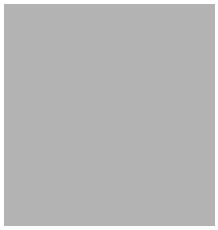
LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (NORWTH00030046) on TOWN HIGHWAY 3 (VT132), crossing the OMPOMPANOOSUC RIVER, NORWICH, VERMONT

U.S. Geological Survey
Open-File Report 96-160



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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (NORWTH00030046) on TOWN HIGHWAY 3 (VT132), crossing the OMPOMPANOOSUC RIVER, NORWICH, VERMONT

By SCOTT A. OLSON and DONALD L. SONG

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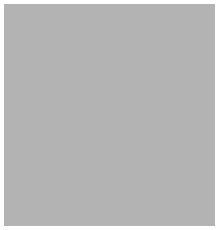

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VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

Pembroke, New Hampshire

1996

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

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

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

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Federal Center
Denver, CO 80225

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FIGURES

TABLES

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 46 (NORWTH00030046) ON TOWN HIGHWAY 3 (VT132), CROSSING THE OMPOMPANOOSUC RIVER, NORWICH, VERMONT

By **Scott A. Olson and Donald L. Song**

INTRODUCTION

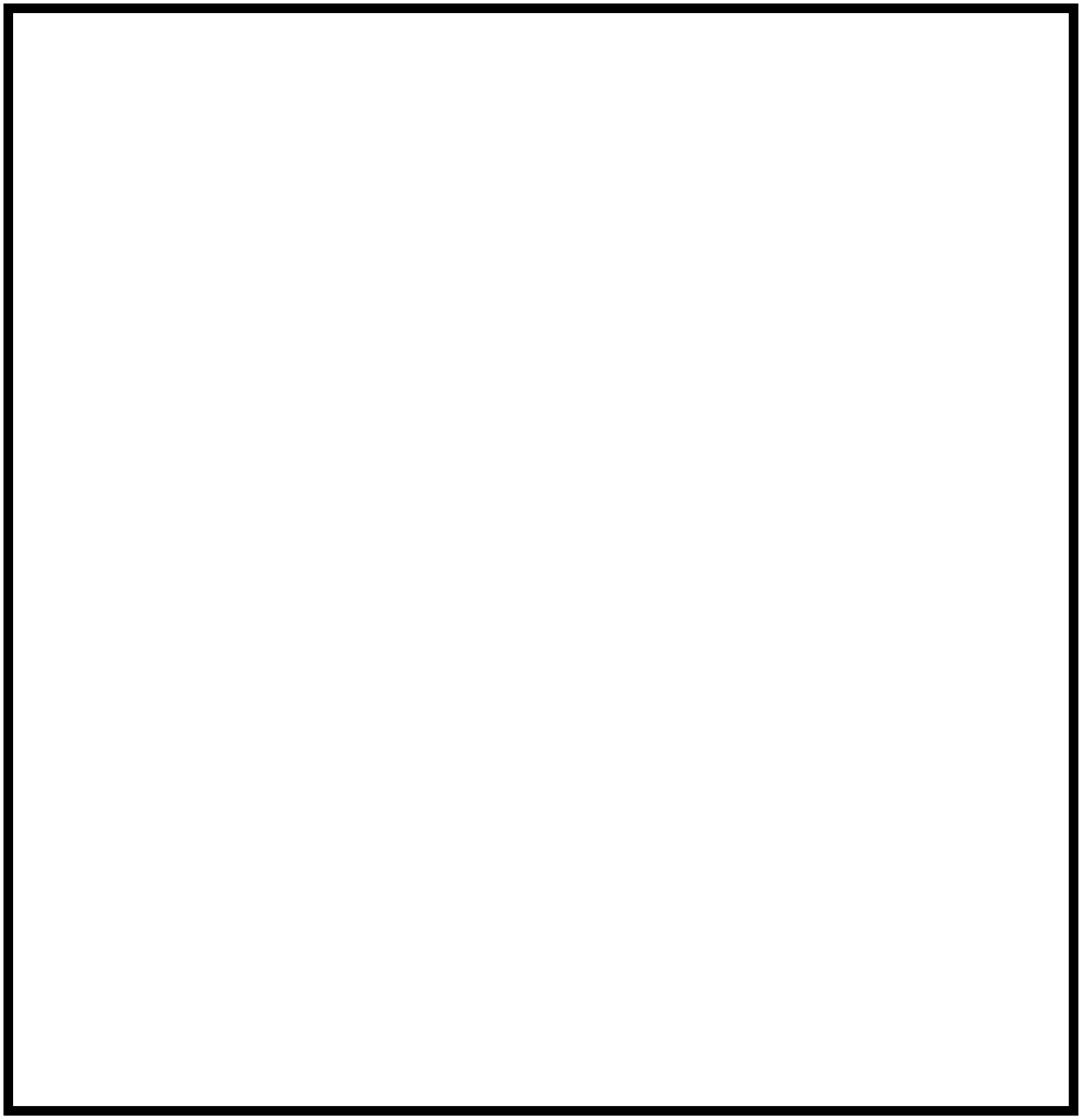
This report provides the results of a detailed Level II analysis of scour potential at structure NORWTH00030046 on town highway 3, which is also Vermont State Route 132 crossing the Ompompanoosuc River, Norwich, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). A Level I study is included in Appendix E of this report. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge, available from VTAOT files, was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the New England Upland physiographic province of east-central Vermont. The 135-mi^2 drainage area is a predominantly rural basin. A flood-control reservoir located approximately 2 mi upstream has 1.66 billion cubic feet of usable storage. In the vicinity of the study site, the left bank is forested and the right bank is covered by shrubs and brush, adjacent to woods. The Ompompanoosuc River is parallel to Town Highway 3.

In the study area, the Ompompanoosuc River has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 166 ft and an average channel depth of 6 ft. The predominant channel bed material is sand (D_{50} is 0.744 mm or 0.00244 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 19, 1994, indicated that the reach was stable.

The town highway 3 crossing of the Ompompanoosuc River is a 100-ft-long, two-lane bridge consisting of two steel-beam spans (Vermont Agency of Transportation, written commun., July 29, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 12 degrees. 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, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The scour analysis results are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

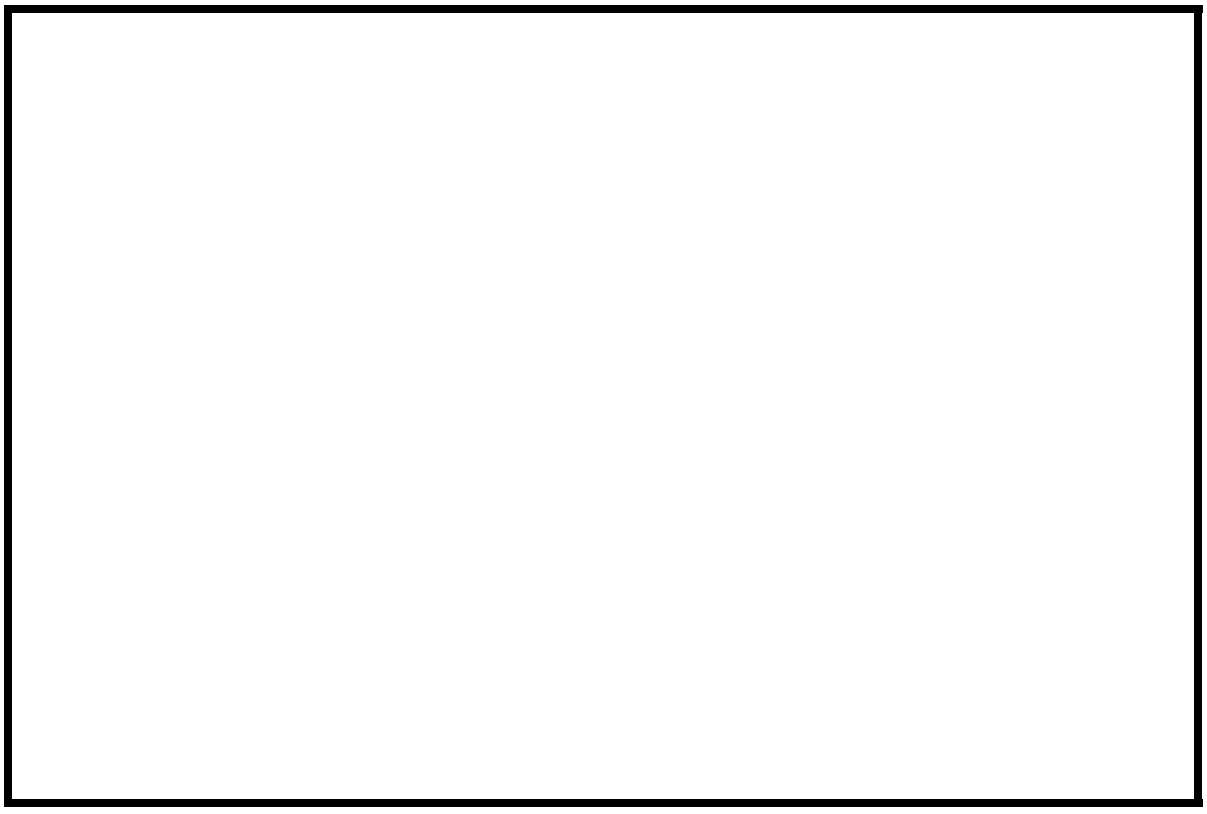


Lyme, N.H.-VT.. Quadrangle, 1:24,000, 1981

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 NORWTH00030046 ***Stream*** Ompompanoosuc River

County Windsor ***Road*** TH003 ***District*** 04

Description of Bridge

Bridge length 100 ***ft*** ***Bridge width*** 27.5 ***ft*** ***Max span length*** 47 ***ft***

Alignment of bridge to road (on curve or straight) Both approaches curve sharply

Abutment type Concrete, vertical ***Embankment type*** sloping

Stone fill on abutment? Left only ***Date of inspection*** 12/07/94

Description of stone fill Type-2 stone fill protects the left and right US road approaches and US and DS right wingwalls. Type-1 protection was noted at the left abutment and US left wingwall. No protection existed at the right abutment and DS left wingwall.

Brief description of piers/abutments Piers and abutments are concrete. Footings of both the pier and abutments are exposed.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 25

Is bridge located on a bend in channel? ***Type of*** ***observed (annual, moderate, severe)***

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	08/19 and 12/07/94 08/19/94	0 0	0 0
Level II			

Potential for debris Low due to fairly stable banks and the flood control reservoir upstream.

Describe any features near or at the bridge that may affect flow (include observation date) There is a flood control reservoir about two miles upstream of bridge site. About 3/4 mile downstream is the Connecticut River. There is backwater from the Connecticut River at the bridge site.

Description of the Geomorphic Setting

General topography The site is in a moderate relief valley with a narrow flood plain. The immediate reach is incised.

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

Date of inspection 12/07/94

DS left: Steep river bank with a flat overbank. State Highway 132 parallels river.

DS right: Moderately steep valley wall.

US left: Flat and low with some swampy areas.

US right: Moderately steep valley wall. State Highway 132 parallels river.

Description of the Channel

Average top width 166 ft ***Average depth*** 5.5 ft

Predominant bed material Sand ***Bank material*** Sand

In the immediate vicinity it is a straight channel. Further upstream it is a meandering channel.

12/07/94

Vegetative co Brush and grass. State Highway 132 parallels river.

DS left: Brush.

DS right: Trees and thick brush.

US left: Brush and grass. State Highway 132 parallels river.

US right: Yes

Do banks appear stable? None.

If not, describe location and type of instability and date of observation.

None

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 135 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
New England Upland	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

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

USGS gage description Ompompanoosuc River at Union Village

USGS gage number 011415000

Gage drainage area 130 ***mi²***

Is there a lake/p Yes The Union Village Reservoir has a capacity of 1.66 billion cubic feet, significantly affecting the hydrology at this site.

Calculated Discharges

Q100 2600 ***ft³/s*** ***Q500*** 4420 ***ft³/s***

The Q100 was obtained from the Flood Insurance Study for the Town of Norwich (Federal Emergency Management Agency, 1988). The Q500 was determined by multiplying the Q100 by 1.7 (Richardson and others, 1983)

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 101.20 feet from surveyed datum to obtain VTAOT datum

Description of reference marks used to determine USGS datum. RM1 is a chiseled square on top of the DS left wingwall where it meets the left abutment with an arbitrary survey elevation of 500.80 feet.

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT	0	1	Exit section
FV	93	2	Downstream Full-valley section (Templated from EXITX)
BRO	93	1	Bridge section
RD	107	1	Road Grade section
APPR	288	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). 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, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.034 to 0.042, and overbank "n" values ranged from 0.085 to 0.090.

The Connecticut River is downstream of the bridge site about 0.75 miles and causes backwater at this bridge. However, the worst-case scenario was modelled for the scour analysis which is to assume the lowest potential downstream water surface elevation (Richardson and others, 1983). Thus, normal depth was assumed as the starting water surface at the exit section (EXIT). 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 0.003 ft/ft which was determined from the river-bed profile of the Ompompanoosuc River in the Flood Insurance Study for the Town of Norwich (Federal Emergency Management Agency, 1988).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.0 *ft*
Average low steel elevation 497.1 *ft*

100-year discharge 2600 *ft³/s*
Water-surface elevation in bridge opening 484.8 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 378 *ft²*
Average velocity in bridge opening 6.9 *ft/s*
Maximum WSPRO tube velocity at bridge 8.1 *ft/s*

Water-surface elevation at Approach section with bridge 485.8
Water-surface elevation at Approach section without bridge 485.5
Amount of backwater caused by bridge 0.3 *ft*

500-year discharge 4420 *ft³/s*
Water-surface elevation in bridge opening 485.9 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 471 *ft²*
Average velocity in bridge opening 9.4 *ft/s*
Maximum WSPRO tube velocity at bridge 10.8 *ft/s*

Water-surface elevation at Approach section with bridge 487.6
Water-surface elevation at Approach section without bridge 487.0
Amount of backwater caused by bridge 0.6

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). 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 contraction scour equation (Richardson and others, 1993, p. 33, equation 16). 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.

Abutment scour for the right abutment was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). The Froehlich equation gives "excessively conservative estimates of scour depths" (Richardson and others, 1993, p. 48). Scour at the left abutment was computed by use of the HIRE equation (Richardson and others, 1993, p. 50, equation 25) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the abutment scour equations equations 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.

Pier scour was computed by use of the Colorado State University pier scour equation (Richardson and others, 1993, p.39, equation 21).

Observed thalweg depths during site inspections were noted to be as much as 1.4 feet below the bottom of the abutment footings. Although abutments were not undermined, a lateral shift in the thalweg may be of concern.

The pier footing elevation as designed, according to the bridge plans at VTAOT, is 369.2 feet (470.4 feet field survey datum). The plans also indicate that the pier footing is 2.5 feet thick vertically. The plans also indicate that the footer should be placed on bedrock if bedrock was reached above 369.2 feet. The pier *may* set on bedrock since the top of the footer is at 377.5 feet (478.7feet field survey datum) and the bottom of the footer, if its 2.5 feet thick, is at 375.0 feet. No additional information was available.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	2.8	4.5	--
Clear-water scour	--	--	--
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank			

Local scour:			
Abutment scour	3.3	5.6	--
Left abutment	9.7	13.0	--
Right abutment			
Pier scour	13.0	15.1	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Rock Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	0.9	1.7	--
Left abutment	0.9	1.7	--
Right abutment	1.0	1.9	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

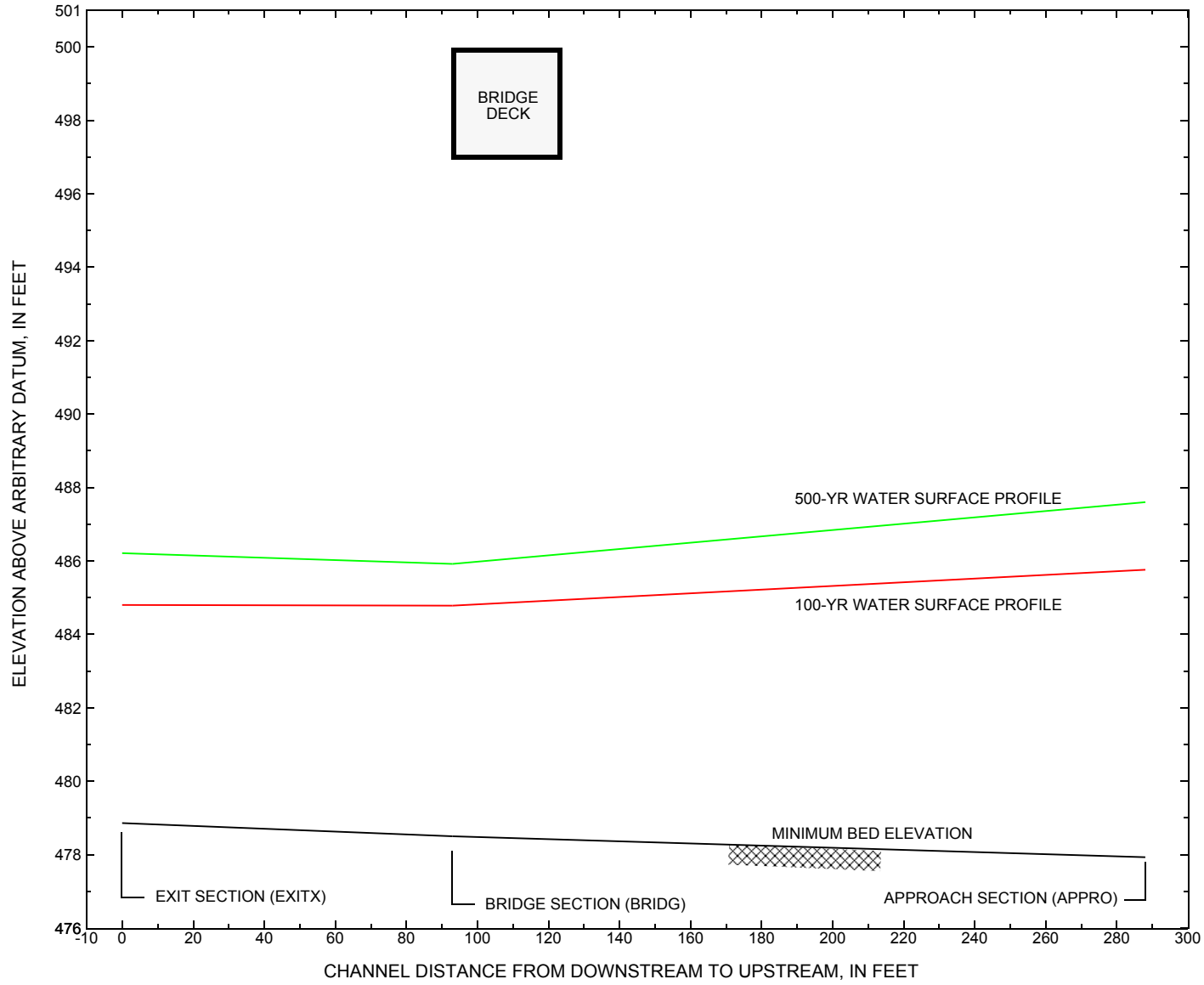


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NORWTH00030046 on town highway 3, crossing the Ompompanoosuc River, Norwich, Vermont.

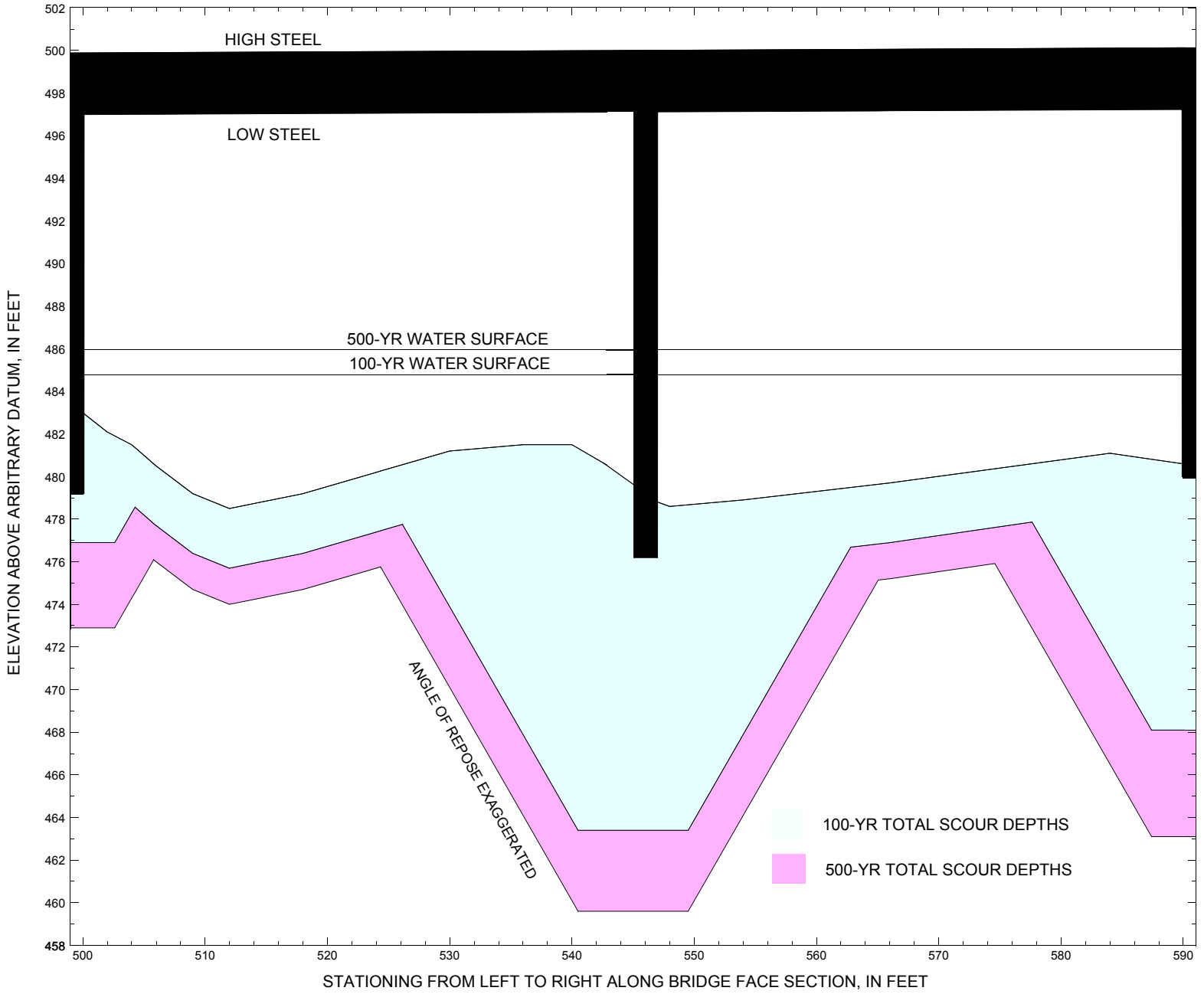


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure NORWTH00030046 on town highway 3, crossing the Ompompanoosuc River, Norwich, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure NORWTH00030046 on Town Highway 3, crossing the Ompompanoosuc River, Norwich, 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 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 2,600 cubic-feet per second											
Left abutment	500	395.9	497.0	479.2	483.0	2.8	3.3	--	6.1	476.9	-2.3
Pier	545	395.9	497.3	476.2	479.2	2.8	--	13.0	15.8	463.4	-12.8
Right abutment	590	395.9	497.1	480.0	480.6	2.8	9.7	--	12.5	468.1	-11.9

[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 NORWTH00030046 on Town Highway 3, crossing the Ompompanoosuc River, Norwich, 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 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 4,420 cubic-feet per second											
Left abutment	500	395.9	497.0	479.2	483.0	4.5	5.6	--	10.1	472.9	-6.3
Pier	545	395.9	497.3	476.2	479.2	4.5	--	15.1	19.6	459.6	-16.6
Right abutment	590	395.9	497.1	480.0	480.6	4.5	13.0	--	17.5	463.1	-16.9

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

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Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

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U.S. Geological Survey, 1981, Lyme, N.H.-VT., 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 norw046.wsp
T2        CREATED ON 23-MAR-95 FOR BRIDGE NORWTH00030046 USING FILE norw046.dca
T3        Ompompanoosuc, Town Highway 3, Town of Norwich, Windsor County
*
J3           6 29 30 28 17 13 23 3 * 5 15 14 7 4 11 12 3
*
Q            2600   4420
SK           0.003  0.003
*
XS   EXIT      0
GR          369., 497.27     384., 496.81     436., 496.65     480., 492.60
GR          497., 488.54     500., 483.92     516., 482.24     522., 480.48
GR          524., 480.04     532., 480.08     542., 479.87     550., 479.79
GR          564., 479.59     575., 478.86     579., 479.49     592., 480.68
GR          602., 481.29     615., 482.05     634., 482.38     643., 482.40
GR          647., 482.80     651., 483.89     654., 484.75     656., 486.57
GR          659., 489.13     684., 488.78     694., 489.09     704., 491.47
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N             0.085       0.042      0.09
SA                  497        659
*
XS   FV       93
*
BR   BRO      93 497.0 25
GR          500., 497.0      500., 483.       502., 482.10     504., 481.50
GR          506., 480.5      509., 479.2      512., 478.5      518., 479.2
GR          524., 480.2      530., 481.2      536., 481.5      540., 481.5
GR          543., 480.5      545.5, 479.2     548, 478.6       554., 478.9
GR          560., 479.3      566., 479.7      572., 480.2      578., 480.7
GR          584., 481.1      590., 480.6      590., 497.148    500., 497.0
N             0.034
CD           1 36.5 * * 32.5 10.6
PW            479,4.5   497,4
*
XR   RD       107 27.5
GR          298., 496.98     342., 497.56     388., 498.76     431., 497.97
GR          500., 499.86     542., 500.26     574., 500.27     602., 500.12
GR          624., 500.65     674., 502.72     717., 505.10     746., 507.70
BP           500
*
AS   APPR     288
GR          181., 495.52     201., 485.51     277., 487.08     435., 484.15
GR          440., 484.28     453., 484.67     460., 485.77
GR          473., 486.89     489., 484.18     500., 479.51     509., 479.44
GR          520., 478.94     530., 478.65     538., 478.06     545., 477.93
GR          565., 479.51     575., 479.33     579., 479.26     585., 479.26
GR          588., 480.29     596., 483.92     600., 485.11     602., 487.61
GR          608., 490.17     617., 492.51     642., 496.94     654., 499.88
GR          672., 503.59     683., 508.27     692., 513.78
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SA                473.
BP           500
*
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HP 1 BRO   484.91 1 484.91
HP 2 BRO   484.91 * * 2600
HP 1 APPR  485.76 1 485.76
HP 2 APPR  485.58 * * 2600
*
HP 1 BRO   485.92 1 485.92
HP 1 BRO   486.11 1 486.11
HP 2 BRO   486.11 * * 4420
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE norw046.wsp
        CREATED ON 23-MAR-95 FOR BRIDGE NORWTH00030046 USING FILE norw046.dca
        Ompompanoosuc, Town Highway 3, Town of Norwich, Windsor County
           *** RUN DATE & TIME: 05-08-95  09:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     378.   43277.    82.    89.                       4615.
  484.78           378.   43277.    82.    89.  1.00   500.   590.   4615.

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     388.   45232.    82.    90.                       4811.
  484.91           388.   45232.    82.    90.  1.00   500.   590.   4811.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
         WSEL     LEW     REW    AREA        K        Q    VEL
       484.91   500.0   590.0   388.5   45232.    2600.   6.69

X STA.       500.0      508.2      511.8      514.7      517.9      521.4
  A(I)            26.9       19.1       16.8       17.0       17.3
  V(I)            4.84       6.80       7.74       7.67       7.53

X STA.       521.4      525.7      531.6      538.8      544.7      547.9
  A(I)            18.4       21.2       22.9       21.7       16.9
  V(I)            7.08       6.13       5.68       6.00       7.69

X STA.       547.9      550.7      553.6      556.8      560.0      563.5
  A(I)            16.1       16.3       16.9       16.7       17.3
  V(I)            8.06       7.99       7.70       7.77       7.50

X STA.       563.5      567.3      571.4      576.3      582.1      590.0
  A(I)            18.1       18.5       20.2       21.5       28.8
  V(I)            7.20       7.02       6.44       6.03       4.52

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR ;  SRD =     288.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      98.    1488.   112.   112.                        522.
             2     684.   75955.   121.   123.                       9232.
  485.76           782.   77443.   233.   235.  1.23   348.   601.   7325.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR ;  SRD =     288.
         WSEL     LEW     REW    AREA        K        Q    VEL
       485.58   357.9   600.4   741.2   73613.    2600.   3.51

X STA.       357.9      499.6      506.2      511.8      517.0      521.8
  A(I)           123.6       39.8       35.1       32.9       31.6
  V(I)            1.05       3.27       3.71       3.95       4.11

X STA.       521.8      526.4      530.8      534.9      538.8      542.5
  A(I)            31.2       30.4       29.4       28.7       28.3
  V(I)            4.16       4.28       4.42       4.53       4.59

X STA.       542.5      546.2      550.1      554.3      558.7      563.5
  A(I)            28.1       29.0       29.2       29.8       30.8
  V(I)            4.63       4.48       4.45       4.37       4.22

X STA.       563.5      568.9      574.0      579.2      584.8      600.4
  A(I)            32.7       32.0       32.3       35.5       50.9
  V(I)            3.98       4.07       4.02       3.67       2.55
```

WSPRO OUTPUT FILE (continued)

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE norw046.wsp
        CREATED ON 23-MAR-95 FOR BRIDGE NORWTH00030046 USING FILE norw046.dca
        Ompompanoosuc, Town Highway 3, Town of Norwich, Windsor County
           *** RUN DATE & TIME: 05-08-95  09:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     471.   61407.    82.    92.                       6419.
  485.92           471.   61407.    82.    92.  1.00   500.   590.   6419.

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     486.   64633.    82.    92.                       6739.
  486.11           486.   64633.    82.    92.  1.00   500.   590.   6739.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRO  ;  SRD =      93.
         WSEL     LEW     REW    AREA        K        Q    VEL
       486.11   500.0   590.0   486.3   64633.    4420.   9.09

X STA.       500.0      508.1      511.8      515.0      518.4      522.0
  A(I)            35.3       23.7       21.5       21.8       21.4
  V(I)            6.26       9.31      10.26      10.12      10.31

X STA.       522.0      526.4      531.8      538.1      543.8      547.4
  A(I)            23.2       25.0       26.8       26.1       21.9
  V(I)            9.54       8.85       8.24       8.46      10.10

X STA.       547.4      550.4      553.5      556.8      560.2      563.7
  A(I)            20.5       20.7       20.9       21.3       21.7
  V(I)           10.80      10.66      10.59      10.39      10.20

X STA.       563.7      567.6      571.8      576.6      582.3      590.0
  A(I)            22.6       23.2       24.9       27.6       36.2
  V(I)            9.80       9.52       8.88       8.00       6.10

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR ;  SRD =     288.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     443.   10132.   273.   273.                      3206.
             2     916.  117899.   129.   133.                     13854.
  487.60          1360.  128031.   402.   406.  1.72   200.   602.  10802.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR ;  SRD =     288.
         WSEL     LEW     REW    AREA        K        Q    VEL
       487.41   200.3   601.8  1283.2  121075.    4420.   3.44

X STA.       200.3      434.0      496.2      503.7      510.2      515.9
  A(I)           304.6      151.1       56.7       51.0       46.8
  V(I)            0.73       1.46       3.90       4.34       4.72

X STA.       515.9      521.2      526.4      531.2      535.8      540.2
  A(I)            44.6       44.5       42.3       41.6       40.3
  V(I)            4.95       4.97       5.22       5.32       5.48

X STA.       540.2      544.5      548.7      553.4      558.2      563.5
  A(I)            40.4       40.1       41.8       41.3       43.4
  V(I)            5.47       5.51       5.28       5.36       5.09

X STA.       563.5      569.0      574.6      580.1      586.2      601.8
  A(I)            43.8       45.3       44.3       49.6       69.6
  V(I)            5.05       4.87       4.99       4.46       3.17
```

WSPRO OUTPUT FILE (continued)

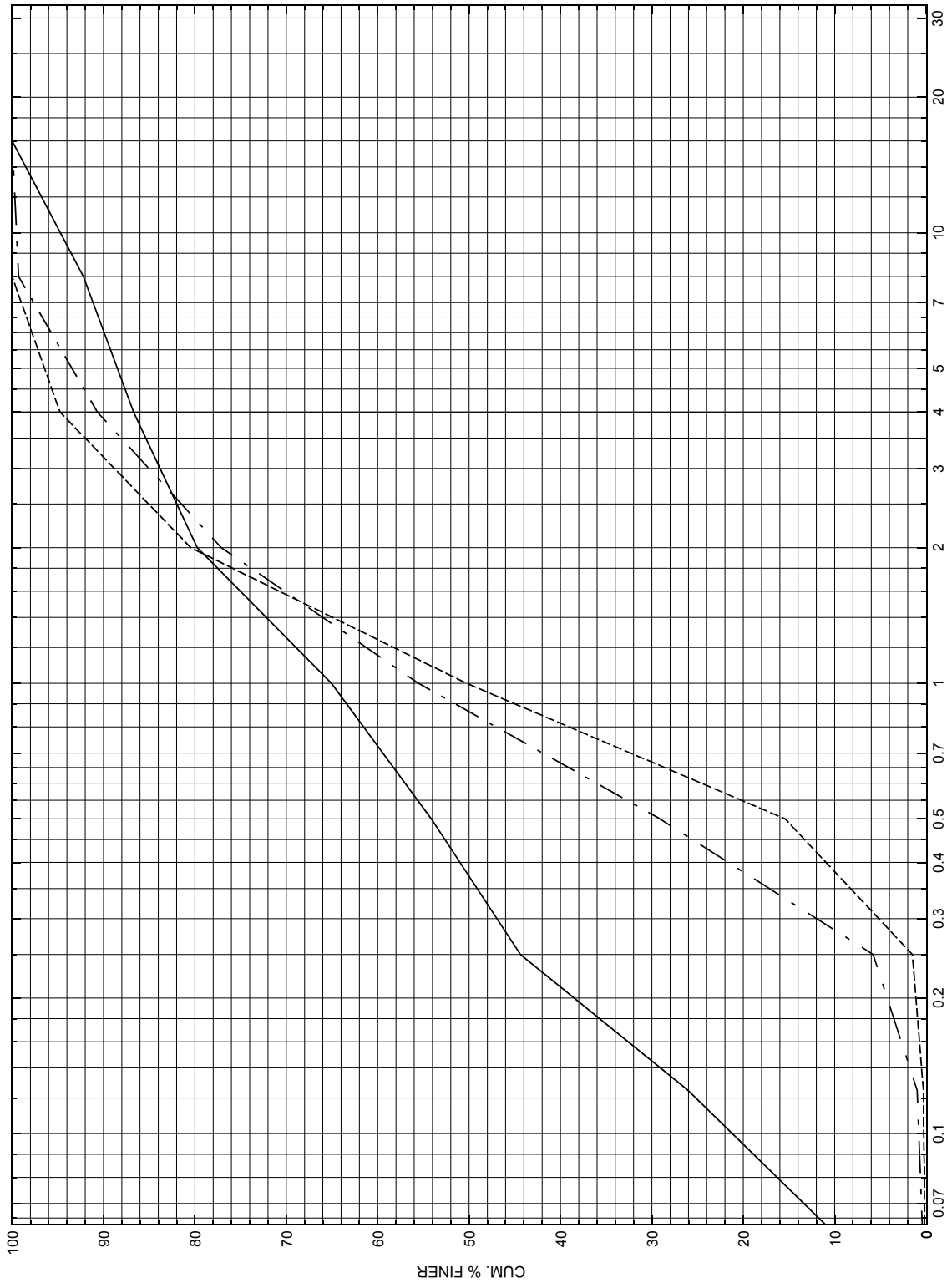
```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE norw046.wsp
        CREATED ON 23-MAR-95 FOR BRIDGE NORWTH00030046 USING FILE norw046.dca
        Ompompanoosuc, Town Highway 3, Town of Norwich, Windsor County
           *** RUN DATE & TIME: 05-08-95  09:39

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

EXIT :XS   ******   499.     566.  0.33 *****  485.13  483.07   2600.  484.80
       0. ******   654.   47461.  1.00 ***** *******    0.42    4.59

FV   :FV      93.   499.     613.  0.28  0.25  485.38 *******   2600.  485.10
      93.    93.   654.   53943.  1.00  0.00    0.01    0.38    4.24
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     195.   363.     721.  0.24  0.34  485.73 *******   2600.  485.49
     288.   195.   600.   71734.  1.18  0.00    0.00    0.38    3.60
        <<<<<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

BRO  :BR      93.   500.     378.  0.74  0.31  485.52  483.50   2600.  484.78
      93.    93.   590.   43326.  1.00  0.08    0.00    0.56    6.88

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.068  497.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RD   :RG     107.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR :AS     159.   348.     782.  0.21  0.33  485.97  481.95   2600.  485.76
     288.   161.   601.   77465.  1.23  0.13    0.01    0.36    3.32

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.621  0.012   76255.   495.   585.   485.57

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW   XSTW     AREA     VEL    YMIN    WSEL
   EXIT :XS       0.   499.   654.   155.     566.    4.59  478.86  484.80
   FV   :FV      93.   499.   654.   155.     613.    4.24  478.86  485.10
   BRO  :BR      93.   500.   590.    82.     378.    6.88  478.50  484.78
   RD   :RG     107.*****************************    1.00  496.98********
   APPR :AS     288.   348.   601.   233.     782.    3.32  477.93  485.76

 SECOND USER DEFINED TABLE.
    XSID:CODE       Q    CRWS     FR#     EGL  VHD     HF    HO     WSEL
   EXIT :XS     2600.  483.07    0.42  485.13  0.33************  484.80
   FV   :FV     2600.********    0.38  485.38  0.28  0.25  0.00  485.10
   BRO  :BR     2600.  483.50    0.56  485.52  0.74  0.31  0.08  484.78
   RD   :RG        0.**********************************************
   APPR :AS     2600.  481.95    0.36  485.97  0.21  0.33  0.13  485.76
```

WSPRO OUTPUT FILE (continued)

```
         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE norw046.wsp
        CREATED ON 23-MAR-95 FOR BRIDGE NORWTH00030046 USING FILE norw046.dca
        Ompompanoosuc, Town Highway 3, Town of Norwich, Windsor County
           *** RUN DATE & TIME: 05-08-95  09:39

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

EXIT :XS   ******   499.     786.  0.49 *****  486.70  484.06   4420.  486.21
       0. ******   656.   80664.  1.00 ***** *******    0.44    5.62

FV   :FV      93.   498.     836.  0.44  0.25  486.96 *******   4420.  486.53
      93.    93.   656.   89020.  1.00  0.00    0.01    0.41    5.29
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     195.   281.    1125.  0.36  0.40  487.36 *******   4420.  487.00
     288.   195.   602.  108302.  1.51  0.00    0.00    0.45    3.93
        <<<<<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

BRO  :BR      93.   500.     471.  1.37  0.37  487.29  484.90   4420.  485.92
      93.    93.   590.   61447.  1.00  0.22    0.00    0.69    9.38

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.065  497.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RD   :RG     107.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR :AS     159.   200.    1360.  0.28  0.41  487.88  483.18   4420.  487.60
     288.   163.   602.  128031.  1.72  0.19    0.01    0.41    3.25

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.719  0.111  113493.   494.   584.   487.40

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW   XSTW     AREA     VEL    YMIN    WSEL
   EXIT :XS       0.   499.   656.   157.     786.    5.62  478.86  486.21
   FV   :FV      93.   498.   656.   158.     836.    5.29  478.86  486.53
   BRO  :BR      93.   500.   590.    82.     471.    9.38  478.50  485.92
   RD   :RG     107.*****************************    1.00  496.98********
   APPR :AS     288.   200.   602.   402.    1360.    3.25  477.93  487.60

 SECOND USER DEFINED TABLE.
    XSID:CODE       Q    CRWS      FR#     EGL  VHD     HF    HO     WSEL
   EXIT :XS     4420.  484.06     0.44  486.70  0.49************  486.21
   FV   :FV     4420.********     0.41  486.96  0.44  0.25  0.00  486.53
   BRO  :BR     4420.  484.90     0.69  487.29  1.37  0.37  0.22  485.92
   RD   :RG        0.************************************************
   APPR :AS     4420.  483.18     0.41  487.88  0.28  0.41  0.19  487.60
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution at the approach cross-section for structure NORWTH00030046, in Norwich, Vermont.

APPENDIX D:

HISTORICAL DATA FORM