LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (BAKEVT01080041) on STATE ROUTE 108, crossing THE BRANCH, BAKERSFIELD, VERMONT

U.S. Geological Survey
Open-File Report 96-643

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

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By Erick M. Boehmler and James R. Degnan

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Pembroke, New Hampshire

1996

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 41 (BAKEVT01080041) ON STATE ROUTE 108, CROSSING THE BRANCH, BAKERSFIELD, VERMONT

***By* Erick M. Boehmler And James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BAKEVT01080041 on State Route 108 crossing The Branch, Bakersfield, 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 8.74-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream of the bridge and pasture downstream with trees along the immediate channel banks.

In the study area, The Branch has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 31 ft and an average channel depth of 3 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 49.6 mm (0.163 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 28, 1995, indicated that the reach was stable.

The State Route 108 crossing of The Branch is a 34-ft-long, two-lane bridge consisting of one 32-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 7, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

The only scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) along the upstream left bank and the upstream end of the upstream left wingwall. 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 1.9 to 3.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.1 to 13.5 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 BAKEVT01080041 ***Stream*** The Branch

County Franklin ***Road*** VT 108 ***District*** 8

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 33.5 ***ft*** ***Max span length*** 32 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/28/95

Description of stone fill Type-2 along the upstream left bank and the upstream end of the upstream left wingwall.

Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to No ***survey?*** Y ***Angle*** 45

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

	Date of inspection	Percent of channel blocked horizontally	Percent of channel blocked vertically
Level I	6/28/95	0	0
Level II	6/28/95	0	0

Potential for debris Low. There is significant tree growth on the banks but the channel is stable.

Describe any features near or at the bridge that may affect flow (include observation date) There is log cribbing noted on 6/28/95 for which there are 15 logs crossing the channel bed downstream of the bridge. The logs are anchored by an old concrete wall on the left bank side.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with narrow, irregular overbank areas and steep valley walls on both sides.

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

Date of inspection 6/28/95

DS left: Moderately sloping bank to a narrow overbank and VT 108 roadway.

DS right: Moderately sloping bank and overbank.

US left: Moderately sloping bank to narrow, irregular overbank.

US right: Gradually sloping bank and overbank to VT 108 roadway.

Description of the Channel

Average top width 31 ft ***Average depth*** 3 ft

Predominant bed material Gravel ***Bank material*** Gravel

Perennial and sinuous but stable with semi-alluvial channel boundaries.

6/28/95

Vegetative co Trees.

DS left: Trees and brush

DS right: Brush

US left: Trees, grass, shrubs, and brush

US right:

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

None evident on 6/28/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.74 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,330 ***ft³/s*** ***Q500*** 1,880 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; Potter, 1957; Talbot, 1887). The median value of the 100- and 500-year discharges was computed and applied for this site.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is the center point of a chiseled "X" on top of the left abutment, upstream end (elev. 499.47 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete curb at the downstream right corner of the bridge deck (elev. 500.39 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	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	25	1	Road Grade section
APPRO	70	2	Modelled Approach section (Templated from APTEM)
APTEM	87	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.040, and overbank "n" values ranged from 0.040 to 0.065.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0097 ft/ft, which was estimated from surveyed thalweg points downstream of the EXITX section.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0079 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This method also provides a consistent approach for determining scour variables.

For the 100- and 500-year discharge, WSPRO assumes critical depth at the full-valley and bridge sections. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, it can be 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 496.8 *ft*

100-year discharge 1,330 *ft³/s*
Water-surface elevation in bridge opening 491.1 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 104.3 *ft²*
Average velocity in bridge opening 12.7 *ft/s*
Maximum WSPRO tube velocity at bridge 15.8 *ft/s*

Water-surface elevation at Approach section with bridge 494.5
Water-surface elevation at Approach section without bridge 492.2
Amount of backwater caused by bridge 2.3 *t*

500-year discharge 1,880 *ft³/s*
Water-surface elevation in bridge opening 492.5 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 131 *ft²*
Average velocity in bridge opening 14.3 *ft/s*
Maximum WSPRO tube velocity at bridge 18.0 */s*

Water-surface elevation at Approach section with bridge 496.4
Water-surface elevation at Approach section without bridge 493.3
Amount of backwater caused by bridge 3.1

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 -- *t*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. Since the critical grain size is greater than the D_{95}, armoring is improbable.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.9	3.0	--
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.1	12.9	--
Right abutment	11.2	13.5	--
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	2.1	2.7	--
Right abutment	2.1	2.7	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

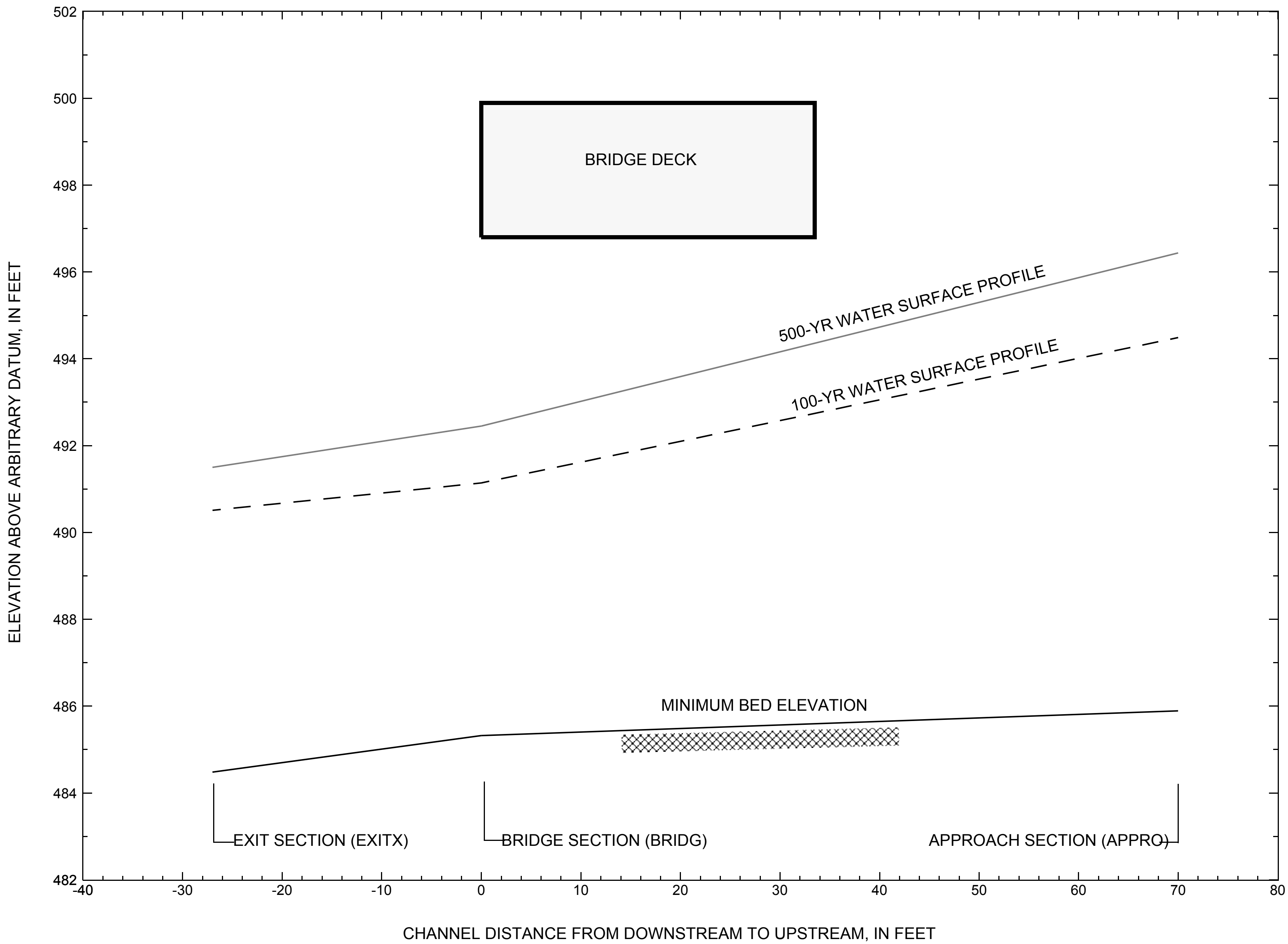

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BAKEVT01080041 on State Route 108, crossing The Branch, Bakersfield, Vermont.

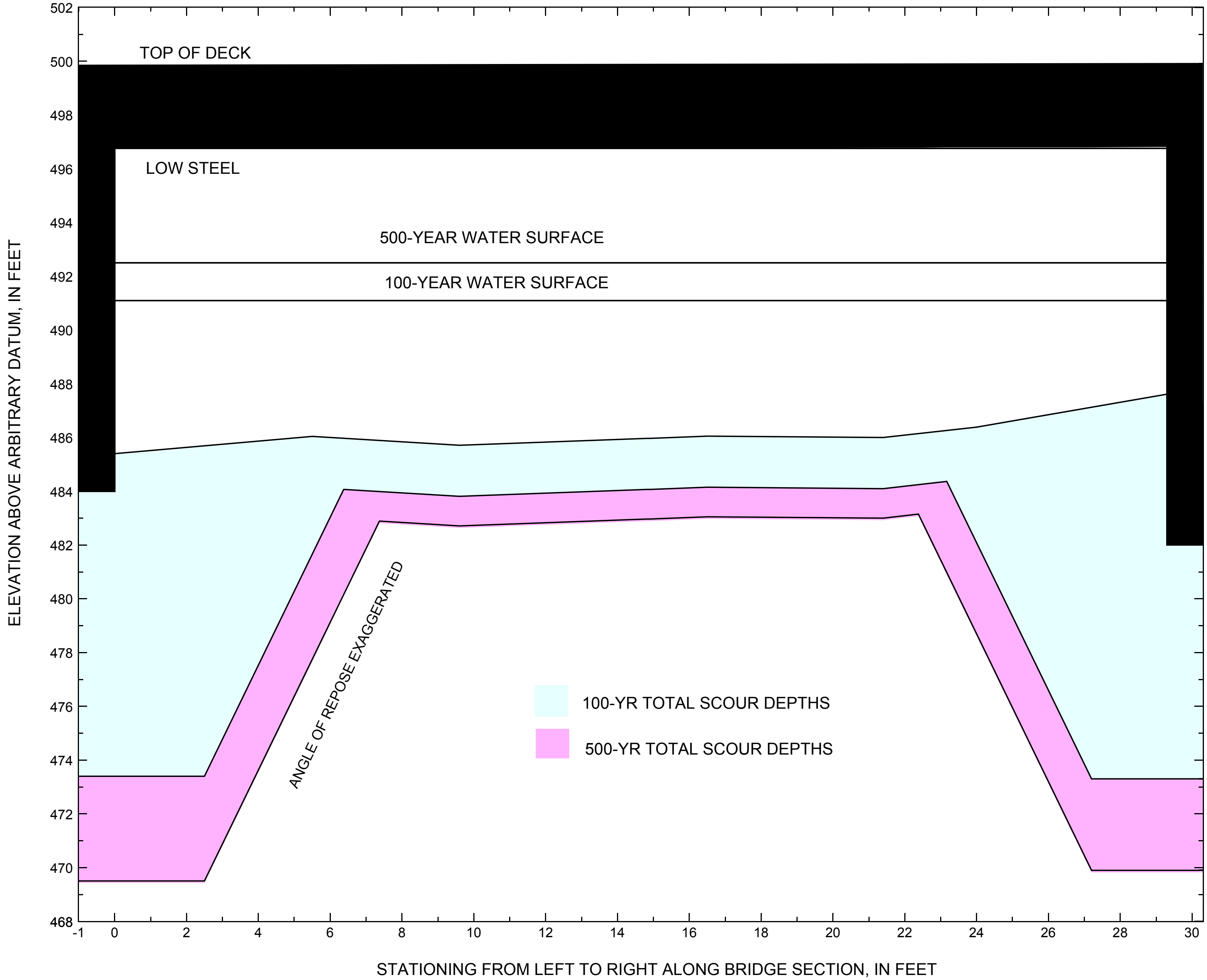

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BAKEVT01080041 on State Route 108, crossing The Branch, Bakersfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BAKEVT01080041 on State Route 108, crossing The Branch, Bakersfield, Vermont.

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

Description	Station[1]	VTAOT Average 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 1,330 cubic-feet per second											
Left abutment	0.0	564.5	496.9	484	485.4	1.9	10.1	--	12.0	473.4	-11
Right abutment	29.3	564.5	496.7	482	486.4	1.9	11.2	--	13.1	473.3	-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 BAKEVT01080041 on State Route 108, crossing The Branch, Bakersfield, 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 1,880 cubic-feet per second											
Left abutment	0.0	564.5	496.9	484	485.4	3.0	12.9	--	15.9	469.5	-15
Right abutment	29.3	564.5	496.7	482	486.4	3.0	13.5	--	16.5	469.9	-12

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, Bakersfield, 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 bake041.wsp
T2        Hydraulic analysis for structure BAKEVT01080041   Date: 16-SEP-96
T3        State Route 108 Crossing The Branch, Bakersfield, VT               EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1330.0   1880.0
SK          0.0097   0.0097
*
XS   EXITX    -27
GR         -151.0, 498.50   -111.0, 494.00    -40.9, 493.63    -14.8, 493.49
GR          -13.2, 492.65     -6.8, 488.45      0.0, 487.55      3.0, 486.85
GR            4.1, 484.48      4.3, 485.11      6.6, 484.59     20.9, 485.12
GR           24.2, 487.12     45.4, 495.40     81.7, 496.71
*
N           0.045        0.040        0.045
SA                 -13.2         45.4
*
XS   FULLV       0  * * *   0.0310
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    496.80      45.0
GR            0.0, 496.86      0.0, 485.40      5.5, 486.04      9.6, 485.71
GR           16.5, 486.05     21.4, 486.00     24.0, 486.39     29.3, 487.61
GR           29.3, 496.74      0.0, 496.86
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      49.5     1.2     499.9     60.0
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY      25      33.5     1
GR         -145.3, 502.61   -130.3, 500.41      0.0, 499.85      0.0, 502.24
GR           34.0, 502.14     34.0, 499.91    168.2, 500.58
*
XT   APTEM      87
GR          -40.6, 512.07    -31.2, 506.16    -29.0, 497.10    -20.4, 493.61
GR           -8.3, 493.36      0.0, 487.89      4.8, 486.84      7.8, 486.02
GR           10.9, 486.51     15.3, 486.75     25.3, 487.79     29.5, 488.86
GR           50.6, 490.40     66.4, 498.40
*
AS   APPRO      70  *  *  *  0.00787
GT
N           0.040        0.040        0.065
SA                  -8.3         29.5
*
HP 1 BRIDG 491.14 1 491.14
HP 2 BRIDG 491.14 * * 1330
HP 1 APPRO 494.49 1 494.49
HP 2 APPRO 494.49 * * 1330
*
HP 1 BRIDG 492.45 1 492.45
HP 2 BRIDG 492.45 * * 1880
HP 1 APPRO 496.44 1 496.44
HP 2 APPRO 496.44 * * 1880
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File bake041.wsp
       Hydraulic analysis for structure BAKEVT01080041   Date: 16-SEP-96
       State Route 108 Crossing The Branch, Bakersfield, VT               EMB
          *** RUN DATE & TIME: 09-23-96  10:20

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      104     10127     21     30                         1329
  491.14           104     10127     21     30  1.00      0     29     1329

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

        WSEL     LEW     REW    AREA       K        Q    VEL
      491.14     0.0    29.3   104.3   10127.    1330.  12.75

X STA.        0.0        2.6        4.2        5.7        7.0        8.3
  A(I)           10.4        6.0        5.3        4.9        4.7
  V(I)           6.40      10.99      12.53      13.63      14.18

X STA.        8.3        9.4       10.6       11.7       12.9       14.0
  A(I)            4.4        4.4        4.4        4.3        4.2
  V(I)          15.01      15.20      15.24      15.58      15.75

X STA.       14.0       15.2       16.4       17.6       18.8       20.0
  A(I)            4.2        4.3        4.3        4.4        4.5
  V(I)          15.66      15.35      15.50      15.26      14.81

X STA.       20.0       21.3       22.6       24.1       26.0       29.3
  A(I)            4.5        4.8        5.1        6.0        9.3
  V(I)          14.73      13.87      12.98      11.17       7.19

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       15       567     15     15                           87
            2      254     32434     38     40                         3729
            3      123      7141     29     31                         1426
  494.49           392     40142     82     85  1.32    -22     59     4238

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

        WSEL     LEW     REW    AREA       K        Q    VEL
      494.49   -22.9    58.9   391.7   40142.    1330.   3.40

X STA.      -22.9       -2.0        1.0        3.4        5.4        7.2
  A(I)           36.0       19.4       16.7       15.7       15.0
  V(I)           1.85       3.42       3.99       4.22       4.43

X STA.        7.2        8.9       10.6       12.3       14.1       15.8
  A(I)           14.3       13.9       13.9       14.1       13.9
  V(I)           4.65       4.79       4.78       4.73       4.79

X STA.       15.8       17.6       19.5       21.5       23.6       25.8
  A(I)           14.1       14.1       14.7       14.7       15.0
  V(I)           4.73       4.70       4.53       4.53       4.44

X STA.       25.8       28.2       32.3       38.0       44.8       58.9
  A(I)           15.8       23.3       30.6       33.2       43.4
  V(I)           4.20       2.86       2.17       2.00       1.53
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File bake041.wsp
       Hydraulic analysis for structure BAKEVT01080041   Date: 16-SEP-96
       State Route 108 Crossing The Branch, Bakersfield, VT               EMB
          *** RUN DATE & TIME: 09-23-96  10:20

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      131     14088     21     33                          1879
  492.45           131     14088     21     33  1.00      0     29      1879

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

        WSEL     LEW     REW    AREA       K        Q    VEL
      492.45     0.0    29.3   131.5   14088.    1880.  14.30

X STA.        0.0        2.8        4.5        5.9        7.3        8.5
  A(I)           13.5        8.0        6.6        6.3        5.8
  V(I)           6.95      11.81      14.23      15.02      16.15

X STA.        8.5        9.7       10.8       12.0       13.1       14.2
  A(I)            5.5        5.4        5.4        5.3        5.2
  V(I)          17.17      17.48      17.49      17.85      18.00

X STA.       14.2       15.4       16.5       17.7       18.9       20.1
  A(I)            5.3        5.2        5.3        5.5        5.4
  V(I)          17.82      17.98      17.83      17.21      17.38

X STA.       20.1       21.3       22.6       24.2       25.9       29.3
  A(I)            5.7        5.9        6.6        7.3       12.4
  V(I)          16.52      15.88      14.28      12.79       7.58

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       48      3229     19     20                           431
            2      327     49617     38     40                          5468
            3      184     12813     33     35                          2458
  496.44           560     65659     90     95  1.35    -27     63      6809

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

        WSEL     LEW     REW    AREA       K        Q    VEL
      496.44   -27.7    62.8   559.8   65659.    1880.   3.36

X STA.      -27.7       -8.1       -1.8        1.1        3.6        5.7
  A(I)           48.8       33.9       24.9       22.7       20.8
  V(I)           1.93       2.77       3.77       4.13       4.52

X STA.        5.7        7.7        9.6       11.6       13.5       15.5
  A(I)           20.4       19.6       19.6       19.8       19.5
  V(I)           4.62       4.79       4.80       4.76       4.81

X STA.       15.5       17.5       19.6       21.8       24.0       26.4
  A(I)           19.3       20.1       20.0       20.5       20.9
  V(I)           4.86       4.67       4.71       4.59       4.50

X STA.       26.4       29.2       34.2       39.9       46.7       62.8
  A(I)           22.7       37.5       40.9       45.8       62.1
  V(I)           4.15       2.51       2.30       2.05       1.51
```

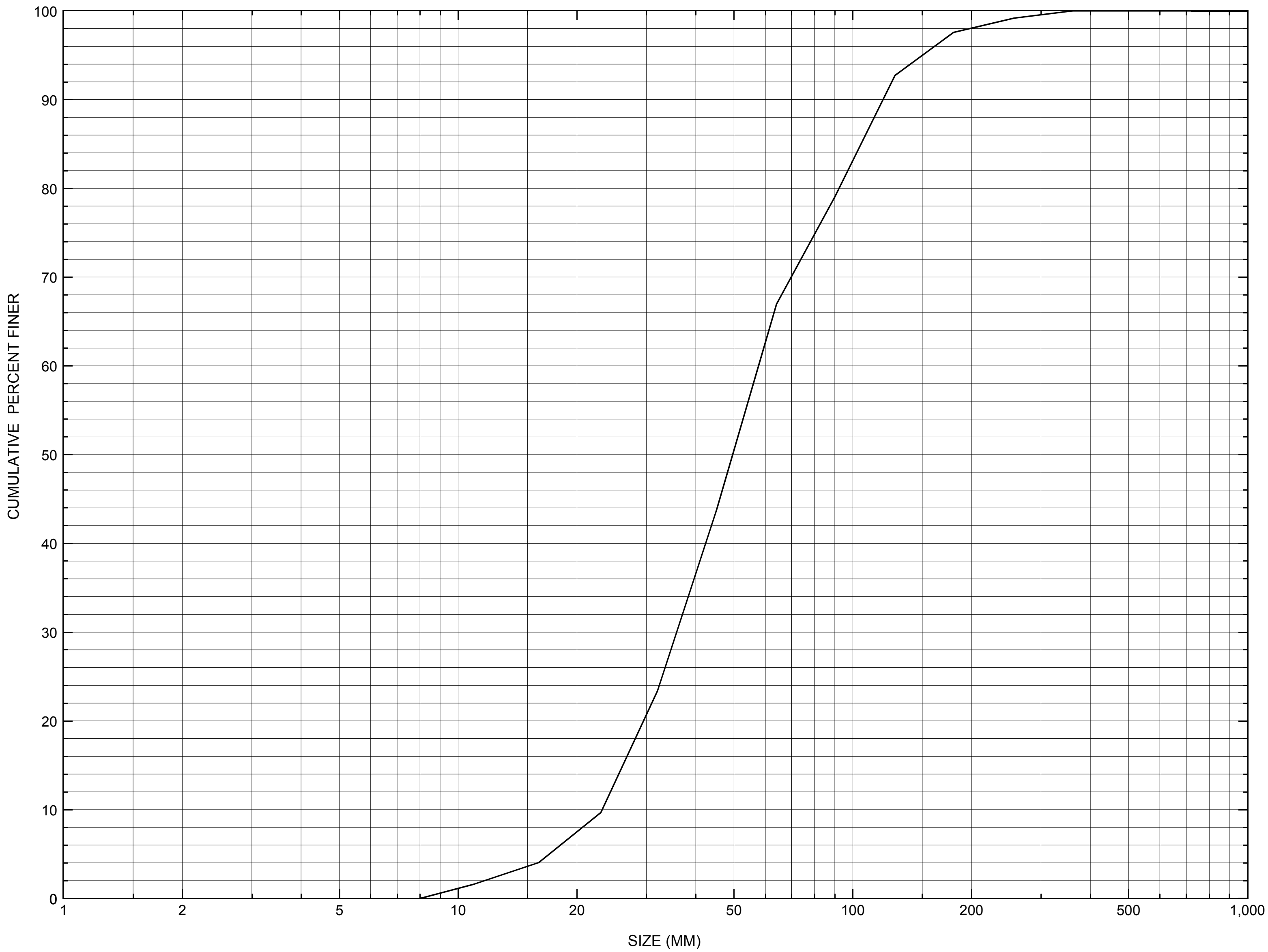
```
        U.S. Geological Survey WSPRO Input File bake041.wsp
        Hydraulic analysis for structure BAKEVT01080041   Date: 16-SEP-96
        State Route 108 Crossing The Branch, Bakersfield, VT               EMB
           *** RUN DATE & TIME: 09-23-96  10:20

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

EXITX:XS   ******     -9      160  1.08 *****  491.59  489.78    1330  490.51
       -26 ******     33    13498  1.00 ***** *******    0.76    8.32

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.03     490.56     490.62

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.01     499.34    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.01     499.34     490.62

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "FULLV"
                  WSBEG,WSEND,CRWS =   490.62     499.34     490.62

FULLV:FV       27     -8      130  1.64 *****  492.25  490.62    1330  490.62
         0     27     31    10008  1.00 ***** *******    1.00   10.26
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.95

APPRO:AS       70     -6      231  0.65  0.63  492.88 *******    1330  492.23
        70     70     54    19555  1.26  0.00    0.00    0.59    5.77
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =   1330.     491.14

             <<<<<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       27      0      104  2.52 *****  493.67  491.14    1330  491.14
         0     27     29    10141  1.00 ***** *******    1.00   12.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  496.80 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      25.        <<<<<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       21    -22      392  0.24  0.10  494.73  490.97    1330  494.49
        70     23     59    40187  1.32  0.96   -0.01    0.31    3.39

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.522  0.243   30495.     1.    31.   494.45

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -27.   -10.    33.   1330.   13498.     160.    8.32  490.51
   FULLV:FV       0.    -9.    31.   1330.   10008.     130.   10.26  490.62
   BRIDG:BR       0.     0.    29.   1330.   10141.     104.   12.73  491.14
   RDWAY:RG      25.**************      0.******************    1.00********
   APPRO:AS      70.   -23.    59.   1330.   40187.     392.    3.39  494.49

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    31.   30495.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    489.78    0.76  484.48  498.50************  1.08  491.59  490.51
   FULLV:FV    490.62    1.00  485.32  499.34************  1.64  492.25  490.62
   BRIDG:BR    491.14    1.00  485.40  496.86************  2.52  493.67  491.14
   RDWAY:RG  ****************  499.85  502.61**********************************
   APPRO:AS    490.97    0.31  485.89  511.94  0.10   0.96  0.24  494.73  494.49
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File bake041.wsp
       Hydraulic analysis for structure BAKEVT01080041   Date: 16-SEP-96
       State Route 108 Crossing The Branch, Bakersfield, VT               EMB
          *** RUN DATE & TIME: 09-23-96  10:20

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

EXITX:XS   ******    -10      204  1.32 *****  492.82  490.71    1880  491.50
       -26 ******     35    19082  1.00 ***** *******    0.78    9.21

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.01     491.52     491.55

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.00     499.34    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.00     499.34     491.55

FULLV:FV       27     -9      168  1.94  0.34  493.48  491.55    1880  491.55
         0     27     33    14537  1.00  0.31    0.01    1.00   11.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.92

APPRO:AS       70    -11      299  0.77  0.61  494.08 *******    1880  493.31
        70     70     57    27967  1.26  0.00   -0.01    0.60    6.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1880.     492.45

            <<<<<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       27      0      131  3.18 *****  495.63  492.45    1880  492.45
         0     27     29    14091  1.00 ***** *******    1.00   14.30

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  496.80 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      25.        <<<<<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       21    -27      560  0.24  0.09  496.67  491.75    1880  496.44
        70     23     63    65626  1.35  0.95   -0.01    0.28    3.36

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.575  0.324   44438.     2.    31.   496.41

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.   -11.    35.   1880.  19082.     204.    9.21  491.50
   FULLV:FV       0.   -10.    33.   1880.  14537.     168.   11.17  491.55
   BRIDG:BR       0.     0.    29.   1880.  14091.     131.   14.30  492.45
   RDWAY:RG      25.**************      0.******************    1.00********
   APPRO:AS      70.   -28.    63.   1880.  65626.     560.    3.36  496.44

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    31.   44438.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    490.71    0.78  484.48  498.50************  1.32  492.82  491.50
   FULLV:FV    491.55    1.00  485.32  499.34  0.34  0.31  1.94  493.48  491.55
   BRIDG:BR    492.45    1.00  485.40  496.86************  3.18  495.63  492.45
   RDWAY:RG  ****************  499.85  502.61**********************************
   APPRO:AS    491.75    0.28  485.89  511.94  0.09  0.95  0.24  496.67  496.44
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect in the channel approach of structure BAKEVT01080041, in Bakersfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BAKEVT01080041

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 02500

Mile marker *(I - 11; nnn.nnn)* 007030

Waterway *(I - 6)* THE BRANCH

Road Name *(I - 7)*: -

Route Number VT108

Vicinity *(I - 9)* 3.4 MI N JCT. VT.36

Topographic Map Bakersfield

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44495

Longitude *(i - 17; nnnnn.n)* 72479

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002700410601

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

Maximum span length *(I - 48; nnnn)* 0032

Year built *(I - 27; YYYY)* 1952

Structure length *(I - 49; nnnnnn)* 000034

Average daily traffic, ADT *(I - 29; nnnnnn)* 001030

Deck Width *(I - 52; nn.n)* 335

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

Channel & Protection *(I - 61; n)* 7

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

Waterway adequacy *(I - 71; n)* 6

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 10.5

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

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

Comments:

The structural inspection report of 8/2/93 indicates the structure is a concrete T-beam type bridge. Both abutment walls have minor scaling along the flow line reported. The right abutment has two vertical cracks. There is some slight forward displacement in the right abutment wall. The left abutment has a vertical crack. The wingwalls also have some hairline cracking noted. The left abutment footing is exposed in a few locations near the roadway centerline. The streambed material is mostly stone and gravel. The waterway proceeds straight through the structure. Just downstream there is a log crib system across the channel, apparently from an older structure. The stream banks are (Continued, page 31)

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Stone and gravel

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -

Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / - / - Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): Y *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: **Bakersfield** Year Built: **1923**
Highway No. : **TH06** Structure No. : **42** Structure Type: **Conc. T-beam**
Clear span (*ft*): **22** Clear Height (*ft*): **5.5** Full Waterway (ft^2): **121.0**

Comments:

noted as well protected with stone fill. Cracking is noted as a possible sign of some settling. There was no road embankment erosion noted.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.74** mi^2 Lake and pond area **0.04** mi^2

Watershed storage *(ST)* **0.5** %

Bridge site elevation **561** ft Headwater elevation **1910** ft

Main channel length **7.99** mi

10% channel length elevation **594** ft 85% channel length elevation **1161** ft

Main channel slope *(S)* **94.61** 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)*: **07** / **1951**

Project Number **-** Minimum channel bed elevation: **553.6**

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

Benchmark location description:

BM# 19, spike in root of 72" elm tree, 20 feet right bankward from the right abutment and 102 feet from the roadway centerline downstream on the right overbank, elev. 562.14. The tree is on the nearest side of the roadway leading to an older structure mentioned earlier for which the bridge was removed just downstream.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **551.6**

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: **3**

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

Briefly describe material at foundation bottom elevation or around piles:

The footings are set in mostly sand and gravel.

Comments:

The average bridge seat elevation noted on the plans is 564.5 feet. The bottom of footing elevation indicated is that for the left abutment. The right abutment footing is shown as set at 549.64 feet. The streambed level shown was graded under the bridge with an elevation shown 2 feet above the top of both abutment footings. The land surface profile before building the bridge and roadway to bridge shows the streambed elevation was higher than the proposed streambed elevation after construction. The channel was moved in order for it to flow through this bridge. Previously, the channel ran through where the current right road approach embankment is located immediately adjacent to the current right abutment.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low 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*)? N

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 3/19/96
Computerized by: RB Date: 3/20/96
Reviewd by: EMB Date: 9/23/96

Structure Number BAKEVT01080041

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 6 / 29 / 1995
2. Highway District Number 08 Mile marker 007030
   County Franklin (011) Town Bakersfield (02500)
   Waterway *(I - 6)* The Branch Road Name -
   Route Number VT 108 Hydrologic Unit Code: 02010007
3. Descriptive comments:

Located 3.4 miles north from the junction of VT 108 with VT 36.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 4 RBDS 4 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 2 UB 2 DS 2 *(**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 34 *(feet)* Span length 32 *(feet)* Bridge width 33.5 *(feet)*

Road approach to bridge:

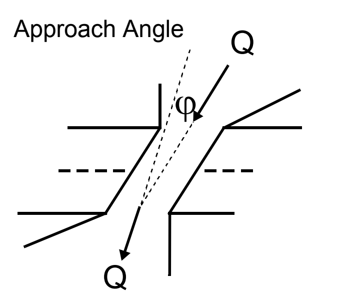
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left 0.0:1 US right 0.0:1

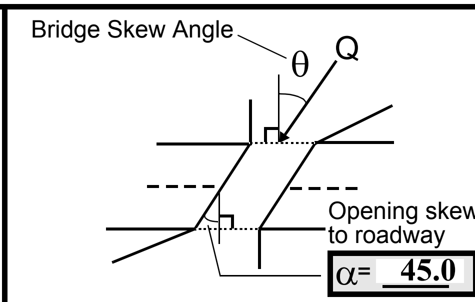
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	2	2
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 45





17. Channel impact zone 1: Exist? Y *(Y or N)*
    Where? LB *(LB, RB)* Severity 2
    Range? 85 feet US *(US, UB, DS)* to 110 feet US
    Channel impact zone 2: Exist? N *(Y or N)*
    Where? - *(LB, RB)* Severity -
    Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: **4**

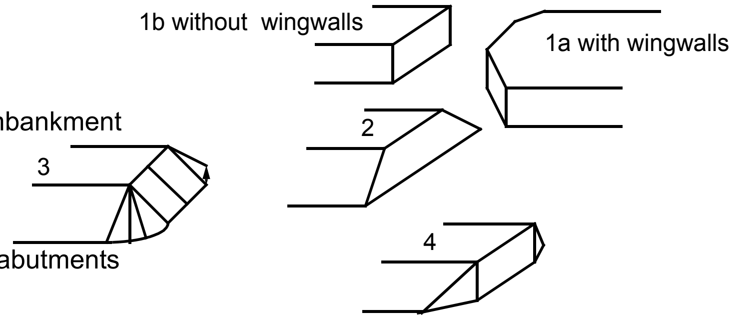
1a- Vertical abutments with wingwalls

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. Values are from the VT AOT files.
11. The DS right bank road approach has a slight gully right behind the DS right wingwall from road wash. The DS left bank road approach erosion does not affect the top of the wingwall because it runs down in gullies from the side of the road.
4. The left bank US has a gravel road that goes along the bank and is forest beyond. The left bank DS has trees on the immediate bank. On the right bank downstream there is a house and on the immediate bank are shrubs.

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
39.5	**5.5**			**1.0**	**1**	**2**	**7**	**34**	**1**	**1**

23. Bank width **30.0** 24. Channel width **15.0** 25. Thalweg depth **38.0** 29. Bed Material **345**

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

30. The left bank protection starts at 125 feet US and ends at the US end of the US left wingwall. It protects the dirt road following the bank.
27. The left bank material is stone fill.
There is a culvert that is not presently flowing that empties out just US of the US left wingwall. It runs under the dirt road on the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **94** 35. Mid-bar width: **6**

36. Point bar extent: **103** feet **US** (US, UB) to **64** feet **DS** (US, UB, DS) positioned **70** %LB to **100** %RB

37. Material: **342**

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

There are a few cobbles and interstitial sand. There is more material extending DS but it is more sporadically deposited with larger components.

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
The left bank would be a cut bank if it wasn't protected.

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) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
25.5		1.0		2	7	7	0

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **90.0** 63. Bed Material **0**

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.):

345
The thalweg wanders from the left bank to the right bank as it passes under the bridge.

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? 2__ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Areas of the reach have significant tree coverage but the banks are stable so debris is unlikely to fall in the stream. The capture potential for the bridge is moderate because it will constrict the bank full flow and the drop structure will lower the under bridge velocity during high flow.

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		-	90	2	2	0	0	90.0
RABUT	1	5	90			2	0	20.5

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

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

-

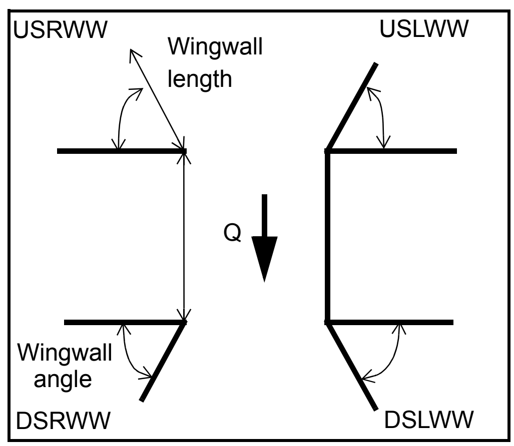
-

1

The top of the left abutment footing is level with the stream bed. The right footing is not exposed. It is deeper than the left footing because the channel is nearly the same depth on each side.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						20.5	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	49.5	
DSRWW:	1		0		-	49.5	



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

82. **Bank / Bridge Protection**:

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

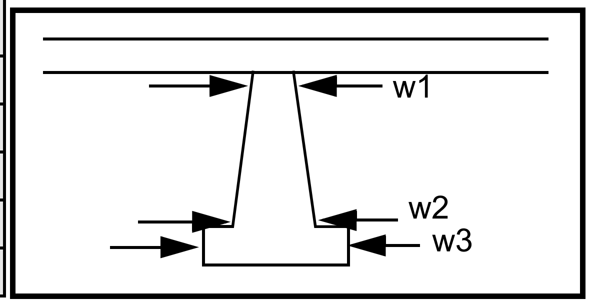
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**105.0**			**9.5**	**15.0**	**19.5**
Pier 2			**105.0**	**15.0**	**21.5**	**10.0**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e US**	**the**	**tact**	**DS**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**left**	**wate**	**the**	**left**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**wing**	**r**	**abut**	**wing**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wall**	**level**	**ment**	**wall**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**and**	**at**	**s.**	**are**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**the**	**The**	**pro-**	
92. Pushed	**DS**	**point**	**US**	**tecte**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**right**	**s**	**right**	**d**	
95. Cross-members	**wing**	**wher**	**wing**	**with**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wall**	**e**	**wall**	**grav**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**are**	**they**	**and**	**el fill**	
98. Exposure depth	**at**	**con-**	**the**	**and**	

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

are not exposed much.

N

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: RS 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.):

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 2

Scour dimensions: Length 2 Width 342 Depth: 342 Positioned 2 %LB to 1 %RB

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

345
0
0
-

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

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

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

Confluence comments (eg. confluence name):

erately just DS from the end of the short concrete wall on the left bank that holds down logs of the drop structure. Elsewhere there is little noticeable erosion on the banks DS. The material in the banks is roughly the

F. Geomorphic Channel Assessment

107. Stage of reach evolution sa

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)*:

me as on the right bank US with more sand.

109. G. Plan View Sketch

- Y

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: BAKEVT01080041 Town: Bakersfield
Road Number: VT 108 County: Franklin
Stream: The Branch

Initials EMB Date: 9/16/96 Checked:

I. 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	1330	1880	0
Main Channel Area, ft2	254	327	0
Left overbank area, ft2	15	48	0
Right overbank area, ft2	123	184	0
Top width main channel, ft	38	38	0
Top width L overbank, ft	15	19	0
Top width R overbank, ft	29	33	0
D50 of channel, ft	0.163	0.163	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.7	8.6	ERR
y1, average depth, LOB, ft	1.0	2.5	ERR
y1, average depth, ROB, ft	4.2	5.6	ERR
Total conveyance, approach	40142	65659	0
Conveyance, main channel	32434	49617	0
Conveyance, LOB	567	3229	0
Conveyance, ROB	7141	12813	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1074.6	1420.7	ERR
Ql, discharge, LOB, cfs	18.8	92.5	ERR
Qr, discharge, ROB, cfs	236.6	366.9	ERR
Vm, mean velocity MC, ft/s	4.2	4.3	ERR
Vl, mean velocity, LOB, ft/s	1.3	1.9	ERR
Vr, mean velocity, ROB, ft/s	1.9	2.0	ERR
Vc-m, crit. velocity, MC, ft/s	8.4	8.8	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	254	327	0
Main channel width, ft	38	38	0
y1, main channel depth, ft	6.68	8.61	ERR
Bridge Section			
(Q) total discharge, cfs	1330	1880	0
(Q) discharge thru bridge, cfs	1330	1880	
Main channel conveyance	10127	14088	
Total conveyance	10127	14088	
Q2, bridge MC discharge,cfs	1330	1880	ERR
Main channel area, ft2	104	132	0
Main channel width (skewed), ft	20.7	20.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.7	20.7	0
y_bridge (avg. depth at br.), ft	5.04	6.35	ERR
Dm, median (1.25*D50), ft	0.20375	0.20375	0
y2, depth in contraction,ft	6.91	9.30	ERR
ys, scour depth (y2-ybridge), ft	1.87	2.95	N/A

ARMORING			
D90	0.3914	0.3914	
D95	0.4924	0.4924	
Critical grain size,Dc, ft	0.6413	0.7371	ERR
Decimal-percent coarser than Dc	0.0204	0.014	
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	1330	1880	0	1330	1880	0
a', abut.length blocking flow, ft	27.2	32	0	33.9	37.8	0
Ae, area of blocked flow ft2	79.2	137.2	0	151.8	221.2	0
Qe, discharge blocked abut.,cfs	229.43	407.3	0	356.7	524.8	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.90	2.97	ERR	2.35	2.37	ERR
ya, depth of f/p flow, ft	2.91	4.29	ERR	4.48	5.85	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	135	135	0	45	45	0
K2	1.05	1.05	0.00	0.91	0.91	0.00
Fr, froude number f/p flow	0.299	0.253	ERR	0.196	0.173	ERR
ys, scour depth, ft	10.06	12.91	N/A	11.20	13.46	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)	27.2	32	0	33.9	37.8	0
y1 (depth f/p flow, ft)	2.91	4.29	ERR	4.48	5.85	ERR
a'/y1	9.34	7.46	ERR	7.57	6.46	ERR
Skew correction (p. 49, fig. 16)	1.10	1.10	0.00	0.80	0.80	0.00
Froude no. f/p flow	0.30	0.25	N/A	0.20	0.17	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5	6.4		5	6.4	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.09	2.68	ERR	2.09	2.68	ERR