LEVEL II SCOUR ANALYSIS FOR BRIDGE 26 (WSTOTH00070026) on TOWN HIGHWAY 7, crossing GREENDALE BROOK, WESTON, VERMONT

U.S. Geological Survey
Open-File Report 97-576

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

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By Lora K. Striker and Robert A. Hammond

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Pembroke, New Hampshire

1997

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

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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	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 26 (WSTOTH00070026) ON TOWN HIGHWAY 7, CROSSING GREENDALE BROOK, WESTON, VERMONT

By **Lora K. Striker and Robert A. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WSTOTH00070026 on Town Highway 7 crossing Greendale Brook, Weston, 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 south central Vermont. The 3.13-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the Greendale Brook has a sinuous, non-incised, non-alluvial channel with a slope of approximately 0.015 ft/ft, an average channel top width of 38 ft and an average bank height of 3 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 64.8 mm (0.213 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 19, 1996, indicated that the reach was laterally unstable. The channel has moved to the right, however, scour countermeasures are in place along the upstream right bank.

The Town Highway 7 crossing of the Greendale Brook is a 52-ft-long, two-lane bridge consisting of one 50-foot steel-beam span with a concrete deck (Vermont Agency of Transportation, written communication, April 07, 1995). The opening length of the structure parallel to the bridge face is 48.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 30 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the upstream right wingwall and right abutment during the Level I assessment. Scour protection measures at the site include: type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left wingwall, along the left bank upstream, at the downstream end of the downstream left wing wall, and along the entire length of the downstream right wing wall; type 4 (less than 60 inches) and type-3 stone fill (less than 48 inches) along the right bank upstream. 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). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows was 0.0 ft. Abutment scour ranged from 3.9 to 9.9 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). The Hire equation (abutment scour) is often used when the horizontal length blocked by flow divided by the depth of flow is greater than 25 (Richardson and others, 1995 p. 49). Although the Hire equation could be applied to the left abutment more conservative scour estimates were given by the Froehlich equation on the left abutment. 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.

Weston, VT. Quadrangle, 1:24,000, 1986

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 WSTOTH00070026 ***Stream*** Greendale Brook

County Windsor ***Road*** TH 7 ***District*** 2

Description of Bridge

Bridge length 52 ***ft*** ***Bridge width*** 16.5 ***ft*** ***Max span length*** 50 ***ft***

Alignment of bridge to road (on curve or straight) Right, Curve; Left, Straight

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

Stone fill on abutment? No ***Date of inspection*** 08/19/96

Description of stone fill -

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one to two foot deep scour hole at the upstream right wingwall and along the right abutment.

Y

Is bridge skewed to flood flow according to Sever ***survey?*** ***Angle*** 50 Y

e. There is sediment build up along the left abutment at the bridge blocking 50% of the channel opening at low flows.

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	08/19/96	0	0
Level II	08/20/96	0	0

Potential for debris Moderate. Base of trees and exposed roots along both banks show scars from ice and/or debris impacts.

Describe any features near or at the bridge that may affect flow (include observation date) There is a pointbar that is vegetated along the left bank at the bridge opening that forces flow along the right abutment during low flows.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley, with little or no flood plains and concave natural levees.

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

Date of inspection 08/19/96

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Moderately sloped channel bank to narrow flood plain.

US right: Moderately sloped overbank

Description of the Channel

Average top width 38 ***ft*** ***Average depth*** 3.0 ***ft***

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

Sinuous and laterally unstable with non-alluvial channel boundaries and little to no flood plains.

08/19/96

Vegetative co Trees

DS left: Trees

DS right: Trees

US left: Trees.

US right: N

Do banks appear stable? The left and right banks are cut from the bridge to 250 feet upstream. The channel is migrating to the right at the bridge. There is a cut-bank along the right bank inside bend from 35 to 85 feet downstream.

date of observation.

-

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 3.13 ***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 820 ***ft³/s*** ***Q500*** 1150 ***ft³/s***

The 100- and 500-year discharges are based on the median values of flood frequency curves determined from empirical relationships for Greendale Brook. (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 500.41 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 500.44 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	-52	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	69	2	Modelled Approach section (Templated from APTEM)
APTEM	77	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” value for the reach was 0.065, and overbank “n” value was 0.075.

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 0.015 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.022 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 500.4 *ft*
Average low steel elevation 496.5 *ft*

100-year discharge 820 *ft³/s*
Water-surface elevation in bridge opening 489.8 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 121 *ft²*
Average velocity in bridge opening 6.8 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 492.0
Water-surface elevation at Approach section without bridge 490.4
Amount of backwater caused by bridge 1.6 *ft*

500-year discharge 1150 *ft³/s*
Water-surface elevation in bridge opening 490.4 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 143 *ft²*
Average velocity in bridge opening 8.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 */s*

Water-surface elevation at Approach section with bridge 492.9
Water-surface elevation at Approach section without bridge 491.1
Amount of backwater caused by bridge 1.8 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100- and 500-year discharges were computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in free surface flow. Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will 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 at the left abutment for the 100- and 500-year discharges was also computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29). The HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation. Although scour was calculated using the HIRE equation the scour results reported in figure 8 and tables 1 and 2 are from the Froehlich equation which gives a more conservative estimate for scour at this site.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	1.7	4.2	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	3.9	7.3	--
Right abutment	8.6	9.9	--
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	0.9	1.1	--
Right abutment	0.9	1.1	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

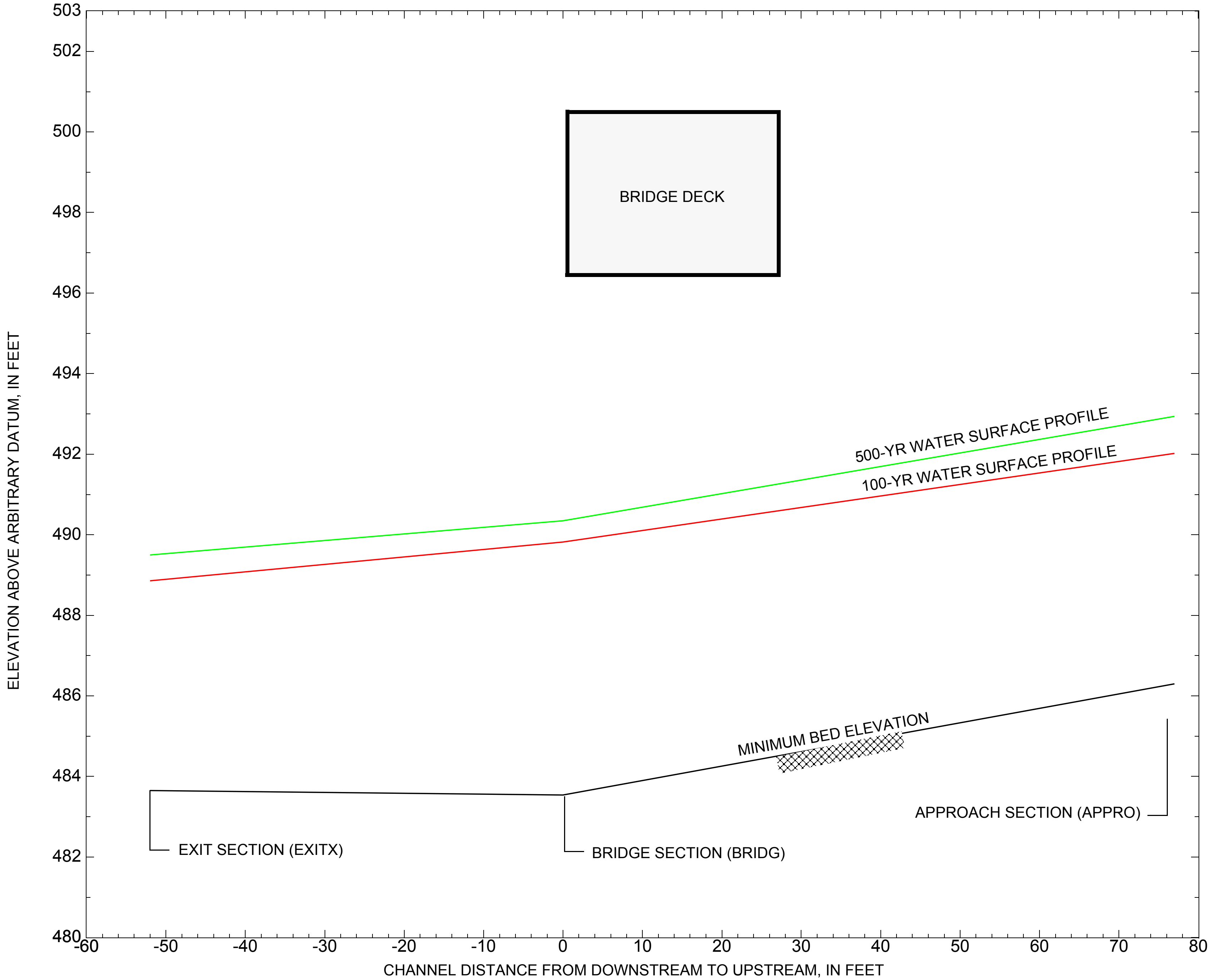

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WSTOTH00070026 on Town Highway 7, crossing Greendale Brook, Weston, Vermont.

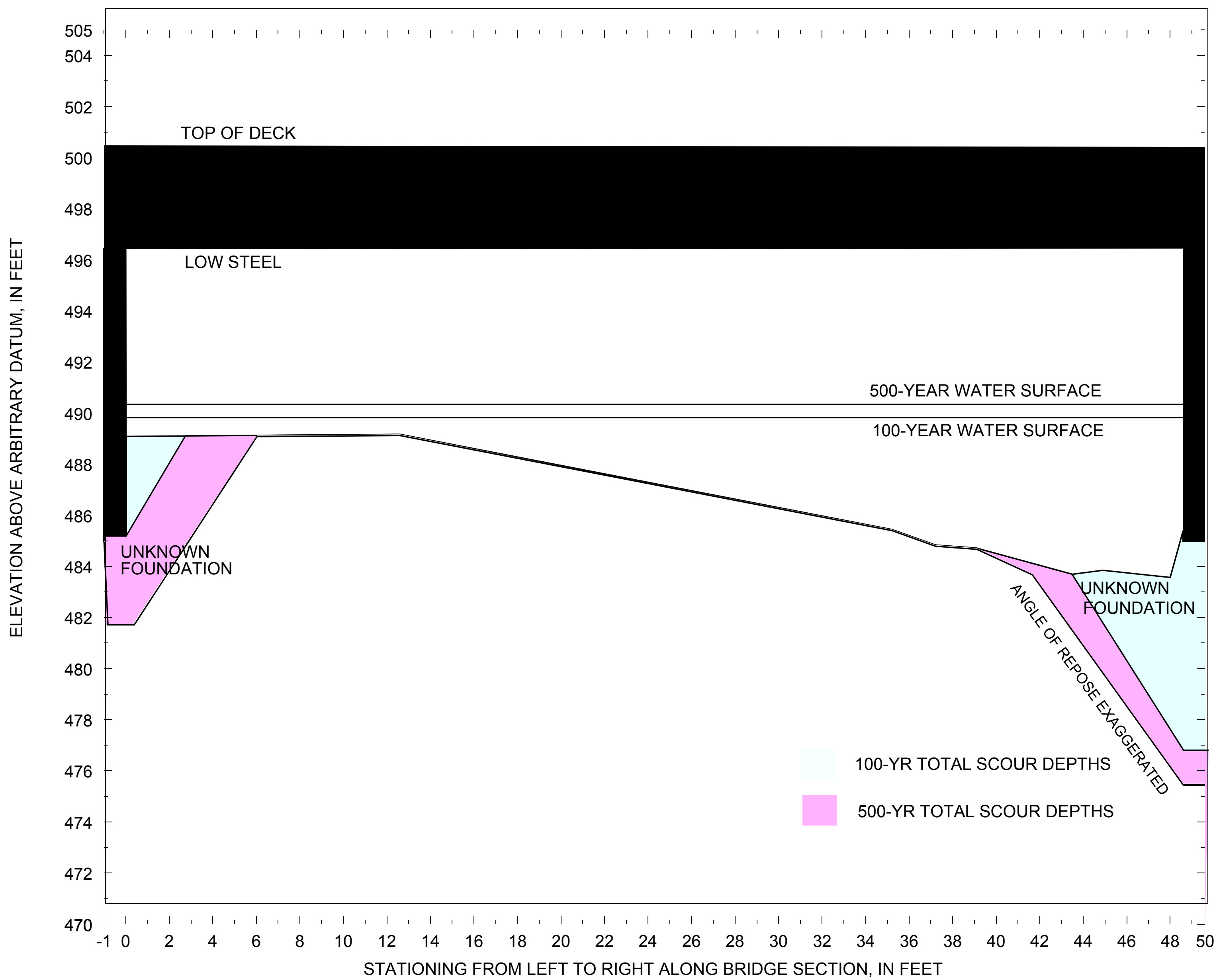

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure WSTOTH00070026 on Town Highway 7, crossing Greendale Brook, Weston, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WSTOTH00070026 on Town Highway 7, crossing Greendale Brook, Weston, 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 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 820 cubic-feet per second											
Left abutment	0.0	--	496.5	--	489.1	0.0	3.9	--	3.9	485.2	--
Right abutment	48.6	--	496.5	--	485.4	0.0	8.6	--	8.6	476.8	--

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-year discharge at structure WSTOTH00070026 on Town Highway 7, crossing Greendale Brook, Weston, 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 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 1150 cubic-feet per second											
Left abutment	0.0	--	496.5	--	489.1	0.0	7.3	--	7.3	481.8	--
Right abutment	48.6	--	496.5	--	485.4	0.0	9.9	--	9.9	475.5	--

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, 1986, Weston, 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 wsto026.wsp
T2        Hydraulic analysis for structure WSTOTH0070026    Date: 06-MAY-97
T3        TH 007 over Greendale Brook located 2.71 miles from junction with VT 1
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            820.0   1150.0
SK          0.0150   0.0150
*
XS   EXITX    -52           0.
GR         -494.0, 501.44   -334.3, 495.15   -246.5, 493.34   -201.3, 491.98
GR         -163.3, 489.90   -102.2, 490.00    -55.5, 490.47
GR            0.0, 487.00      3.8, 484.85     10.9, 484.90     12.2, 484.21
GR           15.2, 483.65     21.6, 484.48     22.6, 484.78     27.0, 487.38
GR           79.1, 491.06    210.9, 495.03    226.6, 494.93
GR          233.9, 494.80    239.8, 498.13
*
N           0.075        0.065      0.075
SA                 0.0          27.0
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.46      30.0
GR            0.0, 496.45      0.1, 489.09     12.6, 489.17     21.2, 487.73
GR           35.2, 485.45     37.2, 484.84     39.1, 484.72     42.1, 483.54
GR           44.9, 483.85     48.0, 483.57     48.3, 485.40     48.6, 496.47
GR            0.0, 496.45
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      26.9      2.2    500.4     60.3
N           0.065
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      16.5     2
GR         -440.3, 502.84   -283.1, 496.14   -194.2, 495.88    -72.4, 499.72
GR            0.0, 500.46     49.1, 500.40    249.0, 495.95    258.2, 495.48
GR          268.6, 495.49    272.2, 498.03    290.9, 502.55
*
*
XT   APTEM     77           0.
GR         -384.1, 501.38   -231.2, 495.40   -148.5, 495.08   -136.6, 492.83
GR         -105.5, 492.00      0.0, 491.42      7.9, 489.73     18.6, 488.90
GR           22.4, 487.51     25.0, 487.17     26.3, 486.85     33.7, 486.48
GR           37.1, 486.74     44.2, 486.99     49.6, 489.45     54.3, 490.55
GR           61.7, 491.11     71.9, 498.23     99.9, 503.03
*
AS   APPRO    69 * * * 0.02192
GT
N           0.075        0.065
SA                   0.0
*
HP 1 BRIDG  489.82 1 489.82
HP 2 BRIDG  489.82 * *  820
HP 1 APPRO  492.02 1 492.02
HP 2 APPRO  492.02 * *  820
*
HP 1 BRIDG  490.35 1 490.35
HP 2 BRIDG  490.35 * * 1150
HP 1 APPRO  492.94 1 492.94
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wsto026.wsp
        Hydraulic analysis for structure WSTOTH0070026    Date: 06-MAY-97
        TH 007 over Greendale Brook located 2.71 miles from junction with VT 1
           *** RUN DATE & TIME: 05-29-97  08:34
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      121      5043     42     49                         1166
   489.82           121      5043     42     49  1.00      0     48     1166

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       489.82     0.1    48.4   120.9    5043.     820.   6.78
X STA.        0.1       19.3       24.2       27.4       29.8       31.8
  A(I)            14.5        9.3        7.7        6.9        6.2
  V(I)            2.83       4.39       5.35       5.91       6.58

X STA.       31.8       33.5       35.0       36.3       37.4       38.5
  A(I)             5.8        5.4        5.2        4.9        4.6
  V(I)            7.02       7.55       7.95       8.42       8.96

X STA.       38.5       39.5       40.5       41.3       42.1       42.9
  A(I)             4.6        4.4        4.3        4.2        4.2
  V(I)            8.96       9.25       9.45       9.74       9.81

X STA.       42.9       43.7       44.5       45.5       46.5       48.4
  A(I)             4.2        4.5        4.8        5.6        9.6
  V(I)            9.73       9.20       8.54       7.31       4.29

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      69.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       52       615    113    113                          200
             2      219     11272     63     65                         2307
   492.02           271     11887    176    178  1.31   -112     63     1663

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      69.
         WSEL     LEW     REW    AREA        K        Q    VEL
       492.02  -112.8    63.3   270.6   11887.     820.   3.03
X STA.     -112.8       -2.6        9.8       14.9       19.0       21.9
  A(I)            49.9       19.7       14.3       12.9       11.8
  V(I)            0.82       2.08       2.86       3.18       3.49

X STA.       21.9       24.1       26.0       27.8       29.5       31.2
  A(I)            10.3        9.8        9.5        9.4        9.2
  V(I)            3.98       4.18       4.32       4.38       4.45

X STA.       31.2       32.8       34.4       36.0       37.7       39.6
  A(I)             9.0        9.1        9.4        9.2        9.9
  V(I)            4.56       4.52       4.38       4.43       4.14

X STA.       39.6       41.4       43.4       45.8       49.7       63.3
  A(I)             9.8       10.6       11.9       14.0       20.9
  V(I)            4.18       3.88       3.44       2.93       1.96
```

```
        U.S. Geological Survey WSPRO Input File wsto026.wsp
        Hydraulic analysis for structure WSTOTH0070026    Date: 06-MAY-97
        TH 007 over Greendale Brook located 2.71 miles from junction with VT 1
           *** RUN DATE & TIME: 05-29-97  08:34
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      143      6585     42     50                         1501
   490.35           143      6585     42     50  1.00      0     48     1501

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       490.35     0.1    48.4   143.1    6585.    1150.   8.04
X STA.         0.1       13.7       20.5       24.3       27.1       29.4
  A(I)            14.4       11.3        9.2        8.2        7.4
  V(I)            3.99       5.07       6.26       7.03       7.73

X STA.        29.4       31.3       33.0       34.5       35.9       37.1
  A(I)             6.9        6.4        6.2        6.0        5.7
  V(I)            8.30       8.92       9.33       9.64      10.15

X STA.        37.1       38.3       39.4       40.4       41.4       42.2
  A(I)             5.4        5.3        5.4        5.2        5.1
  V(I)           10.65      10.83      10.70      10.98      11.35

X STA.        42.2       43.1       44.1       45.1       46.3       48.4
  A(I)             5.2        5.4        5.8        6.7       11.8
  V(I)           11.09      10.56       9.91       8.59       4.86

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      69.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      170      3888    138    138                         1073
             2      277     16494     65     66                         3263
   492.94           448     20382    203    205  1.43   -137     65     3160

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      69.
         WSEL     LEW     REW    AREA        K        Q    VEL
       492.94  -138.1    64.6   447.7   20382.    1150.   2.57
X STA.      -138.1      -78.6      -45.4      -19.1        2.8       10.3
  A(I)            54.0       44.9       39.8       37.0       23.0
  V(I)            1.06       1.28       1.44       1.56       2.50

X STA.        10.3       15.3       19.6       22.8       25.3       27.6
  A(I)            18.8       18.0       16.1       15.0       14.2
  V(I)            3.06       3.20       3.58       3.83       4.06

X STA.        27.6       29.8       31.9       34.0       36.2       38.4
  A(I)            14.0       13.8       13.9       14.0       14.3
  V(I)            4.10       4.16       4.13       4.11       4.03

X STA.        38.4       40.8       43.3       46.3       51.3       64.6
  A(I)            14.9       15.6       17.3       20.5       28.6
  V(I)            3.86       3.69       3.31       2.81       2.01
```

WSPRO OUTPUT FILE (continued)

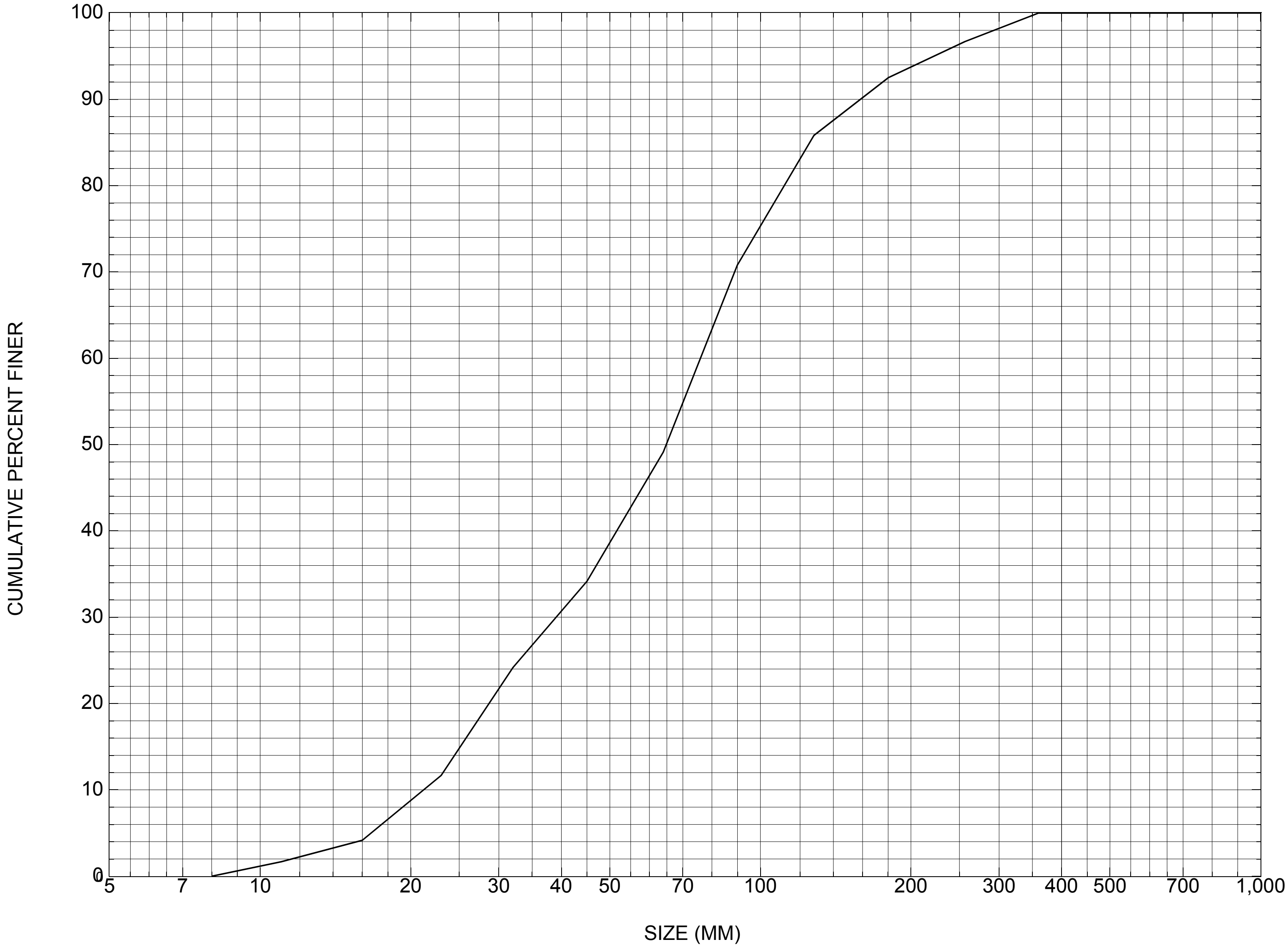
```
        U.S. Geological Survey WSPRO Input File wsto026.wsp
        Hydraulic analysis for structure WSTOTH0070026    Date: 06-MAY-97
        TH 007 over Greendale Brook located 2.71 miles from junction with VT 1
           *** RUN DATE & TIME: 05-29-97  08:34

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

EXITX:XS   ******    -29      150  0.64 *****  489.50  488.20     820  488.86
       -51 ******     48     6690  1.38 ***** *******    0.81    5.46

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.54
FULLV:FV       52    -42      224  0.31  0.51  490.00 *******     820  489.68
         0     52     60    10310  1.52  0.00   -0.01    0.54    3.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  0.48

APPRO:AS       69      4      122  0.70  0.91  491.11 *******     820  490.41
        69     69     55     4938  1.00  0.19    0.01    0.77    6.72
         <<<<<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       52      0      121  0.71  1.04  490.54  488.90     820  489.82
         0     52     48     5047  1.00  0.00    0.00    0.70    6.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  496.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       42   -112      271  0.19  0.47  492.21  489.94     820  492.02
        69     42     63    11892  1.31  1.20    0.00    0.49    3.03

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.051  0.192    9640.    -6.    43.   491.77

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS    -52.   -30.    48.    820.    6690.     150.    5.46  488.86
   FULLV:FV      0.   -43.    60.    820.   10310.     224.    3.65  489.68
   BRIDG:BR      0.     0.    48.    820.    5047.     121.    6.78  489.82
   RDWAY:RG     13.**************      0.******************    2.00********
   APPRO:AS     69.  -113.    63.    820.   11892.     271.    3.03  492.02

  SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    488.20    0.81  483.65  501.44************  0.64  489.50  488.86
   FULLV:FV  ********    0.54  483.65  501.44  0.51  0.00  0.31  490.00  489.68
   BRIDG:BR    488.90    0.70  483.54  496.47  1.04  0.00  0.71  490.54  489.82
   RDWAY:RG  ****************  495.48  502.84**********************************
   APPRO:AS    489.94    0.49  486.30  502.85  0.47  1.20  0.19  492.21  492.02
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wsto026.wsp
        Hydraulic analysis for structure WSTOTH0070026    Date: 06-MAY-97
        TH 007 over Greendale Brook located 2.71 miles from junction with VT 1
           *** RUN DATE & TIME: 05-29-97  08:34
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -39      206  0.72 *****  490.22  488.97    1150  489.50
       -51 ******     57     9383  1.49 ***** *******    0.83    5.59

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.48
FULLV:FV       52   -171      337  0.38  0.53  490.75 *******    1150  490.37
         0     52     69    13880  2.08  0.00    0.00    0.72    3.42
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.50
APPRO:AS       69      1      162  0.79  0.94  491.90 *******    1150  491.11
        69     69     62     6981  1.00  0.20    0.00    0.77    7.11
         <<<<<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       52      0      143  1.00  1.11  491.36  489.80    1150  490.35
         0     52     48     6598  1.00  0.02    0.00    0.77    8.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  496.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       42   -137      448  0.15  0.42  493.09  490.57    1150  492.94
        69     43     65    20425  1.43  1.32    0.00    0.36    2.56

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.212  0.305   14167.    -5.    44.   492.78
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW      Q       K     AREA     VEL    WSEL
   EXITX:XS     -52.   -40.    57.   1150.    9383.    206.    5.59  489.50
   FULLV:FV       0.  -172.    69.   1150.   13880.    337.    3.42  490.37
   BRIDG:BR       0.     0.    48.   1150.    6598.    143.    8.03  490.35
   RDWAY:RG      13.**************      0.*****************    2.00********
   APPRO:AS      69.  -138.    65.   1150.   20425.    448.    2.56  492.94

  SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    488.97    0.83  483.65  501.44************  0.72  490.22  489.50
   FULLV:FV  ********    0.72  483.65  501.44  0.53  0.00  0.38  490.75  490.37
   BRIDG:BR    489.80    0.77  483.54  496.47  1.11  0.02  1.00  491.36  490.35
   RDWAY:RG  ****************  495.48  502.84**********************************
   APPRO:AS    490.57    0.36  486.30  502.85  0.42  1.32  0.15  493.09  492.94
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WSTOTH00070026, in Weston, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WSTOTH00070026

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)* 82000

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

Waterway *(I - 6)* GREENDALE BROOK

Road Name *(I - 7):* -

Route Number TH007

Vicinity *(I - 9)* 2.71 MI TO JCT W VT100

Topographic Map Weston

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43208

Longitude *(i - 17; nnnnn.n)* 72489

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142100261421

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

Maximum span length *(I - 48; nnnn)* 0050

Year built *(I - 27; YYYY)* 1940

Structure length *(I - 49; nnnnnn)* 000052

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 165

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

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

Opening skew to Roadway *(I - 34; nn)* 30

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 010.0

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

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

Comments:

The structural inspection report of 09/16/93 indicates states that the structure is a single span, steel beam type bridge with a bare concrete deck. Both abutments are concrete, and have minor hairline cracks and stains reported. The right abutment footing is exposed along the upstream end but is not undermined. The waterway takes a moderate to sharp turn into the skewed structure. All of the flow is along the right abutment. There is boulder fill placed along the upstream right abutment side. The footing along the left abutment is not in view, due to a gravel point bar with vegetation growth. The banks upstream are well protected from erosion.

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:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 3.13 mi^2 Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1654 ft Headwater elevation 2815 ft

Main channel length 2.36 mi

10% channel length elevation 1693 ft 85% channel length elevation 2264 ft

Main channel slope *(S)* 322.81 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

There is no benchmark elevation data available.

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

There is no foundation material information available.

Comments:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **There is no cross section information available.**

-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **There is no cross section information available.**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/3/96**
Computerized by: **EW** Date: **10/3/96**
Reviewd by: **LKS** Date: **05/20/97**

Structure Number **WSTOTH00070026**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **08** / **19** / 19**96**

2. Highway District Number **02** Mile marker **000000**
   County **WINDSOR 027** Town **WESTON 82000**
   Waterway *(I - 6)* **GREENDALE BROOK** Road Name **-**
   Route Number **TH007** Hydrologic Unit Code: **01080107**

3. Descriptive comments:
The bridge is located 2.71 miles from junction with VT 100, and 0.5 miles upstream of the junction with a road along Jenny Collidge Brook.

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **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 **52** *(feet)* Span length **50** *(feet)* Bridge width **16.5** *(feet)*

Road approach to bridge:

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

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

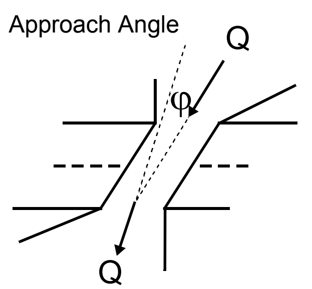
10. Embankment slope (*run / rise in feet / foot*):
US left **2.1:1** US right **2.3:1**

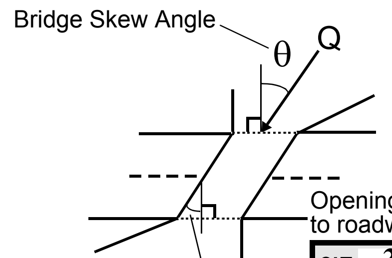
	Protection 11.Type	Protection 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: **10** 16. Bridge skew: **50**





Opening skew to roadway α= **30.0**

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

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **0**
Range? **30** feet **DS** *(US, UB, DS)* to **100** feet **DS**

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

18. Bridge Type: **4**

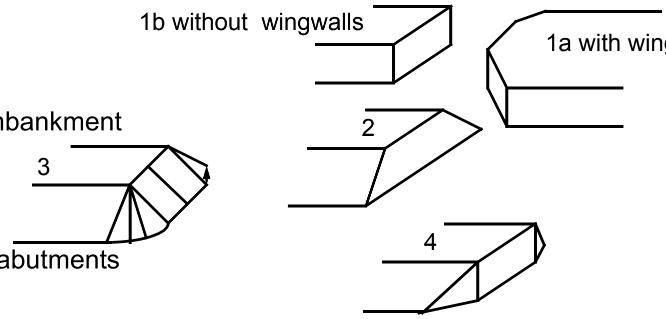
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#7: Measured bridge length = 51.4 feet; bridge span = 49.4 feet; road width = 14 feet and bridge width = 16.5 feet.

#8: Road is even on both approaches for 75 feet, then dips below bridge deck.

#15/ 16: Based on general channel path the ambient channel meanders from side to side throughout the reach.

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
47.5	4.0			2.5	4	4	123	123	2	2

23. Bank width **10.0** 24. Channel width **25.0** 25. Thalweg depth **48.0** 29. Bed Material **453**

30 .Bank protection type: LB **2** RB **43** 31. Bank protection condition: LB **1** 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: Moderate bank erosion extends along both banks from at least 250 feet upstream to 5 feet upstream. The most severely eroded area is at 175 feet upstream. Bank erosion is result of medium to bank full flows.

Drop structures, logs placed in V configuration by the Forest Service to make pools for fish to habitat, are located at 72 feet upstream and 225 feet upstream of the bridge.

The point bar acts as the left bank, during the time of inspection and other low flows.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **1 US** 35. Mid-bar width: **20**

36. Point bar extent: **40** feet **US** (US, UB) to **25** feet **DS** (US, UB, DS) positioned **0** %LB to **50** %RB

37. Material: **345**

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

The point bar is vegetated with brush and small diameter trees upstream and downstream of the bridge. Underneath the bridge the vegetation is annual. The sediment that comprises the pointbar under the bridge is loose and unconsolidated. Another point bar, composed of gravel and cobbles, exists from 185 feet upstream to 115 feet upstream. It is 15 feet wide at 135 feet upstream. The point bar is positioned 0% LB to 40% RB.

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

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

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

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

There are no cut-banks upstream at this bridge.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **10 UB**

47. Scour dimensions: Length **30** Width **7** Depth : **1.5** Position **80** %LB to **100** %RB

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

The scour hole extends from 0 feet upstream to 10 feet downstream.

There is also local scour 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):

There are no major confluences upstream at this site.

D. Under Bridge Channel Assessment

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

56. Height (BF) 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
22.0		0.5		2	7	7	-

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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

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 2____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

The base of trees and exposed roots show scars from ice and/ or debris impact.

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		-	90	2	0	-	-	90.0
RABUT	1	30	90			2	2	42.0

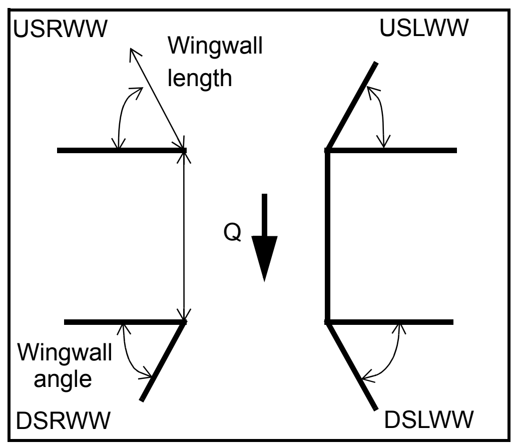
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

1.5
0.1
1
#76: Scour is about 0.1 feet below top of footing.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						42.0	
USRWW:	Y		1		0	2.0	
DSLWW:	-		-		Y	27.0	
DSRWW:	1		2		1.5	27.0	



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	0.1	0		-	1	1	-	-
Condition	Y	-	1	-	2	2	-	-
Extent	1	-	0	2	4	0	0	-

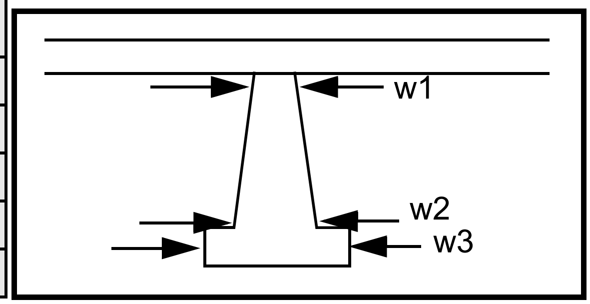
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
2
1
1

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				**30.0**	**24.0**	**90.0**
Pier 2				**15.0**	**90.0**	**14.5**
Pier 3			**-**	**30.0**	**24.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**: Scour**	**r ends**	**the**	**act as**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**is**	**at**	**USR**	**a**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**abou**	**RAB**	**WW**	**wall**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**t 0.1**	**UT**	**area,**	**in**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**feet**	**junc-**	**place**	**front**	*Y- yes; N- no*
91. Attack ∠ (BF)	**belo**	**tion**	**d**	**of**	
92. Pushed	**w**	**with**	**boul-**	**and**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**top**	**DSR**	**ders**	**at**	
95. Cross-members	**of**	**WW.**	**in**	**the**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**foot-**		**impa**	**end**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**ing.**	**#82:**	**ct**	**of**	
98. Exposure depth	**Scou**	**In**	**zone**	**the**	

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

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 (Amb) - Thalweg depth (Amb) - 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.):

-
-
-There are 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.):

4
4
453
543

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

Scour dimensions: Length **345** Width **0** Depth: **0** Positioned - %LB to - %RB

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

The right bank has moderate erosion from 35 feet downstream to 85 feet downstream. The most severely eroded section is 40 feet downstream. This part of the right bank is on the inside of a 90 degree bend in the channel.
There is also a major bend in channel 235 feet downstream.

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)*:

Y

4

The drop structure is formed by two logs placed in a V configuration. The Forest Service has placed logs in a similar V configuration throughout the stream in order to create a stable environment for fish.

Y

65

8

50

DS

109. G. Plan View Sketch

- 85

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:	WSTOTH00070026	Town:	WESTON
Road Number:	TH 007	County:	WINDSOR
Stream:	GREENDALE BROOK		

Initials LKS Date: 05/08/97 Checked: SAO

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	820	1150	0
Main Channel Area, ft2	219	277	0
Left overbank area, ft2	52	170	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	63	65	0
Top width L overbank, ft	113	138	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.21275	0.21275	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.5	4.3	ERR
y1, average depth, LOB, ft	0.5	1.2	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	11887	20382	0
Conveyance, main channel	11272	16494	0
Conveyance, LOB	615	3888	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	777.6	930.6	ERR
Ql, discharge, LOB, cfs	42.4	219.4	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	3.6	3.4	ERR
Vl, mean velocity, LOB, ft/s	0.8	1.3	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.2	8.5	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	820	1150	0
(Q) discharge thru bridge, cfs	820	1150	0
Main channel conveyance	5043	6585	0
Total conveyance	5043	6585	0
Q2, bridge MC discharge,cfs	820	1150	ERR
Main channel area, ft2	121	143	0
Main channel width (normal), ft	42.1	42.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.1	42.1	0
y_bridge (avg. depth at br.), ft	2.87	3.40	ERR
Dm, median (1.25*D50), ft	0.265938	0.265938	0
y2, depth in contraction,ft	2.30	3.08	ERR
ys, scour depth (y2-ybridge), ft	-0.57	-0.32	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	820	1150	N/A
Main channel area (DS), ft2	121	143	0
Main channel width (normal), ft	42.1	42.1	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	42.1	42.1	0.0
D90, ft	0.5917	0.5917	0.0000
D95, ft	0.7295	0.7295	0.0000
Dc, critical grain size, ft	0.2778	0.3611	ERR
Pc, Decimal percent coarser than Dc	0.330	0.206	0.000
Depth to armoring, ft	1.69	4.18	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)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	820	1150	0	820	1150	0
a', abut.length blocking flow, ft	112.8	138.1	0	21.2	22.5	0
Ae, area of blocked flow ft2	54.03	170.97	0	53.69	73.89	0
Qe, discharge blocked abut.,cfs	49.6	222.65	0	149.65	200.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.92	1.30	ERR	2.79	2.71	ERR
ya, depth of f/p flow, ft	0.48	1.24	ERR	2.53	3.28	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	40	40	40	140	140	140
K2	0.90	0.90	0.90	1.06	1.06	1.06
Fr, froude number f/p flow	0.234	0.206	ERR	0.309	0.263	ERR
ys, scour depth, ft	3.94	7.25	N/A	8.61	9.85	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)	112.8	138.1	0	21.2	22.5	0
y1 (depth f/p flow, ft)	0.48	1.24	ERR	2.53	3.28	ERR
a'/y1	235.50	111.55	ERR	8.37	6.85	ERR
Skew correction (p. 49, fig. 16)	0.72	0.72	0.72	1.00	1.00	1.00
Froude no. f/p flow	0.23	0.21	N/A	0.31	0.26	N/A
Ys w/ corr. factor K1/0.55:						
vertical	1.56	3.87	ERR	ERR	ERR	ERR
vertical w/ ww's	1.28	3.17	ERR	ERR	ERR	ERR
spill-through	0.86	2.13	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.7	0.77	0	0.7	0.77	0
y, depth of flow in bridge, ft	2.87	3.04	0.00	2.87	3.04	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.87	1.11	0.00	0.87	1.11	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	0.76	0.97	0.00	0.76	0.97	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR