LEVEL II SCOUR ANALYSIS FOR BRIDGE 145 (HANCVT01000145) on STATE ROUTE 100, crossing the HANCOCK BRANCH of the WHITE RIVER, HANCOCK, VERMONT

U.S. Geological Survey
Open-File Report 96-747

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

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Pembroke, New Hampshire

1996

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

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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 145 (HANCVT01000145) ON STATE ROUTE 100, CROSSING THE HANCOCK BRANCH OF THE WHITE RIVER, HANCOCK, VERMONT

***By* Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HANCVT01000145 on State Route 100 crossing the Hancock Branch of the White River, Hancock, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in central Vermont. The 22.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is urban on left bank and forested on the right bank upstream of the bridge while the immediate banks have woody vegetation. Downstream of the bridge surface cover on both banks is pasture while the immediate banks have woody vegetation.

In the study area, the Hancock Branch of the White River has an incised, sinuous channel with a slope of approximately 0.006 ft/ft, an average channel top width of 48 ft and an average channel depth of 3 ft. The predominant channel bed materials are cobble and gravel with a median grain size (D_{50}) of 71.9 mm (0.236 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 16, 1994, indicated that the reach was stable.

State Route 100 crossing the Hancock Branch of the White River is a 55-ft-long, two-lane bridge consisting of one 53-foot steel-beam span (Vermont Agency of Transportation, written communication, August 26, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is 0 degrees.

The only scour protection measures at the site were type-3 stone fill (less than 48 inches diameter) at the upstream right wingwall, both downstream wingwalls and the downstream ends of both abutments. Also there was type-2 stone fill (less than 36 inches diameter) at the upstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D
and E.

Scour depths and 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 3.4 to 4.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.2 to 11.1 ft. The worst-case abutment scour occurred at the 100-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Hancock, VT. Quadrangle, 1:24,000, 1970

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 HANCVT01000145 ***Stream*** Hancock Branch of the White River

County Addison ***Road*** VT 100 ***District*** 4

Description of Bridge

Bridge length 55 ***ft*** ***Bridge width*** 35.6 ***ft*** ***Max span length*** 53 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 11/16/94

Description of stone fill Type-2, around the upstream left wingwall. Type-3, around the upstream right wingwall, both downstream wingwalls, and the downstream ends of both abutments.

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

Is bridge skewed to flood flow according to Level I survey? No ***Angle*** 0

No

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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	11/16/94	0	0
Level II	11/16/94	0	0

Potential for debris Moderate. There are some trees leaning over the channel upstream.

None 11/16/94.

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

Description of the Geomorphic Setting

General topography The channel has a flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 11/16/94

DS left: Moderately sloping channel bank to flood plain

DS right: Gradually sloping channel bank to flood plain

US left: Gradually sloping levee to flood plain

US right: Gradually sloping levee to narrow flood plain

Description of the Channel

Average top width 48.0 ft ***Average depth*** 3.0 ft

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

Perennial stream with semi-alluvial to non-alluvial channel boundaries.

11/16/94

Vegetative co Brush and Trees

DS left: Trees and brush

DS right: Trees

US left: Trees and brush

US right:

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

None, 11/16/94

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 22.0 ***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***: There are buildings and State Route 125 on the upstream left overbank area and some houses on both of the downstream overbanks.

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 4,800 ***ft³/s*** ***Q500*** 7,000 ***ft³/s***

The 100- and 500-year discharges are based on the Flood Insurance Study for the Town of Hancock, VT (Federal Emergency Management Agency, August 19, 1991). The discharges were within a range defined by frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957 a & b; Talbot, 1987).

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 Add 414.0 ft. to the USGS survey to obtain VTAOT plans' datum and sea level.

Description of reference marks used to determine USGS datum. RM1 is a brass tablet on top of the downstream end of the right abutment (elev. 498.00 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 499.69 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	-1058	2	Downstream Exit section at confluence with the White River (Templated from ETEMP)
EXIT2	-858	2	Downstream Exit section (Templated from ETEMP)
EXIT3	-658	2	Downstream Exit section (Templated from ETEMP)
EXIT4	-458	2	Downstream Exit section (Templated from ETEMP)
EXIT5	-258	2	Downstream Exit section (Templated from ETEMP)
EXIT6	-58	2	Downstream Exit section (Templated from ETEMP)
ETEMP	-58	1	Exit section as surveyed (Used as a template)
FULLV	0	2	Downstream Full-valley section (Templated from ETEMP)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	90	2	Modelled Approach section (Templated from ATEMP)
ATEMP	107	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 0.035 to 0.047, and overbank "n" values ranged from 0.040 to 0.045.

The confluence of the Hancock Branch and the White River is approximately 1000 feet downstream of the bridge. The exit section of the bridge was used as a template section and the reach between the confluence and the bridge was included in the hydraulic analysis. The model was started using water-surface elevations taken from the Flood Insurance Study for the Town of Hancock, VT (Federal Emergency Management Agency, 1991). It was determined that normal depth was achieved within the reach between the confluence and the bridge.

The surveyed approach section (ATEMP) was moved along the approach channel slope (0.0094 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 approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.4 *ft*
Average low steel elevation 494.4 *ft*

100-year discharge 4,800 *ft³/s*
Water-surface elevation in bridge opening 494.6 *ft*
Road overtopping? Yes *Discharge over road* 339 *ft³/s*
Area of flow in bridge opening 353 *ft²*
Average velocity in bridge opening 12.9 *ft/s*
Maximum WSPRO tube velocity at bridge 14.6 *ft/s*

Water-surface elevation at Approach section with bridge 498.8 *ft*
Water-surface elevation at Approach section without bridge 495.4 *ft*
Amount of backwater caused by bridge 3.4 *ft*

500-year discharge 7,000 *ft³/s*
Water-surface elevation in bridge opening 494.6 *ft*
Road overtopping? Yes *Discharge over road* 2,330 *ft³/s*
Area of flow in bridge opening 353 *ft²*
Average velocity in bridge opening 13.3 *ft/s*
Maximum WSPRO tube velocity at bridge 15.4 *ft/s*

Water-surface elevation at Approach section with bridge 500.0 *ft*
Water-surface elevation at Approach section without bridge 496.2 *ft*
Amount of backwater caused by bridge 3.8 *ft*

Incipient overtopping discharge 4,390 *ft³/s*
Water-surface elevation in bridge opening 494.6 *ft*
Area of flow in bridge opening 353 *ft²*
Average velocity in bridge opening 12.2 *ft/s*
Maximum WSPRO tube velocity at bridge 14.4 *ft/s*

Water-surface elevation at Approach section with bridge 498.2 *ft*
Water-surface elevation at Approach section without bridge 495.2 *ft*
Amount of backwater caused by bridge 3.0 *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.

All discharges resulted in 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 was computed by the Chang equation (Richardson and others, 1995, p. 145-146). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in appendix F.

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

Scour at the right abutment for all 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	3.9	4.3	3.4
Depth to armoring	17.8	22.4	14.1
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	11.1	10.0	10.3
Right abutment	8.6	9.2	8.2
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	2.8	2.8	2.8
Right abutment	2.8	2.8	2.8
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

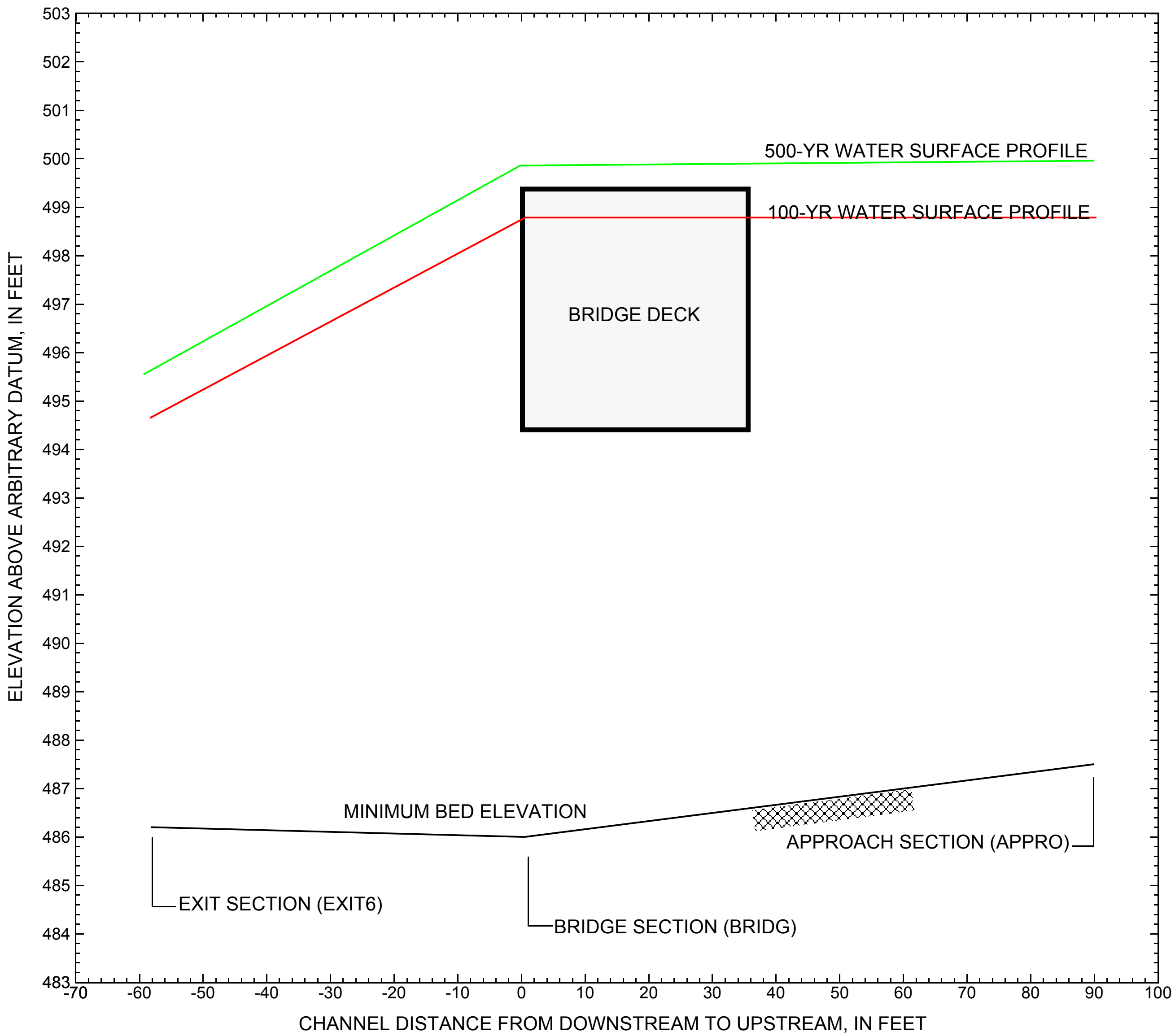

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HANCVT01000145 on State Route 100, crossing the Hancock Branch of the White River, Hancock, Vermont.

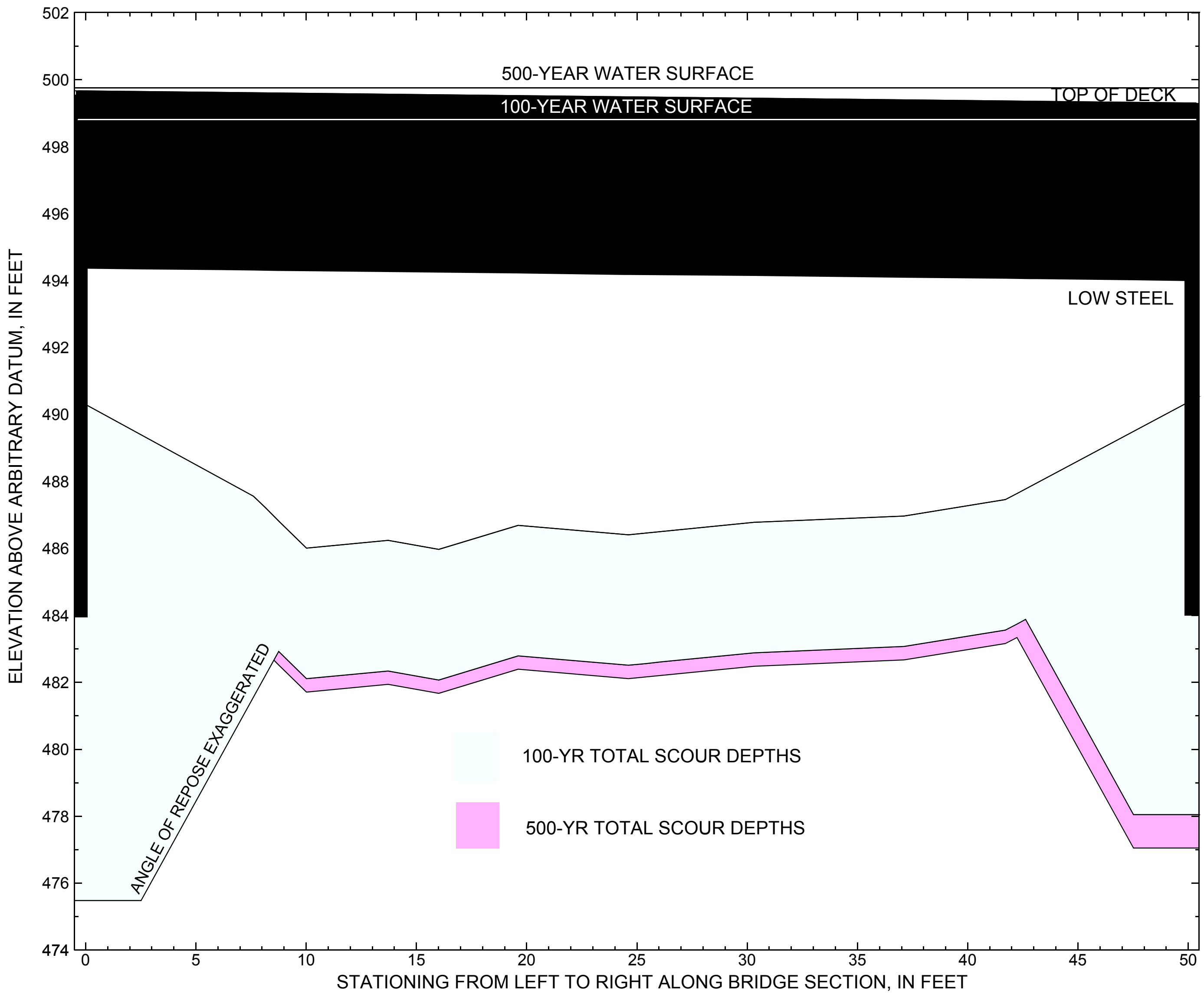

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HANCVT01000145 on State Route 100, crossing the Hancock Branch of the White River, Hancock, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HANCVT01000145 on State Route 100, crossing the Hancock Branch of the White River, Hancock, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat 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 4,800 cubic-feet per second											
Left abutment	0.0	908.8	494.6	484	490.5	3.9	11.1	--	15.0	475.5	-8
Right abutment	50.2	908.6	494.3	484	490.5	3.9	8.6	--	12.5	478.0	-6

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 HANCVT01000145 on State Route 100, crossing the Hancock Branch of the White River, Hancock, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat 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 7,000 cubic-feet per second											
Left abutment	0.0	908.8	494.6	484	490.5	4.3	10.0	--	14.3	476.2	-8
Right abutment	50.2	908.6	494.3	484	490.5	4.3	9.2	--	13.5	477.0	-7

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, 1970, Hancock, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File hanc145.wsp
T2        Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
T3        Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
Q           4800   7000   4390
WS          491.1  492.2  490.6
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XT   ETEMP    -58
GR         -291.8, 498.00    -77.1, 498.55    -57.5, 497.92    -39.7, 492.90
GR           -8.2, 493.05     -3.7, 492.25      0.0, 489.83      5.1, 487.07
GR            9.6, 486.20     15.4, 486.25     20.0, 486.45     27.4, 486.63
GR           37.7, 487.32     44.7, 489.45     52.5, 493.67     75.4, 491.88
GR          191.0, 492.32    230.2, 497.55    371.7, 498.20    371.7, 510.00
*
XS   EXIT1    -1058
GT             -5.7
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   EXIT2    -858
GT             -4.6
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   EXIT3    -658
GT             -3.4
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   EXIT4    -458
GT             -2.3
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   EXIT5    -258
GT             -1.1
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   EXIT6    -58
GT             0.0
N           0.045        0.042        0.045
SA                  -3.7         52.5
*
XS   FULLV      0  * * *   0.0057
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    494.43    0.0
GR            0.0, 494.58      0.0, 490.47      7.6, 487.55     10.0, 486.00
GR           13.7, 486.23     16.0, 485.96     19.6, 486.68     24.6, 486.40
GR           30.3, 486.77     37.1, 486.96     41.7, 487.45     50.0, 490.54
GR           50.2, 494.28      0.0, 494.58
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      51.1 * *     49.4      9.4
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     20      35.6     1
GR         -172.0, 510.00   -172.0, 499.00    -50.3, 499.86     0.0, 499.67
GR           52.6, 499.07     97.1, 498.54    317.1, 498.20   317.1, 510.00
*
XT   ATEMP    107
GR         -264.6, 510.00   -264.6, 500.85    -37.9, 499.16    -20.7, 495.44
GR           -5.2, 494.49      0.0, 491.33      4.7, 488.39     10.6, 487.83
GR           19.5, 487.62     28.2, 487.71     34.7, 487.68     42.3, 488.37
GR           49.3, 492.28     71.1, 492.74    105.9, 494.33    117.6, 495.93
GR          165.4, 497.31    317.8, 498.20    317.8, 510.00
*
AS   APPRO    90
GT            -0.16
N           0.040        0.047        0.04
SA                  -37.9       117.6
*
HP 1 BRIDG   494.58 1 494.58
HP 2 BRIDG   494.58 * * 4542
HP 2 RDWAY   498.83 * * 339
HP 1 APPRO   498.83 1 498.83
HP 2 APPRO   498.83 * * 4800
*
HP 1 BRIDG   494.58 1 494.58
HP 2 BRIDG   494.58 * * 4685
HP 2 RDWAY   499.88 * * 2327
HP 1 APPRO   500.01 1 500.01
HP 2 APPRO   500.01 * * 7000
*
HP 1 BRIDG   494.58 1 494.58
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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       U.S. Geological Survey WSPRO Input File hanc145.wsp
       Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
       Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
          *** RUN DATE & TIME: 11-20-96  16:45
   CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      353     32752      0    110                            0
  494.58           353     32752      0    110  1.00      0     50        0

   VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q     VEL
     494.58     0.0    50.2   353.1   32752.    4542.  12.86

X STA.         0.0         5.2         8.1        10.3        12.2        14.1
  A(I)            26.6        19.4        17.7        16.0        15.8
  V(I)            8.54       11.74       12.82       14.18       14.34

X STA.        14.1        16.0        17.9        19.9        21.9        23.8
  A(I)            16.0        15.2        15.9        15.6        15.8
  V(I)           14.22       14.90       14.24       14.58       14.40

X STA.        23.8        25.8        27.8        29.9        32.0        34.2
  A(I)            15.6        15.9        16.1        16.0        16.4
  V(I)           14.53       14.30       14.12       14.20       13.83

X STA.        34.2        36.4        38.8        41.4        44.4        50.2
  A(I)            16.9        17.1        18.4        19.6        27.0
  V(I)           13.45       13.28       12.36       11.58        8.40

   VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      20.
       WSEL     LEW     REW    AREA        K        Q     VEL
     498.83    72.8   317.1   104.7    1968.     339.   3.24

X STA.        72.8       114.2       134.6       152.1       167.6       182.0
  A(I)             8.7         6.8         6.3         6.0         5.9
  V(I)            1.94        2.50        2.69        2.82        2.87

X STA.       182.0       194.9       206.8       218.2       228.7       238.6
  A(I)             5.5         5.4         5.3         5.1         4.9
  V(I)            3.07        3.15        3.17        3.33        3.43

X STA.       238.6       248.1       257.0       265.6       273.8       281.7
  A(I)             4.9         4.7         4.7         4.5         4.5
  V(I)            3.46        3.59        3.60        3.76        3.77

X STA.       281.7       289.2       296.4       303.5       310.2       317.1
  A(I)             4.4         4.3         4.3         4.1         4.3
  V(I)            3.89        3.96        3.96        4.11        3.93

   CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            2     1023    112567    155    158                        14920
            3      301     14716    200    201                         2100
  498.83          1324    127283    355    359  1.19    -36    318    13308

   VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

       WSEL     LEW     REW    AREA        K        Q     VEL
     498.83   -37.1   317.8  1324.2  127283.    4800.   3.62

X STA.       -37.1        -3.3         5.0        10.0        14.5        18.8
  A(I)           101.3        67.5        54.7        50.5        48.4
  V(I)            2.37        3.56        4.39        4.75        4.96

X STA.        18.8        22.9        26.9        30.8        34.8        38.9
  A(I)            46.3        45.3        44.5        45.6        44.8
  V(I)            5.18        5.30        5.40        5.27        5.35

X STA.        38.9        43.3        50.1        58.8        68.2        78.0
  A(I)            46.8        56.1        57.6        60.3        60.1
  V(I)            5.13        4.28        4.17        3.98        3.99

X STA.        78.0        89.5       103.6       128.0       187.1       317.8
  A(I)            65.0        72.1        86.1       118.0       153.2
  V(I)            3.69        3.33        2.79        2.03        1.57
```

```
      U.S. Geological Survey WSPRO Input File hanc145.wsp
      Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
      Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
         *** RUN DATE & TIME: 11-20-96  16:45
  CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      353     32752      0    110                            0
 494.58           353     32752      0    110  1.00      0     50        0

  VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

       WSEL     LEW     REW    AREA        K        Q    VEL
     494.58     0.0    50.2   353.1   32752.    4685.  13.27

X STA.        0.0        5.2        8.1       10.3       12.2       14.1
  A(I)            26.6       19.4       17.7       16.0       15.8
  V(I)            8.81      12.11      13.23      14.62      14.79

X STA.       14.1       16.0       17.9       19.9       21.9       23.8
  A(I)            16.0       15.2       15.9       15.6       15.8
  V(I)           14.67      15.37      14.69      15.04      14.85

X STA.       23.8       25.8       27.8       29.9       32.0       34.2
  A(I)            15.6       15.9       16.1       16.0       16.4
  V(I)           14.98      14.75      14.57      14.65      14.27

X STA.       34.2       36.4       38.8       41.4       44.4       50.2
  A(I)            16.9       17.1       18.4       19.6       27.0
  V(I)           13.88      13.69      12.75      11.94       8.66

  VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      20.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.88  -172.0   317.1   467.4   17552.    2327.   4.98

X STA.     -172.0     -123.6       59.0       84.5      102.1      118.3
  A(I)            34.3       58.5       26.5       22.8       22.0
  V(I)            3.39       1.99       4.40       5.11       5.29

X STA.      118.3      133.9      149.4      164.1      178.4      192.2
  A(I)            21.6       21.8       21.1       20.8       20.4
  V(I)            5.39       5.33       5.52       5.61       5.70

X STA.      192.2      205.9      219.1      232.3      244.8      257.6
  A(I)            20.5       20.1       20.2       19.5       20.2
  V(I)            5.68       5.78       5.75       5.95       5.77

X STA.      257.6      269.7      281.6      293.5      304.9      317.1
  A(I)            19.3       19.2       19.4       18.9       20.4
  V(I)            6.01       6.06       6.00       6.15       5.71

  CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       68      1616    135    135                          276
           2     1206    147690    156    159                        19061
           3      538     38450    200    202                         5001
 500.01          1812    187757    491    497  1.20   -172    318    18056

  VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.01  -173.4   317.8  1812.3  187757.    7000.   3.86

X STA.     -173.4       -9.4        3.4        9.4       14.7       19.9
  A(I)           175.0       94.7       71.8       65.7       64.0
  V(I)            2.00       3.70       4.88       5.33       5.47

X STA.       19.9       24.8       29.8       34.6       39.6       45.2
  A(I)            62.0       61.7       60.3       61.2       64.6
  V(I)            5.64       5.68       5.80       5.72       5.42

X STA.       45.2       54.3       64.4       75.1       86.8      100.7
  A(I)            76.3       76.9       79.9       81.6       88.6
  V(I)            4.58       4.55       4.38       4.29       3.95

X STA.      100.7      120.3      149.7      193.8      247.5      317.8
  A(I)           101.6      109.8      127.4      136.3      152.9
  V(I)            3.45       3.19       2.75       2.57       2.29
```

```
        U.S. Geological Survey WSPRO Input File hanc145.wsp
        Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
        Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
           *** RUN DATE & TIME: 11-20-96  16:45
    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      353     32752     0    110                            0
   494.58           353     32752     0    110  1.00      0     50        0

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.58     0.0    50.2   353.1   32752.    4390.  12.43

X STA.         0.0        5.2        8.1       10.3       12.2       14.1
  A(I)            26.6       19.4       17.7       16.0       15.8
  V(I)            8.26      11.34      12.39      13.70      13.86

X STA.        14.1       16.0       17.9       19.9       21.9       23.8
  A(I)            16.0       15.2       15.9       15.6       15.8
  V(I)           13.75      14.40      13.77      14.09      13.91

X STA.        23.8       25.8       27.8       29.9       32.0       34.2
  A(I)            15.6       15.9       16.1       16.0       16.4
  V(I)           14.04      13.82      13.65      13.73      13.37

X STA.        34.2       36.4       38.8       41.4       44.4       50.2
  A(I)            16.9       17.1       18.4       19.6       27.0
  V(I)           13.00      12.83      11.94      11.19       8.12


    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             2      926     96637   152    155                        12981
             3      175      5977   200    200                          931
   498.20          1102    102615   352    355  1.19    -33    318    10139


    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      90.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.20   -34.2   317.8  1101.5  102615.    4390.   3.99

X STA.       -34.2       -2.1        5.1        9.6       13.7       17.5
  A(I)            87.4       57.4       46.1       42.6       40.9
  V(I)            2.51       3.83       4.76       5.15       5.37

X STA.        17.5       21.2       24.7       28.4       31.9       35.5
  A(I)            39.2       38.4       38.5       38.1       38.1
  V(I)            5.60       5.72       5.70       5.77       5.76

X STA.        35.5       39.2       43.2       49.2       57.6       66.6
  A(I)            38.9       39.8       46.8       50.8       52.3
  V(I)            5.65       5.52       4.69       4.32       4.20

X STA.        66.6       76.2       87.3      100.5      125.9      317.8
  A(I)            53.2       57.1       60.5       79.5      156.2
  V(I)            4.13       3.84       3.63       2.76       1.41
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File hanc145.wsp
       Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
       Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
          *** RUN DATE & TIME: 11-20-96  16:45
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******    -53     1373  0.24 *****  491.34  488.41    4800  491.10
     -1057 ******    225   145308  1.27 ***** *******    0.31    3.50

EXIT2:XS      200    -49     1132  0.37  0.29  491.69 *******    4800  491.32
      -857    200    218   110709  1.32  0.06    0.00    0.42    4.24

EXIT3:XS      200    -47      917  0.60  0.50  492.30 *******    4800  491.70
      -657    200    212    82891  1.40  0.11   -0.01    0.58    5.24

EXIT4:XS      200    -45      815  0.78  0.78  493.18 *******    4800  492.41
      -457    200    209    70859  1.44  0.09    0.01    0.70    5.89

EXIT5:XS      200    -44      749  0.94  1.02  494.28 *******    4800  493.35
      -257    200    207    63590  1.47  0.08    0.00    0.79    6.41

EXIT6:XS      200    -44      765  0.89  1.11  495.40 *******    4800  494.51
       -57    200    207    65284  1.46  0.00    0.01    0.77    6.28

FULLV:FV       58    -44      766  0.89  0.31  495.74 *******    4800  494.84
         0     58    207    65367  1.46  0.00    0.02    0.77    6.27
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.83     495.43     494.85
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.34     509.84    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.34     509.84     494.85
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPRO”     KRATIO =  0.61
APPRO:AS       90    -20      523  1.31  0.79  496.73  494.85    4800  495.43
        90     90    115    40059  1.00  0.21    0.00    0.83    9.17
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   494.84     494.43
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR       58      0      353  2.57 *****  497.15  493.73    4542  494.58
         0 ******     50    32752  1.00 ***** *******    0.86   12.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  494.43 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      20.    54.  0.08  0.24  498.99    0.02    339.  498.83

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    58.  -172.    24.   0.4   0.2   3.0   4.4   0.4   3.0
   RT:    339.   244.    73.   317.   0.6   0.4   3.5   3.3   0.6   3.1
APPRO:AS       39    -36     1323  0.24  0.21  499.07  494.85    4800  498.83
        90     41    318   127150  1.19  0.00    0.02    0.36    3.63

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXIT1:XS   -1058.   -54.   225.   4800.  145308.    1373.    3.50  491.10
   EXIT2:XS    -858.   -50.   218.   4800.  110709.    1132.    4.24  491.32
   EXIT3:XS    -658.   -48.   212.   4800.   82891.     917.    5.24  491.70
   EXIT4:XS    -458.   -46.   209.   4800.   70859.     815.    5.89  492.41
   EXIT5:XS    -258.   -45.   207.   4800.   63590.     749.    6.41  493.35
   EXIT6:XS     -58.   -45.   207.   4800.   65284.     765.    6.28  494.51
   FULLV:FV       0.   -45.   207.   4800.   65367.     766.    6.27  494.84
   BRIDG:BR       0.     0.    50.   4542.   32752.     353.   12.86  494.58
   RDWAY:RG      20.*******     0.    339.       0.*********    1.00  498.83
   APPRO:AS      90.   -37.   318.   4800.  127150.    1323.    3.63  498.83

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    488.41    0.31  480.50  504.30************  0.24  491.34  491.10
   EXIT2:XS  ********    0.42  481.60  505.40  0.29  0.06  0.37  491.69  491.32
   EXIT3:XS  ********    0.58  482.80  506.60  0.50  0.11  0.60  492.30  491.70
   EXIT4:XS  ********    0.70  483.90  507.70  0.78  0.09  0.78  493.18  492.41
   EXIT5:XS  ********    0.79  485.10  508.90  1.02  0.08  0.94  494.28  493.35
   EXIT6:XS  ********    0.77  486.20  510.00  1.11  0.00  0.89  495.40  494.51
   FULLV:FV  ********    0.77  486.53  510.33  0.31  0.00  0.89  495.74  494.84
   BRIDG:BR    493.73    0.86  485.96  494.58************  2.57  497.15  494.58
   RDWAY:RG  ****************  498.20  510.00  0.08******  0.24  498.99  498.83
   APPRO:AS    494.85    0.36  487.46  509.84  0.21  0.00  0.24  499.07  498.83
```

```
        U.S. Geological Survey WSPRO Input File hanc145.wsp
        Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
        Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
           *** RUN DATE & TIME: 11-20-96  16:45

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

EXIT1:XS   ******    -56     1698  0.37 *****  492.57  489.16    7000  492.20
     -1057 ******    306   178703  1.41 ***** *******    0.40    4.12

EXIT2:XS      200    -54     1459  0.45  0.35  492.95 *******    7000  492.51
      -857    200    227   158406  1.25  0.04    0.00    0.42    4.80

EXIT3:XS      200    -51     1235  0.65  0.49  493.55 *******    7000  492.90
      -657    200    221   125055  1.30  0.10    0.00    0.53    5.67

EXIT4:XS      200    -49     1112  0.82  0.73  494.36 *******    7000  493.54
      -457    200    217   108026  1.33  0.09    0.01    0.63    6.29

EXIT5:XS      200    -48     1026  0.98  0.94  495.40 *******    7000  494.42
      -257    200    215    96565  1.36  0.08    0.02    0.71    6.83

EXIT6:XS      200    -48     1014  1.01  1.07  496.48 *******    7000  495.47
       -57    200    215    95038  1.36  0.01    0.00    0.72    6.91

FULLV:FV       58    -48     1008  1.02  0.32  496.81 *******    7000  495.78
         0     58    214    94355  1.36  0.01    0.00    0.73    6.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     496.22     496.00
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    495.28     509.84    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.28     509.84     496.00
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.57

APPRO:AS       90    -24      638  1.89  0.87  498.11  496.00    7000  496.22
        90     90    133    53682  1.01  0.43    0.00    0.97   10.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   495.78     494.43
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR       58      0      353  2.74 *****  497.32  493.86    4685  494.58
         0 ******     50    32752  1.00 ***** *******    0.88   13.27

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  494.43 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    54.  0.08  0.28  500.21    0.00   2327.  499.88
             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    342.   196.  -172.    24.   0.9   0.3   3.8   5.0   0.7   3.1
   RT:   1985.   293.    24.   317.   1.7   1.4   6.0   5.0   1.7   3.1
APPRO:AS       39   -173     1813  0.28  0.23  500.29  496.00    7000  500.01
        90     42    318   187875  1.20  0.00    0.00    0.39    3.86
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS   -1058.   -57.   306.   7000.  178703.    1698.    4.12  492.20
   EXIT2:XS    -858.   -55.   227.   7000.  158406.    1459.    4.80  492.51
   EXIT3:XS    -658.   -52.   221.   7000.  125055.    1235.    5.67  492.90
   EXIT4:XS    -458.   -50.   217.   7000.  108026.    1112.    6.29  493.54
   EXIT5:XS    -258.   -49.   215.   7000.   96565.    1026.    6.83  494.42
   EXIT6:XS     -58.   -49.   215.   7000.   95038.    1014.    6.91  495.47
   FULLV:FV       0.   -49.   214.   7000.   94355.    1008.    6.94  495.78
   BRIDG:BR       0.     0.    50.   4685.   32752.     353.   13.27  494.58
   RDWAY:RG      20.*******   342.   2327.******************    1.00  499.88
   APPRO:AS      90.  -174.   318.   7000.  187875.    1813.    3.86  500.01
 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    489.16    0.40  480.50  504.30************  0.37  492.57  492.20
   EXIT2:XS  ********    0.42  481.60  505.40  0.35  0.04  0.45  492.95  492.51
   EXIT3:XS  ********    0.53  482.80  506.60  0.49  0.10  0.65  493.55  492.90
   EXIT4:XS  ********    0.63  483.90  507.70  0.73  0.09  0.82  494.36  493.54
   EXIT5:XS  ********    0.71  485.10  508.90  0.94  0.08  0.98  495.40  494.42
   EXIT6:XS  ********    0.72  486.20  510.00  1.07  0.01  1.01  496.48  495.47
   FULLV:FV  ********    0.73  486.53  510.33  0.32  0.01  1.02  496.81  495.78
   BRIDG:BR    493.86    0.88  485.96  494.58************  2.74  497.32  494.58
   RDWAY:RG  ****************  498.20  510.00  0.08******  0.28  500.21  499.88
   APPRO:AS    496.00    0.39  487.46  509.84  0.23  0.00  0.28  500.29  500.01
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File hanc145.wsp
        Hydraulic analysis for structure HANCVT01000145   Date: 20-NOV-96
        Hydraulic Analysis for Hancock bridge 145 over the White River by MAI
           *** RUN DATE & TIME: 11-20-96  16:45

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

EXIT1:XS   ******    -51     1235  0.25 *****  490.85  488.22    4390  490.60
     -1057 ******    221   125118  1.30 ***** *******    0.34    3.55

EXIT2:XS      200    -48     1007  0.40  0.33  491.25 *******    4390  490.85
      -857    200    214    94182  1.36  0.07    0.00    0.46    4.36

EXIT3:XS      200    -45      813  0.65  0.58  491.95 *******    4390  491.30
      -657    200    209    70665  1.44  0.13    0.00    0.64    5.40

EXIT4:XS      200    -44      740  0.80  0.87  492.92 *******    4390  492.11
      -457    200    207    62614  1.47  0.08    0.02    0.74    5.93
 ===125 FR# EXCEEDS FNTEST AT SECID "EXIT5":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    0.82     493.12     492.82
 ===110 WSEL NOT FOUND AT SECID "EXIT5":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   491.61     508.90    0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT5":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   491.61     508.90     492.82
EXIT5:XS      200    -43      691  0.94  1.07  494.05  492.82    4390  493.12
      -257    200    205    57440  1.49  0.07    0.00    0.82    6.35

EXIT6:XS      200    -44      715  0.87  1.12  495.18 *******    4390  494.31
       -57    200    206    59929  1.48  0.00    0.01    0.78    6.14

FULLV:FV       58    -44      715  0.87  0.31  495.51 *******    4390  494.64
         0     58    206    59887  1.48  0.00    0.02    0.78    6.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    0.80     495.25     494.56
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   494.14     509.84    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   494.14     509.84     494.56
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.62
APPRO:AS       90    -19      498  1.21  0.77  496.45  494.56    4390  495.24
        90     90    114    37391  1.00  0.17   -0.01    0.81    8.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =   494.64     494.43
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR       58      0      353  2.32 *****  496.90  493.52    4313  494.58
         0 ******     50    32752  1.00 ***** *******    0.81   12.22

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.000  494.43 ****** ****** ******

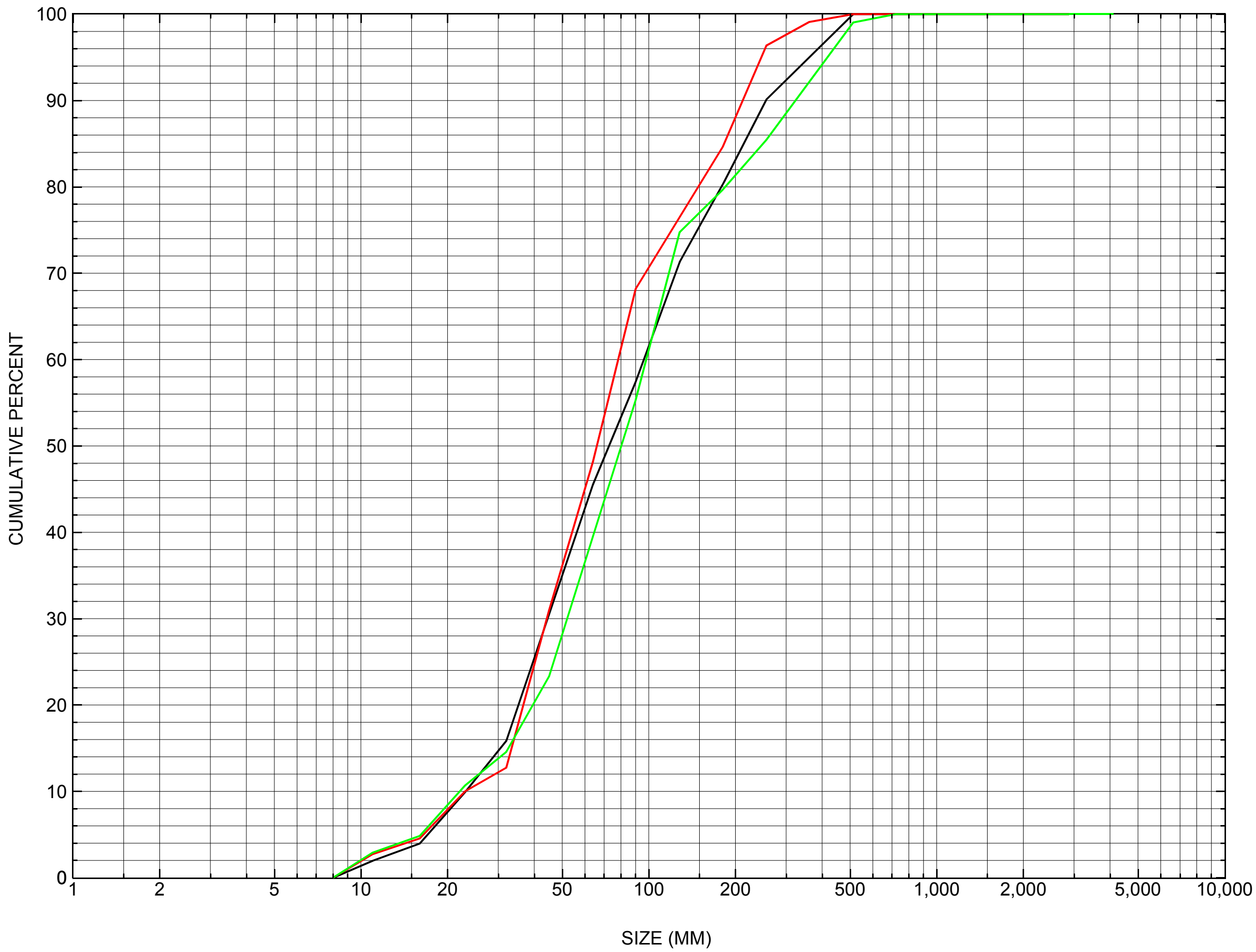
    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      20.          <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>
APPRO:AS       39    -33     1103  0.29  0.24  498.50  494.56    4390  498.20
        90     41    318   102733  1.19  0.00   -0.02    0.43    3.98
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT1:XS   -1058.   -52.   221.   4390.  125118.    1235.    3.55  490.60
   EXIT2:XS    -858.   -49.   214.   4390.   94182.    1007.    4.36  490.85
   EXIT3:XS    -658.   -46.   209.   4390.   70665.     813.    5.40  491.30
   EXIT4:XS    -458.   -45.   207.   4390.   62614.     740.    5.93  492.11
   EXIT5:XS    -258.   -44.   205.   4390.   57440.     691.    6.35  493.12
   EXIT6:XS     -58.   -45.   206.   4390.   59929.     715.    6.14  494.31
   FULLV:FV       0.   -45.   206.   4390.   59887.     715.    6.14  494.64
   BRIDG:BR       0.     0.    50.   4313.   32752.     353.   12.22  494.58
   RDWAY:RG      20.**************      0.       0.       0.    1.00********
   APPRO:AS      90.   -34.   318.   4390.  102733.    1103.    3.98  498.20
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    488.22    0.34  480.50  504.30************  0.25  490.85  490.60
   EXIT2:XS  ********    0.46  481.60  505.40  0.33  0.07  0.40  491.25  490.85
   EXIT3:XS  ********    0.64  482.80  506.60  0.58  0.13  0.65  491.95  491.30
   EXIT4:XS  ********    0.74  483.90  507.70  0.87  0.08  0.80  492.92  492.11
   EXIT5:XS    492.82    0.82  485.10  508.90  1.07  0.07  0.94  494.05  493.12
   EXIT6:XS  ********    0.78  486.20  510.00  1.12  0.00  0.87  495.18  494.31
   FULLV:FV  ********    0.78  486.53  510.33  0.31  0.00  0.87  495.51  494.64
   BRIDG:BR    493.52    0.81  485.96  494.58************  2.32  496.90  494.58
   RDWAY:RG  ****************  498.20  510.00************  0.29  498.40********
   APPRO:AS    494.56    0.43  487.46  509.84  0.24  0.00  0.29  498.50  498.20
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for three pebble count transects in the channel approach of structure HANCVT01000145, in Hancock, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HANCVT01000145

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 26 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 31525

Mile marker *(I - 11; nnn.nnn)* 001190

Waterway *(I - 6)* HANCOCK BRANCH

Road Name *(I - 7)*: -

Route Number VT 100

Vicinity *(I - 9)* 0.1 MI S JCT. VT.125

Topographic Map Hancock

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43556

Longitude *(i - 17; nnnnn.n)* 72505

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001301450108

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0053

Year built *(I - 27; YYYY)* 1979

Structure length *(I - 49; nnnnnn)* 000055

Average daily traffic, ADT *(I - 29; nnnnnn)* 001700

Deck Width *(I - 52; nn.n)* 356

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

Channel & Protection *(I - 61; n)* 7

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

Waterway adequacy *(I - 71; n)* 8

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*) 007.0

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

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

Comments:

Structural inspection report of 9/30/93 indicates a single span rolled beam bridge. The stream is on a slight curve to the right abutment. The right abutment is concrete with numerous longitudinal and transverse cracks. Curtain walls are “like new”. The wings of the right abutment have some minor scaling. The stem of left abutment has areas of scaling and minor cracking with leakage. Channel is straight through the bridge. Stone fill is in place at both abutments. There is vegetation along the banks. No noted erosion or settlement.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **22.4**

Terrain character: **Hills**

Stream character & type: **Fairly straight**

Streambed material: **Gravelly with type I stone**

Discharge Data *(cfs)*: $Q_{2.33}$ **-** Q_{10} **2000** Q_{25} **2600**

Q_{50} **3200** Q_{100} **3800** Q_{500} **-**

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

Estimated Discharge *(cfs)*: **-** Velocity at Q **50** *(ft/s)*: **11.4**

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

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: **Upstream there is a pond. It is a diversion off from the main channel no significant effect on the drainage area, the outlet was dry.**

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

The watershed storage area is: **2** (*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*)	-	**908.4**	**909.4**	**910.3**	**911.2**
Velocity (*ft / sec*)	-	-	--	**11.4**	-

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)* 22.04 mi^2 Lake and pond area 0.01 mi^2
Watershed storage *(ST)* 0.1 %
Bridge site elevation 900 ft Headwater elevation 3482 ft
Main channel length 7.85 mi
10% channel length elevation 950 ft 85% channel length elevation 2200 ft
Main channel slope *(S)* 212.32 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? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **05** / **1979**

Project Number **BHF 013-4(5)S** Minimum channel bed elevation: **903.0**

Low superstructure elevation: USLAB **910.04** DSLAB **908.79** USRAB **909.83** DSRAB **908.59**

Benchmark location description:

BM #1 chiseled square at top of the junction of the right abutment and downstream wing elevation 913.72; BM #2, chiseled square on the concrete deck of "Hubbard's country store", third building on left side of route 125 to Ripton from the intersection with route 100.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **898.0**

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:

Cross-sectional Data

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

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

Comments: **Orientation of the cross sections is inconsistent with any cross section data surveyed for this study and is not comparable. Data was not retrieved.**

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:

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: _______ Date: __________
Computerized by: _______ Date: __________
Reviewd by: _______ Date: __________

Structure Number HANCVT01000145

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND   Date *(MM/DD/YY)* 11 / 16 / 1994

2. Highway District Number 04   Mile marker 001190

County ADDISON(001)   Town HANCOCK (31525)

Waterway *(I - 6)* HANCOCK BRANCH   Road Name VT 100

Route Number VT 100   Hydrologic Unit Code: 01080105

3. Descriptive comments:

Bridge is located 0.1 miles South of junction with VT 125.
Bridge plaque states 'BHF 013-4(5)S' '1980'

B. Bridge Deck Observations

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

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

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

7. Bridge length 55 *(feet)*   Span length 53 *(feet)*   Bridge width 35.6 *(feet)*

Road approach to bridge:

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

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

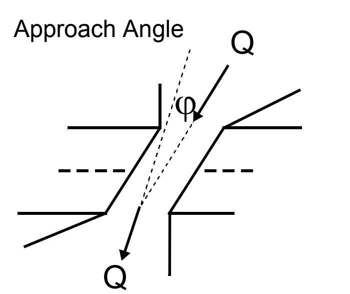
10. Embankment slope (*run / rise in feet / foot*):
US left 2.7:1   US right 2.2:1

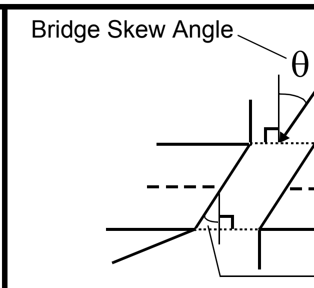
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

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





α= 0.0

17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? LB *(LB, RB)*   Severity 1
Range? 90 feet US *(US, UB, DS)* to 40 feet US

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**

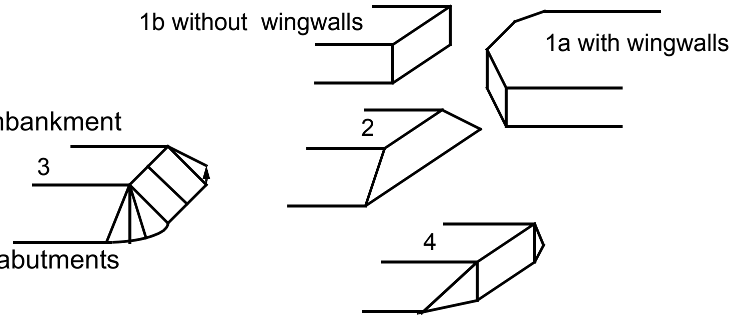
1a- Vertical abutments with wingwalls

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.)

7. Values are from VTAOT database (VTAOT, August 26, 1994). Measured bridge length: 54, span: 52, and width: 35 feet.
Road overflow width is 36 feet.
18. Wingwall tops slope down, but end is above the low chord elevation.

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
105.8	**3.0**			**4.0**	**3**	**4**	**435**	**435**	**0**	**0**

23. Bank width **25.0** 24. Channel width **20.0** 25. Thalweg depth **51.0** 29. Bed Material **435**

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

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

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

26. Some trees along the left bank on levee then grass and a building.
30. The left bank has a levee. The right bank consist of very course material. There appears to be a levee formation along the right bank with fill extending to the narrow flood plain.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **240** 35. Mid-bar width: **20**

36. Point bar extent: **280** feet **US** (US, UB) to **180** feet **US** (US, UB, DS) positioned **0** %LB to **60** %RB

37. Material: **435**

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

Side bar consisting of cobble, gravel, and boulder material

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

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

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

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

NO CUT BANKS

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
37.5		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? **1**___ *(Y or N)* Ice Blockage Potential **N**____ *(**1**- Low; **2**- Moderate; **3**- High)*

70. Debris and Ice Comments:

1

67. No debris accumulation near the bridge. The upstream is laterally stable, but has a few cut banks, and some trees leaning into channel.

68. High channel gradient channel and the span length is more than approximately 80% of the upstream bank width.

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	-	-	90.0
RABUT	1	0	90			0	0	50.0

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

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

-

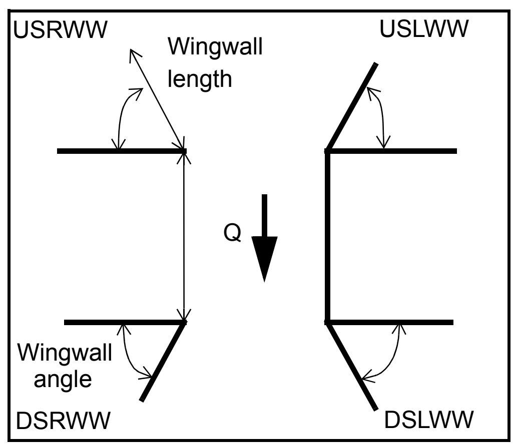
-

1

73. The left abutment protrudes into the channel.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						34.0	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	42.5	
DSRWW:	1		0		-	37.5	



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

82. **Bank / Bridge Protection**:

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

*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*

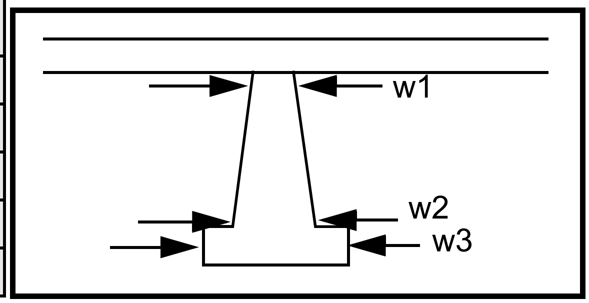
*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

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

Piers:

84. Are there piers? __82.__ *(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				55.0	16.5	45.0
Pier 2			9.5	13.0	40.0	50.0
Pier 3		-	-	11.5	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	Upst	end	dow	start	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	ream	is	nstre	s	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	left	bur-	am	abou	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	wing	ied	end.	t	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	wall	and	At	mid-	*Y- yes; N- no*
91. Attack ∠ (BF)	pro-	erodi	the	way	
92. Pushed	tec-	ng to	left	to	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	tion	almo	abut	the	
95. Cross-members	at	st	ment	dow	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	the	none	large	nstre	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	upst	at	stone	am	
98. Exposure depth	ream	the	fill	end;	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
smaller cobble/ boulders to upstream end.
At the right abutment large stone fill starts about midway to the downstream end.
DS Left and Right WW: large stone fill starts at the corner junction with the abutment, half way up the wall (smaller grade stones at end).

N
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: - ____

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

-
-
-

NO PIERS

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

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

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

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

2
3
345

Is channel scour present? **435** (Y or if N type ctrl-n cs) Mid-scour distance: **0** _____

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

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

-

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

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

N

-

NO DROP STRUCTURE

N

-

-

-

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: HANCVT01000145 Town: Hancock
Road Number: VT 100 County: Addison
Stream: Hancock Branch

Initials MAI Date: 11/20/96 Checked: EMB

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	4800	7000	4390
Main Channel Area, ft2	1023	1206	926
Left overbank area, ft2	0	68	0
Right overbank area, ft2	301	538	175
Top width main channel, ft	155	156	152
Top width L overbank, ft	0	135	0
Top width R overbank, ft	200	200	200
D50 of channel, ft	0.2358	0.2358	0.2358
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.6	7.7	6.1
y1, average depth, LOB, ft	ERR	0.5	ERR
y1, average depth, ROB, ft	1.5	2.7	0.9
Total conveyance, approach	127283	187757	102615
Conveyance, main channel	112567	147690	96637
Conveyance, LOB	0	1616	0
Conveyance, ROB	14716	38450	5977
Percent discrepancy, conveyance	0.0000	0.0005	0.0010
Qm, discharge, MC, cfs	4245.0	5506.2	4134.3
Ql, discharge, LOB, cfs	0.0	60.2	0.0
Qr, discharge, ROB, cfs	555.0	1433.5	255.7
Vm, mean velocity MC, ft/s	4.1	4.6	4.5
Vl, mean velocity, LOB, ft/s	ERR	0.9	ERR
Vr, mean velocity, ROB, ft/s	1.8	2.7	1.5
Vc-m, crit. velocity, MC, ft/s	9.5	9.7	9.4
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

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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	1023	1206	926
Main channel width, ft	155	156	152
y1, main channel depth, ft	6.60	7.73	6.09
Bridge Section			
(Q) total discharge, cfs	4800	7000	4390
(Q) discharge thru bridge, cfs	4542	4685	4390
Main channel conveyance	32752	32752	32752
Total conveyance	32752	32752	32752
Q2, bridge MC discharge,cfs	4542	4685	4390
Main channel area, ft2	353	353	353
Main channel width (skewed), ft	50.2	50.2	50.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	50.2	50.2	50.2
y_bridge (avg. depth at br.), ft	7.03	7.03	7.03
Dm, median (1.25*D50), ft	0.29475	0.29475	0.29475
y2, depth in contraction,ft	8.34	8.57	8.10
ys, scour depth (y2-ybridge), ft	1.31	1.53	1.07

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richarson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q, total, cfs	4800	7000	4390
Q, thru bridge, cfs	4542	4685	4390
Total Conveyance, bridge	32752	32752	32752
Main channel(MC) conveyance, bridge	32752	32752	32752
Q, thru bridge MC, cfs	4542	4685	4390
Vc, critical velocity, ft/s	9.49	9.74	9.36
Vc, critical velocity, m/s	2.89	2.97	2.85
Main channel width (skewed), ft	50.2	50.2	50.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	50.2	50.2	50.2
qbr, unit discharge, ft^2/s	90.5	93.3	87.5
qbr, unit discharge, m^2/s	8.4	8.7	8.1
Area of full opening, ft^2	353.1	353.1	353.1
Hb, depth of full opening, ft	7.03	7.03	7.03
Hb, depth of full opening, m	2.14	2.14	2.14
Fr, Froude number, bridge MC	0.86	0.88	0.81

Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	494.43	494.43	494.43
Elevation of Bed, ft	487.40	487.40	487.40
Elevation of Approach, ft	498.83	500.01	498.2
Friction loss, approach, ft	0.21	0.23	0.24
Elevation of WS immediately US, ft	498.62	499.78	497.96
ya, depth immediately US, ft	11.22	12.38	10.56
ya, depth immediately US, m	3.42	3.77	3.22
Mean elevation of deck, ft	499.37	499.37	499.37
w, depth of overflow, ft (>=0)	0.00	0.41	0.00
Cc, vert contrac correction (<=1.0)	0.87	0.84	0.89
Ys, depth of scour, ft	3.91	4.34	3.43

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	8.341033	8.565626	8.101194
Full valley WSEL, ft	494.84	495.78	494.64
Full valley depth, ft	7.443865	8.383865	7.243865
Ys, depth of scour (y2-yfullv), ft	0.897169	0.181761	0.85733

ARMORING

D90	0.816	0.816	0.816
D95	1.136	1.136	1.136
Critical grain size,Dc, ft	0.7697	0.8189	0.7191
Decimal-percent coarser than Dc	0.115	0.099	0.133
Depth to armoring,ft	17.77	22.36	14.06

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4800	7000	4390	4800	7000	4390
a', abut.length blocking flow, ft	37.1	100	34.2	267.6	267.6	267.6
Ae, area of blocked flow ft2	128.1	134.2	104.1	567.1	611.9	503.6
Qe, discharge blocked abut.,cfs	335.4	--	283.5	--	--	1510.4

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	2.62	2.71	2.72	2.85	3.34	3.00
ya, depth of f/p flow, ft	3.45	1.34	3.04	2.12	2.29	1.88

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	0.82	0.82	0.82	0.82	0.82	0.82

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.248	0.371	0.275	0.317	0.306	0.385
ys, scour depth, ft	11.08	10.05	10.34	17.79	18.31	18.38

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)	37.1	100	34.2	267.6	267.6	267.6
y1 (depth f/p flow, ft)	3.45	1.34	3.04	2.12	2.29	1.88

a'/y1	10.74	74.52	11.24	126.27	117.03	142.20
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.25	0.37	0.28	0.32	0.31	0.39
Ys w/ corr. factor K1/0.55:						
vertical	ERR	7.04	ERR	10.55	11.25	9.99
vertical w/ ww's	ERR	5.77	ERR	8.65	9.23	8.19
spill-through	ERR	3.87	ERR	5.80	6.19	5.49

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.86	0.88	0.81	0.86	0.88	0.81
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.03	7.03	7.03	7.03	7.03	7.03
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.82	2.84	2.77	2.82	2.84	2.77