LEVEL II SCOUR ANALYSIS FOR BRIDGE 6 (MORRTH00030006) on TOWN HIGHWAY 3 (FAS 238), crossing RYDER BROOK, MORRISTOWN, VERMONT

U.S. Geological Survey
Open-File Report 97-105

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

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By Erick M. Boehmler and Robert E. Hammond

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be
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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 6 (MORRTH00030006) ON TOWN HIGHWAY 3 (FAS 238) CROSSING RYDER BROOK, MORRISTOWN, VERMONT

By **Erick M. Boehmler and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MORRTH00030006 on Town Highway 3 crossing Ryder Brook, Morristown, 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 north-central Vermont. The 19.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover also is forested.

In the study area, Ryder Brook has a straight channel with an average channel top width of 450 ft and an average bank height of 7 ft. The predominant channel bed material is silt and clay with a median grain size (D_{50}) of 0.0719 mm (0.000236 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 18, 1996, indicated that the reach was aggraded, but the channel through the bridge was scoured.

The Town Highway 3 crossing of Ryder Brook is a 72-ft-long, two-lane bridge consisting of one 70-foot steel-beam span (Vermont Agency of Transportation, written communication, January 31, 1996). The bridge is supported by vertical, concrete abutments with spill-through embankments and wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

Channel scour under the bridge was evident at this site during the Level I assessment. The depth of the channel increases from 3 feet at the upstream bridge face to 10 feet at the downstream bridge face. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) on the spill-through embankments of each abutment, the upstream road embankments and the downstream left road embankment. 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 20.4 to 25.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.3 to 10.5 ft. The worst-case abutment scour also 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.

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 MORRTH00030006 ***Stream*** Ryder Brook

County Lamoille ***Road*** TH 3 ***District*** 6

Description of Bridge

Bridge length 72 ***ft*** ***Bridge width*** 31.4 ***ft*** ***Max span length*** 70 ***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*** 7/18/96

Description of stone fill Type-2 stone fill is the spill-through embankment material. Type-2 also is present on the road embankments upstream and the left road embankment downstream.

Abutments are vertical concrete walls with spill-through embankments on each wall.

Brief description of piers/abutments No

-

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

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe) 7/18/96

0

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	0	7/18/96	0
Level II	0	Low.	Althoug

Potential for debris h trees exist on the banks upstream, they are old trees predominantly and the banks are stable.

Describe any features near or at the bridge that may affect flow (include observation date) The level I assessment of 7/18/96 indicates the road embankments form a causeway-like feature that blocks more than 80 percent of the waterway.

Description of the Geomorphic Setting

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

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

Date of inspection 7/18/96

DS left: Moderately sloping channel bank and valley wall.

DS right: Moderately sloping channel bank and valley wall.

US left: Moderately sloping channel bank and valley wall.

US right: Moderately sloping channel bank and valley wall.

Description of the Channel

Average top width 450 ***ft*** ***Average depth*** 7 ***ft***

Predominant bed material Silt and Clay ***Bank material*** Silt&Clay/Bedrock

Straight with semi-alluvial channel boundaries and ponded from Cadys Falls Dam downstream.

7/18/96

Vegetative co

Trees

DS left: Trees

DS right: Trees

US left: Trees

US right:

Do banks appear stable? Y

date of observation.

None were noted on 7/18/96

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 19.1 ***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 Yes

Cadys Falls Dam, located about one quarter mile downstream, causes backwater (Lake Lamoille) through this site even during low flow periods. Dam operations may vary the lake level as much as three feet by use of flashboards.

Calculated Discharges

Q100 2,260 ***ft³/s*** ***Q500*** 3,120 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(19.1/17.1)exp 0.67] with bridge number 213 in Morristown. Bridge number 213 crosses Ryder Brook upstream of this site and has flood frequency estimates available from the VTAOT database. These values were within a range defined by discharge frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; 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 Subtract 3.6 feet from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is the center of an engraved triangle on a brass VTAOT survey mark set in the left abutment concrete at the upstream end (elev. 502.03 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the downstream end of the right abutment concrete (elev. 501.72 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	-90	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	17	1	Road Grade section
APPRO	102	1	Approach section

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. 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 were 0.035.

Backwater caused by a dam downstream on the Lamoille River below the confluence of Ryder Brook (Lake Lamoille, Figure 1) affects the water surface at this site even during low flow conditions. Richardson and others (1995, p. 26) recommend use of the "lowest reasonable downstream water surface elevation" as the starting water surface elevation for the hydraulic modeling of the site. Therefore, the starting water surface elevation for each modeled discharge was the pond elevation of 489.7 feet (arbitrary survey datum) at the exit section, as surveyed on July 18, 1996.

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

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions assuming the starting water surface is at or below the elevation applied in these hydraulic analyses.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.7 ***ft***
Average low steel elevation 498.3 ***ft***

100-year discharge 2,260 ***ft^3/s***
Water-surface elevation in bridge opening 490.0 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 202 ***ft^2***
Average velocity in bridge opening 11.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.4 ***ft/s***

Water-surface elevation at Approach section with bridge 493.0
Water-surface elevation at Approach section without bridge 489.8
Amount of backwater caused by bridge 3.2 ***ft***

500-year discharge 3,120 ***ft^3/s***
Water-surface elevation in bridge opening 491.0 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 255 ***ft^2***
Average velocity in bridge opening 12.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 494.4
Water-surface elevation at Approach section without bridge 490.0
Amount of backwater caused by bridge 4.4

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 was computed by use of the live-bed and clear-water contraction scour equations (Richardson and others, 1995, p. 30, 32 equations 17 and 20) because the critical and mean channel velocities are very close. 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. Since there are coarser streambed materials under the bridge, the live-bed contraction scour results were used in tables 1 and 2 and figure 8 in accordance with the recommendations by Richardson and others (1995, p. 31). The results of Laursen's clear-water contraction scour equation also are provided in appendix F.

Abutment scour 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 for the HIRE 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 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.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	20.4	25.8	--
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	8.3	10.5	--
Right abutment	8.5	10.4	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.6	2.0	--
Right abutment	1.6	2.0	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

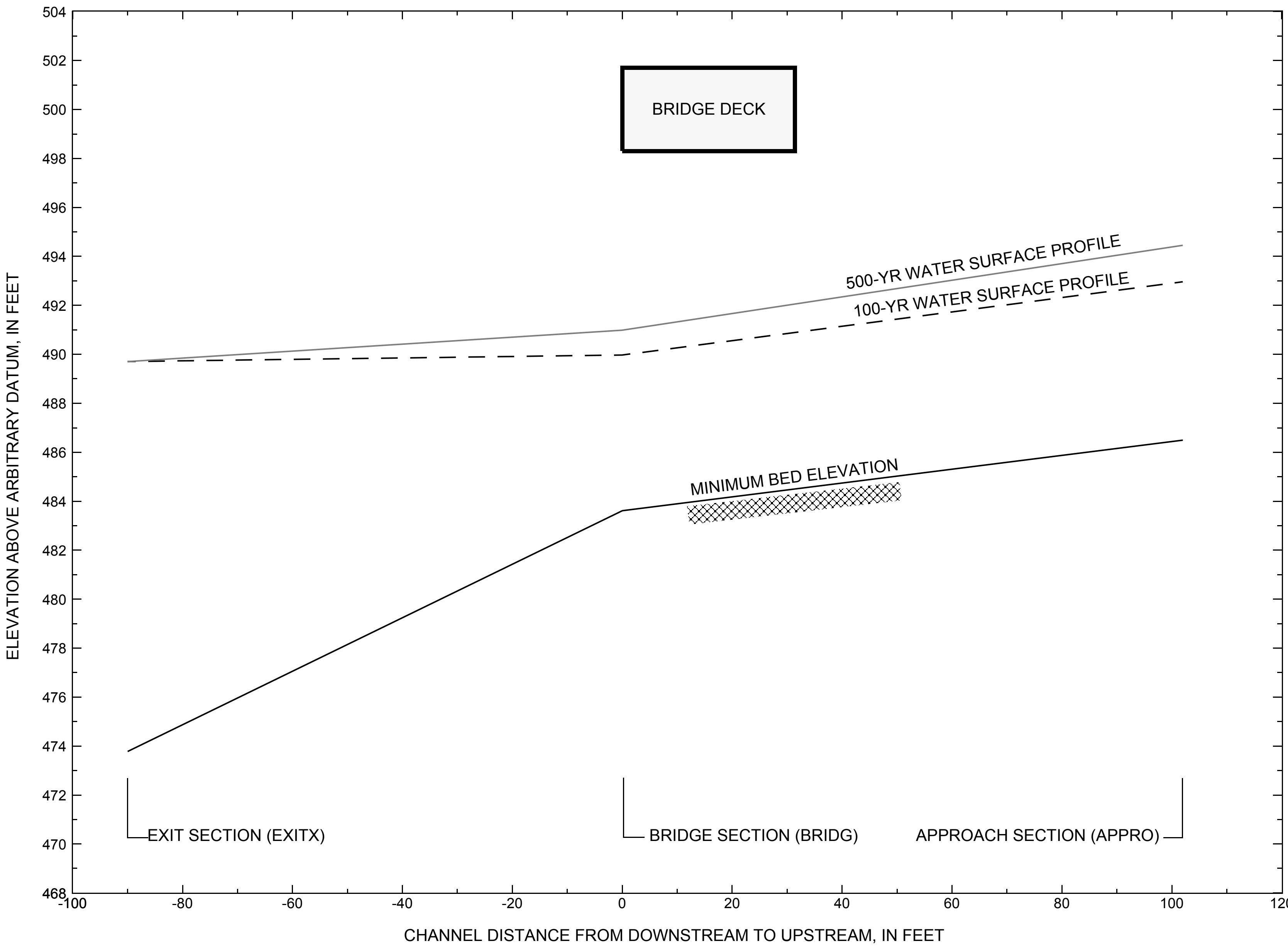

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MORRTH00030006 on Town Highway 3, crossing Ryder Brook, Morristown, Vermont.

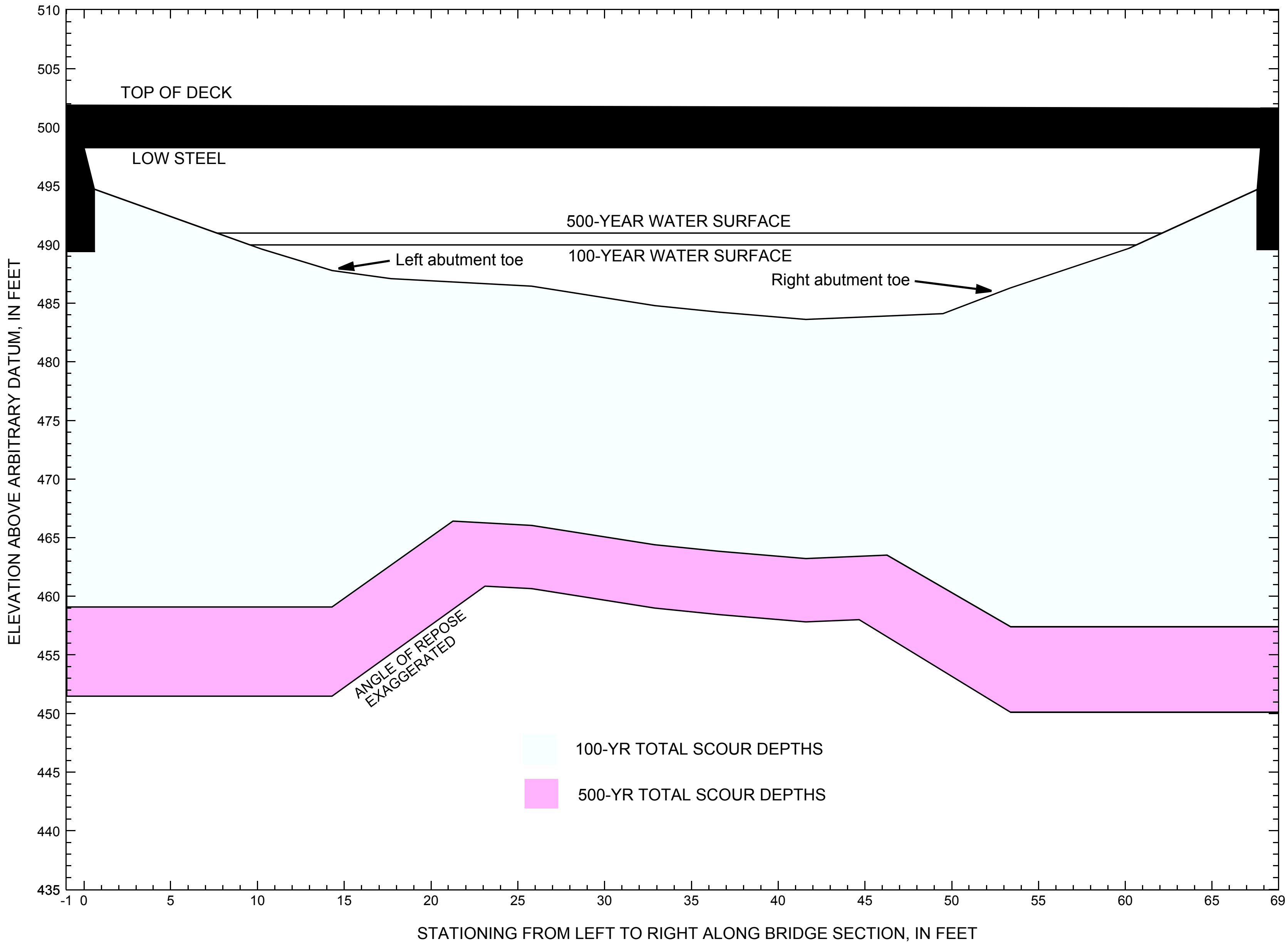

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MORRTH00030006 on Town Highway 3, crossing Ryder Brook, Morristown, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MORRTH00030006 on Town Highway 3, crossing Ryder Brook, Morristown, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,260 cubic-feet per second											
Left abutment	0.0	494.2	498.2	489.4	494.7	--	--	--	--	--	-30.3
Left abutment toe	14.3	--	--	--	487.8	20.4	8.3	--	28.7	459.1	--
Right abutment toe	53.4	--	--	--	486.3	20.4	8.5	--	28.9	457.4	--
Right abutment	67.8	494.3	498.3	489.6	494.7	--	--	--	--	--	-32.2

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 MORRTH00030006 on Town Highway 3, crossing Ryder Brook, Morristown, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,120 cubic-feet per second											
Left abutment	0.0	494.2	498.2	489.4	494.7	--	--	--	--	--	-37.9
Left abutment toe	14.3	--	--	--	487.8	25.8	10.5	--	36.3	451.5	--
Right abutment toe	53.4	--	--	--	486.3	25.8	10.4	--	36.2	450.1	--
Right abutment	67.8	494.3	498.3	489.6	494.7	--	--	--	--	--	-39.5

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

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U.S. Geological Survey, 1986, Morrisville, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photography, 1981; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File morr006.wsp
T2        Hydraulic analysis for structure MORRTH00030006   Date: 10-DEC-96
T3        Town Highway 3 (FAS 238) Crossing of Ryder Brook, Morristown, VT   EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2260.0   3120.0
WS           489.7    489.7
*
XS   EXITX    -90
GR         -146.7, 499.64    -94.2, 496.93    -69.9, 489.74    -25.7, 485.64
GR            0.0, 478.07     31.6, 473.78     56.6, 475.45     91.6, 482.16
GR          165.8, 479.57    196.3, 480.95    244.9, 482.49    268.3, 488.38
GR          275.5, 489.66    287.0, 492.19    300.4, 499.60    322.7, 507.05
GR          459.4, 510.08    499.9, 518.56
*
N           0.035
*
*           The following section was generated by modifying the exit section
*           using both exit and bridge section coordinates.
*
XS   FULLV      0
GR         -146.7, 499.64    -94.2, 496.93    -69.9, 489.74     14.3, 487.78
GR           17.7, 487.09     25.8, 486.45     32.9, 484.79     36.6, 484.23
GR           41.6, 483.61     49.5, 484.11     53.4, 486.30    268.3, 488.38
GR          275.5, 489.66    287.0, 492.19    300.4, 499.60    322.7, 507.05
GR          459.4, 510.08    499.9, 518.56
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    498.26       0.0
GR            0.0, 498.25      0.6, 494.72     10.2, 489.63     14.3, 487.78
GR           17.7, 487.09     25.8, 486.45     32.9, 484.79     36.6, 484.23
GR           41.6, 483.61     49.5, 484.11     53.4, 486.30     60.2, 489.67
GR           67.6, 494.68     67.8, 498.26      0.0, 498.25
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      34.6     1.5     501.7
N           0.035
*          Notice: The embankment side slopes were computed using the BPLAN
*                 LAB, RAB, and WW points as the slope of the concrete appears
*                 to be approximately the slope of the adjacent embankments...
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     17      31.4     1
GR         -258.6, 513.91   -250.8, 509.09   -199.3, 504.51   -196.6, 501.86
GR         -179.5, 500.70   -148.9, 500.60     -1.6, 501.89      0.0, 502.71
GR           67.7, 502.48     69.3, 501.62    235.3, 500.57    339.8, 502.88
GR          416.9, 509.43    491.4, 525.85
*
AS   APPRO    102
GR         -201.5, 506.34   -190.5, 500.01   -185.6, 499.94   -161.3, 500.10
GR         -151.4, 498.68   -136.7, 489.73   -134.3, 488.64   -120.1, 487.51
GR          -85.7, 486.49    -43.8, 488.40    -24.3, 489.26      0.0, 489.20
GR           48.3, 486.70     65.2, 486.61     91.6, 488.01    147.9, 486.71
GR          264.8, 488.14    286.8, 489.41    319.0, 491.92    348.9, 495.90
GR          402.3, 506.42    441.2, 508.70    461.1, 509.97    485.1, 520.16
*
```

```
N           0.035
*
*
*
*
*
*
*
*
HP 1 BRIDG 489.97 1 489.97
HP 2 BRIDG 489.97 * * 2260
HP 1 APPRO 492.96 1 492.96
HP 2 APPRO 492.96 * * 2260
*
HP 1 BRIDG 490.98 1 490.98
HP 2 BRIDG 490.98 * * 3120
HP 1 APPRO 494.45 1 494.45
HP 2 APPRO 494.45 * * 3120
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File morr006.wsp
     Hydraulic analysis for structure MORRTH00030006   Date: 10-DEC-96
     Town Highway 3 (FAS 238) Crossing of Ryder Brook, Morristown, VT   EMB
        *** RUN DATE & TIME: 12-30-96  13:54

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      202     20806     51     53                         2272
489.97           202     20806     51     53  1.00     10     61     2272

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    489.97     9.6    60.6   201.6   20806.    2260.  11.21

X STA.        9.6       18.8       23.0       26.4       29.2       31.4
  A(I)           17.3       13.0       11.8       11.2        9.9
  V(I)           6.55       8.69       9.56      10.07      11.46

X STA.       31.4       33.2       34.9       36.5       37.9       39.3
  A(I)            9.3        9.1        8.5        8.4        8.2
  V(I)          12.14      12.43      13.23      13.41      13.86

X STA.       39.3       40.6       41.8       43.1       44.4       45.7
  A(I)            8.0        7.9        7.9        8.2        8.0
  V(I)          14.16      14.25      14.36      13.74      14.09

X STA.       45.7       47.1       48.6       50.2       52.6       60.6
  A(I)            8.5        8.9        9.4       11.5       16.6
  V(I)          13.25      12.68      12.01       9.85       6.82

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1     2324    287051    469    470                        29368
492.96          2324    287051    469    470  1.00   -141    327    29368

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

      WSEL     LEW     REW    AREA        K        Q    VEL
    492.96  -142.0   326.8  2324.3  287051.    2260.   0.97

X STA.     -142.0     -112.2      -94.7      -78.8      -59.9      -34.4
  A(I)          130.9      103.9      100.6      108.1      120.5
  V(I)           0.86       1.09       1.12       1.04       0.94

X STA.      -34.4        3.9       30.3       48.6       64.4       82.3
  A(I)          145.3      122.3      106.2       99.8      106.1
  V(I)           0.78       0.92       1.06       1.13       1.06

X STA.       82.3      104.3      124.3      142.1      158.8      176.4
  A(I)          112.9      109.6      104.8      103.4      106.0
  V(I)           1.00       1.03       1.08       1.09       1.07

X STA.      176.4      195.4      215.7      238.3      263.8      326.8
  A(I)          109.9      112.7      119.1      127.3      174.9
  V(I)           1.03       1.00       0.95       0.89       0.65
```

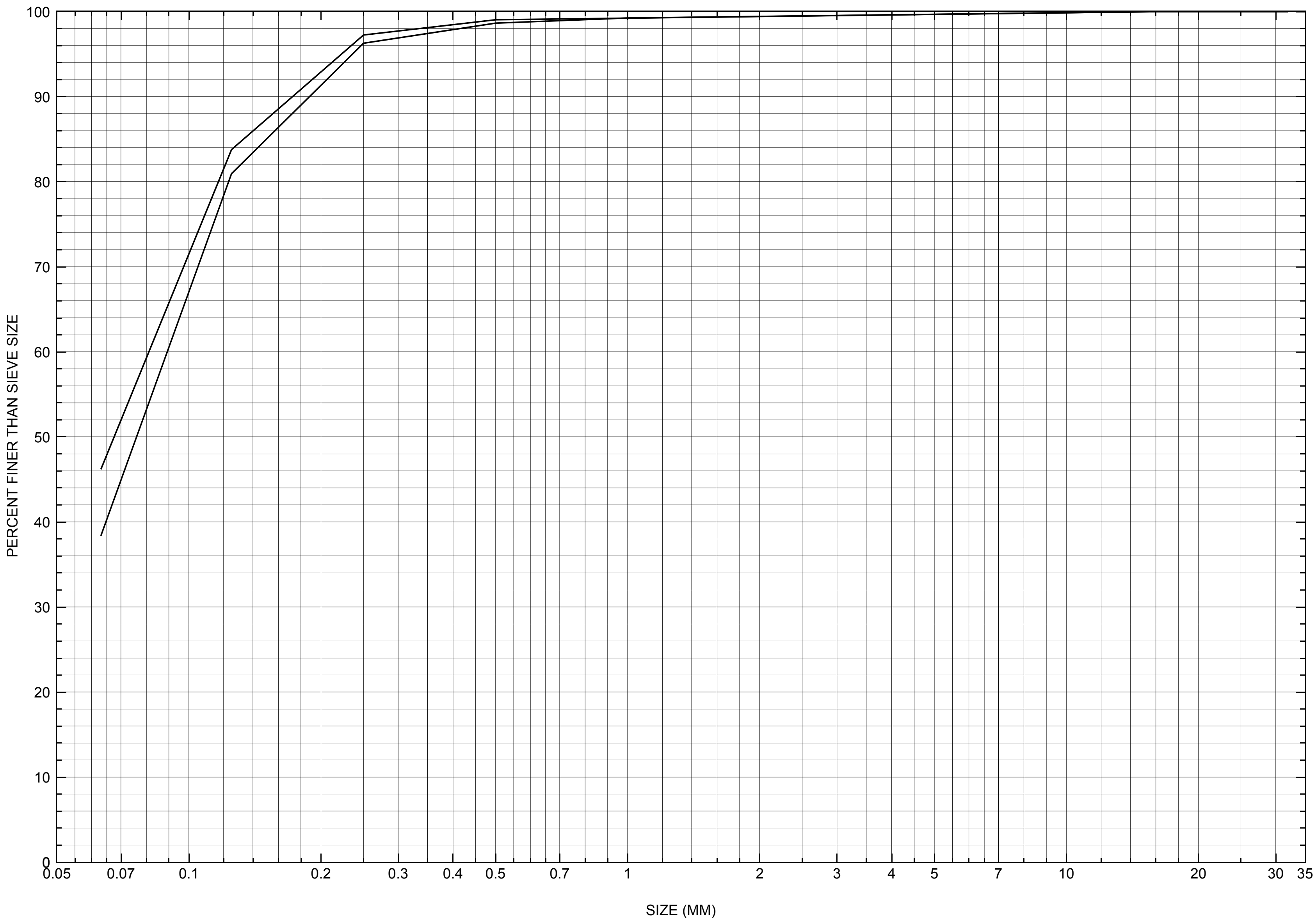
```
        U.S. Geological Survey WSPRO Input File morr006.wsp
        Hydraulic analysis for structure MORRTH00030006   Date: 10-DEC-96
        Town Highway 3 (FAS 238) Crossing of Ryder Brook, Morristown, VT   EMB
           *** RUN DATE & TIME: 12-30-96  13:54

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      255     29331     54     57                         3129
   490.98           255     29331     54     57  1.00      8     62     3129

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       490.98     7.7    62.1   254.9   29331.    3120.  12.24

X STA.         7.7        17.4        21.4        24.6        27.6        30.0
  A(I)            21.8        16.1        14.0        13.8        12.7
  V(I)            7.17        9.70       11.14       11.32       12.26

X STA.        30.0        32.1        33.9        35.6        37.2        38.7
  A(I)            12.1        11.1        10.9        10.7        10.4
  V(I)           12.87       13.99       14.34       14.53       15.01

X STA.        38.7        40.1        41.5        42.9        44.3        45.8
  A(I)            10.2        10.1        10.1        10.4        10.3
  V(I)           15.32       15.43       15.43       15.06       15.19

X STA.        45.8        47.3        48.9        50.8        53.5        62.1
  A(I)            10.9        11.1        12.5        14.6        21.0
  V(I)           14.27       14.05       12.45       10.66        7.42

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     3033    438539    482    485                        43153
   494.45          3033    438539    482    485  1.00   -143    338    43153

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.45  -144.5   338.0  3033.0  438539.    3120.   1.03

X STA.      -144.5      -113.0       -93.9       -76.6       -57.3       -31.6
  A(I)           171.8       142.0       134.3       137.1       156.4
  V(I)            0.91        1.10        1.16        1.14        1.00

X STA.       -31.6         1.4        27.4        46.8        64.2        82.6
  A(I)           173.5       156.0       139.2       135.0       136.7
  V(I)            0.90        1.00        1.12        1.16        1.14

X STA.        82.6       105.0       125.3       144.1       162.1       180.4
  A(I)           148.2       142.1       139.1       137.9       136.6
  V(I)            1.05        1.10        1.12        1.13        1.14

X STA.       180.4       200.7       221.9       245.4       271.2       338.0
  A(I)           146.4       147.7       157.4       163.8       231.7
  V(I)            1.07        1.06        0.99        0.95        0.67
```

```
        U.S. Geological Survey WSPRO Input File morr006.wsp
        Hydraulic analysis for structure MORRTH00030006   Date: 10-DEC-96
        Town Highway 3 (FAS 238) Crossing of Ryder Brook, Morristown, VT   EMB
           *** RUN DATE & TIME: 12-30-96  13:54

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

EXITX:XS   ******    -68     2920  0.01 *****  489.71  478.85    2260  489.70
       -89 ******    276   513007  1.00 ***** *******    0.05    0.77

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.10

FULLV:FV       90    -65      743  0.14  0.02  489.78 *******    2260  489.64
         0     90    275    53058  1.00  0.07   -0.01    0.36    3.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      102   -136      921  0.09  0.15  489.94 *******    2260  489.85
       102    102    292    65178  1.00  0.00    0.01    0.30    2.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2260.     489.97

            <<<<<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       90     10      202  2.36 *****  492.33  489.97    2260  489.97
         0     90     61    20824  1.21 ***** *******    1.09   11.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.910 ******  498.26 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.        <<<<<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       67   -141     2325  0.01  0.08  492.98  488.36    2260  492.96
       102     99    327   287124  1.00  0.56    0.00    0.08    0.97

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.884  0.870   37419.    61.   112.   492.96

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -90.   -69.   276.   2260.  513007.    2920.    0.77  489.70
   FULLV:FV       0.   -66.   275.   2260.   53058.     743.    3.04  489.64
   BRIDG:BR       0.    10.    61.   2260.   20824.     202.   11.20  489.97
   RDWAY:RG      17.**************      0.******************    1.00********
   APPRO:AS     102.  -142.   327.   2260.  287124.    2325.    0.97  492.96

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      61.   112.   37419.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    478.85    0.05  473.78  518.56************  0.01  489.71  489.70
   FULLV:FV  ********    0.36  483.61  518.56  0.02  0.07  0.14  489.78  489.64
   BRIDG:BR    489.97    1.09  483.61  498.26************  2.36  492.33  489.97
   RDWAY:RG ****************  500.57  525.85**********************************
   APPRO:AS    488.36    0.08  486.49  520.16  0.08  0.56  0.01  492.98  492.96
```

```
       U.S. Geological Survey WSPRO Input File morr006.wsp
       Hydraulic analysis for structure MORRTH00030006   Date: 10-DEC-96
       Town Highway 3 (FAS 238) Crossing of Ryder Brook, Morristown, VT   EMB
          *** RUN DATE & TIME: 12-30-96  13:54

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

EXITX:XS   ******    -68     2920  0.02 *****  489.72  479.81    3120  489.70
      -89 ******    276   513007  1.00 ***** *******    0.06    1.07

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.10

FULLV:FV       90    -62      723  0.29  0.03  489.87 *******    3120  489.58
        0     90    275    50947  1.00  0.14   -0.02    0.52    4.32
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.42

APPRO:AS      102   -136      981  0.16  0.27  490.15 *******    3120  489.99
      102    102    294    72210  1.00  0.00    0.00    0.37    3.18
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3120.     490.98

            <<<<<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       90      8      255  2.90 *****  493.88  490.98    3120  490.98
        0     90     62    29366  1.25 ***** *******    1.11   12.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.896 ******  498.26 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.        <<<<<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       67   -143     3034  0.02  0.07  494.47  488.76    3120  494.45
      102     99    338   438688  1.00  0.51   -0.01    0.07    1.03

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.885  0.863   60357.    58.   112.   494.45

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -90.   -69.   276.   3120.  513007.    2920.    1.07  489.70
   FULLV:FV       0.   -63.   275.   3120.   50947.     723.    4.32  489.58
   BRIDG:BR       0.     8.    62.   3120.   29366.     255.   12.23  490.98
   RDWAY:RG      17.**************       0.******************    1.00********
   APPRO:AS     102.  -144.   338.   3120.  438688.    3034.    1.03  494.45

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      58.   112.   60357.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    479.81    0.06  473.78  518.56************  0.02  489.72  489.70
   FULLV:FV  ********    0.52  483.61  518.56  0.03  0.14  0.29  489.87  489.58
   BRIDG:BR    490.98    1.11  483.61  498.26************  2.90  493.88  490.98
   RDWAY:RG  ****************  500.57  525.85**********************************
   APPRO:AS    488.76    0.07  486.49  520.16  0.07  0.51  0.02  494.47  494.45
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for two composite bed samples in the channel approach of structure MORRTH00030006, in Morristown, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MORRTH00030006

General Location Descriptive

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

Date *(MM/DD/YY)* 01 / 31 / 96

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 015

Town *(FIPS place code; I - 4; nnnnn)* 46675

Mile marker *(I - 11; nnn.nnn)* 000040

Waterway *(I - 6)* Ryder Brook

Road Name *(I - 7):* TH 3

Route Number FAS 238

Vicinity *(I - 9)* 0.7 MI W JCT. VT.100

Topographic Map Morrisville

Hydrologic Unit Code: 2010005

Latitude *(I - 16; nnnn.n)* 44341

Longitude *(i - 17; nnnnn.n)* 72367

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20023800060807

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

Maximum span length *(I - 48; nnnn)* 0070

Year built *(I - 27; YYYY)* 1977

Structure length *(I - 49; nnnnnn)* 000072

Average daily traffic, ADT *(I - 29; nnnnnn)* 001140

Deck Width *(I - 52; nn.n)* 314

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 8

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 54

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

Vertical clearance from streambed (*nnn.n ft*) 9.46

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

Waterway of full opening (*nnn.n ft²*) 510

Comments:

According to the structural inspection report dated 7/29/94, the structure is a single span rolled beam bridge. The curtain wall at the left abutment has some minor cracking and light scaling. The bridge seat concrete of both abutments is in good condition. The left abutment wall has some hairline vertical cracking and some staining from the weathering steel. The wingwalls are in good condition. The curtain wall at the right abutment is in good condition. The right abutment wall has some hairline vertical cracking. There is also a large area of moderate to heavy scaling of the wall. The wingwall concrete is in good condition except for some minor cracking. Both abutments are protected with stone fill. **(Continued, page 32)**

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **19.5**

Terrain character: ____

Stream character & type:

Streambed material: ____

Discharge Data *(cfs)*: $Q_{2.33}$ **450** Q_{10} **950** Q_{25} **1370**

Q_{50} **1700** Q_{100} **2000** 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: **The Cadys Falls power dam (23' high) is located approximately 2400' downstream of this site. Headwaters at this site are controlled by the water elevations of Lake Lamoille. Elevations on Lake Lamoille can vary as much as 3'+ depending on whether the flashboards at the dam are installed or not. Less than 100' downstream of this structure the average width of flow is 400' signifying entry into the lake.**

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*)	**493.3**	**494.6**	**495.2**	**496.1**	**496.9**
Velocity (*ft / sec*)			**3**		

Long term stream bed changes:

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

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

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

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

Highway No. : ____ Structure No. : ____ Structure Type: ____

Clear span (*ft*): ____ Clear Height (*ft*): ____ Full Waterway (*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:

The channel is straight through the structure and, overall, is in "good" condition. The water surface elevations noted above are headwater elevations with flashboards. Corresponding headwater elevations without flashboards (which would in most instances be removed during storms of Q10 or greater) are: 490.6, 492.1, 492.8, 394.8, and 494.6 feet.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **19.10** mi^2

Lake and pond area **0.28** mi^2

Watershed storage *(ST)* **1.5** %

Bridge site elevation **570** ft

Headwater elevation **2730** ft

Main channel length **10.38** mi

10% channel length elevation **640** ft

85% channel length elevation **1150** ft

Main channel slope *(S)* **65.51** 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):* - / 1976

Project Number BRS0238(1) 1977 Minimum channel bed elevation: 480

Low superstructure elevation: USLAB 494.24 DSLAB 494.24 USRAB 494.31 DSRAB 494.31

Benchmark location description:

BM #1, S.I.T. 15" pine, assumed elev. 500', located on upstream side of right road approach, approx. 300' from bridge, near shore of Lake Lamoille

BM #2, S.I.T. 40" pine, assumed elev. 497.4', located on downstream side of left road approach, toward south end of small triangle formed by intersection of 3 roads (or driveways).

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

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

If 1: Footing Thickness 2 Footing bottom elevation: 486

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? Y *If no, type ctrl-n bi* Number of borings taken: 2

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

Briefly describe material at foundation bottom elevation or around piles:

Footing at the right abutment is in silt and at the left abutment footing is in silty gravel resting on top of bedrock.

Comments:

Footing bottom elevation given above is for the right abutment. The bottom of the left abutment footing is 485.75 feet.

Cross-sectional Data

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

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

Comments: **Road approach x-sections are available but channel sections are not available from VTAOT.**

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: EW Date: 8/15/96
Computerized by: EW Date: 8/15/96
Reviewd by: EMB Date: 12/30/96

Structure Number MORRTH00030006

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 07 / 18 / 1996
2. Highway District Number 06 Mile marker 000040
County Lamoille (015) Town Morristown (46675)
Waterway *(I - 6)* Ryder Brook Road Name Bridge Street
Route Number TH 3 Hydrologic Unit Code: 02010005
3. Descriptive comments:
This bridge is located about 150 feet from the junction of Bridge Street and Codys Falls Road. The bridge also is part of the federal aid system having the designation FAS 238.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 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 72 *(feet)* Span length 70 *(feet)* Bridge width 31.4 *(feet)*

Road approach to bridge:

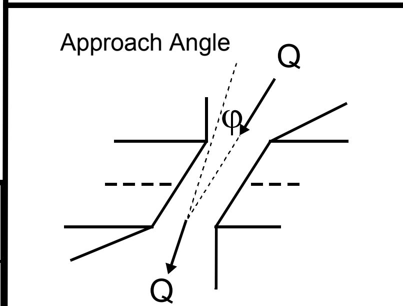
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

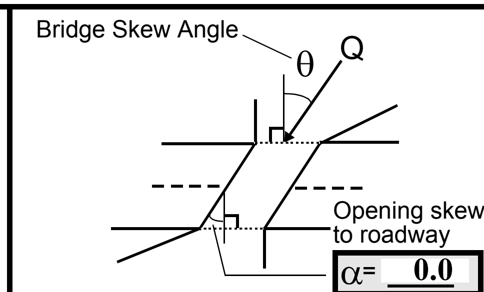
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	2	1	2	1
RBDS	1	1	2	1
LBDS	2	1	2	1

*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: 0 16. Bridge skew: 0





α= 0.0

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

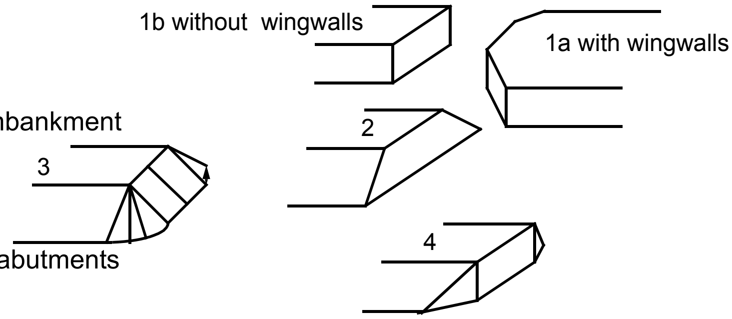
1a- Vertical abutments with wingwalls

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: During site visit, the bridge measured 71.6 feet long and 29.6 feet wide between the cement curbs.

#11: Some asphalt laid over protection to provide a channel for road wash. Some road wash has gone beyond the asphalt protection.

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
76.0	**9.0**			**4.0**	**1**	**1**	**7**	**0**	**0**	**0**

23. Bank width **30.0** 24. Channel width **10.0** 25. Thalweg depth **500.5** 29. Bed Material **1**

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

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

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

On the left bank, the roadway is parallel to Ryder Brook.
The road embankments are composed of stone fill.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **20** 35. Mid-bar width: **50**

36. Point bar extent: **80** feet **US** (US, UB) to **15** feet **US** (US, UB, DS) positioned **15** %LB to **20** %RB

37. Material: **16**

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

This bar is composed of silt and clay material, which deposited on bedrock.

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
455.5		**3.0**		**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.):

51

There is stone fill along each abutment wall, which protrudes into the channel. In the middle of channel, the bed material is silt/ clay.

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

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

-

Some debris is deposited in the ponded area upstream of the 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	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	67.5

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.):

-

-

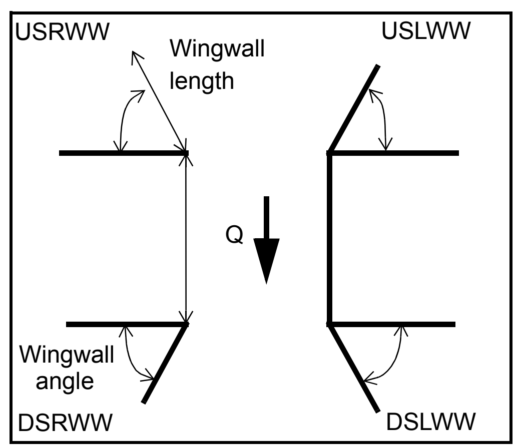
1

Refer to the downstream channel assessment for scour hole under bridge as a result of constriction.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						67.5	
USRWW:	N		-		-	10.0	
DSLWW:	-		-		N	34.5	
DSRWW:	-		-		-	34.5	

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



82. **Bank / Bridge Protection**:

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

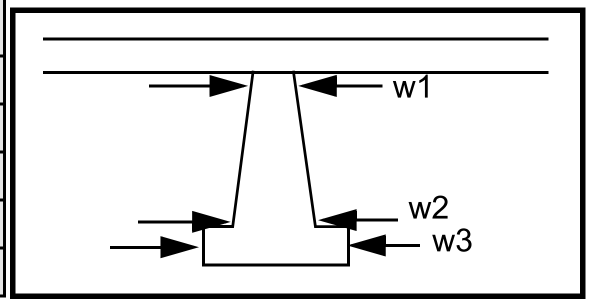
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **Ext** (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	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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 (Amb) - Thalweg depth (Amb) - Bed Material -

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
NO PIERS

101. Is a drop structure present? 2 *(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):
7
6
0
0
1
0

106. Point/Side bar present? 0 *(Y or N. if N type ctrl-n pb)* Mid-bar distance: - Mid-bar width: -

Point bar extent: Veg- feet eta- *(US, UB, DS)* to tion feet cov *(US, UB, DS)* positioned er %LB to alo %RB

Material: ng

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

the roadway on left bank is 0% to 25 %.

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

N

-

-

-

-

-

-

-

109. G. Plan View Sketch

N

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: MORRTH00030006 Town: Morristown
Road Number: TH 3 (FAS 238) County: Lamoille
Stream: Ryder Brook

Initials EMB Date: 12/30/96 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	2260	3120	0
Main Channel Area, ft2	2324.3	3033	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	468.8	482.5	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.000236	0.000236	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.0	6.3	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	287051	438539	0
Conveyance, main channel	287051	438539	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	2260.0	3120.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	1.0	1.0	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	0.9	0.9	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	1	1	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	Approach 500 yr	Approach Other Q	Bridge 100 yr	Bridge 500 yr	Bridge Other Q
Q1, discharge, cfs	2260	3120	0	2260	3120	0
Total conveyance	287051	438539	0	20806	29331	0
Main channel conveyance	287051	438539	0	20806	29331	0
Main channel discharge	2260	3120	ERR	2260	3120	ERR
Area - main channel, ft2	2324.3	3033	0	201.6	254.9	0
(W1) channel width, ft	468.8	482.5	0	45.2	47.3	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	468.8	482.5	0	45.2	47.3	0
D50, ft	0.000236	0.000236	0.000236			
w, fall velocity, ft/s (p. 32)	0.011	0.011	0			
y, ave. depth flow, ft	4.96	6.29	N/A	4.46	5.39	ERR
S1, slope EGL	0.0016	0.0027	0			
P, wetted perimeter, MC, ft	470	485	0			
R, hydraulic Radius, ft	4.945	6.254	ERR			
V*, shear velocity, ft/s	0.505	0.737	N/A			
V*/w	45.887	67.032	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	0.69	0.69	0			
y2,depth in contraction, ft	24.90	31.21	ERR			
ys, scour depth, ft (y2-y_bridge)	20.44	25.82	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	2324.3	3033	0
Main channel width, ft	468.8	482.5	0
y1, main channel depth, ft	4.96	6.29	ERR

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	2260	3120	0
(Q) discharge thru bridge, cfs	2260	3120	0
Main channel conveyance	20806	29331	0
Total conveyance	20806	29331	0
Q2, bridge MC discharge,cfs	2260	3120	ERR
Main channel area, ft2	202	255	0
Main channel width (skewed), ft	45.2	47.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	45.2	47.3	0
y_bridge (avg. depth at br.), ft	4.47	5.39	ERR
Dm, median (1.25*D50), ft	0.000295	0.000295	0
y2, depth in contraction,ft	36.10	45.77	ERR
ys, scour depth (y2-ybridge), ft	31.63	40.38	N/A

ARMORING	Q100	Q500	Qother
D90	0.000591	0.000591	0
D95	0.000753	0.000753	0
Critical grain size,Dc, ft	0.0971	0.1120	ERR
Decimal-percent coarser than Dc	0	0	0
depth to armoring, ft	N/A	N/A	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	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2260	3120	0	2260	3120	0
a’, abut.length blocking flow, ft	153.9	155.3	0	269.7	279.9	0
Ae, area of blocked flow ft2	746.4	971.5	0	1332.8	1734.9	0
Qe, discharge blocked abut.,cfs	712.2	992.4	0	1295.2	1770.7	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.95	1.02	ERR	0.97	1.02	ERR
ya, depth of f/p flow, ft	4.85	6.26	ERR	4.94	6.20	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	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	0.076	0.072	ERR	0.077	0.072	ERR
ys, scour depth, ft	10.43	12.50	N/A	12.15	14.22	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)	153.9	155.3	0	269.7	279.9	0
y1 (depth f/p flow, ft)	4.85	6.26	ERR	4.94	6.20	ERR
a’/y1	31.73	24.83	ERR	54.58	45.16	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.08	0.07	N/A	0.08	0.07	N/A
Ys w/ corr. factor K1/0.55:						
vertical	15.09	19.09	ERR	15.42	18.94	ERR
vertical w/ ww’s	12.38	15.65	ERR	12.65	15.53	ERR
spill-through	8.30	10.50	ERR	8.48	10.42	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	1	1	0	1	1	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.46	5.39	0.00	4.46	5.39	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.87	2.25	ERR	1.87	2.25	ERR