LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (PLYMTH00080037) on TOWN HIGHWAY 8, crossing BROAD BROOK, PLYMOUTH, VERMONT

Open-File Report 98-556

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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By EMILY C. WILD and LAURA MEDALIE

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Pembroke, New Hampshire

1998

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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 37 (PLYMTH00080037) ON TOWN HIGHWAY 8, CROSSING BROAD BROOK, PLYMOUTH, VERMONT

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

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PLYMTH00080037 on Town Highway 8 crossing Broad Brook, Plymouth, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gathered 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 5.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and downstream of the bridge.

In the study area, Broad Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 46 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 87.5 mm (0.287 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 3, 1995, indicated that the reach was laterally unstable due to cut-banks present on the upstream left bank and the downstream left and right banks.

The Town Highway 8 crossing of Broad Brook is a 31-ft-long, one-lane bridge consisting of a 28-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 27.0 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

During the Level I assessment, it was observed that the left abutment footing was exposed 1.25 ft at the downstream end, and the subfooting was exposed 1 ft. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream right wingwall, the right abutment and the downstream right wingwall. Type-2 stone fill (less than 36 inches diameter) was along the upstream left wingwall, the upstream end of the left abutment and the downstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. 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 0.5 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Left abutment scour ranged from 11.1 to 12.0 ft. Right abutment scour ranged from 3.0 to 7.7 ft. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 6.2 to 7.1 ft. The worst-case pier scour also 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 PLYMTH00080037 ***Stream*** Broad Brook

County Windsor ***Road*** TH 8 ***District*** 3

Description of Bridge

Bridge length 31 ***ft*** ***Bridge width*** 12.8 ***ft*** ***Max span length*** 28 ***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*** 10/3/95

Description of stone fill Type-1, along the upstream right wingwall, the right abutment and the downstream right wingwall. Type-2, along the upstream left wingwall, the upstream end of the left abutment and the downstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. The left abutment footing was exposed 1.25 ft and the subfooting was exposed 1 ft at the downstream end during the site visit.

Yes 15

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

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	10/3/95	0	0
Level II	10/3/95	0	0

Potential for debris High. There is some debris in the channel at the bridge.

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

There is a bent-type pier made of wood, located approximately in the center of the channel, as observed on 10/3/95.

Description of the Geomorphic Setting

General topography The channel is located within a narrow flood plain with steep valley walls on both sides.

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

Date of inspection 10/3/95

DS left: Steep channel bank to a narrow flood plain and a steep valley wall

DS right: Narrow flood plain to a steep valley wall

US left: Steep channel bank to a moderately sloped overbank

US right: Narrow flood plain to a steep valley wall

Description of the Channel

Average top width 46 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Gravel and Cobbles ***Bank material*** Sand and Boulders

Sinuous and laterally unstable with non-alluvial channel boundaries and wide point bars.

10/3/95

Vegetative co[...] Trees, brush and Town Highway 8

DS left: Trees and brush

DS right: Trees and brush

US left: Trees, brush and Town Highway 8

US right:

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

There are cut-banks on the left and right banks and on the downstream right bank.

None, 10/3/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.6 ***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***: None

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 1,480 ***ft³/s*** ***Q500*** 2,200 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.6/6.2)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 38 in Plymouth. Bridge number 38 crosses the Broad Brook downstream of this site and has a drainage area above of 6.2 square miles. These area adjusted values were within a range defined by flood frequency curves derived 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 a boulder on the downstream right overbank, 20 ft from the right abutment (elev. 500.57 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 498.73 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPR1	42	2	Modelled Approach section (Templated from APTEM)
APTEM	49	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 0.050 to 0.055, and overbank "n" values ranged from 0.055 to 0.065.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0214 ft/ft, which was estimated from the appropriate topographic map (U.S. Geological Survey, 1966).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0066 ft/ft) to establish the modelled approach section (APPR1), 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 incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing the supercritical and subcritical profiles for the incipient-overtopping discharge, it can be 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 499.9 *ft*
Average low steel elevation 498.6 *ft*

100-year discharge 1,480 *ft³/s*
Water-surface elevation in bridge opening 498.6 *ft*
Road overtopping? Yes *Discharge over road* 163 *ft³/s*
Area of flow in bridge opening 183 *ft²*
Average velocity in bridge opening 7.2 *ft/s*
Maximum WSPRO tube velocity at bridge 11.1 *ft/s*

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 2.8 *ft*

500-year discharge 2,200 *ft³/s*
Water-surface elevation in bridge opening 498.6 *ft*
Road overtopping? Yes *Discharge over road* 663 *ft³/s*
Area of flow in bridge opening 183 *ft²*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 13.3 *ft/s*

Water-surface elevation at Approach section with bridge 500.4
Water-surface elevation at Approach section without bridge 498.0
Amount of backwater caused by bridge 2.4 *ft*

Incipient overtopping discharge 1,290 *ft³/s*
Water-surface elevation in bridge opening 495.7 *ft*
Area of flow in bridge opening 109 *ft²*
Average velocity in bridge opening 11.8 *ft/s*
Maximum WSPRO tube velocity at bridge 14.5 *ft/s*

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 496.5
Amount of backwater caused by bridge 1.4 *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 incipient roadway-overtopping discharge, which resulted in free-surface flow, was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100-year and 500-year discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Contraction scour for the 100-year and 500-year discharges, which resulted in unsubmerged orifice flow, was also computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in appendix F.

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

The length to depth ratio of the embankment blocking flow exceeded 25 for the right abutment for each modeled discharge. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Since the equation was developed from U.S. Army Corps. of Engineers' data obtained for spur dikes in the Mississippi River, the HIRE equation results were not accepted for the narrow, incised, upland valley at this site.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and Davis, 1995, p. 36, eq. 21). Variables for the equation include: pier length, pier width, approach velocity and correction factors for pier shape, flow attack angle, streambed condition, streambed armoring, and average depth and maximum velocity (for the Froude number) immediately upstream of the bridge.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.5
Depth to armoring	12.6 6.1	N/A	--
Left overbank	--	--	--
Right overbank	--	--	11.1

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	12.0	11.2	3.0
Right abutment	7.7	5.0	6.2
Pier scour			
Pier 1	7.1	6.9	--
Pier 2	--	--	--
Pier 3	--	--	1.9

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	2.0	1.8	1.9
Right abutment	2.0	1.8	2.0
Piers:	2.8	4.2	--
Pier 1	--	--	--
Pier 2	--	--	

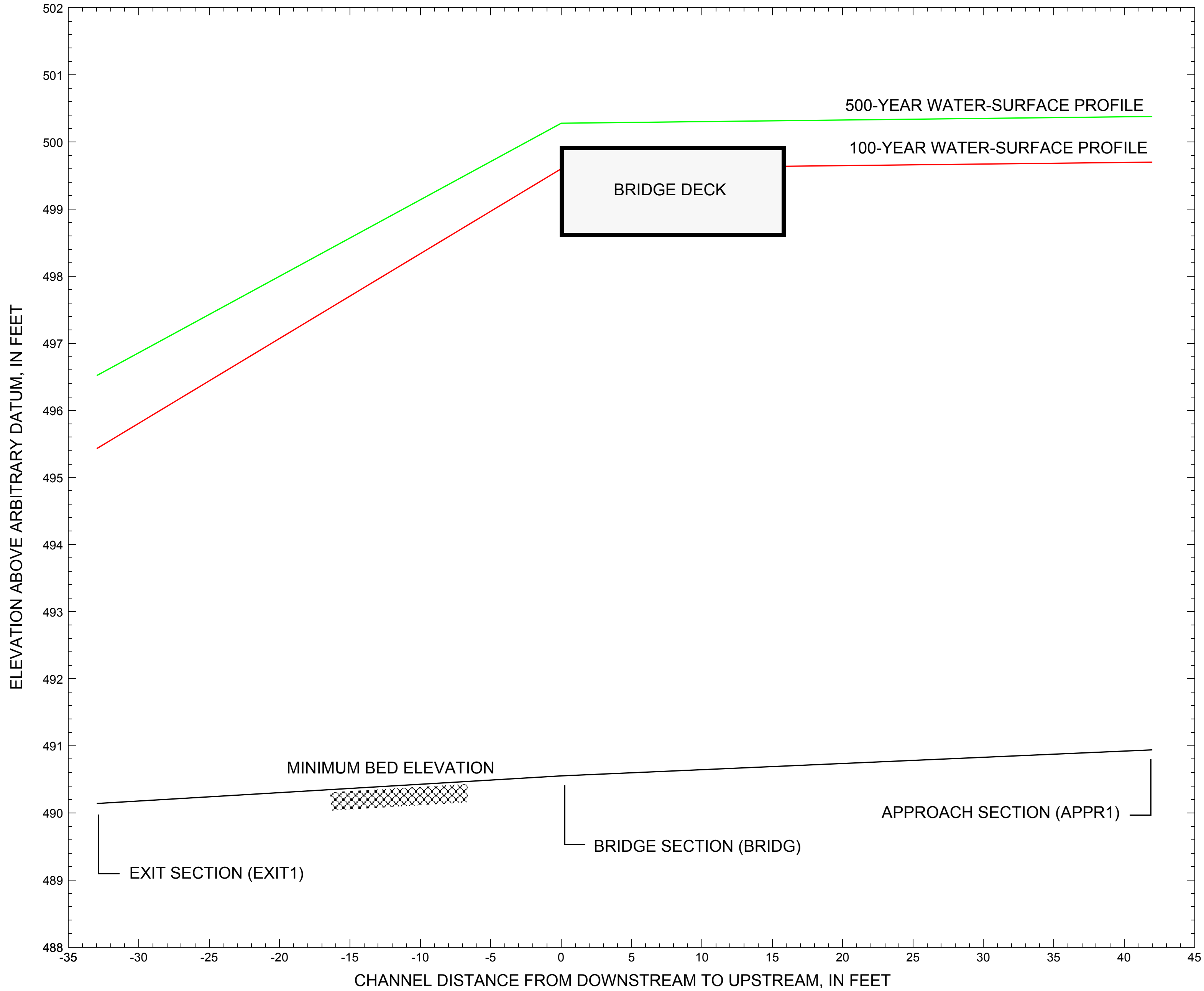

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure PLYMTH00080037 on Town Highway 8, crossing Broad Brook, Plymouth, Vermont.

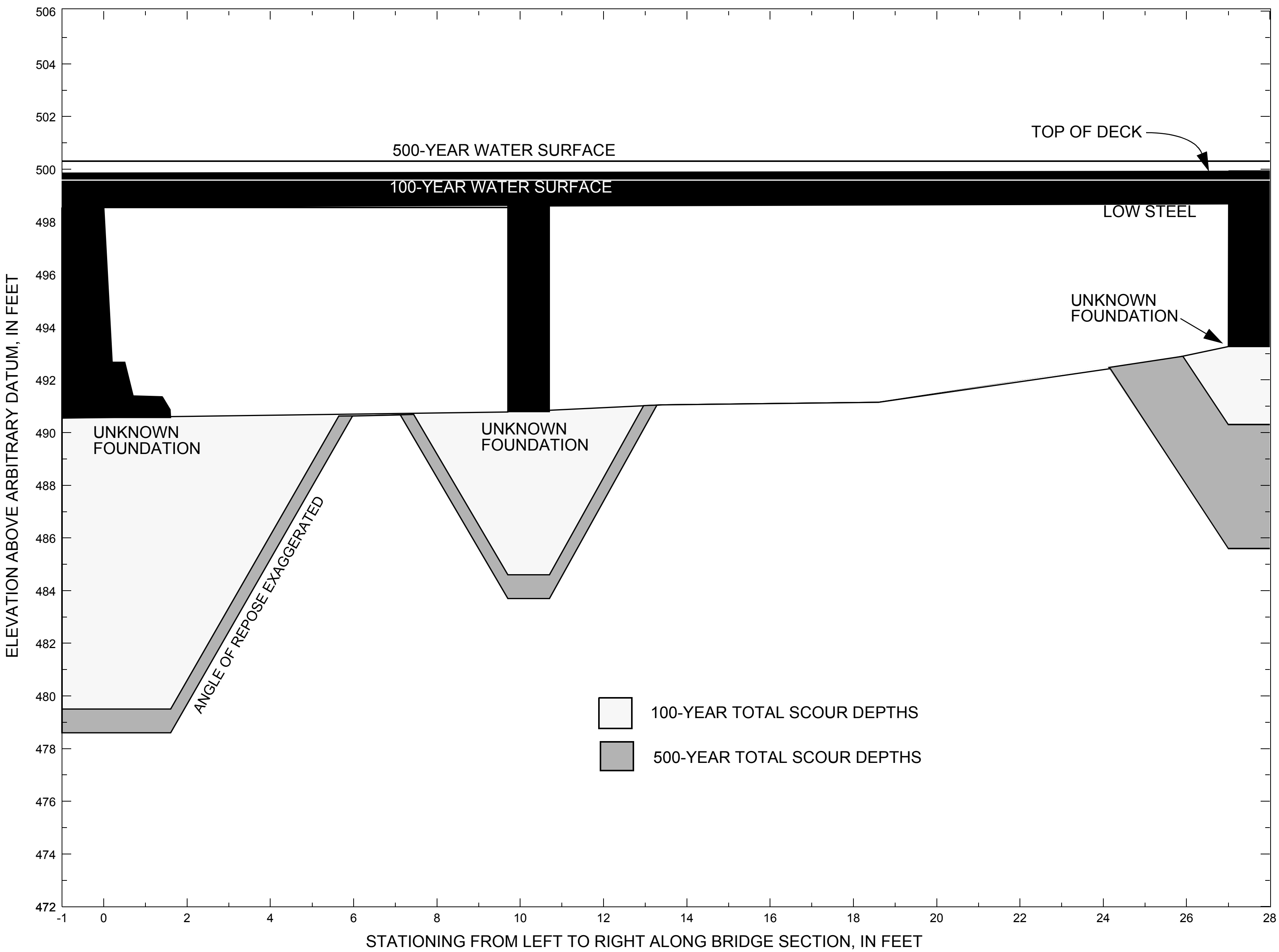

Figure 8. Scour elevations for the 100- and 500-year discharges at structure PLYMTH00080037 on Town Highway 8, crossing Broad Brook, Plymouth, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure PLYMTH00080037 on Town Highway 8, crossing Broad Brook, Plymouth, 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-year discharge is 1,480 cubic-feet per second											
Left abutment	0.0	--	498.6	--	490.6	0.0	11.1	--	11.1	479.5	--
Pier bent	10.1	--	--	--	490.8	--	--	6.2	6.2	484.6	--
Right abutment	27.0	--	498.7	--	493.3	0.0	3.0	--	3.0	490.3	--

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 PLYMTH00080037 on Town Highway 8, crossing Broad Brook, Plymouth, 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-year discharge is 2,200 cubic-feet per second											
Left abutment	0.0	--	498.6	--	490.6	0.0	12.0	--	12.0	478.6	--
Pier bent	10.1	--	--	--	490.8	--	--	7.1	7.1	483.7	--
Right abutment	27.0	--	498.7	--	493.3	0.0	7.7	--	7.7	485.6	--

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, 1966, Plymouth, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File plym037.wsp
T2        Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
T3        TH 8, BROAD BROOK, PLYMOUTH, VT                              ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1480.0   2200.0   1290.0
SK          0.0214   0.0214   0.0214
*
XS   EXIT1    -33           0.
GR         -145.8, 515.20   -124.8, 497.90   -104.8, 498.64    -77.6, 497.21
GR          -45.6, 497.51      0.0, 497.39      4.8, 492.07     12.0, 491.09
GR           13.4, 490.54     14.8, 490.17     19.2, 490.14     22.6, 490.55
GR           27.3, 490.84     36.6, 492.02     50.1, 496.65     68.3, 496.11
GR           92.4, 496.21    126.9, 513.83
*
N           0.065        0.055         0.065
SA                   0.0        50.1
*
XS   FULLV      0  * * *   0.0151
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    498.62      15.0
GR            0.0, 498.55      0.2, 492.67      0.5, 492.67      0.7, 491.39
GR            1.4, 491.36      1.6, 490.87     1.6,  490.55      6.3, 490.64
GR           10.1, 490.78     13.4, 491.05     18.6, 491.15     22.7, 491.83
GR           27.0, 493.27     27.0, 498.68      0.0, 498.55
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      20.4 * *     43.2      4.4
N           0.050
PW 1        490.78, 1.0
*
*            SRD    EMBWID   IPAVE
XR   RDWAY      8      12.8     2
GR         -123.8, 512.74    -76.8, 499.85
GR            0.0, 499.85     27.4, 499.92     57.5, 499.14     81.9, 497.92
GR           94.5, 500.92    114.6, 512.11
*
XT   APTEM     49           0.
GR          -77.8, 512.10    -44.4, 501.88    -27.9, 501.57    -10.4, 497.56
GR           -6.9, 493.80      0.0, 492.34      1.7, 491.87      5.6, 490.99
GR           10.7, 491.45     15.4, 491.93     19.3, 492.99     30.6, 497.40
GR           43.8, 497.29     62.4, 498.63     73.2, 497.65     81.1, 499.91
GR           98.3, 511.79    106.4, 512.66    116.8, 519.13
*
AS   APPR1     42  * * * 0.0066
GT
N           0.055          0.055         0.055
SA                  -10.4          30.6
*
HP 1 BRIDG 498.62 1 498.62
HP 2 BRIDG 498.62 * * 1314
HP 1 BRIDG 496.25 1 496.25
HP 2 RDWAY 499.60 * * 163
HP 1 APPR1 499.70 1 499.70
HP 2 APPR1 499.70 * * 1480
*
HP 1 BRIDG 498.62 1 498.62
HP 2 BRIDG 498.62 * * 1566
HP 1 BRIDG 497.49 1 497.49
HP 2 RDWAY 500.28 * * 663
HP 1 APPR1 500.38 1 500.38
HP 2 APPR1 500.38 * * 2200
*
HP 1 BRIDG 495.65 1 495.65
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File plym037.wsp
     Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
     TH 8, BROAD BROOK, PLYMOUTH, VT                                ECW
        *** RUN DATE & TIME: 04-20-98  08:32
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     191.  13302.    12.    53.                         4307.
498.62          191.  13302.    12.    53.  1.00     0.    27.   4307.

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

      WSEL     LEW     REW    AREA         K        Q    VEL
    498.62     0.0    27.0   190.7   13302.    1314.   6.89

X STA.       0.0        4.1        5.3        6.5        7.6        8.8
  A(I)           29.5        8.8        9.0        9.0        8.9
  V(I)           2.23       7.44       7.32       7.27       7.34

X STA.       8.8       10.0       11.2       12.5       13.8       14.6
  A(I)            9.0        9.3        9.3        9.4        6.4
  V(I)           7.33       7.09       7.07       7.00      10.28

X STA.      14.6       15.5       16.5       17.5       18.5       19.5
  A(I)            5.9        7.3        7.4        7.1        7.3
  V(I)          11.12       8.95       8.87       9.20       8.97

X STA.      19.5       20.5       21.6       22.6       23.8       27.0
  A(I)            7.0        7.2        7.1        7.3       18.4
  V(I)           9.32       9.13       9.31       9.01       3.57

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

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     129.    9311.   26.    35.                         1639.
496.25          129.    9311.   26.    35.  1.00     0.    27.   1639.

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

      WSEL     LEW     REW    AREA         K        Q    VEL
    499.60    39.7    89.0    36.1      746.     163.   4.51

X STA.      39.7       62.4       65.1       67.2       68.9       70.3
  A(I)            6.9        2.1        1.9        1.7        1.6
  V(I)           1.17       3.88       4.38       4.93       5.25

X STA.      70.3       71.7       72.9       74.0       75.0       75.8
  A(I)            1.5        1.5        1.4        1.4        1.0
  V(I)           5.44       5.55       5.84       6.01       7.96

X STA.      75.8       76.6       77.7       78.6       79.5       80.4
  A(I)            1.2        1.5        1.4        1.4        1.4
  V(I)           6.91       5.54       5.79       5.66       5.95

X STA.      80.4       81.2       82.0       82.9       84.0       89.0
  A(I)            1.3        1.3        1.4        1.4        2.9
  V(I)           6.05       6.09       5.93       5.71       2.81

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      10.     295.   10.    10.                           62.
          2     267.  24063.    41.    44.                         3864.
          3      90.    3589.   50.    50.                          685.
499.70          367.  27947.   100.   104.  1.25   -20.    81.   3571.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.
      WSEL     LEW     REW    AREA         K        Q    VEL
    499.70   -19.9    80.5   367.3   27947.    1480.   4.03

X STA.     -19.9       -5.3       -3.0       -0.9        1.0        2.6
  A(I)           34.6       15.1       14.5       13.7       13.3
  V(I)           2.14       4.89       5.09       5.41       5.56

X STA.       2.6        4.3        5.8        7.3        8.8       10.3
  A(I)           13.4       12.9       13.0       12.9       13.1
  V(I)           5.51       5.75       5.68       5.73       5.64

X STA.      10.3       11.9       13.5       15.2       16.9       19.0
  A(I)           12.7       13.3       13.2       13.4       14.4
  V(I)           5.82       5.58       5.61       5.53       5.15

X STA.      19.0       21.4       25.1       37.5       50.4       80.5
  A(I)           15.8       19.2       35.3       29.8       43.7
  V(I)           4.68       3.85       2.10       2.49       1.69
```

WSPRO OUTPUT FILE (continued)

```
         U.S. Geological Survey WSPRO Input File plym037.wsp
         Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
         TH 8, BROAD BROOK, PLYMOUTH, VT                               ECW
            *** RUN DATE & TIME: 04-20-98  08:32
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     191.   13302.    12.    53.                         4307.
    498.62          191.   13302.    12.    53.  1.00     0.    27.   4307.

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

          WSEL     LEW     REW    AREA         K        Q    VEL
        498.62     0.0    27.0   190.7   13302.    1566.   8.21

 X STA.         0.0        4.1        5.3        6.5        7.6        8.8
   A(I)            29.5        8.8        9.0        9.0        8.9
   V(I)            2.66       8.87       8.73       8.66       8.75

 X STA.         8.8       10.0       11.2       12.5       13.8       14.6
   A(I)             9.0        9.3        9.3        9.4        6.4
   V(I)            8.74       8.45       8.43       8.34      12.25

 X STA.        14.6       15.5       16.5       17.5       18.5       19.5
   A(I)             5.9        7.3        7.4        7.1        7.3
   V(I)           13.25      10.66      10.57      10.96      10.68

 X STA.        19.5       20.5       21.6       22.6       23.8       27.0
   A(I)             7.0        7.2        7.1        7.3       18.4
   V(I)           11.11      10.88      11.10      10.74       4.26

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

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     162.   12883.    26.    37.                         2287.
    497.49          162.   12883.    26.    37.  1.00     0.    27.   2287.

     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

          WSEL     LEW     REW    AREA         K        Q    VEL
        500.28   -78.4    91.8   121.2    2726.     663.   5.47

 X STA.       -78.4      -52.4      -28.4       -4.1       20.0       40.1
   A(I)            10.8       10.3       10.5        9.8        9.4
   V(I)            3.07       3.21       3.17       3.37       3.53

 X STA.        40.1       47.5       54.0       59.2       63.1       65.9
   A(I)             5.9        6.2        5.9        5.1        4.2
   V(I)            5.65       5.32       5.66       6.47       7.87

 X STA.        65.9       68.4       70.9       73.1       75.1       77.0
   A(I)             4.1        4.3        4.1        4.0        3.9
   V(I)            8.05       7.71       8.12       8.37       8.40

 X STA.        77.0       78.8       80.4       82.0       83.7       91.8
   A(I)             3.8        3.7        3.6        3.7        7.8
   V(I)            8.73       8.99       9.09       8.93       4.25

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      18.     607.    13.    13.                          122.
              2     295.   28396.    41.    44.                         4486.
              3     124.    6045.    51.    52.                         1100.
    500.38          437.   35048.   105.   109.  1.24   -23.    82.   4558.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.
          WSEL     LEW     REW    AREA         K        Q    VEL
        500.38   -22.9    81.8   437.2   35048.    2200.   5.03

 X STA.       -22.9       -5.7       -3.2       -1.1        1.0        2.9
   A(I)            42.4       18.1       16.4       16.8       15.9
   V(I)            2.60       6.09       6.69       6.55       6.92

 X STA.         2.9        4.6        6.2        7.9        9.6       11.3
   A(I)            15.4       15.2       15.5       15.7       15.4
   V(I)            7.13       7.23       7.07       7.03       7.15

 X STA.        11.3       13.0       14.8       16.7       18.9       21.5
   A(I)            15.1       15.7       16.0       16.7       18.6
   V(I)            7.29       6.99       6.87       6.59       5.90

 X STA.        21.5       25.2       35.0       45.0       58.7       81.8
   A(I)            21.6       35.5       31.0       35.0       45.0
   V(I)            5.09       3.10       3.55       3.14       2.44
```

```
       U.S. Geological Survey WSPRO Input File plym037.wsp
       Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
       TH 8, BROAD BROOK, PLYMOUTH, VT                                ECW
          *** RUN DATE & TIME: 04-20-98  08:32
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     114.    7697.    26.    33.                        1352.
  495.65          114.    7697.    26.    33.  1.00     0.    27.   1352.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      495.65     0.1    27.0   113.9    7697.    1290.  11.33

 X STA.        0.1        3.5        4.4        5.4        6.3        7.3
  A(I)            14.9        4.5        4.5        4.6        4.6
  V(I)            4.33      14.33      14.47      14.10      14.01

 X STA.        7.3        8.2        9.2       10.2       11.2       12.3
  A(I)             4.7        4.6        4.7        4.7        4.8
  V(I)           13.78      13.91      13.65      13.73      13.54

 X STA.       12.3       13.3       14.4       15.5       16.6       17.7
  A(I)             4.9        4.8        4.8        4.8        4.7
  V(I)           13.23      13.39      13.30      13.47      13.59

 X STA.       17.7       18.8       20.0       21.2       22.6       27.0
  A(I)             4.9        4.8        5.1        5.2       13.2
  V(I)           13.12      13.34      12.69      12.29       4.90

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1       0.       3.     2.     2.                           1.
            2     194.   14081.    41.    44.                        2386.
            3      12.     185.    27.    27.                          45.
  497.91          206.   14269.    70.    73.  1.09   -12.    74.   1925.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.91   -12.1    74.3   205.7   14269.    1290.   6.27

 X STA.      -12.1       -4.1       -2.3       -0.6        0.9        2.3
  A(I)            20.8        9.0        8.9        8.6        8.3
  V(I)            3.10       7.13       7.22       7.51       7.78

 X STA.        2.3        3.5        4.8        5.9        7.1        8.2
  A(I)             8.0        8.0        7.9        8.0        7.9
  V(I)            8.10       8.05       8.21       8.03       8.15

 X STA.        8.2        9.4       10.6       11.8       13.1       14.3
  A(I)             7.7        7.8        7.9        7.9        8.0
  V(I)            8.35       8.23       8.12       8.19       8.07

 X STA.       14.3       15.7       17.1       18.8       20.9       74.3
  A(I)             8.1        8.4        8.8        9.9       35.7
  V(I)            7.95       7.67       7.33       6.54       1.81

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.22     0.1    27.0   128.7    9229.    1290.  10.03

 X STA.        0.1        3.7        4.6        5.5        6.5        7.4
  A(I)            17.5        5.0        5.0        5.3        5.0
  V(I)            3.68      12.79      12.91      12.23      12.88

 X STA.        7.4        8.4        9.4       10.4       11.4       12.5
  A(I)             5.2        5.2        5.2        5.3        5.4
  V(I)           12.29      12.39      12.45      12.08      11.90

 X STA.       12.5       13.5       14.6       15.7       16.8       17.9
  A(I)             5.4        5.4        5.4        5.3        5.3
  V(I)           11.93      12.03      11.94      12.08      12.19

 X STA.       17.9       19.0       20.1       21.4       22.7       27.0
  A(I)             5.5        5.4        5.7        5.7       15.3
  V(I)           11.77      11.97      11.31      11.26       4.21
```

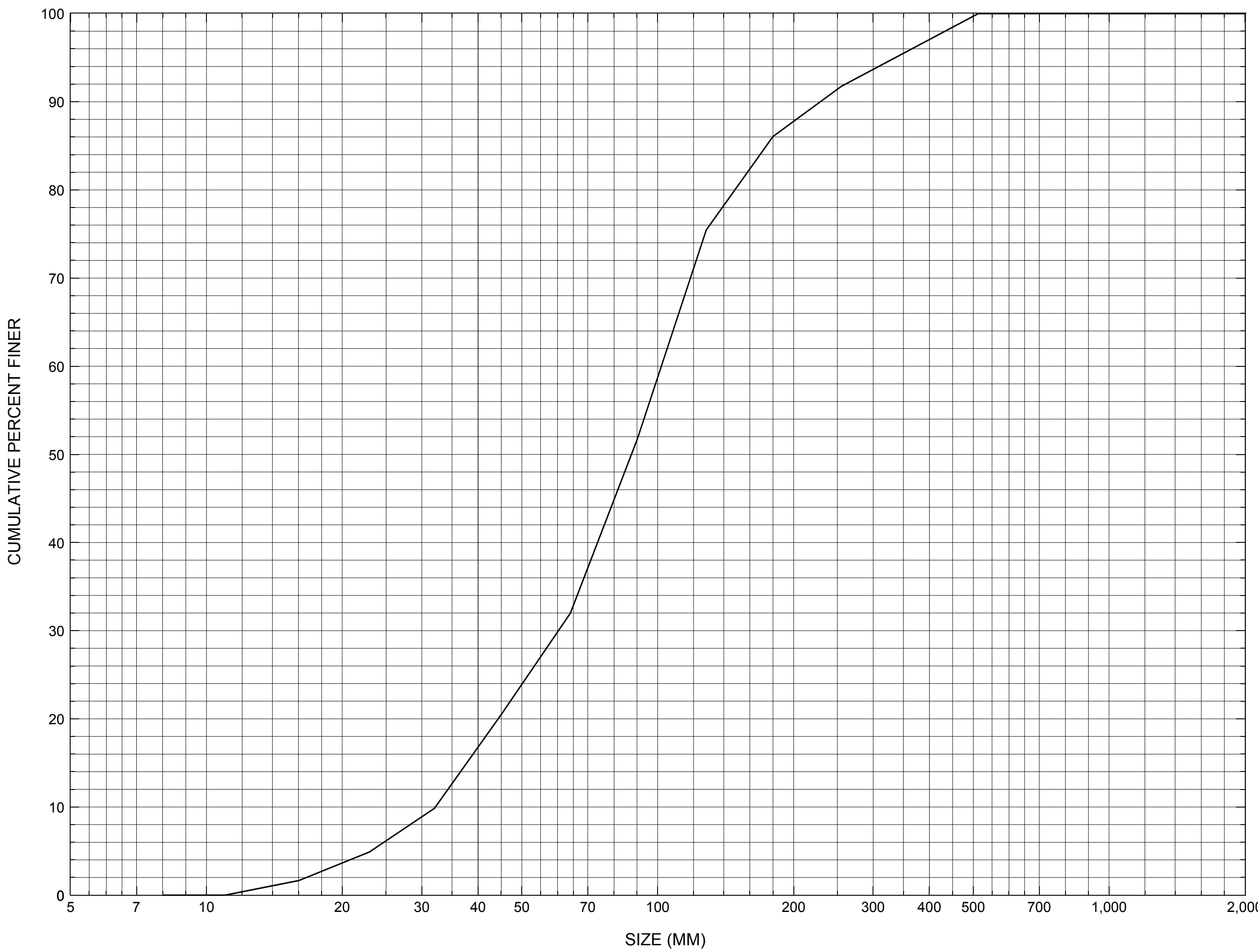
```
        U.S. Geological Survey WSPRO Input File plym037.wsp
        Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
        TH 8, BROAD BROOK, PLYMOUTH, VT                             ECW
           *** RUN DATE & TIME: 04-20-98  08:32

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

 EXIT1:XS   ******     2.     163.  1.28 *****  496.71  494.96   1480.  495.43
      -33. ******    47.   10114.  1.00 ***** *******    0.84    9.07

 FULLV:FV      33.     1.     178.  1.07  0.62  497.33 *******   1480.  496.25
         0.    33.    47.   11466.  1.00  0.00    0.00    0.74    8.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.87     496.88     496.49
  ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.75     519.08    0.50
  ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.75     519.08     496.49
 APPR1:AS      42.   -10.     152.  1.48  0.83  498.36  496.49   1480.  496.88
        42.    42.    29.    9696.  1.00  0.20    0.00    0.88    9.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.53       0.00     496.06     497.92
  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
  ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   501.47         0.      1480.
  ===280 REJECTED FLOW CLASS 4 SOLUTION.
  ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

 BRIDG:BR      33.     0.     183.  0.80 *****  499.42  495.71   1314.  498.62
         0. ******    27.   13302.  1.00 ***** *******    0.49    7.19

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1.   1.   5.  0.415  0.041  498.62 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       8.    29.  0.08  0.31  499.93    0.00    163.  499.60

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:      0.    92.   -80.    12.   0.9   0.9   5.2   5.7   1.4   2.9
    RT:    163.    49.    40.    89.   1.7   0.7   4.7   4.5   1.1   3.0

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

 APPR1:AS      22.   -20.     367.  0.31  0.12  500.01  496.49   1480.  499.70
        42.    23.    81.   27939.  1.25  0.00    0.00    0.41    4.03

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

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS     -33.     2.    47.   1480.   10114.     163.    9.07  495.43
    FULLV:FV       0.     1.    47.   1480.   11466.     178.    8.31  496.25
    BRIDG:BR       0.     0.    27.   1314.   13302.     183.    7.19  498.62
    RDWAY:RG       8.*******     0.    163.       0.*********    2.00  499.60
    APPR1:AS      42.   -20.    81.   1480.   27939.     367.    4.03  499.70

     XSID:CODE   XLKQ   XRKQ       KQ
    APPR1:AS  **********************

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXIT1:XS    494.96    0.84  490.14  515.20************  1.28  496.71  495.43
    FULLV:FV  ********    0.74  490.64  515.70  0.62  0.00  1.07  497.33  496.25
    BRIDG:BR    495.71    0.49  490.55  498.68************  0.80  499.42  498.62
    RDWAY:RG  ****************  497.92  512.74  0.08******  0.31  499.93  499.60
    APPR1:AS    496.49    0.41  490.94  519.08  0.12  0.00  0.31  500.01  499.70
```

```
        U.S. Geological Survey WSPRO Input File plym037.wsp
        Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
        TH 8, BROAD BROOK, PLYMOUTH, VT                              ECW
           *** RUN DATE & TIME: 04-20-98  08:32

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

EXIT1:XS   ******     1.     226.  1.60 *****  498.12  496.06   2200.  496.52
      -33. ******    93.   15033.  1.08 ***** *******    1.11    9.75

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.91     497.49     496.56
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.02     515.70    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.02     515.70     496.56

FULLV:FV      33.     0.     270.  1.21  0.59  498.70  496.56   2200.  497.49
        0.    33.    94.   18127.  1.17  0.00    0.00    0.91    8.15
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPR1”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.14     497.91     497.98
 ===110 WSEL NOT FOUND AT SECID “APPR1”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.99     519.08    0.50
 ===115 WSEL NOT FOUND AT SECID “APPR1”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.99     519.08     497.98
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPR1”
                  WSBEG,WSEND,CRWS =   497.98     519.08     497.98

APPR1:AS      42.   -12.     211.  1.86 *****  499.84  497.98   2200.  497.98
       42.    42.    75.   14668.  1.10 ***** *******    1.13   10.44
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.78       0.00     497.51     497.92
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   501.97         0.      2200.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      33.     0.     183.  1.14 *****  499.76  496.26   1566.  498.62
        0. ******    27.   13302.  1.00 ***** *******    0.58    8.56
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   1.   5.  0.457  0.041  498.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    29.  0.12  0.49  500.75    0.01    663.  500.28
            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    216.    91.   -78.    13.   0.4   0.4   4.0   5.6   0.9   2.8
   RT:    447.    79.    13.    92.   2.4   1.0   5.6   5.4   1.5   3.0

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

APPR1:AS      22.   -23.     437.  0.49  0.18  500.87  497.98   2200.  500.38
       42.    24.    82.   35032.  1.24  0.00    0.01    0.48    5.03

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT1:XS     -33.     1.    93.   2200.   15033.     226.    9.75  496.52
   FULLV:FV       0.     0.    94.   2200.   18127.     270.    8.15  497.49
   BRIDG:BR       0.     0.    27.   1566.   13302.     183.    8.56  498.62
   RDWAY:RG       8.*******   216.    663.       0.*********    2.00  500.28
   APPR1:AS      42.   -23.    82.   2200.   35032.     437.    5.03  500.38

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS     496.06    1.11  490.14  515.20************  1.60  498.12  496.52
   FULLV:FV     496.56    0.91  490.64  515.70  0.59  0.00  1.21  498.70  497.49
   BRIDG:BR     496.26    0.58  490.55  498.68************  1.14  499.76  498.62
   RDWAY:RG  ****************  497.92  512.74  0.12******  0.49  500.75  500.28
   APPR1:AS     497.98    0.48  490.94  519.08  0.18  0.00  0.49  500.87  500.38
```

```
        U.S. Geological Survey WSPRO Input File plym037.wsp
        Hydraulic analysis for structure PLYMTH00080037   Date: 12-MAR-98
        TH 8, BROAD BROOK, PLYMOUTH, VT                               ECW
           *** RUN DATE & TIME: 04-20-98  08:32

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

EXIT1:XS   ******     2.     148.  1.18 *****  496.27  494.64   1290.  495.09
      -33. ******    46.    8813.  1.00 ***** *******    0.83    8.70

FULLV:FV      33.     2.     162.  0.98  0.62  496.89 *******   1290.  495.90
        0.    33.    46.   10020.  1.00  0.00    0.00    0.74    7.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.86     496.54     496.15

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.40     519.08    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.40     519.08     496.15

APPR1:AS      42.    -9.     138.  1.35  0.82  497.89  496.15   1290.  496.54
       42.    42.    29.    8530.  1.00  0.18    0.00    0.86    9.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1290.     495.65

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

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

BRIDG:BR      33.     0.     114.  2.00 *****  497.65  495.65   1290.  495.65
        0.    33.    27.    7691.  1.00 ***** *******    0.96   11.34

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   1.   1.  1.000  0.043  498.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS      22.   -12.     206.  0.67  0.36  498.57  496.15   1290.  497.91
       42.    23.    74.   14259.  1.09  0.57    0.01    0.67    6.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.292  0.045   13570.    -5.    22.   497.67

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -33.     2.    46.   1290.    8813.     148.    8.70  495.09
   FULLV:FV       0.     2.    46.   1290.   10020.     162.    7.96  495.90
   BRIDG:BR       0.     0.    27.   1290.    7691.     114.   11.34  495.65
   RDWAY:RG       8.**************      0.*****************     2.00********
   APPR1:AS      42.   -12.    74.   1290.   14259.     206.    6.27  497.91

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS      -5.    22.   13570.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    494.64    0.83  490.14  515.20************  1.18  496.27  495.09
   FULLV:FV  ********    0.74  490.64  515.70  0.62  0.00  0.98  496.89  495.90
   BRIDG:BR    495.65    0.96  490.55  498.68************  2.00  497.65  495.65
   RDWAY:RG ****************  497.92  512.74**********************************
   APPR1:AS    496.15    0.67  490.94  519.08  0.36  0.57  0.67  498.57  497.91
  ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure PLYMTH00080037, in Plymouth, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **PLYMTH00080037**

General Location Descriptive

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

Date *(MM/DD/YY)* **03 / 22 / 95**

Highway District Number *(I - 2; nn)* **03**

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

Town *(FIPS place code; I - 4; nnnnn)* **56050**

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

Waterway *(I - 6)* **BROAD BROOK**

Road Name *(I - 7):* **-**

Route Number **TH008**

Vicinity *(I - 9)* **0.5 MI TO JCT W CL3 TH5**

Topographic Map **Plymouth**

Hydrologic Unit Code: **01080106**

Latitude *(I - 16; nnnn.n)* **43322**

Longitude *(i - 17; nnnnn.n)* **72404**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10141200371412**

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

Maximum span length *(I - 48; nnnn)* **0028**

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

Structure length *(I - 49; nnnnnn)* **000031**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000040**

Deck Width *(I - 52; nn.n)* **128**

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

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

Opening skew to Roadway *(I - 34; nn)* **15**

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

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

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*) **007.5**

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

Waterway of full opening (*nnn.n ft²*) **-**

Comments:

The structural inspection report of 6/14/93 indicates the structure is a steel stringer type bridge with a timber deck. The abutment walls and wingwalls are concrete. The left abutment and its wingwalls have a concrete footing and subfooting. The report notes some erosion present along the bottom of the footing of the left upstream wingwall. The footing concrete is noted as having minor surface spalling overall. A wooden beam bent is noted as having been added under the structure at midspan consisting of two vertical wood beams, two diagonal wood plank cross braces, and a 4x4 horizontal bearing beam at the top extending under all the steel stringers. Boulder stone fill protection is reported **(Continued, page 33)**

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:

around the vertical beams of the bent. The wooden bent here is considered a temporary repair. Some stone fill is reported in front of the right abutment and its wingwalls. In front of the downstream end of the downstream left wingwall and of the left abutment, stone fill was also noted as present. In addition, stone fill was reported as visible along the banks upstream and downstream.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **5.55** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1230** ft Headwater elevation **2360** ft

Main channel length **3.51** mi

10% channel length elevation **1280** ft 85% channel length elevation **1860** ft

Main channel slope *(S)* **220.32** 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: **This section was created from a sketch dated 6/15/93 that was attached to a bridge inspection report. This section was taken at the US bridge face. The low chord elevations are the same as the DS face used in this report that was surveyed 10/3/95.**

Station	0	1	8	12	17	21	27	28	-	-	-
Feature	LAB	-	-	-	-	-	-	RAB	-	-	-
Low chord elevation	498.60	498.60	498.60	498.60	498.60	498.60	498.60	498.60	-	-	-
Bed elevation	492.75	492.75	490.60	490.60	490.80	490.80	492.60	492.60	-	-	-
Low chord to bed	5.85	5.85	8.00	8.00	7.80	7.80	6.00	6.00	-	-	-

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: CG Date: 02/14/96
Computerized by: CG Date: 02/15/96
Reviewd by: EW Date: 04/21/98

Structure Number PLYMTH00080037

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. Medalie   Date *(MM/DD/YY)* 10 / 03 / 1995

2. Highway District Number 03   Mile marker -

County Windsor (027)   Town Plymouth (56050)

Waterway *(I - 6)* Broad Brook   Road Name -

Route Number TH 08   Hydrologic Unit Code: 01080106

3. Descriptive comments:

The bridge is located 0.5 miles to the junction with CL3 TH5.

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 31 *(feet)*   Span length 28 *(feet)*   Bridge width 12.8 *(feet)*

Road approach to bridge:

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

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

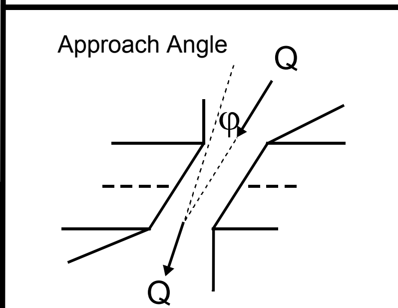
10. Embankment slope (*run / rise in feet / foot*):
US left --   US right --

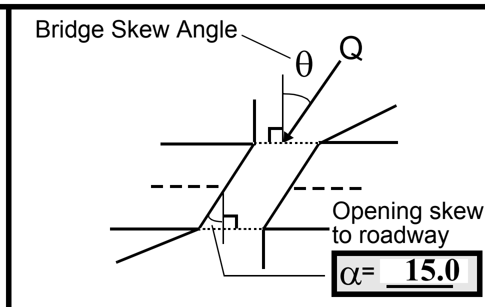
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	1	2	2	1
RBDS	0	-	2	1
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? LB *(LB, RB)*   Severity 1
Range? 35 feet US *(US, UB, DS)* to 35 feet DS

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

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

18. Bridge Type: **1a**

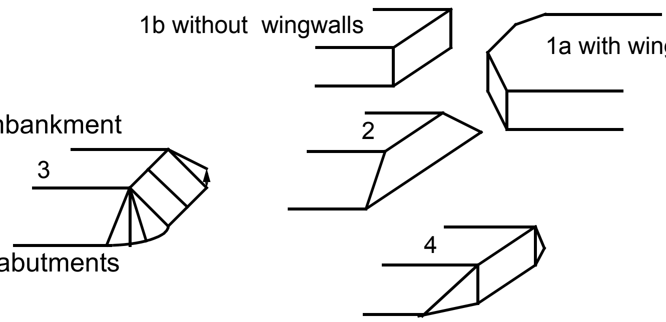
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. The values are from the VTAOT. During the site visit, the measured bridge length was 30.2 feet, the span length was 27.5 feet and the deck width was 16 feet.
11. The right bank upstream protection stone fill material is very loose and slumped.
13. The left bank downstream has a moderately sized road wash channel between the end of the wingwall and the stone protection.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
32.5	**4.0**			**4.5**	**4**	**4**	**23**	**542**	**1**	**0**

23. Bank width **45.0**   24. Channel width **20.0**   25. Thalweg depth **41.0**   29. Bed Material **453**

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

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

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

The channel is all riffle to 10 feet upstream where it flattens to a pool under the bridge.

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

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

37. Material: -

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

NO POINT BARS

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: 33 42. Cut bank extent: 55 feet US (US, UB) to 4 feet US (US, UB, DS)

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

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

The cut-bank extends to the upstream end of the left wingwall.
On the right bank starting from the culvert (refer to no. 54) to approximately 100 ft upstream, there is severe bank erosion which undercuts the road in spots. There are large (12 inch diameter) trees across the stream from both sides of the stream.

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
There are a few small 1-2 feet square holes near boulders 5 and 9 feet upstream of the bridge deck in the center of the channel.

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
There is a culvert pipe under TH 8 at 135 feet upstream; it enters on the right.

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
26.0		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.):

435
There are two very unnatural holes (about 1 foot square) in the bank and protection material along the right abutment. The bed under the bridge consists of cobbles, gravel, boulders and timber shavings.

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

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

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

70. Debris and Ice Comments:

3

The debris at bridge may be mostly scraps from new timber deck. The center pier may act as a capture zone.

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		**15**	**90**	**2**	**2**	**-**	**1**	**90.0**
RABUT	**1**	**0**	**90**			**0**	**2**	**26.0**

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.):

-

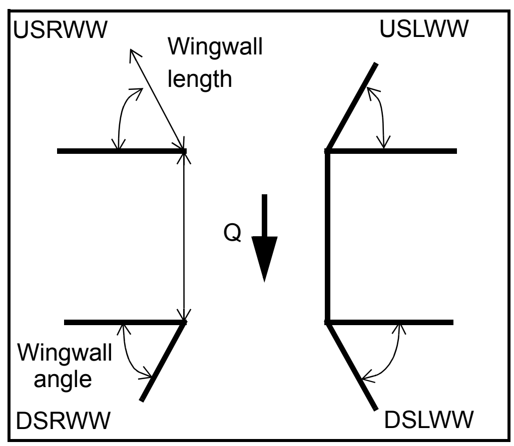
0.5

1

76. The left abutment subfooting is exposed a maximum of 1 foot at the downstream end. The subfooting is exposed from the downstream end of the abutment to 4.5 feet under the bridge (measured horizontally). The footing is exposed 0.75 feet at the upstream end to its complete height of 1.25 feet at the downstream end. The right abutment footing is only exposed for 2 feet toward the downstream end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**26.0**	
USRWW:	**Y**		**1**		**0**	**0.5**	
DSLWW:	**-**		**-**		**Y**	**16.0**	
DSRWW:	**1**		**0**		**-**	**16.0**	



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	**-**	**3**	**Y**	**-**	**1**	**1**	**1**	**1**
Condition	**Y**	**-**	**1**	**-**	**1**	**1**	**2**	**1**
Extent	**1**	**2**	**0**	**2**	**1**	**2**	**1**	**-**

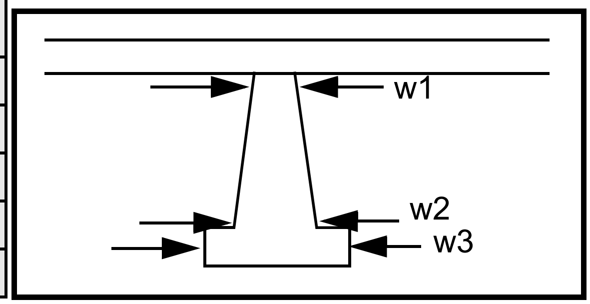
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		7.5	5.5	60.0	25.0	30.0
Pier 2	7.5	5.5		60.0	1.0	490.78
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	foot-		2	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	upst	ing is		2	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	ream	expo		0	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	end	sed 2	Y	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	of	feet.	MC	-	*Y- yes; N- no*
91. Attack ∠ (BF)	the		M	-	
92. Pushed	dow		3	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	nstre		1	-	
95. Cross-members	am		2	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	left		N	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	wing		10	-	
98. Exposure depth	wall		LB	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
This pier is a timber support (lattice) approximately midway under the bridge.

101. Is a drop structure present? ____ *(Y or N, if N type ctrl-n ds)* 102. Distance: 5.5 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):

3
3
542
23
1

106. Point/Side bar present? 0 (Y or N. if N type ctrl-n pb) Mid-bar distance: 345 Mid-bar width: 0

Point bar extent: 0 feet - (US, UB, DS) to - feet Fro (US, UB, DS) positioned m %LB to the %RB

Material: up

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

stream end of the bridge to 63 feet downstream, there is a series of unnatural gravel piles and holes in the channel.
The downstream channel is steeper than the upstream channel.

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.):

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

Confluence 1: Distance Y Enters on 73 (LB or RB) Type 22 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 5 Enters on UB (LB or RB) Type 149 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS
20

F. Geomorphic Channel Assessment

107. Stage of reach evolution 95

__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)*:

345

Y
LB
26’
0
DS
50
DS
1

109. G. Plan View Sketch

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: PLYMTH00080037 Town: PLYMOUTH
Road Number: TOWN HIGHWAY 8 County: WINDSOR
Stream: BROAD BROOK

Initials ECW Date: 3/20/98 Checked: RLB

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 Davis, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1480	2200	1290
Main Channel Area, ft2	267	295	194
Left overbank area, ft2	10	18	0
Right overbank area, ft2	90	124	12
Top width main channel, ft	41	41	41
Top width L overbank, ft	10	13	0
Top width R overbank, ft	50	51	27
D50 of channel, ft	0.287	0.287	0.287
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.5	7.2	4.7
y1, average depth, LOB, ft	1.0	1.4	ERR
y1, average depth, ROB, ft	1.8	2.4	0.4
Total conveyance, approach	27947	35048	14269
Conveyance, main channel	24063	28396	14081
Conveyance, LOB	295	607	0
Conveyance, ROB	3589	6045	185
Percent discrepancy, conveyance	0.0000	0.0000	0.0210
Qm, discharge, MC, cfs	1274.3	1782.4	1273.0
Ql, discharge, LOB, cfs	15.6	38.1	0.0
Qr, discharge, ROB, cfs	190.1	379.5	16.7
Vm, mean velocity MC, ft/s	4.8	6.0	6.6
Vl, mean velocity, LOB, ft/s	1.6	2.1	ERR
Vr, mean velocity, ROB, ft/s	2.1	3.1	1.4
Vc-m, crit. velocity, MC, ft/s	10.1	10.3	9.6
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	0

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	1314	1566	1290
Main channel area (DS), ft2	121	154	109
Main channel width (normal), ft	26.1	26.1	26.0
Cum. width of piers, ft	1.0	1.0	1.0
Adj. main channel width, ft	25.1	25.1	25.0
D90, ft	0.7519	0.7519	0.7519
D95, ft	1.0958	1.0958	1.0958
Dc, critical grain size, ft	0.6255	0.4925	0.7783
Pc, Decimal percent coarser than Dc	0.130	0.196	0.094
Depth to armoring, ft	12.56	6.06	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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1480	2200	1290
(Q) discharge thru bridge, cfs	1314	1566	1290
Main channel conveyance	13302	13302	7697
Total conveyance	13302	13302	7697
Q2, bridge MC discharge,cfs	1314	1566	1290
Main channel area, ft2	183	183	109
Main channel width (normal), ft	26.1	26.1	26.0
Cum. width of piers in MC, ft	1.0	1.0	1.0
W, adjusted width, ft	25.1	25.1	25
y_bridge (avg. depth at br.), ft	7.30	7.30	4.36
Dm, median (1.25*D50), ft	0.35875	0.35875	0.35875
y2, depth in contraction,ft	4.93	5.73	4.87
ys, scour depth (y2-ybridge), ft	-2.36	-1.56	**0.51**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1480	2200	1290
Q, thru bridge MC, cfs	1314	1566	1290
Vc, critical velocity, ft/s	10.10	10.27	9.58
Va, velocity MC approach, ft/s	4.77	6.04	6.56
Main channel width (normal), ft	26.1	26.1	26.0
Cum. width of piers in MC, ft	1.0	1.0	1.0
W, adjusted width, ft	25.1	25.1	25.0
qbr, unit discharge, ft2/s	52.4	62.4	51.6
Area of full opening, ft2	183.2	183.2	109.0
Hb, depth of full opening, ft	7.30	7.30	4.36
Fr, Froude number, bridge MC	0.49	0.58	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	121	154	N/A
**Hb, depth at downstream face, ft	4.82	6.14	N/A
**Fr, Froude number at DS face	0.87	0.72	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	498.62	498.62	0
Elevation of Bed, ft	491.32	491.32	0.00
Elevation of Approach, ft	499.7	500.38	0
Friction loss, approach, ft	0.12	0.18	0
Elevation of WS immediately US, ft	499.58	500.20	0.00
ya, depth immediately US, ft	8.26	8.88	0.00
Mean elevation of deck, ft	499.885	499.885	0
w, depth of overflow, ft (>=0)	0.00	0.32	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.96	ERR
**Cc, for downstream face (<=1.0)	0.838805	0.91513	ERR
Ys, scour w/Chang equation, ft	**-1.96**	**-0.98**	N/A
Ys, scour w/Umbrell equation, ft	-1.51	-0.35	N/A

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

**Ys, scour w/Chang equation, ft	1.36	0.50	N/A
**Ys, scour w/Umbrell equation, ft	0.97	0.81	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	4.93	5.73	4.87
WSEL at downstream face, ft	496.25	497.49	--
Depth at downstream face, ft	4.82	6.14	N/A
Ys, depth of scour (Laursen), ft	0.11	-0.40	N/A

Abutment Scour

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

Characteristic	Left Abutment 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	1480	2200	1290	1480	2200	1290
a’, abut.length blocking flow, ft	20.3	23.3	12.6	54	55.3	47.8
Ae, area of blocked flow ft2	73.57	79.11	45.01	21.69	77.31	31.96
Qe, discharge blocked abut.,cfs	272.63	--	240.8	--	--	57.74
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.71	4.60	5.35	2.04	3.00	1.81
ya, depth of f/p flow, ft	3.62	3.40	3.57	0.40	1.40	0.67
--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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.343	0.415	0.499	0.258	0.330	0.389
ys, scour depth, ft	**11.14**	**12.03**	**11.20**	**3.03**	**7.68**	**4.96**

HIRE equation (a’/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 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)	20.3	23.3	12.6	54	55.3	47.8
y1 (depth f/p flow, ft)	3.62	3.40	3.57	0.40	1.40	0.67
a’/y1	5.60	6.86	3.53	134.44	39.56	71.49
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.34	0.42	0.50	0.26	0.33	0.39
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	1.77	6.70	3.38
vertical w/ ww’s	ERR	ERR	ERR	1.46	5.49	2.77
spill-through	ERR	ERR	ERR	0.98	3.68	1.86

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.87	0.72	0.96	0.87	0.72	0.96
y, depth of flow in bridge, ft	4.82	6.14	4.24	4.82	6.14	4.24
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.97	ERR	ERR	1.97	ERR
Fr>0.8 (vertical abut.)	1.94	ERR	1.75	1.94	ERR	1.75

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and Davis, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)

V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	10.1	10.1	10.1
Area of WSPRO flow tube, ft2	5.9	5.9	5
Skewed width of flow tube, ft	0.9	0.9	0.9
y1, pier approach depth, ft	6.56	6.56	5.56
y1 in meters	1.998	1.998	1.693
V1, pier approach velocity, ft/s	11.1	13.2	12.9
a, pier width, ft	1	1	1
L, pier length, ft	6	6	6
Fr1, Froude number at pier	0.764	0.909	0.964
Pier attack angle, degrees	10	10	10
K1, shape factor	1.1	1.1	1.1
K2, attack factor	1.58	1.58	1.58
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.287	0.287	0.287
D50, m	0.087473	0.087473	0.087473
D90, ft	0.7519	0.7519	0.7519
D90, m	0.229168	0.229168	0.229168
Vc50,critical velocity(D50),m/s	3.084	3.084	3.000
Vc90,critical velocity(D90),m/s	4.251	4.251	4.136
Vi,incipient velocity,m/s	1.862	1.862	1.811
Vr, velocity ratio	0.637	0.905	0.912
K4, armor factor	0.94	1.00	1.00
ys, scour depth (K4 applicable) ft	6.19	7.07	6.85
ys, scour depth (K4 not applied)ft	ERR	ERR	ERR

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and Davis, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.7	1.7	1.7
V, velocity on pier, ft/s	10.335	12.315	15
Used 1.5 to adjust velocity			
D50, median stone diameter, ft	2.01	2.85	4.23