# LEVEL II SCOUR ANALYSIS FOR BRIDGE 57(CHESTH00090057) on TOWN HIGHWAY 9, crossing CHASE BROOK, CHESTER, VERMONT

Open-File Report 97-823

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

**U.S. Department of the Interior**
**U.S. Geological Survey**

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 57 (CHESTH00090057) on TOWN HIGHWAY 9, crossing CHASE BROOK, CHESTER, VERMONT

By SUSAN WILLOUGHBY AND RONDA L. BURNS

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**Pembroke, New Hampshire**

**1997**

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

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

## OTHER ABBREVIATIONS

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

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

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

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

# LEVEL II SCOUR ANALYSIS FOR BRIDGE 57 (CHESTH00090057) ON TOWN HIGHWAY 9, CROSSING CHASE BROOK, CHESTER, VERMONT

*By* **Susan Willoughby and Ronda L. Burns**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESTH00090057 on Town Highway 9 crossing Chase Brook, Chester, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in southern Vermont. The 2.6-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture except on the left bank where it is partly pasture upstream of the bridge.

In the study area, Chase Brook has an incised, sinuous channel with a slope of approximately 0.034 ft/ft, an average channel top width of 35 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size ($D_{50}$) of 59 mm (0.194 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 16, 1996 indicated that the reach was stable.

The Town Highway 34 crossing of Chase Brook is a 29-ft-long, one-lane bridge consisting of one 26-foot concrete slab span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 25.7 ft. 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 5 degrees.

A scour hole 1.75 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left and right banks and left and right wingwalls upstream and downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.6 to 1.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.2 to 6.9 ft. The worst-case abutment scour also occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

**Andover, VT. Quadrangle, 1:24,000, 1971**

**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*** CHESTH00090057 ***Stream*** Chase Brook

***County*** Windsor ***Road*** TH9 ***District*** 2

### Description of Bridge

***Bridge length*** 29.0 ***ft*** ***Bridge width*** 15.4 ***ft*** ***Max span length*** 26.0 ***ft***

***Alignment of bridge to road (on curve or straight)*** Curve

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

***Stone fill on abutment?*** No ***Date of inspection*** 9/16/96

***Description of stone fill*** Type-2, along left and right banks and left and right wingwalls both upstream and downstream.

***Brief description of piers/abutments*** Abutments and wingwalls are concrete. There is a one and three quarter foot deep scour hole extending from 0 feet upstream to 7 feet downstream along the right abutment where the top of the footing is visible.

***Is bridge skewed to flood flow according to*** Yes ***survey?*** Yes ***Angle*** 25

There is a moderate bend through the bridge. The scour hole has developed in the location where the bend impacts the right abutment.

***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*** | 9/16/96 | 0 | 0 |
| ***Level II*** | 9/16/96 | 0 | 0 |

***Potential for debris*** Moderate because of low clearance under the bridge (9/16/96).

***Describe any features near or at the bridge that may affect flow (include observation date)*** There is moderate potential for ice blockage due to the bend through the bridge (9/16/96).

## Description of the Geomorphic Setting

***General topography*** The channel is located within a valley of moderate relief with little to no natural levees, and narrow flood plains.

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

***Date of inspection*** 9/16/96

***DS left:*** Steep channel bank with moderately sloped overbank and steep valley wall

***DS right:*** Steep channel bank and narrow flood plain

***US left:*** Steep channel slope with moderately steep overbank and steep valley wall

***US right:*** Steep channel slope and narrow flood plain

## Description of the Channel

***Average top width*** 35 ft ***Average depth*** 5 ft

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

Sinuous but stable with non-alluvial channel boundaries and a narrow flood plain.

9/16/96

***Vegetative co***

***DS left:*** Trees and lawn on the overbank

***DS right:*** Trees and lawn on the overbank

***US left:*** Trees

***US right:*** Trees and pasture on the overbank.

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

***Describe any obstructions in channel and date of observation.*** A large point bar on the left bank extends from upstream to downstream under the bridge. This affects flow under the bridge and scour against the right abutment.

## Hydrology

***Drainage area*** 2.6 ***mi***$^2$

***Percentage of drainage area in physiographic provinces: (approximate)***

| ***Physiographic province/section*** | ***Percent of drainage area*** |
|---|---|
| New England/New England Upland | 100 |

Rural

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

There are a couple houses on the downstream left and right overbank areas.

***urbanization***:

No

--

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

--

***USGS gage description***

--

***USGS gage number***

No

***Gage drainage area*** ***mi***$^2$

-

***Is there a lake/p***

-

950

### Calculated Discharges

1,300 The

***Q100*** ***ft***$^3$***/s*** ***Q500*** ***ft***$^3$***/s***

100-year discharge is from flood frequency estimates available from the VTAOT database which were extended graphically to the 500-year discharge. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

***Datum tie between USGS survey and VTAOT plans*** Add 1.1 feet to USGS arbitrary survey datum to obtain VTAOT plans' datum.

***Description of reference marks used to determine USGS datum.*** RM1 is a VTAOT brass tablet on top of the downstream end of the right wingwall (elev. 499.470 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment at the junction of the upstream left abutment and wingwall (elev. 500.895 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 | -26 | 1 | Exit section |
| FULLV | 0 | 1 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 10 | 1 | Road Grade section |
| APTEM | 39 | 1 | Approach section as surveyed (Used as a template) |
| APPRO | 45 | 2 | Modelled Approach section (Templated from APTEM)) |

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

### Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.079, and overbank "n" values ranged from 0.037 to 0.055.

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 0.0337 ft/ft which was estimated from surveyed thalweg points downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.035 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

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

## Bridge Hydraulics Summary

*Average bridge embankment elevation* 500.4 *ft*
*Average low steel elevation* 499.0 *ft*

*100-year discharge* 950 *ft³/s*
*Water-surface elevation in bridge opening* 495.8 *ft*
*Road overtopping?* N *Discharge over road* - *ft³/s*
*Area of flow in bridge opening* 89.2 *ft²*
*Average velocity in bridge opening* 10.7 *ft/s*
*Maximum WSPRO tube velocity at bridge* 13.1 *ft/s*

*Water-surface elevation at Approach section with bridge* 498.5
*Water-surface elevation at Approach section without bridge* 497.4
*Amount of backwater caused by bridge* 1.1 *ft*

*500-year discharge* 1,300 *ft³/s*
*Water-surface elevation in bridge opening* 496.6 *ft*
*Road overtopping?* N *Discharge over road* - *ft³/s*
*Area of flow in bridge opening* 110.2 *ft²*
*Average velocity in bridge opening* 11.8 *ft/s*
*Maximum WSPRO tube velocity at bridge* 14.5 */s*

*Water-surface elevation at Approach section with bridge* 499.5
*Water-surface elevation at Approach section without bridge* 498.2
*Amount of backwater caused by bridge* 1.3 *ft*

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

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

## Scour Analysis Summary

### Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100 and 500 year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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* | 0.6 | 1.1 | - |
| *Depth to armoring* | 17.7 | 28.0 | -- |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | - |

| Local scour: | | | |
|---|---|---|---|
| *Abutment scour* | | | |
| *Left abutment* | 5.7 | 6.9 | -- |
| *Right abutment* | 4.2 | 6.4 | -- |
| *Pier scour* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | - | - | - |

## Riprap Sizing

| | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
|---|---|---|---|
| | *($D_{50}$ in feet)* | | |
| *Abutments:* | | | |
| *Left abutment* | 1.5 | 1.8 | -- |
| *Right abutment* | 1.5 | 1.8 | -- |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | |

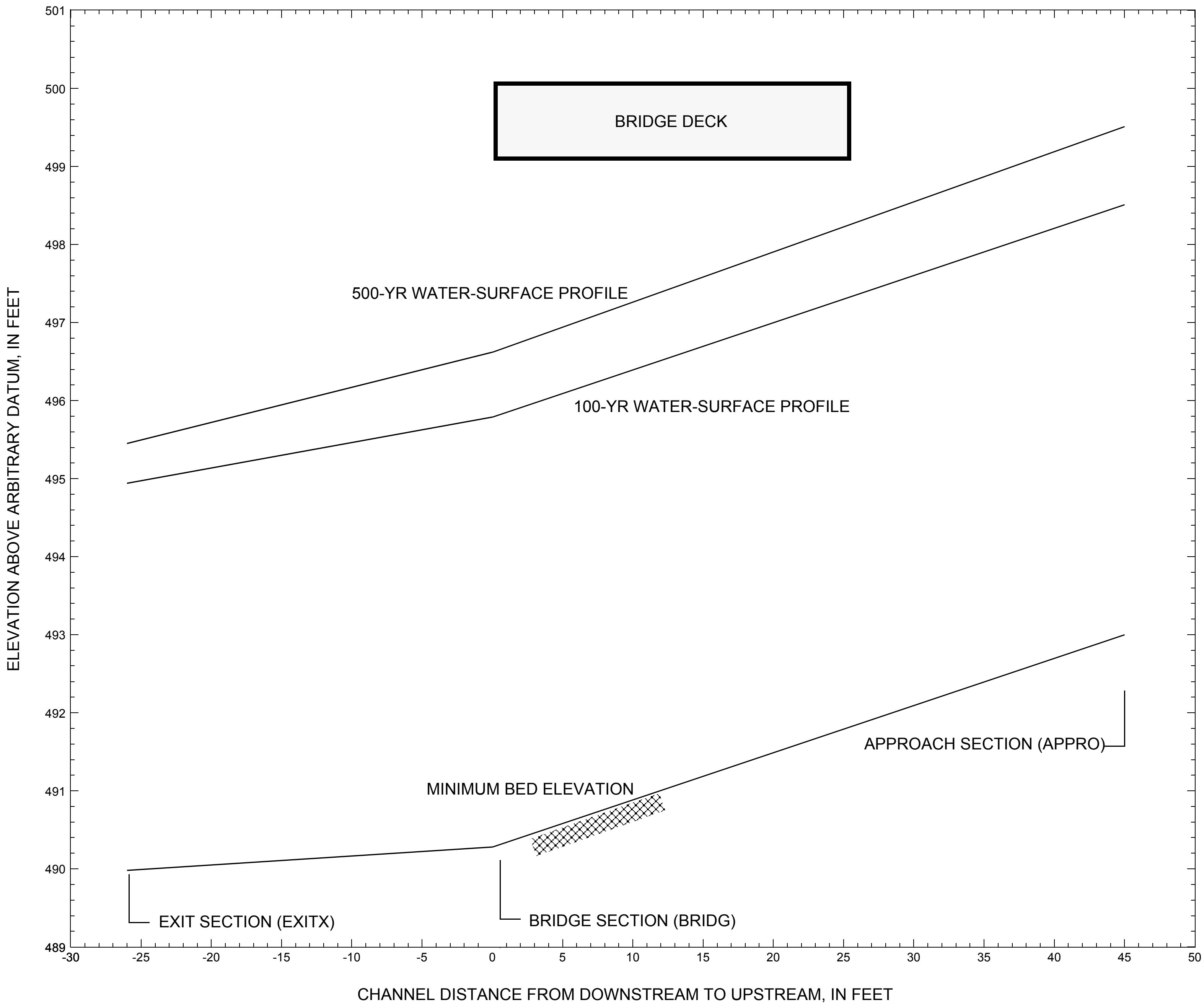


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESTH00090057 on Town Highway 9, crossing Chase Brook, Chester, Vermont.

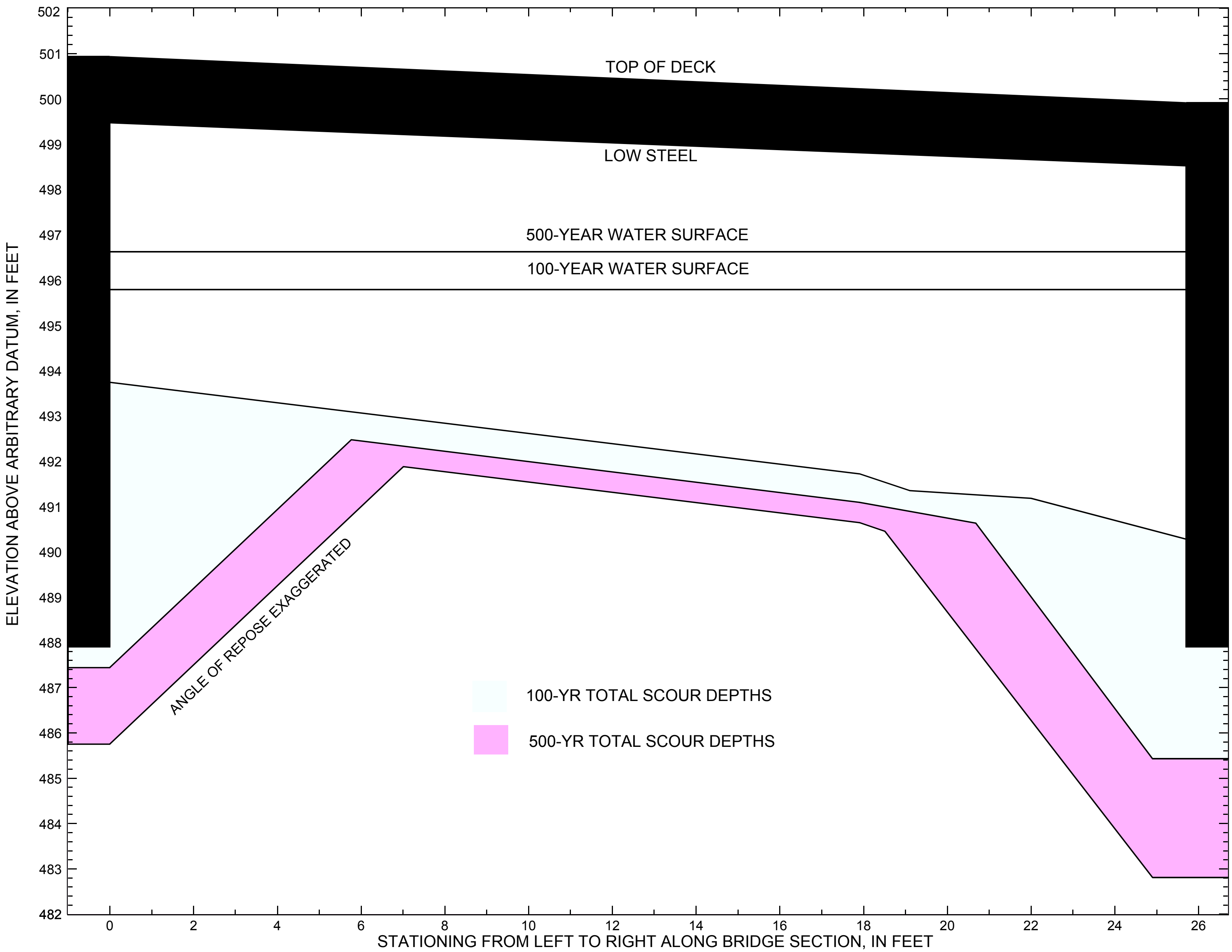


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESTH00090057 on Town Highway 9, crossing Chase Brook, Chester, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESTH00090057 on Town Highway 9, crossing Chase Brook, Chester, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

| Description | Station[1] | VTAOT minimum bridge seat 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 950 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 500.1 | 499.5 | 487.9 | 493.7 | 0.6 | 5.7 | -- | 6.3 | 487.4 | -0.5 |
| Right abutment | 25.7 | 499.0 | 498.5 | 487.9 | 490.3 | 0.6 | 4.2 | -- | 4.8 | 485.5 | -2.4 |

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 CHESTH00090057 on Town Highway 9, crossing Chase Brook, Chester, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

| Description | Station[1] | VTAOT minimum bridge seat 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 1,300 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 500.1 | 499.5 | 487.9 | 493.7 | 1.1 | 6.9 | -- | 8.0 | 485.7 | -2.2 |
| Right abutment | 25.7 | 499.0 | 498.5 | 487.9 | 490.3 | 1.1 | 6.4 | -- | 7.5 | 482.8 | -5.1 |

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, 1971, Andover, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

# APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ches057.wsp
T2        Hydraulic analysis for structure chesth00090057   Date: 15-OCT-97
T3        TH9 CROSSING CHASE BROOK IN CHESTER, VERMONT         SAW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           950.0   1300.0
SK          0.0337   0.0337
*
XS   EXITX    -26           0.
GR         -307.7, 531.33   -246.2, 514.48   -224.7, 514.60   -145.6, 505.31
GR          -80.1, 496.53      0.0, 493.71      3.9, 491.22      9.2, 490.81
GR           11.6, 490.51     14.2, 490.44     19.3, 489.98     23.3, 490.88
GR           34.4, 497.44    114.7, 497.85    161.4, 500.15    358.4, 500.15
GR          461.8, 510.63
*
N           0.040        0.079        0.055
SA                    0.0         34.4
*
*
XS   FULLV      0  * * *   0.0
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0    499.00       5.0
GR            0.0, 499.47      0.0, 493.74     17.9, 491.72     19.1, 491.35
GR           22.0, 491.18     24.9, 490.28     25.1, 491.35     25.7, 498.52
GR            0.0,  499.47
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      19.3      2.4    500.4     38.8
N            0.055
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     10      15.4     2
GR         -319.9, 534.69   -202.5, 515.44      0.0, 500.93     26.1, 499.91
GR           95.7, 498.32    134.6, 500.40    350.8, 500.12    496.2, 514.55
*
*           EXPECTED SRD =   45 AT ONE BR. LENGTH BUT COMPUTED SRD =   37
*
XT   APTEM     39           0.
GR         -297.3, 529.67   -192.0, 514.02    -94.8, 505.03    -17.2, 501.46
GR           -7.0, 499.21      2.0, 493.61      5.3, 493.41      9.0, 492.89
GR           13.2, 492.91     17.0, 492.79     19.7, 493.29     28.7, 499.43
GR           80.6, 499.16    135.4, 500.12    347.6, 500.12    463.7, 512.61
*
AS   APPRO     45 * * *  0.0355
GT
N           0.040        0.075        0.037
SA                  -17.2         28.7
*
HP 1 BRIDG  495.79 1 495.79
HP 2 BRIDG  495.79 * * 950
HP 1 APPRO  498.51 1 498.51
HP 2 APPRO  498.51 * * 950
*
HP 1 BRIDG  496.62 1 496.62
HP 2 BRIDG  496.62 * * 1300
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
1          U.S. Geological Survey WSPRO Input File ches057.wsp
           Hydraulic analysis for structure chesth00090057   Date: 15-OCT-97
           TH9 CROSSING CHASE BROOK IN CHESTER, VERMONT         SAW

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       89      4713     25     33                          948
    495.79            89      4713     25     33  1.00      0     25      948
1
     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.79     0.0    25.5    89.2    4713.     950.  10.66

 X STA.         0.0         3.3         5.4         7.1         8.7        10.1
   A(I)             7.3         5.3         4.8         4.6         4.4
   V(I)            6.53        8.94        9.90       10.41       10.83

 X STA.        10.1        11.4        12.6        13.7        14.8        15.8
   A(I)             4.2         4.1         4.0         3.9         3.8
   V(I)           11.34       11.64       12.00       12.19       12.58

 X STA.        15.8        16.7        17.7        18.6        19.4        20.2
   A(I)             3.7         3.7         3.7         3.6         3.6
   V(I)           12.77       12.82       12.90       13.02       13.08

 X STA.        20.2        21.0        21.9        22.8        23.7        25.5
   A(I)             3.7         3.9         4.1         4.8         8.0
   V(I)           12.83       12.12       11.58        9.91        5.92
1
     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              2      128      6007     33     36                         1447
    498.51           128      6007     33     36  1.00     -5     27     1447
1
     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

          WSEL     LEW     REW    AREA        K        Q    VEL
        498.51    -5.5    27.0   128.4    6007.     950.   7.40

 X STA.        -5.5         0.6         2.3         3.7         5.0         6.2
   A(I)            11.6         7.6         6.5         6.2         5.8
   V(I)            4.09        6.25        7.34        7.72        8.15

 X STA.         6.2         7.3         8.3         9.3        10.3        11.3
   A(I)             5.7         5.6         5.3         5.3         5.3
   V(I)            8.33        8.52        8.94        9.00        9.01

 X STA.        11.3        12.3        13.2        14.2        15.2        16.2
   A(I)             5.3         5.3         5.4         5.3         5.5
   V(I)            8.99        9.00        8.87        8.88        8.66

 X STA.        16.2        17.2        18.3        19.6        21.3        27.0
   A(I)             5.6         5.9         6.3         7.6        11.4
   V(I)            8.44        8.03        7.50        6.28        4.16
1
   *
```

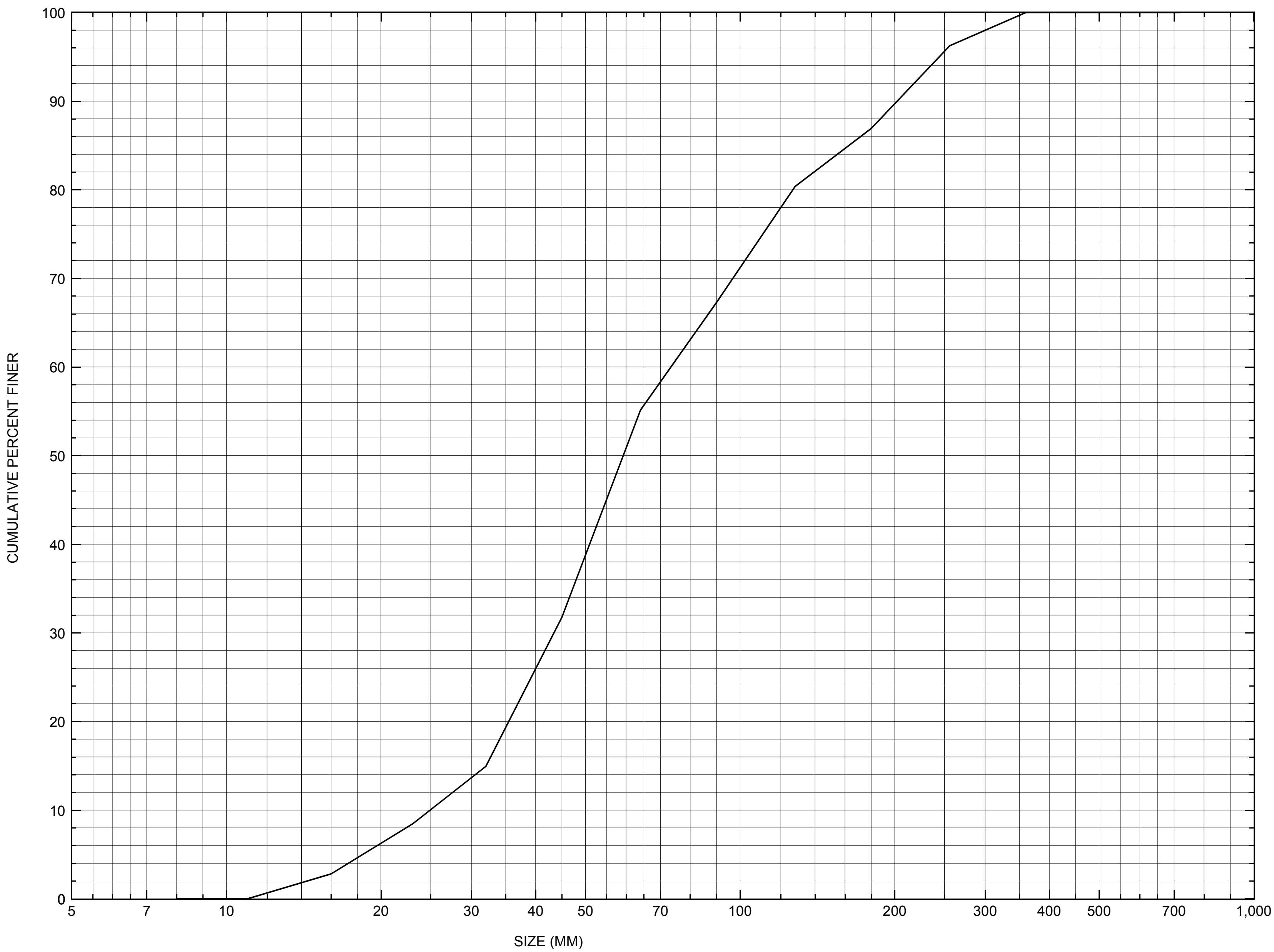
```
         U.S. Geological Survey WSPRO Input File ches057.wsp
         Hydraulic analysis for structure chesth00090057   Date: 15-OCT-97
         TH9 CROSSING CHASE BROOK IN CHESTER, VERMONT         SAW
            *** RUN DATE & TIME: 10-23-97  12:38

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      110      6495     25     34                         1302
    496.62           110      6495     25     34  1.00      0     26     1302


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

          WSEL     LEW     REW    AREA        K        Q    VEL
        496.62     0.0    25.5   110.2    6495.    1300.  11.79

 X STA.        0.0        3.1        5.0        6.6        8.1        9.4
   A(I)            9.3        6.2        5.7        5.5        5.2
   V(I)           6.96      10.40      11.35      11.73      12.53

 X STA.        9.4       10.7       11.9       13.0       14.1       15.1
   A(I)            5.2        4.8        4.8        4.7        4.7
   V(I)          12.61      13.44      13.41      13.91      13.98

 X STA.       15.1       16.1       17.1       18.0       18.9       19.8
   A(I)            4.6        4.5        4.6        4.5        4.6
   V(I)          14.21      14.33      14.11      14.50      14.15

 X STA.       19.8       20.7       21.6       22.5       23.6       25.5
   A(I)            4.7        4.9        5.2        6.1       10.3
   V(I)          13.76      13.34      12.46      10.68       6.28
1
     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              2      163      8299     36     39                         1963
              3        2        16     34     34                            3
    499.51           165      8315     70     74  1.02     -6     88     1419
1
     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

          WSEL     LEW     REW    AREA        K        Q    VEL
        499.51    -7.4    88.4   164.9    8315.    1300.   7.88

 X STA.       -7.4       -0.2        1.8        3.3        4.6        5.9
   A(I)           14.8       10.2        8.2        7.8        7.4
   V(I)           4.40       6.37       7.90       8.32       8.83

 X STA.        5.9        7.0        8.1        9.2       10.2       11.3
   A(I)            7.2        6.8        6.7        6.7        6.7
   V(I)           9.07       9.60       9.69       9.74       9.74

 X STA.       11.3       12.3       13.3       14.4       15.4       16.5
   A(I)            6.6        6.6        6.7        6.7        7.0
   V(I)           9.88       9.89       9.75       9.77       9.31

 X STA.       16.5       17.6       18.8       20.1       22.0       88.4
   A(I)            7.0        7.5        8.1        9.8       16.6
   V(I)           9.28       8.61       8.01       6.63       3.92
1
   *
   EX
```

```
        U.S. Geological Survey WSPRO Input File ches057.wsp
        Hydraulic analysis for structure chesth00090057   Date: 15-OCT-97
        TH9 CROSSING CHASE BROOK IN CHESTER, VERMONT         SAW
           *** RUN DATE & TIME: 10-23-97  12:38

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -34      130  0.88 ***** 495.82  494.83     950  494.94
       -25 ******     30     5174  1.06 ***** *******    0.94    7.32

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.86

FULLV:FV       26    -63      211  0.32  0.47  496.27 *******     950  495.95
         0     26     32     9610  1.02  0.00   -0.02    0.54    4.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.69     496.27     497.37
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.45     529.88    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.45     529.88     497.37
 ===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 "APPRO"
                   WSBEG,WSEND,CRWS =   497.37     529.88     497.37

APPRO:AS       45     -3       93  1.61 ***** 498.98  497.37     950  497.37
        45     45     25     3835  1.00 ***** *******    1.00   10.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.51       0.00     495.79     498.32
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   500.82         1.       949.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.06     499.40     499.63
 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR       26      0       89  1.76  0.96  497.56  490.77     950  495.79
         0     26     25     4721  1.00  0.16    0.00    1.00   10.64

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  499.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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       26     -5      129  0.85  0.84  499.36  497.37     950  498.51
        45     26     27     6014  1.00  0.96    0.00    0.66    7.39

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.123  0.000    6136.    -4.    21.   497.77

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -26.   -35.    30.    950.    5174.     130.    7.32  494.94
   FULLV:FV       0.   -64.    32.    950.    9610.     211.    4.50  495.95
   BRIDG:BR       0.     0.    25.    950.    4721.      89.   10.64  495.79
   RDWAY:RG      10.**************      0.       0.*********    2.00********
   APPRO:AS      45.    -6.    27.    950.    6014.     129.    7.39  498.51

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    21.    6136.
1
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.83    0.94  489.98  531.33************  0.88  495.82  494.94
   FULLV:FV  ********    0.54  489.98  531.33  0.47  0.00  0.32  496.27  495.95
   BRIDG:BR    490.77    1.00  490.28  499.47  0.96  0.16  1.76  497.56  495.79
   RDWAY:RG  ****************  498.32  534.69************  0.49  499.77********
```

```
        U.S. Geological Survey WSPRO Input File ches057.wsp
        Hydraulic analysis for structure chesth00090057   Date: 15-OCT-97
        TH9 CROSSING CHASE BROOK IN CHESTER, VERMONT         SAW
           *** RUN DATE & TIME: 10-23-97  12:38

  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -48      167  0.98 *****  496.43  495.42    1300  495.45
       -25 ******     31     7076  1.04 ***** *******    0.97    7.80

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                         "FULLV"     KRATIO =  1.90

 FULLV:FV       26    -79      272  0.36  0.46  496.89 *******    1300  496.53
         0      26     33    13449  1.01  0.00    0.00    0.55    4.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.03     529.88    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.03     529.88     498.20
  ===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 "APPRO"
                  WSBEG,WSEND,CRWS =   498.20     529.88     498.20

 APPRO:AS       45     -4      118  1.87 *****  500.07  498.20    1300  498.20
        45      45     27     5363  1.00 ***** *******    1.00   10.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   499.51       0.00     496.62     498.32
  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
  ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   501.05         1.      1299.
  ===280 REJECTED FLOW CLASS 4 SOLUTION.
  ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
  ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.09     499.61     499.97
  ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

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

  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
 BRIDG:BR       26      0      110  2.16  0.95  498.78  490.84    1300  496.62
         0      26     26     6503  1.00  0.24    0.00    1.00   11.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  499.00 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      10.        <<<<<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       26     -6      165  0.99  0.86  500.50  498.20    1300  499.51
        45      27     88     8305  1.02  0.86    0.00    0.91    7.90
      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.192  0.000    8636.    -4.    22.   498.78

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
    EXITX:XS     -26.   -49.    31.   1300.    7076.     167.    7.80  495.45
    FULLV:FV       0.   -80.    33.   1300.   13449.     272.    4.78  496.53
    BRIDG:BR       0.     0.    26.   1300.    6503.     110.   11.78  496.62
    RDWAY:RG      10.**************      0.       0.*********    2.00********
    APPRO:AS      45.    -7.    88.   1300.    8305.     165.    7.90  499.51

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      -4.    22.    8636.
1
 SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    495.42    0.97  489.98  531.33************  0.98  496.43  495.45
    FULLV:FV   ********   0.55  489.98  531.33  0.46  0.00  0.36  496.89  496.53
    BRIDG:BR    490.84    1.00  490.28  499.47  0.95  0.24  2.16  498.78  496.62
    RDWAY:RG  ****************  498.32  534.69************  0.66  500.14********
    APPRO:AS    498.20    0.91  493.00  529.88  0.86  0.86  0.99  500.50  499.51
   ER
1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESTH00090057, in Chester, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESTH00090057

## General Location Descriptive

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

Date (MM/DD/YY) 03 / 29 / 95

Highway District Number (I - 2; nn) 02

County (FIPS county code; I - 3; nnn) 027

Town (FIPS place code; I - 4; nnnnn) 13675

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

Waterway (I - 6) CHASE BROOK

Road Name (I - 7): -

Route Number TH009

Vicinity (I - 9) @JCT OF CL3 TH12 & TH9

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude (I - 16; nnnn.n) 43202

Longitude (i - 17; nnnnn.n) 72392

## Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10140700571407

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0026

Year built (I - 27; YYYY) 1978

Structure length (I - 49; nnnnnn) 000029

Average daily traffic, ADT (I - 29; nnnnnn) 000070

Deck Width (I - 52; nn.n) 154

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 6

Opening skew to Roadway (I - 34; nn) 05

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 101

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) 026.0

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 006.0

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

Waterway of full opening (nnn.n ft$^2$) 156.0

Comments:

**The structural inspection report of 9/22/93 indicates a concrete slab type bridge. The abutment walls and wingwall are concrete, which have minor shrinkage cracks reported. Otherwise, the abutments and wing-walls are in good condition. There is some scour taking place that is in front of the right abutment and its footing is exposed for nearly its entire length. The left abutment wall has a large gravel point bar reported in front of it. Currently, all the flow is noted against the right abutment wall. The channel makes a sharp bend just upstream of the bridge into the crossing. The streambed material consists of mostly large boulders, cobbles, and coarse gravel. There is some vegetation (Continued, page 33)**

## Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 2.6

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - $Q_{10}$ 580 $Q_{25}$ 720

$Q_{50}$ 820 $Q_{100}$ 950 $Q_{500}$ -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 10.7

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*) | - | 3.9 | 4.5 | 4.9 | 5.3 |
| Velocity (*ft / sec*) | - | - | 10.7 | - | - |

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at $Q_{100}$ (*ft³/ sec*): -

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

Comments:

**reported in the channel. Stone fill is reported as placed around the wingwalls. The hydraulics report recommended type 2 stone fill be used.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **2.57** $mi^2$  Lake/pond/swamp area ______ $mi^2$
Watershed storage *(ST)* ______ %
Bridge site elevation **0.002** ft  Headwater elevation **0.1** ft
Main channel length **1140** mi
10% channel length elevation **2180** ft  85% channel length elevation **2.88** ft
Main channel slope *(S)* **1100** ft / mi

Watershed Precipitation Data

Average site precipitation **1920** in  Average headwater precipitation **379.24** in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Downstream distance (*miles*): ___________ Town: ___________________ Year Built: ______

Highway No. : ________________ Structure No. : ______ Structure Type: _____________________

Clear span (*ft*): _____ Clear Height (*ft*): ______ Full Waterway ($ft^2$): _______

Comments:

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* - ________ $mi^2$ Lake/pond/swamp area - _________ $mi^2$

Watershed storage *(ST)* __________ %

Bridge site elevation __________ ft Headwater elevation __________ ft

Main channel length __________ mi

10% channel length elevation __________ ft 85% channel length elevation __________ ft

Main channel slope *(S)* __________ 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)*: 05 / 1977

Project Number DSR 0038 & TH 3801 Minimum channel bed elevation: 493.0

Low superstructure elevation: USLAB 500.11 DSLAB 500.06 USRAB 499.01 DSRAB 498.97

Benchmark location description:

**BM#1: spike in root of 10 inch maple; assumed elevation 500.0 feet; 100 feet on the left side of road behind the right abutment at the intersection with a gravel drive.**

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: 489.0

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

**NO FOUNDATION MATERIAL INFORMATION.**

Comments:

**Other elevation points: 1) upstream right wingwall top where concrete slope begins decline, elevation 500.92 feet; and 2) upstream left wingwall top where concrete slope begins to decline, elevation 502.02 feet.**

## Cross-sectional Data

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

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

Comments: **Cross section nearest the upstream bridge face. Surveyed section from left to right bank.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | **1.5** | **4.2** | **14.5** | **24.5** | **27.6** | | | | | | |
| Feature | **LCL** | **footing** | | **footing** | **LCR** | | | | | | |
| Low chord elevation | **499.7** | **edge** | | **edge** | **500.8** | | | | | | |
| Bed elevation | **493.0** | **t491** | **492.3** | **t491** | **493.0** | | | | | | |
| Low chord to bed | **6.7** | **b489** | | **b489** | **7.8** | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | | | | | | | | | | | |
| Feature | | | | | | | | | | | |
| Low chord elevation | | | | | | | | | | | |
| Bed elevation | | | | | | | | | | | |
| Low chord to bed | | | | | | | | | | | |

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

Comments: **Cross section along the roadway centerline under the bridge deck.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | **3.0** | **6.0** | **6.0** | **16.0** | **19.0** | **26.3** | **29.0** | | | | |
| Feature | **LCL** | **footing** | | | | **footing** | **LCR** | | | | |
| Low chord elevation | **499.7** | **edge** | | | | **edge** | **500.8** | | | | |
| Bed elevation | **493.9** | **t491** | **493.2** | **493.1** | **493.2** | **t491** | **493.8** | | | | |
| Low chord to bed | **5.8** | **b489** | | | | **b489** | **7.0** | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | | | | | | | | | | | |
| Feature | | | | | | | | | | | |
| Low chord elevation | | | | | | | | | | | |
| Bed elevation | | | | | | | | | | | |
| Low chord to bed | | | | | | | | | | | |

# APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/16/96**

Computerized by: **EW** Date: **10/16/96**

Reviewd by: ______ Date: ______

Structure Number **CHESTH00090057**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. BURNS** Date *(MM/DD/YY)* **09** / **16** / 19**96**

2. Highway District Number **02** Mile marker **000000**

County **WINDSOR (027)** Town **CHESTER (13675)**

Waterway *(I - 6)* **CHASE BROOK** Road Name **-**

Route Number **TH009** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

**The site is located at the junction of CL3 TH12 and TH9.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** LBDS **4** RBDS **4** Overall **4**
*(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 **1** 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 **29.0** *(feet)* Span length **26.0** *(feet)* Bridge width **15.4** *(feet)*

### Road approach to bridge:

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

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

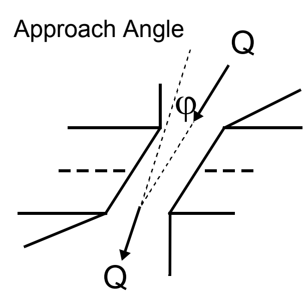
10. Embankment slope *(run / rise in feet / foot)*:
US left **1.9:1** US right **2.9:1**

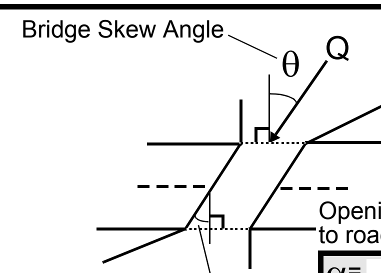
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 0 | - |
| RBUS | 0 | - | 2 | 1 |
| RBDS | 0 | - | 2 | 1 |
| LBDS | 0 | - | 0 | - |

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

### Channel approach to bridge (BF):

15. Angle of approach: **65** 16. Bridge skew: **25**




Opening skew to roadway $\alpha$= **5.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **36** feet **US** *(US, UB, DS)* to **10** feet **UB**

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**

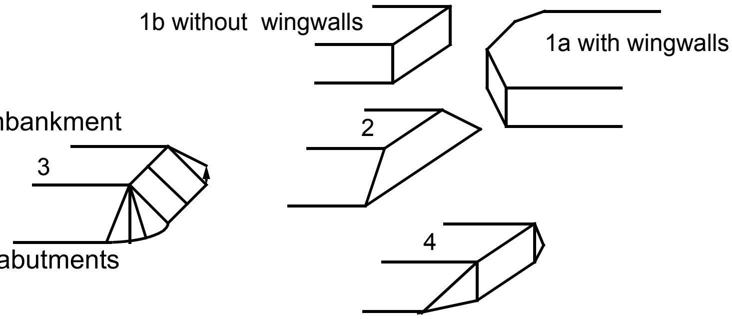
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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




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

**#4: TH9 runs along the upstream left bank, and TH12 is along the upstream right bank. Downstream there are trees along the immediate banks and along the road, then lawn beyond. On the downstream right bank, the house is close to the bank. There is also a small foot bridge across the stream downstream.**

**#7: The measured bridge length is 29.1 feet; bridge span is 25.8 feet; and bridge width is 15.7 feet.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **21.5** | **5.5** | | | **6.0** | **4** | **4** | **453** | **543** | **1** | **1** |

23. Bank width **30.0**  24. Channel width **35.0**  25. Thalweg depth **35.5**  29. Bed Material **543**

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

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

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

**#30: The right bank protection extends from 36 feet upstream to the upstream bridge face.
The left bank protection extends from 59 feet upstream to in front of the upstream left wingwall.**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 10 UB 35. Mid-bar width: 22

36. Point bar extent: 19 feet US (US, UB) to 32 feet DS (US, UB, DS) positioned 0 %LB to 85 %RB

37. Material: 4325

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

**Point bar is vegetated upstream and downstream of bridge with shrubs.**

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

41. Mid-bank distance: 80 42. Cut bank extent: 130 feet US (US, UB) to 68 feet US (US, UB, DS)

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

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

**Another cut-bank is on the right bank from 130 feet upstream to 65 feet upstream. The mid-bank distance is at 100 feet upstream. It is also eroded.**

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**

**Some local scour behind large boulders.**

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 |
|---|---|---|---|---|---|---|---|
| 17.5 | | 0.5 | | 2 | 7 | 7 | - |

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

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

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

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

**543**

**All flow is along the right abutment. The point bar is along the left abutment.**

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 2____ *( 1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

**2**

**The capture efficiency is moderate because of low clearance.**

**Ice blockage potential is moderate because of a bend in the channel.**

| 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 | 0 | - | - | 90.0 |
| RABUT | 1 | 25 | 90 | | | 2 | 2 | 25.5 |

*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**

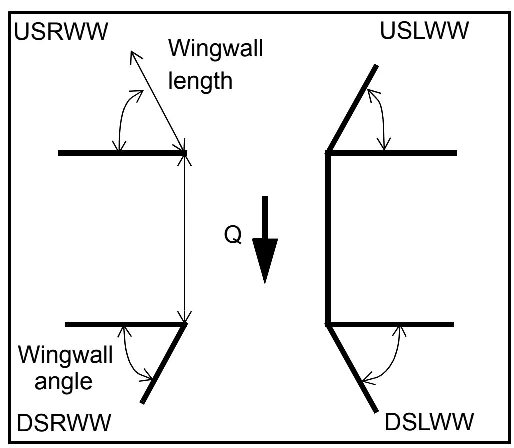
**0**

**1**

**The top of the right abutment footing is visible at the downstream end.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 25.5 | |
| USRWW: | Y | | 1 | | 0 | 0.5 | |
| DSLWW: | - | | - | | Y | 19.5 | |
| DSRWW: | 1 | | 0 | | - | 19.5 | |




*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 | - | 1 | 1 | - | - |
| Condition | Y | - | 1 | - | 1 | 1 | - | - |
| Extent | 1 | - | 0 | 2 | 2 | 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*

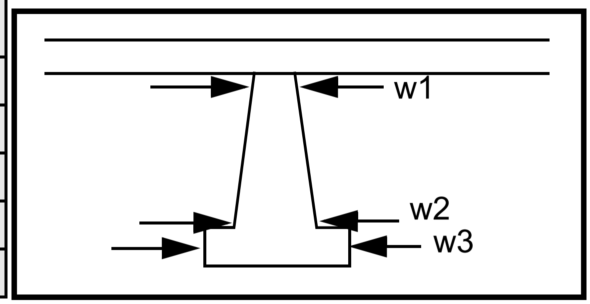
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

**-**
**-**
**-**
**-**
**-**
**2**
**1**
**1**
**2**
**1**
**1**

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | **8.5** | **4.5** | **35.0** | **45.0** | **45.0** |
| Pier 2 | **7.5** | **7.0** | **-** | **45.0** | **-** | **-** |
| Pier 3 | **-** | **-** | **-** | **-** | **-** | **-** |
| Pier 4 | **-** | **-** | **-** | **-** | **-** | **-** |




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

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

## E. Downstream Channel Assessment

100.

| SRD | Bank height (BF) LB | Bank height (BF) RB | Bank angle (BF) LB | Bank angle (BF) RB | % Veg. cover (BF) LB | % Veg. cover (BF) RB | Bank material (BF) LB | Bank material (BF) RB | Bank erosion (BF) LB | Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | NO | PIE | RS | | |

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.):

**3**
**3**
**435**
**543**
**1**
**0**
**453**
**2**
**2**
**1**
**1**
**The right bank protection extends from in front of the wingwall to 80 feet downstream.**

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

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

105. Drop structure comments (eg. downstream scour depth):
**left bank protection extends from in front of the wingwall to 28 feet downstream.**

**There are some exposed tree roots along the left bank from 33 feet downstream to 59 feet downstream.**

**The downstream foot bridge is 83 feet downstream.**

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 N %LB to - %RB

Material: NO

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

**DROP STRUCTURE**

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

Cut bank extent: - feet - *(US, UB, DS)* to - feet - *(US, UB, DS)*

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

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

-
-
-
-

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

Scour dimensions: Length BAR Width S Depth: _____ Positioned ____ %LB to ____ %RB

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

N
-
-
-

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

Confluence 1: Distance - Enters on - *(LB or RB)* Type NO *( **1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

S

## F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

**Y**
**10 UB**
**25**
**2**
**1.75**
**60**
**100**
**The scour is along the right abutment. It extends from 0 feet upstream to 7 feet downstream. The average thalweg is 0.25 feet.**

**Y**

## 109. G. Plan View Sketch

- 1

| | | | |
|---|---|---|---|
| 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: CHESTH00090057 Town: CHESTER
Road Number: TH 9 County: WINDSOR
Stream: CHASE BROOK

Initials SAW Date: 10/17/97 Checked:MAI

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 | 950 | 1300 | 0 |
| Main Channel Area, ft2 | 128 | 163 | 0 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 0 | 2 | 0 |
| Top width main channel, ft | 33 | 36 | 0 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 0 | 34 | 0 |
| D50 of channel, ft | 0.1943 | 0.1943 | 0 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| | | | |
| y1, average depth, MC, ft | 3.9 | 4.5 | ERR |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | ERR | 0.1 | ERR |
| | | | |
| Total conveyance, approach | 6007 | 8299 | 0 |
| Conveyance, main channel | 6007 | 8315 | 0 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 0 | 16 | 0 |
| Percent discrepancy, conveyance | 0.0000 | -0.3856 | ERR |
| Qm, discharge, MC, cfs | 950.0 | 1302.5 | ERR |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | ERR |
| Qr, discharge, ROB, cfs | 0.0 | 2.5 | ERR |
| | | | |
| Vm, mean velocity MC, ft/s | 7.4 | 8.0 | ERR |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | ERR | 1.3 | ERR |
| Vc-m, crit. velocity, MC, ft/s | 8.1 | 8.4 | N/A |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

| Live-bed(1) or Clear-Water(0) Contraction Scour? | | | |
|---|---|---|---|
| Main Channel | 0 | 0 | N/A |
| Left Overbank | N/A | N/A | N/A |
| Right Overbank | N/A | N/A | N/A |

III. Clear Water Contraction Scour in MAIN CHANNEL

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

ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 950 | 1300 | 0 |
| (Q) discharge thru bridge, cfs | 950 | 1300 | 0 |
| Main channel conveyance | 4713 | 6495 | 0 |
| Total conveyance | 4713 | 6495 | 0 |
| Q2, bridge MC discharge,cfs | 950 | 1300 | ERR |
| Main channel area, ft2 | 89 | 110 | 0 |
| Main channel width (normal), ft | 25.4 | 25.4 | 0.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 25.4 | 25.4 | 0 |
| y_bridge (avg. depth at br.), ft | 3.50 | 4.33 | ERR |
| Dm, median (1.25*D50), ft | 0.242875 | 0.242875 | 0 |
| y2, depth in contraction,ft | 4.13 | 5.41 | ERR |
| | | | |
| ys, scour depth (y2-ybridge), ft | 0.63 | 1.08 | N/A |
| | Q100 | Q500 | OtherQ |

V. Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)

| Downstream bridge face property | 100-yr | 500-yr | Other Q |
|---|---|---|---|
| Q, discharge thru bridge MC, cfs | 950 | 1300 | N/A |
| Main channel area (DS), ft2 | 89 | 110 | 0 |
| Main channel width (normal), ft | 25.4 | 25.4 | 0.0 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 25.4 | 25.4 | 0.0 |
| D90, ft | 0.6633 | 0.6633 | 0.0000 |
| D95, ft | 0.8009 | 0.8009 | 0.0000 |
| Dc, critical grain size, ft | 0.6618 | 0.7347 | ERR |
| Pc, Decimal percent coarser than Dc | 0.101 | 0.073 | 0.000 |
| | | | |
| Depth to armoring, ft | 17.67 | 27.99 | ERR |

VII. Abutment Scour

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

| | Left Abutment | | | Right Abutment | | |
|---|---|---|---|---|---|---|
| Characteristic | 100 yr Q | 500 yr Q | Other Q | 100 yr Q | 500 yr Q | Other Q |
| (Qt), total discharge, cfs | 950 | 1300 | 0 | 950 | 1300 | 0 |
| a', abut.length blocking flow, ft | 5.6 | 7.5 | 0 | 1.5 | 62.9 | 0 |
| Ae, area of blocked flow ft2 | 10.65 | 16.33 | 0 | 3 | 15.73 | 0 |
| Qe, discharge blocked abut.,cfs | 43.61 | 74.75 | 0 | 12.5 | 61.57 | 0 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 4.09 | 4.58 | ERR | 4.17 | 3.91 | ERR |
| ya, depth of f/p flow, ft | 1.90 | 2.18 | ERR | 2.00 | 0.25 | ERR |
| | | | | | | |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

| | | | | | | |
|---|---|---|---|---|---|---|
| theta | 85 | 85 | 85 | 95 | 95 | 95 |
| K2 | 0.99 | 0.99 | 0.99 | 1.01 | 1.01 | 1.01 |
| Fr, froude number f/p flow | 0.523 | 0.547 | ERR | 0.519 | 1.379 | ERR |
| ys, scour depth, ft | 5.67 | 6.91 | N/A | 4.22 | 6.39 | 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) | 5.6 | 7.5 | 0 | 1.5 | 62.9 | 0 |
| y1 (depth f/p flow, ft) | 1.90 | 2.18 | ERR | 2.00 | 0.25 | ERR |
| a'/y1 | 2.94 | 3.44 | ERR | 0.75 | 251.52 | ERR |
| Skew correction (p. 49, fig. 16) | 0.98 | 0.98 | 0.98 | 1.01 | 1.01 | 1.01 |
| Froude no. f/p flow | 0.52 | 0.55 | N/A | 0.52 | 1.38 | N/A |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | ERR | 2.04 | ERR |
| vertical w/ ww's | ERR | ERR | ERR | ERR | 1.68 | ERR |
| spill-through | ERR | ERR | ERR | ERR | 1.12 | 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 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 1 | 1 | 0 | 1 | 1 | 0 |
| y, depth of flow in bridge, ft | 3.51 | 4.34 | 0.00 | 3.51 | 4.34 | 0.00 |
| Median Stone Diameter for riprap at: left abutment | | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | ERR | 0.00 | ERR | ERR | 0.00 |
| Fr>0.8 (vertical abut.) | 1.47 | 1.81 | ERR | 1.47 | 1.81 | ERR |
| Fr<=0.8 (spillthrough abut.) | ERR | ERR | 0.00 | ERR | ERR | 0.00 |
| Fr>0.8 (spillthrough abut.) | 1.30 | 1.60 | ERR | 1.30 | 1.60 | ERR |