LEVEL II SCOUR ANALYSIS FOR BRIDGE 58 (SPRITH00060058) on TOWN HIGHWAY 6, crossing BALTIMORE BROOK, SPRINGFIELD, VERMONT

Open-File Report 98-056

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 58 (SPRITH00060058) on TOWN HIGHWAY 6, crossing BALTIMORE BROOK, SPRINGFIELD, VERMONT

By RONDA L. BURNS and LAURA MEDALIE

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 58 (SPRITH00060058) ON TOWN HIGHWAY 6, CROSSING BALTIMORE BROOK, SPRINGFIELD, VERMONT

By **Ronda L. Burns and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SPRITH00060058 on Town Highway 6 crossing Baltimore Brook, Springfield, 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 (Federal Highway Administration, 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 southeastern Vermont. The 3.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is suburban while the immediate banks have trees.

In the study area, Baltimore Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 28 ft and an average bank height of 3 ft. The channel bed material ranges from boulder to sand with a median grain size (D_{50}) of 66.2 mm (0.217 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 23, 1996, indicated that the reach was laterally unstable. There is a severe cut-bank along the upstream left bank.

The Town Highway 6 crossing of Baltimore Brook is a 28-ft-long, two-lane bridge consisting of one 25-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, April 7, 1995). The opening length of the structure parallel to the bridge face is 24.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the computed opening-skew-to-roadway is 15 degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the upstream left wingwall and upstream end of the left abutment during the Level I assessment. The scour countermeasures at the site included type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left wingwall and at the downstream ends of the downstream left and right wingwalls. Also, there was a stone wall along the upstream right bank and downstream left bank. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.8 to 9.8 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number SPRITH00060058 ***Stream*** Baltimore Brook

County Windsor ***Road*** TH 6 ***District*** 2

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 28.6 ***ft*** ***Max span length*** 25 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 9/23/96

Description of stone fill Type-2, at the upstream end of the upstream left wingwall and at the downstream ends of the left and right downstream wingwalls. Also, there is a stone wall on the upstream right bank and downstream left bank.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a two feet deep scour hole in front of the upstream left wingwall and the upstream end of the left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 25

There is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream left wingwall and left abutment.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	9/23/96	0	0
Level II	9/23/96	0	0

Potential for debris Moderate. There is some debris caught on the upstream right bank.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 9/23/96.

Description of the Geomorphic Setting

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

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

Date of inspection 9/23/96

DS left: Steep channel bank to a moderately sloped overbank

DS right: Steep channel bank to a moderately sloped overbank

US left: Steep valley wall

US right: Steep channel bank to a moderately sloped overbank

Description of the Channel

Average top width 28 ***ft*** ***Average depth*** 3 ***ft***

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

Sinuous and unstable with semi-alluvial channel boundaries.

9/23/96

Vegetative co

DS left: Trees and brush with short grass on the overbank

DS right: Shrubs and brush with short grass on the overbank

US left: Trees and brush with short grass on the overbank

US right: Trees and brush with short grass on the overbank

Do banks appear stable? No

There is a severe cut-bank on the upstream left bank and a scour hole in front of the upstream left wingwall and upstream end of the left abutment.

date of observation.

Describe any obstructions in channel and date of observation.

There is a 1 foot diameter pipe supported 5 feet above the stream channel by concrete piers on the left and right banks at the downstream face of the bridge as noted on 9/23/96.

Hydrology

Drainage area 3.6 ***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***: The drainage area is rural, but the bridge is located in a suburban setting.

No

Is there a USGS gage on the stream of interest? --

--

USGS gage description --

USGS gage number No

Gage drainage area ***mi²*** -

Is there a lake/p

-

950

Calculated Discharges

1,580 The

Q100 ***ft³/s*** ***Q500*** ***ft³/s***

100-year and 500-year discharges are the median values from a range of discharges defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 503.05 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 501.99 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	-29	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	16	1	Road Grade section
APPRO	55	2	Modelled Approach section (Templated from APTEM)
APTEM	66	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.060, and the upstream left overbank "n" value was 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 0.0103 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0041 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 502.6 *ft*
Average low steel elevation 499.3 *ft*

100-year discharge 950 *ft³/s*
Water-surface elevation in bridge opening 492.2 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 100 *ft²*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 12.0 *ft/s*

Water-surface elevation at Approach section with bridge 493.6
Water-surface elevation at Approach section without bridge 493.5
Amount of backwater caused by bridge 0.1 *ft*

500-year discharge 1,580 *ft³/s*
Water-surface elevation in bridge opening 493.1 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 120 *ft²*
Average velocity in bridge opening 13.1 *ft/s*
Maximum WSPRO tube velocity at bridge 16.9 *ft/s*

Water-surface elevation at Approach section with bridge 496.2
Water-surface elevation at Approach section without bridge 494.9
Amount of backwater caused by bridge 1.3 *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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.5	--
Depth to armoring	6.1	29.3	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	6.9	9.8	--
Right abutment	4.8	7.1	--
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	1.7	2.2	--
Right abutment	1.7	2.2	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

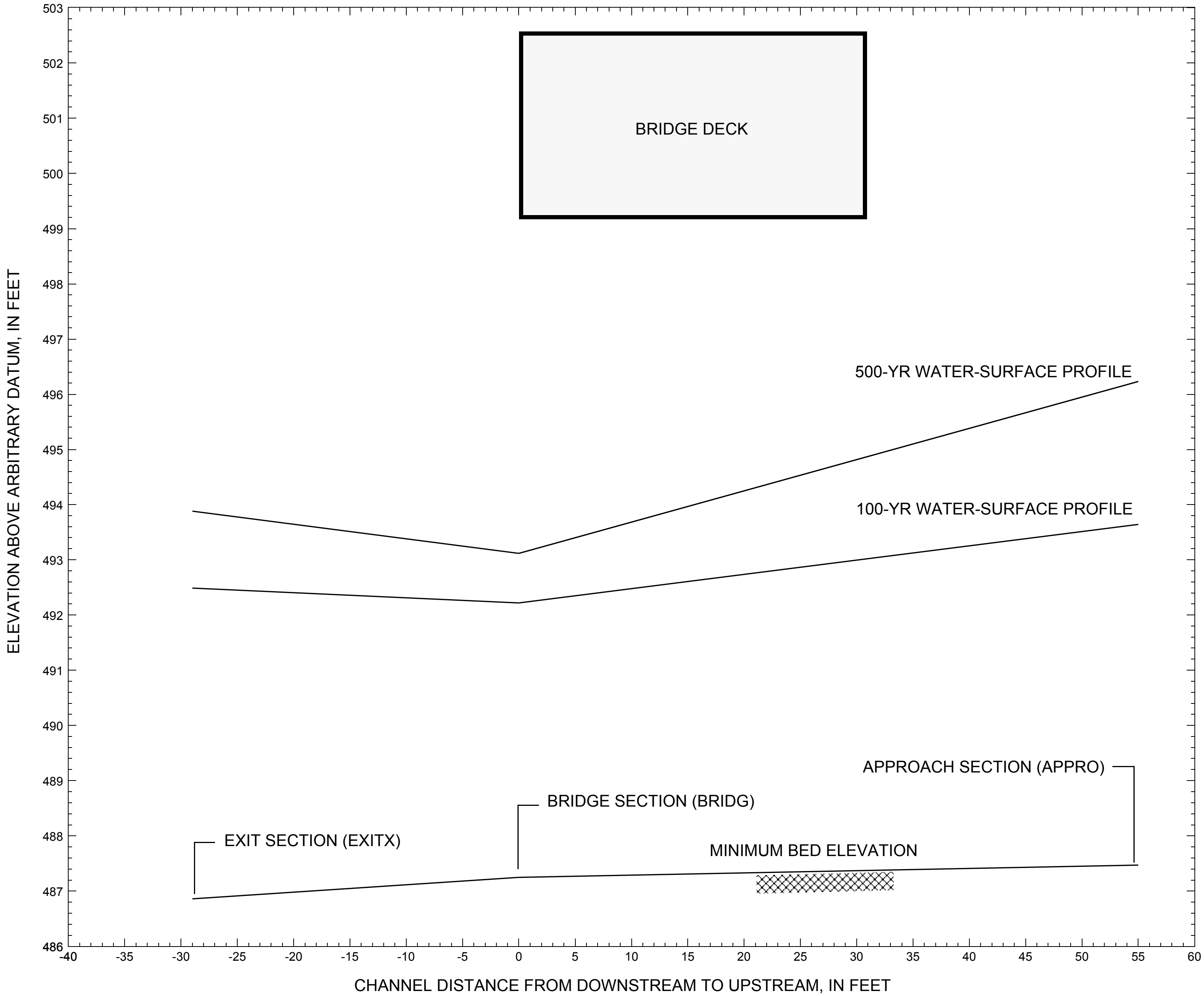

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure SPRITH00060058 on Town Highway 6, crossing Baltimore Brook, Springfield, Vermont.

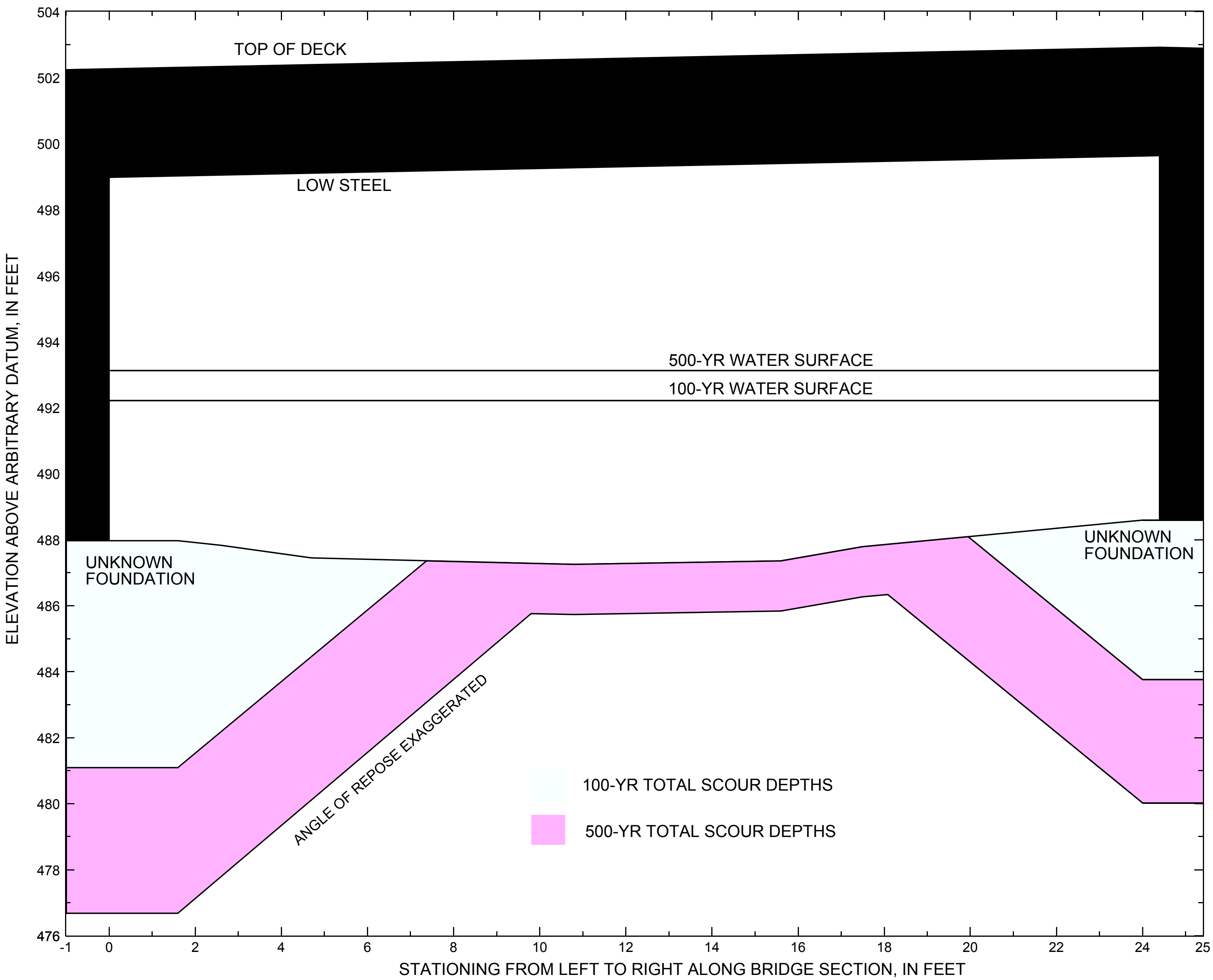

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure SPRITH00060058 on Town Highway 6, crossing Baltimore Brook, Springfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure SPRITH00060058 on Town Highway 6, crossing Baltimore Brook, Springfield, 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 950 cubic-feet per second											
Left abutment	0.0	--	499.0	--	488.0	0.0	6.9	--	6.9	481.1	--
Right abutment	24.4	--	499.6	--	488.6	0.0	4.8	--	4.8	483.8	--

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-yr discharge at structure SPRITH00060058 on Town Highway 6, crossing Baltimore Brook, Springfield, 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 1,580 cubic-feet per second											
Left abutment	0.0	--	499.0	--	488.0	1.5	9.8	--	11.3	476.7	--
Right abutment	24.4	--	499.6	--	488.6	1.5	7.1	--	8.6	480.0	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File spri058.wsp
T2        Hydraulic analysis for structure SPRITH00060058   Date: 05-JAN-98
T3        TH 6 CROSSING BALTIMORE BROOK IN SPRINGFIELD, VT          RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            950.0   1580.0
SK          0.0103   0.0103
*
XS   EXITX    -29          0.
GR         -190.2, 509.89   -151.0, 504.92   -135.0, 500.33   -125.9, 500.23
GR         -125.9, 499.78    -83.7, 499.85    -28.0, 499.26    -19.4, 498.46
GR           -7.5, 491.32      0.0, 491.20      2.0, 487.93      6.9, 487.43
GR           12.8, 486.86     19.1, 487.04     21.2, 487.38     23.1, 488.07
GR           28.9, 491.15     45.6, 495.98     56.2, 500.56     64.6, 503.60
GR           95.5, 505.48    125.1, 506.01    132.2, 508.48    149.1, 510.46
*
N           0.050
*
XS   FULLV      0  * * *   0.0131
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.31      15.0
GR            0.0, 498.98      1.6, 487.97      2.6, 487.83      4.7, 487.45
GR           10.8, 487.25     15.6, 487.36     17.5, 487.79     24.0, 488.59
GR           24.4, 499.64      0.0, 498.98
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL   WWWID
CD           1      37.2        *        *     71.0     9.6
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      28.6     1
GR         -145.6, 508.78   -108.3, 504.61    -95.1, 500.45    -90.0, 500.12
GR          -24.1, 501.60      0.0, 502.27     24.7, 502.92     56.0, 503.69
GR           57.1, 503.31     91.3, 506.05    113.6, 506.42    121.9, 509.30
GR          144.4, 510.92
*
XT   APTEM     66          0.
GR         -102.3, 508.83    -69.4, 503.66    -51.7, 501.34    -47.2, 499.49
GR          -45.8, 497.95    -25.0, 495.36     -8.3, 494.12     -4.4, 492.88
GR            0.0, 488.54      0.4, 488.40      3.4, 487.77      7.8, 487.52
GR           10.6, 488.21     16.8, 488.68     18.8, 488.91     22.8, 491.25
GR           35.3, 494.86     37.1, 498.88     49.3, 502.03     99.7, 506.74
GR          128.0, 507.33    134.3, 509.30    160.3, 510.99
*
AS   APPRO     55  * * *  0.0041
GT
N           0.070       0.060
SA                 -8.3
*
HP 1 BRIDG  492.22 1 492.22
HP 2 BRIDG  492.22 * * 950
HP 1 APPRO  493.64 1 493.64
HP 2 APPRO  493.64 * * 950
*
HP 1 BRIDG  493.12 1 493.12
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File spri058.wsp
       Hydraulic analysis for structure SPRITH00060058   Date: 05-JAN-98
       TH 6 CROSSING BALTIMORE BROOK IN SPRINGFIELD, VT          RLB
          *** RUN DATE & TIME: 01-09-98  14:39

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     100.    8404.    22.    30.                         1205.
  492.22          100.    8404.    22.    30.  1.00     1.    24.   1205.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      492.22     1.0    24.1   100.3    8404.     950.   9.47

X STA.        1.0        4.3        5.2        6.1        6.9        7.8
  A(I)            12.8        4.1        4.1        4.1        4.0
  V(I)            3.70      11.68      11.47      11.67      11.95

X STA.        7.8        8.7        9.5       10.4       11.2       12.1
  A(I)             4.1        4.1        4.0        4.2        4.1
  V(I)           11.48      11.63      11.75      11.43      11.46

X STA.       12.1       13.0       13.8       14.7       15.5       16.4
  A(I)             4.1        4.1        4.1        4.1        4.1
  V(I)           11.62      11.66      11.58      11.71      11.45

X STA.       16.4       17.4       18.4       19.5       20.6       24.1
  A(I)             4.2        4.4        4.3        4.5       12.8
  V(I)           11.32      10.80      11.15      10.57       3.71

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     143.    8116.    38.    41.                         1568.
  493.64          143.    8116.    38.    41.  1.00    -7.    31.   1568.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.64    -6.9    31.2   142.8    8116.     950.   6.65

X STA.       -6.9        0.8        1.8        2.8        3.7        4.6
  A(I)            18.5        5.4        5.6        5.5        5.5
  V(I)            2.57       8.82       8.50       8.71       8.64

X STA.        4.6        5.5        6.5        7.4        8.3        9.2
  A(I)             5.4        5.6        5.5        5.5        5.7
  V(I)            8.85       8.52       8.58       8.63       8.38

X STA.        9.2       10.2       11.2       12.2       13.2       14.3
  A(I)             5.4        5.6        5.5        5.5        5.6
  V(I)            8.77       8.56       8.57       8.61       8.43

X STA.       14.3       15.4       16.5       17.7       18.9       31.2
  A(I)             5.6        5.6        5.8        5.8       24.3
  V(I)            8.47       8.42       8.26       8.13       1.96
```

```
       U.S. Geological Survey WSPRO Input File spri058.wsp
       Hydraulic analysis for structure SPRITH00060058   Date: 05-JAN-98
       TH 6 CROSSING BALTIMORE BROOK IN SPRINGFIELD, VT          RLB
          *** RUN DATE & TIME: 01-09-98  14:39

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     120.   10969.    23.    32.                       1581.
   493.12          120.   10969.    23.    32.  1.00     1.    24.   1581.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.12     0.9    24.2   120.5   10969.    1580.  13.12

X STA.         0.9         4.4         5.3         6.2         7.0         7.9
  A(I)            16.6         4.8         4.7         4.8         4.7
  V(I)            4.77       16.46       16.73       16.45       16.86

X STA.         7.9         8.7         9.6        10.4        11.3        12.2
  A(I)             4.9         4.8         4.8         4.9         4.9
  V(I)           16.21       16.45       16.63       16.19       16.23

X STA.        12.2        13.0        13.9        14.8        15.6        16.5
  A(I)             4.9         4.9         4.7         4.8         4.9
  V(I)           16.14       16.20       16.64       16.44       16.06

X STA.        16.5        17.4        18.4        19.4        20.5        24.2
  A(I)             4.9         5.0         5.1         5.0        16.5
  V(I)           16.18       15.86       15.50       15.65        4.80

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      29.     697.    24.    24.                        181.
             2     254.   18967.    44.    48.                       3444.
   496.23          283.   19664.    68.    73.  1.12   -32.    36.   3083.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.23   -32.3    35.9   282.5   19664.    1580.   5.59

X STA.       -32.3        -4.0        -0.7         0.8         2.1         3.4
  A(I)            41.4        17.9        11.5        10.6        10.5
  V(I)            1.91        4.41        6.90        7.46        7.55

X STA.         3.4         4.6         5.8         7.0         8.2         9.4
  A(I)            10.3        10.4        10.3        10.6        10.3
  V(I)            7.71        7.61        7.67        7.45        7.63

X STA.         9.4        10.6        11.9        13.2        14.5        15.9
  A(I)             9.9        10.3        10.3        10.3        10.5
  V(I)            7.99        7.69        7.67        7.68        7.51

X STA.        15.9        17.2        18.7        20.4        22.8        35.9
  A(I)            10.2        10.8        11.9        13.8        40.8
  V(I)            7.73        7.32        6.64        5.72        1.93
```

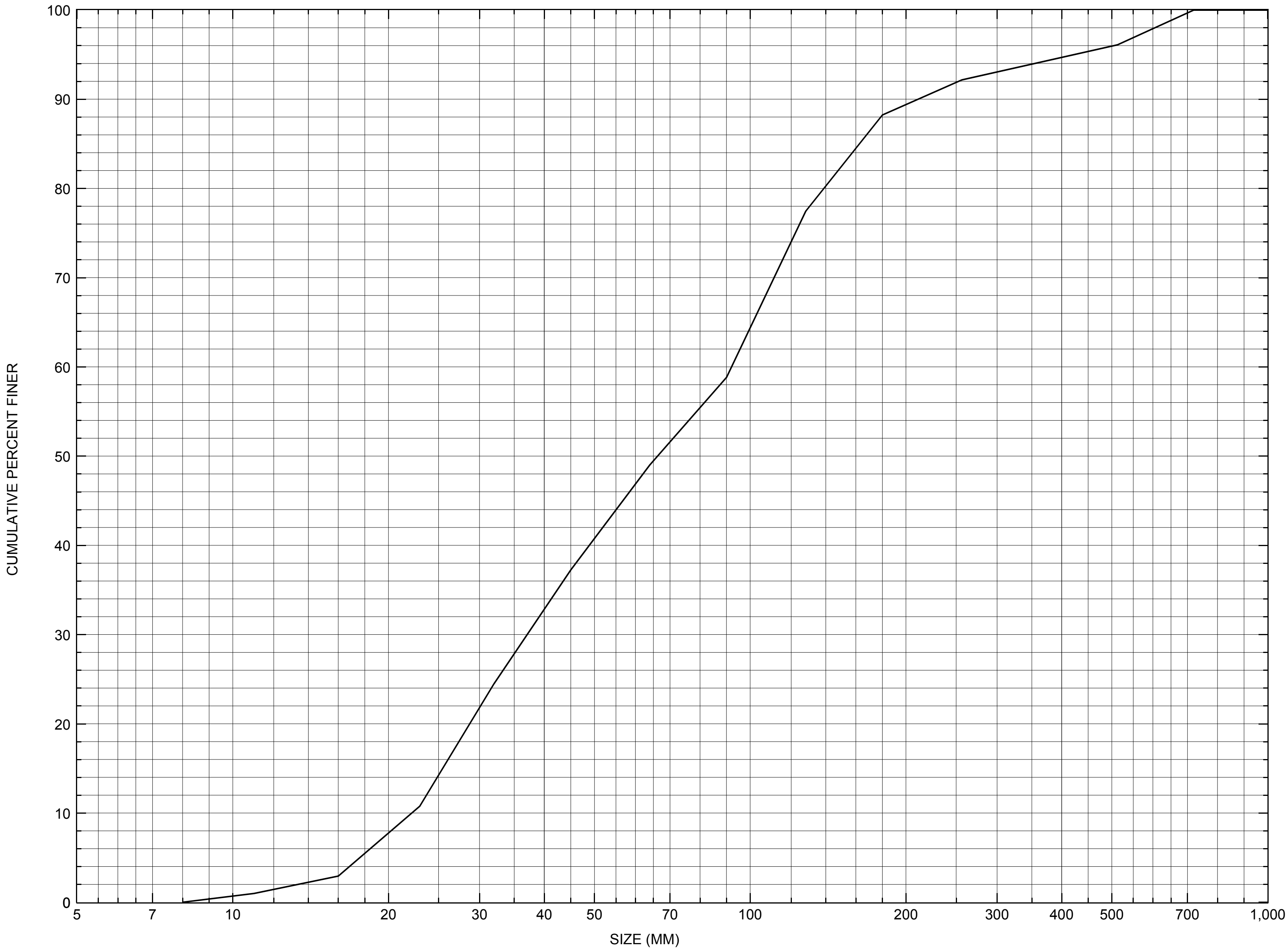
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File spri058.wsp
        Hydraulic analysis for structure SPRITH00060058   Date: 05-JAN-98
        TH 6 CROSSING BALTIMORE BROOK IN SPRINGFIELD, VT          RLB
           *** RUN DATE & TIME: 01-09-98  14:39

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

EXITX:XS   ******    -9.     146.  0.66 *****  493.14  491.12    950.  492.49
      -29. ******    34.    9356.  1.00 ***** *******    0.62    6.51

FULLV:FV      29.    -9.     143.  0.69  0.31  493.48 *******    950.  492.79
        0.    29.    33.    9062.  1.00  0.02    0.01    0.64    6.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      55.    -6.     137.  0.75  0.71  494.23 *******    950.  493.49
       55.    55.    31.    7708.  1.00  0.03    0.02    0.64    6.93
         <<<<<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      29.     1.     100.  1.40  0.33  493.62  491.56    950.  492.22
        0.    29.    24.    8398.  1.00  0.14    0.00    0.79    9.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.31 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      18.    -7.     143.  0.69  0.25  494.33  492.21    950.  493.64
       55.    19.    31.    8121.  1.00  0.48    0.02    0.61    6.65

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.374  0.000    8777.    -2.    21.  493.28

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -29.    -9.    34.    950.    9356.     146.    6.51  492.49
   FULLV:FV       0.    -9.    33.    950.    9062.     143.    6.66  492.79
   BRIDG:BR       0.     1.    24.    950.    8398.     100.    9.48  492.22
   RDWAY:RG      16.**************       0.******************     1.00********
   APPRO:AS      55.    -7.    31.    950.    8121.     143.    6.65  493.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    21.    8777.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD     EGL    WSEL
   EXITX:XS    491.12    0.62  486.86  510.46************  0.66  493.14  492.49
   FULLV:FV  ********    0.64  487.24  510.84  0.31  0.02  0.69  493.48  492.79
   BRIDG:BR    491.56    0.79  487.25  499.64  0.33  0.14  1.40  493.62  492.22
   RDWAY:RG  ****************  500.12  510.92**********************************
   APPRO:AS    492.21    0.61  487.47  510.94  0.25  0.48  0.69  494.33  493.64
```

```
        U.S. Geological Survey WSPRO Input File spri058.wsp
        Hydraulic analysis for structure SPRITH00060058   Date: 05-JAN-98
        TH 6 CROSSING BALTIMORE BROOK IN SPRINGFIELD, VT          RLB
           *** RUN DATE & TIME: 01-09-98  14:39

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

EXITX:XS   ******   -12.     211.  0.87 *****  494.75  492.58   1580.  493.88
      -29. ******    38.   15562.  1.00 ***** *******    0.64    7.50

FULLV:FV      29.   -12.     207.  0.91  0.31  495.09 *******   1580.  494.18
        0.    29.    38.   15162.  1.00  0.02    0.01    0.66    7.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      55.   -19.     198.  1.02  0.73  495.89 *******   1580.  494.87
       55.    55.    35.   12406.  1.03  0.06    0.02    0.75    7.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1580.     493.12

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

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

BRIDG:BR      29.     1.     121.  2.67 *****  495.80  493.12   1580.  493.12
        0.    29.    24.   10980.  1.00 ***** *******    1.00   13.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.31 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.         <<<<<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      18.   -32.     283.  0.54  0.21  496.78  493.67   1580.  496.23
       55.    18.    36.   19693.  1.12  0.77    0.00    0.51    5.59

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.567  0.123   17244.    -2.    21.  496.06

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.   -12.    38.   1580.   15562.     211.    7.50  493.88
   FULLV:FV       0.   -12.    38.   1580.   15162.     207.    7.64  494.18
   BRIDG:BR       0.     1.    24.   1580.   10980.     121.   13.11  493.12
   RDWAY:RG      16.**************      0.*****************     1.00********
   APPRO:AS      55.   -32.    36.   1580.   19693.     283.    5.59  496.23

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    21.   17244.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.58    0.64  486.86  510.46************  0.87  494.75  493.88
   FULLV:FV  ********    0.66  487.24  510.84  0.31  0.02  0.91  495.09  494.18
   BRIDG:BR    493.12    1.00  487.25  499.64************  2.67  495.80  493.12
   RDWAY:RG  ****************  500.12  510.92**********************************
   APPRO:AS    493.67    0.51  487.47  510.94  0.21  0.77  0.54  496.78  496.23
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SPRITH00060058, in Springfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SPRITH00060058

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 07 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 69475

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

Waterway *(I - 6)* BALTIMORE BROOK

Road Name *(I - 7):* -

Route Number TH006

Vicinity *(I - 9)* 0.04 MI TO JCT CL3 TH740

Topographic Map Chester

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43200

Longitude *(i - 17; nnnnn.n)* 72312

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141800581418

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1933

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000800

Deck Width *(I - 52; nn.n)* 286

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 00

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

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

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

Structure type *(I - 43; nnn)* 104

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*) 012.0

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

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

Comments:

The structural inspection report of 09/28/93 indicates the structure is a concrete T-beam type bridge with an asphalt roadway surface. Both abutments are concrete, which have some minor shrinkage cracks and stains reported with some minor scaling along the flow line. The concrete wingwalls, overall, have only minor cracks and stains noted. Just upstream of the right abutment, there is a laid up stone retaining wall. The waterway has a poor alignment with the substructure, and the flow is directed into the upstream end of the left abutment. There is some bank erosion directly upstream of the upstream left wingwall. Also, the streambed has some local scour, apparently down to the top of the abutment footing **(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*): U *If No or Unknown, type ctrl-n os*

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

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

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

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

Comments:
at the upstream end of the left abutment. It does not appear that the footing was ever undermined. The streambed consists of stone and gravel. There are some sand deposits at the upstream end of the right abutment. The stone fill consist of natural stone. Some trees are reported on the left bank of the channel.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **3.60** mi^2 Lake/pond/swamp area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **460** ft Headwater elevation **2092** ft
Main channel length **3.80** mi
10% channel length elevation **520** ft 85% channel length elevation **1080** ft
Main channel slope *(S)* **196.75** 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 BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): - Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **The elevations and stations are in feet. This cross section was part of a 9-28-93 bridge inspection report. The elevation coordinates have been made to match those of this report using the low chord points as line ups.**

Station	0	16	25	-	-	-	-	-	-	-	-
Feature	LAB	-	LAB	-	-	-	-	-	-	-	-
Low chord elevation	498.98	499.21	499.64	-	-	-	-	-	-	-	-
Bed elevation	485.28	487.71	489.24	-	-	-	-	-	-	-	-
Low chord to bed	13.7	11.5	10.4	-	-	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/16/96**
Computerized by: **RB** Date: **10/16/96**
Reviewd by: **RB** Date: **1/9/98**

Structure Number **SPRITH00060058**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. MEDALIE** Date *(MM/DD/YY)* **09** / **23** / 19**96**

2. Highway District Number **02** Mile marker **00000**

County **WINDSOR (027)** Town **SPRINGFIELD (69475)**

Waterway *(I - 6)* **BALTIMORE BROOK** Road Name **-**

Route Number **TH006** Hydrologic Unit Code: **01080106**

3. Descriptive comments:
The bridge is located 0.04 miles from the junction with CL3 TH740, at the intersection with Maple St. on the right bank and 0.02 miles to the junction with Mill Road on the left bank.

B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **2** LBDS **2** RBDS **2** Overall **2**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **28** *(feet)* Span length **25** *(feet)* Bridge width **28.6** *(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)*

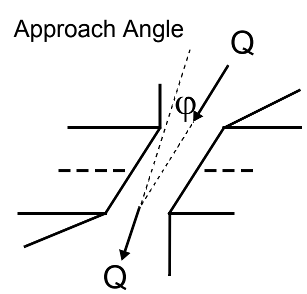
10. Embankment slope (*run / rise in feet / foot*):
US left **2.2:1** US right **6.3:1**

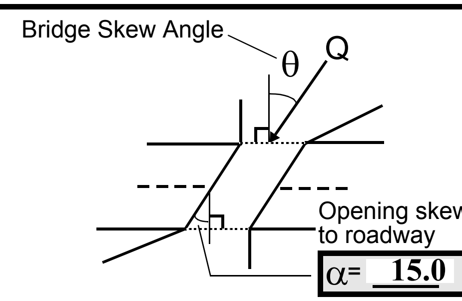
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	1	1	3	1
RBUS	1	1	2	1
RBDS	2	1	0	-
LBDS	2	1	0	-

*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: **20** 16. Bridge skew: **25**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **0** feet **US** *(US, UB, DS)* to **50** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **10** feet **UB** *(US, UB, DS)* to **18** feet **DS**

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

18. Bridge Type: **1a**

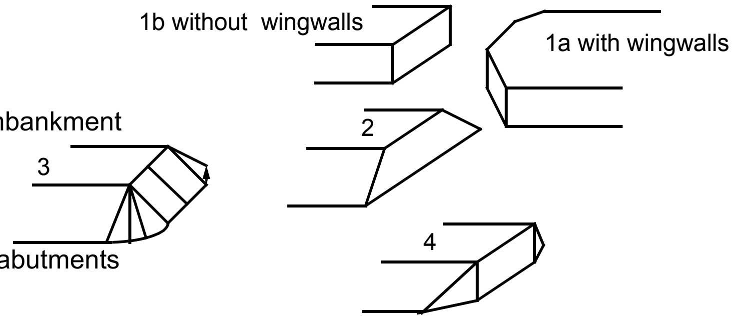
1a- Vertical abutments with wingwalls

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 immediate banks are tree lined except for the DS right bank which just has some shrubs and brush along the bank.

7. Values are from the VTAOT files. Measured bridge length is 27.8 ft, span length is 25 ft, and the bridge width is 31.3 ft between the outsides of the curbs and 24.8 ft between the insides of the curbs.

11. The left bank US protection is gravelly fill between the wingwall and the curb, plus one other larger stone 15 ft to the left of the end of the wingwall. The right bank US protection is also gravel fill behind the wingwall. The DS right and left banks are protected with 9 in. average stones, some larger on the left bank, that is successfully preventing erosion.

17. A third impact zone exists from 120 ft US to 72 ft US. It is on the right bank and has slight severity.

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
35.5	**4.5**			**2.5**	**3**	**3**	**453**	**324**	**3**	**2**

23. Bank width **45.0** 24. Channel width **30.0** 25. Thalweg depth **27.0** 29. Bed Material **543**

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

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.):

28. A large, 2 ft in diameter, tree is torn up and leaning US at a 45 degree angle. The tree root mass is projecting into the stream on the right bank.

30. On the right bank a stone wall extends from the end of the US right wingwall along the same plane as the right abutment out to 44 ft US.

The left bank from the US end of the wingwall to 20 ft US is impacted the most by the flow. Stones have been added for protection, but it is slumped severely.

A stone pile is across the stream at 116 ft US.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **106** 35. Mid-bar width: **8**

36. Point bar extent: **88** feet **US** *(US, UB)* to **123** feet **US** *(US, UB, DS)* positioned **0** %LB to **40** %RB

37. Material: **3**

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

An additional point bar exists from 35 ft US to 10 ft under the bridge. Mid-bar distance is at 25 ft US where it is 25 ft wide. It is positioned from 45% LB to 100% 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: **24** 42. Cut bank extent: **115** feet **US** *(US, UB)* to **20** feet **US** *(US, UB, DS)*

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

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

The cut bank begins at the upstream end of the US left wingwall.

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

A small 4 ft round pool is behind the boulders that are across the channel at 116 ft US. The pool is centered at 118 ft and is 1 ft deep. Average thalweg US is 1 ft.

49. Are there major confluences? **N** *(Y or if N type ctrl-n mc)* 50. How many? **-**

51. Confluence 1: Distance **-** 52. Enters on **-** *(LB or RB)* 53. Type **-** *(**1**- perennial; **2**- ephemeral)*

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** 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
19.0		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.):

342

63. The finer bed material, sand, is at the US end and along the right side of the channel under the bridge. A large black plastic sheet is in the center left of the channel under the bridge and is partially anchored by stones. A second plastic sheet lays on top of the sand partly in the channel from 14 ft US to mid way under the bridge.

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

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

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

70. Debris and Ice Comments:

2

65. Debris is piled along the right bank beginning at the base of the stone wall.

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	1	2	0	90.0
RABUT	1	20	90			0	0	23.5

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.):

-

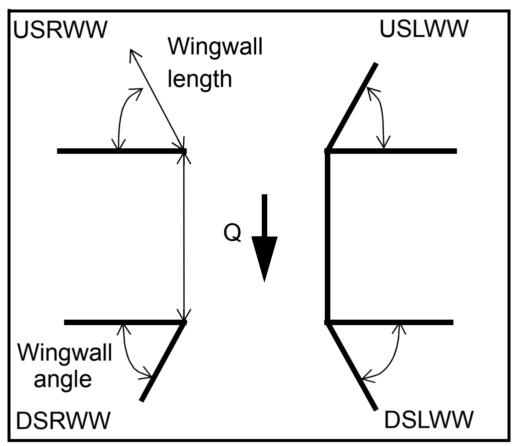
-

1

74. The left abutment scour is a continuation of the scour along the US left wingwall and continues to 8 ft under the bridge measured from the US bridge face. The maximum depth is 2 ft at the corner with the wing-wall.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.5	
USRWW:	Y		1		1	0.5	
DSLWW:	2		0		Y	31.5	
DSRWW:	1		0		-	31.0	



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	-	2	-	-	-
Condition	Y	-	1	-	2	-	-	-
Extent	1	-	0	2	0	0	0	-

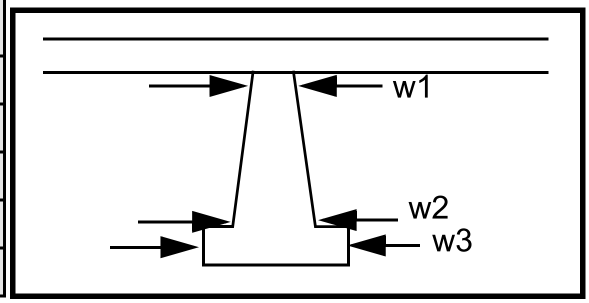
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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				**35.0**	**12.0**	**105.0**
Pier 2	**5.5**			**40.0**	**12.0**	**35.0**
Pier 3		-	-	**11.5**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**At the**	**the**	**ects 5**	**wing-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**US**	**wate**	**ft**	**wall**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**left**	**r**	**into**	**from**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**dept**	**the**	**the**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**h is 3**	**chan**	**cor-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**cor-**	**ft, 2**	**nel**	**ner**	
92. Pushed	**ner**	**ft of**	**and**	**of**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**with**	**scou**	**begi**	**the**	
95. Cross-members	**the**	**r.**	**ns 7**	**left**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**left**	**The**	**ft US**	**abut**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**abut**	**hole**	**alon**	**ment**	
98. Exposure depth	**ment**	**proj-**	**g the**	**.**	

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

The US right wingwall protection is a stone wall that extends US from the end of the wingwall. The DS right wingwall protection is a 3 ft x 4.5 ft x 4 in. concrete block laying horizontally into the channel at the edge with the right abutment.

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.):

-
-
-
-

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

Cut bank extent: RS 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.):

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

Scour dimensions: Length 1 Width 7 Depth: 5 Positioned 0 %LB to 0 %RB

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

345
5
0
1

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? On

Confluence 1: Distance the Enters on left (LB or RB) Type ban (1- perennial; 2- ephemeral)

Confluence 2: Distance k a Enters on ston (LB or RB) Type e (1- perennial; 2- ephemeral)

Confluence comments (eg. confluence name):

wall extends from 17 ft DS to 78 ft DS. Beyond the stone wall the bank is mostly boulders. On the right bank the protection is occasional natural boulders. The right bank is completely covered with vegetation, but it is

F. Geomorphic Channel Assessment

107. Stage of reach evolution all

- *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)*:

shrubs and no trees. A horizontal pipe crosses the channel 9 ft DS from the DS face. It rests on top of two concrete supporting piers at either end. There is no evidence on the metal of the pipe of scarring or staining from water, ice or debris.

109. G. Plan View Sketch

- N

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: SPRITH00060058 Town: SPRINGFIELD
Road Number: TH 6 County: WINDSOR
Stream: BALTIMORE BROOK

Initials RLB Date: 1/7/98 Checked: ECW

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	950	1580	0
Main Channel Area, ft2	143	254	0
Left overbank area, ft2	0	29	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	38	44	0
Top width L overbank, ft	0	24	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.2173	0.2173	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.8	5.8	ERR
y1, average depth, LOB, ft	ERR	1.2	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	8116	19664	0
Conveyance, main channel	8116	18967	0
Conveyance, LOB	0	697	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	950.0	1524.0	ERR
Ql, discharge, LOB, cfs	0.0	56.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	6.6	6.0	ERR
Vl, mean velocity, LOB, ft/s	ERR	1.9	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.4	9.0	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	950	1580	0
(Q) discharge thru bridge, cfs	950	1580	0
Main channel conveyance	8404	10969	0
Total conveyance	8404	10969	0
Q2, bridge MC discharge,cfs	950	1580	ERR
Main channel area, ft2	100	121	0
Main channel width (normal), ft	22.3	22.5	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.3	22.5	0
y_bridge (avg. depth at br.), ft	4.50	5.36	ERR
Dm, median (1.25*D50), ft	0.271625	0.271625	0
y2, depth in contraction,ft	4.48	6.87	ERR
ys, scour depth (y2-ybridge), ft	-0.02	1.52	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	950	1580	N/A
Main channel area (DS), ft2	100.3	120.5	0
Main channel width (normal), ft	22.3	22.5	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	22.3	22.5	0.0
D90, ft	0.6920	0.6920	0.0000
D95, ft	1.3840	1.3840	0.0000
Dc, critical grain size, ft	0.4729	0.8381	ERR
Pc, Decimal percent coarser than Dc	0.188	0.079	0.000
Depth to armoring, ft	6.13	29.31	ERR

Abutment Scour

Froehlich's Abutment Scour

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

(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	950	1580	0	950	1580	0
a', abut.length blocking flow, ft	8.3	33.6	0	7.5	12.1	0
Ae, area of blocked flow ft2	21.74	74.88	0	14.82	37.69	0
Qe, discharge blocked abut.,cfs	76	267.38	0	28.96	72.97	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.50	3.57	ERR	1.95	1.94	ERR
ya, depth of f/p flow, ft	2.62	2.23	ERR	1.98	3.11	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	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.381	0.422	ERR	0.245	0.193	ERR
ys, scour depth, ft	6.88	9.77	N/A	4.83	7.05	N/A

HIRE equation (a'/ya > 25)

$$ys = 4 \cdot Fr^{0.33} \cdot y_1 \cdot K/0.55$$

(Richardson and others, 1995, p. 49, eq. 29)

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
a'(abut length blocked, ft)	8.3	33.6	0	7.5	12.1	0
y1 (depth f/p flow, ft)	2.62	2.23	ERR	1.98	3.11	ERR
a'/y1	3.17	15.08	ERR	3.80	3.88	ERR
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.06	1.06	1.06
Froude no. f/p flow	0.38	0.42	N/A	0.24	0.19	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	0.79	1	0	0.79	1	0
y, depth of flow in bridge, ft	4.50	5.36	0.00	4.50	5.36	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.74	ERR	0.00	1.74	ERR	0.00
Fr>0.8 (vertical abut.)	ERR	2.24	ERR	ERR	2.24	ERR