LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (PUTNTH00210029) on TOWN HIGHWAY 21, crossing EAST PUTNEY BROOK, PUTNEY, VERMONT

U.S. Geological Survey
Open-File Report 97-406

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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By ERICK M. BOEHMLER and MICHAEL A. IVANOFF

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U.S. DEPARTMENT OF THE INTERIOR
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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 29 (PUTNTH00210029) ON TOWN HIGHWAY 21, CROSSING EAST PUTNEY BROOK, PUTNEY, VERMONT

By **Erick M. Boehmler and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PUTNTH00210029 on Town Highway 21 crossing East Putney Brook, Putney, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in southeastern Vermont. The 10.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of pasture and forest.

In the study area, East Putney Brook has an incised, sinuous channel with a slope of approximately 0.009 ft/ft, an average channel top width of 33 ft and an average bank height (channel depth) of 3 ft. The channel bed material is cobbles predominantly with a median grain size (D_{50}) of 80.7 mm (0.265 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 stable.

The Town Highway 21 crossing of East Putney Brook is a 35-ft-long, one-lane bridge consisting of one 29-foot steel-beam span (Vermont Agency of Transportation, written communication, March 30, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening. Historical records show an opening-skew-to-roadway of 10 degrees but 20 degrees was computed using field survey data and used in this study.

The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) on each abutment wall, the upstream right wingwall and the upstream right bank, and type-3 stone fill (less than 48 inches diameter) on the left bank upstream, the upstream left wingwall, and the downstream right bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 ranged from 0.0 to 0.9 feet. The worst-case contraction scour occurred at the incipient-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 6.1 to 18.4 feet. The worst-case abutment scour occurred at the 500-year discharge for the right abutment and the incipient overtopping discharge for the left abutment. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Walpole, NH-VT, 1985; Keene, NH-VT, 1984; Townshend, VT, 1984; and Newfane, VT, 1984. All scales are 1:25,000 and contour intervals are 6 meters.

NORTH

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

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

LEVEL II SUMMARY

Structure Number PUTNTH00210029 ***Stream*** East Putney Brook

County Windham ***Road*** TH 21 ***District*** 2

Description of Bridge

Bridge length 35 ***ft*** ***Bridge width*** 15.5 ***ft*** ***Max span length*** 29 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/19/96

Description of stone fill Type-2 along each abutment wall, the upstream right bank, and the upstream right wingwall. Type-3 along the upstream left bank, upstream left wingwall, and the downstream right bank.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Level I survey? Yes ***Angle*** 40

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe) No

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	8/19/96	0	0
Level II	8/19/96	0	0

Potential for debris Moderate. There is significant vegetation growth on the immediate banks but banks are stable.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 8/19/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with narrow, flat to slightly irregular flood plains and steep valley walls on both sides.

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

Date of inspection 8/19/96

DS left: Moderately sloping channel bank to a narrow flood plain

DS right: Moderately sloping channel bank to a narrow overbank.

US left: Steep channel bank to a narrow flood plain.

US right: Mildly sloping channel bank to a narrow overbank.

Description of the Channel

Average top width 33

Average depth 3

Predominant bed material Cobbles

Bank material Gravel/Cobbles

Straight and stable with non-alluvial channel boundaries and irregular point and lateral bars.

8/19/96

Vegetative cover Grass and brush with a few trees.

DS left: Trees with some brush

DS right: Shrubs and brush.

US left: Shrubs, brush and a few trees.

US right:

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

None noted in the assessment of 8/19/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.3 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

-

Calculated Discharges

Q100 2,330 ***ft³/s*** ***Q500*** 3,400 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency curve values available from the VTAOT database for bridge number 18 in Putney and corrected by use of a drainage area relationship [(10.3/11.8)exp 0.67]. Bridge number 18 in Putney is just downstream of this site with a drainage area of 11.8 square miles. The flood frequency curve computed with the area relationship was within a range of other flood frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; Potter, 1957a&b; and 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 the center point of a chiseled "X" on top of the right abutment concrete at the downstream end (elev. 497.19 feet, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the left abutment at the upstream end (elev. 497.00 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-31	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APTEM	47	2	Approach section as surveyed (Used as a template)
APPRO	51	1	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.045, and overbank "n" values ranged from 0.050 to 0.065.

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 0.00926 ft/ft, which was estimated from the topographic map downstream of the site (U.S. Geological Survey, 1985).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0248 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.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it 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 497.2 ***ft***

100-year discharge 2,330 ***ft³/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 200 ***ft³/s***
Area of flow in bridge opening 224 ***ft²***
Average velocity in bridge opening 9.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.1 ***ft/s***

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 496.2
Amount of backwater caused by bridge 3.5 ***ft***

500-year discharge 3,400 ***ft³/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 1060 ***ft³/s***
Area of flow in bridge opening 224 ***ft²***
Average velocity in bridge opening 10.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 3.7

Incipient overtopping discharge 1,820 ***ft³/s***
Water-surface elevation in bridge opening 494.7 ***ft***
Area of flow in bridge opening 146 ***ft²***
Average velocity in bridge opening 12.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.6 ***ft/s***

Water-surface elevation at Approach section with bridge 497.4
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 1.6 ***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 incipient-overtopping discharge was 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 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- and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed indicate that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28) for the right abutment. 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 computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because 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.

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	0.6	0.9
Depth to armoring	N/A	12.0	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.1	6.7	11.0
Right abutment	15.7	18.4	12.9
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	2.4	2.4	2.0
Right abutment	2.4	2.4	2.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

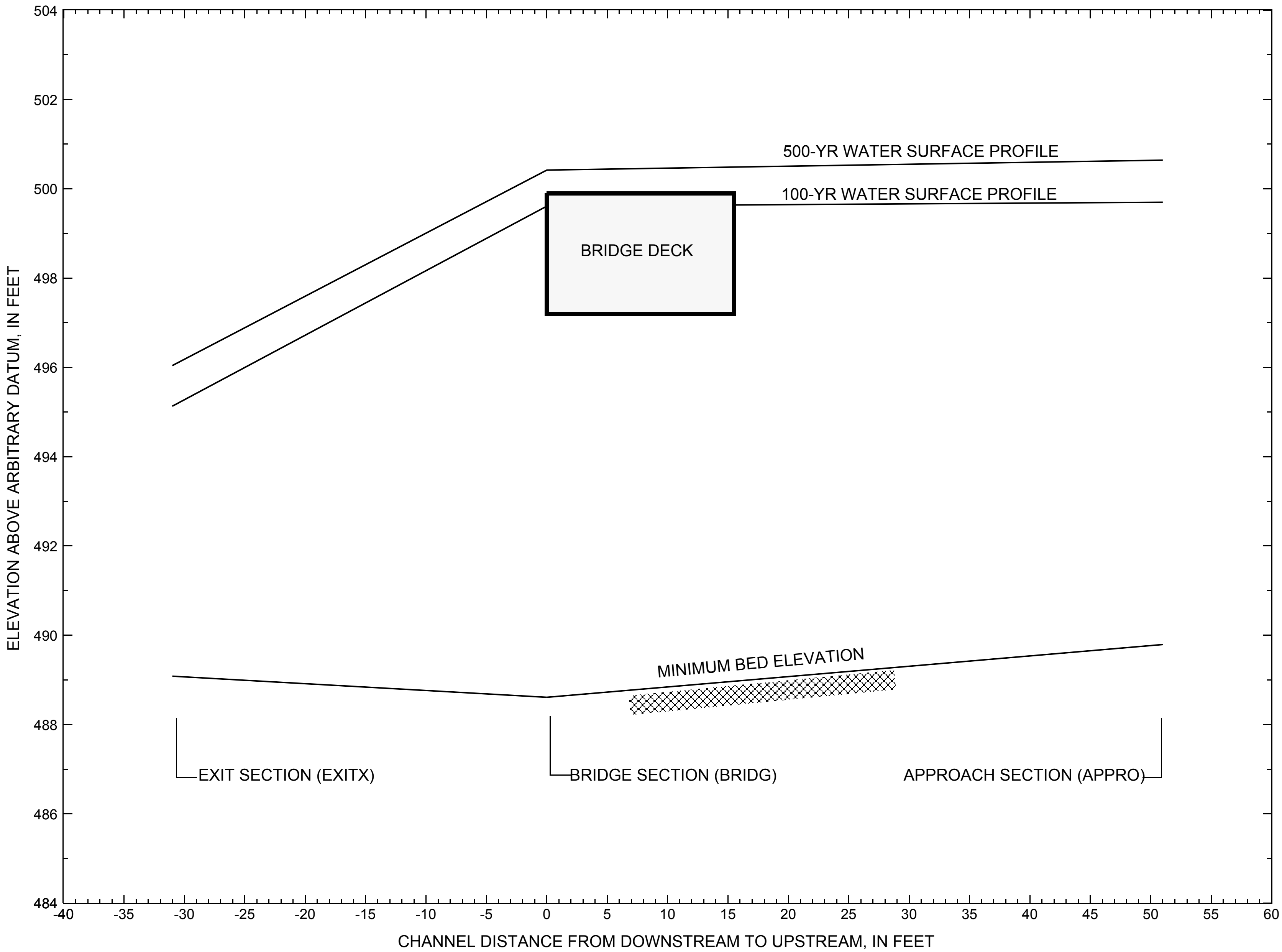

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure PUTNTH00210029 on Town Highway 21, crossing East Putney Brook, Putney, Vermont.

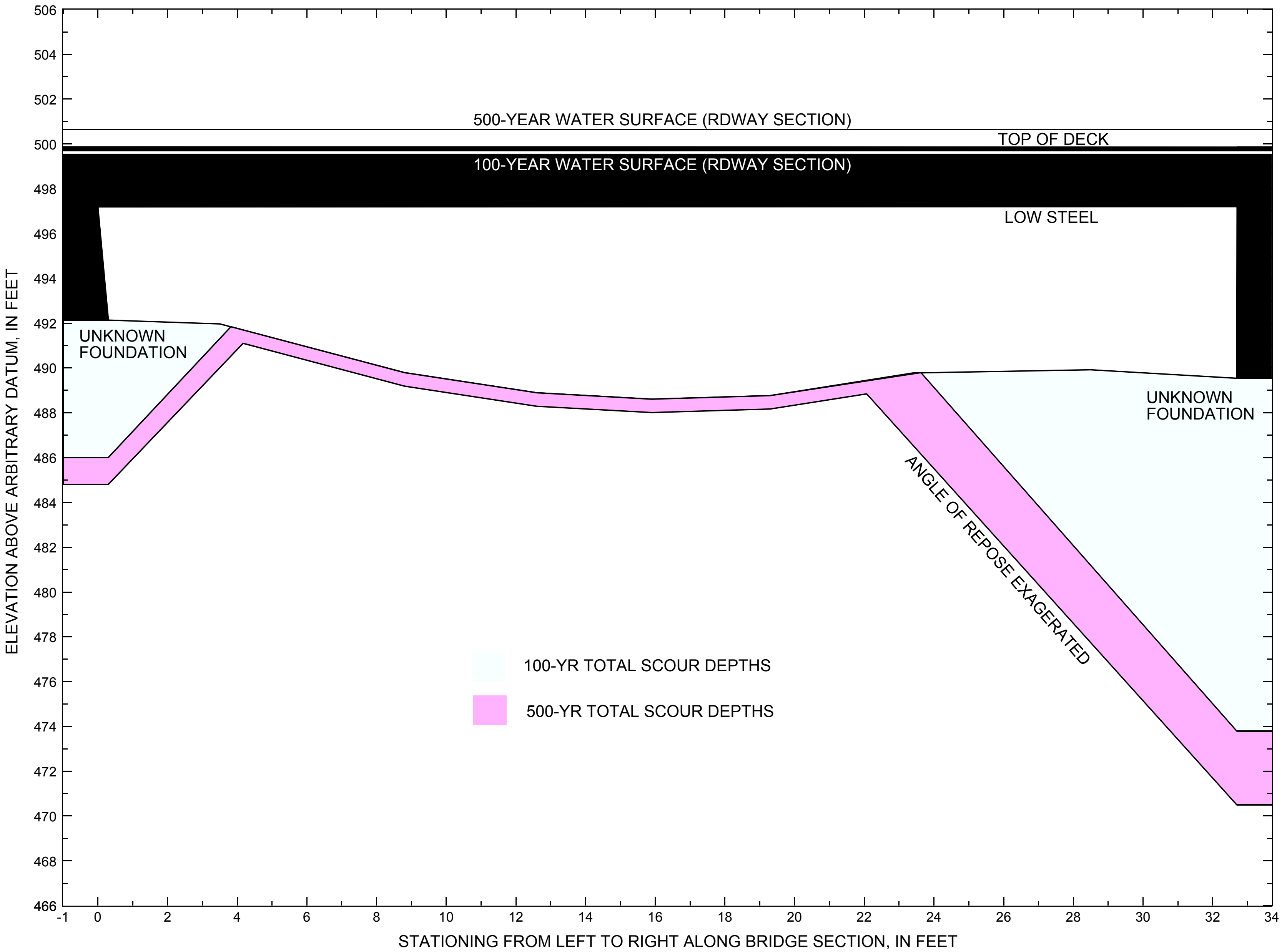

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure PUTNTH00210029 on Town Highway 21, crossing East Putney Brook, Putney, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure PUTNTH00210029 on Town Highway 21, crossing East Putney Brook, Putney, 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 2,330 cubic-feet per second											
Left abutment	0.0	--	497.2	--	492.1	0.0	6.1	--	6.1	486.0	--
Right abutment	32.7	--	497.2	--	489.5	0.0	15.7	--	15.7	473.8	--

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 PUTNTH00210029 on Town Highway 21, crossing East Putney Brook, Putney, 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 3,400 cubic-feet per second											
Left abutment	0.0	--	497.2	--	492.1	0.6	6.7	--	7.3	484.8	--
Right abutment	32.7	--	497.2	--	489.5	0.6	18.4		19.0	470.5	--

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, 1985, Walpole New Hampshire / Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 19; Contour interval, 6 meters; Scale 1:25,000.

U.S. Geological Survey, 1984, Keene, New Hampshire / Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1984; Contour interval, 6 meters; Scale 1:25,000.

U.S. Geological Survey, 1984, Townshend, Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1977; Contour interval, 6 meters; Scale 1:25,000.

U.S. Geological Survey, 1984, Newfane, Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1977; Contour interval, 6 meters; Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File putn029.wsp
T2        Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
T3        Town Highway 21 over East Putney Brook, Putney, VT           EMB
*
J1         *  *  0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2330.0   3400.0   1820.0
SK          0.00926  0.00926  0.00926
*
XS   EXITX    -31
*
GR         -229.3, 507.63   -187.4, 500.77   -168.0, 497.60    -54.6, 497.60
GR          -41.6, 495.79    -17.3, 493.26     -4.8, 492.33      0.0, 490.41
GR            5.4, 489.77      8.6, 489.43     12.4, 489.08     15.7, 489.18
GR           16.9, 489.77     22.1, 490.06     27.8, 492.16     75.2, 493.23
GR          105.9, 505.83
*
N           0.050        0.040        0.060
SA                  -4.8         27.8
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    497.19      20.0
GR            0.0, 497.19      0.3, 492.14      3.5, 491.97      8.8, 489.79
GR           12.6, 488.89     15.9, 488.61     19.3, 488.77     23.4, 489.78
GR           28.5, 489.92     32.7, 489.54     32.7, 497.20      0.0, 497.19
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      21.9 * *    38.0      3.3
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      15.5     2
GR         -229.3, 507.47   -152.9, 500.92   -110.4, 499.25    -45.3, 498.66
GR            0.0, 499.87     32.8, 499.86     80.6, 499.65    105.2, 500.48
GR          156.9, 502.91
*           269.4, 498.03    347.4, 502.97    686.3, 506.13
*
*
XT   APTEM     47
GR         -210.1, 507.47   -133.8, 500.92   -123.2, 497.66
GR          -10.0, 497.33     -8.4, 494.31      0.0, 490.09
GR            2.0, 489.69      8.2, 489.78     12.3, 489.89     15.7, 490.08
GR           21.7, 491.19     40.0, 493.59     59.1, 494.90    105.7, 495.01
GR          125.0, 506.95
*
AS   APPRO     51  * * *  0.0248
GT
N           0.065        0.045        0.050
SA                 -10.0         21.7
*
```

```
HP 1 BRIDG 497.19 1 497.19
HP 2 BRIDG 497.19 * * 2126
HP 2 RDWAY 499.61 * * 200
HP 1 APPRO 499.70 1 499.70
HP 2 APPRO 499.70 * * 2330
*
HP 1 BRIDG 497.20 1 497.20
HP 2 BRIDG 497.20 * * 2336
HP 2 RDWAY 500.42 * * 1056
HP 1 APPRO 500.64 1 500.64
HP 2 APPRO 500.64 * * 3400
*
HP 1 BRIDG 494.65 1 494.65
HP 2 BRIDG 494.65 * * 1820
HP 1 APPRO 497.39 1 497.39
HP 2 APPRO 497.39 * * 1820
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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     U.S. Geological Survey WSPRO Input File putn029.wsp
     Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
     Town Highway 21 over East Putney Brook, Putney, VT           EMB
        *** RUN DATE & TIME: 03-20-97  08:04

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      224     24742     31     44                          3433
497.19           224     24742     31     44  1.00      0     33     3433

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    497.19     0.0    32.7   224.1   24742.   2126.   9.49

X STA.         0.0         4.3         6.6         8.4         9.9        11.3
 A(I)            20.0        13.5        11.5        10.4        10.0
 V(I)            5.32        7.85        9.22       10.24       10.62

X STA.        11.3        12.5        13.7        14.8        15.9        17.0
 A(I)             9.6         9.1         9.1         8.8         8.8
 V(I)           11.05       11.70       11.69       12.11       12.09

X STA.        17.0        18.1        19.3        20.5        21.7        23.1
 A(I)             9.0         8.9         9.2         9.3         9.9
 V(I)           11.82       11.89       11.58       11.42       10.79

X STA.        23.1        24.5        26.0        27.7        29.6        32.7
 A(I)            10.2        10.5        11.5        13.2        21.6
 V(I)           10.41       10.14        9.25        8.06        4.92

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.61  -119.6    -9.7    61.2    1234.     200.   3.27

X STA.      -119.6      -102.2       -94.2       -87.8       -82.5       -77.6
 A(I)             4.9         3.8         3.4         3.1         3.1
 V(I)            2.04        2.65        2.93        3.19        3.24

X STA.       -77.6       -73.4       -69.6       -65.9       -62.6       -59.4
 A(I)             2.9         2.7         2.7         2.6         2.5
 V(I)            3.47        3.69        3.69        3.85        3.95

X STA.       -59.4       -56.5       -53.6       -50.8       -48.1       -45.5
 A(I)             2.5         2.5         2.4         2.5         2.5
 V(I)            4.02        4.02        4.08        4.07        3.99

X STA.       -45.5       -42.7       -39.4       -35.3       -29.5        -9.7
 A(I)             2.5         2.7         3.1         3.5         5.2
 V(I)            3.97        3.64        3.26        2.89        1.91

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      245      9018    120    120                          1984
          2      275     36291     32     35                          4605
          3      468     40944     91     93                          6004
499.70           988     86253    243    247  1.45   -129    113     9377

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.70  -129.5   113.1   987.6   86253.   2330.   2.36

X STA.      -129.5       -66.5       -15.2        -2.5         1.2         4.4
 A(I)           120.8       111.8        57.8        34.2        30.8
 V(I)            0.96        1.04        2.01        3.40        3.78

X STA.         4.4         7.4        10.4        13.4        16.5        19.8
 A(I)            29.8        29.5        29.3        29.6        29.9
 V(I)            3.92        3.95        3.97        3.93        3.89

X STA.        19.8        24.0        29.0        34.8        42.1        50.5
 A(I)            34.8        38.9        41.4        45.6        46.8
 V(I)            3.35        2.99        2.81        2.55        2.49

X STA.        50.5        61.2        72.3        83.8        95.3       113.1
 A(I)            52.7        51.8        53.5        53.2        65.1
 V(I)            2.21        2.25        2.18        2.19        1.79
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       U.S. Geological Survey WSPRO Input File putn029.wsp
       Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
       Town Highway 21 over East Putney Brook, Putney, VT           EMB
          *** RUN DATE & TIME: 03-20-97  08:04

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      224     17388      0     75                            0
  497.20           224     17388      0     75  1.00      0     33        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.20     0.0    32.7   224.2   17388.    2336.  10.42

X STA.        0.0        3.9        6.3        8.2        9.7       11.1
  A(I)           18.2       13.2       11.9       10.9       10.3
  V(I)           6.42       8.82       9.78      10.76      11.34

X STA.       11.1       12.5       13.7       14.9       16.1       17.2
  A(I)           10.2        9.6        9.6        9.3        9.3
  V(I)          11.48      12.13      12.11      12.54      12.54

X STA.       17.2       18.4       19.6       20.9       22.2       23.7
  A(I)            9.5        9.4        9.6        9.9       10.3
  V(I)          12.30      12.39      12.17      11.79      11.34

X STA.       23.7       25.1       26.7       28.3       30.0       32.7
  A(I)           10.3       10.7       11.3       11.7       18.8
  V(I)          11.35      10.91      10.33       9.96       6.21

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.42  -140.2   103.4   223.9    6659.    1056.   4.72

X STA.     -140.2     -111.1     -101.3      -93.2      -85.9      -79.2
  A(I)           16.6       11.8       10.5        9.9        9.5
  V(I)           3.18       4.48       5.02       5.31       5.54

X STA.      -79.2      -72.9      -67.2      -61.7      -56.5      -51.6
  A(I)            9.3        8.8        8.7        8.4        8.4
  V(I)           5.70       5.98       6.07       6.29       6.31

X STA.      -51.6      -46.8      -42.1      -36.8      -30.6      -22.6
  A(I)            8.2        8.2        8.5        9.0       10.0
  V(I)           6.47       6.46       6.20       5.84       5.30

X STA.      -22.6      -11.3        9.7       35.6       64.7      103.4
  A(I)           11.4       13.3       14.4       18.5       20.5
  V(I)           4.65       3.96       3.66       2.86       2.58

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      358     16751    123    123                         3476
            2      305     43070     32     35                         5372
            3      554     53664     93     95                         7684
  500.64          1218    113485    247    252  1.42   -132    115    12880

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.64  -132.6   114.6  1217.8  113485.    3400.   2.79

X STA.     -132.6      -83.9      -45.1       -8.2       -1.7        2.2
  A(I)          129.1      118.3      119.4       51.7       40.5
  V(I)           1.32       1.44       1.42       3.29       4.20

X STA.        2.2        5.6        9.0       12.4       15.8       19.5
  A(I)           37.4       36.3       36.1       36.6       37.3
  V(I)           4.54       4.69       4.71       4.65       4.56

X STA.       19.5       24.0       29.4       35.7       43.3       52.3
  A(I)           41.9       46.9       50.1       53.8       57.5
  V(I)           4.06       3.63       3.39       3.16       2.96

X STA.       52.3       62.7       73.8       84.7       96.1      114.6
  A(I)           60.6       61.9       61.2       63.2       78.1
  V(I)           2.80       2.75       2.78       2.69       2.18
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        U.S. Geological Survey WSPRO Input File putn029.wsp
        Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
        Town Highway 21 over East Putney Brook, Putney, VT           EMB
           *** RUN DATE & TIME: 03-20-97  08:04

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      146     13182     31     39                         1813
   494.65           146     13182     31     39  1.00      0     33     1813

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.65     0.2    32.7   146.2   13182.    1820.  12.45

X STA.        0.2        5.2        7.6        9.3       10.8       12.0
  A(I)           12.7        8.7        7.9        6.9        6.6
  V(I)           7.18      10.45      11.58      13.15      13.80

X STA.       12.0       13.2       14.3       15.4       16.4       17.5
  A(I)            6.3        6.0        6.1        5.9        5.8
  V(I)          14.50      15.09      15.01      15.53      15.62

X STA.       17.5       18.5       19.6       20.8       22.0       23.4
  A(I)            6.0        5.9        6.2        6.3        6.6
  V(I)          15.25      15.40      14.75      14.54      13.82

X STA.       23.4       24.9       26.4       28.1       29.9       32.7
  A(I)            6.9        7.0        7.4        8.1       13.1
  V(I)          13.22      13.05      12.22      11.26       6.94

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      202     21696     32     35                         2897
             3      261     15982     88     89                         2554
   497.39           463     37677    119    123  1.24     -9    109     4642

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.39   -10.0   109.4   463.0   37677.    1820.   3.93

X STA.      -10.0       -2.4        0.5        2.8        5.1        7.2
  A(I)           29.4       19.6       17.2       16.8       15.8
  V(I)           3.09       4.64       5.28       5.40       5.76

X STA.        7.2        9.2       11.3       13.4       15.5       17.8
  A(I)           15.6       15.5       15.4       15.6       16.0
  V(I)           5.82       5.87       5.91       5.84       5.68

X STA.       17.8       20.3       23.4       27.4       32.2       38.6
  A(I)           16.2       19.2       22.2       24.4       27.2
  V(I)           5.63       4.73       4.09       3.73       3.35

X STA.       38.6       47.0       58.8       74.3       90.1      109.4
  A(I)           29.7       33.4       36.6       36.9       40.1
  V(I)           3.07       2.73       2.48       2.46       2.27
```

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       U.S. Geological Survey WSPRO Input File putn029.wsp
       Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
       Town Highway 21 over East Putney Brook, Putney, VT           EMB
          *** RUN DATE & TIME: 03-20-97  08:04

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

EXITX:XS   ******    -34      328  1.23 *****  496.37  495.01    2330  495.13
      -30 ******     80    24204  1.57 ***** *******    0.93    7.10

FULLV:FV       31    -40      403  0.81  0.22  496.57 *******    2330  495.76
         0     31     81    31602  1.56  0.00   -0.02    0.70    5.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.14     495.84     496.16
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.26     507.57    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.26     507.57     496.16
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   496.16     507.57     496.16

APPRO:AS       51     -8      318  1.17 *****  497.33  496.16    2330  496.16
        51     51    107    22417  1.40 ***** *******    0.93    7.34
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.71       0.00     495.52     498.66
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   501.58         0.      2330.
 ===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       31      0      224  1.40 *****  498.59  495.18    2126  497.19
         0 ******     33    24742  1.00 ***** *******    0.62    9.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.483  0.000  497.19 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      10.    36.  0.03  0.13  499.80    0.00    200.  499.61

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    200.   110.  -120.   -10.   1.0   0.6   3.6   3.3   0.7   2.8
   RT:      0.     7.    74.    81.   0.0   0.0   1.8  19.1   0.2   2.6

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

APPRO:AS       29   -129      989  0.13  0.07  499.83  496.16    2330  499.70
        51     32    113    86352  1.45  0.00    0.00    0.25    2.36

       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
   EXITX:XS     -31.   -35.    80.   2330.   24204.     328.    7.10  495.13
   FULLV:FV       0.   -41.    81.   2330.   31602.     403.    5.79  495.76
   BRIDG:BR       0.     0.    33.   2126.   24742.     224.    9.49  497.19
   RDWAY:RG      10.*******   200.    200.*********       0.    2.00  499.61
   APPRO:AS      51.  -130.   113.   2330.   86352.     989.    2.36  499.70

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.01    0.93  489.08  507.63************  1.23  496.37  495.13
   FULLV:FV  ********    0.70  489.08  507.63  0.22  0.00  0.81  496.57  495.76
   BRIDG:BR    495.18    0.62  488.61  497.20************  1.40  498.59  497.19
   RDWAY:RG  ****************  498.66  507.47  0.03******  0.13  499.80  499.61
   APPRO:AS    496.16    0.25  489.79  507.57  0.07  0.00  0.13  499.83  499.70
```

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        U.S. Geological Survey WSPRO Input File putn029.wsp
        Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
        Town Highway 21 over East Putney Brook, Putney, VT           EMB
           *** RUN DATE & TIME: 03-20-97  08:04

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

EXITX:XS   ******    -42      438  1.45 *****  497.49  495.87    3400  496.04
       -30 ******     82    35325  1.55 ***** *******    0.91    7.77

FULLV:FV       31    -47      522  1.00  0.23  497.70 *******    3400  496.70
         0     31     84    44742  1.52  0.00   -0.02    0.71    6.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.91     496.91     496.86
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.20     507.57    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.20     507.57     496.86
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.70

APPRO:AS       51     -9      406  1.41  0.42  498.32  496.86    3400  496.91
        51     51    109    31302  1.30  0.20    0.00    0.91    8.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.17       0.00     497.15     498.66
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.44     499.90     500.06     497.19
 ===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       31      0      224  1.69 *****  498.89  495.54    2336  497.20
         0 ******     33    17388  1.00 ***** *******    0.70   10.42

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.494  0.000  497.19 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    36.  0.03  0.17  500.78    0.00   1056.  500.42

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    837.   157.  -140.    17.   1.8   1.1   5.4   4.8   1.5   3.0
   RT:    218.    86.    17.   104.   0.8   0.6   4.1   4.4   0.9   2.8

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

APPRO:AS       29   -132     1217  0.17  0.14  500.81  496.86    3400  500.64
        51     33    115   113368  1.42  0.42    0.00    0.26    2.79

       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
   EXITX:XS     -31.   -43.    82.   3400.   35325.     438.    7.77  496.04
   FULLV:FV       0.   -48.    84.   3400.   44742.     522.    6.51  496.70
   BRIDG:BR       0.     0.    33.   2336.   17388.     224.   10.42  497.20
   RDWAY:RG      10.*******   837.   1056.******************    2.00  500.42
   APPRO:AS      51.  -133.   115.   3400.  113368.    1217.    2.79  500.64

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    495.87    0.91  489.08  507.63************  1.45  497.49  496.04
   FULLV:FV  ********    0.71  489.08  507.63  0.23  0.00  1.00  497.70  496.70
   BRIDG:BR    495.54    0.70  488.61  497.20************  1.69  498.89  497.20
   RDWAY:RG  ***************  498.66  507.47  0.03******  0.17  500.78  500.42
   APPRO:AS    496.86    0.26  489.79  507.57  0.14  0.42  0.17  500.81  500.64
```
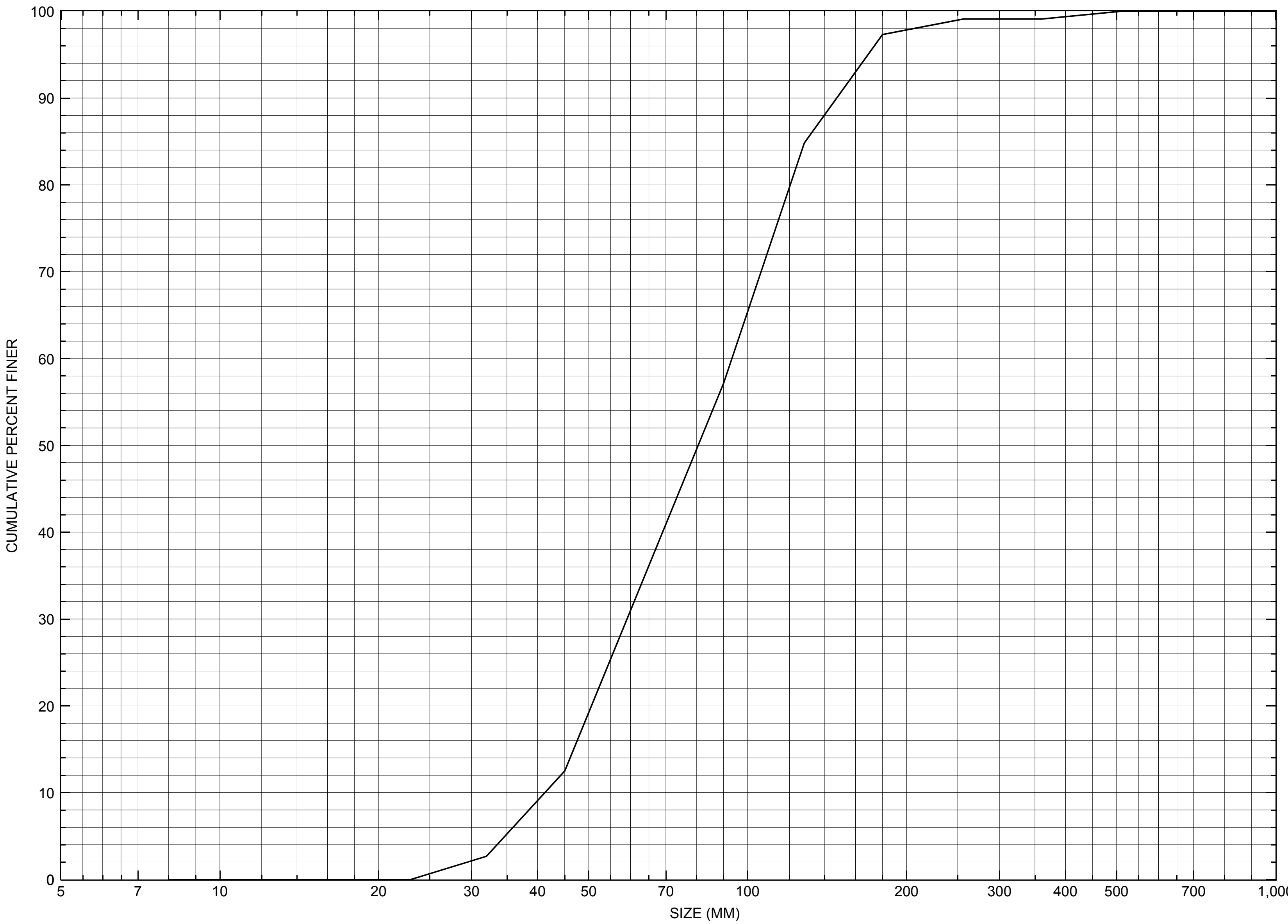

```
       U.S. Geological Survey WSPRO Input File putn029.wsp
       Hydraulic analysis for structure PUTNTH00210029   Date: 28-JAN-97
       Town Highway 21 over East Putney Brook, Putney, VT           EMB
          *** RUN DATE & TIME: 03-20-97  08:04

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

EXITX:XS   ******    -29      270  1.12 *****  495.73  494.53    1820  494.62
      -30 ******      79    18900  1.58 ***** *******    0.95    6.74

FULLV:FV       31    -35      339  0.70  0.21  495.93 *******    1820  495.23
        0      31     80    25271  1.57  0.00   -0.02    0.69    5.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.48     495.15     495.75
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.73     507.57    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.73     507.57     495.75
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   495.75     507.57     495.75

APPRO:AS       51     -8      270  1.04 *****  496.78  495.75    1820  495.75
       51      51    107    18226  1.46 ***** *******    0.94    6.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1820.     494.65

            <<<<<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       31      0      146  2.41 *****  497.06  494.65    1820  494.65
        0      31     33    13203  1.00 ***** *******    1.00   12.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.19 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      10.        <<<<<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       29     -9      463  0.30  0.21  497.69  495.75    1820  497.39
       51      32    109    37706  1.24  0.42    0.00    0.39    3.93

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.719  0.325   25416.    -5.    28.   497.31

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -31.   -30.    79.   1820.   18900.     270.    6.74  494.62
   FULLV:FV       0.   -36.    80.   1820.   25271.     339.    5.37  495.23
   BRIDG:BR       0.     0.    33.   1820.   13203.     146.   12.44  494.65
   RDWAY:RG      10.**************      0.******************     2.00********
   APPRO:AS      51.   -10.   109.   1820.   37706.     463.    3.93  497.39

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    28.   25416.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.53    0.95  489.08  507.63************  1.12  495.73  494.62
   FULLV:FV  ********    0.69  489.08  507.63  0.21  0.00  0.70  495.93  495.23
   BRIDG:BR    494.65    1.00  488.61  497.20************  2.41  497.06  494.65
   RDWAY:RG  ****************  498.66  507.47**********************************
   APPRO:AS    495.75    0.39  489.79  507.57  0.21  0.42  0.30  497.69  497.39
  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 PUTNTH00210029, in Putney, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number PUTNTH00210029

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 30 / 95

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

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 57700

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

Waterway *(I - 6)* EAST PUTNEY BROOK

Road Name *(I - 7):* -

Route Number TH021

Vicinity *(I - 9)* 0.2 MI TO JCT W CL3 TH17

Topographic Map Walpole

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 43004

Longitude *(i - 17; nnnnn.n)* 72294

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10131300291313

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1930

Structure length *(I - 49; nnnnnn)* 000035

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 155

Year of ADT *(I - 30; YY)* 90

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

Opening skew to Roadway *(I - 34; nn)* 10

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.5

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

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

Comments:

The structural inspection report of 6/27/94 indicates that the structure is a single span, steel beam type bridge with a timber deck. Both abutments are concrete. The right abutment is entirely new. The footing is noted as "not in view". The left abutment consists of older concrete with very minor stains. There is "good" stone fill around the structure. The streambed consists of stone and gravel. The stream makes a moderate turn into the structure.

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)* 10.33 mi^2 Lake and pond area 0.03 mi^2
Watershed storage *(ST)* 0.3 %
Bridge site elevation 472 ft Headwater elevation 1637 ft
Main channel length 8.06 mi
10% channel length elevation 532 ft 85% channel length elevation 1102 ft
Main channel slope *(S)* 94.40 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? N *If no, type ctrl-n xs*

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

Comments: **NO CROSS SECTION INFORMATION**

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*)? -

Comments: **NO CROSS SECTION INFORMATION**

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: **RB** Date: **5/13/97**
Computerized by: **RB** Date: **5/13/97**
Reviewd by: **EB** Date: **5/20/97**

Structure Number **PUTNTH00210029**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **8** / **19** / 19**96**

2. Highway District Number **02**
   Mile marker **000000**
   County **RUTLAND (025)**
   Town **PUTNEY (57700)**
   Waterway *(I - 6)* **East Putney Brook**
   Road Name **--**
   Route Number **TH 21**
   Hydrologic Unit Code: **01080104**

3. Descriptive comments:
The bridge is located 0.2 miles from the intersection of town highway 21 with town highway 17.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** LBDS **4** 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 **1** *(**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 **35** *(feet)* Span length **29** *(feet)* Bridge width **15.5** *(feet)*

Road approach to bridge:

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

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

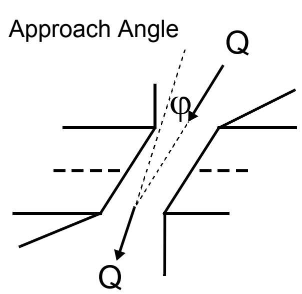
10. Embankment slope (*run / rise in feet / foot*):
US left **-** US right **-**

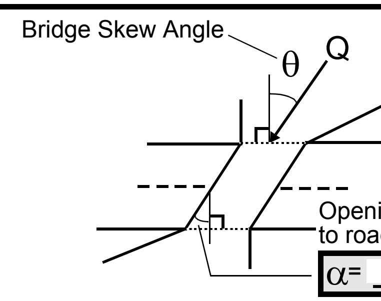
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	5	1	0	-
RBUS	0	-	-	-
RBDS	5	1	0	-
LBDS	5	1	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **20** 16. Bridge skew: **40**





Opening skew to roadway
α= **20.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **20** feet **US** *(US, UB, DS)* to **10** 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**

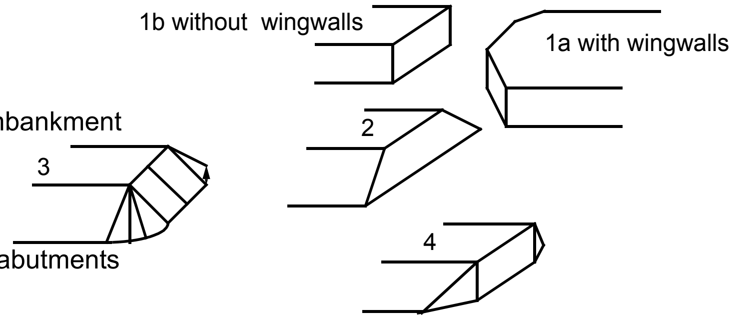
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

In addition to the pasture on the left overbank downstream there is a house, a barn, and a garden. The bridge dimensions on the previous page are historical values from the VTAOT database. The field measured bridge length was 36 feet, span length was 32 feet, and the deck width was 16.0 feet. The downstream wingwalls are laid-up stone walls parallel to the road.

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
33.5	7.0			1.0	3	1	435	34	1	1

23. Bank width **35.0** 24. Channel width **10.0** 25. Thalweg depth **31.5** 29. Bed Material **43**

30 .Bank protection type: LB **3** RB **2** 31. Bank protection condition: LB **2** 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.):

The left bank protection extends 20 feet upstream of the end of the wingwall along the roadway embankment. The right bank protection extends 25 feet upstream of the bridge. There is a small stone pile dam 250 feet upstream.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **100** 35. Mid-bar width: **10**

36. Point bar extent: **72** feet **US** (US, UB) to **135** feet **US** (US, UB, DS) positioned **0** %LB to **30** %RB

37. Material: **4**

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

This is a side bar composed primarily of cobbles with a few boulders and nearly 100 percent of the bar area is covered by grass. There is an additional side bar from 180 to 247 feet upstream with a mid-bar distance of 240 feet. The width at mid-bar was 11 feet positioned 80% LB to 100% RB. This side bar is composed of gravel and cobbles.

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: **190** 42. Cut bank extent: **155** feet **US** (US, UB) to **245** feet **US** (US, UB, DS)

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

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

-

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
15.5		**0.5**		**2**	**7**	**7**	**0**

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **90.0** 63. Bed Material **0**

*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

-

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

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

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

70. Debris and Ice Comments:

2

There is significant vegetation on the banks upstream of this site and the channel is stable. The bridge opening is narrow and skewed to flood flows.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	0	0	90.0
RABUT	1	30	90			2	0	30.5

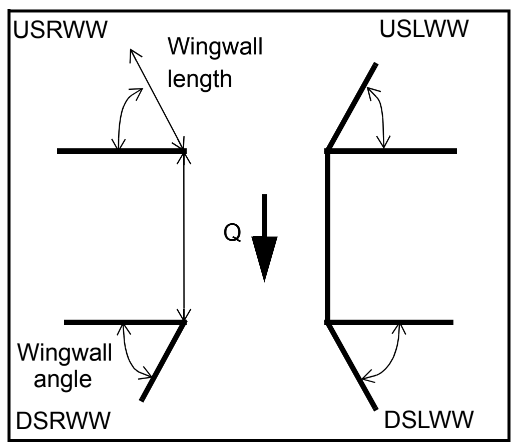
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

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

0
0
1
-

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						30.5	
USRWW:	Y		1		0	1.0	
DSLWW:	0		0		Y	20.0	
DSRWW:	1		0		0	20.0	



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

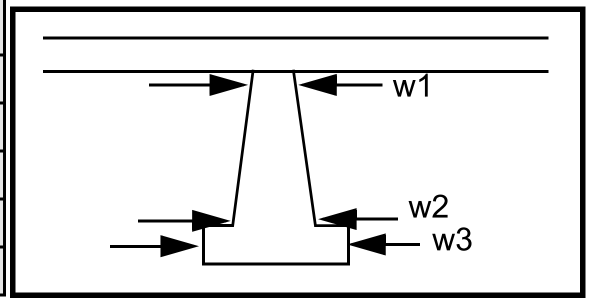
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		5.5	4.5	180.0	75.0	0.0
Pier 2	-	-	-	0.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	but	pro-	the	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	dow	the	tec-	right	**1**- Solid pier, **2**- column, **3**- bent
88. Material	nstre	lengt	tion	abut	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	am	hs	alon	ment	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	wing	were	g the	.	Y- yes; N- no
91. Attack ∠ (BF)	wall	not	dow		
92. Pushed	angl	mea-	nstre		LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	es	sure	am-		
95. Cross-members	were	d.	most		**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	zero	Ther	three		**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	degr	e is	feet		
98. Exposure depth	ees	no	of		

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

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 NO %LB to PI %RB

Material: ER

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

S

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 1 (US, UB, DS)

Bank damage: 4 (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

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

453
43
1
2

Is channel scour present? 43 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length 3 Width - Depth: 1 Positioned The %LB to rig %RB

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

ht bank protection extends 22 feet downstream of the bridge. A resident mentioned that the previous bridge created a scour hole about 4 feet deep along the right bank from 22 to 45 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)*:

N

-

NO DROP STRUCTURE

Y

32

8

5

DS

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: PUTNTH00210029 Town: Putney
Road Number: TH 21 County: Windham
Stream: East Putney Brook

Initials EMB Date: 4/3/97 Checked: RLB 4/7/97

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	2330	3400	1820
Main Channel Area, ft2	275	305	202
Left overbank area, ft2	245	358	0
Right overbank area, ft2	468	554	261
Top width main channel, ft	32	32	32
Top width L overbank, ft	120	123	0
Top width R overbank, ft	91	93	88
D50 of channel, ft	0.2648	0.2648	0.2648
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.6	9.5	6.3
y1, average depth, LOB, ft	2.0	2.9	ERR
y1, average depth, ROB, ft	5.1	6.0	3.0
Total conveyance, approach	86253	113485	37677
Conveyance, main channel	36291	43070	21696
Conveyance, LOB	9018	16751	0
Conveyance, ROB	40944	53664	15982
Percent discrepancy, conveyance	0.0000	0.0000	-0.0027
Qm, discharge, MC, cfs	980.3	1290.4	1048.0
Ql, discharge, LOB, cfs	243.6	501.9	0.0
Qr, discharge, ROB, cfs	1106.0	1607.8	772.0
Vm, mean velocity MC, ft/s	3.6	4.2	5.2
Vl, mean velocity, LOB, ft/s	1.0	1.4	ERR
Vr, mean velocity, ROB, ft/s	2.4	2.9	3.0
Vc-m, crit. velocity, MC, ft/s	10.3	10.5	9.8
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	2126	2336	1820
Main channel area (DS), ft2	180.2	209	146.2
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	30.7	30.7	30.5
D90, ft	0.4836	0.4836	0.4836
D95, ft	0.5543	0.5543	0.5543
Dc, critical grain size, ft	0.5620	0.4757	0.6796
Pc, Decimal percent coarser than Dc	0.045	0.106	0.020
Depth to armoring, ft	N/A	12.04	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	2330	3400	1820
(Q) discharge thru bridge, cfs	2126	2336	1820
Main channel conveyance	24742	17388	13182
Total conveyance	24742	17388	13182
Q2, bridge MC discharge,cfs	2126	2336	1820
Main channel area, ft2	224	224	146
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.7	30.7	30.5
y_bridge (avg. depth at br.), ft	7.30	7.30	4.79
Dm, median (1.25*D50), ft	0.331	0.331	0.331
y2, depth in contraction,ft	6.42	6.96	5.65
ys, scour depth (y2-ybridge), ft	-0.88	-0.35	0.85

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 other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	2330	3400	1820
Q, thru bridge MC, cfs	2126	2336	1820
Vc, critical velocity, ft/s	10.30	10.48	9.79
Va, velocity MC approach, ft/s	3.56	4.23	5.19
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.7	30.7	30.5
qbr, unit discharge, ft2/s	69.3	76.1	59.7
Area of full opening, ft2	224.1	224.2	146.2
Hb, depth of full opening, ft	7.30	7.30	4.79
Fr, Froude number, bridge MC	0.62	0.7	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	180.2	209	N/A
**Hb, depth at downstream face, ft	5.87	6.81	N/A
**Fr, Froude number at DS face	0.86	0.75	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.19	497.19	497.19
Elevation of Bed, ft	489.89	489.89	492.40
Elevation of Approach, ft	499.7	500.64	0
Friction loss, approach, ft	0.07	0.14	0
Elevation of WS immediately US, ft	499.63	500.50	0.00
ya, depth immediately US, ft	9.74	10.61	-492.40
Mean elevation of deck, ft	499.87	499.87	499.87
w, depth of overflow, ft (>=0)	0.00	0.63	0.00
Cc, vert contrac correction (<=1.0)	0.93	0.92	ERR
**Cc, for downstream face (<=1.0)	0.855314	0.900429	ERR
Ys, scour w/Chang equation, ft	-0.05	0.58	N/A
Ys, scour w/Umbrell equation, ft	-1.64	-0.78	N/A
**=for UNsubmerged orifice flow only.			
**Ys, scour w/Chang equation, ft	1.99	1.25	N/A
**Ys, scour w/Umbrell equation, ft	-0.21	-0.29	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	6.42	6.96	5.65
WSEL at downstream face, ft	495.76	496.70	--
Depth at downstream face, ft	5.87	6.81	ERR
Ys, depth of scour (Laursen), ft	0.55	0.14	N/A

Abutment Scour

Froehlich's Abutment Scour

$Ys/Y1 = 2.27*K1*K2*(a'/Y1)^{0.43}*Fr1^{0.61}+1$

(Richardson and others, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	2330	3400	1820	2330	3400	1820
a', abut.length blocking flow, ft	130.5	133.6	11.2	81.4	70.8	77.7
Ae, area of blocked flow ft2	261.6	286.5	54.2	390.8	417	206.4
Qe, discharge blocked abut.,cfs	--	--	209.7	877.8	--	555.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.42	1.79	3.87	2.25	2.77	2.69
ya, depth of f/p flow, ft	2.00	2.14	4.84	4.80	5.89	2.66
--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	70	70	70	110	110	110
K2	0.97	0.97	0.97	1.03	1.03	1.03
Fr, froude number f/p flow	0.160	0.172	0.310	0.181	0.206	0.291
ys, scour depth, ft	9.12	9.95	10.96	15.71	18.40	12.86

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)	130.5	133.6	11.2	81.4	70.8	77.7
y1 (depth f/p flow, ft)	2.00	2.14	4.84	4.80	5.89	2.66
a'/y1	65.10	62.30	2.31	16.95	12.02	29.25
Skew correction (p. 49, fig. 16)	0.93	0.93	0.93	1.04	1.04	1.04
Froude no. f/p flow	0.16	0.17	0.31	0.18	0.21	0.29
Ys w/ corr. factor K1/0.55:						
vertical	7.41	8.11	ERR	ERR	ERR	13.37
vertical w/ ww's	6.07	6.65	ERR	ERR	ERR	10.96
spill-through	4.07	4.46	ERR	ERR	ERR	7.35

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 (DS)	0.86	0.75	1	0.86	0.75	1
y, depth of flow in bridge (DS), ft	5.87	6.81	4.79	5.87	6.81	4.79

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.37	ERR	ERR	2.37	ERR
Fr>0.8 (vertical abut.)	2.35	ERR	2.00	2.35	ERR	2.00