LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (STRATH00020028) on TOWN HIGHWAY 2, crossing the WEST BRANCH OMPOMPANOOSUC RIVER, STRAFFORD, VERMONT

Open-File Report 98-293

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By EMILY C. WILD

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (STRATH00020028) ON TOWN HIGHWAY 2, CROSSING THE WEST BRANCH OMPOMPANOOSUC RIVER, STRAFFORD, VERMONT

***By* Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure STRATH00020028 on Town Highway 2 crossing the West Branch Ompompanoosuc River, Strafford, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gathered from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in central Vermont. The 25.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge.

In the study area, the West Branch Ompompanoosuc River has a sinuous channel with a slope of approximately 0.002 ft/ft, an average channel top width of 34 ft and an average bank height of 6 ft. The channel bed material ranges from silt and clay to cobbles with a median grain size (D_{50}) of 20.4 mm (0.0669 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 24, 1996, indicated that the reach was laterally unstable, because of moderate fluvial erosion.

The Town Highway 2 crossing of the West Branch Ompompanoosuc River is a 31-ft-long, two-lane bridge consisting of a 26-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, October 23, 1995). The opening length of the structure parallel to the bridge face is 24.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 3.2 ft deeper than the mean thalweg depth was observed under the bridge along the right side of the channel during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream right bank, the upstream right wingwall, the right abutment and the downstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D
and E.

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

Contraction scour for all modelled flows ranged from 3.2 to 4.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 4.4 to 7.5 ft. Right abutment scour ranged from 7.2 to 10.1 ft.The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number STRATH00020028 ***Stream*** West Branch Ompompanoosuc River

County Orange ***Road*** TH 2 ***District*** 4

Description of Bridge

Bridge length 31 ***ft*** ***Bridge width*** 22.5 ***ft*** ***Max span length*** 26 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? Yes ***Date of inspection*** 7/24/96

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

Abutments and wingwalls are concrete. There is a scour hole approximately 3 feet deep along the right side of the channel under the bridge.

Yes 45

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

There is a moderate channel bend in the channel upstream and downstream of the bridge. The scour hole has developed where the bend impacts the upstream end of the right abutment.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	7/24/96	0	0
Level II	7/24/96	0	0

Potential for debris Moderate. There is some debris caught in the channel upstream and in front of the left abutment.

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

None, 7/24/96.

Description of the Geomorphic Setting

General topography The channel is located within a wide, slightly irregular flood plain in a moderate relief valley.

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

Date of inspection 7/24/96

DS left: Wide flood plain

DS right: Moderately sloped overbank

US left: Wide flood plain

US right: Moderately sloped overbank

Description of the Channel

Average top width 34 *ft* ***Average depth*** 6 *ft*

Predominant bed material Silt/Clay/ Gravel ***Bank material*** Silt/Clay/Gravel

Sinuous with semi-alluvial boundaries and wide point bars.

7/24/96

Vegetative co Pasture

DS left: Pasture and Town Highway 2 along the immediate bank

DS right: Pasture and Town Highway 2 along the immediate bank

US left: Pasture

US right:

Do banks appear stable? No ***date of observation.***

Since slip failure of the upstream and downstream banks have resulted from moderate fluvial erosion, the banks were described as laterally unstable during the 7/24/96 site visit.

None, 7/24/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 25.4 ***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 4,150 ***ft³/s*** ***Q500*** 6,060 ***ft³/s***

The 100-year and 500-year discharges are values obtained from the VTAOT database (written communication, May 1995) for this bridge. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 499.69 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream right wingwall (elev. 497.37 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXITX	-31	1	Exit section
FULLV	0	1	Downstream Full-valley section
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	53	1	Approach section

[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. Although flow approaches this site at an angle greater than the opening-skew-to-roadway, flow was assumed to align with the abutments in the bridge. 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 0.045 to 0.055, and overbank "n" values ranged from 0.035 to 0.055.

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 0.0015 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1981).

The surveyed approach section (APPRO) was modelled one bridge length upstream of the upstream face, as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.4 *ft*
Average low steel elevation 497.7 *ft*

100-year discharge 4,150 *ft³/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Yes *Discharge over road* 2,374 *ft³/s*
Area of flow in bridge opening 201 *ft²*
Average velocity in bridge opening 8.7 *ft/s*
Maximum WSPRO tube velocity at bridge 10.6 *ft/s*

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 497.1
Amount of backwater caused by bridge 2.5 *ft*

500-year discharge 6,060 *ft³/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Yes *Discharge over road* 4,229 *ft³/s*
Area of flow in bridge opening 201 *ft²*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 */s*

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 497.9
Amount of backwater caused by bridge 2.2 *ft*

Incipient overtopping discharge 1,560 *ft³/s*
Water-surface elevation in bridge opening 494.7 *ft*
Area of flow in bridge opening 126 *ft²*
Average velocity in bridge opening 12.4 *ft/s*
Maximum WSPRO tube velocity at bridge 15.8 *ft/s*

Water-surface elevation at Approach section with bridge 497.8
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 2.2 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100-year and 500-year discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

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

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

Scour at the left abutment was computed by use of the HIRE equation (Richardson and Davis, 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-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	3.2	4.1	3.7
Depth to armoring	N/A N/–	A N/–	A–
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	6.7 7.5	4.4 8.8	10.1
Left abutment	7.2–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	1.9	1.8
Pier 3			

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.1	1.9	1.8
Left abutment	2.1	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

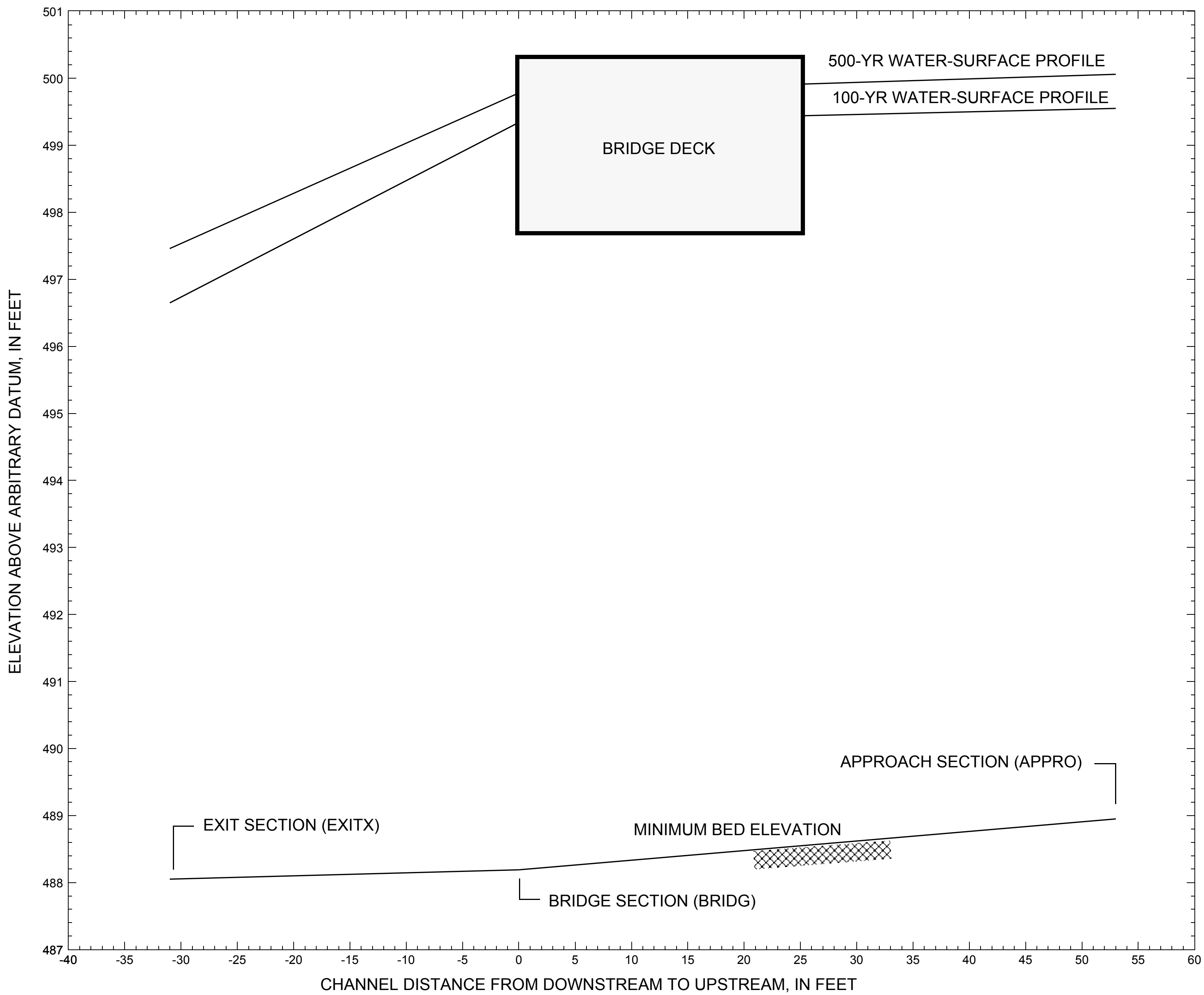

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure STRATH00020028 on Town Highway 2, crossing the West Branch Ompompanoosuc River, Strafford, Vermont.

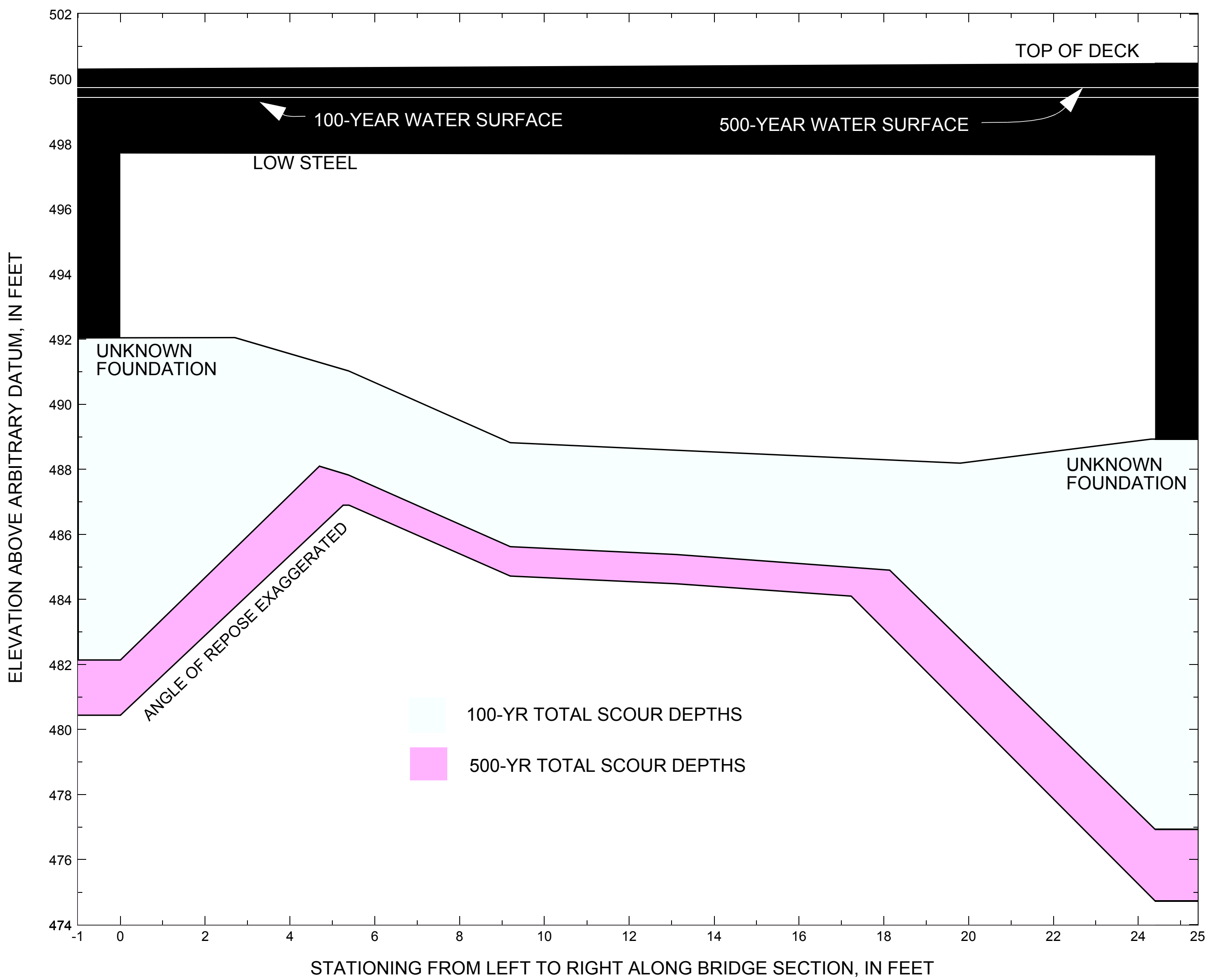

Figure 8. Scour elevations for the 100- and 500-year discharges at structure STRATH00020028 on Town Highway 2, crossing the West Branch Ompompanoosuc River, Strafford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure STRATH00020028 on Town Highway 2, crossing the West Branch Ompompanoosuc River, Strafford, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 4,150 cubic-feet per second											
Left abutment	0.0	--	497.7	--	492.0	3.2	6.7	--	9.9	482.1	--
Right abutment	24.6	--	497.7	--	488.9	3.2	8.8	--	12.0	476.9	--

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 STRATH00020028 on Town Highway 2, crossing the West Branch Ompompanoosuc River, Strafford, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 6,060 cubic-feet per second											
Left abutment	0.0	--	497.7	--	492.0	4.1	7.5	--	11.6	480.4	--
Right abutment	24.6	--	497.7	--	488.9	4.1	10.1	--	14.2	474.7	--

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, 1981, South Strafford, 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 stra028.wsp
T2        Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
T3        Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
*
J1         * * 0.01
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4150.0   6060.0   1560.0
SK          0.0015   0.0015   0.0015
*
XS   EXITX    -31           0.
GR         -631.4, 511.84   -613.9, 505.68   -547.1, 495.13   -497.8, 493.06
GR         -396.5, 494.35   -356.4, 492.40   -167.2, 492.95     -3.0, 496.61
GR            3.7, 490.94      8.1, 489.26     11.5, 488.05     13.1, 488.22
GR           23.6, 489.35     26.0, 490.86     29.7, 495.30     75.8, 496.92
GR          102.6, 498.59    153.1, 499.47    170.2, 503.74    185.6, 503.65
GR          198.4, 511.63
*
N           0.055       0.055        0.055
SA                -3.0         29.7
*
XS   FULLV      0
GR         -631.4, 513.62   -613.9, 507.46   -547.1, 496.91   -497.8, 494.84
GR         -396.5, 496.13   -356.4, 494.18   -167.2, 494.73     -8.3, 496.58
GR           -4.8, 495.75      0.0, 490.99      1.1, 489.49      6.4, 487.56
GR           12.0, 486.35     16.5, 486.27     24.7, 487.86     30.7, 489.84
GR           30.9, 491.05     36.6, 495.17     41.3, 498.81     42.9, 499.14
GR           75.8, 498.70    102.6, 500.37    153.1, 501.25    170.2, 505.52
GR          185.6, 505.43    198.4, 513.41
*
N            0.035      0.055        0.035
SA                 -8.3        42.9
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.70       5.0
GR            0.0, 497.73      0.0, 492.04      2.7, 492.05      5.4, 491.02
GR            9.2, 488.82     13.1, 488.58     19.8, 488.19     24.3, 488.93
GR           24.4, 490.99     24.6, 497.67      0.0, 497.73
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD            1      29.9 * *     31.0      8.4
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      22.0     1
GR        -1204.7, 505.86   -994.5, 501.19   -512.2, 498.29   -241.4, 498.20
GR         -120.2, 498.17      0.0, 500.30     26.9, 500.47     55.7, 500.33
GR           95.7, 500.52    103.9, 505.88    128.5, 506.74    135.1, 511.14
*
AS   APPRO     53
GR        -1276.0, 505.31   -807.8, 498.08   -387.6, 496.88    -66.2, 494.53
GR          -13.4, 495.97     -3.4, 494.63     -1.4, 490.90     -1.3, 490.35
GR            2.0, 489.08     14.0, 489.18     18.1, 488.95     21.6, 490.11
GR           22.4, 491.00     29.2, 495.12     32.7, 497.96     51.0, 499.69
GR           77.5, 503.42     98.6, 507.77
*
N           0.055        0.050        0.055
SA                 -3.4         32.7
*
HP 1 BRIDG 497.73 1 497.73
HP 2 BRIDG 497.73 * * 1741
HP 1 BRIDG 496.63 1 496.63
HP 2 RDWAY 499.34 * * 2374
HP 1 APPRO 499.55 1 499.55
HP 2 APPRO 499.55 * * 4150
*
HP 1 BRIDG 497.73 1 497.73
HP 2 BRIDG 497.73 * * 1873
HP 1 BRIDG 497.44 1 497.44
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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       U.S. Geological Survey WSPRO Input File stra028.wsp
       Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
       Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
          *** RUN DATE & TIME: 10-06-97  15:27

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      201     14247     0     64                            0
  497.73           201     14247     0     64  1.00      0     25        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.73     0.0    24.6   200.8   14247.    1741.   8.67

X STA.         0.0        3.0        5.0        6.6        7.9        9.0
  A(I)            17.1       12.5       10.9       10.0        9.5
  V(I)            5.08       6.99       7.98       8.70       9.13

X STA.         9.0       10.0       11.0       12.0       12.9       13.8
  A(I)             8.9        8.7        8.6        8.3        8.3
  V(I)            9.75      10.04      10.08      10.50      10.44

X STA.        13.8       14.7       15.6       16.5       17.4       18.3
  A(I)             8.3        8.3        8.2        8.4        8.6
  V(I)           10.49      10.43      10.62      10.40      10.14

X STA.        18.3       19.2       20.2       21.2       22.5       24.6
  A(I)             8.6        8.9        9.7       11.1       17.8
  V(I)           10.15       9.75       8.96       7.86       4.89

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      175     16158    24     37                         2646
  496.63           175     16158    24     37  1.00      0     25     2646

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.34  -686.8   -54.2   566.8   22425.    2374.   4.19

X STA.      -686.8     -556.9     -517.6     -488.7     -461.9     -435.9
  A(I)            50.7       35.3       30.4       28.4       27.8
  V(I)            2.34       3.36       3.91       4.17       4.27

X STA.      -435.9     -411.4     -387.2     -363.2     -340.3     -317.4
  A(I)            26.5       26.4       26.3       25.3       25.4
  V(I)            4.48       4.50       4.52       4.70       4.67

X STA.      -317.4     -294.9     -272.5     -250.6     -229.2     -207.8
  A(I)            25.1       25.3       24.8       24.3       24.5
  V(I)            4.73       4.70       4.78       4.88       4.84

X STA.      -207.8     -186.3     -164.9     -143.1     -120.0      -54.2
  A(I)            24.7       24.8       25.3       27.0       38.4
  V(I)            4.80       4.79       4.69       4.40       3.09

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1     2445    128996   900    900                        22874
            2      312     35501    36     42                         5202
            3       13       310    17     17                           68
  499.55          2770    164807   953    958  1.40   -902     50    22622

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.55  -903.0    49.5  2770.3  164807.    4150.   1.50

X STA.      -903.0     -685.6     -574.9     -485.5     -411.0     -346.0
  A(I)           270.9      218.8      202.4      186.0      179.1
  V(I)            0.77       0.95       1.03       1.12       1.16

X STA.      -346.0     -294.9     -252.2     -214.2     -180.6     -150.9
  A(I)           161.4      149.8      144.2      136.5      127.3
  V(I)            1.29       1.39       1.44       1.52       1.63

X STA.      -150.9     -123.7      -98.1      -74.9      -51.7      -23.9
  A(I)           122.6      120.1      112.8      113.6      118.0
  V(I)            1.69       1.73       1.84       1.83       1.76

X STA.       -23.9        1.1        6.9       12.8       19.0       49.5
  A(I)           118.8       61.1       61.6       64.2      101.1
  V(I)            1.75       3.40       3.37       3.23       2.05
```

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       U.S. Geological Survey WSPRO Input File stra028.wsp
       Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
       Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
          *** RUN DATE & TIME: 10-06-97  15:27

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#    AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
            1     201    14247      0     64                            0
  497.73          201    14247      0     64  1.00      0     25        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.73     0.0    24.6   200.8   14247.    1873.   9.33

X STA.         0.0        3.0        5.0        6.6        7.9        9.0
 A(I)             17.1       12.5       10.9       10.0        9.5
 V(I)             5.47       7.52       8.58       9.36       9.83

X STA.         9.0       10.0       11.0       12.0       12.9       13.8
 A(I)              8.9        8.7        8.6        8.3        8.3
 V(I)            10.49      10.80      10.85      11.29      11.23

X STA.        13.8       14.7       15.6       16.5       17.4       18.3
 A(I)              8.3        8.3        8.2        8.4        8.6
 V(I)            11.28      11.22      11.42      11.19      10.91

X STA.        18.3       19.2       20.2       21.2       22.5       24.6
 A(I)              8.6        8.9        9.7       11.1       17.8
 V(I)            10.92      10.48       9.64       8.46       5.26

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

    WSEL  SA#    AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
            1     194    18792     24     39                         3108
  497.44          194    18792     24     39  1.00      0     25     3108

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.78  -760.0   -29.3   866.7   41348.    4229.   4.88

X STA.      -760.0     -594.5     -546.5     -512.3     -483.5     -455.4
 A(I)             82.4       54.6       47.4       43.1       42.1
 V(I)             2.57       3.87       4.46       4.90       5.02

X STA.      -455.4     -428.5     -402.5     -376.7     -352.2     -327.6
 A(I)             40.8       39.6       39.4       37.8       38.0
 V(I)             5.18       5.34       5.37       5.59       5.56

X STA.      -327.6     -303.2     -279.5     -256.1     -232.2     -209.1
 A(I)             38.0       37.0       36.9       37.7       36.7
 V(I)             5.57       5.72       5.73       5.62       5.76

X STA.      -209.1     -185.8     -161.8     -138.2     -112.1      -29.3
 A(I)             37.0       38.3       37.9       41.4       60.6
 V(I)             5.71       5.53       5.57       5.11       3.49

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
    WSEL  SA#    AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
            1    2912   168543    933    933                        29203
            2     330    39062     36     42                         5669
            3      23      665     21     21                          138
  500.06         3266   208271    990    996  1.31   -935     54    29389

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.06  -936.0    53.6  3265.7  208271.    6060.   1.86

X STA.      -936.0     -718.9     -616.8     -532.1     -458.1     -391.6
 A(I)            314.3      242.9      224.1      212.7      204.3
 V(I)             0.96       1.25       1.35       1.42       1.48

X STA.      -391.6     -333.9     -286.6     -244.5     -207.9     -174.5
 A(I)            193.9      177.3      171.2      159.9      154.2
 V(I)             1.56       1.71       1.77       1.89       1.97

X STA.      -174.5     -144.4     -116.2      -90.7      -66.7      -40.5
 A(I)            145.6      142.8      134.2      130.5      135.7
 V(I)             2.08       2.12       2.26       2.32       2.23

X STA.       -40.5       -8.0        4.6       11.3       18.4       53.6
 A(I)            144.9      101.5       73.4       78.4      123.8
 V(I)             2.09       2.99       4.13       3.86       2.45
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        U.S. Geological Survey WSPRO Input File stra028.wsp
        Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
        Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
           *** RUN DATE & TIME: 10-06-97  15:27
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      126     10135     24     33                          1628
   494.65           126     10135     24     33  1.00      0     25      1628

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       494.65     0.0    24.5   126.2   10135.    1560.  12.36

X STA.        0.0        4.3        6.5        8.0        9.2       10.1
  A(I)            11.6        8.0        7.0        6.4        5.7
  V(I)            6.70       9.73      11.13      12.28      13.67

X STA.       10.1       11.0       11.9       12.8       13.6       14.5
  A(I)             5.4        5.3        5.2        5.0        5.1
  V(I)           14.43      14.60      14.92      15.49      15.37

X STA.       14.5       15.3       16.1       16.9       17.7       18.5
  A(I)             5.0        5.0        5.0        5.1        5.2
  V(I)           15.61      15.50      15.75      15.39      14.98

X STA.       18.5       19.4       20.2       21.2       22.4       24.5
  A(I)             5.4        5.6        6.1        7.0       12.1
  V(I)           14.55      13.86      12.75      11.22       6.47

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      981     33087    706    706                          6562
             2      249     24446     36     42                          3715
   497.80          1230     57533    742    748  2.17   -709     33      6092

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

         WSEL     LEW     REW    AREA         K        Q    VEL
       497.80  -709.8    32.5  1229.9   57533.    1560.   1.27

X STA.     -709.8     -351.4     -270.1     -220.8     -183.1     -152.3
  A(I)           186.2      120.6       96.4       86.0       77.7
  V(I)            0.42       0.65       0.81       0.91       1.00

X STA.     -152.3     -126.4     -103.5      -83.4      -64.8      -45.1
  A(I)            71.1       66.6       61.7       59.6       58.6
  V(I)            1.10       1.17       1.26       1.31       1.33

X STA.      -45.1      -17.4        0.4        3.4        6.2        9.0
  A(I)            64.1       56.4       25.5       24.4       24.3
  V(I)            1.22       1.38       3.06       3.20       3.22

X STA.        9.0       11.8       14.7       17.8       21.3       32.5
  A(I)            24.5       25.2       26.8       29.3       44.8
  V(I)            3.18       3.10       2.91       2.66       1.74
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        U.S. Geological Survey WSPRO Input File stra028.wsp
        Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
        Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
           *** RUN DATE & TIME: 10-06-97  15:27

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

EXITX:XS   ******   -556     1850  0.08 *****  496.74  494.69    4150  496.65
       -30 ******     68   107078  1.08 ***** *******    0.24    2.24

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  0.66

FULLV:FV       31   -539     1096  0.26  0.07  496.89 *******    4150  496.63
         0     31     38    70863  1.18  0.09    0.00    0.53    3.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   496.13     507.77    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   496.13     507.77     497.11
 ===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 =   497.11     507.77     497.11

APPRO:AS       53   -468      803  0.90 *****  498.01  497.11    4150  497.11
        53     53     32    39073  2.17 ***** *******    1.06    5.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
         WS1,WSSD,WS3,RGMIN =   505.98       0.00     497.68     498.17
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
         WS3,WSIU,WS1,LSEL =   496.85     499.32     499.46     497.70
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                 QRD,QRDMAX,RATIO =    2374.      2318.    1.02

            <<<<<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      201  1.17 *****  498.90  494.90    1741  497.73
         0 ******     25    14247  1.00 ***** *******    0.54    8.67

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.448  0.000  497.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    31.  0.02  0.05  499.58   -0.01   2374.  499.34

            Q    WLEN    LEW    REW   DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   2374.   633.  -687.   -54.   1.2   0.9   5.0   4.2   1.1   3.1
   RT:      0.    84.    14.    98.   1.6   1.5   6.9   6.9   2.3   3.0

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

APPRO:AS       23   -902     2769  0.05  0.15  499.60  497.11    4150  499.55
        53     40     50   164712  1.40  0.43   -0.01    0.18    1.50

       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.  -557.    68.   4150.  107078.    1850.    2.24  496.65
   FULLV:FV       0.  -540.    38.   4150.   70863.    1096.    3.79  496.63
   BRIDG:BR       0.     0.    25.   1741.   14247.     201.    8.67  497.73
   RDWAY:RG      13.******* 2374.   2374.*********       0.    1.00  499.34
   APPRO:AS      53.  -903.    50.   4150.  164712.    2769.    1.50  499.55

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

  SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.69    0.24  488.05  511.84************  0.08  496.74  496.65
   FULLV:FV  ********    0.53  486.27  513.62  0.07  0.09  0.26  496.89  496.63
   BRIDG:BR    494.90    0.54  488.19  497.73************  1.17  498.90  497.73
   RDWAY:RG  ****************  498.17  511.14  0.02******  0.05  499.58  499.34
   APPRO:AS    497.11    0.18  488.95  507.77  0.15  0.43  0.05  499.60  499.55
```
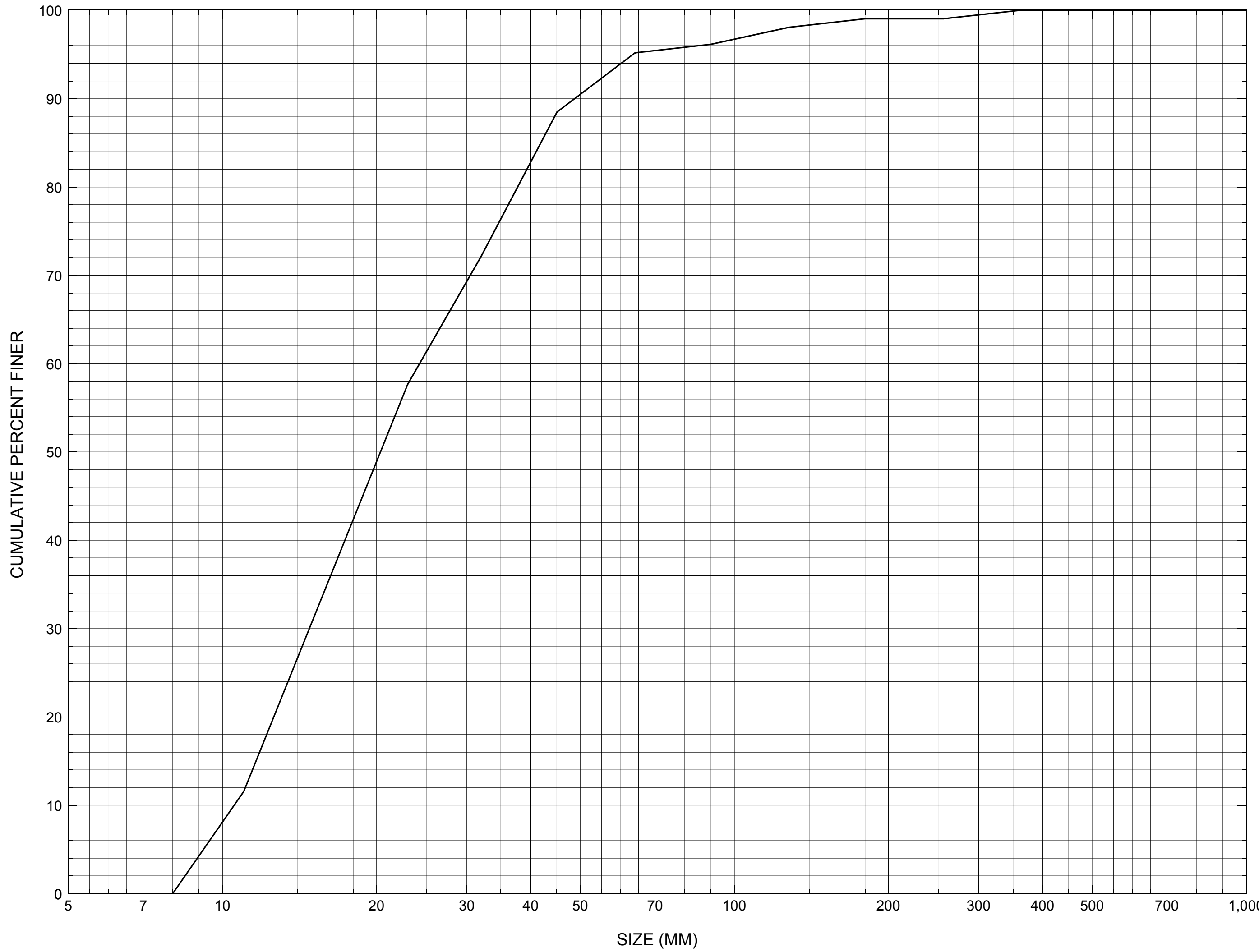

```
       U.S. Geological Survey WSPRO Input File stra028.wsp
       Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
       Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
          *** RUN DATE & TIME: 10-06-97  15:27

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

EXITX:XS   ******   -561     2361  0.11 *****  497.56  495.06    6060  497.46
       -30 ******     84   156436  1.06 ***** *******    0.24    2.57

FULLV:FV       31   -549     1567  0.24  0.06  497.68 *******    6060  497.44
         0     31     40   121667  1.04  0.07   -0.01    0.43    3.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.94     507.77    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.94     507.77     497.86
 ===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 =   497.86     507.77     497.86

APPRO:AS       53   -729     1274  0.76 *****  498.62  497.86    6060  497.86
        53     53     33    59558  2.16 ***** *******    0.95    4.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===210 QUESTIONABLE CRITICAL-FLOW SOLUTION.
                  SECID "BRIDG"     Q,CRWS =  6060.00     497.73
 ===230 REJECTED FLOW CLASS 1 SOLUTION.
             WS1,WSSD,WS3 =   507.77       0.00     497.73
                     CRWS =   497.86   ********     497.73
                     YMAX =   507.77   ********     497.73

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   497.73     499.71     500.07     497.70
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    4229.      3945.    1.07

            <<<<<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      201  1.35 *****  499.08  495.16    1873  497.73
         0 ******     25    14247  1.00 ***** *******    0.58    9.33

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.465  0.000  497.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    31.  0.03  0.07  500.10    0.01   4229.  499.78

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:  4229.   731.  -760.   -29.   1.6   1.2   5.7   4.9   1.5   3.1
   RT:     0.    84.    14.    98.   1.7   1.5   6.9   6.9   2.3   3.0

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

APPRO:AS       23   -935     3266  0.07  0.25  500.13  497.86    6060  500.06
        53     49     54   208287  1.31  0.50    0.01    0.21    1.86

       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.  -562.    84.   6060.  156436.    2361.    2.57  497.46
   FULLV:FV       0.  -550.    40.   6060.  121667.    1567.    3.87  497.44
   BRIDG:BR       0.     0.    25.   1873.   14247.     201.    9.33  497.73
   RDWAY:RG      13.******* 4229.   4229.*********       0.    1.00  499.78
   APPRO:AS      53.  -936.    54.   6060.  208287.    3266.    1.86  500.06

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

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.06    0.24  488.05  511.84************  0.11  497.56  497.46
   FULLV:FV  ********    0.43  486.27  513.62  0.06  0.07  0.24  497.68  497.44
   BRIDG:BR    495.16    0.58  488.19  497.73************  1.35  499.08  497.73
   RDWAY:RG  ****************  498.17  511.14  0.03******  0.07  500.10  499.78
   APPRO:AS    497.86    0.21  488.95  507.77  0.25  0.50  0.07  500.13  500.06
```

```
        U.S. Geological Survey WSPRO Input File stra028.wsp
        Hydraulic analysis for structure STRATH00020028   Date: 21-AUG-97
        Town Highway 2, West Br. Ompompanoosuc River, Strafford, VT   ECW
           *** RUN DATE & TIME: 10-06-97  15:27

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

EXITX:XS   ******   -543      930  0.06 *****  495.07  493.81    1560  495.01
       -30 ******     29    40272  1.27 ***** *******    0.24    1.68

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.90     494.86     492.03
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.51     513.62    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.51     513.62     492.03
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.54

FULLV:FV       31   -498      327  0.50  0.09  495.37  492.03    1560  494.88
         0     31     36    21704  1.40  0.22    0.00    0.89    4.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.36     494.81     495.59
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.38     507.77    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.38     507.77     495.59
 ===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 =   495.59     507.77     495.59

APPRO:AS       53   -210      274  0.89 *****  496.49  495.59    1560  495.59
        53     53     30    15878  1.77 ***** *******    1.21    5.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       31      0      126  2.38  0.18  497.03  494.51    1560  494.65
         0     31     25    10129  1.00  1.77    0.00    0.96   12.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.70 ****** ****** ******

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

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

APPRO:AS       23   -710     1232  0.05  0.12  497.86  495.59    1560  497.80
        53     29     33    57622  2.17  0.71    0.00    0.26    1.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.898  0.625   21582.     -5.    20.   497.78

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -31.  -544.    29.   1560.   40272.     930.    1.68  495.01
   FULLV:FV       0.  -499.    36.   1560.   21704.     327.    4.77  494.88
   BRIDG:BR       0.     0.    25.   1560.   10129.     126.   12.37  494.65
   RDWAY:RG      13.**************       0.*****************     1.00********
   APPRO:AS      53.  -711.    33.   1560.   57622.    1232.    1.27  497.80

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    20.   21582.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.81    0.24  488.05  511.84************  0.06  495.07  495.01
   FULLV:FV    492.03    0.89  486.27  513.62  0.09  0.22  0.50  495.37  494.88
   BRIDG:BR    494.51    0.96  488.19  497.73  0.18  1.77  2.38  497.03  494.65
   RDWAY:RG  ***************  498.17  511.14**********************************
   APPRO:AS    495.59    0.26  488.95  507.77  0.12  0.71  0.05  497.86  497.80
  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 STRATH00020028, in Strafford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number STRATH00020028

General Location Descriptive

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

Date *(MM/DD/YY)* 10 / 23 / 95

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

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 70675

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

Waterway *(I - 6)* W. BR. OMPOMPANOOSUC R.

Road Name *(I - 7)*: -

Route Number TH02

Vicinity *(I - 9)* 0.2 miles to jct. with TH 24

Topographic Map CHELSEA

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 435410

Longitude *(i - 17; nnnnn.n)* 72223

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10091000280910

Maintenance responsibility *(I - 21; nn)* 3

Maximum span length *(I - 48; nnnn)* 26

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 31

Average daily traffic, ADT *(I - 29; nnnnnn)* 000600

Deck Width *(I - 52; nn.n)* 22.5

Year of ADT *(I - 30; YY)* 94

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)* 104

Year Reconstructed *(I - 106)* 000

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

Clear span (*nnn.n ft*) 000

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

Vertical clearance from streambed (*nnn.n ft*) 0000

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

Waterway of full opening (*nnn.n ft²*) 9.5

Comments:

Structural Inspection report of 6/20/94 indicates the structure is a concrete T-beam bridge with an asphalt road surface. Both abutments are concrete. The right abutment has a full-length newer concrete facing. It is half of the stem height near midsection, and the full stem height at the facias and wingwalls. The upstream end of the left abutment has a newer half height concrete facing. The left abutment wingwalls have some deep spalling. The upstream end of the left abutment half height facing has a void beneath it at the streambed elevation. Overall, there does not appear to be any undermining of the original stem. **(cont., page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): -

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*): - Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): - *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 (*ft²*): -

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

Comments:

The waterway makes a sharp turn into the structure and the majority of the flow is directed into the right abutment. There is a sand bar along the left abutment and stone and gravel along the streambed in front of the right abutment. There are some random medium sized boulders placed along the stream bank at the upstream end of the right abutment. There is a log in the streambed across the channel which acts more or less as a check dam for the streambed at the downstream face.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **25.41** mi^2 Lake/pond/swamp area **0.08** mi^2

Watershed storage *(ST)* **0.3** %

Bridge site elevation **900** ft Headwater elevation **2380** ft

Main channel length **9.25** mi

10% channel length elevation **910** ft 85% channel length elevation **1790** ft

Main channel slope *(S)* **126.85** 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: - (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness - Footing bottom elevation: 4

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

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

Comments: -
-

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **11/05/96**

Computerized by: **RB** Date: **11/05/96**

Reviewd by: **EW** Date: **1/26/98**

Structure Number **STRATH00020028**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **07** / **24** / 19**96**

2. Highway District Number **04** Mile marker **0000**

County **ORANGE (017)** Town **STRAFFORD (70675)**

Waterway *(I - 6)* **W. BR. OMPOMPANOOSUC R.** Road Name **-**

Route Number **TH02** Hydrologic Unit Code: **01080103**

3. Descriptive comments:

Located 0.2 miles to the junction with TH 24. This bridge has a concrete T-beam span with an asphalt road surface.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **4** RBDS **4** 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 **1** 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 **30.3** *(feet)* Span length **25** *(feet)* Bridge width **22** *(feet)*

Road approach to bridge:

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

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

10. Embankment slope (*run / rise in feet / foot*):

US left **--** US right **--**

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

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

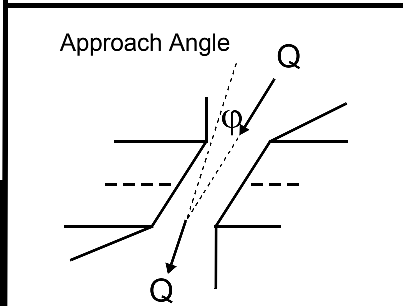
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

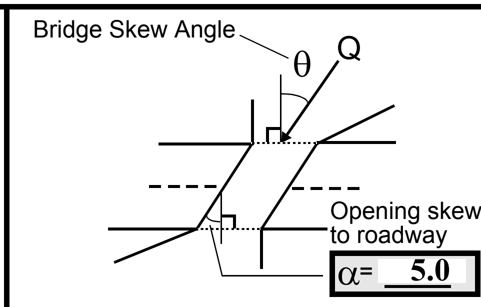
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **10** 16. Bridge skew: **45**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **RB** *(LB, RB)* Severity **1**

Range? **65** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*

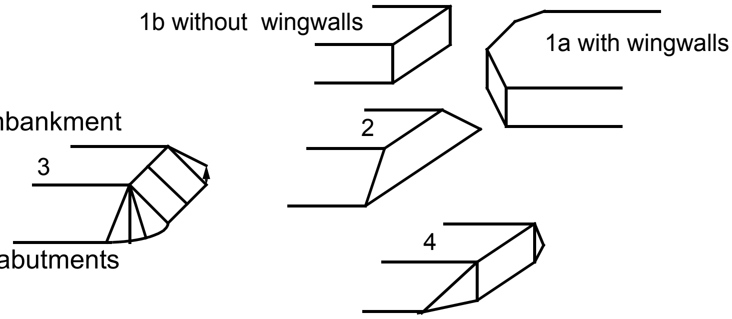
Where? **LB** *(LB, RB)* Severity **2**

Range? **19** feet **DS** *(US, UB, DS)* to **125** feet **DS**

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

18. Bridge Type: **1a/4**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. On the right bank upstream there is a two story house with two sheds surrounded by a hay field. The left bank upstream and the right bank downstream are both grass and TH02 runs across the overbanks. On the left bank downstream there is a horse pasture with horses.
5. The water is moving along pretty well through the reach, but it is not a raging riffle. Where the channel makes a sharp bend to the right downstream of the bridge, the water pools, hence the water surface is classified as pool.
7. Values are the measured dimensions. There were no VTAOT measurements indicated in the historical form. The bridge width was measured from the outside edge of the bridge rail to the outside edge of the bridge rail.
18. The upstream left wingwall and both downstream wingwalls are type 1a. The upstream right wingwall is a type 4. The right abutment and wingwalls all have new concrete faces.

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
33.0	4.5			8.0	1	1	13	13	1	2

23. Bank width **65.0** 24. Channel width **35.0** 25. Thalweg depth **36.0** 29. Bed Material **314**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **1**

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

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

28. Both banks are eroded and roots are exposed.
30. The right bank protection extends from 23 ft US to the US bridge face.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **2UB** 35. Mid-bar width: **11.5**

36. Point bar extent: **28** feet **US** (US, UB) to **22** feet **US** (US, UB, DS) positioned **0** %LB to **50** %RB

37. Material: **123**

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

This point bar starts upstream and continues around the corner of the upstream left wingwall and extends the full length of the left abutment under the bridge. The point bar is composed of finely grained silt and clay material on the left side, whereas the right side of the point bar is gravel.

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

41. Mid-bank distance: **24** 42. Cut bank extent: **93** feet **US** (US, UB) to **23** feet **US** (US, UB, DS)

43. Bank damage: **12** (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

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

The cut bank ends where the right bank protection starts. Between 35 ft US and 67 ft US on the right bank, there is slip failure.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **15DS**

47. Scour dimensions: Length **92** Width **7.5** Depth : **3.2** Position **50** %LB to **90** %RB

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

Thalweg is assumed to be 2 ft. The scour hole extends from 29 ft US to 41 ft DS.

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 Approximately 9.5 ft US on the right bank, at the end of the wingwall, a culvert exists with a diameter of 0.75 ft. It is presently flowing.

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
23.0		2.0		2	7	7	-

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

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

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

317

The bed material is gravel, silt and stone fill. The stone fill is protecting the right abutment, the gravel is predominant in the scour hole and streamward side of the point bar, and the fines are the predominate material of the point bar under the bridge.

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

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

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

70. Debris and Ice Comments:

2

65. There is debris in the channel upstream and under the bridge, at the upstream end of the point bar in front of the left abutment.

69. Though there is no evidence of ice build up, if it where to happen the ice blockage potential would be significant. There is no evidence of ice build up because there are no trees along the banks.

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**	**2**	**0**	**5**	**90.0**
RABUT	**1**	**35**	**90**			**2**	**3**	**24.5**

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

0.5

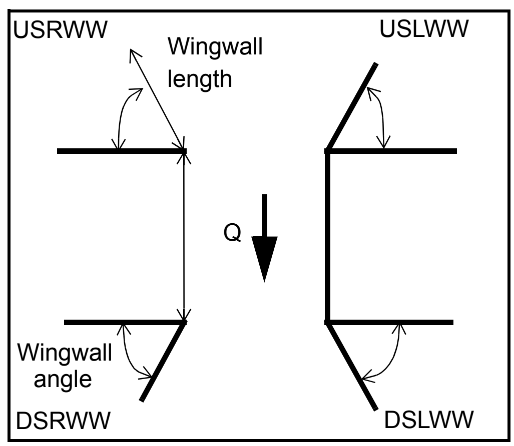
1

76. It is possible to penetrate 0.3 ft under the right abutment.

74. The left abutment footing, added to the upstream left wingwall and upstream end of the left abutment, only extends to 14 ft under the bridge from the upstream bridge face. There is a point bar in front of the left abutment from this point to the downstream bridge face.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**24.5**	
USRWW:	**Y**		**1**		**2**	**3.0**	
DSLWW:	**-**		**5**		**Y**	**25.5**	
DSRWW:	**1**		**0**		**-**	**25.5**	



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

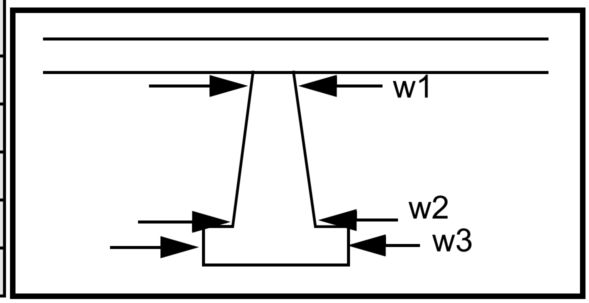
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**0.0**			**12.0**	**60.0**	**10.0**
Pier 2	**0.0**	**0.0**	**-**	**11.0**	**12.0**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**feet. It**	**recentl**	**and**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**upst**	**looks**	**y.**	**the**	*1- Solid pier, 2- column, 3- bent*
88. Material	**ream**	**like**	**Refe**	**his-**	*1- Wood; 2- concrete; 3- metal; 4- stone*
89. Shape	**left**	**the**	**r to**	**tori-**	*1- Round; 2- Square; 3- Pointed*
90. Inclined?	**wing**	**foot-**	**the**	**cal**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wall**	**ing**	**upst**	**form**	
92. Pushed	**foot-**	**was**	**ream**	**.**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**ing is**	**adde**	**brid**		
95. Cross-members	**expo**	**d to**	**ge**		*0- none; 1- laterals; 2- diagonals; 3- both*
96. Scour Condition	**sed**	**the**	**face**		*0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed*
97. Scour depth	**for**	**wing**	**pho-**		
98. Exposure depth	**five**	**wall**	**tos**		

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 -_____ Thalweg depth -_____ Bed Material -_____

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

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

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

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

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

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

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

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

Material: __NO__

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

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 __1__ *(US, UB, DS)*

Bank damage: __1__ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

1234
1234
2
2

Is channel scour present? __321__ *(Y or if N type ctrl-n cs)* Mid-scour distance: __4__

Scour dimensions: Length __0__ Width __0__ Depth: __-__ Positioned __-__ %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 __N__

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)*:

-

NO DROP STRUCTURE

There is a log that runs parallel to the bridge in the channel at 0 ft DS that is acting like a drop structure. It has been buried with silt, clay and sand.

Y
97
13
65
DS
223

109. G. Plan View Sketch

- D

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: STRATH00020028 Town: STRAFFORD
Road Number: TH 2 County: ORANGE
Stream: WEST BRANCH OMPOMPANOOSUC RIVER

Initials ECW Date: 10/6/97 Checked: RHF

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	4150	6060	1560
Main Channel Area, ft2	312	330	249
Left overbank area, ft2	2445	2912	981
Right overbank area, ft2	13	23	0
Top width main channel, ft	36	36	36
Top width L overbank, ft	900	933	706
Top width R overbank, ft	17	21	0
D50 of channel, ft	0.0669	0.0669	0.0669
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.7	9.2	6.9
y1, average depth, LOB, ft	2.7	3.1	1.4
y1, average depth, ROB, ft	0.8	1.1	ERR
Total conveyance, approach	164807	208271	57533
Conveyance, main channel	35501	39062	24446
Conveyance, LOB	128996	168543	33087
Conveyance, ROB	310	665	0
Percent discrepancy, conveyance	0.0000	0.0005	0.0000
Qm, discharge, MC, cfs	893.9	1136.6	662.9
Ql, discharge, LOB, cfs	3248.2	4904.0	897.1
Qr, discharge, ROB, cfs	7.8	19.3	0.0
Vm, mean velocity MC, ft/s	2.9	3.4	2.7
Vl, mean velocity, LOB, ft/s	1.3	1.7	0.9
Vr, mean velocity, ROB, ft/s	0.6	0.8	ERR
Vc-m, crit. velocity, MC, ft/s	6.5	6.6	6.3
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
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7) Converted to English Units
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	4150	6060	1560
(Q) discharge thru bridge, cfs	1741	1873	1560
Main channel conveyance	14247	14247	10135
Total conveyance	14247	14247	10135
Q2, bridge MC discharge,cfs	1741	1873	1560
Main channel area, ft2	201	201	126
Main channel width (normal), ft	24.5	24.5	24.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.5	24.5	24.4
y_bridge (avg. depth at br.), ft	8.20	8.20	5.16
Dm, median (1.25*D50), ft	0.083625	0.083625	0.083625
y2, depth in contraction,ft	9.72	10.35	8.88
ys, scour depth (y2-ybridge), ft	1.51	2.14	**3.71**

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	1741	1873	1560
Main channel area (DS), ft2	175	194	126
Main channel width (normal), ft	24.5	24.5	24.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	24.5	24.5	24.4
D90, ft	0.1600	0.1600	0.1600
D95, ft	0.2079	0.2079	0.2079
Dc, critical grain size, ft	0.2516	0.2294	0.4330
Pc, Decimal percent coarser than Dc	0.043	0.046	0.018
Depth to armoring, ft	N/A	N/A	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	4150	6060	1560
Q, thru bridge MC, cfs	1741	1873	1560
Vc, critical velocity, ft/s	6.52	6.58	6.28
Va, velocity MC approach, ft/s	2.87	3.44	2.66
Main channel width (normal), ft	24.5	24.5	24.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.5	24.5	24.4
qbr, unit discharge, ft2/s	71.1	76.4	63.9
Area of full opening, ft2	201.0	201.0	126.0
Hb, depth of full opening, ft	8.20	8.20	5.16
Fr, Froude number, bridge MC	0.54	0.58	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	175	194	N/A
**Hb, depth at downstream face, ft	7.14	7.92	N/A
**Fr, Froude number at DS face	0.66	0.60	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.7	497.7	0
Elevation of Bed, ft	489.50	489.50	-5.16
Elevation of Approach, ft	499.55	500.06	0
Friction loss, approach, ft	0.15	0.25	0
Elevation of WS immediately US, ft	499.40	499.81	0.00
ya, depth immediately US, ft	9.90	10.31	5.16
Mean elevation of deck, ft	500.4	500.4	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.94	1.00
**Cc, for downstream face (<=1.0)	0.916966	0.934126	ERR
Ys, scour w/Chang equation, ft	**3.22**	**4.10**	N/A
Ys, scour w/Umbrell equation, ft	-1.56	-0.51	N/A

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

**Ys, scour w/Chang equation, ft	4.74	4.51	N/A

**Ys, scour w/Umbrell equation, ft	-0.50	-0.23	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	9.72	10.35	8.88
WSEL at downstream face, ft	496.63	497.44	--
Depth at downstream face, ft	7.14	7.92	N/A
Ys, depth of scour (Laursen), ft	2.58	2.43	N/A

Abutment Scour

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

	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	4150	6060	1560	4150	6060	1560
a', abut.length blocking flow, ft	903	936	709.8	25	29.1	8
Ae, area of blocked flow ft2	1910.37	2086.24	1003.73	82.87	102.35	32
Qe, discharge blocked abut.,cfs	--	--	934.25	170.08	250.49	55.71
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.34	1.71	0.93	2.05	2.45	1.74
ya, depth of f/p flow, ft	2.12	2.23	1.41	3.31	3.52	4.00
--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.142	0.169	0.138	0.199	0.230	0.153
ys, scour depth, ft	18.42	21.19	12.89	**8.76**	**10.09**	**7.17**

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)	903	936	709.8	25	29.1	8
y1 (depth f/p flow, ft)	2.12	2.23	1.41	3.31	3.52	4.00
a'/y1	426.83	419.94	501.94	7.54	8.27	2.00
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.14	0.17	0.14	0.20	0.23	0.15
Ys w/ corr. factor K1/0.55:						
vertical	8.17	9.11	5.41	ERR	ERR	ERR
vertical w/ ww's	**6.70**	**7.47**	**4.43**	ERR	ERR	ERR
spill-through	4.49	5.01	2.97	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.66	0.6	0.96	0.66	0.6	0.96
y, depth of flow in bridge, ft	7.14	7.92	5.16	7.14	7.92	5.16
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.92	1.76	ERR	1.92	1.76	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.13	ERR	ERR	2.13