LEVEL II SCOUR ANALYSIS FOR BRIDGE 2 (RYEGTH00020002) on TOWN HIGHWAY 2, crossing the WELLS RIVER, RYEGATE, VERMONT

U.S. Geological Survey
Open-File Report 97-646

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 2 (RYEGTH00020002) ON TOWN HIGHWAY 2, CROSSING THE WELLS RIVER, RYEGATE, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RYEGTH00020002 on Town Highway 2 crossing the Wells River, Ryegate, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 75.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of cut grass, trees, and brush on the flood plains while the immediate banks have dense woody vegetation.

In the study area, the Wells River has an incised, sinuous channel with a slope of approximately 0.006 ft/ft, an average channel top width of 110 ft and an average bank height of 12 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 82.3 mm (0.270 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 24, 1995, indicated that the reach was laterally unstable with moderate fluvial erosion and meandering downstream of the bridge.

The Town Highway 2 crossing of the Wells River is a 79-ft-long, two-lane bridge consisting of one 75-foot steel-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 75.1 ft. The bridge is supported by vertical, concrete abutments, the left has a spill-through embankment, with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

A scour hole 3 ft deeper than the mean thalweg depth was observed in the channel from upstream and through the bridge during the Level I assessment. The scour protection counter-measures at the site included type-4 stone fill (less than 60 inches diameter) along the base of the left abutment forming a spill-through embankment. There was also type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream right wingwall, the upstream right bank and downstream left bank. There was a stone wall along the upstream left bank extending 130 ft from the bridge. In addition there was type-1 stone fill (less than 12 inches diameter) along the downstream right bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. 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 was zero. Abutment scour ranged from 7.1 to 11.4 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 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.

Groton, VT. Quadrangle, 1:24,000, 1973

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 RYEGTH00020002 ***Stream*** Wells River

County Caledonia ***Road*** TH 2 ***District*** 7

Description of Bridge

Bridge length 79 ***ft*** ***Bridge width*** 27.0 ***ft*** ***Max span length*** 75 ***ft***

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

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

Stone fill on abutment? Yes, left ***Date of inspection*** 8/24/95

Description of stone fill Type-4, along the base of the left abutment forming a spill-through embankment. Type-2, along the entire base length of the upstream right wingwall.

Abutments and wingwalls are concrete. The left abutment has a spill-through embankment covered with rip-rap protection.

Brief description of piers/abutments

No

Is bridge skewed to flood flow according to There ***survey?*** 0 ***Angle*** Yes

is a mild channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/24/95	0	0
Level II	8/24/95	0	0

Potential for debris Low. There is some debris caught on left spill-through embankment and trees leaning over the channel upstream.

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

None 8/24/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with narrow flood plains and steep valley walls on both sides.

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

Date of inspection 8/24/95

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

DS right: Steep channel bank to a narrow flood plain.

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

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

Description of the Channel

Average top width 110 *ft* ***Average depth*** 12 *ft*

Predominant bed material Sand / Cobble ***Bank material*** Gravel/Boulder

Sinuous with semi-alluvial channel boundaries and a narrow flood plain.

8/24/95

Vegetative co Trees and brush with cut grass on the flood plain.

DS left: Trees and brush with cut grass on the flood plain.

DS right: Few trees and brush with cut grass on the flood plain.

US left: Trees and brush with cut grass on the flood plain.

US right: No

Do banks appear stable? The upstream banks are protected but the downstream right bank has moderate fluvial erosion.

If not, ... date of observation.

The assessment of 8/24/95 noted flow conditions up to bank-full level are influenced by a pile of debris on the right bank side of the downstream channel. The debris is caught on the piers of an old railroad bridge without a deck in the channel downstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 75.7 ***mi***^{2}

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***: There are a couple of houses on the left bank upstream.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Wells River at Wells River, VT

USGS gage number 01139000

Gage drainage area 98.4 ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 5,300 ***ft***^{3}***/s*** ***Q500*** 6,680 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(75.7/98.4)exp 0.7] with gage 01139000 on the Wells River at Wells River, VT. The 100- and 500- year discharges at the gage were developed using a log-Pearson type-III analysis of annual peak-flow data (Interagency Advisory Committee on Water Data, 1982). These discharge values are within a range of several flood frequency curves based on empirical relationships for this site (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Add 34.8 ft to the USGS arbitrary survey datum to obtain National Geodetic Vertical Datum 1929.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 699.87 ft, arbitrary survey datum). RM2 is a chiseled square on top of the downstream end of the right abutment (elev. 699.92 ft, arbitrary survey datum). RM3 is a chiseled X on the top of the downstream end of the left abutment (elev. 700.06 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	-38	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APTEM	76	1	Approach section as surveyed (Used as a template)
APPRO	103	2	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.045, and overbank "n" values ranged from 0.035 to 0.040.

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 0.0055 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1973). The affects of an abandoned railroad bridge with no deck, in the downstream channel (figure 4) were not considered in the hydraulic model.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0197 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 699.3 ***ft***
Average low steel elevation 695.4 ***ft***

100-year discharge 5,300 ***ft^3/s***
Water-surface elevation in bridge opening 693.6 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 542 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.3 ***ft/s***

Water-surface elevation at Approach section with bridge 693.9
Water-surface elevation at Approach section without bridge 694.0
Amount of backwater caused by bridge 0.0 ***ft***

500-year discharge 6,680 ***ft^3/s***
Water-surface elevation in bridge opening 695.4 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 681 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 696.9
Water-surface elevation at Approach section without bridge 695.9
Amount of backwater caused by bridge 1.0 ***ft***

Incipient overtopping discharge - ***ft^3/s***
Water-surface elevation in bridge opening - ***ft***
Area of flow in bridge opening - ***ft^2***
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 for the 100-year discharge was computed by use of the Laursen live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). At this site, the 500-year discharge resulted in submerged 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 this discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F.

Abutment scour 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.

Because the influence of scour processes on the left spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment wall is unknown. Therefore, the total scour depth was applied for the entire spill-through embankment below the elevation at the toe of the embankment, as shown in figure 8.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	--
Depth to armoring	4.2	3.4	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	7.1	7.6	--
Left abutment	7.1	11.4	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.8	1.8	--
Left abutment	2.1	2.0	--
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

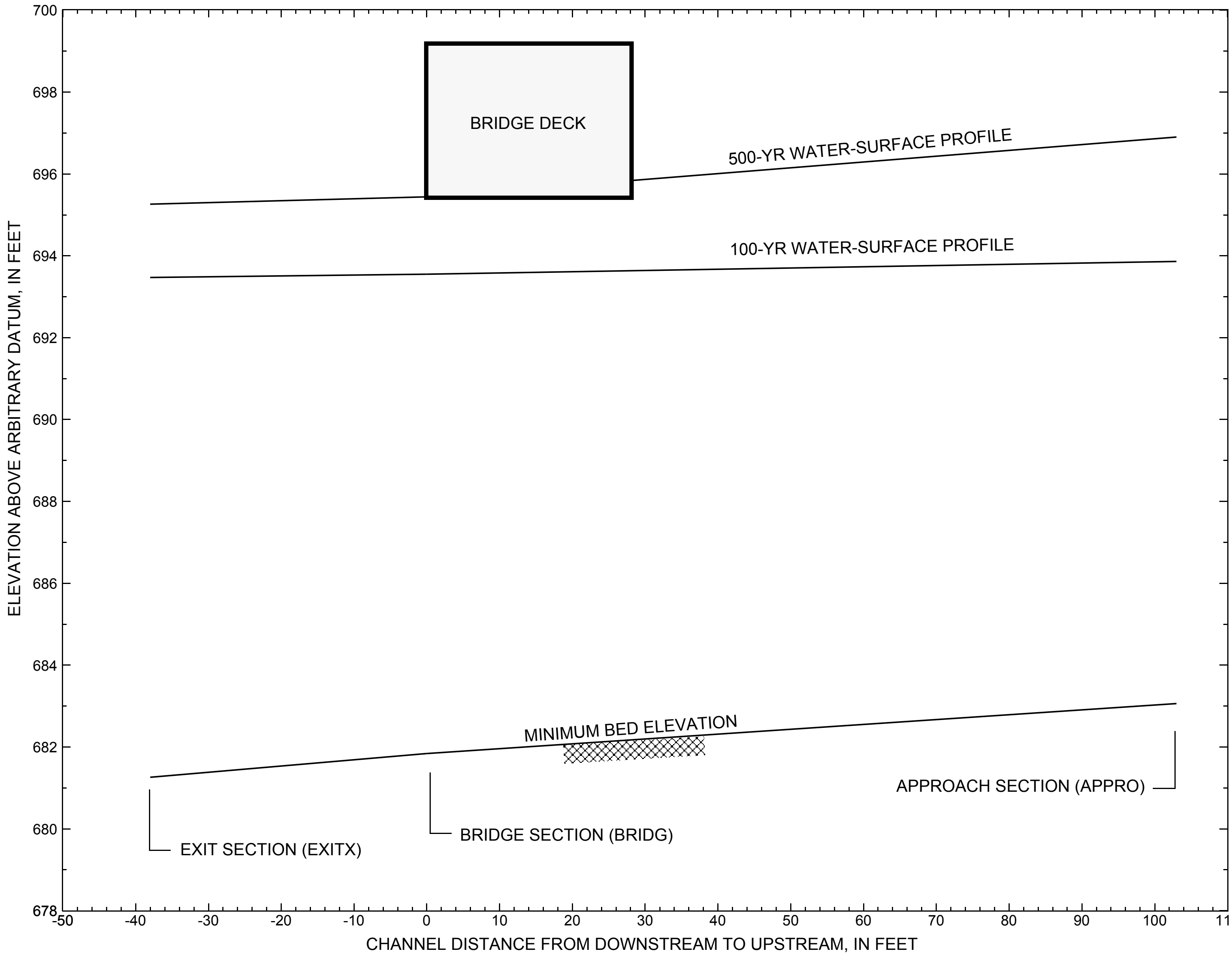

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RYEGTH00020002 on Town Highway 2, crossing the Wells River, Ryegate, Vermont.

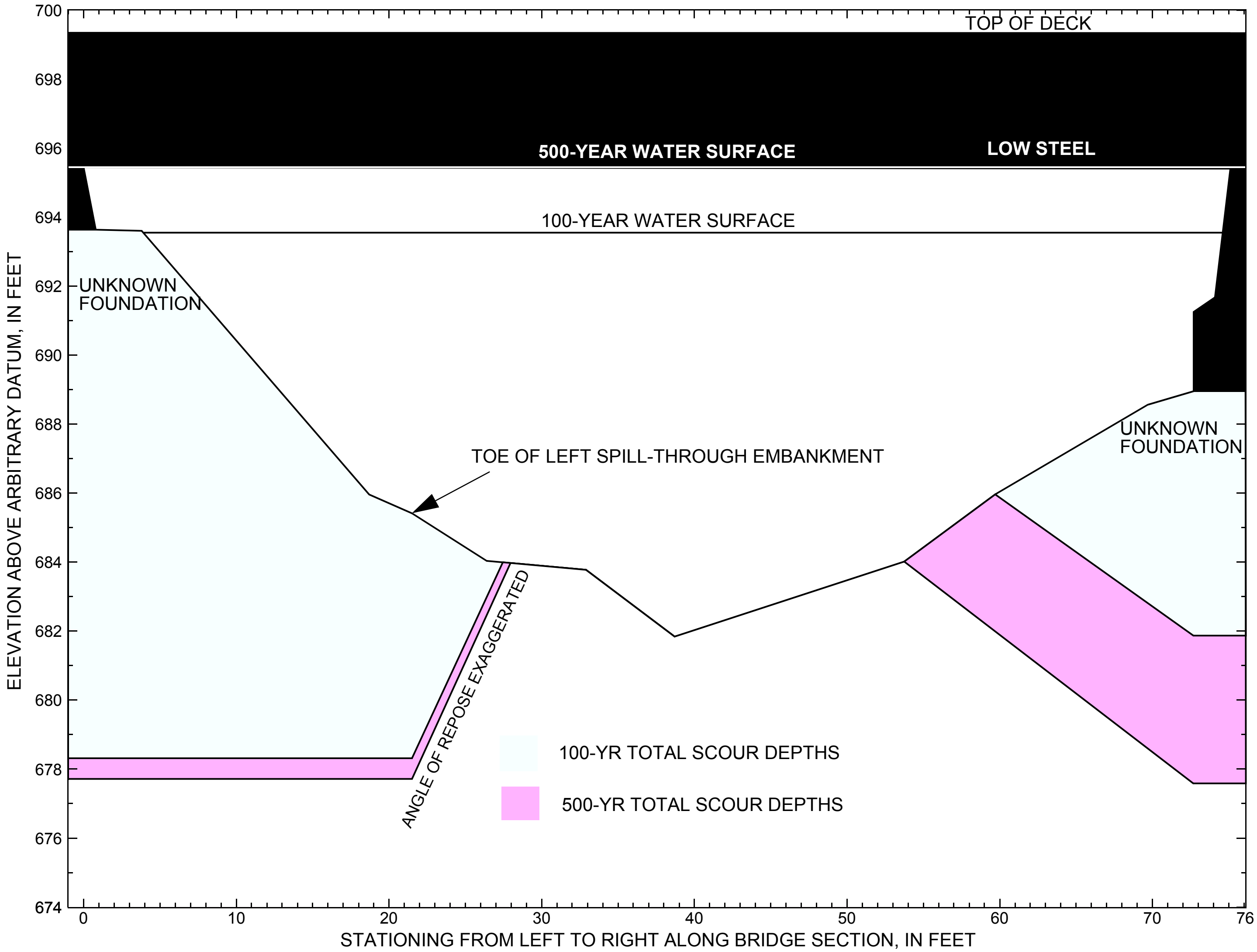

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RYEGTH00020002 on Town Highway 2, crossing the Wells River, Ryegate, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RYEGTH00020002 on Town Highway 2, crossing the Wells River, Ryegate, 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-yr. discharge is 5,300 cubic-feet per second											
Left abutment	0.0	--	695.4	--	--	--	--	--	--	--	--
Toe of left spill-through embankment	21.5	--	--	--	685.4	0.0	7.1	--	7.1	678.3	--
Right abutment	75.1	--	695.4	--	689.0	0.0	7.1	--	7.1	681.9	--

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 RYEGTH00020002 on Town Highway 2, crossing the Wells River, Ryegate, 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-yr. discharge is 6,680 cubic-feet per second											
Left abutment	0.0	--	695.4	--	--	--	--	--	--	--	--
Toe of left spill-through embankment	21.5	--	--	--	685.4	0.0	7.6	--	7.6	677.8	--
Right abutment	75.1	--	695.4	--	689.0	0.0	11.4	--	11.4	677.6	--

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

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U.S. Geological Survey, 1973, Groton, 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 ryeg002.wsp
T2        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
T3        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5300.0   6680.0
SK          0.0055   0.0055
*
XS   EXITX    -38
GR         -307.9, 712.00   -304.6, 708.11   -281.7, 708.36   -210.8, 705.30
GR         -187.7, 701.71      0.0, 697.40     13.7, 690.31     22.1, 685.88
GR           25.6, 683.41     29.6, 682.92     42.2, 682.53     56.8, 681.26
GR           56.9, 682.54     65.8, 685.98     68.0, 686.55     74.5, 690.02
GR           76.2, 693.65    111.7, 698.60    181.7, 698.61    198.9, 699.60
GR          237.8, 699.20    502.7, 700.22    626.4, 704.07    738.6, 706.93
N           0.035        0.045        0.035
SA                   0.0        111.7
*
XS   FULLV       0 * * *   0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    695.42       0.0
GR            0.0, 695.44      0.8, 693.63      3.8, 693.60     18.7, 685.96
GR           21.5, 685.41     26.4, 684.03     32.9, 683.77     38.7, 681.84
GR           44.1, 682.52     50.2, 682.85     59.7, 685.96     69.7, 688.56
GR           72.7, 688.95     72.7, 691.25     74.1, 691.67     75.1, 695.40
GR            0.0, 695.44
*
*         BRTYPE BRWDTH    EMBSS   EMBELV
CD            3      28.1      8.4    699.3
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY      14      27.0     1
GR         -345.2, 712.34   -342.4, 708.35   -325.5, 708.71   -304.4, 706.14
GR         -117.8, 700.05     -2.4, 699.22     -2.3, 699.85     -1.9, 699.88
GR           -1.9, 703.24      0.0, 703.26     74.8, 703.29     75.8, 703.31
GR           75.9, 699.93     76.6, 699.92     76.6, 699.19    129.0, 699.52
GR          162.3, 700.31    255.6, 699.31    567.5, 703.19    685.0, 705.86
GR          685.8, 709.49
*
XT   APTEM      76
GR         -553.1, 723.38   -424.6, 712.06   -298.4, 704.31   -177.0, 699.94
GR          -66.6, 698.10      0.0, 695.93     16.4, 693.42     17.1, 689.74
GR           22.3, 685.95     26.2, 684.22     36.6, 684.49     41.0, 683.32
GR           46.9, 682.53     58.9, 683.42     64.3, 686.02     72.5, 690.32
GR           85.4, 695.02    107.7, 699.69    153.5, 699.91    278.1, 699.33
GR          336.3, 701.92    349.5, 709.32
*
AS   APPRO      103 * * * 0.0197
GT
N           0.040        0.036        0.040
SA                   0.0        107.7
*
HP 1 BRIDG   693.55 1 693.55
HP 2 BRIDG   693.55 * * 5300
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File ryeg002.wsp
       Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
       Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT by MAI
          *** RUN DATE & TIME: 06-19-97 14:31


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

     WSEL SA#     AREA        K   TOPW   WETP ALPH    LEW    REW     QCR
             1     542.  84091.    71.    78.                       8509.
   693.55          542.  84091.    71.    78. 1.00     4.    75.   8509.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       693.55     3.9    74.6   541.7   84091.    5300.   9.78

X STA.         3.9       17.6       21.7       25.0       27.8       30.3
  A(I)            48.5       31.7       28.6       25.8       24.8
  V(I)            5.47       8.36       9.26      10.27      10.70

X STA.        30.3       32.7       35.1       37.2       39.1       40.9
  A(I)            23.4       23.6       22.9       21.6       21.7
  V(I)           11.35      11.21      11.59      12.28      12.23

X STA.        40.9       42.9       44.8       46.9       48.9       51.1
  A(I)            21.6       21.9       22.3       22.3       23.3
  V(I)           12.25      12.12      11.90      11.90      11.38

X STA.        51.1       53.6       56.4       60.0       64.6       74.6
  A(I)            24.7       25.9       28.9       32.0       46.5
  V(I)           10.74      10.22       9.18       8.29       5.69

    CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD =     103.

     WSEL SA#     AREA        K   TOPW   WETP ALPH    LEW    REW     QCR
             2     483.  71665.    64.    71.                       7521.
   693.86          483.  71665.    64.    71. 1.00    16.    81.   7521.


    VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD =     103.

         WSEL     LEW     REW    AREA        K        Q    VEL
       693.86    16.4    80.8   483.5   71665.    5300. 10.96

X STA.        16.4       23.5       26.6       29.1       31.6       34.0
  A(I)            38.8       26.3       23.1       22.5       21.5
  V(I)            6.83      10.08      11.46      11.79      12.34

X STA.        34.0       36.4       38.7       40.8       42.8       44.7
  A(I)            21.5       20.9       20.3       20.2       19.5
  V(I)           12.33      12.70      13.03      13.11      13.61

X STA.        44.7       46.6       48.4       50.3       52.2       54.2
  A(I)            19.8       19.4       20.4       20.3       20.8
  V(I)           13.41      13.68      13.01      13.05      12.77

X STA.        54.2       56.4       58.7       61.5       65.5       80.8
  A(I)            22.4       23.0       25.7       31.3       46.0
  V(I)           11.85      11.51      10.32       8.47       5.76
```

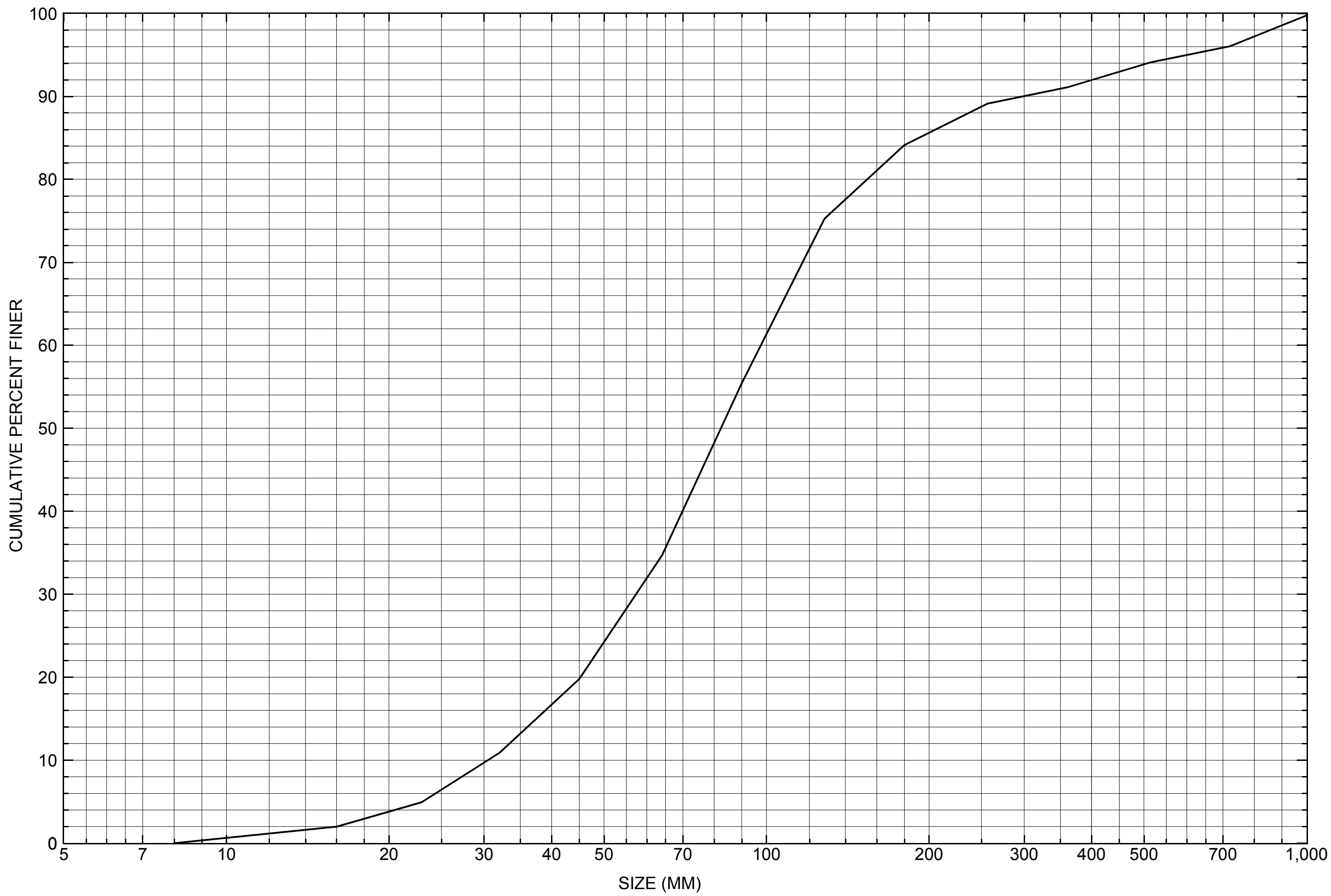
```
        U.S. Geological Survey WSPRO Input File ryeg002.wsp
        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT by MAI
           *** RUN DATE & TIME: 06-19-97 14:31


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

     WSEL SA#     AREA         K   TOPW   WETP ALPH    LEW    REW     QCR
             1     681.   76120.     0.   160.                          0.
   695.44          681.   76120.     0.   160. 1.00     0.    75.      0.



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

         WSEL     LEW     REW    AREA        K        Q    VEL
       695.44     0.0    75.1   680.7   76120.    6680.   9.81

X STA.         0.0       15.4       20.1       23.7       26.7       29.4
  A(I)            62.0       42.0       36.6       33.0       31.5
  V(I)            5.39       7.95       9.13      10.13      10.59

X STA.        29.4       32.1       34.6       37.0       39.0       41.1
  A(I)            30.5       30.4       29.1       27.4       27.6
  V(I)           10.97      11.00      11.47      12.17      12.10

X STA.        41.1       43.2       45.3       47.5       49.8       52.1
  A(I)            27.9       27.4       28.4       28.4       28.7
  V(I)           11.96      12.19      11.75      11.74      11.64

X STA.        52.1       54.8       57.9       61.6       66.2       75.1
  A(I)            30.8       32.6       34.9       38.5       52.9
  V(I)           10.83      10.25       9.57       8.66       6.31


    CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD =     103.

     WSEL SA#     AREA         K   TOPW   WETP ALPH    LEW    REW     QCR
             1       3.      40.    13.    13.                          8.
             2     721. 111823.    92.   100.                      11474.
   696.90          724. 111863.   105.   113. 1.01   -13.    92.  10743.



    VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD =     103.

         WSEL     LEW     REW    AREA        K        Q    VEL
       696.90   -13.4    91.8   724.4 111863.    6680.   9.22

X STA.       -13.4       22.2       26.0       29.0       31.8       34.5
  A(I)            77.5       42.4       36.6       33.2       32.2
  V(I)            4.31       7.87       9.13      10.06      10.37

X STA.        34.5       37.0       39.4       41.7       43.8       45.8
  A(I)            30.7       29.6       29.0       27.9       27.6
  V(I)           10.89      11.29      11.52      11.96      12.09

X STA.        45.8       47.8       49.8       51.9       54.1       56.3
  A(I)            27.5       27.3       28.3       28.9       29.1
  V(I)           12.14      12.22      11.80      11.57      11.47

X STA.        56.3       58.7       61.4       64.8       69.9       91.8
  A(I)            31.4       34.0       37.3       44.4       69.5
  V(I)           10.62       9.84       8.96       7.52       4.81
```

```
        U.S. Geological Survey WSPRO Input File ryeg002.wsp
        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT by MAI
           *** RUN DATE & TIME: 06-19-97 14:31

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

EXITX:XS   ******     8.     567.  1.36 *****  694.83  690.56   5300.  693.47
      -38. ******    76.   71461.  1.00 ***** *******    0.57    9.35

FULLV:FV      38.     7.     588.  1.26  0.20  695.04 *******   5300.  693.78
        0.    38.    77.   74828.  1.00  0.00    0.01    0.55    9.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     103.    16.     495.  1.78  0.52  695.82 *******   5300.  694.04
      103.   103.    81.   73744.  1.00  0.26    0.00    0.69   10.70
         <<<<<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      38.     4.     542.  1.49  0.20  695.04  691.21   5300.  693.55
        0.    38.    75.   84161.  1.00  0.00   -0.02    0.62    9.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  695.42 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      75.    16.     484.  1.87  0.40  695.73  692.06   5300.  693.86
      103.    75.    81.   71720.  1.00  0.29   -0.01    0.70   10.96

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   73552.     7.    78.   693.45


        U.S. Geological Survey WSPRO Input File ryeg002.wsp
        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT  by MAI
           *** RUN DATE & TIME: 06-19-97  14:31
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXITX:XS     -38.     8.    76.   5300.   71461.     567.    9.35  693.47
   FULLV:FV       0.     7.    77.   5300.   74828.     588.    9.02  693.78
   BRIDG:BR       0.     4.    75.   5300.   84161.     542.    9.78  693.55
   RDWAY:RG      14.**************       0.******************    1.00********
   APPRO:AS     103.    16.    81.   5300.   71720.     484.   10.96  693.86

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS       7.    78.   73552.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    690.56    0.57  681.26  712.00************  1.36  694.83  693.47
   FULLV:FV   ********   0.55  681.26  712.00  0.20  0.00  1.26  695.04  693.78
   BRIDG:BR    691.21    0.62  681.84  695.44  0.20  0.00  1.49  695.04  693.55
   RDWAY:RG   ****************  699.19  712.34**********************************
   APPRO:AS    692.06    0.70  683.06  723.91  0.40  0.29  1.87  695.73  693.86
```

```
        U.S. Geological Survey WSPRO Input File ryeg002.wsp
        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT  by MAI
           *** RUN DATE & TIME: 06-19-97 14:31

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

EXITX:XS   ******     4.     702.  1.41 *****  696.67  691.66   6680.  695.26
      -38. ******    88.   90050.  1.00 ***** *******    0.58    9.52

FULLV:FV      38.     4.     728.  1.31  0.20  696.88 *******   6680.  695.57
        0.    38.    90.   93811.  1.00  0.00    0.01    0.56    9.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     103.     4.     630.  1.75  0.52  697.61 *******   6680.  695.86
      103.   103.    87.   94985.  1.00  0.22    0.00    0.68   10.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    695.57     695.42

            <<<<<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      38.     0.     681.  1.44 *****  696.88  692.21   6559.  695.44
        0. ******    75.   76120.  1.00 ***** *******    0.56    9.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   3.  0.800 ******  695.42 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.         <<<<<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      75.   -13.     724.  1.33  0.41  698.23  693.22   6680.  696.90
      103.    78.    92.  111806.  1.01  0.29   -0.02    0.62    9.23

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   696.63

        U.S. Geological Survey WSPRO Input File ryeg002.wsp
        Hydraulic analysis for structure RYEGTH00020002   Date: 11-JUN-97
        Bridge 2 on Town Highway 2 over the Wells River, Ryegate, VT by MAI
           *** RUN DATE & TIME: 06-19-97 14:31
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -38.     4.    88.   6680.   90050.     702.    9.52  695.26
   FULLV:FV       0.     4.    90.   6680.   93811.     728.    9.17  695.57
   BRIDG:BR       0.     0.    75.   6559.   76120.     681.    9.64  695.44
   RDWAY:RG      14.**************      0.*****************    1.00********
   APPRO:AS     103.   -13.    92.   6680.  111806.     724.    9.23  696.90


 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    691.66    0.58  681.26  712.00************  1.41  696.67  695.26
   FULLV:FV  ********    0.56  681.26  712.00  0.20  0.00  1.31  696.88  695.57
   BRIDG:BR    692.21    0.56  681.84  695.44************  1.44  696.88  695.44
   RDWAY:RG ****************  699.19  712.34************  0.18  702.81********
   APPRO:AS    693.22    0.62  683.06  723.91  0.41  0.29  1.33  698.23  696.90
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure RYEGTH00020002, in Ryegate, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RYEGTH00020002

General Location Descriptive

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

Date (MM/DD/YY) 03 / 27 / 95

Highway District Number (I - 2; nn) 07

County (FIPS county code; I - 3; nnn) 005

Town (FIPS place code; I - 4; nnnnn) 61525

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

Waterway (I - 6) WELLS RIVER

Road Name (I - 7): -

Route Number TH002

Vicinity (I - 9) 0.05 MI JCT TH 2 + US302

Topographic Map Groton

Hydrologic Unit Code: 01080103

Latitude (I - 16; nnnn.n) 44113

Longitude (i - 17; nnnnn.n) 72083

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10031000020310

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0075

Year built (I - 27; YYYY) 1940

Structure length (I - 49; nnnnnn) 000079

Average daily traffic, ADT (I - 29; nnnnnn) 000300

Deck Width (I - 52; nn.n) 270

Year of ADT (I - 30; YY) 93

Channel & Protection (I - 61; n) 5

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

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 302

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) -

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 010.8

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

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

Comments:

The structural inspection report of 7/5/93 indicates that the structure is a steel stringer type bridge with a concrete deck and an asphalt roadway surface. The right abutment and its wingwalls are grouted, "laid-up" stone blocks with a concrete cap and exposed concrete footing. The concrete footing has fallen away from the wall about two inches at the downstream end. The concrete footing has at least 4 vertical, randomly distributed cracks on the upstream half. The concrete cap has fine cracks overall, including cracks under nearly every steel beam. On the retaining wall, the top couple rows of stone blocks have loosened and slid out 3 to 4 inches. **(Continued, 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*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ 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 (*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 footing also has a few deep spalls and voided areas along the bottom, especially on the downstream half. The left abutment is concrete. Only a small portion of the wall is exposed at the top with the remainder buried beneath an embankment covered with laid-in-place cut stone. A couple of fine cracks and minor spalls are noted. The downstream embankments are noted as showing signs of erosion. Stone fill and a retaining wall protect the banks upstream. Channel scour is noted as normal. Point bar and debris accumulation problems are reported as minor at this site. The type of foundation recorded for this site is an unknown foundation. The streambed consists of mainly sand and boulders.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **75.92** mi^2 Lake/pond/swamp area **2.22** mi^2

Watershed storage *(ST)* **2.9** %

Bridge site elevation **720** ft Headwater elevation **2369** ft

Main channel length **16.16** mi

10% channel length elevation **730** ft 85% channel length elevation **1437** ft

Main channel slope *(S)* **58.33** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS.

Cross-sectional Data

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

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

Comments: **This cross-section is the upstream face. The low cord elevation is from the survey log done for this report on 8/24/95. The low cord to bed length is from the sketch attached to a bridge inspection report dated 7/5/93. The sketch was done on 6/30/93.**

Station	0	22	37	52	59	75	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low cord elevation	695.4	695.4	695.4	695.4	695.4	695.4	-	-	-	-	-
Bed elevation	693.6	684.6	682.7	683.1	684.6	691.2	-	-	-	-	-
Low cord to bed length	1.8	10.8	12.7	12.3	10.8	4.2	-	-	-	-	-

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: **EW** Date: **03/15/96**
Computerized by: **EW** Date: **03/15/96**
Reviewd by: **MAI** Date: **07/08/97**

Structure Number **RYEGTH00020002**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **08** / **24** / 19**95**

2. Highway District Number **07** Mile marker **-**

County **Caledonia (005)** Town **Ryegate (61525)**

Waterway *(I - 6)* **Wells River** Road Name **Church Street**

Route Number **TH 2** Hydrologic Unit Code: **01080103**

3. Descriptive comments:

The site is located 0.05 miles from the junction with US 302. In 1974 the deck was overtopped.

B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **2** LBDS **2** RBDS **2** Overall **2**
*(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 **79** *(feet)* Span length **75** *(feet)* Bridge width **27** *(feet)*

Road approach to bridge:

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

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

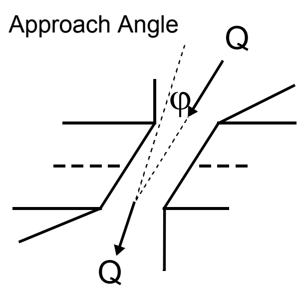
10. Embankment slope (*run / rise in feet / foot*):
US left **13.7:1** US right **3.1:1**

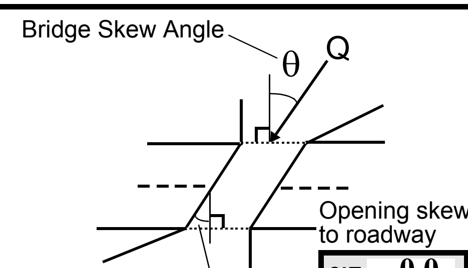
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: **10** 16. Bridge skew: **27**





α= **0.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **90** feet **US** *(US, UB, DS)* to **20** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **0** feet **DS** *(US, UB, DS)* to **70** feet **DS**

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

18. Bridge Type: 3

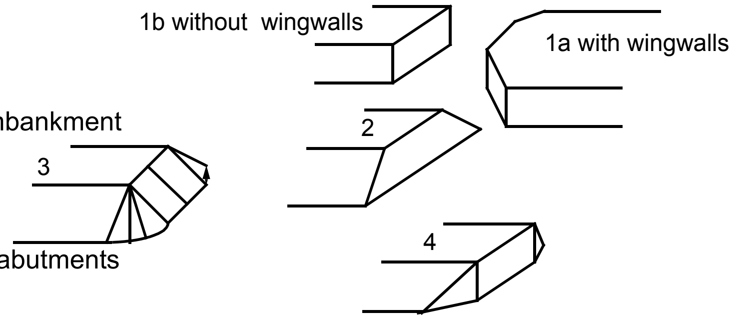
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

#18 The right abutment type is 1a. The left abutment has a spill-through embankment, with laid-up stone along the bank.

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
48.0	11.5			13.5	1	1	735	543	0	0

23. Bank width 25.0 24. Channel width 15.0 25. Thalweg depth 108.0 29. Bed Material 452

30 .Bank protection type: LB 7 RB 2 31. Bank protection condition: LB 1 RB 1

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

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

The right bank protection extends beyond 300 feet as it runs along US 302.
The left bank protection is a laid-up stone wall that extends 130 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 40 35. Mid-bar width: 12

36. Point bar extent: 60 feet US (US, UB) to 0 feet US (US, UB, DS) positioned 20 %LB to 55 %RB

37. Material: 2

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

The mid-bar is underwater.

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

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

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

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

NO CUT BANKS

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 13 UB

47. Scour dimensions: Length 240 Width 10 Depth : 3 Position 50 %LB to 80 %RB

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

The scour extends from 90 feet upstream to 130 feet downstream.

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
38.0		3.5		2	7	7	-

58. Bank width (BF) 8.0 59. Channel width 3.0 60. Thalweg depth 25.0 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.):

425

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

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

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

70. Debris and Ice Comments:

1

There is debris (log) along the left abutment.

Downstream of the bridge, there is an accumulation of debris on the right bank in front of a pier for a previously existing railroad bridge.

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	30	2	0	0	0	15.0
RABUT	2	0	90			2	3	69.0

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

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

0

4

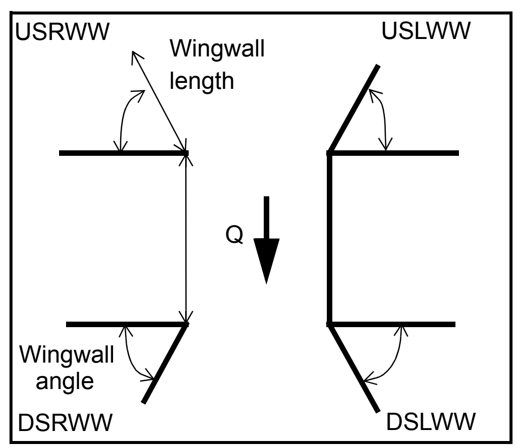
1

The right abutment is undermined 1 foot.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						38.0	
USRWW:	N		-		-	3.5	
DSLWW:	-		-		Y	27.5	
DSRWW:	2		0		0	29.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0	-	N	-	-	1	1	-
Condition	N	-	-	-	-	1	1	-
Extent	-	-	-	0	2	4	0	-

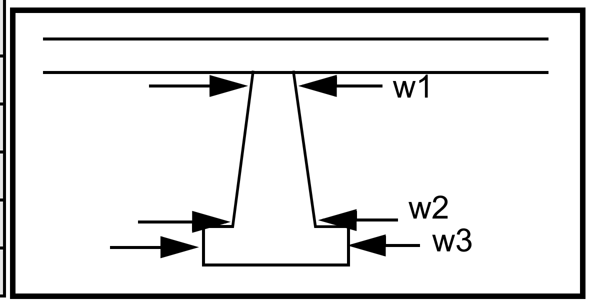
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-			-	**70.0**	**15.5**
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e left**	**blocks**		-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**abut**	**form**		-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ment**	**ing a**		-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**pro-**	**spill-**		-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**tec-**	**thro**		-	*Y- yes; N- no*
91. Attack ∠ (BF)	**tion**	**ugh**		-	
92. Pushed	**con-**	**emb**		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**sists**	**ank-**		-	
95. Cross-members	**of**	**ment**	**N**	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**place**	**.**	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**d cut**		-	-	
98. Exposure depth	**stone**		-	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

NO PIERS

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):

3

106. Point/Side bar present? 3 (Y or N. if N type ctrl-n pb) Mid-bar distance: 34 Mid-bar width: 345

Point bar extent: 1 feet 2 (US, UB, DS) to 24 feet 2 (US, UB, DS) positioned 1 %LB to 1 %RB

Material: 2

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

The protection on the left and right banks extends over 200 feet downstream.

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

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

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

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

N

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

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

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

RE

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

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

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

Confluence comments (eg. confluence name):

-

-

F. Geomorphic Channel Assessment

107. Stage of reach evolution -

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

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

-

NO POINT BARS

Y
RB
45
0
DS
90
DS
1

109. **G. Plan View Sketch**

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: RYEGTH00020002 Town: Ryegate
Road Number: TH 2 County: Caledonia
Stream: Wells River

Initials MAI Date: 06/20/97 Checked: RLB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5300	6680	0
Main Channel Area, ft2	483	721	0
Left overbank area, ft2	0	3	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	64	92	0
Top width L overbank, ft	0	13	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.27005	0.27005	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	7.8	ERR
y1, average depth, LOB, ft	ERR	0.2	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	71665	111863	0
Conveyance, main channel	71665	111823	0
Conveyance, LOB	0	40	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	5300.0	6677.6	ERR
Ql, discharge, LOB, cfs	0.0	2.4	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	11.0	9.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	0.8	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.1	10.2	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?

	100 yr	500 yr	other Q
Main Channel	1	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour

y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)

ys=y2-y_bridge

(Richardson and others, 1995, p. 30, eq. 17 and 18)

Characteristic	Approach 100 yr	500 yr	Other Q	Bridge 100 yr	500 yr	Other Q
Q1, discharge, cfs	5300	6680	0	5300	6680	0
Total conveyance	71665	111863	0	84091	76120	0
Main channel conveyance	71665	111823	0	84091	76120	0
Main channel discharge	5300	6678	ERR	5300	6680	ERR
Area - main channel, ft2	483	721	0	541.7	681	0
(W1) channel width, ft	64	92	0	61.9	64.3	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	64	92	0	61.9	64.3	0
D50, ft	0.27005	0.27005	0.27005			
w, fall velocity, ft/s (p. 32)	4.25167	4.25167	0			
y, ave. depth flow, ft	7.55	7.84	N/A	8.75	10.59	ERR
S1, slope EGL	0.0076	0.0071	0			
P, wetted perimeter, MC, ft	71	100	0			
R, hydraulic Radius, ft	6.803	7.210	ERR			
V*, shear velocity, ft/s	1.290	1.284	N/A			
V*/w	0.303	0.302	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.59	0			
y2,depth in contraction, ft	7.70	9.68	ERR			
ys, scour depth, ft (y2-y_bridge)	-1.05	-0.91	N/A			

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units

ys=y2-y_bridge

(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	5300	6680	0
(Q) discharge thru bridge, cfs	5300	6680	0
Main channel conveyance	84091	76120	0
Total conveyance	84091	76120	0
Q2, bridge MC discharge,cfs	5300	6680	ERR
Main channel area, ft2	542	681	0
Main channel width (normal), ft	61.9	64.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0

W, adjusted width, ft	61.9	64.3	0
y_bridge (avg. depth at br.), ft	8.75	10.59	ERR
Dm, median (1.25*D50), ft	0.337563	0.337563	0
y2, depth in contraction,ft	7.65	9.03	ERR
ys, scour depth (y2-ybridge), ft	-1.10	-1.56	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 other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	5300	6680	0
Q, thru bridge MC, cfs	5300	6680	N/A
Vc, critical velocity, ft/s	10.15	10.21	N/A
Va, velocity MC approach, ft/s	10.97	9.26	N/A
Main channel width (normal), ft	61.9	64.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	61.9	64.3	0.0
qbr, unit discharge, ft2/s	85.6	103.9	ERR
Area of full opening, ft2	541.7	681.0	0.0
Hb, depth of full opening, ft	8.75	10.59	ERR
Fr, Froude number, bridge MC	0	0.56	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	ERR
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	0	695.42	0
Elevation of Bed, ft	-8.75	684.83	N/A
Elevation of Approach, ft	0	696.9	0
Friction loss, approach, ft	0	0.41	0
Elevation of WS immediately US, ft	0.00	696.49	0.00
ya, depth immediately US, ft	8.75	11.66	N/A
Mean elevation of deck, ft	0	699.20	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.98	ERR
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	N/A	**-0.17**	N/A
Ys, scour w/Umbrell equation, ft	N/A	1.53	N/A

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

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

**Ys, scour w/Umbrell equation, ft	ERR	N/A	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	7.42	8.99	0.00
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), ft	N/A	N/A	N/A

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	5300	6680	N/A
Main channel area (DS), ft2	541.7	681	0
Main channel width (normal), ft	61.9	64.3	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	61.9	64.3	0.0
D90, ft	0.9792	0.9792	0.0000
D95, ft	1.9751	1.9751	0.0000
Dc, critical grain size, ft	0.4385	0.4070	ERR
Pc, Decimal percent coarser than Dc	0.236	0.265	0.000
Depth to armoring, ft	4.25	3.38	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)

	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	5300	6680	0	5300	6680	0
a', abut.length blocking flow, ft	0.5	28.4	0	2	12.5	0
Ae, area of blocked flow ft2	2.73	61.8	0	6	39.7	0
Qe, discharge blocked abut.,cfs	18.7	266.4	0	34.6	190.6	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	6.85	4.31	ERR	5.77	4.80	ERR
ya, depth of f/p flow, ft	5.46	2.18	ERR	3.00	3.18	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.517	0.515	ERR	0.587	0.475	ERR
ys, scour depth, ft	**7.09**	**7.65**	N/A	**7.13**	**11.43**	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)	0.5	28.4	0	2	12.5	0
y1 (depth f/p flow, ft)	5.46	2.18	ERR	3.00	3.18	ERR
a'/y1	0.09	13.05	ERR	0.67	3.94	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.52	0.51	N/A	0.59	0.47	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	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 others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.62	0.56	0	0.62	0.56	0
y, depth of flow in bridge, ft	8.75	10.59	0.00	8.75	10.59	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.08	2.05	0.00	**2.08**	**2.05**	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	**1.81**	**1.79**	0.00	1.81	1.79	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR