Modified Level II Streambed-Scour Analysis for Structure I-65-118-4838 Crossing Crooked Creek in Marion County, Indiana

By BRET A. ROBINSON, DAVID C. VOELKER, and ROBERT L. MILLER

Prepared in cooperation with the INDIANA DEPARTMENT OF TRANSPORTATION

U.S. GEOLOGICAL SURVEY
Open-File Report 97-316

Indianapolis, Indiana
1997
CONVERSION FACTORS AND ABBREVIATIONS

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Abbreviations used in this report:

- D₅₀ median diameter of bed material
- Q100 100-year discharge
- FEMA Federal Emergency Management Agency
- HEC Hydraulic Engineering Circular
- IDNR Indiana Department of Natural Resources
- INDOT Indiana Department of Transportation
- USGS U. S. Geological Survey
- WSPRO Water Surface PROfile model
ABSTRACT

Level II scour evaluations follow a process in which hydrologic, hydraulic, and sediment-transport data are evaluated to calculate the depth of scour that may result when a given discharge is routed through a bridge opening. The results of the modified Level II analysis for structure I-65-118-4838 on Interstate 65 crossing Crooked Creek in Marion County, Indiana, are presented. The site is in the city of Indianapolis in the central part of Marion County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 8.3 feet for the modeled discharge of 7,000 cubic feet per second and approximately 9.2 feet for the modeled discharge of 9,870 cubic feet per second.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Indiana Department of Transportation (INDOT), is conducting Level II scour analyses at a number of bridges throughout Indiana. This report describes the methods applied and the modeling results for bridge I-65-118-4838.

Background and Scope

Level I scour assessment is a process where a large number of bridges are studied as a group. Assessments usually are made by evaluating a combination of geomorphic, hydrologic, and bridge-characteristic data. The results help investigators determine which bridges appear to be most likely to experience streambed-scour problems and which bridges appear to be relatively immune to problems brought on by streambed scour (for example, bridges built on bedrock).
When applied correctly, Level I scour assessments provide an investigator with information to identify those bridges that appear to be relatively safe and those bridges that fall into higher risk categories.

Level II scour evaluations describe the process for an investigator to apply a model to a bridge site and calculate the potential depth of scour that may result from a given flood event. Level II analyses involve the application of basic hydrologic, hydraulic, and sediment-transport engineering concepts and may include an evaluation of flood history, channel hydraulic conditions (for example, water-surface profile analysis), and basic sediment-transport analyses such as scour calculations (Lagasse and others, 1995).

The methods and model outlined in Hydraulic Engineering Circular (HEC) No. 18 (Richardson and Davis, 1995) formulate the basis for Level II scour evaluations. Methods used in this study for Level II scour evaluations are a modification of the HEC-18 standards. These modifications were made to comply with the methodology requested by INDOT (Merril Dougherty, Indiana Department of Transportation, oral commun., 1996). Descriptions of the specific modifications are given in the “Evaluation Methods” section of this report.

This report presents the methods followed for modeling, special considerations for this study site, and the input for and the output from the Water Surface PROfile (WSPRO) model.

**Site Description**

The study site is located in the city of Indianapolis in the central part of Marion County. The drainage area for the site is approximately 18.1 mi² (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is urban; in the immediate vicinity of the bridge, the land is predominantly pasture.

Within the immediate vicinity of the bridge, Crooked Creek has a channel-bed slope of approximately 0.00313 ft/ft. The channel-bed material is gravelly silty sand, and the channel banks consist of sandy silt-clay. At the time of the Level I site visit on June 17, 1994, the banks were observed to have 26 to 50 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 65 crossing of Crooked Creek is a 196-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping concrete spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.
EVALUATION METHODS

The methods described in this section apply to a number of bridge sites in Indiana being evaluated for scour and outline the procedures requested by INDOT for these modified Level II scour analyses. The principal modification requested by INDOT was that the input data to the model come from or be estimated from existing data sources; no additional field data were collected. Actual methods used in the scour evaluation at this particular bridge site use the most applicable method possible, given the data available.

To determine drainage area, either published values found in Hoggatt (1975) or 7.5-minute topographic maps with Hoggatt’s original drainage-area delineations were used. Where there are no published data, drainage-area segments measured from the maps produced by Hoggatt were either subtracted from downstream sites or added to upstream sites published by Hoggatt (1975).

In Indiana, flood discharges are coordinated by agreement among State and Federal agencies. At sites where flood discharges officially are coordinated among State and Federal agencies in Indiana, the coordinated 100-year discharge (Q100) was modeled. INDOT also provided an additional flood discharge for these coordinated sites in excess of the Q100 to be modeled.

If a flood discharge was not coordinated, the USGS examined Federal Emergency Management Agency (FEMA) studies for Q100 determinations. Where FEMA studies did not produce a Q100, the USGS contacted IDNR for an estimated Q100 in the vicinity of the site being studied. If IDNR did not have a Q100, data from nearby USGS streamflow-gaging stations were analyzed with nearby and similar drainage basins that have been coordinated. At sites having no coordinated discharge data, the two discharges used in the model were 1) the approximated Q100 and 2) a discharge equal to 1.7 times the approximated Q100.

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1963) provided by INDOT. Bridge plans are presumed to be representative of current conditions at the site. To determine the cross-section geometry, a line was drawn on the bridge plans parallel to the bridge stationing and approximately one bridge width from the bridge. For sites where the bridge plans did not extend far enough laterally for collection of all cross-section data required for WSPRO model analysis, additional data were collected from 7.5-minute topographic maps.

The roadway and embankment profile was taken from the bridge and highway plans for those sites where roadway overtopping was expected. The INDOT bridge plans and 7.5-minute topographic maps were used as a guide, based on the water-surface elevations calculated by the WSPRO model, to determine if roadway overtopping might occur.
Roughness values (n-values) for the main channel were estimated by viewing photographs archived from the Level I scour assessments. The n-values for the overbanks were assigned on the basis of the surface-cover data summarized in the Level I data base (Hopkins and Robinson, unpub. data, 1997). From those data, the following roughness values were assigned to the surface-cover categories: urban—0.050, suburban—0.035, row crop—0.045, pasture—0.035, brush—0.120, forest—0.100, and wetland (any area covered by standing water)—0.100. The n-values for the overbanks were adjusted if the Level I photographs provided sufficient detail to warrant an adjustment.

WSPRO version V050196 was used to model flow through the study site. Starting water-surface elevation was obtained with a slope-conveyance computation. The channel-bed slope in the immediate vicinity of the bridge was estimated from the 7.5-minute topographic map and was used as the slope of the energy grade line for this computation.

WSPRO version V050196 includes a field that allows the input of up to four scour-adjustment factors (K1 to K4). For this modeling, the default value for K4 (bed armoring) was chosen. For scour-adjustment factors K1 and K2 (pier-nose shape and angle of attack, respectively), input values were determined by evaluating the data archived in the Level I data base (Hopkins and Robinson, unpub. data, 1997). For the K3 factor (bed forms), a value of 1.1 was applied in all cases.

In some cases, piers set on the overbanks are constructed with footings that are higher in elevation than pier footings in the main channel. In these situations, if the channel position changes, the piers that were initially constructed on the overbank may become part of the main channel. Therefore, to evaluate total potential scour, the model results obtained for contraction scour and deepest local scour in the main channel were added and applied to all piers in the bridge opening. This methodology allowed for an evaluation of potential undermining of pier supports in the event that future channel movement placed overbank piers in the main channel.

Where bridge pairs have a continuous abutment or fill between the bridges that does not allow expansion of flow, the bridge pair was modeled as one bridge. Sites with discontinuous abutments, allowing expansion between the bridges, were modeled as two separate bridges. In those cases, a valley cross section was measured between the bridges and used as the approach section for the downstream bridge and as the exit section for the upstream bridge.

At sites with no embankment to function as a weir or at sites where the tailwater drowns out the embankment, a composite bridge and road section was used to compute flow. Those sites were computed with friction-loss equations rather than with a bridge routine.

Total scour is taken as the sum of local scour plus contraction scour. If the model predicted negative contraction scour (aggradation), the contraction-scour value was assumed to be zero in determining the total scour depth (table 1). This assumption was made so that a negative contraction scour would not mask the potentially detrimental effects of local scour at a pier. No abutment scour evaluations were made in this study.
Table 1. Cumulative scour depths for the modeled discharges at structure I-65-118-4838 crossing Crooked Creek in Marion County, Indiana

|--, no value

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<th>Pier number¹</th>
<th>Stationing from bridge plans²</th>
<th>Initial bed-elevation at pier (feet)</th>
<th>Main-channel contraction scour depth (feet)</th>
<th>Local scour depth (feet)</th>
<th>Worst-case total-scour depth³ (feet)</th>
<th>Bottom elevation of pier (feet)</th>
<th>Worst-case bed elevation after scour⁴ (feet)</th>
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Modeled discharge⁵ is 7,000 cubic feet per second

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Modeled discharge is 9,870 cubic feet per second

¹Pier numbers were assigned from left to right as shown on the bridge plans.

²Stationing is the center line of the pier as determined from the bridge plans. Stationing from bridge plan, 251+80, represents a point 25,180 feet from an arbitrary starting location referenced on the bridge plans.

³Worst-case total-scour depths are generated by summing the calculated contraction-scour depth with the worst case of local scour.

⁴Worst-case bed elevation is computed by subtracting the worst-case total-scour depth from the lowest initial bed elevation in the bridge opening (707.8 feet).

⁵Coordinated discharge.
SPECIAL CONSIDERATIONS

Model runs indicate the water-surface elevation at the bridge is lower than the low-steel elevation for the modeled discharges. Therefore, there should be no pressure flow through the bridge opening for the discharges modeled.

RESULTS

Scour depths were computed with a version of WSPRO (Larry Arneson, Federal Highway Administration, written commun., 1996) modified from Shearman (1990). This version of WSPRO includes scour calculations in the model output. Scour depths were calculated assuming an infinite depth of material that could erode and a homogeneous particle-size distribution. The results of the scour analysis are presented in table 1; a complete input file and output results are presented in the appendix.

REFERENCES


APPENDIX
WSPRO INPUT FILE

T1  I65 Over Crooked Creek  I-65-118-4838
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T3  05-06-97  Bret A. Robinson
SI  0
Q  7000 9870
SK  .00313 .00313
XS  EXIT 0
GR  24756 745 24908 725 24934 720 25005 715 25101 710 25194 710
GR  25223 710 25232 708 25258 707.8 25283 708 25292 710 25325 710
GR  25426 710 25661 715 25695 720 25756 725 25856 740
N  .120 .032 .120
SA  25223 25292
XS  FULLV 200
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GR  25194 710.6 25223 710.6 25232 708.6 25258 708.4 25283 708.6
GR  25292 710.6 25325 710.6 25426 710.6 25661 715.6 25695 720.6
GR  25756 725.6 25856 740.6
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SA  25223 25292
BR  BRIDGE 200 723.5
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GR  25255 0712.1 25296 0712.9 25317 0723.3 25320 0723.5 25320 0724.1
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CD  3 220 2 723.5
DC  0 BRIDGE 25190 25255 25105 25190 * 4
* LPierEdge RPierEdge PierWdth * K1 K2 K3(1.1)
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DP  25124 25322 2 * 1 1 1.1
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GR  25599 730 25768 740
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SA  25118 25191
EX  
ER  
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Federal Highway Administration - U. S. Geological Survey  
Model for Water-Surface Profile Computations.

Run Date & Time: 8/5/97 11:00 am  
Version V050196

Input File: 4838.dat  
Output File: 4838.LST

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I65 OVER CROOKED CREEK  
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7000 9870

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**T2**  
COUNTY: MARION  
QUAD: INDIANAPOLIS WEST 111C  
S  
0

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**T3**  
05-06-97  
BRET A. ROBINSON

---

*** Processing Flow Data; Placing Information into Sequence 1 ***

**SK**  
.00313 .00313

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**Federal Highway Administration - U. S. Geological Survey**  
**Model for Water-Surface Profile Computations.**

Input Units: English / Output Units: English

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**I65 OVER CROOKED CREEK**  
COUNTY: MARION  
QUAD: INDIANAPOLIS WEST 111C  
05-06-97  
BRET A. ROBINSON

---

**XS**  
EXIT 0

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24756 745 24908 725 24934 720 25005 715 25010 710 25194 710

**710**

**GR**  
25223 710 25232 708 25258 707.8 25283 708 25292 710 25325

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**N**  
.120 .032 .120

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**SA**  
25223 25292

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Averaging Conveyance By Geometric Mean.

Energy Loss Coefficients -> Expansion: .50  Contraction: .00

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Minimum Y-Elevation: 707.800 (associated X-Station: 25258.000)
Maximum Y-Elevation: 745.000 (associated X-Station: 24756.000)

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Federal Highway Administration - U.S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English
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I-65 OVER CROOKED CREEK
COUNTY: MARION
05-06-97 BRET A. ROBINSON

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X,Y-coordinates (17 pairs)

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Minimum and Maximum X,Y-coordinates

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Maximum X-Station: 25856.000 (associated Y-Elevation: 740.600)
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Maximum Y-Elevation: 745.600 (associated X-Station: 24756.000)

Roughness Data (3 SubAreas)

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** Federal Highway Administration - U. S. Geological Survey **
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

I-65 OVER CROOKED CREEK
COUNTY: MARION
QUAD: INDIANAPOLIS WEST 111C
05-06-97
BRET A. ROBINSON

* Starting To Process Header Record BRIDGE *

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0707.9
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0724.1
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  - **Contraction:** 0.00

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**Minimum and Maximum X,Y-coordinates**
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- **Maximum X-Station:** 25322.100 (associated Y-Elevation: 725.400)
- **Minimum Y-Elevation:** 707.300 (associated X-Station: 25221.000)
- **Maximum Y-Elevation:** 725.400 (associated X-Station: 25124.000)

### Roughness Data (3 SubAreas)

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### Discharge coefficient parameters

- **BRTType:** 3
- **BRWdth:** 220.000
- **EMRSS:** 2.00
- **EMBELv:** 723.500

### Pressure flow elevations

- **AVBCel:** 723.500
- **PFElev:**

### Abutment Parameters

- **ABSLPL:**
- **ABSLPR:**
- **XTOELT:**
- **YTOELT:**
- **XTOERT:**
- **YTOERT:**
WSPRO OUTPUT

Pier/Pile Data ( 1 Group(s) )
Code Indicates Bridge Uses Piers
Group Elevation Gross Width Number
--- --- --- --- --- --- --- ---
1  712.000  4.000  1
--- --- --- --- --- --- --- ---

* Finished Processing Header Record BRDGE *

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

I65 OVER CROOKED CREEK
COUNTY: MARION QUAD: INDIANAPOLIS WEST 111C
05-06-97 BRET A. ROBINSON
DC 0 BRDGE 25190 25255 25105 25190 * 4
DP 25124 25322 2 * * 1 1 1.1
DP 25124 25322 2 * * 1 1 1.1

* Starting To Process Header Record APPR *

XS APPR 620
GR 24734 745 24932 715 25019 715 25077 713 25101 712 25118 710
725
GR 25128 709 25163 708 25184 708.2 25191 712 25256 713 25513
GR 25599 730 25768 740
N .120 .032 .120
SA 25118 25191

*** Completed Reading Data Associated With Header Record APPR ***
*** Storing X-Section Data In Temporary File As Record Number 4 ***

*** Data Summary For Header Record APPR ***
SRD Location: 620. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00000 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
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<tr>
<td>24734.000</td>
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<td>24932.000</td>
<td>715.000</td>
<td>25019.000</td>
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<tr>
<td>25077.000</td>
<td>713.000</td>
<td>25101.000</td>
<td>712.000</td>
<td>25118.000</td>
<td>710.000</td>
</tr>
<tr>
<td>25128.000</td>
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<td>25163.000</td>
<td>708.000</td>
<td>25184.000</td>
<td>708.200</td>
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<tr>
<td>25191.000</td>
<td>712.000</td>
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<td>713.000</td>
<td>25513.000</td>
<td>725.000</td>
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<tr>
<td>25599.000</td>
<td>730.000</td>
<td>25768.000</td>
<td>740.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WSPRO OUTPUT

Minimum and Maximum X,Y-coordinates
Minimum X-Station: 24734.000 (associated Y-Elevation: 745.000)
Maximum X-Station: 25768.000 (associated Y-Elevation: 740.000)
Minimum Y-Elevation: 708.000 (associated X-Station: 25163.000)
Maximum Y-Elevation: 745.000 (associated X-Station: 24734.000)

Roughness Data (3 SubAreas)

<table>
<thead>
<tr>
<th>SubArea</th>
<th>Coefficient</th>
<th>Breakpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>.032</td>
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</tr>
<tr>
<td>3</td>
<td>.120</td>
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</tr>
</tbody>
</table>

Bridge datum projection(s): XREFLT XREFRT FDSTLT FDSTRT

*--------------------------------------------------------*
* Finished Processing Header Record APPR *
*--------------------------------------------------------*

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

*--------------------------------------------------------*
* Summary of Boundary Condition Information *
*--------------------------------------------------------*

<table>
<thead>
<tr>
<th>Reach</th>
<th>Water Surface Friction</th>
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<tbody>
<tr>
<td>#</td>
<td>Discharge</td>
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<tr>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>7000.00</td>
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<tr>
<td>2</td>
<td>9870.00</td>
</tr>
</tbody>
</table>

*--------------------------------------------------------*
* Beginning 2 Profile Calculation(s) *
*--------------------------------------------------------*
WSGRO OUTPUT

I65 OVER CROOKED CREEK
COUNTY: MARION
05-06-97

WSPRO OUTPUT

WSEL VHD Q AREA SRDL LEW
EGEL HF V K FLEN REW
CRWS HO PR # SF ALPHA ERR

Section: EXIT
Header Type: XS
SRD: .000

Section: FULLV
Header Type: FV
SRD: 200.000

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

===125 FR# EXCEEDS FNTEST AT SECID "APPR ": TRIALS CONTINUED.
FNTEST, FR#, WSEL, CRWS: .80 .95 716.29 715.60

===110 WSEL NOT FOUND AT SECID "APPR ": REDUCED DELTAY.
WSLIM1, WSLIM2, DELTAY: 715.60 745.00 .50

===115 WSEL NOT FOUND AT SECID "APPR ": USED WSMIN = CRWS.
WSLIM1, WSLIM2, CRWS: 715.60 745.00 715.60

Section: APPR
Header Type: AS
SRD: 620.000

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

<<< The Following Data Reflect The "Constricted" Profile >>>

<<< Beginning Bridge/Culvert Hydraulic Computations >>

WSEL VHD Q AREA SRDL LEW
EGEL HF V K FLEN REW
CRWS HO PR # SF ALPHA ERR

Section: BRIDGE
Header Type: BR
SRD: 200.000

Specific Bridge Information
Bridge Type 3 Flow Type 1
Pier/Pile Code 0

-15-
WSPRO OUTPUT

Section: APPR 717.949 .770 7000.000 2056.725 200.000 24912.540
Header Type: AS 718.719 .669 3.403 178061.20 223.986 25361.990
SRD: 620.000 715.600 1.326 .580 .0033 4.274 .011

Approach Section APPR Flow Contraction Information
M( G ) M( K ) KQ XLKQ XRKQ OTEL

.616 .120 156291.7 ******** ******** 717.949

<<< End of Bridge Hydraulics Computations >>>

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

I65 OVER CROOKED CREEK I-65-118-4838
COUNTY: MARION QUAD: INDIANAPOLIS WEST 111C
05-06-97 BRET A. ROBINSON

Section: EXIT 715.760 .843 9870.000 3082.412 ********* 24994.200
Header Type: XS 716.603 ****** 3.202 176345.70 ********* 25666.170
SRD: .000 714.822 ****** .606 ****** 5.287 ****

Section: FULLV 716.400 .828 9870.000 3108.901 200.000 24993.640
Header Type: FV 717.227 .619 3.175 178364.30 200.000 25666.440
SRD: 200.000 714.822 .000 .598 .0031 5.280 .005

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

===125 FR# EXCEEDS FNTEST AT SECID "APPR ": TRAILS CONTINUED.
FNTEST, FR#, WSEL, CRWS: .80 .97 717.33 716.82

===110 WSEL NOT FOUND AT SECID "APPR ": REDUCED DELTAY.
WSLIM1, WSLIM2, DELTAY: 716.82 745.00 .50

===115 WSEL NOT FOUND AT SECID "APPR ": USED WSMIN = CRWS.
WSLIM1, WSLIM2, CRWS: 716.82 745.00 .50

Section: APPR 717.338 1.932 9870.000 1787.345 420.000 24916.570
Header Type: AS 719.270 1.491 5.522 153843.60 420.000 25348.910
SRD: 620.000 716.818 .552 .967 .0036 4.074 .011

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

<<< The Following Data Reflect The "Constricted" Profile >>>

<<< Beginning Bridge/Culvert Hydraulic Computations >>>
### WSPRO OUTPUT

---210 QUESTIONABLE CRITICAL-FLOW SOLUTION AT SECID "BRDGE".

Q, CRWS: 9870.00  716.25

<table>
<thead>
<tr>
<th>WSEL</th>
<th>VHD</th>
<th>Q</th>
<th>AREA</th>
<th>SRDL</th>
<th>LEW</th>
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</thead>
<tbody>
<tr>
<td>CRWS</td>
<td>HO</td>
<td>FR #</td>
<td>SF</td>
<td>ALPHA</td>
<td>ERR</td>
</tr>
</tbody>
</table>

#### Section: BRDGE

- **Header Type**: BR
- **SRD**: 200.000
- **Section**: 716.252
- **Area**: 864.012
- **SRD**: 200.000
- **2RD**: 716.252
- **ERR**: 1.018

#### Specific Bridge Information

- **Bridge Type**: 3
- **Flow Type**: 1
- **Pier/Pile Code**: 0
- **WSEL**: 0.9909
- **VHD**: 0.020
- **Q**: 723.500
- **AREA**: 864.012
- **SRDL**: 200.000
- **LEW**: 25144.100

#### Approach Section APPR

- **Header Type**: AS
- **SRD**: 620.000
- **Section**: 716.818
- **Area**: 864.012
- **SRD**: 200.000
- **2RD**: 716.818
- **ERR**: 1.018

---

<< End of Bridge Hydraulics Computations >>

------------------------- W S P R O -------------------------
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

I-65 OVER CROOKED CREEK      I-65-118-4838
COUNTY: MARION                QUAD: INDIANAPOLIS WEST 111C
05-06-97 BRET A. ROBINSON

*** Live-Bed Contraction Scour Calculations for Header Record BRDGE ***

Constants and Input Variables

- **Bed Material Transport Mode Factor (k1)**: .64
- **Total Pier Width Value (Pw)**: 4.000

Scour -- Flow -- Width -- X-Limits --
## Pier Scour Calculations for Header Record BRDGE

### Constants and Input Variables

**Pier Width:** 2.000

- **Pier Shape Factor** $(K_1)$: 1.00
- **Flow Angle of Attack Factor** $(K_2)$: 1.00
- **Bed Condition Factor** $(K_3)$: 1.10
- **Bed Material Factor** $(K_4)$: 1.00
- **Velocity Multiplier** $(V_M)$: 1.00
- **Depth Multiplier** $(Y_M)$: 1.00

### Scour Localized Hydraulic Properties

<table>
<thead>
<tr>
<th>#</th>
<th>Depth</th>
<th>Flow</th>
<th>WSE</th>
<th>Depth</th>
<th>Velocity</th>
<th>Froude</th>
<th>#</th>
<th>Left</th>
<th>Right</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
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<td>.658</td>
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<td>25322.000</td>
<td></td>
</tr>
</tbody>
</table>

---

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

---

I65 OVER CROOKED CREEK
COUNTY: MARION
QUAD: INDIANAPOLIS WEST 111C
05-06-97 BRET A. ROBINSON

---

*** Pier Scour Calculations for Header Record BRDGE ***

### Constants and Input Variables

**Pier Width:** 2.000

---

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

---

I65 OVER CROOKED CREEK
COUNTY: MARION
QUAD: INDIANAPOLIS WEST 111C
05-06-97 BRET A. ROBINSON

---

*** Pier Scour Calculations for Header Record BRDGE ***
**WSPRO OUTPUT**

Pier Shape Factor (K1): 1.00  
Flow Angle of Attack Factor (K2): 1.00  
Bed Condition Factor (K3): 1.10  
Bed Material Factor (K4): 1.00  
Velocity Multiplier (VM): 1.00  
Depth Multiplier (YM): 1.00  

*--------------------------------------------------*

<table>
<thead>
<tr>
<th>Scour</th>
<th>Localized Hydraulic Properties</th>
<th>X-Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Depth</td>
<td>Flow</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>------</td>
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<tr>
<td>1</td>
<td>6.02</td>
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<tr>
<td>2</td>
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<td>9870.000</td>
</tr>
</tbody>
</table>

ER

*************** Normal end of WSPro execution. ***************

*************** Elapsed Time: 0 Minutes 5 Seconds ***************

-19-