LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (LYNDTH00020017) on TOWN HIGHWAY 2, crossing HAWKINS BROOK, LYNDON, VERMONT

Open-File Report 97-752

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

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (LYNDTH00020017) on TOWN HIGHWAY 2, crossing HAWKINS BROOK, LYNDON, VERMONT

By EMILY C. WILD and LAURA MEDALIE

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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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (LYNDTH00020017) ON TOWN HIGHWAY 2, CROSSING HAWKINS BROOK, LYNDON, VERMONT

By **Emily C. Wild and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LYNDTH00020017 on Town Highway 2 crossing Hawkins Brook, Lyndon, 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 Green Mountain section of the New England physiographic province in northeastern Vermont. The 7.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the left and right upstream overbanks. The downstream left and right overbanks are brushland.

In the study area, Hawkins Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 78 ft and an average bank height of 7.3 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 46.6 mm (0.153 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 4, 1995, indicated that the reach was laterally unstable with the presence of point bars and side bars.

The Town Highway 2 crossing of Hawkins Brook is a 49-ft-long, two-lane bridge consisting of a 46-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 43 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the computed opening-skew-to-roadway is zero degrees.

A scour hole 0.75 ft deeper than the mean thalweg depth was observed along the downstream left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D
and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. 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 0.1 to 0.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 3.8 to 6.6 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 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.

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 LYNDTH00020017 ***Stream*** Hawkins Brook

County Calendonia ***Road*** TH2 ***District*** 7

Description of Bridge

Bridge length 49 ***ft*** ***Bridge width*** 23.1 ***ft*** ***Max span length*** 46 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 08/04/95

Description of stone fill Type-2, around the upstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. There is a 0.75 foot deep scour hole in front of the upstream left abutment.

Y

Is bridge skewed to flood flow according to There ***survey?*** 45 ***Angle*** Y

is a mild channel bend in the upstream reach.

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	08/04/95	0	0
Level II	08/04/95	0	0

Potential for debris Low. There is some debris caught on the boulders in the channel upstream, and on the I-beams under the bridge.

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

None (8/04/95).

Description of the Geomorphic Setting

General topography The channel is located within a moderately sloped valley.

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

Date of inspection 08/04/95

DS left: Narrow flood plain.

DS right: Moderately sloped overbank.

US left: Moderately sloped overbank.

US right: Narrow flood plain.

Description of the Channel

Average top width 78 ***ft*** ***Average depth*** 7.3 ***ft***

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

Sinuous and laterally unstable with non-alluvial channel boundaries and a narrow flood plain.

Vegetative co[ver] ... Date of inspection 8/04/95

Brush and trees.

DS left: Brush and trees.

DS right: Trees.

US left: Trees with some brush.

US right: N

Do banks appear stable? Banks are laterally unstable, especially where a moderate channel impact zone is present along the upstream left bank. ***If not, describe location and type of instability and date of observation.***

The assessment of 8/04/95 noted a few boulders on the left bank side of the channel under the bridge, and some piles of cobbles along the right abutment.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/Green Mountain	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 980 ***ft³/s*** ***Q500*** 1,600 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(7.7/11.5)exp 0.7] with Flood Insurance Study discharge values for the Town of Lyndon at the confluence with the Passumpic River (Federal Emergency Management Agency, 1988). Hawkins Brook enters the Passumpic River downstream of this bridge site. These values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 499.89 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 501.67 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXIT1	-58	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	68	2	Modelled Approach section (Templated from APTEM)
APTEM	80	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.060, and overbank "n" values ranged from 0.050 to 0.080.

Normal depth at the exit section (EXIT1) 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 0.02 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1988).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.029 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.0 *ft*
Average low steel elevation 497.5 *ft*

100-year discharge 980 *ft³/s*
Water-surface elevation in bridge opening 491.9 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 122 *ft²*
Average velocity in bridge opening 8.0 *ft/s*
Maximum WSPRO tube velocity at bridge 10.7 *ft/s*

Water-surface elevation at Approach section with bridge 493.9
Water-surface elevation at Approach section without bridge 493.5
Amount of backwater caused by bridge 0.4 *ft*

500-year discharge 1,600 *ft³/s*
Water-surface elevation in bridge opening 492.6 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 152 *ft²*
Average velocity in bridge opening 10.6 *ft/s*
Maximum WSPRO tube velocity at bridge 13.6 */s*

Water-surface elevation at Approach section with bridge 495.7
Water-surface elevation at Approach section without bridge 494.3
Amount of backwater caused by bridge 1.4 *ft*

Incipient overtopping discharge N *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). At this site, the 100-year and 500-year discharges resulted in free-surface bridge flow. 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	0.1	0.9	--
Depth to armoring	4.7	20.0	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	5.2	6.6	--
Right abutment	3.8	6.0	--
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	1.1	1.5	--
Right abutment	1.1	1.5	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

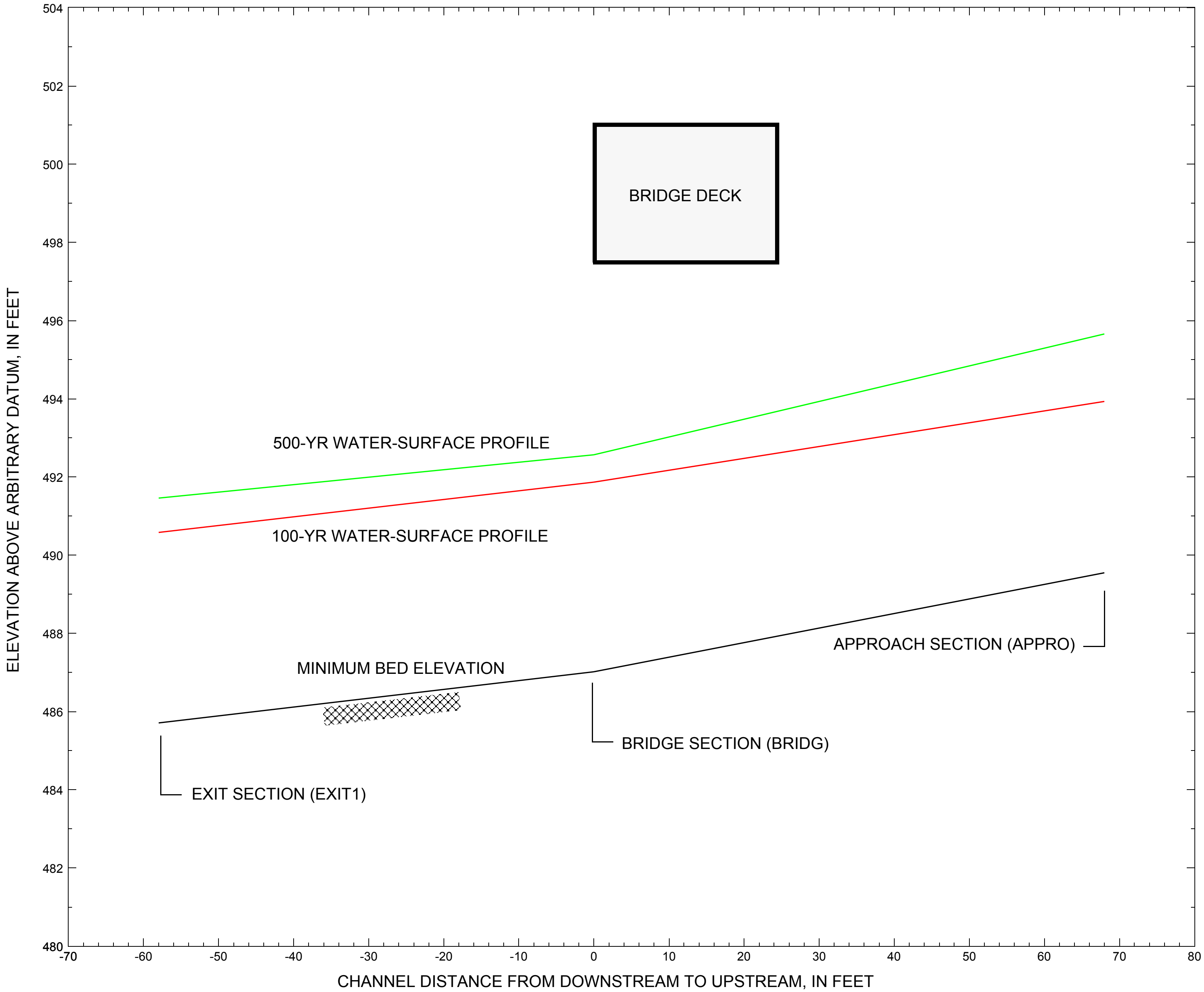

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LYNDTH00020017 on Town Highway 2, crossing Hawkins Brook, Lyndon, Vermont.

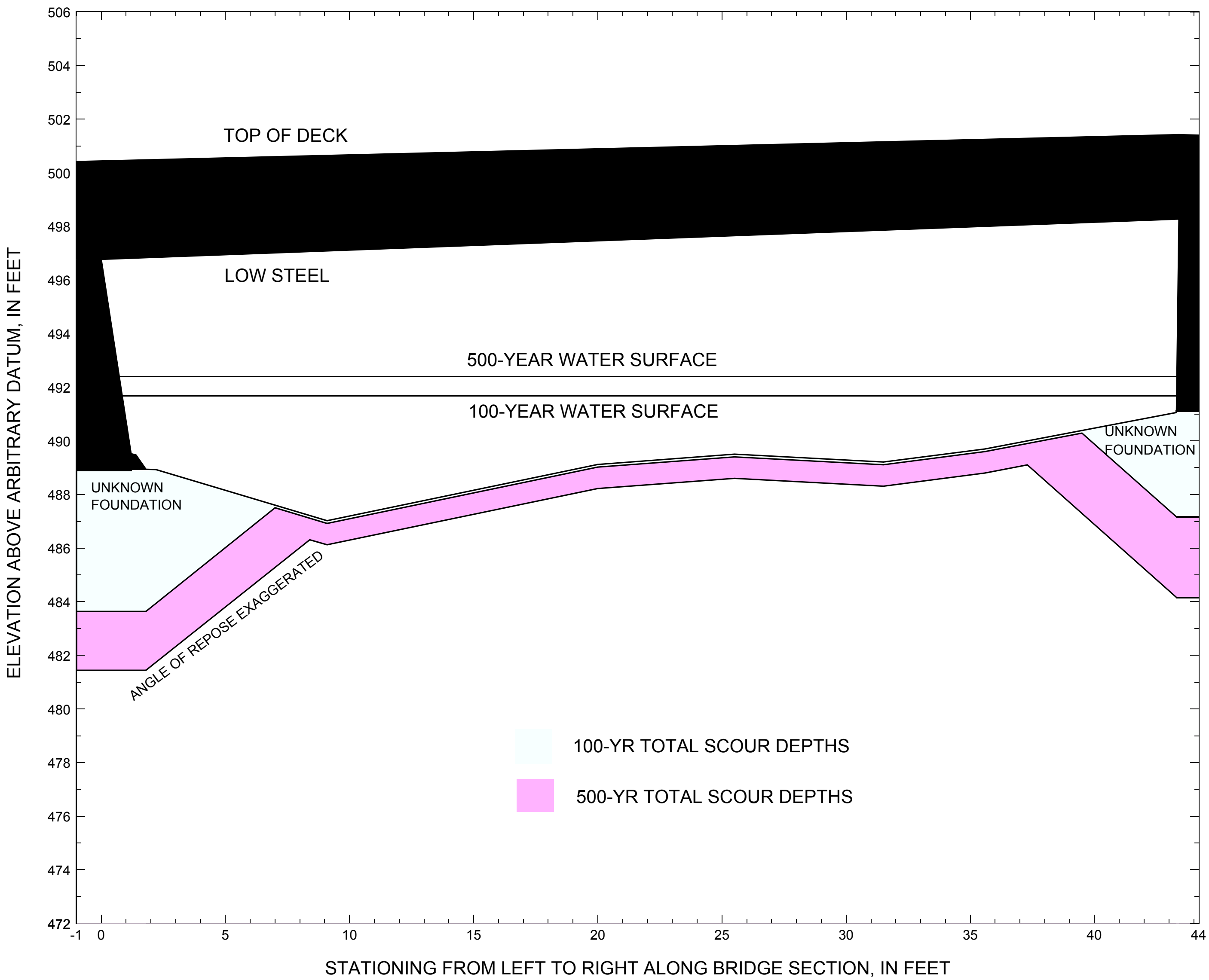

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure LYNDTH00020017 on Town Highway 2, crossing Hawkins Brook, Lyndon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LYNDTH00020017 on Town Highway 2, crossing Hawkins Brook, Lyndon, 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 980 cubic-feet per second											
Left abutment	0.0	--	496.8	--	488.9	0.1	5.2	--	5.3	483.6	--
Right abutment	43.4	--	498.3	--	491.1	0.1	3.8	--	3.9	487.2	--

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 LYNDTH00020017 on Town Highway 2, crossing Hawkins Brook, Lyndon, 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 1,600 cubic-feet per second											
Left abutment	0.0	--	496.8	--	488.9	0.9	6.6	--	7.5	481.4	--
Right abutment	43.4	--	498.3	--	491.1	0.9	6.0	--	6.9	484.2	--

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

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U.S. Geological Survey, 1988, Burke Mountain, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File lynd017.wsp
T2        Hydraulic analysis for structure LYNDTH00020017   Date: 17-JUL-97
T3        Town Highway 2, Hawkins Brook, Lyndon, Vermont          ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            980.0   1600.0
SK          0.0211   0.0211
*
XS   EXIT1    -58           0.
GR         -123.2, 499.69    -97.9, 497.96    -88.0, 494.22
GR          -74.9, 493.53    -55.9, 493.95    -34.6, 494.30    -27.8, 492.57
GR          -20.7, 491.82    -17.0, 490.88    -14.1, 489.20     -5.7, 488.72
GR            0.0, 486.77      7.4, 486.24      9.7, 486.30     14.1, 485.71
GR           16.7, 486.59     18.8, 488.73     29.1, 488.90     29.9, 489.96
GR           37.5, 490.11     45.3, 490.20     53.3, 490.80     55.6, 491.95
GR           73.5, 493.42    100.0, 511.71
*
N           0.050        0.055         0.060
SA                 -34.6         29.9
*
*
XS   FULLV      0  * * *  0.0157
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.52       0.0
GR            0.0, 496.77      1.2, 489.52      1.4, 489.47      1.8, 488.94
GR            2.2, 488.93      9.1, 487.02     15.4, 488.27     20.0, 489.12
GR           25.5, 489.50     31.5, 489.21     35.6, 489.70     43.3, 491.06
GR           43.4, 498.27      0.0, 496.77
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      34.4 * *     46.9      9.5
N           0.060
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      23.1     1
GR         -109.7, 501.49   -102.4, 498.96    -51.2, 499.62      0.0, 500.44
GR           49.1, 501.52    104.1, 503.06
*
*
*
XT   APTEM     80
GR         -100.0, 565.00    -31.2, 499.01    -20.7, 498.95     -3.0, 494.93
GR           -2.3, 492.79      5.5, 491.38      6.7, 490.87      9.9, 489.90
GR           13.4, 490.46     25.6, 490.80     35.9, 491.19     39.3, 492.45
GR           43.9, 493.68     70.4, 501.92    128.3, 504.41    153.3, 505.88
*
AS   APPRO     68  * * *    0.0288
GT
N           0.080        0.060        0.065
SA                -20.7         70.4
*
HP 1 BRIDG 491.87 1 491.87
HP 2 BRIDG 491.87 * * 980
HP 1 APPRO 493.93 1 493.93
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File lynd017.wsp
Hydraulic analysis for structure LYNDTH00020017   Date: 17-JUL-97
Town Highway 2, Hawkins Brook, Lyndon, Vermont          ECW
   *** RUN DATE & TIME: 09-15-97  10:33

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

   WSEL  SA#     AREA         K    TOPW    WETP  ALPH    LEW    REW      QCR
           1      122      5775      43      46                         1170
 491.87           122      5775      43      46  1.00      1     43     1170


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

     WSEL     LEW     REW    AREA        K        Q    VEL
   491.87     0.8    43.3   121.8    5775.     980.   8.04

X STA.        0.8         3.9         5.5         6.9         8.0         9.0
 A(I)              8.7         5.8         5.4         4.9         4.8
 V(I)             5.64        8.51        8.99       10.00       10.13

X STA.        9.0        10.0        11.0        12.1        13.3        14.6
 A(I)              4.6         4.7         4.8         4.9         5.1
 V(I)            10.71       10.41       10.26        9.95        9.64

X STA.       14.6        16.1        17.8        19.8        22.2        24.8
 A(I)              5.4         5.6         6.0         6.3         6.6
 V(I)             9.12        8.76        8.10        7.72        7.42

X STA.       24.8        27.6        30.3        32.9        36.1        43.3
 A(I)              6.9         6.7         6.9         7.3        10.4
 V(I)             7.10        7.33        7.11        6.68        4.73

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

   WSEL  SA#     AREA         K    TOPW    WETP  ALPH    LEW    REW      QCR
           2      141      6916      49      51                         1359
 493.93           141      6916      49      51  1.00     -2     46     1359


 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

     WSEL     LEW     REW    AREA        K        Q    VEL
   493.93    -2.8    45.8   140.8    6916.     980.   6.96

X STA.       -2.8         2.9         5.9         7.9         9.5        10.9
 A(I)             10.6         8.0         6.9         6.4         6.0
 V(I)             4.63        6.13        7.12        7.62        8.12

X STA.       10.9        12.3        13.9        15.4        17.0        18.7
 A(I)              5.9         6.0         6.0         6.0         6.1
 V(I)             8.33        8.20        8.18        8.21        8.06

X STA.       18.7        20.4        22.1        23.8        25.7        27.6
 A(I)              6.1         6.1         6.3         6.5         6.4
 V(I)             7.97        8.07        7.81        7.53        7.62

X STA.       27.6        29.6        31.7        34.0        36.7        45.8
 A(I)              6.7         7.0         7.5         8.2        12.1
 V(I)             7.30        6.99        6.55        5.98        4.04
```

```
 U.S. Geological Survey WSPRO Input File lynd017.wsp
 Hydraulic analysis for structure LYNDTH00020017   Date: 17-JUL-97
 Town Highway 2, Hawkins Brook, Lyndon, Vermont          ECW
    *** RUN DATE & TIME: 09-15-97  10:33

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      152      8151     43     48                         1623
 492.57           152      8151     43     48  1.00      1     43     1623


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

       WSEL     LEW     REW    AREA         K        Q    VEL
     492.57     0.7    43.3   151.6    8151.    1600.  10.55

X STA.         0.7         4.0         5.7         7.1         8.4         9.5
  A(I)            11.2         7.5         6.9         6.3         6.1
  V(I)            7.13       10.68       11.68       12.62       13.17

X STA.         9.5        10.6        11.7        13.0        14.4        15.8
  A(I)             5.9         6.0         6.1         6.3         6.5
  V(I)           13.62       13.25       13.07       12.69       12.30

X STA.        15.8        17.5        19.4        21.6        24.0        26.6
  A(I)             6.8         7.1         7.6         7.7         8.1
  V(I)           11.73       11.27       10.53       10.42        9.86

X STA.        26.6        29.1        31.5        34.0        37.3        43.3
  A(I)             7.9         7.9         8.2         9.3        12.2
  V(I)           10.11       10.17        9.74        8.63        6.54

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           2      233     13943     59     62                         2617
 495.66           233     13943     59     62  1.00     -7     51     2617



 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

       WSEL     LEW     REW    AREA         K        Q    VEL
     495.66    -7.7    51.4   232.5   13943.    1600.   6.88

X STA.        -7.7         2.2         5.2         7.6         9.5        11.1
  A(I)            20.4        13.1        11.7        10.7         9.8
  V(I)            3.93        6.10        6.81        7.49        8.15

X STA.        11.1        12.8        14.6        16.3        18.1        19.9
  A(I)             9.9         9.8         9.6         9.7         9.6
  V(I)            8.05        8.13        8.35        8.23        8.31

X STA.        19.9        21.7        23.6        25.5        27.4        29.5
  A(I)             9.8         9.7        10.0        10.0        10.5
  V(I)            8.18        8.26        7.96        7.97        7.62

X STA.        29.5        31.6        33.9        36.3        39.8        51.4
  A(I)            10.5        11.3        11.8        14.0        20.4
  V(I)            7.59        7.07        6.80        5.70        3.92
```

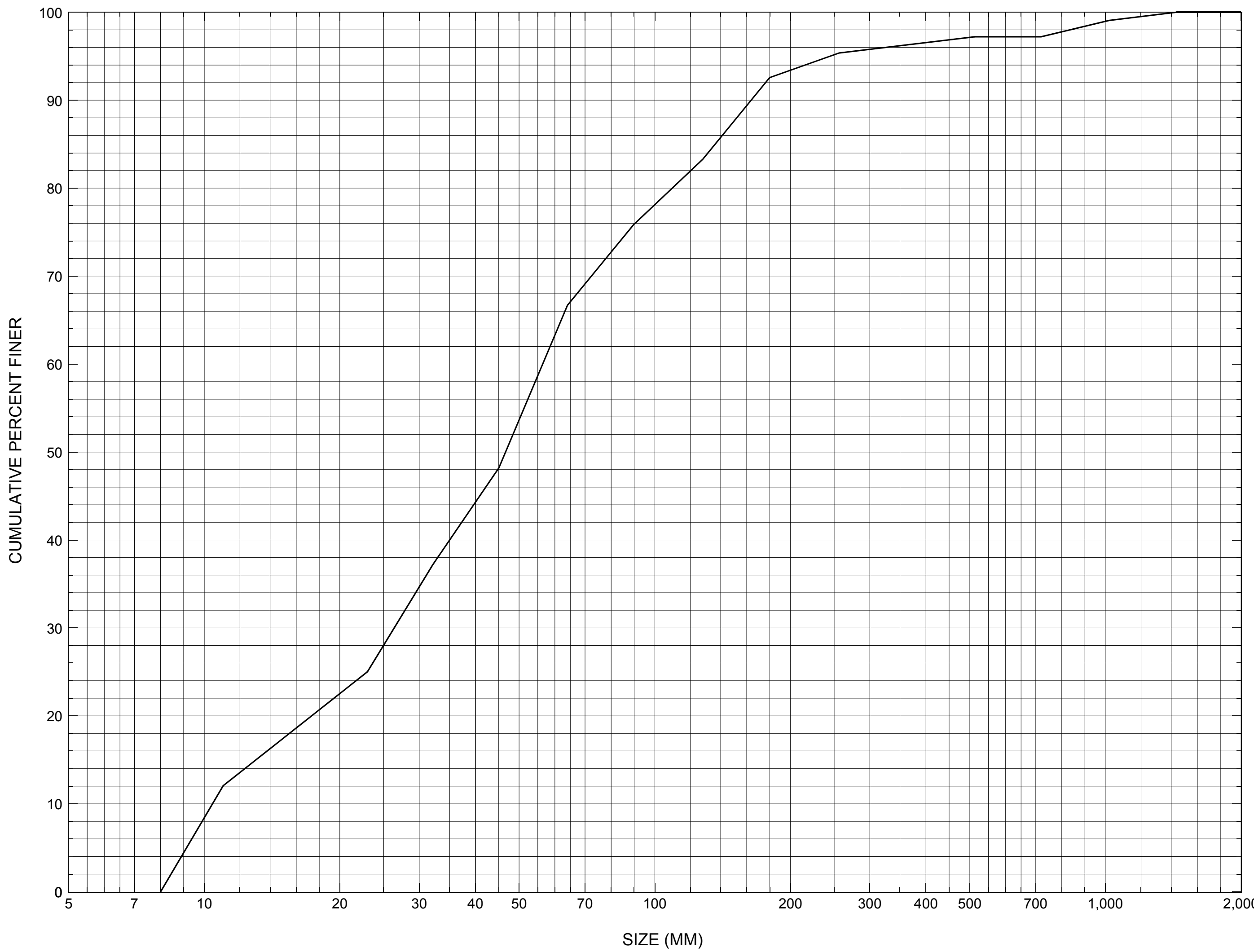
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File lynd017.wsp
        Hydraulic analysis for structure LYNDTH00020017   Date: 17-JUL-97
        Town Highway 2, Hawkins Brook, Lyndon, Vermont          ECW
           *** RUN DATE & TIME: 09-15-97  10:33
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******    -15      137  0.86 *****  491.44  490.30     980  490.58
       -57 ******     50     6746  1.08 ***** *******    0.92    7.17

FULLV:FV       58    -16      158  0.66  1.01  492.46 *******     980  491.80
         0     58     53     8157  1.11  0.00    0.01    0.77    6.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.05     493.24     493.50

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   491.30     564.65    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   491.30     564.65     493.50

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   493.50     564.65     493.50

APPRO:AS       68     -2      120  1.03 *****  494.53  493.50     980  493.50
        68     68     44     5450  1.00 ***** *******    0.90    8.16
         <<<<<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       58      1      122  1.01  1.43  492.88  491.56     980  491.87
         0     58     43     5769  1.00  0.00    0.00    0.84    8.05

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.52 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       34     -2      141  0.75  0.81  494.68  493.50     980  493.93
        68     34     46     6909  1.00  0.99    0.00    0.72    6.97

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.097  0.067    6458.     5.    47.   493.03
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q       K     AREA     VEL    WSEL
   EXIT1:XS     -58.   -16.    50.    980.    6746.     137.    7.17  490.58
   FULLV:FV       0.   -17.    53.    980.    8157.     158.    6.19  491.80
   BRIDG:BR       0.     1.    43.    980.    5769.     122.    8.05  491.87
   RDWAY:RG      12.**************      0.******************    1.00********
   APPRO:AS      68.    -3.    46.    980.    6909.     141.    6.97  493.93

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    490.30    0.92  485.71  511.71************  0.86  491.44  490.58
   FULLV:FV  ********    0.77  486.62  512.62  1.01  0.00  0.66  492.46  491.80
   BRIDG:BR    491.56    0.84  487.02  498.27  1.43  0.00  1.01  492.88  491.87
   RDWAY:RG  ****************  498.96  503.06**********************************
   APPRO:AS    493.50    0.72  489.55  564.65  0.81  0.99  0.75  494.68  493.93
```

```
        U.S. Geological Survey WSPRO Input File lynd017.wsp
        Hydraulic analysis for structure LYNDTH00020017   Date: 17-JUL-97
        Town Highway 2, Hawkins Brook, Lyndon, Vermont          ECW
           *** RUN DATE & TIME: 09-15-97  10:33

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

EXIT1:XS   ******    -18      199  1.11 *****  492.57  491.30    1600  491.46
       -57 ******     55    11015  1.11 ***** *******    0.91    8.02

FULLV:FV       58    -20      228  0.84  1.02  493.60 *******    1600  492.76
         0     58     55    13204  1.10  0.00    0.00    0.75    7.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.11     494.05     494.29
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.26     564.65    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.26     564.65     494.29
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   494.29     564.65     494.29

APPRO:AS       68     -2      158  1.59 *****  495.87  494.29    1600  494.29
        68     68     47     8249  1.00 ***** *******    1.00   10.10
         <<<<<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       58      1      152  1.73  1.65  494.30  492.55    1600  492.57
         0     58     43     8148  1.00  0.07    0.00    0.99   10.55
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.52 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       34     -7      233  0.74  0.77  496.40  494.29    1600  495.66
        68     34     51    13950  1.00  1.33    0.01    0.61    6.88

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.145  0.000  14032.     3.    46.   495.07
                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -58.   -19.    55.   1600.   11015.     199.    8.02  491.46
   FULLV:FV       0.   -21.    55.   1600.   13204.     228.    7.01  492.76
   BRIDG:BR       0.     1.    43.   1600.    8148.     152.   10.55  492.57
   RDWAY:RG      12.**************      0.******************    1.00********
   APPRO:AS      68.    -8.    51.   1600.   13950.     233.    6.88  495.66

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.30    0.91  485.71  511.71************  1.11  492.57  491.46
   FULLV:FV  ********    0.75  486.62  512.62  1.02  0.00  0.84  493.60  492.76
   BRIDG:BR    492.55    0.99  487.02  498.27  1.65  0.07  1.73  494.30  492.57
   RDWAY:RG  ****************  498.96  503.06**********************************
   APPRO:AS    494.29    0.61  489.55  564.65  0.77  1.33  0.74  496.40  495.66
  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 LYNDTH00020017, in Lyndon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LYNDTH00020017

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 41725

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

Waterway *(I - 6)* HAWKINS BROOK

Road Name *(I - 7)*: -

Route Number TH002

Vicinity *(I - 9)* 0.15 MI TO JCT W C3 TH75

Topographic Map Burke Mountain

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44307

Longitude *(i - 17; nnnnn.n)* 71576

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030700170307

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

Maximum span length *(I - 48; nnnn)* 0046

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

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 000650

Deck Width *(I - 52; nn.n)* 231

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

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

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)* 1974

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

Clear span (*nnn.n ft*) 043.6

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

Vertical clearance from streambed (*nnn.n ft*) 007.7

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

Waterway of full opening (*nnn.n* ft^2) 336.0

Comments:

The structural inspection report of 10/31/94 indicates the structure is a steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are constructed of concrete. The concrete footing is exposed on the left abutment. The LABUT reportedly is fairly new. The LABUT wall has a few fine cracks and small leaks at the up- and downstream ends and its wingwalls. A low, coarse gravel point bar is reported in the channel along the right abutment and blocks one third of the channel. The report indicates that most of the flow is against the upstream end of the LABUT. Some boulder and stone fill is noted in front of the right abutment and on all of the wingwalls. **(Continued, page 31)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): ____ *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft^2*): -

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

Comments:

There is some stone fill reported on the banks upstream and downstream. The report notes that there has been no undermining or significant signs of settling. Debris accumulation is noted as minor at this site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **7.68** mi^2 Lake/pond/swamp area **0.082** mi^2
Watershed storage *(ST)* **1.1** %
Bridge site elevation **855** ft Headwater elevation **2750** ft
Main channel length **4.47** mi
10% channel length elevation **890** ft 85% channel length elevation **1720** ft
Main channel slope *(S)* **247.1** ft / mi

Watershed Precipitation Data

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

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCKMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION

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 cord elevations are from the survey log done for this report on 8/4/95. The low cord to bed length data is from the sketch attached to a bridge inspection report dated 10/31/94. The sketch was done on 6/9/92.**

Station	0	15.3	23.8	30.8	43.8	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	496.8	497.3	497.5	497.7	498.3	-	-	-	-	-	-
Bed elevation	490.2	488.8	488.6	489.7	491.6	-	-	-	-	-	-
Low chord-bed	6.6	8.5	8.9	8.0	6.7	-	-	-	-	-	-

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

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/01/96
Computerized by: EW Date: 03/01/96
Reviewd by: EW Date: 09/15/97

Structure Number LYNDTH00020017

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE   Date *(MM/DD/YY)* 08 / 04 / 1996
2. Highway District Number 07   Mile marker -
   County CALEDONIA (005)   Town LYNDON (41725)
   Waterway *(I - 6)* HAWKINS BROOK   Road Name -
   Route Number TH002   Hydrologic Unit Code: 01080102
3. Descriptive comments:

The bridge structure is a steel stringer with concrete deck and wingwalls. The bridge was built in 1928, but has been recently constructed with concrete (RABUT). It is located 0.15 miles from the junction with Town Highway 75.

B. Bridge Deck Observations

4. Surface cover... LBUS 6   RBUS 6   LBDS 5   RBDS 5   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 49 *(feet)*   Span length 46 *(feet)*   Bridge width 23.1 *(feet)*

Road approach to bridge:

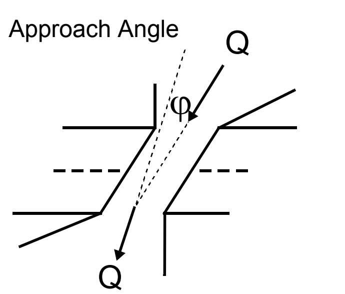
8. LB 1   RB 2   *(**0** even, **1**- lower, **2**- higher)*
9. LB 1   RB 1   *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left --   US right --

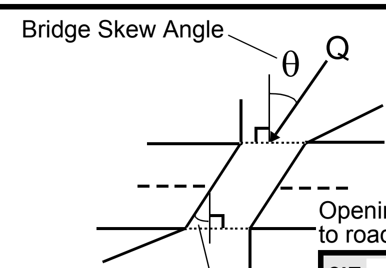
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: 65   16. Bridge skew: 45





α= 0.0

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

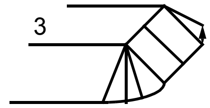
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls

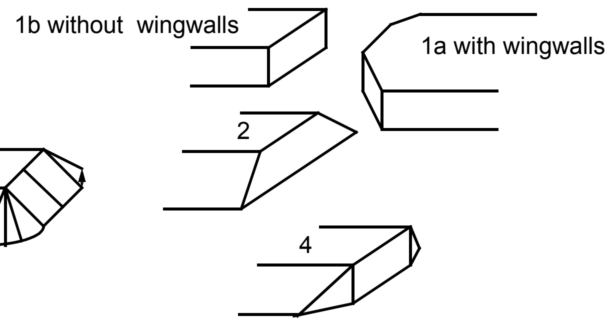
1b- Vertical abutments without wingwalls

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.)

#4: The downstream right bank has a strip of forest cover, 60-80 feet wide, from the bank and up the sloping overbank, then surface cover is pasture (lawn). The downstream left bank is mostly forest, but also fairly significant shrubbery, refer to report photos. A dirt driveway on the upstream left bank leads to house with small lawn, but this area is surounded by forest.
#7: Values are from VTAOT. The measured bridge length is 49.8 feet, bridge span is 44.6 feet, and bridge width is 22.9 feet.
#8: The measured road width is 19 feet about 12 feet from bridge.
#11: Along the upstream right bank, type 2 boulders serve as protection

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
61.5	7.5			10.5	3	3	245	453	0	0

23. Bank width 15.0   24. Channel width 15.0   25. Thalweg depth 91.5   29. Bed Material 435

30 .Bank protection type: LB 0 RB 0   31. 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*

32. Comments (bank material variation, minor inflows, protection extent, etc.):
#26: The right bank vegetation cover is zero percent from the bridge to 40 feet upstream, then the bank is fifty-one to seventy-five percent (category 3).

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 58 35. Mid-bar width: 12

36. Point bar extent: 30 feet US (US, UB) to 112 feet US (US, UB, DS) positioned 65 %LB to 80 %RB

37. Material: 345

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

#37: Bed material is unsorted.

A side bar is present on the LB from 92 to 132 feet US. The mid-bar distance is at 122 feet where it is 6 feet wide. The bed material is gravel, cobble and boulder. The bar is positioned 30% LB to 40% RB.

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

41. Mid-bank distance: 78 42. Cut bank extent: 70 feet US (US, UB) to 83 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.):

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

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

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

NO CHANNEL SCOUR

Local channel scour exists behind boulders

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

A minor confluence exists at 30 feet US on the LB. It is ephemeral.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
30.5		1.0		2	7	7	-

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

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

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

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

435

Bed slopes down slightly from the RABUT towards the LABUT.

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 1____ (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

#65: A very, very slight amount of debris accumulation both US and at the bridge; twigs are caught behind boulders and on the protruding low steel

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		50	85	2	2	0.75	3	90.0
RABUT	1	0	85			2	0	43.5

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

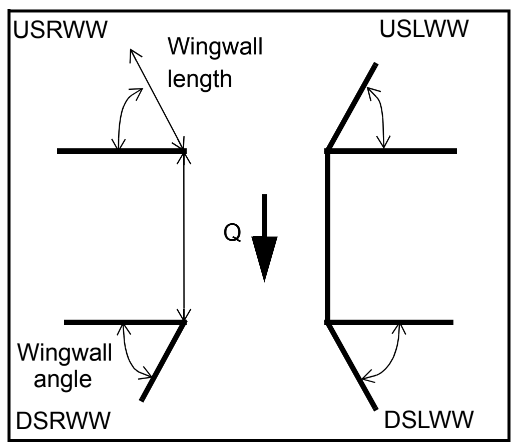
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
-
1

#75: The average thalweg is 0.5 feet. Since the water depth is 1.25 feet at the scour hole, the scour depth is 0.75 feet. Scour at the LABUT begins midway under bridge to the DS end.
#76: The LABUT exposure depth grades from 3 feet at the DS end to 0.3 feet at the US end.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						43.5	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	25.0	
DSRWW:	1		0		-	25.0	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	2	Y	-	-	-	-	1
Condition	Y	1	1	-	-	-	-	4
Extent	1	3	0	0	0	0	5*	-

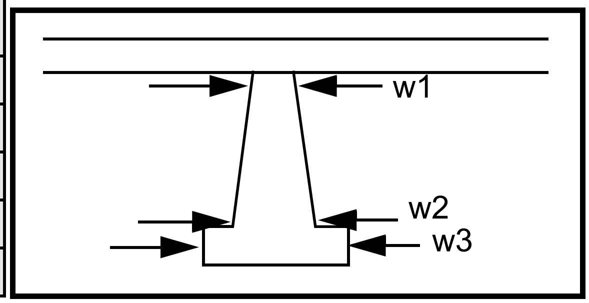
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **#80** (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		**9.5**		**55.0**	**40.0**	**17.5**
Pier 2				**10.0**	**18.5**	**45.0**
Pier 3		-	-	**14.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**: Along**	**adja-**	**bank**	**a pile**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**the**	**cent**	**at 30**	**of**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**DSL**	**with**	**degr**	**strea**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**WW,**	**the**	**ees.**	**mbe**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**scou**	**LAB**	**#82:**	**d**	*Y- yes; N- no*
91. Attack ∠ (BF)	**r is**	**UT.**	**Alon**	**mate**	
92. Pushed	**only**	**The**	**g the**	**rial**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**pres-**	**foot-**	**USL**	**is**	
95. Cross-members	**ent**	**ing**	**WW**	**agai**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**at**	**slope**	**and**	**nst**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**cor-**	**s up**	**LAB**	**the**	
98. Exposure depth	**ner**	**with**	**UT,**	**wing**	

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

wall, forming a small talus pile. The material serves as protection, and extends halfway across the LABUT. *Along the RABUT three piles of cobbles have been placed against the abutment wall.

N

-

E. Downstream Channel Assessment

100.

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

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

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

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

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

101. Is a drop structure present? - (*Y or N, if N type ctrl-n ds*)   102. Distance: - feet

103. Drop: - feet   104. Structure material: - (***1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other*)

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: - ____

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

-
-
-
NO PIERS

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

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

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

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

2
2
5432

Is channel scour present? **453** (Y or if N type ctrl-n cs) Mid-scour distance: **0** ____

Scour dimensions: Length **0** ____ Width **4352** ____ Depth: **0** ____ Positioned **0** ____ %LB to - ____ %RB

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

-
-

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

N
-
NO DROP STRUCTURE

Y
9
15
0

109. G. Plan View Sketch

- U

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: LYNDTH00020017            Town:    LYNDON
Road Number:      TH 2                      County:  CALEDONIA
Stream:  HAWKINS BROOK

Initials ECW      Date:    9-11-97  Checked: MAI
```

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	980	1600	0
Main Channel Area, ft2	141	233	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	49	59	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.153	0.153	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	2.9	3.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	6916	13943	0
Conveyance, main channel	6916	13943	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	980.0	1600.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	7.0	6.9	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	7.2	7.5	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	980	1600	0
(Q) discharge thru bridge, cfs	980	1600	0
Main channel conveyance	5775	8151	0
Total conveyance	5775	8151	0
Q2, bridge MC discharge,cfs	980	1600	ERR
Main channel area, ft2	122	152	0
Main channel width (normal), ft	42.5	42.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.5	42.6	0
y_bridge (avg. depth at br.), ft	2.87	3.57	ERR
Dm, median (1.25*D50), ft	0.19125	0.19125	0
y2, depth in contraction,ft	2.92	4.44	ERR
ys, scour depth (y2-ybridge), ft	0.05	0.87	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	980	1600	N/A
Main channel area (DS), ft2	122	152	0
Main channel width (normal), ft	42.5	42.6	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	42.5	42.6	0.0
D90, ft	0.5368	0.5368	0.0000
D95, ft	0.8014	0.8014	0.0000
Dc, critical grain size, ft	0.3726	0.5781	ERR
Pc, Decimal percent coarser than Dc	0.192	0.080	0.000
Depth to armoring, ft	4.71	19.97	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	980	1600	0	980	1600	0
a', abut.length blocking flow, ft	3.6	8.4	0	2.5	8.1	0
Ae, area of blocked flow ft2	6.7	17.3	0	3.3	14.2	0
Qe, discharge blocked abut.,cfs	31	67.9	0	13.5	55.9	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.63	3.92	ERR	4.09	3.94	ERR
ya, depth of f/p flow, ft	1.86	2.06	ERR	1.32	1.75	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	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	0.598	0.482	ERR	0.627	0.524	ERR
ys, scour depth, ft	5.22	6.55	N/A	3.75	6.00	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)	3.6	8.4	0	2.5	8.1	0
y1 (depth f/p flow, ft)	1.86	2.06	ERR	1.32	1.75	ERR
a'/y1	1.93	4.08	ERR	1.89	4.62	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.60	0.48	N/A	0.63	0.52	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)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.84	0.99	0	0.84	0.99	0
y, depth of flow in bridge, ft	2.87	3.57	0.00	2.87	3.57	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.14	1.49	ERR	1.14	1.49	ERR