LEVEL II SCOUR ANALYSIS FOR BRIDGE 125 (MIDBUS00070125) on US ROUTE 7, crossing the MIDDLEBURY RIVER, MIDDLEBURY, VERMONT

U.S. Geological Survey
Open-File Report 97-103

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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By Erick M. Boehmler and Robert H. Flynn

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Pembroke, New Hampshire

1997

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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 125 (MIDBUS00070125) ON U.S. ROUTE 7, CROSSING THE MIDDLEBURY RIVER, MIDDLEBURY, VERMONT

By **Erick M. Boehmler and Robert H. Flynn**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MIDBUS00070125 on U.S. Route 7 crossing the Middlebury River, Middlebury, 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 west-central Vermont. The 46.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of row crops on the right overbank upstream and downstream, and trees on the left overbank.

In the study area, the Middlebury River has a straight channel with a slope of approximately 0.005 ft/ft, an average channel top width of 77 ft and an average channel depth of 4 ft. The predominant channel bed materials are sand and cobbles with a median grain size (D_{50}) of 59.4 mm (0.195 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 18, 1996, indicated that the reach was stable.

The U.S. Route 7 crossing of the Middlebury River is a 202-ft-long, two-lane bridge consisting of one 91-foot, and two 55-foot steel-beam spans (Vermont Agency of Transportation, written communication, December 14, 1995). The bridge is supported by vertical, concrete abutment walls with spill-through embankments. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) on the spill-through embankments of each abutment and type-1 stone fill (less than 12 inches diameter) on the right bank upstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.5 to 11.0 ft. The worst-case abutment scour occurred at the 500-year discharge at the left abutment. Pier scour ranged from 8.3 to 15.9 ft. for each modeled discharge. The worst-case pier scour occurred at the 500-year discharge. In this report, piers are numerically designated “1” and “2” for the left and right piers respectively. 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.

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 MIDBUS00070125 ***Stream*** Middlebury River

County Addison ***Road*** U.S. 7 ***District*** 5

Description of Bridge

Bridge length 202 ***ft*** ***Bridge width*** 35.0 ***ft*** ***Max span length*** 91 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 6/18/96

Description of stone fill Type-2 is noted on the spill-through embankments of each abutment and type-1 is noted on the right bank upstream.

Brief description of piers/abutments Abutments and piers are concrete. The piers are solid concrete walls (as opposed to multiple columns) with rounded ends aligned with the flow direction.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 45

There is a mild channel bend at the bridge.

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	6/18/96	0	0
Level II	6/18/96	0	0

Potential for debris Moderate. There is some debris accumulation (dead trees and branches) on the left overbank upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 6/18/96.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting, with irregular flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 6/18/96

DS left: Steep channel bank to a narrow overbank.

DS right: Moderately sloping channel bank to a wide flood plain.

US left: Moderately sloping channel bank to a narrow overbank.

US right: Steep channel bank to a wide flood plain.

Description of the Channel

Average top width 77 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Sand / Cobbles ***Bank material*** Sand / Cobbles

Straight and stable with semi-alluvial boundaries.

6/18/96

Vegetative co Trees

DS left: Trees with brush and row crops on the flood plain.

DS right: Trees

US left: Trees with pasture and row crops on the flood plain.

US right: Yes

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

None evident on 6/18/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 46.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p - No

Calculated Discharges

Q100 6,000 ***ft³/s*** ***Q500*** 8,500 ***ft³/s***

The 100- and 500-year discharges are based on discharge frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957 a&b; and Talbot, 1887) and that provided in the VTAOT database. The values of the 100- and 500-year discharge from the VTAOT discharge frequency curve were selected for the hydraulic analyses at this site due to their central tendency with the values from the other curves.

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 Subtract 117.1 feet from the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is the center of an engraved triangle on a brass tablet on top of the concrete left abutment at the upstream end (elev. 503.59 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete right abutment at the downstream end (elev. 501.32 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	-200	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	24	1	Road Grade section
APPRO	187	2	Modelled Approach section (Templated from APTEM)
APTEM	274	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 0.050, and overbank "n" values ranged from 0.035 to 0.060.

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 0.0047 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1944).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0061 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 501.4 *ft*
Average low steel elevation 497.5 *ft*

100-year discharge 6,000 *ft³/s*
Water-surface elevation in bridge opening 491.5 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 740 *ft²*
Average velocity in bridge opening 8.1 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 493.6
Water-surface elevation at Approach section without bridge 492.7
Amount of backwater caused by bridge 0.9 *ft*

500-year discharge 8,500 *ft³/s*
Water-surface elevation in bridge opening 491.8 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 768 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.4 *ft/s*

Water-surface elevation at Approach section with bridge 495.5
Water-surface elevation at Approach section without bridge 493.6
Amount of backwater caused by bridge 1.9

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The depths of armoring computed suggest that streambed armoring will not impede contraction scour.

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 the 100- and 500-year discharges was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths computed at the toe of each spill-through embankment were applied for the entire area of each embankment as shown in figure 8.

Pier scour was computed by use of a modified equation developed at Colorado State University (Richardson and others, 1995, p. 36, equation 21) for all discharges modeled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the froude number) immediately upstream of the bridge, and four correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring. Computed pier scour depths were below the bottom of the pier footing only at pier 1.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.2	--
Depth to armoring	2.0	47.8	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	8.3	11.0	--
Right abutment	9.6	7.5	--
Pier scour			
Pier 1	13.9	15.9	--
Pier 2	8.3	9.5	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	2.6	--
Right abutment	1.9	2.6	--
Piers:			
Pier 1	0.9	1.6	--
Pier 2	0.9	1.6	--

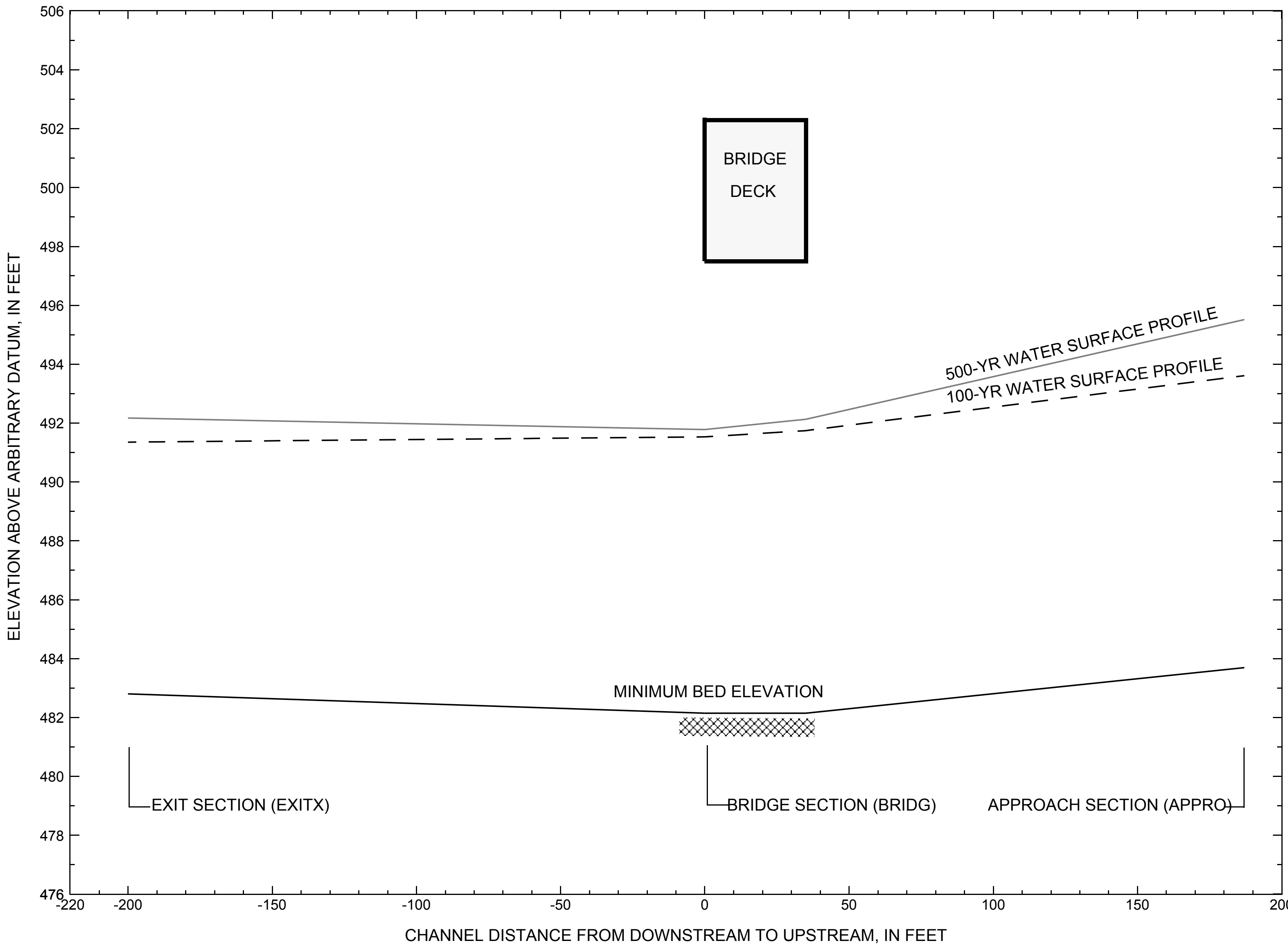

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MIDBUS00070125 on U.S. Route 7, crossing Middlebury River, Middlebury, Vermont.

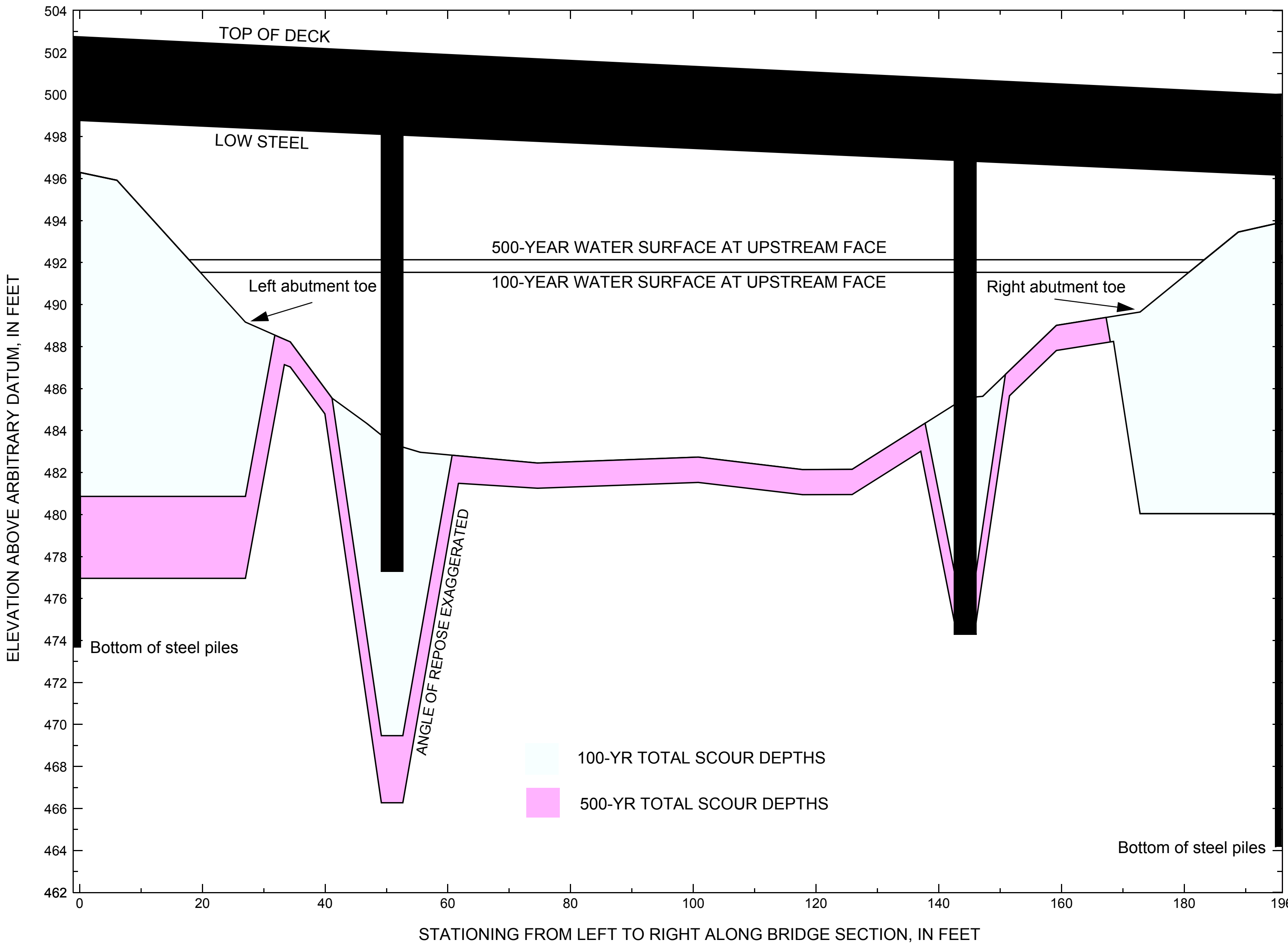

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MIDBUS00070125 on U.S. Route 7, crossing Middlebury River, Middlebury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MIDBUS00070125 on U.S. Route 7, crossing the Middlebury River, Middlebury, Vermont.

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

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Low cord 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-yr. discharge is 6,000 cubic-feet per second											
Left abutment	0.0	381.7	498.8	473.7	496.3	--	--	--	--	--	7.2
Left abutment toe	27.0	--	--	--	489.2	0.0	8.3	--	8.3	480.9	--
Pier 1	50.9	380.4	497.9	477.3	483.4	0.0	--	13.9	13.9	469.5	-7.8
Pier 2	144.3	379.2	496.8	474.3	485.5	0.0	--	8.3	8.3	477.2	2.9
Right abutment toe	172.8	--	--	--	489.6	0.0	9.6	--	9.6	480.0	--
Right abutment	194.9	379.1	496.2	464.2	493.8	--	--	--	--	--	15.8

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure MIDBUS00070125 on U.S. Route 7, crossing the Middlebury River, Middlebury, Vermont.

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

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Low cord 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-yr. discharge is 8,500 cubic-feet per second											
Left abutment	0.0	381.7	498.8	473.7	496.3	--	--	--	--	--	3.3
Left abutment toe	27.0	--	--	--	489.2	1.2	11.0	--	12.2	477.0	--
Pier 1	50.9	380.4	497.9	477.3	483.4	1.2	--	15.9	17.1	466.3	-11.0
Pier 2	144.3	379.2	496.8	474.3	485.5	1.2	--	9.5	10.7	474.8	0.5
Right abutment toe	172.8	--	--	--	489.6	1.2	7.5	--	8.7	480.9	--
Right abutment	194.9	379.1	496.2	464.2	493.8	--	--	--	--	--	16.7

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, 1944, East Middlebury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Photorevised, 1972; Photoinspected 1983; Contour interval, 20 feet; Scale 1:24,000.

U.S. Geological Survey, 1943, Cornwall, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Photoinspected, 1983; Contour interval, 20 feet; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File midb125.wsp
T2        Hydraulic analysis for structure MIDBUS00070125   Date: 05-DEC-96
T3        U.S. Route 7 Crossing the Middlebury River, Middlebury, VT         EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          6000.0   8500.0
SK         0.0047   0.0047
*
XS   EXITX   -200
GR          -82.3, 505.39    -49.0, 494.30      0.0, 490.55     37.4, 489.90
GR           46.3, 488.14     50.6, 485.54     51.3, 483.80     56.3, 482.80
GR           71.8, 483.53     88.3, 483.60     99.5, 483.70    114.0, 484.15
GR          115.0, 485.49    139.5, 489.49    307.0, 489.05    378.8, 491.55
GR          528.9, 493.85    725.2, 494.02    817.2, 492.42   1499.1, 493.92
*
N           0.060        0.050        0.040         0.050
SA                  37.4         139.5         378.8
*
XS   FULLV      0  * * *  0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    497.47      45.0
GR            0.0, 498.77      0.1, 496.29      6.1, 495.92     27.0, 489.16
GR           34.3, 488.22     41.1, 485.55     44.1, 485.55     46.7, 484.36
GR           50.9, 483.35     55.5, 482.96     74.6, 482.45    100.8, 482.73
GR          117.8, 482.14    125.9, 482.15    140.4, 484.83    144.3, 485.54
GR          147.2, 485.63    159.2, 489.01    172.8, 489.64    188.8, 493.45
GR          194.9, 493.85    194.9, 496.17      0.0, 498.77
*         Notice: Toe of left and right abutment slopes at stations 27.0
*                 and 172.8 respectively. Piers are located at stations
*                 50.9 and 144.3.
*
PW 0        483.35, 3.5  485.54, 3.5  485.54, 7.0  496.84, 7.0  496.84, 3.5
PW 0        497.91, 3.5  497.91, 0.0
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      48.0      2.1    502.3
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     24      35.0     1
GR        -381.8, 512.61   -364.2, 510.10   -316.9, 509.14    -92.8, 503.98
GR          -9.7, 502.75     -7.8, 503.60      0.0, 503.58    203.3, 500.95
GR         212.5, 500.77    213.9, 500.01    323.7, 498.36    498.9, 496.13
GR         592.0, 495.57    713.0, 495.42   1272.9, 498.14
*
XT   APTEM    274
GR          -9.8, 497.38      0.0, 490.63     75.9, 489.27     79.0, 488.54
GR          81.6, 485.77     83.5, 485.06    102.8, 484.98    119.5, 484.80
GR         127.5, 484.22    131.5, 485.77    139.6, 491.60    159.8, 491.36
GR         300.9, 489.93    427.1, 491.34    475.6, 494.84    544.3, 495.41
GR         592.0, 495.57    713.0, 495.42   1272.9, 498.14
*
AS   APPRO    187 *  *  *  0.0061
GT
N           0.060        0.050        0.035
SA                  75.9         139.6
*
HP 1 BRIDG 491.53 1 491.53
HP 2 BRIDG 491.53 * * 6000
HP 2 BRIDG 491.74 * * 6000
HP 1 APPRO 493.61 1 493.61
HP 2 APPRO 493.61 * * 6000
*
HP 1 BRIDG 491.78 1 491.78
HP 2 BRIDG 491.78 * * 8500
HP 2 BRIDG 492.13 * * 8500
HP 1 APPRO 495.51 1 495.51
HP 2 APPRO 495.51 * * 8500
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File midb125.wsp
Hydraulic analysis for structure MIDBUS00070125   Date: 05-DEC-96
U.S. Route 7 Crossing the Middlebury River, Middlebury, VT         EMB
   *** RUN DATE & TIME: 12-13-96  14:59

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

  WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      740    107686    114    117                         10708
491.53           740    107686    114    117  1.00     20    181     10708

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    491.53    19.7   180.7   740.2  107686.    6000.   8.11

X STA.        19.7        45.2        52.8        58.7        64.2        69.3
  A(I)             60.5        41.1        35.8        33.9        32.0
  V(I)             4.96        7.30        8.37        8.86        9.39

X STA.        69.3        74.3        79.2        84.0        88.9        93.8
  A(I)             31.7        31.3        30.7        31.2        31.0
  V(I)             9.45        9.58        9.79        9.62        9.67

X STA.        93.8        98.8       103.9       108.8       113.7       118.6
  A(I)             31.3        31.3        31.1        32.2        31.8
  V(I)             9.57        9.58        9.64        9.31        9.42

X STA.       118.6       123.7       129.0       135.8       145.4       180.7
  A(I)             34.0        34.9        38.8        45.7        69.6
  V(I)             8.81        8.59        7.73        6.57        4.31

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    491.74    19.0   181.6   764.2  112830.    6000.   7.85

X STA.        19.0        44.8        52.5        58.5        64.0        69.2
  A(I)             62.6        42.2        37.0        35.0        33.0
  V(I)             4.79        7.11        8.10        8.56        9.08

X STA.        69.2        74.2        79.1        84.0        89.0        94.0
  A(I)             32.8        32.4        31.7        32.3        32.1
  V(I)             9.14        9.26        9.46        9.30        9.35

X STA.        94.0        99.0       104.0       109.0       114.0       118.9
  A(I)             32.3        32.2        32.0        33.2        33.6
  V(I)             9.30        9.30        9.36        9.05        8.93

X STA.       118.9       124.0       129.5       136.5       146.4       181.6
  A(I)             34.2        36.8        40.8        46.9        70.9
  V(I)             8.77        8.15        7.35        6.39        4.23

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     187.

  WSEL  SA#     AREA          K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      327     20406     81     82                          3729
          2      539     64355     64     67                          8905
          3     1044     96440    326    326                         10593
493.61          1910    181201    471    476  1.12     -4    466     20665

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     187.

      WSEL     LEW     REW    AREA        K        Q    VEL
    493.61    -5.1   465.9  1910.1  181201.    6000.   3.14

X STA.        -5.1        39.0        68.8        85.3        93.2       100.9
  A(I)            159.6       133.2       101.6        71.8        70.2
  V(I)             1.88        2.25        2.95        4.18        4.27

X STA.       100.9       108.5       116.1       123.5       131.2       166.0
  A(I)             70.1        70.8        69.7        72.5       118.2
  V(I)             4.28        4.24        4.31        4.14        2.54

X STA.       166.0       200.3       228.8       254.3       276.8       297.9
  A(I)            103.6        94.9        92.1        86.7        86.1
  V(I)             2.90        3.16        3.26        3.46        3.49

X STA.       297.9       318.8       342.2       369.2       400.3       465.9
  A(I)             86.1        90.8        97.1       101.9       133.4
  V(I)             3.48        3.30        3.09        2.94        2.25
```

WSPRO OUTPUT FILE (continued)

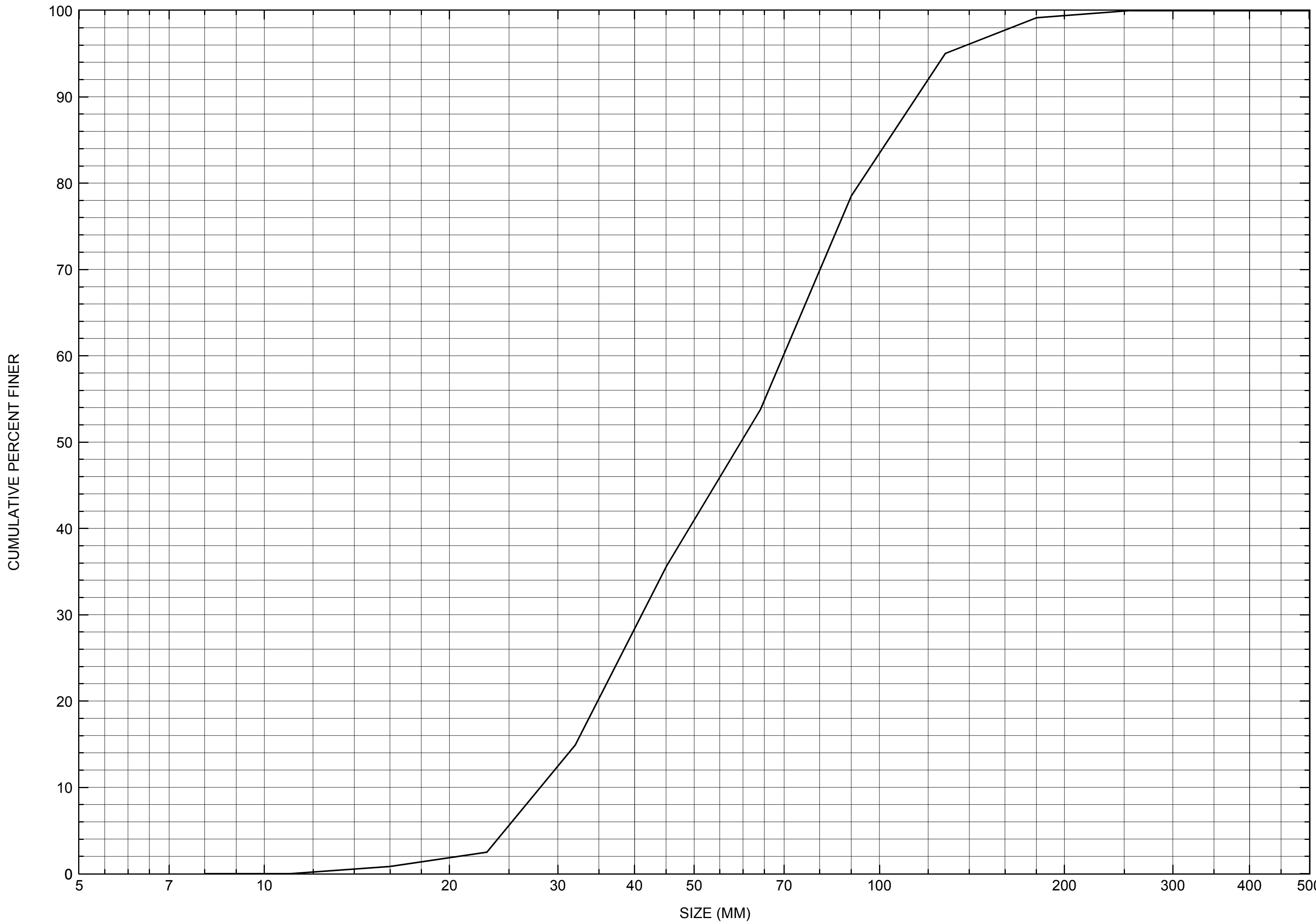
```
        U.S. Geological Survey WSPRO Input File midb125.wsp
        Hydraulic analysis for structure MIDBUS00070125   Date: 05-DEC-96
        U.S. Route 7 Crossing the Middlebury River, Middlebury, VT         EMB
           *** RUN DATE & TIME: 12-13-96  14:59

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      769    113823    115    119                        11272
   491.78           769    113823    115    119  1.00     19    182    11272

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.78    18.9   181.8   768.8  113823.    8500.  11.06

 X STA.       18.9       44.7       52.4       58.6       64.0       69.2
   A(I)           62.9       42.4       38.3       34.2       34.0
   V(I)           6.75      10.02      11.10      12.42      12.50

 X STA.       69.2       74.3       79.2       84.0       89.0       94.0
   A(I)           32.9       32.4       31.7       32.3       32.1
   V(I)          12.93      13.11      13.39      13.15      13.23

 X STA.       94.0       99.0      104.1      109.1      114.0      119.0
   A(I)           32.1       33.1       32.4       32.9       33.8
   V(I)          13.23      12.83      13.11      12.93      12.57

 X STA.      119.0      124.1      129.6      136.6      146.5      181.8
   A(I)           34.4       37.0       41.0       47.2       71.5
   V(I)          12.35      11.48      10.36       9.01       5.95

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.13    17.8   183.3   809.5  122690.    8500.  10.50

 X STA.       17.8       44.1       52.1       58.2       63.8       69.0
   A(I)           66.4       45.3       39.1       37.0       34.9
   V(I)           6.40       9.37      10.86      11.47      12.17

 X STA.       69.0       74.1       79.1       84.1       89.1       94.2
   A(I)           34.7       34.2       33.5       34.1       33.9
   V(I)          12.26      12.42      12.69      12.46      12.53

 X STA.       94.2       99.3      104.4      109.4      114.4      119.5
   A(I)           34.3       34.3       34.1       34.5       35.5
   V(I)          12.40      12.39      12.47      12.31      11.98

 X STA.      119.5      124.6      130.4      137.5      147.8      183.3
   A(I)           36.1       39.6       42.7       50.6       74.5
   V(I)          11.78      10.72       9.95       8.39       5.71

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     187.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      484     38130     84     85                         6593
             2      660     90185     64     67                        12064
             3     1874    153574    701    701                        17380
   495.51          3018    281889    849    854  1.20     -7    841    29480

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     187.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.51    -7.9   840.8  3017.5  281889.    8500.   2.82

 X STA.       -7.9       31.2       58.3       81.1       90.6       99.2
   A(I)          198.8      168.2      156.8      102.7       95.6
   V(I)           2.14       2.53       2.71       4.14       4.45

 X STA.       99.2      107.9      116.5      125.0      135.5      164.5
   A(I)           96.0       96.3       95.9      109.1      138.8
   V(I)           4.43       4.41       4.43       3.90       3.06

 X STA.      164.5      190.6      215.0      238.8      262.1      285.8
   A(I)          126.6      125.2      127.6      130.2      138.2
   V(I)           3.36       3.40       3.33       3.27       3.07

 X STA.      285.8      309.5      336.4      369.2      412.8      840.8
   A(I)          143.8      157.5      181.3      222.8      406.2
   V(I)           2.96       2.70       2.34       1.91       1.05
1
   *
   EX
```

```
        U.S. Geological Survey WSPRO Input File midb125.wsp
        Hydraulic analysis for structure MIDBUS00070125   Date: 05-DEC-96
        U.S. Route 7 Crossing the Middlebury River, Middlebury, VT         EMB
           *** RUN DATE & TIME: 12-13-96  14:59

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

EXITX:XS   ******     -9     1107  0.57 *****  491.93  490.45    6000  491.35
      -199 ******    373    87502  1.25 ***** *******    0.63    5.42

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.47

FULLV:FV      200    -21     1480  0.31  0.64  492.57 *******    6000  492.26
         0    200    425   128204  1.21  0.00    0.00    0.43    4.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      187     -3     1485  0.30  0.42  492.99 *******    6000  492.69
       187    187    453   123890  1.18  0.00    0.01    0.43    4.04
         <<<<<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      200     20      740  1.64  0.91  493.16  489.32    6000  491.53
         0    200    181   107621  1.60  0.33    0.00    0.71    8.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.790  0.067  497.47 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.        <<<<<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      139     -4     1910  0.17  0.41  493.78  491.50    6000  493.61
       187    188    466   181209  1.12  0.21    0.01    0.29    3.14

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.636  0.497   90612.    54.   215.   493.44

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -200.   -10.   373.   6000.   87502.    1107.    5.42  491.35
   FULLV:FV       0.   -22.   425.   6000.  128204.    1480.    4.05  492.26
   BRIDG:BR       0.    20.   181.   6000.  107621.     740.    8.11  491.53
   RDWAY:RG      24.**************       0.*****************    1.00********
   APPRO:AS     187.    -5.   466.   6000.  181209.    1910.    3.14  493.61

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      54.   215.   90612.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    490.45    0.63  482.80  505.39************  0.57  491.93  491.35
   FULLV:FV  ********    0.43  482.80  505.39  0.64  0.00  0.31  492.57  492.26
   BRIDG:BR    489.32    0.71  482.14  498.77  0.91  0.33  1.64  493.16  491.53
   RDWAY:RG  ***************  495.42  512.61**********************************
   APPRO:AS    491.50    0.29  483.69  497.61  0.41  0.21  0.17  493.78  493.61
```

```
        U.S. Geological Survey WSPRO Input File midb125.wsp
        Hydraulic analysis for structure MIDBUS00070125   Date: 05-DEC-96
        U.S. Route 7 Crossing the Middlebury River, Middlebury, VT         EMB
           *** RUN DATE & TIME: 12-13-96  14:59

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

EXITX:XS   ******    -20     1442  0.65 *****  492.83  491.17    8500  492.17
      -199 ******    419   123939  1.21 ***** *******    0.63    5.89

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.43

FULLV:FV      200    -32     2011  0.37  0.66  493.48 *******    8500  493.11
         0    200   1130   177585  1.33  0.00    0.00    0.56    4.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      187     -4     1886  0.35  0.43  493.91 *******    8500  493.56
       187    187    465   177675  1.12  0.00    0.00    0.42    4.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   495.51       0.00     491.78     495.42

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR      200     19      768  3.09  1.02  494.86  490.80    8500  491.78
         0    200    182   113735  1.62  1.01    0.00    0.96   11.06

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   4.  0.785  0.067  497.47 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.        <<<<<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      139     -7     3014  0.15  0.45  495.65  491.99    8500  495.51
       187    198    840   281566  1.20  0.35    0.02    0.29    2.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.633  0.481  145323.    88.   251. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -200.   -21.   419.   8500.  123939.    1442.    5.89  492.17
   FULLV:FV       0.   -33.  1130.   8500.  177585.    2011.    4.23  493.11
   BRIDG:BR       0.    19.   182.   8500.  113735.     768.   11.06  491.78
   RDWAY:RG      24.**************      0.       0.       0.    1.00********
   APPRO:AS     187.    -8.   840.   8500.  281566.    3014.    2.82  495.51

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      88.   251.  145323.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.17    0.63  482.80  505.39************  0.65  492.83  492.17
   FULLV:FV  ********    0.56  482.80  505.39  0.66  0.00  0.37  493.48  493.11
   BRIDG:BR    490.80    0.96  482.14  498.77  1.02  1.01  3.09  494.86  491.78
   RDWAY:RG  ****************  495.42  512.61  0.14******  0.15  495.50********
   APPRO:AS    491.99    0.29  483.69  497.61  0.45  0.35  0.15  495.65  495.51
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count transect at the channel approach of structure MIDBUS00070125, in Middlebury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MIDBUS00070125

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 12 / 14 / 95

Highway District Number *(I - 2; nn)* 05

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

Town *(FIPS place code; I - 4; nnnnn)* 44350

Mile marker *(I - 11; nnn.nnn)* 000650

Waterway *(I - 6)* MIDDLEBURY RIVER

Road Name *(I - 7):* -

Route Number US7 ML

Vicinity *(I - 9)* 0.3 MI S JCT. VT.116

Topographic Map East.Middlebury

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 43580

Longitude *(i - 17; nnnnn.n)* 73069

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001901250111

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

Maximum span length *(I - 48; nnnn)* 0091

Year built *(I - 27; YYYY)* 1964

Structure length *(I - 49; nnnnnn)* 000202

Average daily traffic, ADT *(I - 29; nnnnnn)* 007639

Deck Width *(I - 52; nn.n)* 350

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

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

Opening skew to Roadway *(I - 34; nn)* 45

Waterway adequacy *(I - 71; n)* 7

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)* 003

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

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

Waterway of full opening (*nnn.n* ft^2) 618.5

Comments:

According to the structural inspection report dated 9/29/93, structure is a 3-span steel beam bridge. The curtain wall, bridge seat, stem and wings at the right abutment are in good condition except for some minor shrinkage cracking. Both abutments are protected with stone fill. The channel is straight through the structure. Flow is mostly through the middle span, where there is also a silt and sand buildup. There is some minor scour at the upstream end of the right pier; however, the footing is not exposed. There are cracks, scaling, and cracks in the tie walls of the columns of the piers.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 47.12

Terrain character: Hilly to mountainous

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)* : Moderate Debris *(Heavy, Moderate, Light)*: Moderate

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

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

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft^2*): -

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

Comments:

Hydraulic information on sheet 12 of plans includes ordinary high water elev. = 371.3 feet, extreme high-water elev. = 376.6 feet, low water elev. = 368.3 feet, velocity at high water stage = 9.8 fps with an estimated Q = 5400 cfs and a moderate to heavy scour potential.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **46.778** mi^2

Lake and pond area **0.196** mi^2

Watershed storage *(ST)* **0.42** %

Bridge site elevation **370** ft

Headwater elevation **3234** ft

Main channel length **12.12** mi

10% channel length elevation **440** ft

85% channel length elevation **1720** ft

Main channel slope *(S)* **140.81** ft / mi

Watershed Precipitation Data

Average site precipitation - in

Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 9 / 1958

Project Number F019-3(10) Minimum channel bed elevation: -

Low superstructure elevation: USLAB 381.31 DSLAB 381.71 USRAB 378.69 DSRAB 379.08

Benchmark location description:

BM #23, chiseled square on right abutment (US end?) of old structure, elev. 376.12 feet.

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

If 2: Pile Type: 2 (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: 18-25

If 3: Footing bottom elevation: ______

Is boring information available? Y *If no, type ctrl-n bi* Number of borings taken: 8

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

Briefly describe material at foundation bottom elevation or around piles:

Average steel pile length at the left abutment is 18' and at the right abutment is 25 feet. Material around the top quarter of the piles at the Labut is loose sand; beneath that the material becomes very compact. Around the piles at the right abutment, material is hard and coarse sand, gravel, and some clay.

Comments:

The bottom of the concrete footing of the left and right abutment are at elevations 374.6 and 372.1 feet respectively. The bottom of footing at the left pier (pier 1) is 360.2 feet and the right pier (pier 2) is 357.18 feet. The low superstructure elevations are bridge seat elevations from the bridge plans.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTIONAL INFORMATION**

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

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 11/1/96
Computerized by: RB Date: 11/4/96
Reviewd by: EB Date: 12/16/96

Structure Number MIDBUS00070125

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. FLYNN Date *(MM/DD/YY)* 06 / 18 / 1996
2. Highway District Number 05 Mile marker 00650
County Addison (001) Town Middlebury (44350)
Waterway *(I - 6)* MIDDLEBURY RIVER Road Name -
Route Number US 7 Hydrologic Unit Code: 02010002
3. Descriptive comments:
Located 0.3 miles south of the junction of VT 116 with U.S. 7.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 3 LBDS 6 RBDS 3 Overall 3
*(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 2 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 202 *(feet)* Span length 91 *(feet)* Bridge width 35 *(feet)*

Road approach to bridge:

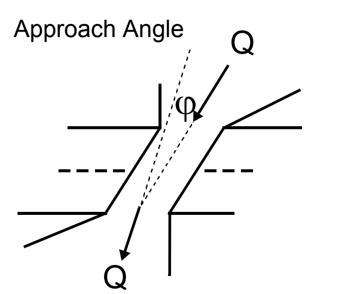
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 2.3:1 US right 1.9:1

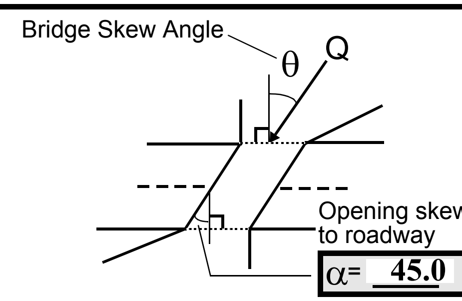
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	2	1	2	1
RBDS	0	-	2	1
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

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





$\alpha=$ 45.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 80 feet US *(US, UB, DS)* to 250 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: **3**

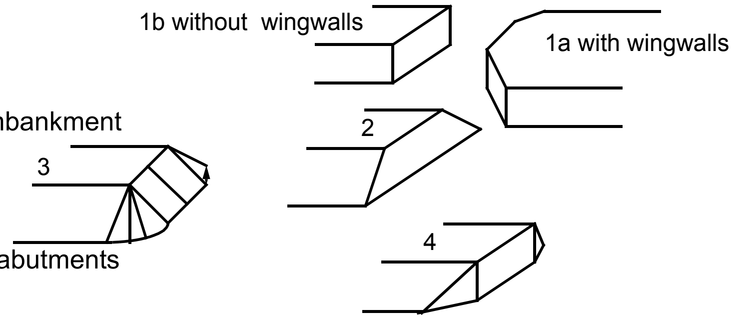
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Measured bridge length is 203 ft. and the bridge width is 34.7 ft.
8. The right road approach has a slight slope for 200 ft. then it levels out.
11. The right bank protection US extends approximately 50 ft. US and 50 ft. along the road embankment.
18. There are piers on the left and right edges of the channel with sloping embankments behind them up to the abutments.

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
224.0	**3.0**			**6.0**	**3**	**2**	**234**	**452**	**1**	**2**

23. Bank width **45.0**   24. Channel width **35.0**   25. Thalweg depth **60.5**   29. Bed Material **432**

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

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.):

30. The right bank protection extends to 1000 ft. US and is generally in good condition with some slumping evident.
A riffle zone extends from 145 ft. US to 300 ft. US. The bed material is primarily cobble in the area of the riffle and becomes mostly sand from 60 ft. US to the bridge.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 85 35. Mid-bar width: 20
36. Point bar extent: 0 feet US (US, UB) to 200 feet US (US, UB, DS) positioned 0 %LB to 70 %RB
37. Material: 234
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

This point bar is submerged and blends into the cobble streambed about 200 ft. US. A tree approximately 10 ft. long and 20 ft. from the left edge of water is lodged on the point bar at 58 ft. US.

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: 125 42. Cut bank extent: 165 feet US (US, UB) to 88 feet US (US, UB, DS)
43. Bank damage: 1 (1- eroded and/or creep; 2- slip failure; 3- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

There is slumping of cobble protection and tree root exposure is evident from 92 ft. to 98 ft. US.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 5
47. Scour dimensions: Length 10 Width 8 Depth : 2 Position 0 %LB to 50 %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):

Scour is at the US face of the right bridge pier.

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
50.0		1.5		2	7	7	-

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

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

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

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

234

Piers are located at the left and right banks with river deposited sand behind them. The spill-through embankments are sand with type-2 stone fill covering the sand. The right edge of water at the US right pier is 7 ft. to the right of the right side of the concrete pier.

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

67. Debris Potential 1 ____ *(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:

1

There are some fallen trees and branches on the left overbank upstream. However, the banks are stable and covered by "old growth" trees predominantly.

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		5	30	0	0	-	-	90.0
RABUT	1	-	10			0	0	138.5

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.):

-

-

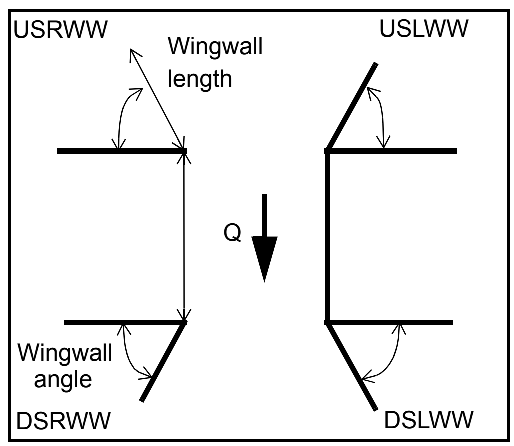
1

The spill-through embankments in front of the left and right abutment are sloping at angles of 30 and 10 degrees respectively.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						138.5	
USRWW:	N		-		-	3.0	
DSLWW:	-		-		N	48.0	
DSRWW:	-		-		-	48.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	2	2	-

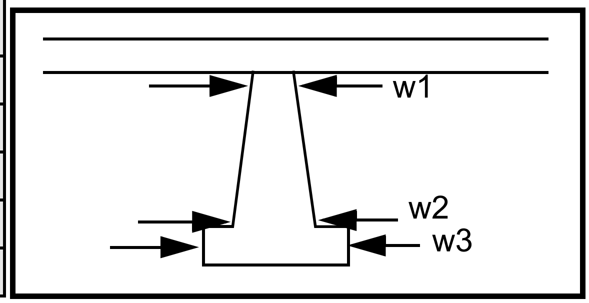
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? _-____ *(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	-	-	-	-	-	-
Pier 2	-	**3.5**	**3.5**	-	**483.35**	**497.91**
Pier 3	-	**3.5**	**3.5**	-	**485.54**	**496.84**
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (Amb) 48.0 Thalweg depth (Amb) 48.0 Bed Material ment

Bank protection type (Qmax): LB und RB er Bank protection condition: LB #48. RB The

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.):
re are 2 concrete piers. The footings are not evident on the streambed surface around either pier. Cobbles and boulders are along the pier base.

3
2
234
24
2
2

101. Is a drop structure present? 23 *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
0
0
-
-
-

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.):

N

Is a cut-bank present? **-** *(Y or if N type ctrl-n cb)* Where? **NO** *(LB or RB)* Mid-bank distance: **DR**

Cut bank extent: **OP** feet **ST** *(US, UB, DS)* to **RUC** feet **TU** *(US, UB, DS)*

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

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

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

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

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

-
-
-
-

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

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

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

Confluence comments (eg. confluence name):

N

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)*:
-
-
-
-
-
-
NO CUT BANKS

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: MIDBUS00070125            Town:    Middlebury
Road Number:      US 7                      County:  Addison
Stream:           Middlebury River

Initials EMB      Date:    12/13/96 Checked:

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             6000     8500     0
  Main Channel Area, ft2           539      660      0
  Left overbank area, ft2          327      484      0
  Right overbank area, ft2         1044     1874     0
  Top width main channel, ft       64       64       0
  Top width L overbank, ft         81       84       0
  Top width R overbank, ft         326      701      0
  D50 of channel, ft               0.195    0.195    0
  D50 left overbank, ft            --       --       --
  D50 right overbank, ft           --       --       --

y1, average depth, MC, ft            8.4      10.3   ERR
y1, average depth, LOB, ft           4.0       5.8   ERR
y1, average depth, ROB, ft           3.2       2.7   ERR

  Total conveyance, approach       181201   281889   0
  Conveyance, main channel         64355    90185    0
  Conveyance, LOB                  20406    38130    0
  Conveyance, ROB                  96440    153574   0
  Percent discrepancy, conveyance  0.0000   0.0000   ERR
  Qm, discharge, MC, cfs           2130.9   2719.4   ERR
  Ql, discharge, LOB, cfs          675.7    1149.8   ERR
  Qr, discharge, ROB, cfs          3193.4   4630.8   ERR

Vm, mean velocity MC, ft/s         4.0      4.1      ERR
Vl, mean velocity, LOB, ft/s       2.1      2.4      ERR
Vr, mean velocity, ROB, ft/s       3.1      2.5      ERR
Vc-m, crit. velocity, MC, ft/s       9.3      9.6    N/A
Vc-l, crit. velocity, LOB, ft/s    ERR      ERR      ERR
Vc-r, crit. velocity, ROB, ft/s    ERR      ERR      ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?
  Main Channel                     0        0        N/A
```

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	539	660	0
Main channel width, ft	64	64	0
y1, main channel depth, ft	8.42	10.31	ERR
Bridge Section			
(Q) total discharge, cfs	6000	8500	0
(Q) discharge thru bridge, cfs	6000	8500	0
Main channel conveyance	107686	113823	0
Total conveyance	107686	113823	0
Q2, bridge MC discharge,cfs	6000	8500	ERR
Main channel area, ft2	691	717	0
Main channel width (skewed), ft	107.8	109.2	0.0
Cum. width of piers in MC, ft	7.0	7.0	0.0
W, adjusted width, ft	100.8	102.2	0
y_bridge (avg. depth at br.), ft	6.85	7.02	ERR
Dm, median (1.25*D50), ft	0.24375	0.24375	0
y2, depth in contraction,ft	6.15	8.19	ERR
ys, scour depth (y2-ybridge), ft	-0.70	1.17	N/A
ARMORING			
D90	0.3772	0.3772	0
D95	0.4196	0.4196	0
Critical grain size,Dc, ft	0.2676	0.4930	ERR
Decimal-percent coarser than Dc	0.286	0.03	0
Depth to armoring,ft	2.00	47.82	ERR

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	6000	8500	0	6000	8500	0
a', abut.length blocking flow, ft	50.7	53.1	0	311.3	685.6	0
Ae, area of blocked flow ft2	189.1	285.7	0	1011.42	1803.9	0
Qe, discharge blocked abut.,cfs	366.4	644.6	0	3098.3	4386.3	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.94	2.26	ERR	3.06	2.43	ERR
ya, depth of f/p flow, ft	3.73	5.38	ERR	3.25	2.63	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.177	0.171	ERR	0.299	0.264	ERR
ys, scour depth, ft	8.27	10.98	N/A	17.83	19.44	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	50.7	53.1	0	311.3	685.6	0
y1 (depth f/p flow, ft)	3.73	5.38	ERR	3.25	2.63	ERR
a'/y1	13.59	9.87	ERR	95.81	260.57	ERR
Skew correction (p. 49, fig. 16)	0.80	0.80	0.80	1.10	1.10	1.10
Froude no. f/p flow	0.18	0.17	N/A	0.30	0.26	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	17.46	13.57	ERR
vertical w/ ww's	ERR	ERR	ERR	14.32	11.12	ERR
spill-through	ERR	ERR	ERR	9.60	7.46	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.71	0.96	0	0.71	0.96	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.85	7.02	0.00	6.85	7.02	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	1.86	ERR	0.00	1.86	ERR	0.00
Fr>0.8 (spillthrough abut.)	ERR	2.57	ERR	ERR	2.57	ERR

Pier Scour (both live-bed and clear water scour)

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

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

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

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

K4, corr. factor for armoring (the following equations are in Si units)
  K4=[1-0.89*(1-Vr)^2]^0.5
  Vr=(V1-Vi)/(Vc90-Vi)
  V1=0.645*((D50/a)^0.053)*Vc50
  Vc=6.19*(y^1/6)*(Dc^1/3)

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

Pier 1	Q100	Q500	Qother
Pier stationing, ft	50.9	50.9	0
Area of WSPRO flow tube, ft2	31.7	33.5	0
Skewed width of flow tube, ft	3.5	3.5	0
y1, pier approach depth, ft	9.06	9.57	ERR
y1 in meters	2.760	2.917	N/A
V1, pier approach velocity, ft/s	9.46	12.69	0
a, pier width, ft	3.5	3.5	0
L, pier length, ft	48	48	0
Fr1, Froude number at pier	0.554	0.723	ERR
Pier attack angle, degrees	5	5	0
K1, shape factor	1	1	0
K2, attack factor	1.67	1.67	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.195	0.195	0
D50, m	0.059433	0.059433	0
D90, ft	0.3772	0.3772	0
D90, m	0.114965	0.114965	0
Vc50,critical velocity(D50),m/s	2.861	2.888	N/A
Vc90,critical velocity(D90),m/s	3.565	3.598	N/A
Vi,incipient velocity,m/s	1.584	1.598	ERR
Vr, velocity ratio	0.656	1.135	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	13.87	15.86	ERR

Pier 2	Q100	Q500	Qother
Pier stationing, ft	144.3	144.3	0
Area of WSPRO flow tube, ft2	31.7	33.5	0
Skewed width of flow tube, ft	3.5	3.5	0
y1, pier approach depth, ft	9.06	9.57	ERR
y1 in meters	2.760	2.917	N/A
V1, pier approach velocity, ft/s	9.46	12.69	0
a, pier width, ft	3.5	3.5	0
L, pier length, ft	48	48	0
Fr1, Froude number at pier	0.554	0.723	ERR
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	0
K2, attack factor	1.00	1.00	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.195	0.195	0
D50, m	0.059433	0.059433	0
D90, ft	0.3772	0.3772	0
D90, m	0.114965	0.114965	0
Vc50,critical velocity(D50),m/s	2.861	2.888	N/A
Vc90,critical velocity(D90),m/s	3.565	3.598	N/A
Vi,incipient velocity,m/s	1.584	1.598	ERR
Vr, velocity ratio	0.656	1.135	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	8.33	9.52	ERR

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

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

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	0
V, char. aver. velocity, ft/s	7.85	10.5	0
D50, median stone diameter, ft	0.90	1.62	0.00

Pier 2			
K, pier shape coeff.	1.5	1.5	0
V, char. aver. velocity, ft/s	7.85	10.5	0
D50, median stone diameter, ft	0.90	1.62	0.00