3	-335.9	
A(I)	44.4	43.0	42.5	41.9	41.7		
V(I)	6.12	6.32	6.40	6.49	6.52		

WSPRO OUTPUT FILE (continued)

X STA.	-335.9	-315.8	-295.6	-274.5	-252.7	-229.9
A(I)	42.8	42.1	43.4	44.0	45.2	
V(I)	6.36	6.46	6.26	6.18	6.02	

X STA.	-229.9	-206.1	-180.6	-149.2	-107.2	88.3
A(I)	46.4	48.0	52.8	59.1	81.1	
V(I)	5.86	5.67	5.15	4.60	3.36	

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 75.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	2501	309043	636	637				28137
	2	610	81508	70	73				10222
	3	552	44669	266	266				4518
504.18		3663	435219	972	976	1.05	-635	336	39333

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 75.

WSEL	LEW	REW	AREA	K	Q	VEL
504.18	-636.2	335.7	3663.1	435219.	8200.	2.24

X STA.	-636.2	-516.6	-471.9	-431.3	-394.1	-359.0
A(I)	263.1	188.1	178.4	168.2	162.3	
V(I)	1.56	2.18	2.30	2.44	2.53	

X STA.	-359.0	-325.2	-292.1	-260.7	-229.7	-198.7
A(I)	159.7	159.6	154.3	155.3	153.9	
V(I)	2.57	2.57	2.66	2.64	2.66	

X STA.	-198.7	-162.6	-119.0	-62.6	-3.0	10.9
A(I)	163.8	174.5	193.9	202.5	140.8	
V(I)	2.50	2.35	2.11	2.03	2.91	

X STA.	10.9	23.9	37.8	73.4	139.5	335.7
A(I)	143.9	149.2	213.3	219.6	318.8	
V(I)	2.85	2.75	1.92	1.87	1.29	

U.S. Geological Survey WSPRO Input File cori034.wsp

Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97

Bridge 34 on Town Highway 50 over South Branch Waits River by MAI

*** RUN DATE & TIME: 09-08-97 09:11

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	156	19060	37	40				1824
498.24		156	19060	37	40	1.00	6	44	1824

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

WSEL	LEW	REW	AREA	K	Q	VEL
498.24	6.0	44.0	156.0	19060.	1830.	11.73

X STA.	6.0	13.2	15.3	17.0	18.6	20.0
A(I)	14.0	9.2	8.1	7.6	7.3	
V(I)	6.52	9.89	11.36	12.06	12.53	

X STA.	20.0	21.2	22.4	23.5	24.5	25.6
A(I)	6.7	6.6	6.4	6.3	6.2	
V(I)	13.61	13.90	14.32	14.48	14.66	

X STA.	25.6	26.6	27.6	28.7	29.8	31.1
A(I)	6.3	6.2	6.3	6.6	6.8	
V(I)	14.61	14.71	14.54	13.81	13.48	

X STA.	31.1	32.4	34.0	35.6	37.6	44.0
A(I)	7.1	7.5	7.8	9.1	13.9	

WSPRO OUTPUT FILE (continued)

V(I) 12.91 12.13 11.77 10.10 6.60

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 75.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	978	69661	568	569				7279
	2	433	46060	70	73				6116
	3	63	2295	102	102				284
501.65		1474	118016	739	743	1.16	-567	171	10963

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 75.

	WSEL	LEW	REW	AREA	K	Q	VEL
	501.65	-567.9	171.5	1474.0	118016.	1830.	1.24
X STA.	-567.9	-480.8	-436.8	-397.2	-361.0	-327.9	
A(I)		105.9	81.2	78.2	75.4	72.5	
V(I)		0.86	1.13	1.17	1.21	1.26	
X STA.	-327.9	-296.5	-267.5	-239.1	-211.2	-176.6	
A(I)		71.5	68.9	69.8	69.8	75.6	
V(I)		1.28	1.33	1.31	1.31	1.21	
X STA.	-176.6	-115.2	1.9	7.5	12.6	18.1	
A(I)		94.6	127.4	46.7	44.7	47.6	
V(I)		0.97	0.72	1.96	2.05	1.92	
X STA.	18.1	24.0	30.2	36.7	44.0	171.5	
A(I)		48.7	50.3	54.0	61.1	130.2	
V(I)		1.88	1.82	1.70	1.50	0.70	

U.S. Geological Survey WSPRO Input File cori034.wsp
 Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97
 Bridge 34 on Town Highway 50 over South Branch Waits River by MAI
 *** RUN DATE & TIME: 08-18-97 12:23

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
EXITX:XS	*****	-554	1135	0.54	*****	501.09	500.54	5450	500.55
-50	*****	232	78664	1.51	*****	*****	0.87	4.80	
===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.									
"FULLV" KRATIO = 1.44									
FULLV:FV	51	-559	1486	0.27	0.17	501.26	*****	5450	500.99
0	51	240	113110	1.28	0.00	0.00	0.54	3.67	
<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>									
APPRO:AS	75	-553	1109	0.46	0.24	501.60	*****	5450	501.13
75	75	126	81716	1.24	0.10	0.00	0.74	4.91	
<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>									
===210 QUESTIONABLE CRITICAL-FLOW SOLUTION.									
SECID "BRIDG" Q,CRWS = 5450.00 502.66									
===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.									
WS1,WSSD,WS3,RGMIN = 509.34 0.00 502.66 501.62									
===260 ATTEMPTING FLOW CLASS 4 SOLUTION.									
===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.									
WS3,WSIU,WS1,LSEL = 501.28 503.40 503.52 502.67									
===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	51	0	358	0.63	*****	503.31	499.01	2273	502.68
0	*****	52	39489	1.00	*****	*****	0.43	6.36	

WSPRO OUTPUT FILE (continued)

TYPE	PPCD	FLOW	C	P/A	LSEL	BLN	XLAB	XRAB
3.	****	5.	0.382	0.000	502.67	*****	*****	*****

XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	10.	63.	0.02	0.05	503.60	-0.02	3074.	503.27

	Q	WLEN	LEW	REW	DMAX	DAVG	VMAX	VAVG	HAVG	CAVG
LT:	3074.	591.	-621.	-30.	1.6	1.1	5.4	4.7	1.4	3.0
RT:	0.	193.	62.	255.	0.6	0.3	4.0	6.9	0.9	2.8

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
	SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL
APPRO:AS	55	-619	3075	0.05	0.12	503.61	500.82	5450	503.56
	75	103	307	337199	1.06	0.07	-0.02	0.18	1.77

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-51.	-555.	232.	5450.	78664.	1135.	4.80	500.55
FULLV:FV	0.	-560.	240.	5450.	113110.	1486.	3.67	500.99
BRIDG:BR	0.	0.	52.	2273.	39489.	358.	6.36	502.68
RDWAY:RG	10.*****		3074.	3074.*****		0.	2.00	503.27
APPRO:AS	75.	-620.	307.	5450.	337199.	3075.	1.77	503.56

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	500.54	0.87	491.91	509.53*****			0.54	501.09	500.55
FULLV:FV	*****	0.54	491.91	509.53	0.17	0.00	0.27	501.26	500.99
BRIDG:BR	499.01	0.43	491.80	502.68*****			0.63	503.31	502.68
RDWAY:RG	*****		501.62	509.06	0.02*****		0.05	503.60	503.27
APPRO:AS	500.82	0.18	492.81	511.44	0.12	0.07	0.05	503.61	503.56

U.S. Geological Survey WSPRO Input File cori034.wsp
 Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97
 Bridge 34 on Town Highway 50 over South Branch Waits River by MAI
 *** RUN DATE & TIME: 08-18-97 12:23

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
	SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL
EXITX:XS	*****	-560	1533	0.56	*****	501.61	500.90	8200	501.05
-50	*****	241	118248	1.26	*****	*****	0.76	5.35	
FULLV:FV	51	-567	1831	0.36	0.19	501.78	*****	8200	501.42
0	51	247	152929	1.16	0.00	-0.02	0.57	4.48	

<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

APPRO:AS	75	-565	1429	0.60	0.29	502.19	*****	8200	501.59
	75	166	112997	1.17	0.12	0.00	0.78	5.74	
<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>									

===210 QUESTIONABLE CRITICAL-FLOW SOLUTION.
 SECID "BRIDG" Q,CRWS = 8200.00 502.68

===230 REJECTED FLOW CLASS 1 SOLUTION.
 WS1, WSSD, WS3 = 511.44 0.00 502.68
 CRWS = 501.38 ***** 502.68
 YMAX = 511.44 ***** 502.68

===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

===225 NO ENERGY BALANCE IN 15 ITERATIONS.
 FLOW, Q = 4 264.
 WS1, WSSD, WS3 = 502.80 0.00 502.36

===235 CONTINUE FLOW CLASS 4 COMPUTATIONS.
 ITER, QRD = 4 7936.
 WS, WSMIN, WSMAX = 504.69 504.08 505.30

===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
 WS3, WSIU, WS1, LSEL = 501.95 503.95 504.20 502.67

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

WSPRO OUTPUT FILE (continued)

<<<<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	51	0	358	0.95	*****	503.63	499.84	2790	502.68
0	*****	52	39489	1.00	*****	*****	0.52	7.80	

TYPE	PPCD	FLOW	C	P/A	LSEL	BLN	XLAB	XRAB
3.	****	5.	0.441	0.000	502.67	*****	*****	*****

XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	10.	63.	0.02	0.08	504.24	0.00	5440.	503.80

	Q	WLEN	LEW	REW	DMAX	DAVG	VMAX	VAVG	HAVG	CAVG
LT:	5416.	621.	-627.	-7.	2.2	1.6	6.5	5.5	2.0	3.0
RT:	25.	27.	62.	89.	0.1	0.1	2.8	16.7	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	55	-635	3661	0.08	0.19	504.26	501.38	8200	504.18
75	109	336	434767	1.05	0.06	0.00	0.21	2.24	

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-51.	-561.	241.	8200.	118248.	1533.	5.35	501.05
FULLV:FV	0.	-568.	247.	8200.	152929.	1831.	4.48	501.42
BRIDG:BR	0.	0.	52.	2790.	39489.	358.	7.80	502.68
RDWAY:RG	10.	*****	5416.	5440.	*****	0.	2.00	503.80
APPRO:AS	75.	-636.	336.	8200.	434767.	3661.	2.24	504.18

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	500.90	0.76	491.91	509.53	*****	0.56	501.61	501.05	
FULLV:FV	*****	0.57	491.91	509.53	0.19	0.00	0.36	501.78	
BRIDG:BR	499.84	0.52	491.80	502.68	*****	0.95	503.63	502.68	
RDWAY:RG	*****	501.62	509.06	0.02	*****	0.08	504.24	503.80	
APPRO:AS	501.38	0.21	492.81	511.44	0.19	0.06	0.08	504.26	

U.S. Geological Survey WSPRO Input File cori034.wsp

Hydraulic analysis for structure CORITH00500034 Date: 06-AUG-97

Bridge 34 on Town Highway 50 over South Branch Waits River by MAI

*** RUN DATE & TIME: 08-18-97 12:23

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
EXITX:XS	*****	-2	286	0.64	*****	499.36	496.25	1830	498.72
-50	*****	107	26410	1.01	*****	*****	0.56	6.40	

FULLV:FV	51	-3	318	0.56	0.22	499.60	*****	1830	499.04
0	51	130	28839	1.08	0.00	0.02	0.66	5.76	

<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===125 FR# EXCEEDS FNTEST AT SECID "APPRO": TRIALS CONTINUED.

FNTEST,FR#,WSEL,CRWS = 0.80 0.81 499.35 497.12

===110 WSEL NOT FOUND AT SECID "APPRO": REDUCED DELTAY.

WSLIM1,WSLIM2,DELTAY = 498.54 511.44 0.50

===115 WSEL NOT FOUND AT SECID "APPRO": USED WSMIN = CRWS.

WSLIM1,WSLIM2,CRWS = 498.54 511.44 497.12

WSPRO OUTPUT FILE (continued)

APPRO:AS 75 -300 309 0.62 0.32 499.95 497.12 1830 499.33
 75 75 54 27207 1.13 0.03 0.00 0.80 5.92
 <<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.

 WS1, WSSD, WS3, RGMIN = 501.64 0.00 498.26 501.62

===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

===285 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D !!!!!

 SECID "BRIDG" Q, CRWS = 1830. 498.24

 <<<<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	51	6	156	3.13	*****	501.37	498.24	1830	498.24
0	51	44	19076	1.46	*****	*****	1.21	11.72	

TYPE	PPCD	FLOW	C	P/A	LSEL	BLN	XLAB	XRAB
3.	****	4.	0.826	*****	502.67	*****	*****	*****

XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	10.	63.	0.02	0.03	501.67	0.00	0.	501.66

	Q	WLEN	LEW	REW	DMAX	DAVG	VMAX	VAVG	HAVG	CAVG
LT:	0.	34.	-372.	-338.	0.0	0.0	0.7	0.7	0.0	2.5
RT:	0.	301.	62.	363.	2.0	1.4	6.8	7.2	2.2	3.1

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
APPRO:AS	55	-567	1477	0.03	0.09	501.68	497.12	1830	501.65
75	62	172	118348	1.16	0.22	0.01	0.17	1.24	

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
0.884	0.640	42388.	1.	39.	*****

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-51.	-3.	107.	1830.	26410.	286.	6.40	498.72
FULLV:FV	0.	-4.	130.	1830.	28839.	318.	5.76	499.04
BRIDG:BR	0.	6.	44.	1830.	19076.	156.	11.72	498.24
RDWAY:RG	10.	*****	0.	0.	*****	0.	2.00	501.66
APPRO:AS	75.	-568.	172.	1830.	118348.	1477.	1.24	501.65

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	496.25	0.56	491.91	509.53	*****	0.64	499.36	498.72	
FULLV:FV	*****	0.66	491.91	509.53	0.22	0.00	0.56	499.60	
BRIDG:BR	498.24	1.21	491.80	502.68	*****	3.13	501.37	498.24	
RDWAY:RG	*****	501.62	509.06	0.02	*****	0.03	501.67	501.66	
APPRO:AS	497.12	0.17	492.81	511.44	0.09	0.22	0.03	501.68	

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION

Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CORITH00500034, in Corinth, Vermont.

APPENDIX D:
HISTORICAL DATA FORM

Structure Number CORITH00500034

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) 017

Town (FIPS place code; I - 4; nnnnn) 15700

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

Waterway (I - 6) SOUTH BRANCH WAITS RIVER

Road Name (I - 7): -

Route Number TH050

Vicinity (I - 9) 0.1 MI JCT TH 50 + TH 2

Topographic Map East Corinth

Hydrologic Unit Code: 01080103

Latitude (I - 16; nnnn.n) 44005

Longitude (I - 17; nnnnn.n) 72145

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10090500340905

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0054

Year built (I - 27; YYYY) 1954

Structure length (I - 49; nnnnnn) 000056

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

Deck Width (I - 52; nn.n) 117

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 6

Opening skew to Roadway (I - 34; nn) 15

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) E

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

Structure type (I - 43; nnn) 310

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) -

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 008.5

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

Waterway of full opening (nnn.n ft²) -

Comments:

The structural inspection report of 6/29/93 indicates the structure is a steel thru-truss type bridge with a timber deck. The abutments are the spill-through type (earth embankments protected with some boulders). There are concrete stub abutments at the top of each embankment, which support the deck. A four foot section of the left abutment concrete stub is partially undermined, with no sign of piles in the voided area. The undermining has occurred during recent flooding. Some of the boulder fill on the spill-through embankments also lines the banks upstream and downstream from the bridge. Settlement is noted on the report as possible but not clearly visible. (Continued, page 35)

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 of 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:

The report indicates a 3.5 feet deep scour hole has developed in the channel about 10 feet from the left abutment. This may have resulted in the slumping of the spill-through embankment and the undermining of the concrete abutment footing the report notes. There is some bank erosion noted, but point bars and debris accumulation problems are minor.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area (*DA*) 35.91 mi² Lake/pond/swamp area 0.55 mi²
Watershed storage (*ST*) 1.5 %
Bridge site elevation 780 ft Headwater elevation 2267 ft
Main channel length 12.21 mi
10% channel length elevation 810 ft 85% channel length elevation 1770 ft
Main channel slope (*S*) 104.83 ft / mi

Watershed Precipitation Data

Average site precipitation - _____ in Average headwater precipitation - _____ in
Maximum 2yr-24hr precipitation event (*I*(24,2) - _____ 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? N *If no, type ctrl-n xs*

Source (FEMA, VTAOT, Other)? -

Comments: **NO ACCURATE CROSS SECTION INFORMATION AVAILABLE.**

-

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

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

Source (FEMA, VTAOT, Other)? -

Comments: **NO CROSS SECTION INFORMATION**

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

Structure Number CORITH00500034

Qa/Qc Check by: EW Date: 2/21/96

Computerized by: EW Date: 2/21/96

Reviewed by: MAI Date: 8/19/97

A. General Location Descriptive

1. Data collected by (First Initial, Full last name) M. IVANOFF Date (MM/DD/YY) 09 / 05 / 1995
2. Highway District Number 07 Mile marker - _____
- County ORANGE (017) Town CORINTH (15700)
- Waterway (I - 6) SOUTH BRANCH WAITS RIVER Road Name - _____
- Route Number TH 50 Hydrologic Unit Code: 01080103
3. Descriptive comments:
Located 0.1 miles to junction with Town Highway 2

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 RBDS 4 Overall 4
(2b us,ds,lb,rb: 1- Urban; 2- Suburban; 3- Row crops; 4- Pasture; 5- Shrub- and brushland; 6- Forest; 7- Wetland)
5. Ambient water surface... US 1 UB 1 DS 1 (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 56.0 (feet) Span length 54.0 (feet) Bridge width 11.7 (feet)

Road approach to bridge:

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

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

10. Embankment slope (run / rise in feet / foot):

US left 1.9:1 US right 1.9:1

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

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: 20

16. Bridge skew: 30

17. Channel impact zone 1: Exist? Y (Y or N)
Where? LB (LB, RB) Severity 2
Range? 10 feet US (US, UB, DS) to 0 feet DS
- Channel impact zone 2: Exist? Y (Y or N)
Where? LB (LB, RB) Severity 1
Range? 25 feet DS (US, UB, DS) to 75 feet DS

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

18. Bridge Type: 3

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: The bridge dimension values are from VTAOT files. The measured values are: bridge width between outer beams is 15.6 ft; bridge width of the vehicle deck is 12.1 ft; clear span is 52 ft.

C. Upstream Channel Assessment

21. Bank height (BF)		22. Bank angle (BF)		26. % Veg. cover (BF)		27. Bank material (BF)		28. Bank erosion (BF)			
20. SRD	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	
<u>63.5</u>	<u>7.0</u>			<u>5.0</u>	<u>3</u>	<u>2</u>	<u>1234</u>	<u>123</u>	<u>1</u>	<u>1</u>	
23. Bank width		<u>25.0</u>	24. Channel width		<u>25.0</u>	25. Thalweg depth		<u>70.0</u>	29. Bed Material		<u>32</u>
30. Bank protection type:		LB	<u>2</u>	RB	<u>2</u>	31. Bank protection condition:		LB	<u>1</u>	RB	<u>1</u>

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.):

#30: The left bank protection extends 12 feet from the bridge.

On the right bank the protection extends 32 feet from the bridge.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 160 35. Mid-bar width: 20
 36. Point bar extent: 208 feet US (US, UB) to 54 feet US (US, UB, DS) positioned 0 %LB to 75 %RB
 37. Material: 32
 38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This is a side bar consisting of gravel and some sand.

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: 80 42. Cut bank extent: 90 feet US (US, UB) to 32 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.):
Ambient flow is impacting the banks by scalloping the material around a fallen tree.

45. Is channel scour present? N (Y or if N type ctrl-n cs) 46. Mid-scour distance: -
 47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB
 48. Scour comments (eg. additional scour areas, local scouring process, etc.):
NO CHANNEL SCOUR

***See channel scour comment in downstream section.**

49. Are there major confluences? Y (Y or if N type ctrl-n mc) 50. How many? 1
 51. Confluence 1: Distance 240 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):
Minor confluence.

D. Under Bridge Channel Assessment

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

56. Height (BF)		57. Angle (BF)	
LB	RB	LB	RB
<u>43.5</u>		<u>0.5</u>	

61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB
<u>1</u>	<u>342</u>	<u>432</u>	<u>0</u>

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

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

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

64. Comments (bank material variation, minor inflows, protection extent, etc.):
234

-

65. **Debris and Ice** Is there debris accumulation? ____ (Y or N) 66. Where? Y (1- Upstream; 2- At bridge; 3- Both)
 67. Debris Potential 1 (1- Low; 2- Moderate; 3- High) 68. Capture Efficiency 2 (1- Low; 2- Moderate; 3- High)
 69. Is there evidence of ice build-up? 1 (Y or N) Ice Blockage Potential N (1- Low; 2- Moderate; 3- High)
 70. Debris and Ice Comments:

1

#66: Debris exists along the banks both upstream and downstream.

#67: Banks are well vegetated with small trees and brush, some of which are leaning into the channel.

<u>Abutments</u>	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		25	30	2	0	0	0	90.0
RABUT	1	0	30			2	0	49.5

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.):

0

0

1

The structural inspection of 6/29/93 noted undermining at the left abutment. Stone fill is now in place at the base of the left and right concrete abutments and creates spill-through embankments.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?
USLWW:					
USRWW:	N		-		-
DSLWW:	-		-		N
DSRWW:	-		-		-

81.	Angle?	Length?
	49.5	
	2.0	
	20.0	
	19.5	

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

82. Bank / Bridge Protection:

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

Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches;
 5- wall / artificial levee

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

Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

-
-
-
-
-
-
-
-
-
-
-

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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-

Level 1 Pier Descr.	1	2	3	4
86. Location (BF)	ere are	set	pro-	ream
87. Type	no	back	tec-	and
88. Material	wing	on	tion	dow
89. Shape	walls	the	exte	nstre
90. Inclined?	. The	spill-	ndin	am
91. Attack ∠ (BF)	ver-	thro	g	thro
92. Pushed	tical	ugh	alon	ugh
93. Length (feet)	-	-	-	-
94. # of piles	con-	emb	g	the
95. Cross-members	crete	ank-	both	brid
96. Scour Condition	abut	ment	bank	ge.
97. Scour depth	ment	s	s	
98. Exposure depth	s are	with	upst	

LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP

1- Solid pier, 2- column, 3- bent

1- Wood; 2- concrete; 3- metal; 4- stone

1- Round; 2- Square; 3- Pointed

Y- yes; N- no

LB or RB

0- none; 1- laterals; 2- diagonals; 3- both

0- not evident; 1- evident (comment);
2- footing exposed; 3- piling exposed;
4- undermined footing; 5- settled; 6- failed

N
-
-

100.

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

[illegible]

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.):

2

1

32

314

Is channel scour present? 2 (Y or if N type ctrl-n cs) Mid-scour distance: 1

Scour dimensions: Length 23 Width 2 Depth: 2 Positioned 1 %LB to 2 %RB

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

Protection on the right bank extends 10 ft downstream from the bridge. Protection on the left bank extends 25 ft from the bridge.

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

170

25

75

DS

109. G. Plan View Sketch

24

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: CORITH00500034 Town: Corinth
 Road Number: TH 50 County: Orange
 Stream: South Branch Waits River

Initials MAI Date: 08/07/97 Checked: RLB

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

Critical Velocity of Bed Material (converted to English units)
 $V_c = 11.21 \cdot y_1^{0.1667} \cdot D_{50}^{0.33}$ with $S_s = 2.65$
 (Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5450	8200	1830
Main Channel Area, ft ²	567	610	433
Left overbank area, ft ²	2112	2501	978
Right overbank area, ft ²	396	552	63
Top width main channel, ft	70	70	70
Top width L overbank, ft	620	636	568
Top width R overbank, ft	237	266	102
D50 of channel, ft	0.0777	0.0777	0.0777
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
 y ₁ , average depth, MC, ft	 8.1	 8.7	 6.2
y ₁ , average depth, LOB, ft	3.4	3.9	1.7
y ₁ , average depth, ROB, ft	1.7	2.1	0.6
 Total conveyance, approach	 337096	 435219	 118016
Conveyance, main channel	72085	81508	46060
Conveyance, LOB	237282	309043	69661
Conveyance, ROB	27729	44669	2295
Percent discrepancy, conveyance	0.0000	-0.0002	0.0000
Q _m , discharge, MC, cfs	1165.4	1535.7	714.2
Q _l , discharge, LOB, cfs	3836.3	5822.7	1080.2
Q _r , discharge, ROB, cfs	448.3	841.6	35.6
 V _m , mean velocity MC, ft/s	 2.1	 2.5	 1.6
V _l , mean velocity, LOB, ft/s	1.8	2.3	1.1
V _r , mean velocity, ROB, ft/s	1.1	1.5	0.6
V _{c-m} , crit. velocity, MC, ft/s	6.8	6.9	6.5
V _{c-l} , crit. velocity, LOB, ft/s	ERR	ERR	ERR
V _{c-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

$y_2 = (Q_2^2 / (131 * D_m^{(2/3)} * W_2^2))^{(3/7)}$ Converted to English Units
 $y_s = y_2 - y_{\text{bridge}}$
 (Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	5450	8200	1830
(Q) discharge thru bridge, cfs	2273	2790	1830
Main channel conveyance	39489	39489	19060
Total conveyance	39489	39489	19060
Q2, bridge MC discharge, cfs	2273	2790	1830
Main channel area, ft ²	358	358	156
Main channel width (normal), ft	36.7	36.7	30.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	36.7	36.7	30.2
y _{bridge} (avg. depth at br.), ft	9.74	9.74	5.17
D _m , median (1.25*D ₅₀), ft	0.097125	0.097125	0.097125
y ₂ , depth in contraction, ft	8.28	9.87	8.12
y _s , scour depth (y ₂ -y _{bridge}), ft	-1.47	0.12	2.96

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation $H_b + Y_s = C_q * q_{br} / V_c$
 $C_q = 1 / C_f * C_c$ $C_f = 1.5 * Fr^{0.43}$ (≤ 1) $C_c = \text{SQRT}[0.10 (H_b / (y_a - w) - 0.56)] + 0.79$ (≤ 1)
 Umbrell pressure flow equation
 $(H_b + Y_s) / y_a = 1.1021 * [(1 - w / y_a) * (V_a / V_c)]^{0.6031}$
 (Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	5450	8200	1830
Q, thru bridge MC, cfs	2273	2790	1830
V _c , critical velocity, ft/s	6.78	6.86	6.48
V _a , velocity MC approach, ft/s	2.06	2.52	1.65
Main channel width (normal), ft	36.7	36.7	30.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	36.7	36.7	30.2
q _{br} , unit discharge, ft ² /s	61.9	76.0	60.6
Area of full opening, ft ²	357.6	357.6	156.0
H _b , depth of full opening, ft	9.74	9.74	5.17
Fr, Froude number, bridge MC	0.43	0.52	0
C _f , Fr correction factor (≤ 1.0)	1.00	1.00	0.00
**Area at downstream face, ft ²	274	295	N/A
**H _b , depth at downstream face, ft	7.47	8.04	N/A
**Fr, Froude number at DS face	0.54	0.59	ERR
**C _f , for downstream face (≤ 1.0)	1.00	1.00	N/A

Elevation of Low Steel, ft	502.67	502.67	0
Elevation of Bed, ft	492.93	492.93	-5.17
Elevation of Approach, ft	503.56	504.18	0
Friction loss, approach, ft	0.12	0.19	0
Elevation of WS immediately US, ft	503.44	503.99	0.00
ya, depth immediately US, ft	10.51	11.06	5.17
Mean elevation of deck, ft	506.1	506.1	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.97	1.00
**Cc, for downstream face (<=1.0)	0.912517	0.919043	ERR

Ys, scour w/Chang equation, ft	-0.44	1.69	N/A
Ys, scour w/Umbrell equation, ft	-4.10	-3.08	N/A

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

**Ys, scour w/Chang equation, ft	2.55	4.02	N/A
**Ys, scour w/Umbrell equation, ft	-1.82	-1.38	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed ($y_s = y_2 - y_{\text{bridgeDS}}$)

y2, from Laursen's equation, ft	8.28	9.87	8.12
WSEL at downstream face, ft	500.99	501.42	--
Depth at downstream face, ft	7.47	8.04	N/A
Ys, depth of scour (Laursen), ft	0.81	1.83	N/A

Armoring

$$D_c = [(1.94 * V^2) / (5.75 * \log(12.27 * y / D_{90}))^2] / [0.03 * (165 - 62.4)]$$

Depth to Armoring = $3 * (1 / P_c - 1)$

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2273	2790	1830
Main channel area (DS), ft ²	274	295	156
Main channel width (normal), ft	36.7	36.7	30.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	36.7	36.7	30.2
D90, ft	0.1533	0.1533	0.1533
D95, ft	0.1837	0.1837	0.1837
Dc, critical grain size, ft	0.1702	0.2162	0.3832
Pc, Decimal percent coarser than Dc	0.071	0.012	0.169

Depth to armoring, ft	6.67	N/A	5.65
-----------------------	------	-----	------

Abutment Scour

Froehlich's Abutment Scour

$$Y_s / Y_1 = 2.27 * K_1 * K_2 * (a' / Y_1)^{0.43} * Fr_1^{0.61} + 1$$

(Richardson and others, 1995, p. 48, eq. 28)

Characteristic	Left Abutment			Right Abutment		
	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	5450	8200	1830	5450	8200	1830
a', abut.length blocking flow, ft	627.2	643.9	578.5	262.6	291.3	130.7
Ae, area of blocked flow ft ²	1529.68	1641.12	1064.67	520.32	701.25	156.98
Qe, discharge blocked abut., cfs	--	--	1245.12	630.59	--	131.61

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

Ve, (Qe/Ae), ft/s	1.83	2.34	1.17	1.21	1.62	0.84
ya, depth of f/p flow, ft	2.44	2.55	1.84	1.98	2.41	1.20
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.173	0.206	0.152	0.152	0.183	0.135
ys, scour depth, ft	14.02	15.91	10.64	8.23	10.60	4.44
HIRE equation ($a'/y_a > 25$)						
$y_s = 4 * Fr^{0.33} * y_1 * K / 0.55$						
(Richardson and others, 1995, p. 49, eq. 29)						
a' (abut length blocked, ft)	627.2	643.9	578.5	262.6	291.3	130.7
y1 (depth f/p flow, ft)	2.44	2.55	1.84	1.98	2.41	1.20
a'/y1	257.16	252.64	314.33	132.53	121.01	108.82
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.17	0.21	0.15	0.15	0.18	0.13
Ys w/ corr. factor K1/0.55:						
vertical	10.27	11.37	7.42	7.35	9.50	4.28
vertical w/ ww's	8.42	9.32	6.09	6.03	7.79	3.51
spill-through	5.65	6.25	4.08	4.04	5.22	2.36

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	0.54	0.59	1.21	0.54	0.59	1.21
y, depth of flow in bridge, ft	7.47	8.04	5.17	7.47	8.04	5.17
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.35	1.73	ERR	1.35	1.73	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.28	ERR	ERR	2.28
Fr<=0.8 (spillthrough abut.)	1.17	1.51	ERR	1.17	1.51	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	2.02	ERR	ERR	2.02