

LEVEL II SCOUR ANALYSIS FOR  
BRIDGE 13 (LINCTH00010013) on  
TOWN HIGHWAY 1, crossing  
COTA BROOK,  
LINCOLN, VERMONT

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Open-File Report 98-157

Prepared in cooperation with  
VERMONT AGENCY OF TRANSPORTATION  
and

FEDERAL HIGHWAY ADMINISTRATION



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

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By EMILY C. WILD

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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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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	Max	maximum
D <sub>50</sub>	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 <sup>2</sup>	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 13 (LINCTH00010013) ON TOWN HIGHWAY 1, CROSSING THE COTA BROOK, LINCOLN, VERMONT**

*By Emily C. Wild*

## **INTRODUCTION AND SUMMARY OF RESULTS**

This report provides the results of a detailed Level II analysis of scour potential at structure LINCTH00010013 on Town Highway 1 crossing Cota Brook, Lincoln, 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 Green Mountain section of the New England physiographic province in west-central Vermont. The 3.0-mi<sup>2</sup> drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest along the upstream right bank and brushland along the upstream left bank. Downstream of the bridge, the surface cover is pasture along the left and right banks.

In the study area, Cota Brook has an sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 30 ft and an average bank height of 2 ft. The channel bed material ranges from sand to cobble with a median grain size ( $D_{50}$ ) of 34.7 mm (0.114 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 10, 1996, indicated that the reach was laterally unstable due to cut-banks and wide, vegetated point bars upstream and downstream of the bridge.

The Town Highway 1 crossing of Cota Brook is a 38-ft-long, two-lane bridge consisting of a 36-foot steel-stringer span (Vermont Agency of Transportation, written communication, December 14, 1995). The opening length of the structure parallel to the bridge face is 34.4 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the upstream right bank during the Level I assessment. Along the right abutment, it is 0.25 ft deeper than the mean thalweg depth. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream right bank and type-2 stone fill (less than 36 inches diameter) along the left and right abutments and along the downstream left bank. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 9.1 to 11.3 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 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

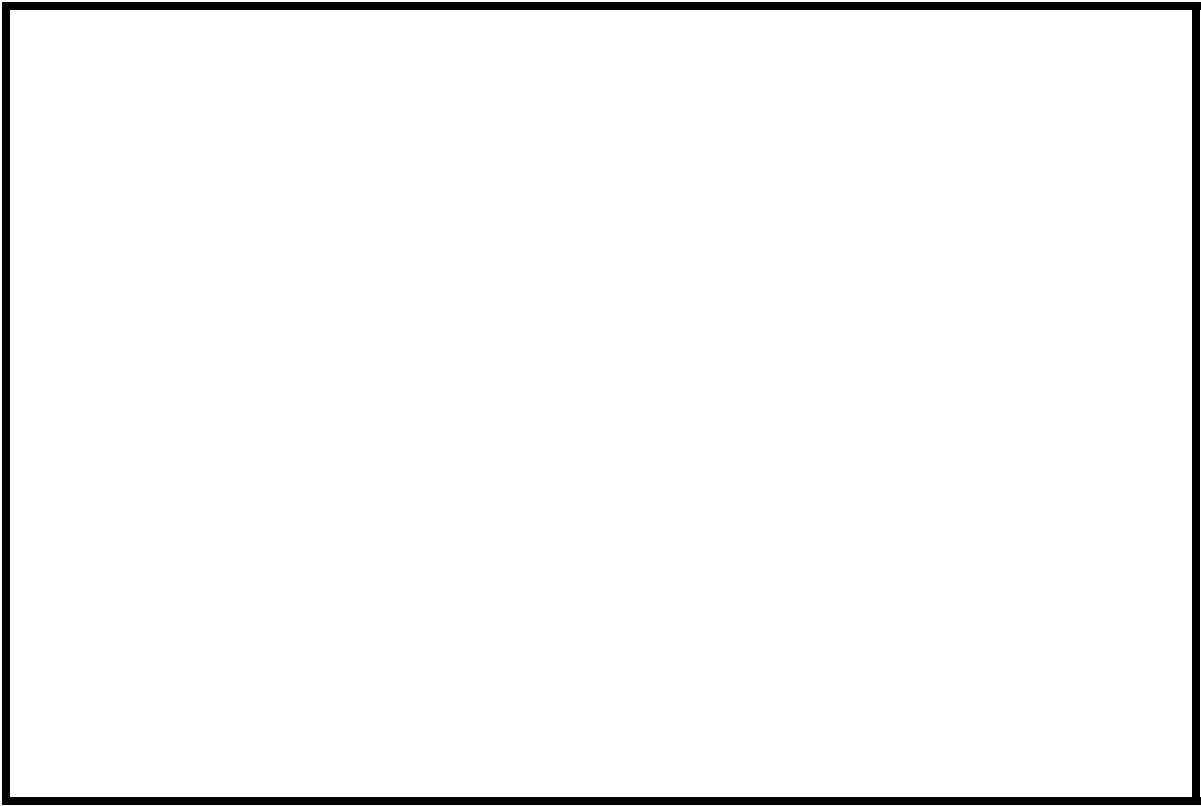


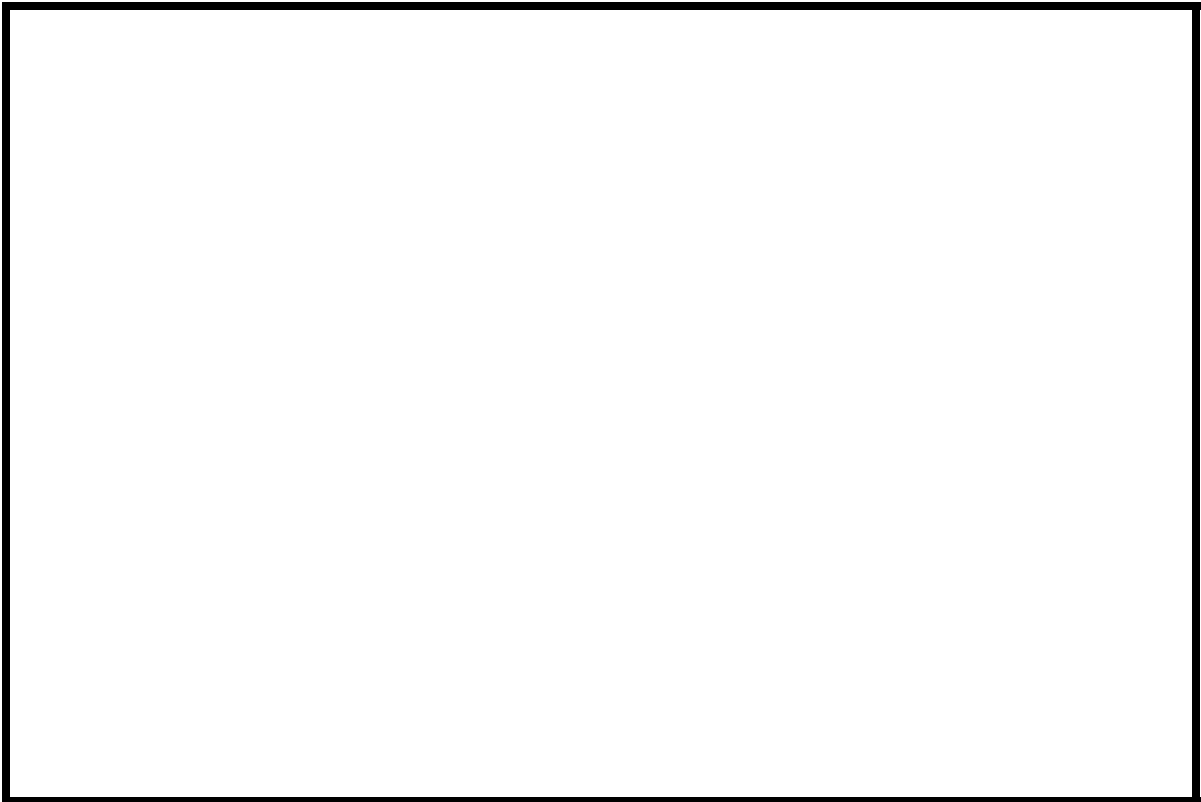
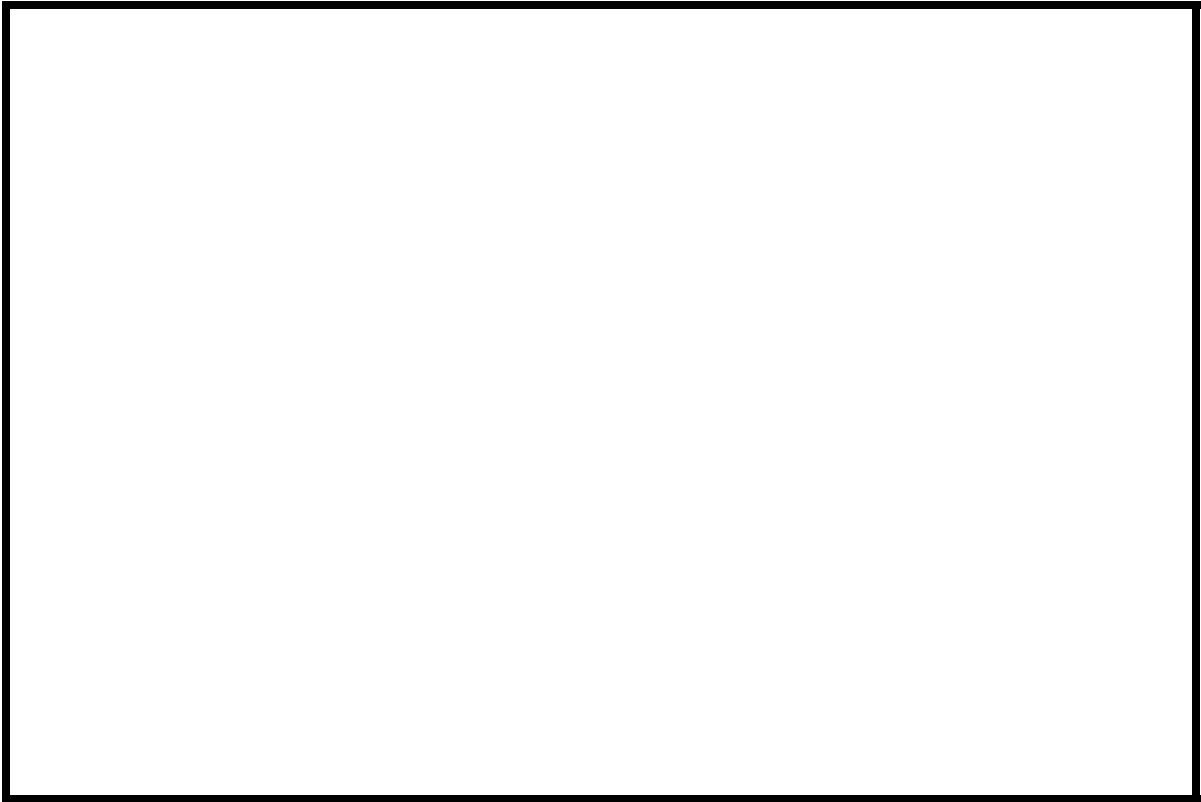
NORTH

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** LINCTH00010013      **Stream** Cota Brook  
**County** Addison      **Road** TH 1      **District** 5

### Description of Bridge

**Bridge length** 38 ft      **Bridge width** 23.3 ft      **Max span length** 36 ft  
**Alignment of bridge to road (on curve or straight)** Curve  
**Abutment type** Vertical, concrete      **Embankment type** Sloping  
**Stone fill on abutment?** Yes      **Date of inspection** 6/10/96  
**Description of stone fill** Type-2, along the left and right abutments.

Abutments are concrete. There is a 0.25 foot deep scour hole in front of the right abutment.

**Is bridge skewed to flood flow according to** Yes **survey?**      **Angle** 15

There is a moderate bend in the channel in the upstream reach. There is a scour hole along the upstream right bank, where the flow impacts the bank.

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

	<b>Date of inspection</b>	<b>Percent of channel blocked horizontally</b>	<b>Percent of channel blocked vertically</b>
<b>Level I</b>	<u>6/10/96</u>	<u>0</u>	<u>0</u>
<b>Level II</b>	<u>6/10/96</u>	<u>0</u>	<u>0</u>

**Potential for debris** High. There is some debris caught within the trees leaning over the channel upstream.

None, 6/10/96.

**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 moderate relief valley.

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

**Date of inspection** 6/10/96

**DS left:** Narrow flood plain

**DS right:** Little flood plain to a steep valley wall

**US left:** Moderately sloped overbank

**US right:** Steep valley wall

## Description of the Channel

<b>Average top width</b>	<u>30</u>			<u>2</u>
	<sup>ft</sup>			<sup>ft</sup>
	<u>Sand/ Gravel</u>	<b>Average depth</b>		<u>Sand/ Gravel</u>

<b>Predominant bed material</b>	<b>Bank material</b>
<u>alluvial channel boundaries and a narrow flood plain.</u>	<u>Sinuuous with semi-</u>

<b>Vegetative cover</b>	<u>6/10/96</u>
<u>Pasture</u>	

**DS left:** Pasture

**DS right:** Shrubs and brush

**US left:** Trees

**US right:** No

**Do banks appear stable?** It was noted (6/10/96) that the banks are laterally unstable; evidence of the instability is apparent in the cut-banks and wide, vegetated point bars upstream and downstream of the bridge.

*date of observation.*

On 6/10/96, a concrete

**Describe any obstructions in channel and date of observation.** step was observed in the channel 22 feet downstream of the bridge. The step extends 6 feet into the channel and diverts flow into the right bank.

## Hydrology

Drainage area 3.0  $mi^2$

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area --  $mi^2$  No

Is there a lake/p...

790 **Calculated Discharges** 1,180

**Q100**  $ft^3/s$  **Q500**  $ft^3/s$

The 100-year and 500-year discharges are the median values taken from a range defined by several empirical flood frequency curves (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*      None

*Description of reference marks used to determine USGS datum.*      RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.86 ft, arbitrary survey datum). RM2 is a chiseled X on the roadway, 22 feet from the downstream end of the left abutment (elev. 499.75 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

<i><sup>1</sup>Cross-section</i>	<i>Section Reference Distance (SRD) in feet</i>	<i><sup>2</sup>Cross-section development</i>	<i>Comments</i>
EXITX	-29	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	64	1	Approach section

<sup>1</sup> For location of cross-sections see plan-view sketch included with Level I field form, Appendix E. For more detail on how cross-sections were developed see WSPRO input file.

### **Data and Assumptions Used in WSPRO Model**

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.035 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0109 ft/ft, determined from surveyed thalweg points downstream of the structure .

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.



## Bridge Hydraulics Summary

*Average bridge embankment elevation*      500.1 *ft*  
*Average low steel elevation*              497.1 *ft*

*100-year discharge*              790 *ft<sup>3</sup>/s*  
*Water-surface elevation in bridge opening*      497.3 *ft*  
*Road overtopping?*      No      *Discharge over road*      -- *ft<sup>3</sup>/s*  
*Area of flow in bridge opening*              136 *ft<sup>2</sup>*  
*Average velocity in bridge opening*              5.8 *ft/s*  
*Maximum WSPRO tube velocity at bridge*              7.0 *ft/s*

*Water-surface elevation at Approach section with bridge*      498.0  
*Water-surface elevation at Approach section without bridge*      497.1  
*Amount of backwater caused by bridge*              0.9 *ft*

*500-year discharge*              1,180 *ft<sup>3</sup>/s*  
*Water-surface elevation in bridge opening*      497.3 *ft*  
*Road overtopping?*      No      *Discharge over road*      -- *ft<sup>3</sup>/s*  
*Area of flow in bridge opening*              136 *ft<sup>2</sup>*  
*Average velocity in bridge opening*              8.7 *ft/s*  
*Maximum WSPRO tube velocity at bridge*              10.4 *ft/s*

*Water-surface elevation at Approach section with bridge*      500.0  
*Water-surface elevation at Approach section without bridge*      497.8  
*Amount of backwater caused by bridge*              2.2 *ft*

*Incipient overtopping discharge*              -- *ft<sup>3</sup>/s*  
*Water-surface elevation in bridge opening*              -- *ft*  
*Area of flow in bridge opening*              -- *ft<sup>2</sup>*  
*Average velocity in bridge opening*              -- *ft/s*  
*Maximum WSPRO tube velocity at bridge*              -- *ft/s*

*Water-surface elevation at Approach section with bridge*      --  
*Water-surface elevation at Approach section without bridge*      --  
*Amount of backwater caused by bridge*              -- *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 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). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, 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**

<i>Contraction scour:</i>	<i>100-year discharge</i>	<i>500-year discharge</i>	<i>Incipient overtopping discharge</i>
	<i>(Scour depths in feet)</i>		
<i>Main channel</i>			
<i>Live-bed scour</i>	--	--	--
<i>Clear-water scour</i>	0.0	1.7	--
<i>Depth to armoring</i>	N/A	N/A	--
<i>Left overbank</i>	--	--	--
<i>Right overbank</i>	--	--	--
<i>Local scour:</i>			
<i>Abutment scour</i>	9.4	11.2	--
<i>Left abutment</i>	9.1	11.3	--
<i>Right abutment</i>			
<i>Pier scour</i>	--	--	--
<i>Pier 1</i>	--	--	--
<i>Pier 2</i>	--	--	--
<i>Pier 3</i>	--	--	--

**Riprap Sizing**

	<i>100-year discharge</i>	<i>500-year discharge (D<sub>50</sub> in feet)</i>	<i>Incipient overtopping discharge</i>
	<i>Abutments:</i>	1.1	1.4
<i>Left abutment</i>	1.1	1.4	--
<i>Right abutment</i>	--	--	--
<i>Piers:</i>	--	--	--
<i>Pier 1</i>	--	--	--
<i>Pier 2</i>	--	--	--

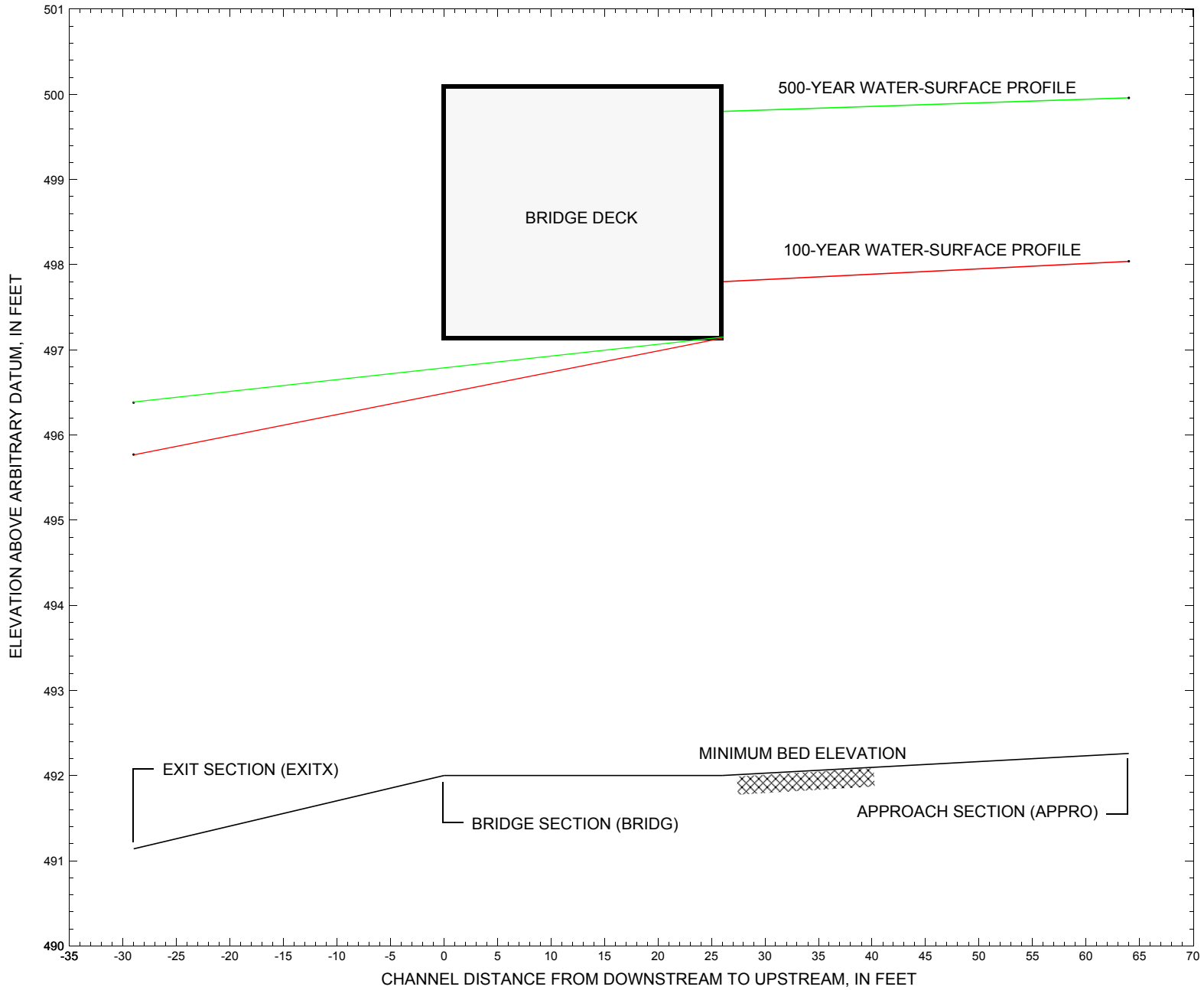


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.

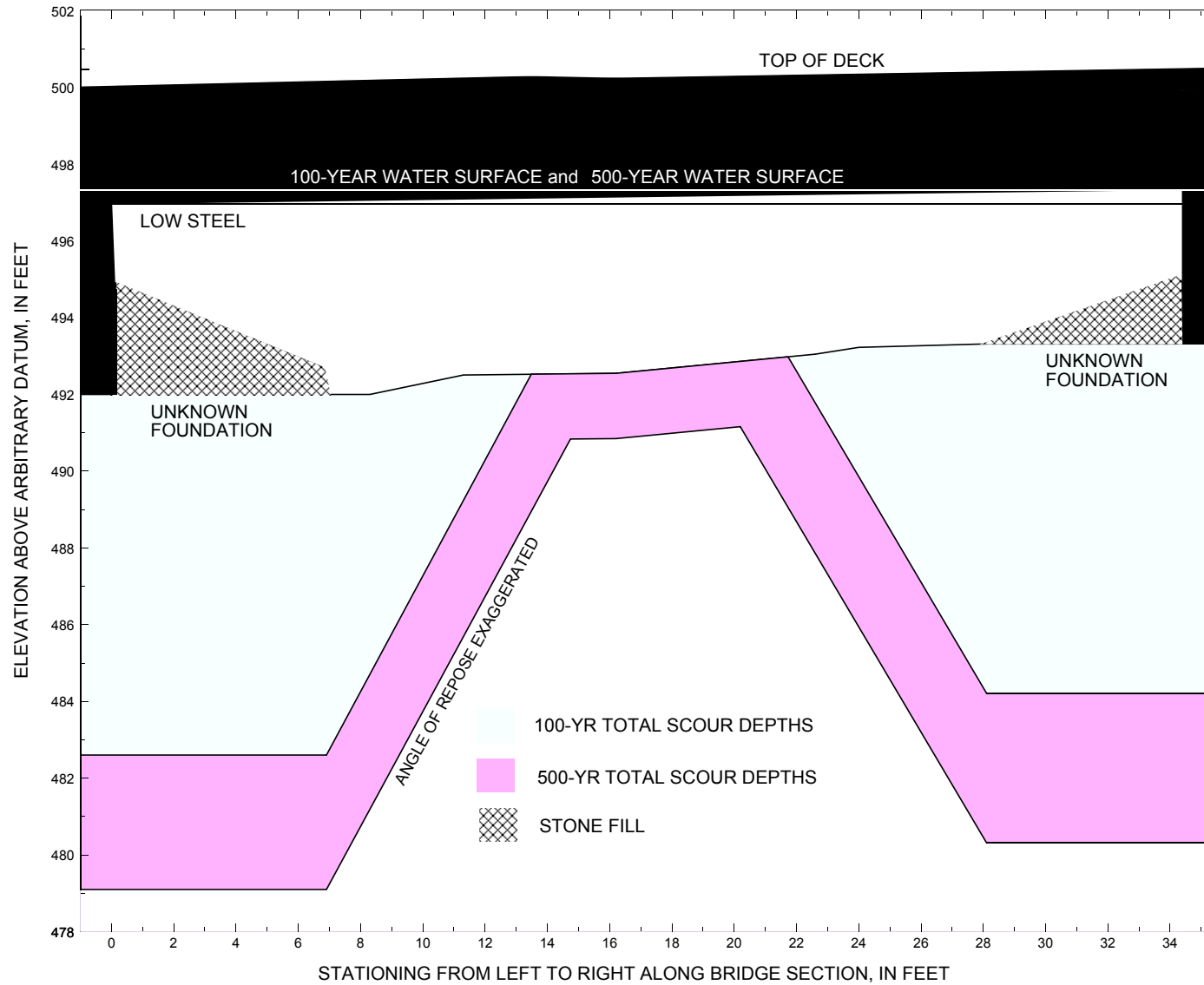


Figure 8. Scour elevations for the 100- and 500-year discharges at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont. [VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station <sup>1</sup>	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation <sup>2</sup> (feet)	Bottom of footing/pile elevation <sup>2</sup> (feet)	Channel elevation at abutment/pier <sup>2</sup> (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour <sup>2</sup> (feet)	Remaining footing/pile depth (feet)
100-year discharge is 790 cubic-feet per second											
Left abutment	0.0	--	497.0	--	492.0	0.0	9.4	--	9.4	482.6	--
Right abutment	34.4	--	497.3	--	493.3	0.0	9.1	--	9.1	484.2	--

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 LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont. [VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station <sup>1</sup>	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation <sup>2</sup> (feet)	Bottom of footing/pile elevation <sup>2</sup> (feet)	Channel elevation at abutment/pier <sup>2</sup> (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour <sup>2</sup> (feet)	Remaining footing/pile depth (feet)
500-year discharge is 1,180 cubic-feet per second											
Left abutment	0.0	--	497.0	--	492.0	1.7	11.2	--	12.9	479.1	--
Right abutment	34.4	--	497.3	--	493.3	1.7	11.3	--	13.0	480.3	--

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

2. Arbitrary datum for this study.

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APPENDIX A:  
**WSPRO INPUT FILE**



# WSPRO INPUT FILE

```

T1      U.S. Geological Survey WSPRO Input File linc013.wsp
T2      Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
T3      Town Highway 1, Cota Brook, Lincoln, Vermont           ECW
*
J1      * * 0.01
J3      6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q        790.0    1180.0
SK       0.0109   0.0109
*
XS      EXITX    -29                0.
GR      -17.4, 498.02    0.0, 496.64    1.9, 496.16    7.9, 491.99
GR      8.2, 491.95     9.1, 491.36    10.9, 491.14   16.4, 491.27
GR      18.4, 491.49   21.0, 491.95   23.9, 492.93   34.3, 494.55
GR      65.9, 494.50   77.7, 499.73   114.1, 501.66  146.2, 502.31
GR      164.9, 505.07  182.9, 513.53
*
N        0.045        0.060        0.035
SA       0.0         23.9
*
*
XS      FULLV    0 * * * 0.0169
*
*          SRD      LSEL      XSSKEW
BR      BRIDG    0    497.14    0.0
GR      0.0, 496.96    0.1, 494.92    6.7, 492.74    6.9, 492.00
GR      8.3, 492.00    11.3, 492.51   16.2, 492.55   22.6, 493.05
GR      24.0, 493.23   28.1, 493.32   34.4, 494.95   34.4, 497.33
GR      0.0, 496.96
*
*          BRTYPE  BRWDTH
CD       1         25.8
N        0.045
*
*          SRD      EMBWID   IPAVE
XR      RDWAY    13      23.3    1
GR      -274.3, 501.25  -201.1, 500.98  -120.8, 500.52    0.0, 499.92
GR      33.4, 500.21   114.1, 501.66   146.2, 502.31   164.9, 505.07
GR      182.9, 513.53
*
*
AS      APPRO    64                0.
GR      -274.3, 501.25  -201.1, 500.98  -120.8, 500.52  -87.2, 500.05
GR      -43.5, 499.60  -36.5, 497.27   -29.9, 495.64   -16.2, 494.55
GR      -7.6, 495.54   0.0, 495.04    2.0, 493.25     6.3, 492.74
GR      9.5, 492.77    14.6, 492.26   18.1, 492.45   24.2, 493.27
GR      38.5, 494.73   61.9, 495.82   65.7, 497.86   114.1, 501.66
GR      146.2, 502.31  164.9, 505.07  182.9, 513.53
*
N        0.055        0.060        0.070
SA      -43.5        65.7
*
HP 1 BRIDG 497.33 1 497.33
HP 2 BRIDG 497.33 * * 790
HP 1 BRIDG 496.08 1 496.08
HP 1 APPRO 498.04 1 498.04
HP 2 APPRO 498.04 * * 790

```

APPENDIX B:  
**WSPRO OUTPUT FILE**

# WSPRO OUTPUT FILE

U.S. Geological Survey WSPRO Input File linc013.wsp  
 Hydraulic analysis for structure LINCTH00010013 Date: 16-JUL-97  
 Town Highway 1, Cota Brook, Lincoln, Vermont ECW

\*\*\* RUN DATE & TIME: 02-12-98 12:59

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	136.	6711.	0.	74.				0.
497.33		136.	6711.	0.	74.	1.00	0.	34.	0.

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

WSEL	LEW	REW	AREA	K	Q	VEL
497.33	0.0	34.4	135.7	6711.	790.	5.82

X STA.	0.0	4.5	6.3	7.6	8.8	9.9
A(I)	12.3	6.8	6.5	5.7	5.7	
V(I)	3.21	5.82	6.04	6.95	6.96	

X STA.	9.9	11.2	12.5	13.8	15.1	16.4
A(I)	5.9	5.9	6.0	5.9	5.9	
V(I)	6.67	6.64	6.58	6.66	6.65	

X STA.	16.4	17.7	19.1	20.5	22.0	23.4
A(I)	6.1	5.9	6.1	6.3	6.1	
V(I)	6.52	6.65	6.48	6.30	6.43	

X STA.	23.4	25.1	26.7	28.3	30.2	34.4
A(I)	6.5	6.4	6.4	6.9	12.3	
V(I)	6.08	6.20	6.15	5.73	3.22	

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	99.	6236.	34.	38.				955.
496.08		99.	6236.	34.	38.	1.00	0.	34.	955.

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 64.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	2	351.	19362.	105.	106.				3657.
	3	0.	1.	2.	2.				0.
498.04		352.	19363.	107.	109.	1.00	-39.	68.	3619.

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 64.

WSEL	LEW	REW	AREA	K	Q	VEL
498.04	-38.8	68.0	351.7	19363.	790.	2.25

X STA.	-38.8	-21.4	-16.0	-10.1	-1.8	3.0
A(I)	34.7	17.6	18.6	22.1	18.1	
V(I)	1.14	2.24	2.13	1.79	2.18	

X STA.	3.0	5.7	8.3	10.9	13.3	15.7
A(I)	13.5	13.6	13.8	13.7	13.3	
V(I)	2.92	2.91	2.86	2.89	2.96	

X STA.	15.7	18.1	20.6	23.4	26.6	29.9
A(I)	13.6	13.9	14.1	14.8	14.6	
V(I)	2.90	2.84	2.80	2.67	2.71	

X STA.	29.9	33.9	38.7	44.4	51.2	68.0
A(I)	15.9	16.9	18.2	19.6	31.1	
V(I)	2.48	2.34	2.18	2.02	1.27	

# WSPRO OUTPUT FILE (continued)

U.S. Geological Survey WSPRO Input File linc013.wsp  
 Hydraulic analysis for structure LINCTH00010013 Date: 16-JUL-97  
 Town Highway 1, Cota Brook, Lincoln, Vermont ECW

\*\*\* RUN DATE & TIME: 02-12-98 12:59

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	136.	6711.	0.	74.				0.
497.33		136.	6711.	0.	74.	1.00	0.	34.	0.

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

WSEL	LEW	REW	AREA	K	Q	VEL
497.33	0.0	34.4	135.7	6711.	1180.	8.70
X STA.	0.0	4.5	6.3		7.6	8.8
A(I)		12.3	6.8		6.5	5.7
V(I)		4.79	8.70		9.02	10.39
X STA.	9.9	11.2	12.5		13.8	15.1
A(I)		5.9	5.9		6.0	5.9
V(I)		9.96	9.92		9.84	9.94
X STA.	16.4	17.7	19.1		20.5	22.0
A(I)		6.1	5.9		6.1	6.3
V(I)		9.73	9.93		9.68	9.41
X STA.	23.4	25.1	26.7		28.3	30.2
A(I)		6.5	6.4		6.4	6.9
V(I)		9.08	9.26		9.19	8.55

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	120.	8371.	34.	39.				1267.
496.68		120.	8371.	34.	39.	1.00	0.	34.	1267.

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 64.  

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	6.	54.	35.	35.				15.
	2	557.	40525.	109.	111.				7147.
	3	28.	616.	27.	27.				163.
499.96		592.	41195.	171.	173.	1.07	-78.	92.	6029.

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 64.

WSEL	LEW	REW	AREA	K	Q	VEL
499.96	-78.5	92.4	591.8	41195.	1180.	1.99
X STA.	-78.5	-24.9	-19.2		-14.0	-7.9
A(I)		62.5	28.5		27.6	29.2
V(I)		0.94	2.07		2.14	2.02
X STA.	-1.1	3.6	6.9		10.0	13.1
A(I)		27.8	23.5		22.7	22.9
V(I)		2.12	2.51		2.60	2.57
X STA.	16.0	19.1	22.4		26.0	29.9
A(I)		23.0	24.0		24.1	24.7
V(I)		2.57	2.46		2.45	2.39
X STA.	34.4	39.3	45.0		51.0	57.8
A(I)		26.5	28.6		28.8	30.8
V(I)		2.22	2.06		2.05	1.92

# WSPRO OUTPUT FILE (continued)

U.S. Geological Survey WSPRO Input File linc013.wsp  
 Hydraulic analysis for structure LINCTH00010013 Date: 16-JUL-97  
 Town Highway 1, Cota Brook, Lincoln, Vermont ECW  
 \*\*\* RUN DATE & TIME: 02-12-98 12:59

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
EXITX:XS	*****	2.	139.	0.50	*****	496.27	495.35	790.	495.77
-29.	*****	69.	7560.	1.00	*****	*****	0.69	5.67	
FULLV:FV	29.	3.	128.	0.60	0.36	496.68	*****	790.	496.08
0.	29.	68.	6597.	1.01	0.05	0.00	0.79	6.20	

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.  
 "APPRO" KRATIO = 1.73

APPRO:AS	64.	-36.	251.	0.15	0.53	497.21	*****	790.	497.06
64.	64.	64.	11398.	1.00	0.00	0.00	0.35	3.15	

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

===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.  
 WS3,WSIU,WS1,LSEL = 495.75 497.53 497.81 497.14

===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	29.	0.	136.	0.52	*****	497.85	495.73	787.	497.33
0.	*****	34.	6711.	1.00	*****	*****	0.52	5.80	
TYPE PPCD FLOW		C	P/A	LSEL	BLEN	XLAB	XRAB		
1.	****	2.	0.436	0.000	497.14	*****	*****	*****	

XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	13.							

<<<<EMBANKMENT IS NOT OVERTOPPED>>>>

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
APPRO:AS	38.	-39.	351.	0.08	0.20	498.12	495.68	790.	498.04
64.	41.	68.	19330.	1.00	0.61	0.00	0.22	2.25	

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
*****	*****	*****	*****	*****	497.97

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

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-29.	2.	69.	790.	7560.	139.	5.67	495.77
FULLV:FV	0.	3.	68.	790.	6597.	128.	6.20	496.08
BRIDG:BR	0.	0.	34.	787.	6711.	136.	5.80	497.33
RDWAY:RG	13.	*****	*****	0.	*****	*****	1.00	*****
APPRO:AS	64.	-39.	68.	790.	19330.	351.	2.25	498.04

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

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	495.35	0.69	491.14	513.53	*****	*****	0.50	496.27	495.77
FULLV:FV	*****	0.79	491.63	514.02	0.36	0.05	0.60	496.68	496.08
BRIDG:BR	495.73	0.52	492.00	497.33	*****	*****	0.52	497.85	497.33
RDWAY:RG	*****	*****	499.92	513.53	*****	*****	0.02	501.25	*****
APPRO:AS	495.68	0.22	492.26	513.53	0.20	0.61	0.08	498.12	498.04

# WSPRO OUTPUT FILE (continued)

U.S. Geological Survey WSPRO Input File linc013.wsp  
 Hydraulic analysis for structure LINCTH00010013 Date: 16-JUL-97  
 Town Highway 1, Cota Brook, Lincoln, Vermont ECW

\*\*\* RUN DATE & TIME: 02-12-98 12:59

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

EXITX:XS	*****	1.	181.	0.67	*****	497.05	495.82	1180.	496.38
	-29.	*****	70.	11295.	1.01	*****	*****	0.72	6.53

FULLV:FV	29.	2.	168.	0.77	0.35	497.45	*****	1180.	496.68
	0.	29.	70.	10108.	1.00	0.05	0.00	0.79	7.03

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.

"APPRO" KRATIO = 1.68

APPRO:AS	64.	-38.	324.	0.21	0.52	497.98	*****	1180.	497.77
	64.	64.	66.	16989.	1.00	0.00	0.01	0.36	3.65

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

===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.

WS3,WSIU,WS1,LSEL = 496.52 498.67 498.93 497.14

===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	29.	0.	136.	1.16	*****	498.49	496.50	1171.	497.33
	0.	*****	34.	6711.	1.00	*****	*****	0.77	8.63

TYPE PPCD FLOW C P/A LSEL BLEN XLAB XRAB

1. \*\*\*\* 2. 0.499 0.000 497.14 \*\*\*\*\* \*\*\*\*\* \*\*\*\*\*

XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	13.							

<<<<EMBANKMENT IS NOT OVERTOPPED>>>>

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

APPRO:AS	38.	-78.	591.	0.07	0.21	500.02	496.13	1180.	499.96
	64.	41.	92.	41153.	1.07	0.59	-0.01	0.20	2.00

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
*****	*****	*****	*****	*****	499.92

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

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-29.	1.	70.	1180.	11295.	181.	6.53	496.38
FULLV:FV	0.	2.	70.	1180.	10108.	168.	7.03	496.68
BRIDG:BR	0.	0.	34.	1171.	6711.	136.	8.63	497.33
RDWAY:RG	13.	*****		0.	0.	0.	1.00	*****
APPRO:AS	64.	-78.	92.	1180.	41153.	591.	2.00	499.96

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

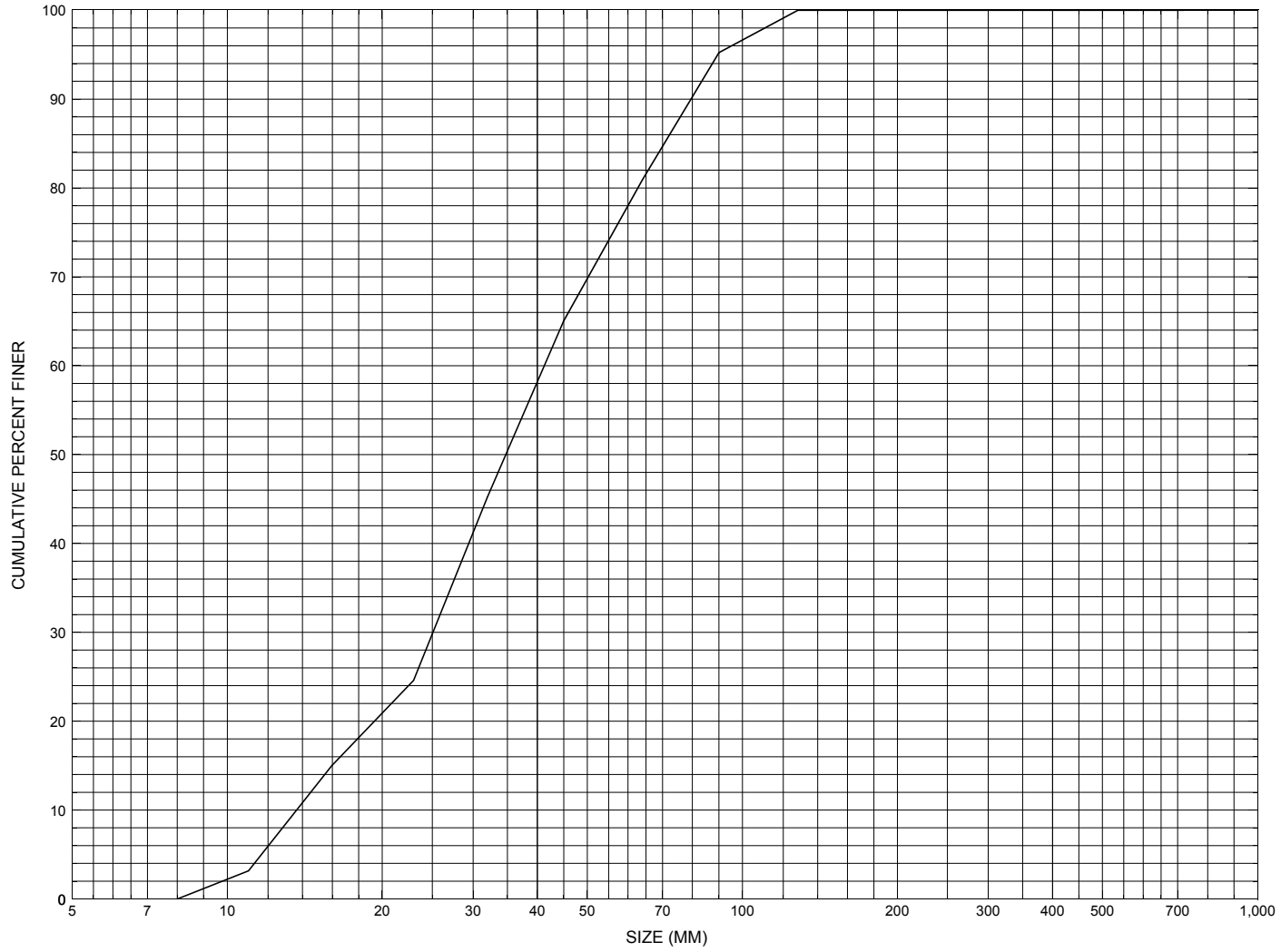
SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	495.82	0.72	491.14	513.53	*****		0.67	497.05	496.38
FULLV:FV	*****	0.79	491.63	514.02	0.35	0.05	0.77	497.45	496.68
BRIDG:BR	496.50	0.77	492.00	497.33	*****		1.16	498.49	497.33
RDWAY:RG	*****		499.92	513.53	*****		0.07	499.99	*****
APPRO:AS	496.13	0.20	492.26	513.53	0.21	0.59	0.07	500.02	499.96

ER

NORMAL END OF WSPRO EXECUTION.

APPENDIX C:  
**BED-MATERIAL PARTICLE-SIZE DISTRIBUTION**



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LINCTH00010013, in Lincoln, Vermont.



APPENDIX D:  
**HISTORICAL DATA FORM**



Structure Number LINCTH00010013

### General Location Descriptive

Data collected by (First Initial, Full last name) L. Medalie  
Date (MM/DD/YY) 12 / 14 / 95  
Highway District Number (I - 2; nn) 05 County (FIPS county code; I - 3; nnn) 001  
Town (FIPS place code; I - 4; nnnnn) 40075 Mile marker (I - 11; nnn.nnn) 000000  
Waterway (I - 6) COTA BROOK Road Name (I - 7): -  
Route Number C2001 Vicinity (I - 9) 0.5 MI TO JCT W CL2 TH2  
Topographic Map Lincoln Hydrologic Unit Code: 02010002  
Latitude (I - 16; nnnn.n) 44054 Longitude (I - 17; nnnnn.n) 72588

### Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10011000130110  
Maintenance responsibility (I - 21; nn) 03 Maximum span length (I - 48; nnnn) 0036  
Year built (I - 27; YYYY) 1939 Structure length (I - 49; nnnnnn) 000038  
Average daily traffic, ADT (I - 29; nnnnnn) 000400 Deck Width (I - 52; nn.n) 233  
Year of ADT (I - 30; YY) 92 Channel & Protection (I - 61; n) 5  
Opening skew to Roadway (I - 34; nn) 00 Waterway adequacy (I - 71; n) 5  
Operational status (I - 41; X) A Underwater Inspection Frequency (I - 92B; XYY) N  
Structure type (I - 43; nnn) 302 Year Reconstructed (I - 106) 0000  
Approach span structure type (I - 44; nnn) 000 Clear span (nnn.n ft) 35.58  
Number of spans (I - 45; nnn) 001 Vertical clearance from streambed (nnn.n ft) 3.84  
Number of approach spans (I - 46; nnnn) 0000 Waterway of full opening (nnn.n ft<sup>2</sup>) 136.7

**Comments:**

**According to the structural inspection report dated 11/13/94, the structure has a concrete bridge deck. The abutments and backwalls are concrete and have minor cracks and leaks. Boulder riprap has been placed in front of and around their ends. A vegetated gravel bar in the upstream channel on the left side blocks much of the channel, and pushes the flow toward the US end of the RABUT. Some erosion is noted at the US end of the RABUT.**

## Bridge Hydrologic Data

Is there hydrologic data available? N if No, type ctrl-n h VTAOT Drainage area (mi<sup>2</sup>): - \_\_\_\_\_

Terrain character: - \_\_\_\_\_

Stream character & type: - \_\_\_\_\_

Streambed material: - \_\_\_\_\_

Discharge Data (cfs):      Q<sub>2.33</sub> - \_\_\_\_\_      Q<sub>10</sub> - \_\_\_\_\_      Q<sub>25</sub> - \_\_\_\_\_  
    Q<sub>50</sub> - \_\_\_\_\_      Q<sub>100</sub> - \_\_\_\_\_      Q<sub>500</sub> - \_\_\_\_\_

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 <sub>2.33</sub>	Q <sub>10</sub>	Q <sub>25</sub>	Q <sub>50</sub>	Q <sub>100</sub>
Water surface elevation (ft)	-	-	-	-	-
Velocity (ft / sec)	-	-	-	-	-

Long term stream bed changes: -  
 -

Is the roadway overtopped below the Q<sub>100</sub>? (Yes, No, Unknown): - \_\_\_\_\_      Frequency: - \_\_\_\_\_

Relief Elevation (ft): - \_\_\_\_\_      Discharge over roadway at Q<sub>100</sub> (ft<sup>3</sup>/sec): - \_\_\_\_\_

Are there other structures nearby? (Yes, No, Unknown): - \_\_\_\_\_ 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<sup>2</sup>): - \_\_\_\_\_

Downstream distance (*miles*): - \_\_\_\_\_ Town: - \_\_\_\_\_ Year Built: - \_\_\_\_\_  
Highway No. : - \_\_\_\_\_ Structure No. : - \_\_\_\_\_ Structure Type: - \_\_\_\_\_  
Clear span (*ft*): - \_\_\_\_\_ Clear Height (*ft*): - \_\_\_\_\_ Full Waterway (*ft*<sup>2</sup>): - \_\_\_\_\_

Comments:

-  
-  
-  
-  
-

## USGS Watershed Data

### Watershed Hydrographic Data

Drainage area (*DA*) 3.00 mi<sup>2</sup>      Lake/pond/swamp area 0 mi<sup>2</sup>  
Watershed storage (*ST*) 0 %  
Bridge site elevation 1060 ft      Headwater elevation 3261 ft  
Main channel length 3.54 mi  
10% channel length elevation 1190 ft      85% channel length elevation 2540 ft  
Main channel slope (*S*) 508.48 ft / mi

### Watershed Precipitation Data

Average site precipitation - \_\_\_\_\_ in      Average headwater precipitation - \_\_\_\_\_ in  
Maximum 2yr-24hr precipitation event (*I24,2*) - \_\_\_\_\_ in  
Average seasonal snowfall (*Sn*) - \_\_\_\_\_ ft

## Bridge Plan Data

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

Project Number -      Minimum channel bed elevation: -

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

Benchmark location description:

-  
-  
-  
-

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? - *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:

**Foundation type is unknown.**

-  
-  
-  
-  
-

Comments:

-  
-  
-  
-  
-  
-

### Cross-sectional Data

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

Source (FEMA, VTAOT, Other)? VTAOT

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 6/10/96. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 11/13/94. The sketch was done on 10/16/92.**

Station	0	13.8	26.3	30.6	35.6	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.0	497.1	497.2	497.2	497.3	-	-	-	-	-	-
Bed elevation	494.7	493.1	491.4	493.0	494.9	-	-	-	-	-	-
Low chord to bed	2.3	4.0	5.8	4.2	2.4	-	-	-	-	-	-

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**



Structure Number LINCTH00010013

### A. General Location Descriptive

1. Data collected by (First Initial, Full last name) R. BURNS Date (MM/DD/YY) 06 / 10 / 1996

2. Highway District Number 05 Mile marker 000000  
 County ADDISON (001) Town LINCOLN (40075)  
 Waterway (1 - 6) COTA BROOK Road Name -  
 Route Number TH001 Hydrologic Unit Code: 02010002

3. Descriptive comments:  
**The bridge is located 0.5 miles to junction with CL2 TH2.**  
**The bridge deck and abutments are concrete. The disk on the bridge says No. 81.**

### B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 6 LBDS 2 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 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 38 (feet) Span length 36 (feet) Bridge width 23.3 (feet)

#### Road approach to bridge:

8. LB 0 RB 0 (0 even, 1- lower, 2- higher)  
 9. LB 1 RB 1 (1- Paved, 2- Not paved)

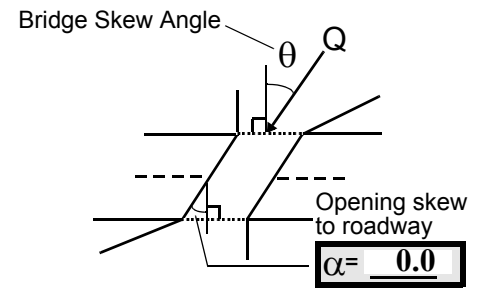
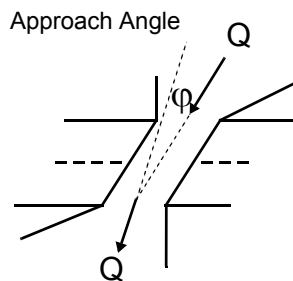
10. Embankment slope (run / rise in feet / foot):  
 US left -- US right --

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</u>
RBUS	<u>1</u>	<u>3</u>	<u>2</u>	<u>2</u>
RBDS	<u>0</u>	<u>-</u>	<u>2</u>	<u>1</u>
LBDS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</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: 15



17. Channel impact zone 1: Exist? Y (Y or N)  
 Where? RB (LB, RB) Severity 2  
 Range? 30 feet US (US, UB, DS) to 10 feet US  
 Channel impact zone 2: Exist? Y (Y or N)  
 Where? LB (LB, RB) Severity 1  
 Range? 0 feet DS (US, UB, DS) to 10 feet DS

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



18. Bridge Type: 1b

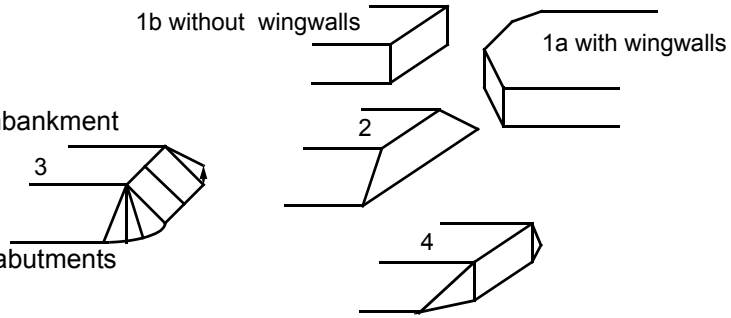
1a- Vertical abutments with wingwalls

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.)

**4: A house and lawn are on the left bank downstream. Small trees and shrubs are on the left bank upstream, beyond is pasture. Along the right bank upstream, forest is along the bank with pasture on top of the hill. Some small trees are along the downstream right bank.**

**7: Measured lengths are the same as the historical form.**

**18: The wingwalls are three feet long and flush with the abutment face. They angle down like type 2, but not below low steel because they are so short. Therefore, bridge is considered type 1b.**

### 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>39.0</u>	<u>1.5</u>			<u>1.5</u>	<u>3</u>	<u>4</u>	<u>23</u>	<u>23</u>	<u>0</u>	<u>2</u>
23. Bank width <u>-</u>		24. Channel width <u>5.0</u>		25. Thalweg depth <u>38.5</u>		29. Bed Material <u>324</u>				
30. Bank protection type: LB <u>0</u> RB <u>1</u>		31. Bank protection condition: LB <u>-</u> RB <u>2</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 right bank protection extends from 14 feet upstream to 6 feet upstream. Also, two large boulders are present at the upstream end of the USRWW.**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 36 35. Mid-bar width: 22  
 36. Point bar extent: 84 feet US (US, UB) to 8 feet UB (US, UB, DS) positioned 0 %LB to 60 %RB  
 37. Material: 23  
 38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):  
**Point bar is substantially vegetated with shrubs and brush.**

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: 20 42. Cut bank extent: 42 feet US (US, UB) to 14 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.):  
**Bank erosion continues upstream for an additional 50 feet. There are many small trees leaning into the channel.**

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 12 US  
 47. Scour dimensions: Length 32 Width 8 Depth : 2.5 Position 80 %LB to 100 %RB  
 48. Scour comments (eg. additional scour areas, local scouring process, etc.):  
**The scour depth assumes the thalweg is 0.5 feet.**  
**The scour extends from 24 feet upstream to 8 feet under the bridge.**

49. Are there major confluences? N (Y or if N type ctrl-n mc) 50. How many? -  
 51. Confluence 1: Distance - 52. Enters on - (LB or RB) 53. Type - (1- perennial; 2- ephemeral)  
 Confluence 2: Distance - Enters on - (LB or RB) Type - (1- perennial; 2- ephemeral)  
 54. Confluence comments (eg. confluence name):  
**NO MAJOR CONFLUENCES**

**D. Under Bridge Channel Assessment**

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

56. Height (BF)		57. Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
<u>22.0</u>		<u>1.0</u>		<u>2</u>	<u>7</u>	<u>7</u>	-

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.):  
32  
**The point bar from the LBUS extends 8 feet along the LABUT.**  
**The scour hole on the RBUS extends 8 feet along the RABUT.**

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

2

**66: Debris is caught in the trees leaning upstream and along the road embankment on the right bank and on the point bar upstream.**

**68: Capture efficiency is high because of low bridge clearance.**

<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		10	90	2	0	-	-	90.0
RABUT	1	0	90			2	1	34.5

*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.):

0.25

-

1

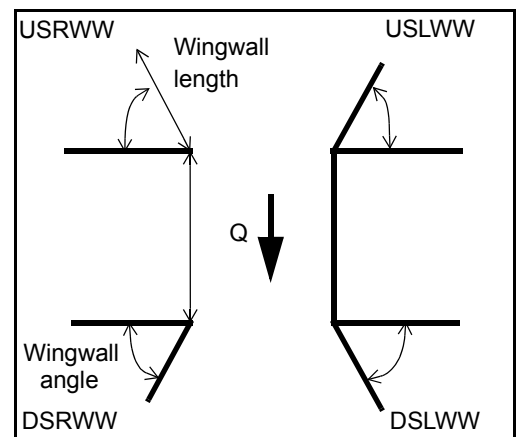
**72: Protection is piled at a 60 degree angle up to the abutment.**

**74: Scour along the RABUT is a continuation of the upstream scour hole.**

80. **Wingwalls:**

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?
USLWW:	_____	_____	_____	_____	_____
USRWW:	<u>N</u>	_____	-	_____	-
DSLWW:	-	_____	-	_____	<u>N</u>
DSRWW:	-	_____	-	_____	-

81. Angle?	Length?
<u>34.5</u>	_____
<u>1.0</u>	_____
<u>26.0</u>	_____
<u>26.0</u>	_____



*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	-	-	<u>N</u>	-	-	-	<u>1</u>	<u>1</u>
Condition	<u>N</u>	-	-	-	-	-	<u>1</u>	<u>1</u>
Extent	-	-	-	-	-	<u>2</u>	<u>2</u>	-

*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*

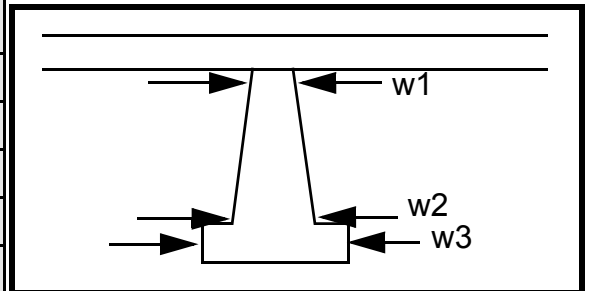
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-  
-  
-  
-  
-  
-  
-  
-  
-  
-

**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 is a	LABU	ream	
87. Type	retai	T.	end	
88. Material	ning	Ther	of	
89. Shape	wall	e are	the	N
90. Inclined?	at	large	RAB	-
91. Attack ∠ (BF)	the	type	UT.	-
92. Pushed	dow	3		-
93. Length (feet)	-	-	-	-
94. # of piles	nstre	boul-		-
95. Cross-members	am	ders		-
96. Scour Condition	end	at		-
97. Scour depth	of	the		-
98. Exposure depth	the	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

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

-  
-  
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-

### E. Downstream Channel Assessment

100.

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

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-

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):

-  
-

**NO PIERS**

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 1 (US, UB, DS) positioned 1 %LB to 2 %RB

Material: 2

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

**0**

**1**

**432**

**2**

Is a cut-bank present? 0 (Y or if N type ctrl-n cb) Where? 2 (LB or RB) Mid-bank distance: - \_\_\_\_\_

Cut bank extent: **The** feet **left** (US, UB, DS) to **bank** feet **pro** (US, UB, DS)

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

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

**tion extends from the downstream bridge face to 60 feet downstream.**

**There is a concrete step in the channel 22 feet downstream. The step extends 6 feet into the channel and diverts flow into the right bank.**

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

Scour dimensions: Length \_\_\_\_\_ Width \_\_\_\_\_ Depth: \_\_\_\_\_ Positioned \_\_\_\_\_ %LB to \_\_\_\_\_ %RB

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

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

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

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

Confluence comments (eg. confluence name):

**RE**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution \_\_\_\_\_




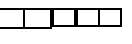
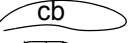

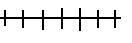
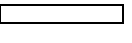


- 1- Constructed
- 2- Stable
- 3- Aggraded
- 4- Degraded
- 5- Laterally unstable
- 6- Vertically and laterally unstable

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

**Y**  
**4**  
**6**  
**6**  
**UB**  
**14**  
**US**  
**70**  
**100**  
**342**

# 109. G. Plan View Sketch

Po

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



APPENDIX F:  
**SCOUR COMPUTATIONS**

SCOUR COMPUTATIONS

Structure Number: LINCTH00010013                      Town:      LINCOLN  
 Road Number:      TH1                                      County:    ADDISON  
 Stream:      COTA BROOK

Initials ECW      Date:      2-12-98      Checked: RLB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	790	1180	0
Main Channel Area, ft <sup>2</sup>	351	557	0
Left overbank area, ft <sup>2</sup>	0	6	0
Right overbank area, ft <sup>2</sup>	0	28	0
Top width main channel, ft	105	109	0
Top width L overbank, ft	0	35	0
Top width R overbank, ft	0	27	0
D50 of channel, ft	0.1139	0.1139	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y <sub>1</sub> , average depth, MC, ft	3.3	5.1	ERR
y <sub>1</sub> , average depth, LOB, ft	ERR	0.2	ERR
y <sub>1</sub> , average depth, ROB, ft	ERR	1.0	ERR
Total conveyance, approach	19363	41195	0
Conveyance, main channel	19362	40525	0
Conveyance, LOB	0	54	0
Conveyance, ROB	0	616	0
Percent discrepancy, conveyance	0.0052	0.0000	ERR
Q <sub>m</sub> , discharge, MC, cfs	790.0	1160.8	ERR
Q <sub>l</sub> , discharge, LOB, cfs	0.0	1.5	ERR
Q <sub>r</sub> , discharge, ROB, cfs	0.0	17.6	ERR
V <sub>m</sub> , mean velocity MC, ft/s	2.3	2.1	ERR
V <sub>l</sub> , mean velocity, LOB, ft/s	ERR	0.3	ERR
V <sub>r</sub> , mean velocity, ROB, ft/s	ERR	0.6	ERR
V <sub>c-m</sub> , crit. velocity, MC, ft/s	6.6	7.1	N/A
V <sub>c-l</sub> , crit. velocity, LOB, ft/s	ERR	ERR	ERR
V <sub>c-r</sub> , crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	790	1180	0
(Q) discharge thru bridge, cfs	790	1180	0
Main channel conveyance	6711	6711	0
Total conveyance	6711	6711	0
Q2, bridge MC discharge, cfs	790	1180	ERR
Main channel area, ft <sup>2</sup>	136	136	0
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.4	34.4	0
y <sub>bridge</sub> (avg. depth at br.), ft	3.95	3.95	ERR
D <sub>m</sub> , median (1.25*D <sub>50</sub> ), ft	0.142375	0.142375	0
y <sub>2</sub> , depth in contraction, ft	3.17	4.47	ERR
y <sub>s</sub> , scour depth (y <sub>2</sub> -y <sub>bridge</sub> ), ft	-0.78	0.52	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	790	1180	N/A
Main channel area (DS), ft <sup>2</sup>	99	120	0
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	34.4	34.4	0.0
D <sub>90</sub> , ft	0.2606	0.2606	0.0000
D <sub>95</sub> , ft	0.2936	0.2936	0.0000
D <sub>c</sub> , critical grain size, ft	0.2671	0.3755	ERR
P <sub>c</sub> , Decimal percent coarser than D <sub>c</sub>	0.090	0.015	0.000
Depth to armoring, ft	N/A	N/A	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	790	1180	0
Q, thru bridge MC, cfs	790	1180	N/A
Vc, critical velocity, ft/s	6.64	7.13	N/A
Va, velocity MC approach, ft/s	2.25	2.08	N/A
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.4	34.4	0.0
qbr, unit discharge, ft <sup>2</sup> /s	23.0	34.3	ERR
Area of full opening, ft <sup>2</sup>	136.0	136.0	0.0
Hb, depth of full opening, ft	3.95	3.95	ERR
Fr, Froude number, bridge MC	0.52	0.77	0
Cf, Fr correction factor ( $\leq 1.0$ )	1.00	1.00	0.00
**Area at downstream face, ft <sup>2</sup>	99	120	N/A
**Hb, depth at downstream face, ft	2.88	3.49	ERR
**Fr, Froude number at DS face	0.83	0.93	ERR
**Cf, for downstream face ( $\leq 1.0$ )	1.00	1.00	N/A
Elevation of Low Steel, ft	497.14	497.14	0
Elevation of Bed, ft	493.19	493.19	N/A
Elevation of Approach, ft	498.04	499.96	0
Friction loss, approach, ft	0.2	0.21	0
Elevation of WS immediately US, ft	497.84	499.75	0.00
y <sub>a</sub> , depth immediately US, ft	4.65	6.56	N/A
Mean elevation of deck, ft	500.07	500.07	0
w, depth of overflow, ft ( $\geq 0$ )	0.00	0.00	0.00
Cc, vert contrac correction ( $\leq 1.0$ )	0.96	0.86	ERR
**Cc, for downstream face ( $\leq 1.0$ )	0.866447	0.79	ERR
Ys, scour w/Chang equation, ft	-0.35	1.67	N/A
Ys, scour w/Umbrell equation, ft	-1.28	-0.51	N/A

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

\*\*Ys, scour w/Chang equation, ft 1.11 2.60 N/A

\*\*Ys, scour w/Umbrell equation, ft -0.21 -0.04 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 (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	3.17	4.47	0.00
WSEL at downstream face, ft	496.08	496.68	--
Depth at downstream face, ft	2.88	3.49	N/A
Ys, depth of scour (Laursen), ft	0.29	0.98	N/A

#### 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)

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	790	1180	0	790	1180	0
a', abut.length blocking flow, ft	38.8	78.5	0	33.6	58	0
Ae, area of blocked flow ft2	99.79	185.41	0	84.04	171.9	0
Qe, discharge blocked abut., cfs	172.81	308.81	0	153.89	295	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.73	1.67	ERR	1.83	1.72	ERR
ya, depth of f/p flow, ft	2.57	2.36	ERR	2.50	2.96	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.190	0.191	ERR	0.204	0.176	ERR
ys, scour depth, ft	9.39	11.17	N/A	9.08	11.33	N/A

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)	38.8	78.5	0	33.6	58	0
y1 (depth f/p flow, ft)	2.57	2.36	ERR	2.50	2.96	ERR
a'/y1	15.09	33.24	ERR	13.43	19.57	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.19	N/A	0.20	0.18	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	9.95	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	8.16	ERR	ERR	ERR	ERR
spill-through	ERR	5.47	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

$$D50=y*K*Fr^2/(Ss-1) \text{ and } D50=y*K*(Fr^2)^{0.14}/(Ss-1)$$

(Richardson and Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.83	0.93	0	0.83	0.93	0
y, depth of flow in bridge, ft	2.88	3.49	0.00	2.88	3.49	0.00
Median Stone Diameter for riprap at: left abutment						
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.14	1.43	ERR	1.14	1.43	ERR
				right abutment, ft		