# LEVEL II SCOUR ANALYSIS FOR BRIDGE 40 (ROCKTH00140040) on TOWN HIGHWAY 14, crossing the WILLIAMS RIVER, ROCKINGHAM, VERMONT

Open-File Report 98-543

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 40 (ROCKTH00140040) on TOWN HIGHWAY 14, crossing the WILLIAMS RIVER, ROCKINGHAM, VERMONT

By RONDA L. BURNS and EMILY C. WILD

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**Pembroke, New Hampshire**

**1998**

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

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 40 (ROCKTH00140040) ON TOWN HIGHWAY 14, CROSSING THE WILLIAMS RIVER, ROCKINGHAM, VERMONT

***By*** **Ronda L. Burns and Emily C. Wild**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ROCKTH00140040 on Town Highway 14 crossing the Williams River, Rockingham, 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 (FHWA, 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 southeastern Vermont. The 99.2-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture downstream of the bridge. Upstream of the bridge, the left bank is forested and the right bank is suburban.

In the study area, the Williams River has an incised, sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 154 ft and an average bank height of 11 ft. The channel bed material ranges from silt and clay to cobble with a median grain size ($D_{50}$) of 45.4 mm (0.149 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 4, 1996, indicated that the reach was stable.

The Town Highway 14 crossing of the Williams River is a 106-ft-long, one-lane covered bridge consisting of two steel-beam spans with a maximum span length of 73 ft (Vermont Agency of Transportation, written communication, April 6, 1995). The opening length of the structure parallel to the bridge face is 94.5 ft. The bridge is supported by a vertical, concrete abutment with wingwalls on the left, a vertical, laid-up stone abutment on the right and a concrete pier. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.1 ft deeper than the mean thalweg depth was observed towards the left side of the channel under and just downstream of the bridge during the Level I assessment. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the upstream end of the upstream left wingwall and type-2 stone fill (less than 36 inches diameter) along the upstream left bank and the left abutment. 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 Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows was zero ft. Left abutment scour ranged from 13.9 to 19.2 ft. Right abutment scour ranged from 7.0 to 11.7 ft. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 18.7 to 24.7 ft and the worst case occurred at the incipient roadway-overtopping 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 Davis, 1995, p. 46). 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*** ROCKTH00140040 ***Stream*** Williams River

***County*** Windham ***Road*** TH 14 ***District*** 2

## Description of Bridge

***Bridge length*** 106 ***ft*** ***Bridge width*** 14 ***ft*** ***Max span length*** 73 ***ft***

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

***Abutment type*** Concrete,left/Stone,right ***Embankment type*** Sloping

***Stone fill on abutment?*** Yes ***Date of inspection*** 9/4/96

***Description of stone fill*** Type-1, along the upstream end of the upstream left wingwall. Type-2, along the left abutment.

***Brief description of piers/abutments*** The left abutment, upstream left wingwall, and pier are concrete. The right abutment and downstream left wingwall are laid-up stone. There is a spill through type embankment in front of the right abutment.

***Is bridge skewed to flood flow according to*** Yes ***survey?*** Yes ***Angle*** 10

There is a mild channel bend through the bridge. A scour hole has developed in the channel under the bridge where the flow is most constricted by the bend.

***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*** | 9/4/96 | 0 | 0 |
| ***Level II*** | 9/4/96 | 0 | 0 |

***Potential for debris*** Moderate. There is some debris caught in the trees on the upstream banks.

***Describe any features near or at the bridge that may affect flow (include observation date)*** The pier is located at the base of the spill-through embankment along the right abutment. During low flow, the pier is the channel restraint, as observed on 9/4/96.

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley with a narrow flood plain.

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

***Date of inspection*** 9/4/96

***DS left:*** Moderately sloped channel bank and overbank

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

***US left:*** Steep valley wall

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

## Description of the Channel

***Average top width*** 154 ft ***Average depth*** 11 ft

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

Sinuous but stable with semi-alluvial channel boundaries and wide point bars.

9/4/96

***Vegetative co*** Few trees with grass on the overbank

***DS left:*** Brush with grass on the overbank

***DS right:*** Trees and brush

***US left:*** Brush and a few trees

***US right:***

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

The assessment of 9/4/96 noted bedrock in the channel on the upstream left bank. There is also a railroad bridge about 300 ft downstream of this bridge.

***Describe any obstructions in channel and date of observation.***

## Hydrology

***Drainage area*** 99.2 ***mi²***

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

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

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***: There is a salvage yard on the right bank upstream.

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

***USGS gage description*** Williams River near Rockingham, VT

***USGS gage number*** 01153550

***Gage drainage area*** 112 ***mi²***

***Is there a lake/p*** No

### Calculated Discharges

***Q100*** 13,700 ***ft³/s*** ***Q500*** 20,000 ***ft³/s***

***Method used to determine discharges*** The 100- and 500-year discharges are based on a drainage area relationship [(99.2/96.7)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 44 in Rockingham. Bridge number 44 crosses the Williams River upstream of this site and has a drainage area of 96.7 square miles. The flood frequency estimates for bridge number 44 are the same as the estimates given for the Williams River at Lower Bartonsville Road in the Flood Insurance Study for Rockingham (FEMA, November 1979). 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). Each curve was extended graphically to the 500-year event.

## 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 a chiseled X on top of the downstream end of the left abutment (elev. 499.95 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream left corner of the pier footing (elev. 483.20 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| RREXT | -695 | 1 | Railroad Bridge Exit section |
| RRFLV | -300 | 2 | Railroad Bridge Full-valley section (Templated from RREXT) |
| RRBRG | -300 | 1 | Railroad Bridge section |
| RROAD | -289 | 1 | Railroad Grade section |
| RRAPR | -172 | 2 | Railroad Bridge Approach section (Templated from EXTEM) |
| EXTEM | -105 | 1 | Exit section as surveyed (Used as a template) |
| EXITX | -105 | 2 | Modelled Exit section (Templated from EXTEM) |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 11 | 1 | Road Grade section |
| APPRO | 116 | 1 | Approach section |

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

## Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.056, and overbank "n" values ranged from 0.041 to 0.095.

Normal depth at the railroad bridge exit section (RREXT) 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 0.0051 ft/ft, which was estimated from the 100-year water surface profile in the Flood Insurance Study for Rockingham (FEMA, November 1979).

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

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 498.4 ***ft***
***Average low steel elevation*** 495.8 ***ft***

***100-year discharge*** 13,700 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 496.3 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 7,710 ***$ft^3/s$***
***Area of flow in bridge opening*** 1,128 ***$ft^2$***
***Average velocity in bridge opening*** 5.3 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 5.8 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 498.1
***Water-surface elevation at Approach section without bridge*** 497.8
***Amount of backwater caused by bridge*** 0.3 ***ft***

***500-year discharge*** 20,000 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 496.3 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 15,400 ***$ft^3/s$***
***Area of flow in bridge opening*** 1,128 ***$ft^2$***
***Average velocity in bridge opening*** 4.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 4.5 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 501.0
***Water-surface elevation at Approach section without bridge*** 500.9
***Amount of backwater caused by bridge*** 0.1 ***ft***

***Incipient overtopping discharge*** 7,780 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 493.7 ***ft***
***Area of flow in bridge opening*** 1,098 ***$ft^2$***
***Average velocity in bridge opening*** 7.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 9.0 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 494.3
***Water-surface elevation at Approach section without bridge*** 494.2
***Amount of backwater caused by bridge*** 0.1 ***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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented in appendix F.

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

Because the influence of scour processes on the embankment material along the right abutment is uncertain, the scour depth at the vertical concrete abutment wall is unknown. Therefore, the total scour depth computed at the toe of the embankment was applied to the entire embankment and abutment area as shown in figure 8.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and Davis, 1995, p. 36, equation 21) for all discharges modelled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the Froude number) immediately upstream of the bridge, and correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

## Scour Results

| Contraction scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | (Scour depths in feet) | | |
| *Main channel* | | | |
| *Live-bed scour* | -- | -- | -- |
| *Clear-water scour* | 0.0 | 0.0 | 0.0 |
| *Depth to armoring* | 0.0 | 0.0 | 0.9 |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | -- |
| **Local scour:** | | | |
| *Abutment scour* | | | |
| *Left abutment* | 17.6 | 19.2 | 13.9 |
| *Right abutment* | 7.0 | 11.7 | 7.2 |
| *Pier scour* | | | |
| *Pier 1* | 20.8 | 18.7 | 24.7 |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | | ($D_{50}$ in feet) | |
| **Abutments:** | | | |
| *Left abutment* | 0.6 | 0.4 | 1.1 |
| *Right abutment* | 0.5 | 0.3 | 0.9 |
| **Piers:** | | | |
| *Pier 1* | 0.5 | 0.3 | 1.2 |
| *Pier 2* | -- | -- | -- |
| | -- | -- | -- |

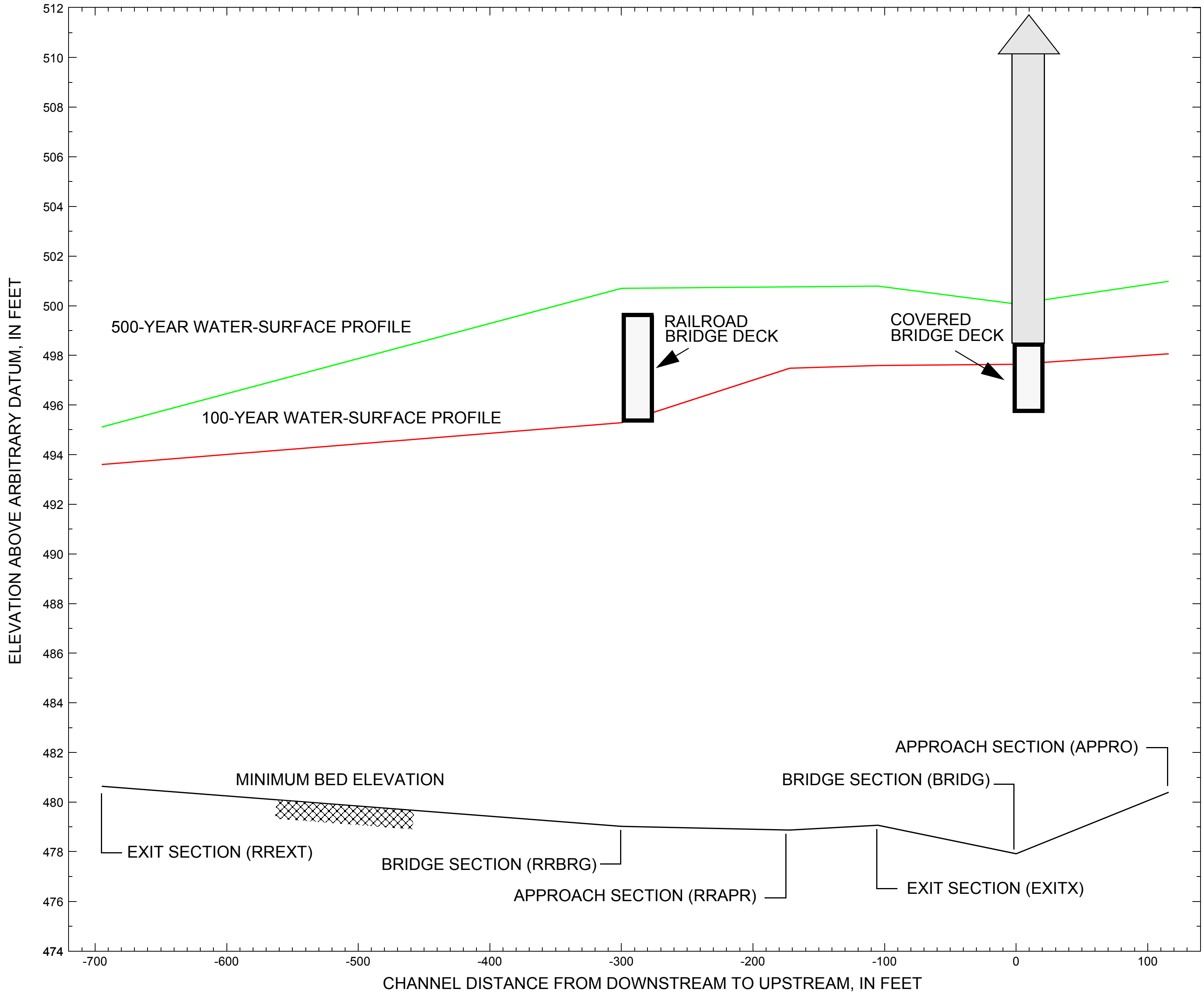


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure ROCKTH00140040 on Town Highway 14, crossing the Williams River, Rockingham, Vermont.

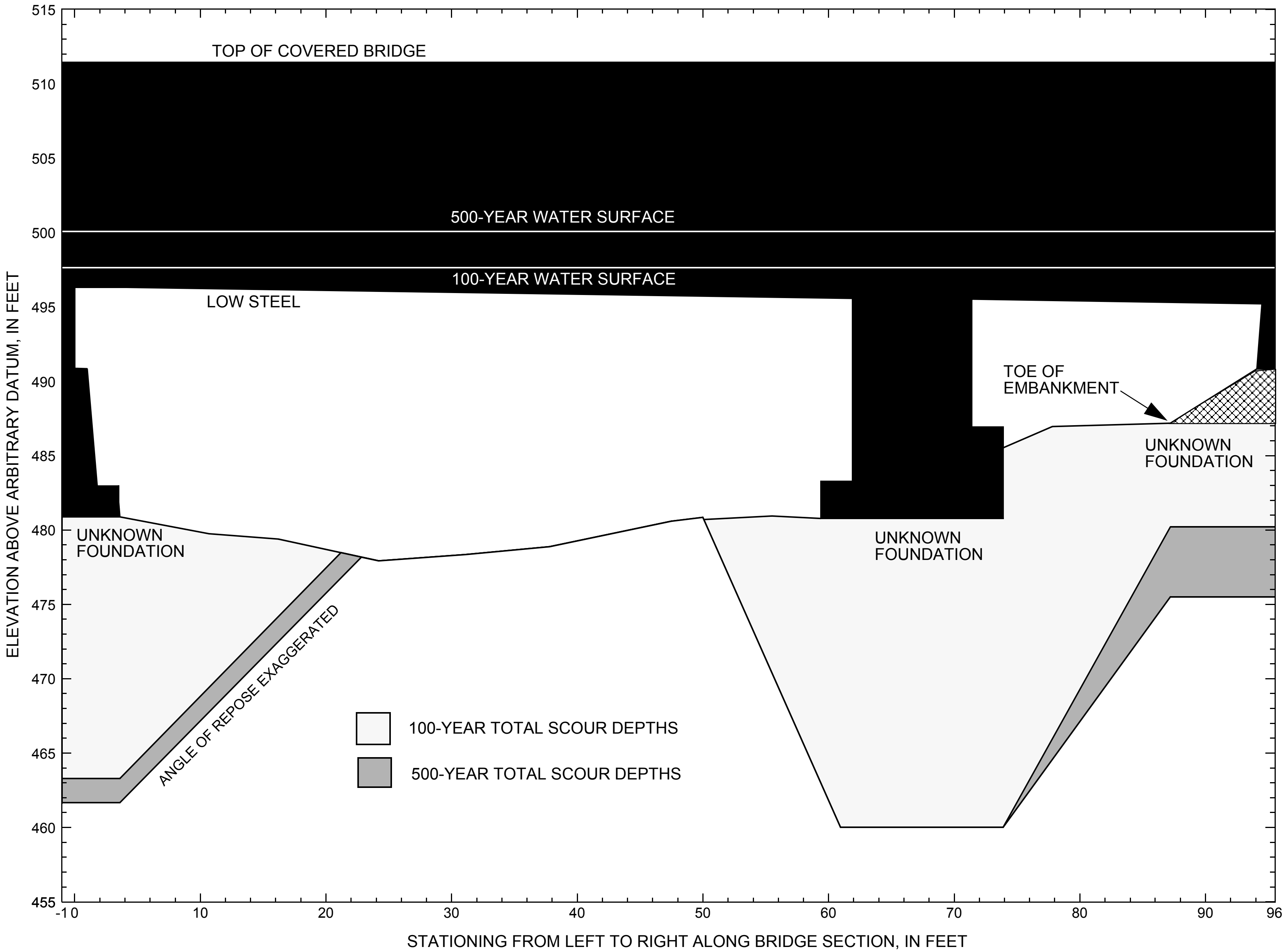


Figure 8. Scour elevations for the 100- and 500-year discharges at structure ROCKTH00140040 on Town Highway 14, crossing the Williams River, Rockingham, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure ROCKTH00140040 on Town Highway 14, crossing the Williams River, Rockingham, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-year discharge is 13,700 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 496.3 | -- | 480.9 | 0.0 | 17.6 | -- | 17.6 | 463.3 | -- |
| Pier 1 | 68.2 | -- | -- | -- | 480.8 | 0.0 | -- | 20.8 | 20.8 | 460.0 | -- |
| Embankment toe | 87.2 | -- | -- | -- | 487.2 | 0.0 | 7.0 | -- | 7.0 | -- | -- |
| Right abutment | 94.5 | -- | 495.2 | -- | 490.8 | -- | -- | -- | -- | 480.2 | -- |

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

**Table 2.** Remaining footing/pile depth at abutments for the 500-year discharge at structure ROCKTH00140040 on Town Highway 14, crossing the Williams River, Rockingham, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-year discharge is 20,000 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 496.3 | -- | 480.9 | 0.0 | 19.2 | -- | 19.2 | 461.7 | -- |
| Pier 1 | 68.2 | -- | -- | -- | 480.8 | 0.0 | -- | 18.7 | 18.7 | 462.4 | -- |
| Embankment toe | 87.2 | -- | -- | -- | 487.2 | 0.0 | 11.7 | -- | 11.7 | -- | -- |
| Right abutment | 94.5 | -- | 495.2 | -- | 490.8 | -- | -- | -- | -- | 475.5 | -- |

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

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APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File rock040.wsp
T2        Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
T3        TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          13700.0  20000.0  7780.0
SK          0.0051   0.0051  0.0051
*
XS   RREXT   -695           0.
GR         -472.0, 508.61   -456.0, 506.06   -450.0, 503.65   -441.0, 503.19
GR         -426.0, 503.29   -412.0, 500.43   -397.0, 500.92   -360.0, 495.01
GR         -356.0, 494.47   -321.0, 495.09    -69.0, 492.09    -61.0, 490.43
GR          -32.0, 489.22    -22.0, 488.70      0.0, 486.31      9.0, 482.11
GR           10.0, 481.80     16.0, 481.21     28.0, 480.64     40.0, 481.09
GR           58.0, 481.34     76.0, 481.82     93.0, 482.14    100.0, 490.29
GR          128.0, 491.10    170.0, 491.76    223.0, 490.63    272.0, 490.35
GR          288.0, 494.30    332.0, 494.63    342.0, 501.63
*
N           0.045        0.055        0.055
SA                 -69.0        100.0
*
XS   RRFLV   -300   * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   RRBRG   -300   495.27      10.0
GR            0.0, 495.28      0.4, 487.11     18.3, 485.96     30.7, 482.31
GR           48.1, 481.90     59.8, 481.08     72.0, 479.73     81.2, 479.24
GR           96.1, 479.02    108.1, 479.83    108.7, 481.91    108.9, 495.25
GR            0.0, 495.28
*
*        BRTYPE  BRWDTH        WWANGL    WWWID
CD          1      33.1 * *     43.6     12.6
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RROAD   -289      17.7     2
GR         -453.6, 501.16      0.0, 499.53    108.9, 499.54    473.9, 500.15
*
XT   EXTEM   -105           0.
GR         -164.8, 501.01   -139.2, 497.89   -108.9, 496.38    -83.3, 495.39
GR          -66.9, 493.02    -43.9, 492.89    -10.3, 486.98      0.0, 482.85
GR           18.7, 481.90     23.2, 481.02     32.4, 480.20     46.9, 479.85
GR           60.9, 479.39     68.6, 479.07     73.1, 479.77     74.8, 480.23
GR           76.7, 481.86     89.0, 490.37    101.3, 491.64    115.9, 491.43
GR          140.3, 493.82    321.0, 494.74    328.1, 498.29    339.2, 500.01
GR          389.2, 518.21
*
AS   RRAPR   -172   * * *   0.0030
GT
N           0.041        0.056        0.041
SA                 -43.9        140.3
*
XS   EXITX   -105   * * *   0.0
GT
N           0.041        0.056        0.041
SA                 -43.9        140.3
```

```
*
XS   FULLV       0  * * *   0.0
GT
N           0.041        0.056        0.041
SA                 -43.9        140.3
*



*             SRD     LSEL    XSSKEW
BR   BRIDG     0    495.77       0.0
GR            0.0, 496.32      0.0, 490.86      1.0, 490.84      1.8, 482.95
GR            3.5, 482.95      3.6, 481.90      3.6, 480.88     10.7, 479.75
GR           16.2, 479.39     24.2, 477.92     31.1, 478.34     37.8, 478.87
GR           47.5, 480.59     55.5, 480.94     62.5, 480.77     73.9, 485.53
GR           77.8, 486.96     87.2, 487.18     94.1, 490.83     94.5, 495.21
GR           0.0, 496.32
*
*          BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      26.3 * *      40.2     11.3
PW         480.77, 14.5  483.26, 14.5  483.26, 12.0  486.90, 12.0  486.90, 9.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      14.0     2
GR          -76.0, 503.30    -43.5, 502.68    -23.7, 500.11      0.0, 499.92
GR            0.0, 511.45    100.1, 511.45    100.1, 496.87    161.3, 494.25
GR          199.5, 493.61    339.3, 494.75    430.2, 494.71    453.3, 497.44
GR          499.6, 499.04
*
AS   APPRO    116           0.
GR          -28.2, 503.56    -18.9, 496.54      0.0, 482.27      1.4, 482.05
GR            5.8, 481.33     10.8, 480.40     27.0, 480.46     37.4, 481.26
GR           44.6, 481.45     52.3, 481.33     54.2, 482.06     58.3, 485.38
GR           77.4, 484.91     88.0, 488.76     96.2, 487.94    109.6, 493.47
GR          332.3, 494.70    451.3, 496.10    464.9, 498.00    505.9, 499.21
GR          705.9, 499.21    710.9, 503.87
*
N           0.056        0.095
SA                 109.6
*
HP 1 BRIDG  496.32 1 496.32
HP 2 BRIDG  496.32 * * 5948
HP 2 RDWAY  497.64 * * 7706
HP 1 APPRO  498.06 1 498.06
HP 2 APPRO  498.06 * * 13700
*
HP 1 BRIDG  496.32 1 496.32
HP 2 BRIDG  496.32 * * 4644
HP 2 RDWAY  500.07 * * 15380
HP 1 APPRO  500.98 1 500.98
HP 2 APPRO  500.98 * * 20000
*
HP 1 BRIDG  493.65 1 493.65
HP 2 BRIDG  493.65 * * 7780
HP 1 APPRO  494.25 1 494.25
HP 2 APPRO  494.25 * * 7780
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File rock040.wsp
        Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
        TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
           *** RUN DATE & TIME: 05-05-98  12:28

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1298.  144651.     0.   210.                          0.
   496.32         1298.  144651.     0.   210.  1.00     0.    95.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       496.32     0.0    94.5  1297.8  144651.    5948.   4.58

X STA.         0.0        8.9       12.3       15.6       18.8       21.9
  A(I)           120.0       56.2       54.9       54.2       53.9
  V(I)            2.48       5.29       5.42       5.49       5.52

X STA.        21.9       24.9       27.8       31.0       34.1       37.2
  A(I)            53.6       53.5       55.6       54.1       53.3
  V(I)            5.55       5.56       5.35       5.49       5.58

X STA.        37.2       40.2       43.6       47.2       51.0       54.9
  A(I)            51.7       54.8       56.3       57.1       57.7
  V(I)            5.75       5.43       5.28       5.20       5.16

X STA.        54.9       58.8       62.7       67.3       73.7       94.5
  A(I)            57.3       57.5       63.1       73.1      159.9
  V(I)            5.19       5.17       4.72       4.07       1.86

    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      11.
         WSEL     LEW     REW    AREA         K        Q    VEL
       497.64   100.1   459.1  1054.0   78734.    7706.   7.31

X STA.       100.1      148.6      164.4      177.6      189.7      201.2
  A(I)            87.6       50.3       47.0       45.5       45.3
  V(I)            4.40       7.66       8.20       8.47       8.50

X STA.       201.2      212.4      224.2      236.4      249.2      261.2
  A(I)            44.7       45.8       45.8       47.1       43.0
  V(I)            8.62       8.41       8.41       8.18       8.96

X STA.       261.2      273.6      288.1      303.1      319.5      337.4
  A(I)            43.1       48.8       48.9       51.2       53.2
  V(I)            8.95       7.90       7.87       7.53       7.24

X STA.       337.4      356.4      375.1      393.1      411.9      459.1
  A(I)            54.9       54.2       52.5       55.0       90.2
  V(I)            7.02       7.11       7.34       7.01       4.27

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1692.  238127.   131.   139.                      34577.
             2    1216.   43111.   357.   357.                      12722.
   498.06         2908.  281238.   488.   497.  1.81   -21.   467.  29919.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
         WSEL     LEW     REW    AREA         K        Q    VEL
       498.06   -20.9   466.9  2907.8  281238.   13700.   4.71

X STA.       -20.9        2.6        7.5       12.3       16.8       21.4
  A(I)           206.0       81.4       83.7       81.0       79.9
  V(I)            3.33       8.41       8.18       8.45       8.58

X STA.        21.4       26.2       30.8       35.8       40.8       45.8
  A(I)            84.2       82.0       84.2       84.6       83.9
  V(I)            8.14       8.35       8.13       8.10       8.17

X STA.        45.8       50.7       56.4       64.1       71.5       79.0
  A(I)            81.1       90.9       99.5       95.8       98.0
  V(I)            8.45       7.54       6.88       7.15       6.99

X STA.        79.0       90.3      114.4      192.2      286.0      466.9
  A(I)           119.9      178.4      338.1      363.5      491.8
  V(I)            5.71       3.84       2.03       1.88       1.39
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    U.S. Geological Survey WSPRO Input File rock040.wsp
    Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
    TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
       *** RUN DATE & TIME: 05-05-98  12:28

 CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1    1298.  144651.     0.   210.                            0.
 496.32        1298.  144651.     0.   210.  1.00     0.    95.       0.

 VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    496.32     0.0    94.5  1297.8  144651.    4644.   3.58

X STA.        0.0        8.9       12.3       15.6       18.8       21.9
  A(I)          120.0       56.2       54.9       54.2       53.9
  V(I)           1.93       4.13       4.23       4.29       4.31

X STA.       21.9       24.9       27.8       31.0       34.1       37.2
  A(I)           53.6       53.5       55.6       54.1       53.3
  V(I)           4.33       4.34       4.18       4.29       4.36

X STA.       37.2       40.2       43.6       47.2       51.0       54.9
  A(I)           51.7       54.8       56.3       57.1       57.7
  V(I)           4.49       4.24       4.12       4.06       4.03

X STA.       54.9       58.8       62.7       67.3       73.7       94.5
  A(I)           57.3       57.5       63.1       73.1      159.9
  V(I)           4.05       4.04       3.68       3.18       1.45

 VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      11.
      WSEL     LEW     REW    AREA        K        Q    VEL
    500.07   -18.7   499.6  1997.8  205358.   15380.   7.70

X STA.      -18.7      144.1      160.5      175.3      189.2      202.8
  A(I)          183.5       89.4       87.6       86.0       86.5
  V(I)           4.19       8.60       8.78       8.94       8.89

X STA.      202.8      216.0      229.5      243.6      258.1      271.7
  A(I)           84.2       84.7       87.4       87.4       80.5
  V(I)           9.13       9.08       8.80       8.80       9.55

X STA.      271.7      285.1      300.7      317.0      334.0      351.4
  A(I)           77.7       89.1       90.6       92.5       92.9
  V(I)           9.89       8.63       8.49       8.31       8.27

X STA.      351.4      368.9      385.9      403.3      420.8      499.6
  A(I)           93.1       90.4       93.4       93.5      227.3
  V(I)           8.26       8.50       8.23       8.22       3.38

 CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1    2079.  328004.   134.   144.                        46401.
          2    2706.  115978.   598.   599.                        32659.
 500.98        4785.  443982.   733.   743.  2.19   -25.   708.  46873.

 VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
      WSEL     LEW     REW    AREA        K        Q    VEL
    500.98   -24.8   707.8  4785.0  443982.   20000.   4.18

X STA.      -24.8        3.2        9.0       14.6       20.3       25.8
  A(I)          291.8      115.0      114.3      117.9      113.3
  V(I)           3.43       8.69       8.75       8.48       8.83

X STA.       25.8       31.6       37.5       43.6       49.8       56.5
  A(I)          117.3      118.5      119.5      122.4      126.2
  V(I)           8.53       8.44       8.37       8.17       7.92

X STA.       56.5       65.0       73.4       82.3       94.4      121.2
  A(I)          133.7      134.1      137.8      156.3      247.6
  V(I)           7.48       7.46       7.26       6.40       4.04

X STA.      121.2      171.5      227.6      287.1      351.6      707.8
  A(I)          367.5      393.8      397.9      408.9     1051.4
  V(I)           2.72       2.54       2.51       2.45       0.95
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        U.S. Geological Survey WSPRO Input File rock040.wsp
        Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
        TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
           *** RUN DATE & TIME: 05-05-98  12:28

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1098.  167156.    94.   111.                       21254.
   493.65         1098.  167156.    94.   111.  1.00     0.    94.  21254.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      493.65     0.0    94.4  1098.0  167156.    7780.   7.09

X STA.         0.0       11.0       14.3       17.4       20.4       23.2
  A(I)           127.0       45.3       44.4       44.5       43.4
  V(I)            3.06       8.59       8.76       8.74       8.96

X STA.        23.2       26.1       28.9       31.8       34.7       37.7
  A(I)            44.3       43.8       44.4       44.2       44.9
  V(I)            8.79       8.88       8.75       8.81       8.67

X STA.        37.7       40.7       43.9       47.4       50.9       54.5
  A(I)            43.7       44.7       46.6       45.5       46.3
  V(I)            8.91       8.70       8.35       8.55       8.40

X STA.        54.5       58.2       61.9       65.8       71.3       94.4
  A(I)            46.9       47.2       48.6       57.1      145.3
  V(I)            8.30       8.24       8.00       6.82       2.68

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1205.  139392.   125.   133.                       21180.
             2      55.     461.   141.   141.                         195.
   494.25         1260.  139853.   267.   274.  1.08   -16.   251.  14929.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =     116.
        WSEL     LEW     REW    AREA        K        Q    VEL
      494.25   -15.9   250.8  1259.7  139853.    7780.   6.18

X STA.       -15.9        1.9        5.8        9.5       13.1       16.6
  A(I)           117.8       49.9       49.2       48.6       48.9
  V(I)            3.30       7.79       7.91       8.00       7.96

X STA.        16.6       20.1       23.7       27.3       31.0       34.6
  A(I)            48.6       50.0       49.2       50.5       47.9
  V(I)            8.01       7.78       7.91       7.70       8.12

X STA.        34.6       38.1       41.8       45.6       49.4       53.3
  A(I)            45.7       48.1       48.5       49.1       49.7
  V(I)            8.51       8.09       8.02       7.93       7.82

X STA.        53.3       59.3       66.2       72.9       79.6      250.8
  A(I)            63.0       62.0       61.6       61.3      210.1
  V(I)            6.17       6.27       6.32       6.35       1.85

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      493.71     0.0    94.4  1103.7  168474.    7780.   7.05

X STA.         0.0       11.1       14.3       17.4       20.4       23.3
  A(I)           127.8       45.5       44.6       44.7       43.6
  V(I)            3.04       8.55       8.72       8.70       8.92

X STA.        23.3       26.1       28.9       31.8       34.8       37.7
  A(I)            44.5       44.0       44.6       45.1       44.4
  V(I)            8.75       8.85       8.71       8.63       8.77

X STA.        37.7       40.8       44.0       47.4       51.0       54.6
  A(I)            44.2       45.2       45.6       47.4       45.7
  V(I)            8.80       8.60       8.53       8.21       8.50

X STA.        54.6       58.2       61.9       65.9       71.6       94.4
  A(I)            47.2       47.5       48.8       58.8      144.5
  V(I)            8.25       8.19       7.97       6.62       2.69
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        U.S. Geological Survey WSPRO Input File rock040.wsp
        Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
        TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
           *** RUN DATE & TIME: 05-05-98  12:28

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RREXT:XS   ******  -196.    2040.  0.89 *****  494.49  491.00  13700.  493.60
     -695. ******   285.  191797.  1.27 ***** *******    0.65    6.72

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "RRFLV"     KRATIO =  1.56

RRFLV:FV     395.  -362.    3079.  0.42  1.29  495.78 *******  13700.  495.36
     -300.   395.   333.  299384.  1.37  0.00    0.00    0.44    4.45
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

RRAPR:AS     128.   -93.    2142.  0.73  0.35  496.28 *******  13700.  495.55
     -172.   128.   323.  229368.  1.15  0.16    0.00    0.53    6.40
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   495.36     495.27

             <<<<<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
RRBRG:BR     395.     0.    1431.  1.40 *****  496.68  489.83  13567.  495.28
     -300. ******   109.  176379.  1.00 ***** *******    0.46    9.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.000  495.27 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RROAD:RG    -289.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RRAPR:AS      95.  -135.    2992.  0.37  0.31  497.85  490.11  13700.  497.48
     -172.   103.   327.  352770.  1.13  0.00   -0.01    0.34    4.58

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.31
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS      67.  -133.    2948.  0.38  0.10  497.97 *******  13700.  497.59
     -105.    67.   327.  345721.  1.14  0.01    0.01    0.34    4.65

FULLV:FV     105.  -137.    3035.  0.36  0.16  498.13 *******  13700.  497.77
        0.   105.   327.  359596.  1.13  0.00    0.01    0.33    4.51
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     116.   -21.    2799.  0.67  0.22  498.51 *******  13700.  497.84
      116.   116.   464.  270517.  1.80  0.16    0.00    0.48    4.89
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   497.77     495.77
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =     7706.      7611.    1.01

             <<<<<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     105.     0.    1128.  0.43 *****  496.75  487.38   5948.  496.32
        0. ******    95.  144651.  1.00 ***** *******    0.27    5.27

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   6.  0.800  0.130  495.77 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.   102.  0.24  0.63  498.44    0.00   7706.  497.64

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:       0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:   7706.   359.   100.   459.   4.0   2.9   8.6   7.3   3.7   3.0

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      90.   -21.    2907.  0.63  0.24  498.69  491.60  13700.  498.06
      116.   100.   467.  281195.  1.81  0.00    0.00    0.46    4.71
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

```
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   RREXT:XS    -695.  -196.   285.  13700.  191797.    2040.    6.72  493.60
   RRFLV:FV    -300.  -362.   333.  13700.  299384.    3079.    4.45  495.36
   RRBRG:BR    -300.     0.   109.  13567.  176379.    1431.    9.48  495.28
   RROAD:RG    -289.**************      0.******************    2.00********
   RRAPR:AS    -172.  -135.   327.  13700.  352770.    2992.    4.58  497.48

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS    -105.  -133.   327.  13700.  345721.    2948.    4.65  497.59
   FULLV:FV       0.  -137.   327.  13700.  359596.    3035.    4.51  497.77
   BRIDG:BR       0.     0.    95.   5948.  144651.    1128.    5.27  496.32
   RDWAY:RG      11.*******     0.   7706.        0.*********    2.00  497.64
   APPRO:AS     116.   -21.   467.  13700.  281195.    2907.    4.71  498.06

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   RREXT:XS    491.00    0.65  480.64  508.61************  0.89  494.49  493.60
   RRFLV:FV  ********    0.44  480.64  508.61  1.29  0.00  0.42  495.78  495.36
   RRBRG:BR    489.83    0.46  479.02  495.28************  1.40  496.68  495.28
   RROAD:RG  ****************  499.53  501.16************  0.14  501.11********
   RRAPR:AS    490.11    0.34  478.87  518.01  0.31  0.00  0.37  497.85  497.48
   EXITX:XS  ********    0.34  479.07  518.21  0.10  0.01  0.38  497.97  497.59
   FULLV:FV  ********    0.33  479.07  518.21  0.16  0.00  0.36  498.13  497.77
   BRIDG:BR    487.38    0.27  477.92  496.32************  0.43  496.75  496.32
   RDWAY:RG  ****************  493.61  511.45  0.24******  0.63  498.44  497.64
   APPRO:AS    491.60    0.46  480.40  503.87  0.24  0.00  0.63  498.69  498.06

         U.S. Geological Survey WSPRO Input File rock040.wsp
         Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
         TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
            *** RUN DATE & TIME: 05-05-98  12:28

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RREXT:XS   ******  -361.    2909.  1.02 *****  496.13  493.17  20000.  495.11
     -695. ******   333.  279850.  1.38 ***** *******    0.70    6.87

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "RRFLV"     KRATIO =  1.60

RRFLV:FV     395.  -372.    4189.  0.45  1.26  497.39 *******  20000.  496.94
     -300.   395.   335.  448013.  1.27  0.00    0.00    0.39    4.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

RRAPR:AS     128.  -127.    2800.  0.91  0.35  497.97 *******  20000.  497.06
     -172.   128.   326.  322646.  1.14  0.23   -0.01    0.54    7.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   496.94      495.27

            <<<<<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
RRBRG:BR     395.     0.    1431.  2.42 *****  497.70  491.44  17853.  495.28
     -300. ******   109.  176379.  1.00 ***** *******    0.61   12.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.130  495.27 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RROAD:RG    -289.   110.  0.11  0.32  500.94    0.01   2388.  500.70

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    993.   392.  -327.    66.   1.2   0.7   4.1   3.7   0.9   2.9
   RT:   1394.   408.    66.   474.   1.2   0.9   4.6   3.8   1.1   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RRAPR:AS      95.  -164.    4567.  0.32  0.33  501.04  493.05  20000.  500.73
     -172.   105.   342.  645409.  1.07  0.00    0.01    0.27    4.38
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS      67.  -163.    4499.  0.33  0.07  501.12 *******  20000.  500.79
     -105.    67.   341.  631113.  1.07  0.01    0.00    0.27    4.45

FULLV:FV     105.  -164.    4558.  0.32  0.10  501.23 *******  20000.  500.91
        0.   105.   342.  643574.  1.07  0.00    0.01    0.27    4.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.68
```

```
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS     116.   -25.    4745.  0.61  0.16  501.53 *******  20000.  500.93
      116.   116.   708.  439922.  2.19  0.14    0.00    0.43    4.21
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   500.91     495.77
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =   15380.     14370.    1.07

             <<<<<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     105.     0.    1128.  0.26 *****  496.58  485.98   4644.  496.32
        0. ******    95.  144651.  1.00 ***** *******    0.21    4.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   6.  0.800  0.130  495.77 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.   102.  0.21  0.60  501.37    0.00  15380.  500.07

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     90.    19.   -19.     0.   0.2   0.1   5.1  60.0   1.4   2.9
   RT:  15290.   400.   100.   500.   6.5   5.0   9.1   7.7   6.3   2.4

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      90.   -25.    4784.  0.60  0.25  501.57  494.89  20000.  500.98
      116.   108.   708.  443929.  2.19  0.00    0.00    0.43    4.18
                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   RREXT:XS    -695.  -361.   333.  20000.  279850.    2909.    6.87  495.11
   RRFLV:FV    -300.  -372.   335.  20000.  448013.    4189.    4.77  496.94
   RRBRG:BR    -300.     0.   109.  17853.  176379.    1431.   12.48  495.28
   RROAD:RG    -289.*******   993.   2388.       0.       0.    2.00  500.70
   RRAPR:AS    -172.  -164.   342.  20000.  645409.    4567.    4.38  500.73

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -105.  -163.   341.  20000.  631113.    4499.    4.45  500.79
   FULLV:FV       0.  -164.   342.  20000.  643574.    4558.    4.39  500.91
   BRIDG:BR       0.     0.    95.   4644.  144651.    1128.    4.11  496.32
   RDWAY:RG      11.*******    90.  15380.******************    2.00  500.07
   APPRO:AS     116.   -25.   708.  20000.  443929.    4784.    4.18  500.98

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   RREXT:XS    493.17    0.70  480.64  508.61************  1.02  496.13  495.11
   RRFLV:FV  ********    0.39  480.64  508.61  1.26  0.00  0.45  497.39  496.94
   RRBRG:BR    491.44    0.61  479.02  495.28************  2.42  497.70  495.28
   RROAD:RG  ****************  499.53  501.16  0.11******  0.32  500.94  500.70
   RRAPR:AS    493.05    0.27  478.87  518.01  0.33  0.00  0.32  501.04  500.73
   EXITX:XS  ********    0.27  479.07  518.21  0.07  0.01  0.33  501.12  500.79
   FULLV:FV  ********    0.27  479.07  518.21  0.10  0.00  0.32  501.23  500.91
   BRIDG:BR    485.98    0.21  477.92  496.32************  0.26  496.58  496.32
   RDWAY:RG  ****************  493.61  511.45  0.21******  0.60  501.37  500.07
   APPRO:AS    494.89    0.43  480.40  503.87  0.25  0.00  0.60  501.57  500.98

       U.S. Geological Survey WSPRO Input File rock040.wsp
       Hydraulic analysis for structure ROCKTH00140040   Date: 21-APR-98
       TH 14, WILLIAMS RD, CROSSING THE WILLIAMS RIVER IN ROCKINGHAM, VT  RLB
          *** RUN DATE & TIME: 05-05-98  12:28

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RREXT:XS   ******   -66.    1229.  0.70 *****  492.25  487.80   7780.  491.54
     -695. ******   277.  108888.  1.12 ***** *******    0.60    6.33

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "RRFLV"     KRATIO =  1.57

RRFLV:FV     395.  -161.    1849.  0.34  1.28  493.53 *******   7780.  493.19
     -300.   395.   283.  171484.  1.25  0.00    0.00    0.41    4.21
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

RRAPR:AS     128.   -71.    1412.  0.48  0.32  493.91 *******   7780.  493.43
     -172.   128.   138.  142042.  1.02  0.07    0.00    0.38    5.51
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
```

```
RRBRG:BR     395.     0.    1181.  0.69  1.37  493.62  487.36   7780.  492.93
     -300.   395.   109.  195732.  1.02  0.00    0.00    0.35    6.59

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.990 ******  495.27 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RROAD:RG    -289.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA  VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
RRAPR:AS      95.   -71.    1421.  0.47  0.28  493.95  487.17   7780.  493.48
     -172.   105.   139.  143128.  1.02  0.05    0.00    0.37    5.48

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.481  0.000  159803.   -29.    79.   493.15
                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 XSID:CODE   SRDL    LEW     AREA  VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS      67.   -72.    1423.  0.47  0.20  494.16 *******   7780.  493.69
     -105.    67.   139.  143369.  1.02  0.00    0.01    0.37    5.47

FULLV:FV     105.   -74.    1498.  0.43  0.29  494.45 *******   7780.  494.02
        0.   105.   180.  153699.  1.02  0.00    0.00    0.38    5.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     116.   -16.    1257.  0.64  0.33  494.88 *******   7780.  494.24
      116.   116.   249.  139616.  1.08  0.11    0.00    0.52    6.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   494.25       0.00     493.65     493.61
 ===260 ATTEMPTING FLOW CLASS 4 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     105.     0.    1098.  0.90  0.32  494.54  488.55   7780.  493.65
        0.   105.    94.  167085.  1.15  0.07    0.00    0.39    7.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   4.  0.933  0.131  495.77 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      90.   -16.    1259.  0.64  0.29  494.89  489.00   7780.  494.25
      116.    93.   250.  139762.  1.08  0.06    0.00    0.52    6.18

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.644  0.000  139804.    -3.    91. ********
                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   RREXT:XS    -695.   -66.   277.   7780.  108888.    1229.    6.33  491.54
   RRFLV:FV    -300.  -161.   283.   7780.  171484.    1849.    4.21  493.19
   RRBRG:BR    -300.     0.   109.   7780.  195732.    1181.    6.59  492.93
   RROAD:RG    -289.**************      0.******************    2.00********
   RRAPR:AS    -172.   -71.   139.   7780.  143128.    1421.    5.48  493.48

    XSID:CODE   XLKQ   XRKQ       KQ
   RRAPR:AS     -29.    79.  159803.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -105.   -72.   139.   7780.  143369.    1423.    5.47  493.69
   FULLV:FV       0.   -74.   180.   7780.  153699.    1498.    5.19  494.02
   BRIDG:BR       0.     0.    94.   7780.  167085.    1098.    7.09  493.65
   RDWAY:RG      11.**************      0.       0.       0.    2.00********
   APPRO:AS     116.   -16.   250.   7780.  139762.    1259.    6.18  494.25

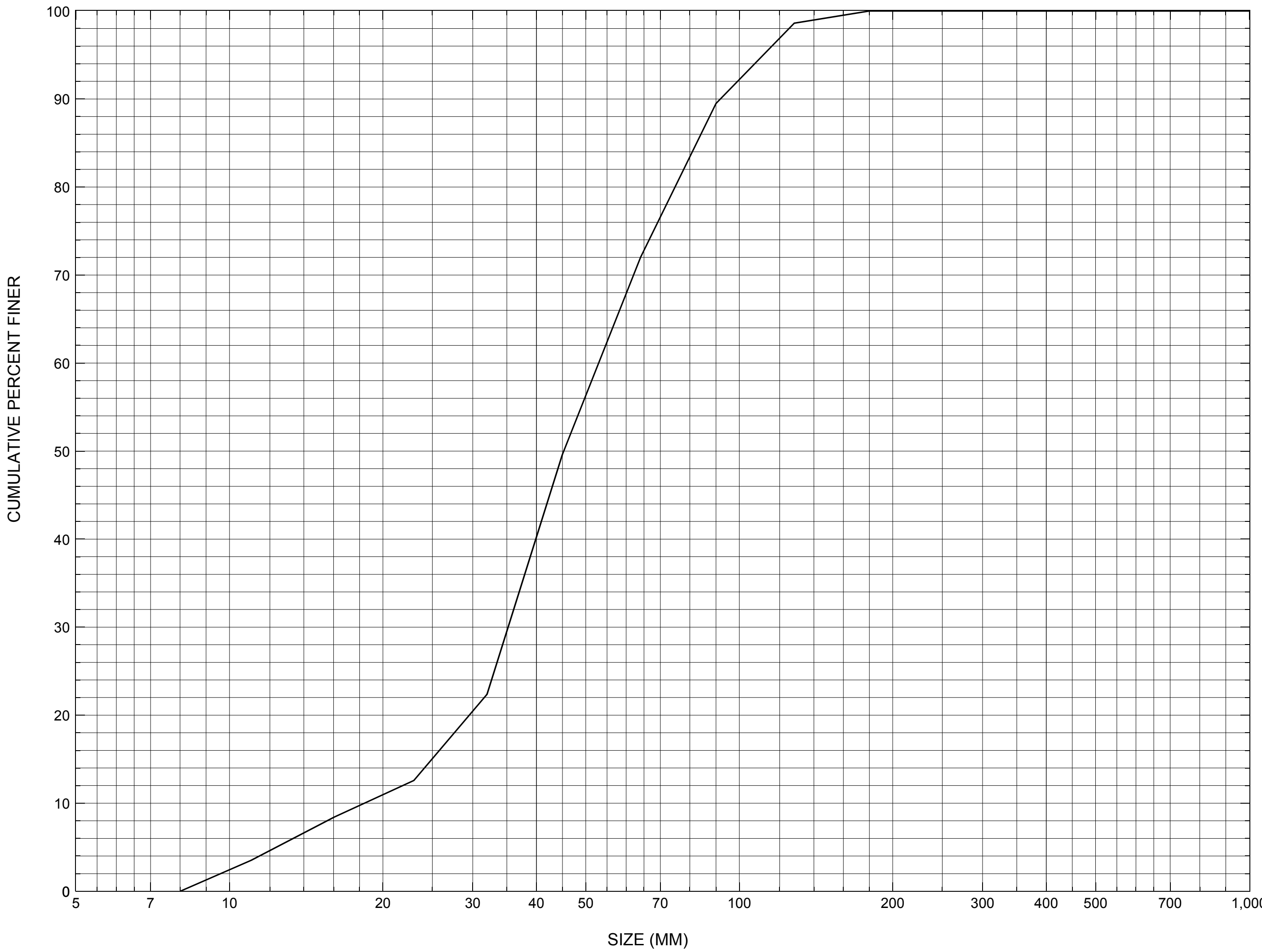
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.    91.  139804.
```

SECOND USER DEFINED TABLE.

| XSID:CODE | CRWS | FR# | YMIN | YMAX | HF | HO | VHD | EGL | WSEL |
|---|---|---|---|---|---|---|---|---|---|
| RREXT:XS | 487.80 | 0.60 | 480.64 | 508.61************ | | | 0.70 | 492.25 | 491.54 |
| RRFLV:FV | ******** | 0.41 | 480.64 | 508.61 | 1.28 | 0.00 | 0.34 | 493.53 | 493.19 |
| RRBRG:BR | 487.36 | 0.35 | 479.02 | 495.28 | 1.37 | 0.00 | 0.69 | 493.62 | 492.93 |
| RROAD:RG | **************** | | 499.53 | 501.16*********************************** | | | | | |
| RRAPR:AS | 487.17 | 0.37 | 478.87 | 518.01 | 0.28 | 0.05 | 0.47 | 493.95 | 493.48 |
| EXITX:XS | ******** | 0.37 | 479.07 | 518.21 | 0.20 | 0.00 | 0.47 | 494.16 | 493.69 |
| FULLV:FV | ******** | 0.38 | 479.07 | 518.21 | 0.29 | 0.00 | 0.43 | 494.45 | 494.02 |
| BRIDG:BR | 488.55 | 0.39 | 477.92 | 496.32 | 0.32 | 0.07 | 0.90 | 494.54 | 493.65 |
| RDWAY:RG | **************** | | 493.61 | 511.45 | 0.32****** | | 0.65 | 494.56******** | |
| APPRO:AS | 489.00 | 0.52 | 480.40 | 503.87 | 0.29 | 0.06 | 0.64 | 494.89 | 494.25 |

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ROCKTH00140040, in Rockingham, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ROCKTH00140040

## General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 06 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 60250

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

Waterway *(I - 6)* WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number TH014

Vicinity *(I - 9)* 0.2 MI TO JCT W VT103

Topographic Map Saxtons River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43127

Longitude *(i - 17; nnnnn.n)* 72321

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10131400401314

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

Maximum span length *(I - 48; nnnn)* 0073

Year built *(I - 27; YYYY)* 1868

Structure length *(I - 49; nnnnnn)* 000106

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 140

Year of ADT *(I - 30; YY)* 90

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

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

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 710

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 302

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 015.5

Number of approach spans *(I - 46; nnnn)* 0001

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

Comments:

**The structural inspection report of 08/24/94 indicates that the structure is a lattice covered bridge with a steel beam and timber deck approach span behind the right abutment. The low chords and floor system were inspected with a special staging apparatus in the spring of 1993. Both abutment walls are constructed of laid-up stone with concrete caps. Along the bottom 2/3 of the left abutment wall, there is a newer concrete facing. There is also a newer concrete footing along the bottom, which apparently was freely poured onto some stone fill. The pier is a massive solid concrete wall with a smaller concrete extension supporting the approach span. The pier footing is exposed along the bridge (Continued, page 36)**

## Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

Comments:

**side of the crossing. There are no apparent problems with scour along the substructure units. The waterway has a fairly straight alignment through the structure. All of the flow is beneath the covered bridge span. There is a sand point bar beneath the approach span with growing vegetation. There is stone fill along the upstream side of the left abutment. There is a bedrock outcrop roughly 150 feet upstream. Stone fill is noted as placed upstream of the right abutment.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **99.16** mi$^2$  Lake/pond/swamp area **0.24** mi$^2$
Watershed storage *(ST)* **0.5** %
Bridge site elevation **472.4** ft  Headwater elevation **2882** ft
Main channel length **20.05** mi
10% channel length elevation **532** ft  85% channel length elevation **1400** ft
Main channel slope *(S)* **57.75** ft / mi

Watershed Precipitation Data

Average site precipitation - in  Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

## Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

**NO BENCHMARK INFORMATION**

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

**NO FOUNDATION MATERIAL INFORMATION**

Comments:

**NO PLANS**

## Cross-sectional Data

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

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

Comments: **Station and elevation measurements are in feet. This cross section is part of a 9/4/96 bridge inspection report. The elevation coordinate has been made to line up with those used in this report by the low chord points.**

| Station | 0 | 16 | 36.5 | 54 | 63 | 73 | - | - | - | - | - |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature | LAB | - | - | - | - | RAB | - | - | - | - | - |
| Low chord elevation | 496.32 | 496.08 | 495.77 | 495.51 | 495.38 | 495.21 | - | - | - | - | - |
| Bed elevation | 483.22 | 477.58 | 478.77 | 479.51 | 479.98 | 482.21 | - | - | - | - | - |
| Low chord to bed | 13.1 | 18.5 | 17 | 16 | 15.4 | 13 | - | - | - | - | - |

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

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

Comments: -
-

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

| 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: **RB** Date: **10/09/96**
Computerized by: **RB** Date: **10/11/96**
Reviewd by: **RB** Date: **06/05/98**

Structure Number **ROCKTH00140040**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **09** / **04** / 19**96**

2. Highway District Number **02** Mile marker **00000**

County **WINDHAM (025)** Town **ROCKINGHAM (60250)**

Waterway *(I - 6)* **WILLIAMS RIVER** Road Name **WILLIAMS ROAD**

Route Number **TH14** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

**The bridge is located 0.2 miles from the junction with VT 103. This is a covered bridge with a railroad bridge 300 ft DS.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **2** 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 **1** UB **1** DS **1** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **2** *( **1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **106** *(feet)* Span length **73** *(feet)* Bridge width **14** *(feet)*

### Road approach to bridge:

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

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

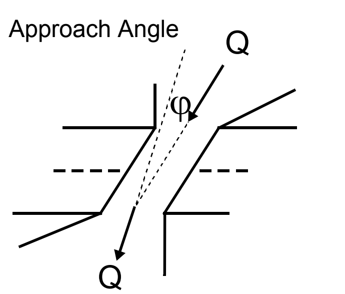
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

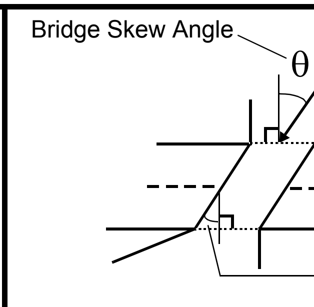
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 1 | 2 | 2 | 1 |
| RBUS | 0 | - | 0 | - |
| RBDS | 0 | - | 2 | 1 |
| LBDS | 0 | - | 2 | 1 |

*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: **5** 16. Bridge skew: **10**




α= **0.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **100** feet **US** *(US, UB, DS)* to **25** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **68** feet **DS** *(US, UB, DS)* to **327** feet **DS**

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

18. Bridge Type: **1a/1b**

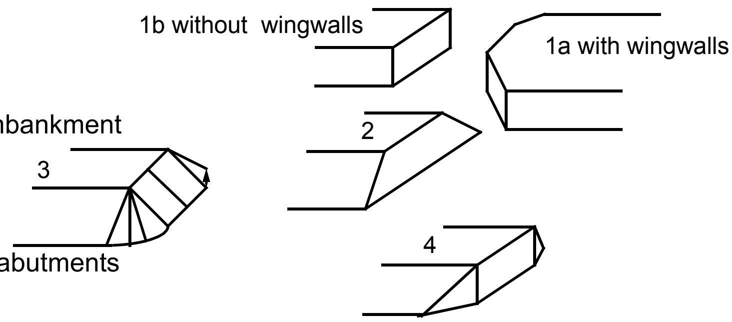
1a- Vertical abutments with wingwalls

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. The left bank US is forested, with a small cabin on the hill about 45 ft from the left abutment. On the right bank US is the McDermott salvage yard and a house. The salvage yard has a high metal fence along its perimeter. The DS banks are fields with railroad tracks crossing at 320 ft DS on the left and at 290 ft DS on the right.**

**7. Values are from the VTAOT files. Measured bridge length is 103 ft, bridge span is 63 ft from the streamward side of the left abutment to the streamward side of the pier, and bridge width is 18 ft between the outsides of the walls and 15 ft between the inside curbs.**

**18. The right abutment is even with bank full and type 1b. The left abutment is type 1a. The pier acts like an abutment on the right side.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **98.5** | **14.5** | | | **5.5** | **3** | **2** | **2367** | **230** | **0** | **1** |

23. Bank width **35.0** 24. Channel width **20.0** 25. Thalweg depth **128.5** 29. Bed Material **3264**

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.):

**27. The left bank is bedrock from 360 ft US to 160 ft US. From 160 ft US to 20 ft US the bank is sand, gravel and protection.**

**29. Bedrock and gravel is along the left side of the bed from 360 ft to 151 ft US and from 50 ft to 30 ft US. Bedrock is also along the channel side of the point bar on the right bank from 300 ft US to 290 ft US.**

**30. The left bank protection extends from 160 ft US to 21 ft US.**

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **68** 35. Mid-bar width: **38**

36. Point bar extent: **93** feet **US** (US, UB) to **0** feet **DS** (US, UB, DS) positioned **40** %LB to **80** %RB

37. Material: **34**

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

**The high point of this bar is in the middle of the channel. An additional side bar exists from 126 ft US to 9 ft US with mid-bar distance at 101 ft US where it is 22 ft wide. It is positioned from 60% LB to 100% RB and is composed of sand, silt/clay, and organics. There are a lot of small brush and trees on this bar. A third point bar exists from 355 ft US to 225 ft US with mid-bar at 290 ft US where it is 24.5 ft wide. This bar's material is gravel, sand, cobbles, and bedrock and it has some vegetation. It is positioned 50% LB to 100% RB.**

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

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

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

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

**NO CUT BANKS**

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

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

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

**NO CHANNEL SCOUR**

**There is some local scouring behind boulders and bedrock in the channel. A predominantly DS scour hole extends US; see DS channel assessment. There is also pier scour, see #96.**

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 |
|---|---|---|---|---|---|---|---|
| 96.5 | | 1.5 | | 2 | 7 | 7 | - |

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **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.):

**2314**

**55. The stone masonry right abutment is even with the water at bank full. At lower flows, the pier acts like the right abutment, protruding into the channel. The left abutment is concrete and laid-up stone. The bridge sits on concrete.**

**63. The bed material grades from silt on the right side of the bed, to sand and gravel in the center of the channel, then to stone fill, which was placed to protect the left abutment, on the left side of the bed.**

**The main channel is between the left abutment and the pier.**

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

67. Debris Potential 1____ ( 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**

**65. Debris caught in the trees along both banks US mark high water.**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | 0 | 90 | 2 | 2 | 2.5 | 2.4 | 90.0 |
| RABUT | 1 | 20 | 90 | | | 0 | 0 | 109.0 |

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

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

**-**

**-**

**2**

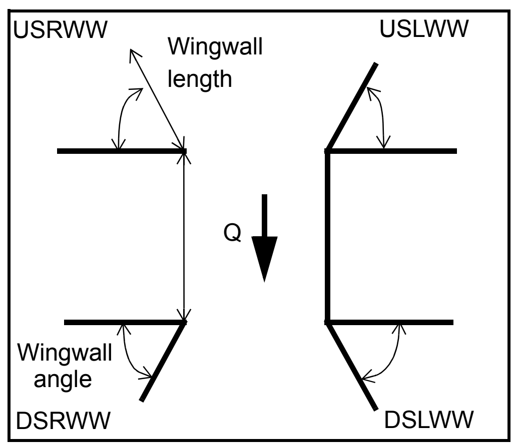
**75. The scour hole extends from the US bridge face to the DS section.**

**76. A subfooting is present from the US left wingwall to 9 ft under the bridge. The footing is 1.7 ft thick and the subfooting is exposed another 0.7 ft from its top to the stream bed. Where there is no subfooting, from 9 ft under the bridge to 0 ft DS, the exposure depth is 2.0 ft.**

**77. The right abutment is stacked stones with a concrete bridge seat.**

80. Wingwalls:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 109.0 | |
| USRWW: | Y | | 1 | | 2 | 4.0 | |
| DSLWW: | - | | 2.4 | | N | 23.5 | |
| DSRWW: | - | | - | | - | 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 | N | - | 1 | - | 1 | - |
| Condition | Y | - | - | - | 2 | - | 1 | - |
| Extent | 2 | - | - | 1 | - | 2 | 0 | - |

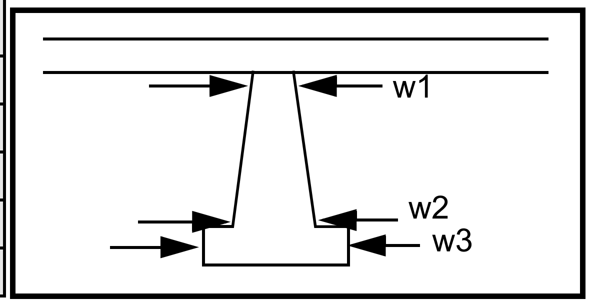
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

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

## Piers:

84. Are there piers? 80. (Y or if N type ctrl-n pr)

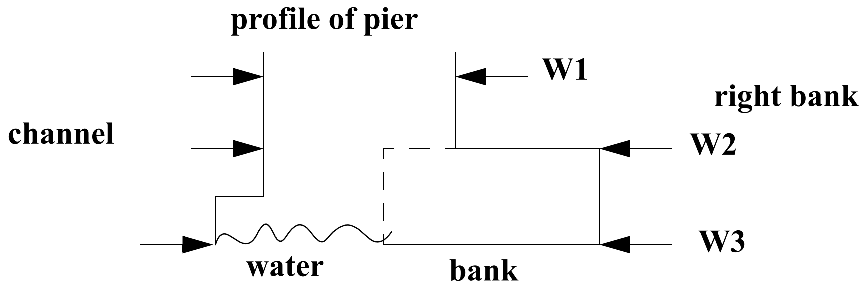
| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | | - | 40.0 | 15.0 | - |
| Pier 2 | | | - | 10.0 | 36.5 | - |
| Pier 3 | 9.5 | 12.0 | 14.5 | - | - | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | At | by the | g the | extend | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | bank | flow | wing | ing | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | -full | of | wall. | per- | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | flows | wate | The | pen- | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | , the | r, at | DS | dicul | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | US | low | right | ar to | |
| 92. Pushed | left | flows | wing | the | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | wing | the | wall | right | |
| 95. Cross-members | wall | wate | is | abut | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | is | r | laid- | ment | ***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | attac | flows | up | . | |
| 98. Exposure depth | ked | alon | stone | 82. | |

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

**The US left wingwall protection extends from the end of the footing at the middle of the wingwall to the US end of the wingwall. The left abutment protection extends from the exposed footing to the scour hole.**




**Y**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | RB | 1 | 2 | 2 | N | 10 |

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

Bank protection type (Qmax): LB **1** RB **0** Bank protection condition: LB **2** RB **1.5**

*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.):

**4.1**
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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? 85. (Y or if N type ctrl-n cb) Where? Pier (LB or RB) Mid-bank distance: widt

Cut bank extent: hs feet are (US, UB, DS) to for feet the (US, UB, DS)

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

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

**end of the pier.**
**98. Exposure depth given is at the US end of the pier. At 7 ft under the bridge and at the DS end, the exposure depth is 2.2 ft.**

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

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

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

**2**
**123**
**123**
**1**

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? 3241

Confluence 1: Distance 0 Enters on 0 (LB or RB) Type - ( **1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

**road bridge 300 ft DS, there is no channel scour and the stream flows straight under the bridge. Right bank protection for the railroad bridge embankment extends from 209 ft DS to 273 ft DS, measured from the down-**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution str

**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)*:

**eam bridge face of ROCK040. It is type-2 protection in good condition. The bed material is tightly packed across the channel and the point bar.**

## 109. G. Plan View Sketch

N

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

APPENDIX F:

# SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ROCKTH00140040 Town: ROCKINGHAM
Road Number: TH 14 County: WINDHAM
Stream: WILLIAMS RIVER

Initials RLB Date: 5/5/98 Checked: MAI

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 Davis, 1995, p. 28, eq. 16)

| Approach Section Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 13700 | 20000 | 7780 |
| Main Channel Area, ft2 | 1692 | 2079 | 1205 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 1216 | 2706 | 55 |
| Top width main channel, ft | 131 | 134 | 125 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 357 | 598 | 141 |
| D50 of channel, ft | 0.1485 | 0.1485 | 0.1485 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| | | | |
| y1, average depth, MC, ft | 12.9 | 15.5 | 9.6 |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | 3.4 | 4.5 | 0.4 |
| | | | |
| Total conveyance, approach | 281238 | 443982 | 139853 |
| Conveyance, main channel | 238127 | 328004 | 139392 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 43111 | 115978 | 461 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | 0.0000 |
| Qm, discharge, MC, cfs | 11599.9 | 14775.6 | 7754.4 |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | 0.0 |
| Qr, discharge, ROB, cfs | 2100.1 | 5224.4 | 25.6 |
| | | | |
| Vm, mean velocity MC, ft/s | 6.9 | 7.1 | 6.4 |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | 1.7 | 1.9 | 0.5 |
| Vc-m, crit. velocity, MC, ft/s | 9.1 | 9.4 | 8.7 |
| 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 | 0 |
| Left Overbank | N/A | N/A | N/A |
| Right Overbank | N/A | N/A | 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 Davis, 1995, p. 32, eq. 20, 20a)

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 13700 | 20000 | 7780 |
| (Q) discharge thru bridge, cfs | 5948 | 4644 | 7780 |
| Main channel conveyance | 144651 | 144651 | 167156 |
| Total conveyance | 144651 | 144651 | 167156 |
| Q2, bridge MC discharge,cfs | 5948 | 4644 | 7780 |
| Main channel area, ft2 | 1128 | 1128 | 954 |
| Main channel width (normal), ft | 94.5 | 94.5 | 94.4 |
| Cum. width of piers in MC, ft | 10.9 | 10.9 | 10.9 |
| W, adjusted width, ft | 83.6 | 83.6 | 83.5 |
| y_bridge (avg. depth at br.), ft | 13.49 | 13.49 | 11.43 |
| Dm, median (1.25*D50), ft | 0.185625 | 0.185625 | 0.185625 |
| y2, depth in contraction,ft | 7.75 | 6.27 | 9.76 |
| ys, scour depth (y2-ybridge), ft | -5.75 | -7.23 | **-1.66** |

**Pressure Flow Scour** (contraction scour for orifice flow conditions)

Chang pressure flow equation        Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

| | Q100 | Q500 | OtherQ |
|---|---|---|---|
| Q, total, cfs | 13700 | 20000 | 7780 |
| Q, thru bridge MC, cfs | 5948 | 4644 | 7780 |
| Vc, critical velocity, ft/s | 9.09 | 9.38 | 8.66 |
| Va, velocity MC approach, ft/s | 6.86 | 7.11 | 6.44 |
| Main channel width (normal), ft | 94.5 | 94.5 | 94.4 |
| Cum. width of piers in MC, ft | 10.9 | 10.9 | 10.9 |
| W, adjusted width, ft | 83.6 | 83.6 | 83.5 |
| qbr, unit discharge, ft2/s | 71.1 | 55.6 | 93.2 |
| Area of full opening, ft2 | 1128.0 | 1128.0 | 954.0 |
| Hb, depth of full opening, ft | 13.49 | 13.49 | 11.43 |
| Fr, Froude number, bridge MC | 0.27 | 0.21 | 0 |
| Cf, Fr correction factor (<=1.0) | 0.85 | 0.77 | 0.00 |
| **Area at downstream face, ft2 | 0 | 0 | 0 |
| **Hb, depth at downstream face, ft | 0.00 | 0.00 | 0.00 |
| **Fr, Froude number at DS face | ERR | ERR | ERR |
| **Cf, for downstream face (<=1.0) | N/A | N/A | N/A |
| Elevation of Low Steel, ft | 495.77 | 495.77 | 0 |
| Elevation of Bed, ft | 482.28 | 482.28 | -11.43 |

| | | | |
|---|---|---|---|
| Elevation of Approach, ft | 498.06 | 500.98 | 0 |
| Friction loss, approach, ft | 0.24 | 0.25 | 0 |
| Elevation of WS immediately US, ft | 497.82 | 500.73 | 0.00 |
| ya, depth immediately US, ft | 15.54 | 18.45 | 11.43 |
| Mean elevation of deck, ft | 511.5 | 511.5 | 0 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.00 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.97 | 0.92 | 1.00 |
| **Cc, for downstream face (<=1.0) | ERR | ERR | ERR |
| | | | |
| Ys, scour w/Chang equation, ft | **-4.01** | **-5.10** | N/A |
| Ys, scour w/Umbrell equation, ft | 0.95 | 3.72 | N/A |

**Armoring**

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

| Downstream bridge face property | 100-yr | 500-yr | Other Q |
|---|---|---|---|
| Q, discharge thru bridge MC, cfs | 5948 | 4644 | 7780 |
| Main channel area (DS), ft2 | 1133.7 | 1133.7 | 954.1 |
| Main channel width (normal), ft | 94.5 | 94.5 | 94.4 |
| Cum. width of piers, ft | 10.9 | 10.9 | 10.9 |
| Adj. main channel width, ft | 83.6 | 83.6 | 83.5 |
| D90, ft | 0.3009 | 0.3009 | 0.3009 |
| D95, ft | 0.3653 | 0.3653 | 0.3653 |
| Dc, critical grain size, ft | 0.0698 | 0.0425 | 0.1780 |
| Pc, Decimal percent coarser than Dc | 0.883 | 0.944 | 0.385 |
| | | | |
| Depth to armoring, ft | **0.03** | **0.01** | **0.85** |

**Abutment Scour**

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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 | 13700 | 20000 | 7780 | 13700 | 20000 | 7780 |
| a', abut.length blocking flow, ft | 20.9 | 24.8 | 15.9 | 382.7 | 623.6 | 166.6 |
| Ae, area of blocked flow ft2 | 183.21 | 237.37 | 105.23 | 381.91 | 1135.07 | 204.45 |
| Qe, discharge blocked abut.,cfs | 609.21 | -- | 347.48 | -- | -- | 378.55 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 3.33 | 3.43 | 3.30 | 2.16 | 2.28 | 1.85 |
| ya, depth of f/p flow, ft | 8.77 | 9.57 | 6.62 | 1.00 | 1.82 | 1.23 |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 0.82 | 0.82 | 0.82 | 0.55 | 0.55 | 0.55 |
| --Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US) | | | | | | |
| theta | 90 | 90 | 90 | 90 | 90 | 90 |

| | | | | | | |
|---|---|---|---|---|---|---|
| K2 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fr, froude number f/p flow | 0.198 | 0.187 | 0.226 | 0.197 | 0.183 | 0.295 |
| ys, scour depth, ft | **17.59** | **19.22** | **13.87** | **6.97** | **11.74** | **7.23** |

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 20.9 | 24.8 | 15.9 | 382.7 | 623.6 | 166.6 |
| y1 (depth f/p flow, ft) | 8.77 | 9.57 | 6.62 | 1.00 | 1.82 | 1.23 |
| a'/y1 | 2.38 | 2.59 | 2.40 | 383.49 | 342.60 | 135.76 |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.20 | 0.19 | 0.23 | 0.20 | 0.18 | 0.29 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | 4.25 | 7.56 | 5.96 |
| vertical w/ ww's | ERR | ERR | ERR | 3.48 | 6.20 | 4.89 |
| spill-through | ERR | ERR | ERR | 2.34 | 4.16 | 3.28 |

**Abutment riprap Sizing**

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

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.27 | 0.21 | 0.39 | 0.27 | 0.21 | 0.39 |
| y, depth of flow in bridge, ft | 13.56 | 13.56 | 11.43 | 13.56 | 13.56 | 11.43 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | **0.61** | **0.37** | **1.07** | 0.61 | 0.37 | 1.07 |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |
| Fr<=0.8 (spillthrough abut.) | 0.53 | 0.32 | 0.94 | **0.53** | **0.32** | **0.94** |
| Fr>0.8 (spillthrough abut.) | ERR | ERR | ERR | ERR | ERR | ERR |

**Pier Scour**

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and Davis, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)

K4=[1-0.89*(1-Vr)^2]^0.5

Vr=(V1-Vi)/(Vc90-Vi)

V1=0.645*((D50/a)^0.053)*Vc50

Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:

ys<=2.4 times the pier width (a) for Fr<=0.8

ys<=3.0 times the pier width (a) for Fr>0.8

| Pier 1 | Q100 | Q500 | Qother |
|---|---|---|---|
| Pier stationing, ft | 68.2 | 68.2 | 68.2 |
| Area of WSPRO flow tube, ft2 | 51.7 | 51.7 | 43.6 |
| Skewed width of flow tube, ft | 3 | 3 | 2.9 |
| y1, pier approach depth, ft | 17.23 | 17.23 | 15.03 |
| y1 in meters | 5.252 | 5.252 | 4.582 |
| V1, pier approach velocity, ft/s | 5.75 | 4.49 | 8.92 |
| a, pier width, ft | 10.9 | 10.9 | 10.9 |
| L, pier length, ft | 24.9 | 24.9 | 24.9 |
| Fr1, Froude number at pier | 0.244 | 0.191 | 0.405 |
| Pier attack angle, degrees | 10 | 10 | 10 |
| K1, shape factor | 1.1 | 1.1 | 1.1 |
| K2, attack factor | 1.23 | 1.23 | 1.23 |
| K3, bed condition factor | 1.1 | 1.1 | 1.1 |
| D50, ft | 0.1485 | 0.1485 | 0.1485 |
| D50, m | 0.045261 | 0.045261 | 0.045261 |
| D90, ft | 0.3009 | 0.3009 | 0.3009 |
| D90, m | 0.09171 | 0.09171 | 0.09171 |
| Vc50,critical velocity(D50),m/s | 2.908 | 2.908 | 2.843 |
| Vc90,critical velocity(D90),m/s | 3.680 | 3.680 | 3.598 |
| Vi,incipient velocity,m/s | 1.494 | 1.494 | 1.460 |
| Vr, velocity ratio | 0.118 | -0.057 | 0.589 |
| K4, armor factor | 0.00 | 0.00 | 0.00 |
| ys, scour depth (K4 applicable) ft | ERR | ERR | ERR |
| ys, scour depth (K4 not applied)ft | **20.83** | **18.73** | **24.70** |

**Pier rip-rap sizing**

D50=0.692(K*V)^2/(Ss-1)*2*g

(Richardson and Davis, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7

Characteristic avg. channel velocity, V, (Q/A):

(Mult. by 0.9 for bankward piers in a straight, uniform reach, up to 1.7 for a pier in main current of flow around a bend)

| Pier 1 | Q100 | Q500 | Qother |
|---|---|---|---|
| K, pier shape coeff. | 1.7 | 1.7 | 1.7 |
| V, velocity on pier, ft/s | 5.27 | 4.12 | 8.11 |
| D50, median stone diameter, ft | **0.52** | **0.32** | **1.24** |