LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (WALDTH00180022) on TOWN HIGHWAY 18, crossing COLES BROOK, WALDEN, VERMONT

Open-File Report 97-768

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

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

USGS
science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (WALDTH00180022) on TOWN HIGHWAY 18, crossing COLES BROOK, WALDEN, VERMONT

By LORA K. STRIKER AND MICHAEL A. IVANOFF

U.S. Geological Survey
Open-File Report 97-768

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

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (WALDTH00180022) ON TOWN HIGHWAY 18, CROSSING COLES BROOK, WALDEN, VERMONT

By **Lora K. Striker and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALDTH00180022 on Town Highway 18 crossing Coles Brook also known as Joes Brook, Walden, 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 northeastern Vermont. The 12.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly forested while the downstream left bank is shrub and brushland.

In the study area, the Coles Brook has an incised, sinuous channel with a slope of approximately 0.004 ft/ft, an average channel top width of 54 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 124.1 mm (0.407 ft). The D_{50} was taken from a pebble count in the downstream channel, because the upstream channel is primarily bedrock. The geomorphic assessment at the time of the Level I and Level II site visit on August 8, 1995, indicated that the reach was stable.

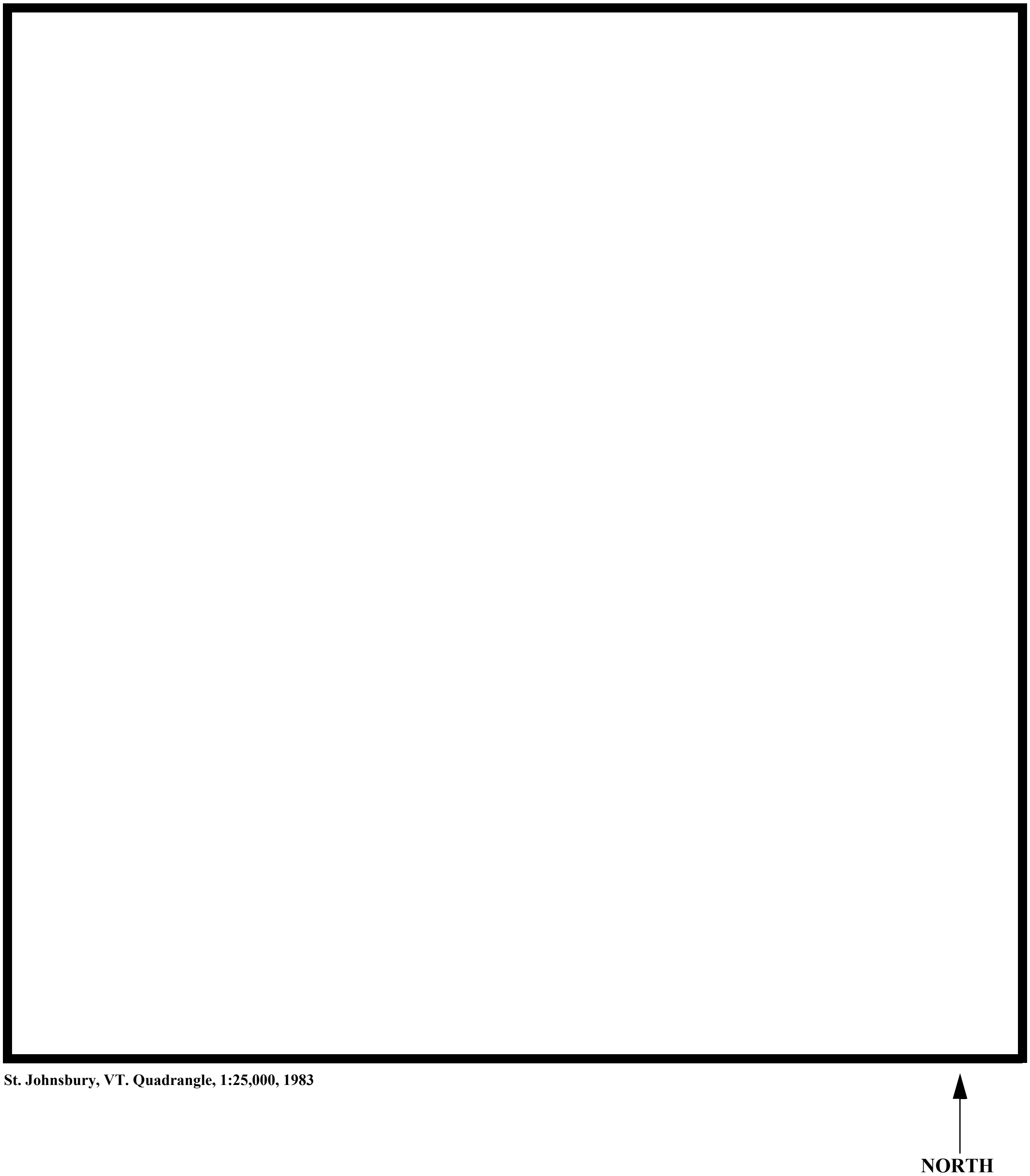
The Town Highway 18 crossing of the Coles Brook is a 46-ft-long, one-lane bridge consisting of one 44-foot steel-beam span with a wooden deck (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 41.4 ft. The bridge is supported by a vertical, concrete abutment with wingwalls on the left and by a vertical, stone abutment with stone wingwalls with a concrete cap on the right. The channel is skewed approximately 5 degrees to the opening while the computed opening-skew-to-roadway is 10 degrees.

The only scour protection measure at the site was a stone wall along the upstream left bank and type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream left wingwall, left abutment, and downstream left wing wall. 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-year 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 was 0.0 ft. Abutment scour ranged from 6.4 to 7.9 ft at the left abutment and from 11.8 to 14.9 ft at the right abutment. 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 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.



St. Johnsbury, VT. Quadrangle, 1:25,000, 1983

Figure 1. Location of study area on USGS 1:25,000 scale map.

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

LEVEL II SUMMARY

Structure Number WALDTH00180022 ***Stream*** Coles Brook

County Caledonia ***Road*** TH18 ***District*** 7

Description of Bridge

Bridge length 46 ***ft*** ***Bridge width*** 16.0 ***ft*** ***Max span length*** 44 ***ft***

Alignment of bridge to road (on curve or straight) Curve, left; Straight, right

Abutment type Vertical ***Embankment type*** Sloping; near vertical

Stone fill on abutment? Yes ***Date of inspection*** 08/08/95

Description of stone fill Type-2, along the entire base length of the upstream left wingwall, the left abutment, and the downstream left wingwall.

The downstream right wingwall has settled. The left abutment and wingwalls are poured concrete and the right abutment and wingwalls are placed stone with a concrete cap.

Yes 10

Is bridge skewed to flood flow according to No ***survey?*** ***Angle***

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	08/08/95	0	0
Level II	08/08/95	0	0

Potential for debris Moderate. There is debris potential from dense vegetation along banks upstream as well as a pond and dam.

Describe any features near or at the bridge that may affect flow (include observation date) There is a dam located 150 ft upstream of the bridge, 08/08/95.

Description of the Geomorphic Setting

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

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

Date of inspection 08/08/95

DS left: Moderately sloping channel bank

DS right: Moderately sloping channel bank

US left: Steep channel bank to road

US right: Moderately sloping channel bank

Description of the Channel

Average top width 54 ft

Average depth 4 ft

Predominant bed material Cobble/Boulder

Bank material Cobble/Boulder

Sinuous but stable

with non-alluvial channel boundaries.

08/08/95

Vegetative co

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right: Trees and brush

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

None, 11/08/94.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 12.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area - ***mi²***

Is there a lake/p - No

-

Calculated Discharges

Q100 2,190 ***ft³/s*** ***Q500*** 3,100 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(12.5/16.4)exp 0.67] with bridge number 83 in Walden. Bridge number 83 crosses the Coles Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 83 is 16.4 square miles. These values fall within a range defined by several empirical equations (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 upstream end of the left abutment (elev. 499.55 ft, arbitrary survey datum). RM2 is a chiseled X on top of right abutment at junction with wingwall (elev. 499.73 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	58	1	Approach section as surveyed.

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning’s “n”) used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel “n” values for the reach ranged from 0.050 to 0.068, and overbank “n” values ranged from 0.065 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 0.004 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed 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 497.7 *ft*

100-year discharge 2,190 *ft³/s*
Water-surface elevation in bridge opening 492.3 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 240 *ft²*
Average velocity in bridge opening 9.1 *ft/s*
Maximum WSPRO tube velocity at bridge 10.8 *ft/s*

Water-surface elevation at Approach section with bridge 493.4
Water-surface elevation at Approach section without bridge 492.8
Amount of backwater caused by bridge 0.6 *ft*

500-year discharge 3,100 *ft³/s*
Water-surface elevation in bridge opening 493.2 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 278 *ft²*
Average velocity in bridge opening 11.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.4 */s*

Water-surface elevation at Approach section with bridge 494.9
Water-surface elevation at Approach section without bridge 493.9
Amount of backwater caused by bridge 1.0 *ft*

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

Water-surface elevation at Approach section with bridge -
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 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 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Contraction scour computed for all modelled discharges was equal to zero feet. The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	3.7	9.7	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.4	7.9	--
Right abutment	11.8	14.9	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:			
Left abutment	1.6	2.4	--
Right abutment	1.6	2.4	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

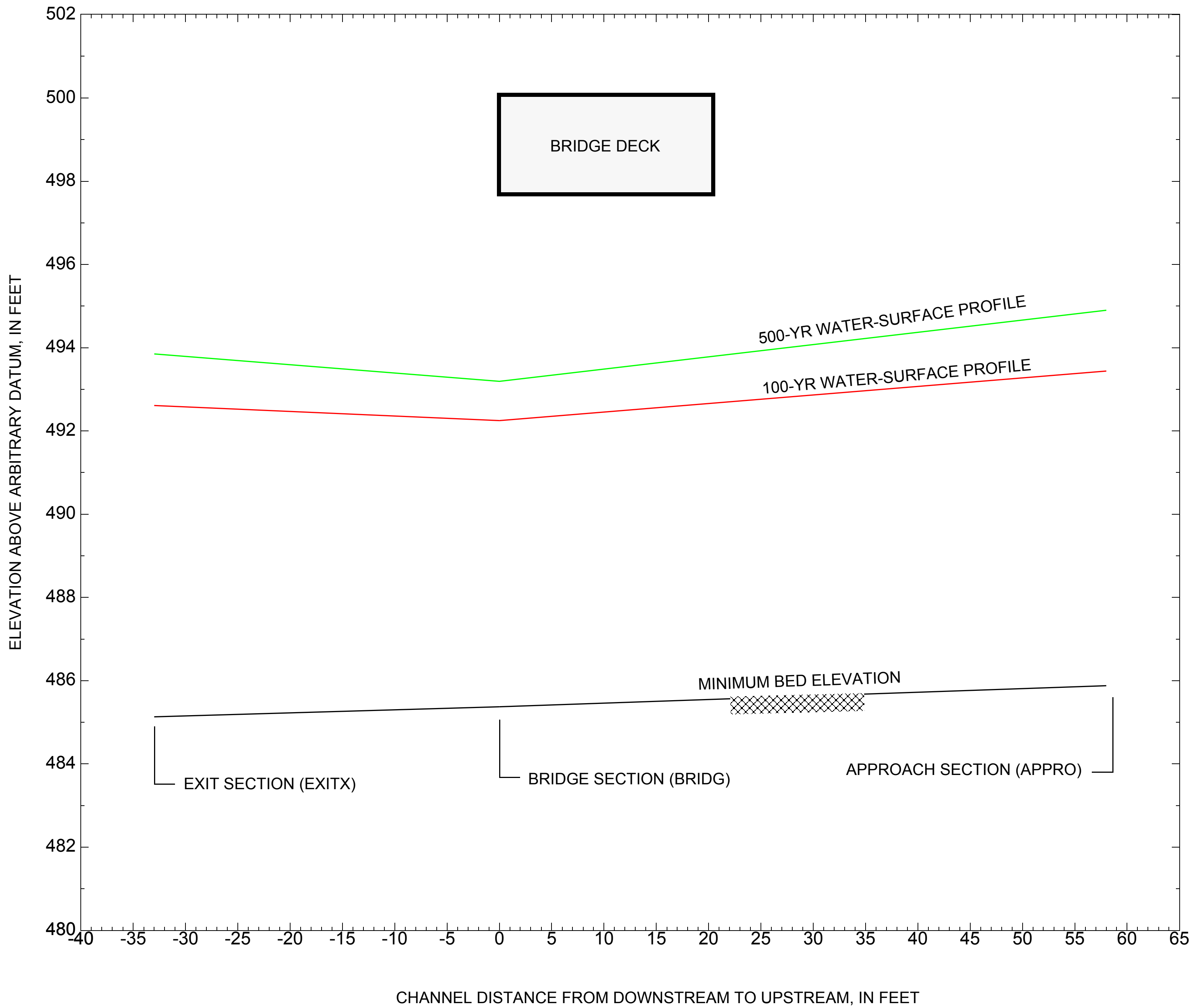


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure WALDTH00180022 on Town Highway 18, crossing Coles Brook, Walden, Vermont.

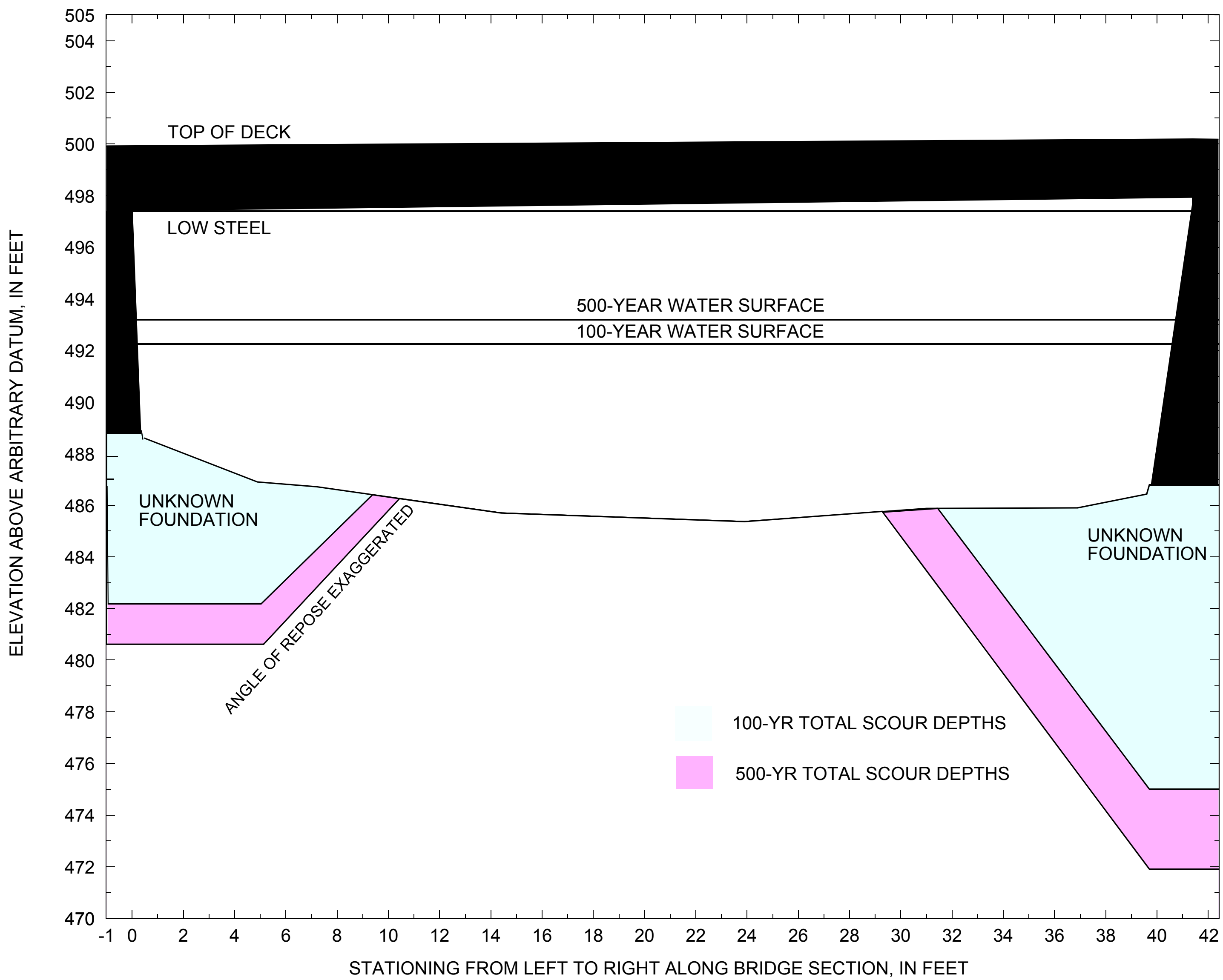


Figure 8. Scour elevations for the 100-year and 500-year discharges at structure WALDTH00180022 on Town Highway 18, crossing Coles Brook, Walden, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WALDTH00180022 on Town Highway 18, crossing Coles Brook, Walden, 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 2,190 cubic-feet per second											
Left abutment	0.0	--	497.4	--	488.6	0.0	6.4	--	6.4	482.2	--
Right abutment	41.4	--	497.9	--	486.8	0.0	11.8	--	11.8	475.0	--

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 WALDTH00180022 on Town Highway 18, crossing Coles Brook Walden, 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 3,100 cubic-feet per second											
Left abutment	0.0	--	497.4	--	488.6	0.0	7.9	--	7.9	480.7	--
Right abutment	41.4	--	497.9	--	486.8	0.0	14.9	--	14.9	471.9	--

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

2.Arbitrary datum for this study.

SELECTED REFERENCES

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

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

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

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

Federal 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, 1983, St. Johnsbury, Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wald022.wsp
T2        Hydraulic analysis for structure WALDTH00180022   Date: 05-JUN-97
T3        TH 18 crossing Coles Brook 0.1 miles to the junction with TH 2
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2190.0   3100.0
SK          0.0040   0.0040
*
XS   EXITX    -33           0.
GR         -140.8, 503.04   -122.5, 503.08    -98.6, 501.40    -81.4, 500.01
GR          -60.0, 499.37    -40.0, 490.24    -24.9, 488.95    -22.0, 487.56
GR            0.0, 486.37      1.2, 485.56      8.0, 485.13     17.6, 485.51
GR           23.0, 485.23     33.3, 485.94     33.6, 486.61     50.2, 489.95
GR           71.8, 494.58     78.3, 496.27     95.5, 496.42
*
N           0.065        0.068        0.070
SA                  -24.9        50.2
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.66      10.0
GR            0.0, 497.40      0.4, 488.64      4.9, 486.90      7.2, 486.72
GR           14.4, 485.70     23.9, 485.37     31.0, 485.88     36.9, 485.90
GR           39.6, 486.43     39.7, 486.80     41.4, 497.92      0.0, 497.40
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      20.4 * *     30.5      4.2
N          0.050
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      16.0     2
GR          -97.3, 502.84    -81.8, 501.87    -65.6, 500.79      0.0, 499.93
GR           41.9, 500.19    105.7, 500.47    257.9, 508.16    308.8, 510.24
*
*
AS   APPRO     58           0.
GR          -65.6, 499.55    -39.7, 499.74    -24.0, 497.30     -2.0, 494.29
GR            0.0, 490.85      6.5, 487.34      9.3, 486.09     13.3, 485.98
GR           19.9, 485.88     23.4, 486.23     27.4, 487.53     32.3, 489.12
GR           56.9, 490.32     64.8, 497.94    106.2, 498.80    127.2, 499.23
*
N           0.070        0.065     0.070
SA                -2.0        32.3
*
HP 1 BRIDG   492.25 1 492.25
HP 2 BRIDG   492.25 * * 2190
HP 1 APPRO   493.44 1 493.44
HP 2 APPRO   493.44 * * 2190
*
HP 1 BRIDG   493.19 1 493.19
HP 2 BRIDG   493.19 * * 3100
HP 1 APPRO   494.90 1 494.90
HP 2 APPRO   494.90 * * 3100
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File wald022.wsp
         Hydraulic analysis for structure WALDTH00180022   Date: 05-JUN-97
         TH 18 crossing Coles Brook 0.1 miles to the junction with TH 2
            *** RUN DATE & TIME: 07-17-97  13:17

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        492.25     0.2    40.5   240.4   20793.    2190.   9.11

 X STA.         0.2        4.8        7.4        9.6       11.6       13.4
   A(I)            19.9       13.8       12.2       11.7       11.3
   V(I)            5.51       7.93       8.95       9.39       9.68

 X STA.        13.4       15.1       16.7       18.2       19.8       21.3
   A(I)            10.7       10.5       10.2       10.4       10.1
   V(I)           10.21      10.44      10.71      10.58      10.83

 X STA.        21.3       22.8       24.4       25.9       27.5       29.1
   A(I)            10.2       10.2       10.2       10.4       10.6
   V(I)           10.77      10.70      10.69      10.51      10.31

 X STA.        29.1       30.9       32.6       34.5       36.6       40.5
   A(I)            11.1       11.1       12.0       13.1       20.6
   V(I)            9.86       9.89       9.15       8.36       5.30

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.
        WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW    REW      QCR
                2      205      14776     34     37                         2872
                3       97       4570     28     29                         1021
      493.44           302      19346     62     66  1.09     -1     60     3629

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.
          WSEL     LEW     REW    AREA        K        Q    VEL
        493.44    -1.5    60.1   301.9   19346.    2190.   7.25

 X STA.        -1.5        5.4        7.9        9.9       11.6       13.3
   A(I)            23.6       15.8       13.9       12.9       12.3
   V(I)            4.64       6.93       7.89       8.50       8.90

 X STA.        13.3       14.9       16.4       18.0       19.5       21.0
   A(I)            12.0       11.7       11.6       11.5       11.5
   V(I)            9.12       9.35       9.44       9.52       9.56

 X STA.        21.0       22.6       24.3       26.2       28.4       31.3
   A(I)            11.6       12.0       12.4       13.3       14.7
   V(I)            9.47       9.16       8.80       8.20       7.43

 X STA.        31.3       35.3       39.8       44.9       50.7       60.1
   A(I)            17.3       18.5       19.3       20.6       25.4
   V(I)            6.34       5.92       5.69       5.31       4.30
```

```
      U.S. Geological Survey WSPRO Input File wald022.wsp
      Hydraulic analysis for structure WALDTH00180022   Date: 05-JUN-97
      TH 18 crossing Coles Brook 0.1 miles to the junction with TH 2
         *** RUN DATE & TIME: 07-17-97  13:17
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      278     25794     40     50                          4160
 493.19           278     25794     40     50  1.00      0     41      4160

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     493.19     0.2    40.7   277.8   25794.    3100.  11.16

X STA.         0.2         4.8         7.3         9.5        11.4        13.2
  A(I)            23.8        15.7        14.2        13.1        13.0
  V(I)            6.52        9.88       10.92       11.81       11.90

X STA.        13.2        14.9        16.5        18.1        19.6        21.2
  A(I)            12.3        12.0        11.7        11.7        11.7
  V(I)           12.60       12.89       13.23       13.29       13.20

X STA.        21.2        22.7        24.2        25.8        27.4        29.0
  A(I)            11.6        11.7        11.7        12.0        12.2
  V(I)           13.35       13.26       13.21       12.96       12.69

X STA.        29.0        30.8        32.5        34.5        36.6        40.7
  A(I)            12.8        12.8        13.8        15.1        24.8
  V(I)           12.11       12.13       11.23       10.26        6.25

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.
   WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW    REW      QCR
           1        1        13      4      4                             4
           2      255     20860     34     38                          3951
           3      138      7939     29     31                          1704
 494.90           395     28812     68     74  1.08     -5     62      5194

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.
       WSEL     LEW     REW    AREA        K        Q    VEL
     494.90    -6.5    61.6   394.9   28812.    3100.   7.85

X STA.        -6.5         4.7         7.6         9.7        11.6        13.4
  A(I)            30.8        21.4        18.2        17.0        15.9
  V(I)            5.04        7.25        8.51        9.12        9.77

X STA.        13.4        15.2        17.0        18.6        20.3        22.0
  A(I)            15.9        15.7        14.9        15.3        15.1
  V(I)            9.76        9.85       10.40       10.13       10.26

X STA.        22.0        23.8        25.8        28.0        30.7        34.3
  A(I)            15.3        16.4        16.9        18.3        20.8
  V(I)           10.13        9.47        9.15        8.45        7.45

X STA.        34.3        38.2        42.4        47.0        52.0        61.6
  A(I)            21.9        22.8        23.7        24.9        33.7
  V(I)            7.08        6.81        6.53        6.22        4.60
```

WSPRO OUTPUT FILE (continued)

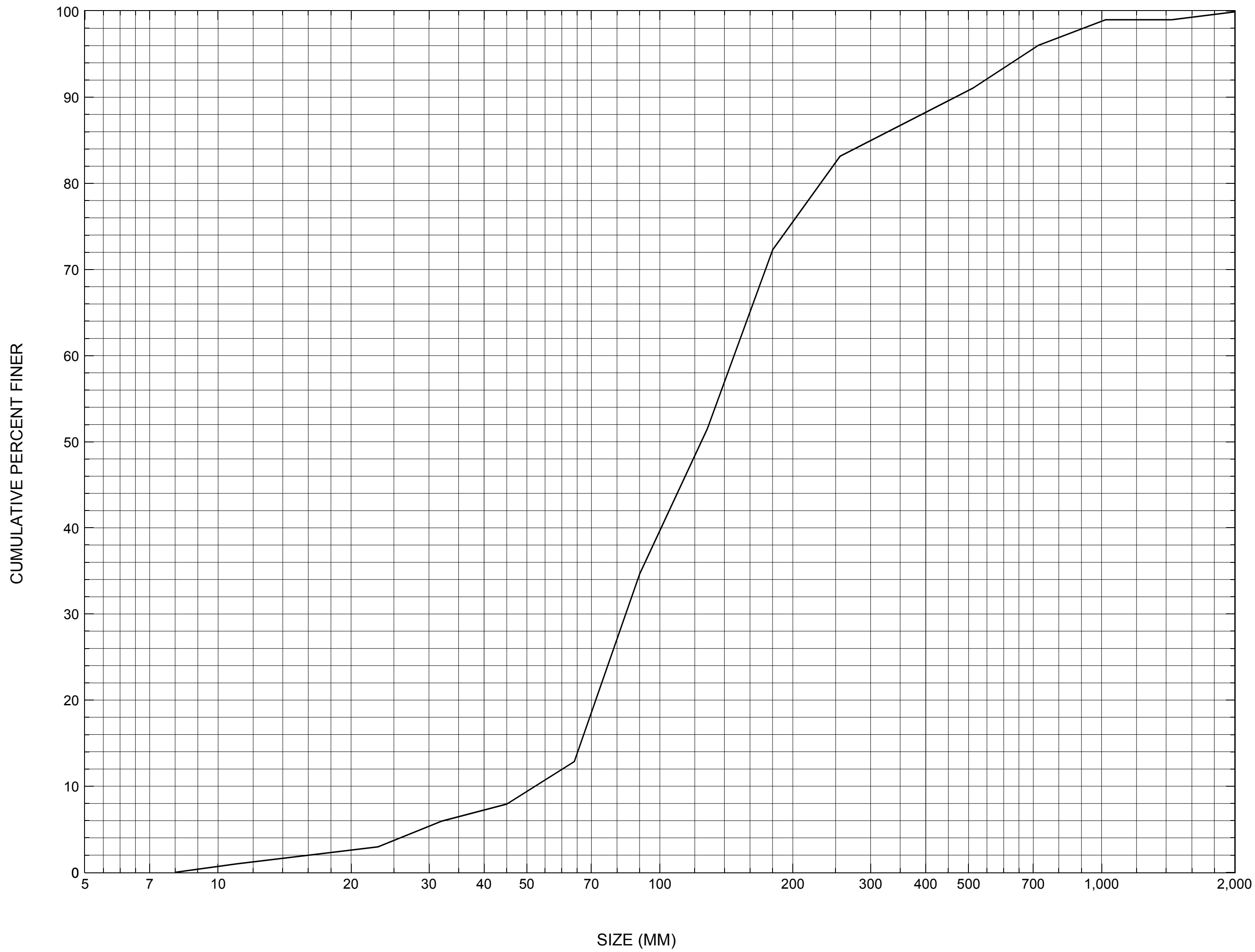
```
      U.S. Geological Survey WSPRO Input File wald022.wsp
      Hydraulic analysis for structure WALDTH00180022   Date: 05-JUN-97
      TH 18 crossing Coles Brook 0.1 miles to the junction with TH 2
         *** RUN DATE & TIME: 07-17-97  13:17

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

EXITX:XS   ******    -44      517  0.30 *****  492.91  489.61    2190  492.61
       -32 ******     63    34618  1.08 ***** *******    0.35    4.23

FULLV:FV       33    -45      534  0.28  0.13  493.04 *******    2190  492.76
         0     33     63    36233  1.08  0.00    0.01    0.34    4.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.43

APPRO:AS       58      0      261  1.21  0.49  493.98 *******    2190  492.77
        58     58     59    15626  1.11  0.47   -0.02    0.75    8.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       33      0      240  1.29  0.27  493.54  490.73    2190  492.25
         0     33     41    20808  1.00  0.37    0.00    0.65    9.11

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.66 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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     -1      302  0.89  0.56  494.33  492.06    2190  493.44
        58     38     60    19342  1.09  0.23    0.00    0.60    7.25

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.333  0.127   16889.    -1.    40.   492.90
                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
   XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -45.    63.   2190.   34618.     517.    4.23  492.61
   FULLV:FV       0.   -46.    63.   2190.   36233.     534.    4.10  492.76
   BRIDG:BR       0.     0.    41.   2190.   20808.     240.    9.11  492.25
   RDWAY:RG       9.**************      0.******************    2.00********
   APPRO:AS      58.    -2.    60.   2190.   19342.     302.    7.25  493.44

 SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.61    0.35  485.13  503.08************  0.30  492.91  492.61
   FULLV:FV  ********    0.34  485.13  503.08  0.13  0.00  0.28  493.04  492.76
   BRIDG:BR    490.73    0.65  485.37  497.92  0.27  0.37  1.29  493.54  492.25
   RDWAY:RG  ****************  499.93  510.24**********************************
   APPRO:AS    492.06    0.60  485.88  499.74  0.56  0.23  0.89  494.33  493.44
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald022.wsp
        Hydraulic analysis for structure WALDTH00180022   Date: 05-JUN-97
        TH 18 crossing Coles Brook 0.1 miles to the junction with TH 2
           *** RUN DATE & TIME: 07-17-97  13:17

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -47      656  0.38 *****  494.23  490.48    3100  493.85
       -32 ******     68    49013  1.09 ***** *******    0.37    4.72

FULLV:FV       33    -47      674  0.36  0.13  494.36 *******    3100  494.00
         0     33     69    50968  1.09  0.00    0.01    0.35    4.60
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPRO”     KRATIO =  0.44

APPRO:AS       58     -1      332  1.47  0.49  495.39 *******    3100  493.93
        58     58     61    22257  1.08  0.55   -0.01    0.74    9.33
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       33      0      278  1.94  0.26  495.13  491.94    3100  493.19
         0     33     41    25780  1.00  0.64    0.00    0.75   11.16

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.66 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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     -5      395  1.03  0.52  495.93  493.02    3100  494.90
        58     39     62    28817  1.08  0.29    0.01    0.60    7.85

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.349  0.134   24924.     1.    41.   494.41
                           <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -48.    68.   3100.   49013.     656.    4.72  493.85
   FULLV:FV       0.   -48.    69.   3100.   50968.     674.    4.60  494.00
   BRIDG:BR       0.     0.    41.   3100.   25780.     278.   11.16  493.19
   RDWAY:RG       9.**************      0.******************    2.00********
   APPRO:AS      58.    -6.    62.   3100.   28817.     395.    7.85  494.90

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL     WSEL
   EXITX:XS    490.48    0.37  485.13  503.08************  0.38  494.23  493.85
   FULLV:FV  ********    0.35  485.13  503.08  0.13  0.00  0.36  494.36  494.00
   BRIDG:BR    491.94    0.75  485.37  497.92  0.26  0.64  1.94  495.13  493.19
   RDWAY:RG  ****************  499.93  510.24**********************************
   APPRO:AS    493.02    0.60  485.88  499.74  0.52  0.29  1.03  495.93  494.90
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel exit of structure WALDTH00180022, in Walden, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALDTH00180022

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 05 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 75700

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

Waterway *(I - 6)* COLES BROOK (JOES BROOK)

Road Name *(I - 7)*: -

Route Number TH018

Vicinity *(I - 9)* 0.1 MI TO JCT W CL2 TH2

Topographic Map St Johnsbury

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44278

Longitude *(i - 17; nnnnn.n)* 72133

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031500220315

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

Maximum span length *(I - 48; nnnn)* 0044

Year built *(I - 27; YYYY)* 1974

Structure length *(I - 49; nnnnnn)* 000046

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

Deck Width *(I - 52; nn.n)* 160

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 05

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 12.8

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

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

Comments:

The structural inspection report of 06/07/93 indicates that the structure is a steel stringer type bridge with a wooden deck. The right abutment and its wingwalls are “laid up” stone, with a concrete cap. Some of the stones have broken or spalled out at the ends and along the bottom of the right abutment and wingwalls. The left abutment and its wingwalls are concrete. Some stone and boulder fill is present in front of the left abutment and along the entire base length of the wingwalls, with some boulders showing along the up- and downstream banks. The upstream channel bottom is bedrock. A wooden dam is in place across the upstream channel. The dam appears to be in poor condition with a section broken out **(Cont., page 31)**

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): Y *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 (*ft²*): -

Downstream distance (*miles*): **0.3** Town: **Walden** Year Built: **1945**
Highway No. : **TH 2** Structure No. : **7** Structure Type: **302**
Clear span (*ft*): **-** Clear Height (*ft*): **-** Full Waterway (ft^2): **-**

Comments:
along the top at the right embankment. The embankments consist of boulders and some ledge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.474** mi^2 Lake/pond/swamp area **.325** mi^2
Watershed storage *(ST)* **2.61** %
Bridge site elevation **1663** ft Headwater elevation **2500** ft
Main channel length **7.43** mi
10% channel length elevation **1693** ft 85% channel length elevation **2172** ft
Main channel slope *(S)* **86.0** 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:

There is no benchmark information available.

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:

There is no foundation material information available.

Comments:

There are no bridge plans available.

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 of the upstream face. The low chord elevation is determined from the survey log done for this report on 08/08/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 06/07/93.**

Station	0	10	19	33.4	41.4	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.56	497.65	497.73	497.86	497.94	-	-	-	-	-	-
Bed elevation	490.06	484.85	484.43	485.66	488.24	-	-	-	-	-	-
Low chord - bed length	7.5	12.8	13.3	12.2	9.7	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord - bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 3/22/96
Computerized by: RB Date: 3/22/96
Reviewd by: LKS Date: 07/17/97

Structure Number WALDTH00180022

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 8 / 8 / 1995
2. Highway District Number 07 Mile marker 000
County Caledonia (005) Town Walden (75700)
Waterway *(I - 6)* Coles Brook Road Name -
Route Number TH018 Hydrologic Unit Code: 01080102
3. Descriptive comments:
The bridge is located 0.1 miles from the junction with Town Highway 2.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 5 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 46 *(feet)* Span length 44 *(feet)* Bridge width 16 *(feet)*

Road approach to bridge:

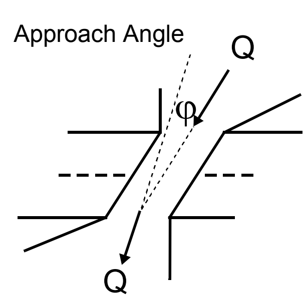
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

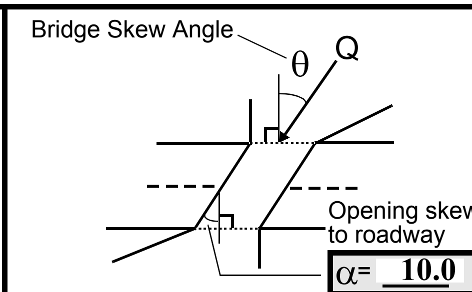
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	3	2
RBDS	0	-	0	-
LBDS	0	-	0	-

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 5

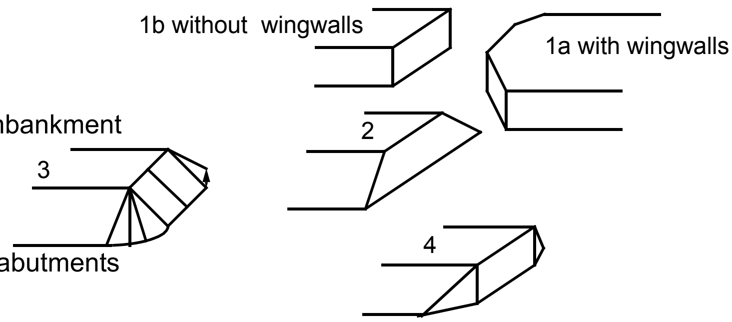




17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 60 feet DS *(US, UB, DS)* to 75 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

7. Values are from the VT AOT files. Measured span between the abutment walls is 42 feet and the span of the bridge deck at the abutment seat backwalls is 44 feet.
13. The material near the US right wingwall is slumping.
18. The right abutment is laid up stone to 18 inches below the bridge low chord then there is a concrete cap. The stones for the wingwalls are slightly angled from the abutment and also are capped with concrete.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
42.5	**5.0**			**1.5**	**3**	**3**	**453**	**453**	**0**	**0**

23. Bank width **25.0** 24. Channel width **10.0** 25. Thalweg depth **34.0** 29. Bed Material **4536**

30 .Bank protection type: LB **5** RB **0** 31. Bank protection condition: LB **1** 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*

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

30. There is a significant amount of stone fill along both banks with a short stone wall extending from the dam US to about 68 feet from the bridge. The dam sits on top of a bedrock ledge 150 feet US.
29. The bed material is cobble and boulder with gravel overlying a bedrock ledge.

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

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

37. Material: -

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

There are no point bars upstream.

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

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

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

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

There are no cut-banks upstream.

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

There was no channel scour upstream as of 08/08/95.

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):

There are no major confluences upstream at this site.

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
18.5		1.5		2	7	7	-

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

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

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

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

453

The right abutment is laid up stone and the left is concrete.

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

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

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

70. Debris and Ice Comments:

1

There is debris potential from the pond and dam US if the dam should completely fail. The bridge opening appears adequate as much of the debris is DS of the bridge but not within the channel. The span is 80% of the bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	-	-	90.0
RABUT	1	5	90			2	0	41.0

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

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

-

-

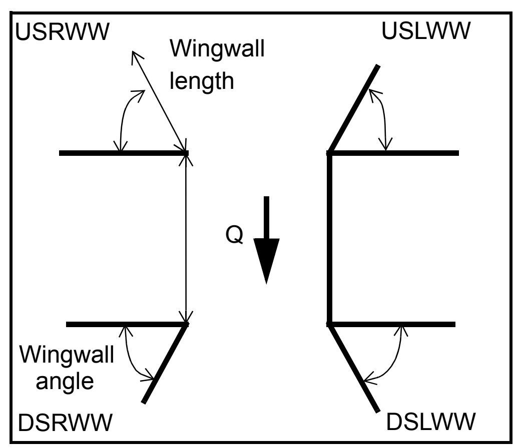
2

The right abutment has a concrete cap over the laid up stone wall and wingwalls.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						41.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	17.5	
DSRWW:	2		0		-	18.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	-	1	-
Condition	Y	-	2	-	1	-	1	-
Extent	1	-	5	2	0	2	0	-

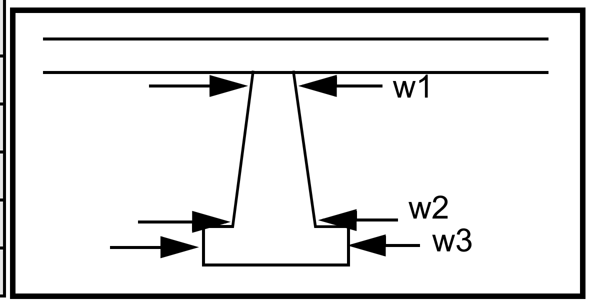
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		6.0	5.0	55.0	5.0	40.0
Pier 2	7.0	7.5	-	25.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	base of	top		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	dow	the	angl		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	nstre	wing	ed		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	am	wall	away		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	right	in	from		*Y- yes; N- no*
91. Attack ∠ (BF)	wing	line	the	N	
92. Pushed	wall	with	strea	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	has	the	m.	-	
95. Cross-members	set-	abut		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	tled	ment		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	with	and		-	
98. Exposure depth	the	the		-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

Material: 4

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

453
453
1
1

Is a cut-bank present? 45 *(Y or if N type ctrl-n cb)* Where? 3 *(LB or RB)* Mid-bank distance: 0

Cut bank extent: 0 feet - *(US, UB, DS)* to - feet Th *(US, UB, DS)*

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

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

banks have slight fluvial erosion due to recent high water flows.
There is a bedrock embankment 300 feet DS of the bridge.

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
110
35
0
DS
240
DS
0
50
45

109. G. Plan View Sketch

- Ve

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

```
Structure Number: WALDTH00180022            Town:    WALDEN
Road Number:      TH 18                     County:  CALEDONIA
Stream:           COLES BROOK

Initials LKS      Date:    06/27/97 Checked: RF
```

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

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2190	3100	0
Main Channel Area, ft2	205	255	0
Left overbank area, ft2	0	1	0
Right overbank area, ft2	97	138	0
Top width main channel, ft	34	34	0
Top width L overbank, ft	0	4	0
Top width R overbank, ft	28	29	0
D50 of channel, ft	0.4071	0.4071	0.4071
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	7.5	ERR
y1, average depth, LOB, ft	ERR	0.3	ERR
y1, average depth, ROB, ft	3.5	4.8	ERR
Total conveyance, approach	19346	28812	0
Conveyance, main channel	14776	20860	0
Conveyance, LOB	0	13	0
Conveyance, ROB	4570	7939	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1672.7	2244.4	ERR
Ql, discharge, LOB, cfs	0.0	1.4	ERR
Qr, discharge, ROB, cfs	517.3	854.2	ERR
Vm, mean velocity MC, ft/s	8.2	8.8	ERR
Vl, mean velocity, LOB, ft/s	ERR	1.4	ERR
Vr, mean velocity, ROB, ft/s	5.3	6.2	ERR
Vc-m, crit. velocity, MC, ft/s	11.2	11.6	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

```
 y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)    Converted to English Units
 ys=y2-y_bridge
 (Richardson and others, 1995, p. 32, eq. 20, 20a)
```

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2190	3100	0
(Q) discharge thru bridge, cfs	2190	3100	0
Main channel conveyance	20793	25794	0
Total conveyance	20793	25794	0
Q2, bridge MC discharge,cfs	2190	3100	ERR
Main channel area, ft2	240	278	0
Main channel width (normal), ft	39.7	39.9	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.7	39.9	0
y_bridge (avg. depth at br.), ft	6.05	6.97	ERR
Dm, median (1.25*D50), ft	0.508875	0.508875	0.508875
y2, depth in contraction,ft	4.67	6.26	ERR
ys, scour depth (y2-ybridge), ft	-1.38	-0.70	N/A

Armoring

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2190	3100	N/A
Main channel area (DS), ft2	240	278	0
Main channel width (normal), ft	39.7	39.9	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	39.7	39.9	0.0
D90, ft	1.5247	1.5247	0.0000
D95, ft	2.1990	2.1990	0.0000
Dc, critical grain size, ft	0.5577	0.7751	ERR
Pc, Decimal percent coarser than Dc	0.312	0.193	0.000
Depth to armoring, ft	3.69	9.72	ERR

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	2190	3100	0	2190	3100	0
a', abut.length blocking flow, ft	2	7	0	19.9	21.2	0
Ae, area of blocked flow ft2	6.8	19.3	0	63.8	93.2	0
Qe, discharge blocked abut.,cfs	31.7	96.9	0	319.9	538.8	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.66	5.02	ERR	5.01	5.78	ERR
ya, depth of f/p flow, ft	3.40	2.76	ERR	3.21	4.40	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.446	0.533	ERR	0.493	0.486	ERR
ys, scour depth, ft	6.43	7.90	N/A	11.83	14.90	N/A

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

a'(abut length blocked, ft)	2	7	0	19.9	21.2	0
y1 (depth f/p flow, ft)	3.40	2.76	ERR	3.21	4.40	ERR
a'/y1	0.59	2.54	ERR	6.21	4.82	ERR
Skew correction (p. 49, fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.45	0.53	N/A	0.49	0.49	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.65	0.75	0	0.65	0.75	0
y, depth of flow in bridge, ft	6.05	6.97	0.00	6.05	6.97	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.58	2.42	0.00	1.58	2.42	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.38	2.11	0.00	1.38	2.11	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR