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

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
square foot (ft^2)	929.0	square centimeter
feet per second (ft/s)	0.3048	meters per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Abbreviations used in this report:

D_{50}	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

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By Bret A. Robinson, David C. Voelker, *and* Robert L. Miller

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 mi^2 (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]

Pier number[1]	Stationing from bridge plans[2]	Initial bed-elevation at pier (feet)	Main-channel contraction scour depth (feet)	Local scour depth (feet)	Worst-case total-scour depth[3] (feet)	Bottom elevation of pier (feet)	Worst-case bed elevation after scour[4] (feet)
Modeled discharge[5] is 7,000 cubic feet per second							
1	251+80	712	2.3	6.0	8.3	702.1	699.5
2	252+54	712	2.3	6.0	8.3	701.9	699.5
Modeled discharge is 9,870 cubic feet per second							
1	251+80	712	2.7	6.5	9.2	702.1	698.6
2	252+54	712	2.7	6.5	9.2	701.9	698.6

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

[2]Stationing 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.

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

[4]Worst-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).

[5]Coordinated 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

Hoggatt, R.E., 1975, Drainage areas of Indiana streams: U.S. Geological Survey, Water Resources Division, 231 p.

Indiana State Highway Commission, 1963, Bridge plans Interstate Route 65: Bridge File I-65-118-4838.

Lagasse, P.F.; Schall, J.D.; Johnson, F.; Richardson, E.V.; and Chang, F., 1995, Stream stability at highway structures (2d ed.): Federal Highway Administration, Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Richardson, E.V., and Davis, S.R., 1995, Evaluating scour at bridges (3d ed.): Federal Highway Administration, Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Shearman, J.O., 1990, User's manual for WSPRO, a computer model for water-surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 177 p.

APPENDIX

WSPRO INPUT FILE

```
T1        I65 Over Crooked Creek                I-65-118-4838
T2        County:Marion                         Quad:Indianapolis West 111C
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
GR        24756 745.6  24908 725.6  24934 720.6  25005 715.6  25101 710.6
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
N         .120 .032 .120
SA          25223 25292
BR   BRDGE 200 723.5
GR       25124 0725.4  25124 0723.7  25126 0723.8  25126 0723.1  25130 0723.1
GR       25151 0712.9  25190 0711.6  25197 0707.7  25221 0707.3  25247 0707.9
GR       25255 0712.1  25296 0712.9  25317 0723.3  25320 0723.5  25320 0724.1
GR        25322 0724.1  25322 0725.4  25124 0725.4
N         .035 .032 .035
SA          25190  25254
PD        712 4 1
CD        3 220 2 723.5
DC 0 BRDGE 25190 25255 25105 25190 * 4
*         LPierEdge RPierEdge PierWdth * * K1 K2 K3(1.1)
DP        25124 25322 2 * * 1 1 1.1
DP        25124 25322 2 * * 1 1 1.1
XS   APPR 620
GR        24734 745  24932 715  25019 715  25077 713  25101 712  25118 710
GR        25128 709  25163 708  25184 708.2  25191 712  25256 713  25513 725
GR        25599 730  25768 740
N         .120 .032 .120
SA           25118 25191
EX
ER
```

WSPRO OUTPUT

```
      ************************  W S P R O  ***************************
         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
      *-------------------------------------------------------------*
   T1        I65 OVER CROOKED CREEK            I-65-118-4838
   T2        COUNTY:MARION                     QUAD:INDIANAPOLIS WEST 111C
   T3        05-06-97                          BRET A. ROBINSON
   SI        0
   Q         7000 9870

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

   SK        .00313 .00313

      ************************  W S P R O  ***************************
         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

            *-------------------------------------------------*
            *      Starting To Process Header Record EXIT     *
            *-------------------------------------------------*

   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

    ***   Completed Reading Data Associated With Header Record EXIT    ***
    ***  Storing X-Section Data In Temporary File As Record Number  1  ***

    ***              Data Summary For Header Record EXIT              ***
    SRD Location:        0.   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 (17 pairs)
        X          Y            X          Y            X          Y
   ----------  ----------   ----------  ----------   ----------  ----------
    24756.000     745.000    24908.000     725.000    24934.000     720.000
    25005.000     715.000    25101.000     710.000    25194.000     710.000
    25223.000     710.000    25232.000     708.000    25258.000     707.800
    25283.000     708.000    25292.000     710.000    25325.000     710.000
    25426.000     710.000    25661.000     715.000    25695.000     720.000
    25756.000     725.000    25856.000     740.000
```

WSPRO OUTPUT

```
---------  ---------  ---------  ---------  ---------  ---------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   24756.000  ( associated Y-Elevation:  745.000 )
  Maximum X-Station:   25856.000  ( associated Y-Elevation:  740.000 )
  Minimum Y-Elevation:   707.800  ( associated X-Station:  25258.000 )
  Maximum Y-Elevation:   745.000  ( associated X-Station:  24756.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .120        ---
                                ---       ********
                      2         .032        ---
                                ---       ********
                      3         .120        ---
                   -------  -----------  ----------

         *-----------------------------------------------------*
         *      Finished Processing Header Record EXIT         *
         *-----------------------------------------------------*

   ************************* W S P R O ****************************
      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

         *-----------------------------------------------------*
         *      Starting To Process Header Record FULLV        *
         *-----------------------------------------------------*

XS   FULLV 200
GR        24756 745.6  24908 725.6  24934 720.6  25005 715.6  25101 710.6
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
N         .120 .032 .120
SA          25223 25292

 ***   Completed Reading Data Associated With Header Record FULLV   ***
 ***  Storing X-Section Data In Temporary File As Record Number  2  ***

 ***              Data Summary For Header Record FULLV              ***
 SRD Location:      200.   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 (17 pairs)
    X          Y             X          Y             X          Y
```

WSPRO OUTPUT

```
---------  ---------   ---------  ---------   ---------  ---------
 24756.000     745.600   24908.000     725.600   24934.000     720.600
 25005.000     715.600   25101.000     710.600   25194.000     710.600
 25223.000     710.600   25232.000     708.600   25258.000     708.400
 25283.000     708.600   25292.000     710.600   25325.000     710.600
 25426.000     710.600   25661.000     715.600   25695.000     720.600
 25756.000     725.600   25856.000     740.600
---------  ---------   ---------  ---------   ---------  ---------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   24756.000  ( associated Y-Elevation:  745.600 )
  Maximum X-Station:   25856.000  ( associated Y-Elevation:  740.600 )
  Minimum Y-Elevation:   708.400  ( associated X-Station:  25258.000 )
  Maximum Y-Elevation:   745.600  ( associated X-Station:  24756.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---       ********
                     2         .032        ---
                               ---       ********
                     3         .120        ---
                  -------  -----------  ----------

         *-----------------------------------------------------*
         *      Finished Processing Header Record FULLV        *
         *-----------------------------------------------------*

   ************************  W S P R O  ****************************
      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

         *-----------------------------------------------------*
         *      Starting To Process Header Record BRDGE        *
         *-----------------------------------------------------*

   BR   BRDGE 200 723.5
   GR        25124 0725.4  25124 0723.7  25126 0723.8  25126 0723.1  25130
0723.1
   GR        25151 0712.9  25190 0711.6  25197 0707.7  25221 0707.3  25247
0707.9
   GR        25255 0712.1  25296 0712.9  25317 0723.3  25320 0723.5  25320
0724.1
   GR        25322 0724.1  25322 0725.4  25124 0725.4
   N         .035 .032 .035
   SA          25190  25254
   PD        712 4 1
```

WSPRO OUTPUT

```
 CD        3 220 2 723.5

   ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 4 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #15 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #17 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE              ***
   SRD Location:      200.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (18 pairs)
      X          Y           X          Y           X          Y
 ----------  ----------  ----------  ----------  ----------  ----------
  25124.000     725.400    25124.100     723.700    25126.000     723.800
  25126.100     723.100    25130.000     723.100    25151.000     712.900
  25190.000     711.600    25197.000     707.700    25221.000     707.300
  25247.000     707.900    25255.000     712.100    25296.000     712.900
  25317.000     723.300    25320.000     723.500    25320.100     724.100
  25322.000     724.100    25322.100     725.400    25124.000     725.400
 ----------  ----------  ----------  ----------  ----------  ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:   25124.000  ( associated Y-Elevation:  725.400 )
   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 )
                              Roughness   Horizontal
                     SubArea  Coefficient  Breakpoint
                     -------  -----------  ----------
                        1         .035         ---
                                   ---       ********
                        2         .032         ---
                                   ---       ********
                        3         .035         ---
                     -------  -----------  ----------

                     Discharge coefficient parameters
                   BRType   BRWdth    EMBSS    EMBElv    UserCD
                     3      220.000    2.00    723.500 **********

                        Pressure flow elevations
                           AVBCEL      PFElev
                         *********     723.500

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

   ************************* W S P R O ***************************
      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
  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
  GR         25128 709  25163 708  25184 708.2  25191 712  25256 713  25513
725
  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)
       X          Y            X          Y            X          Y
   ----------  ----------   ----------  ----------   ----------  ----------
    24734.000     745.000    24932.000     715.000    25019.000     715.000
    25077.000     713.000    25101.000     712.000    25118.000     710.000
    25128.000     709.000    25163.000     708.000    25184.000     708.200
    25191.000     712.000    25256.000     713.000    25513.000     725.000
    25599.000     730.000    25768.000     740.000
   ----------  ----------   ----------  ----------   ----------  ----------
```

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 )
                           Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---        ********
                     2         .032        ---
                               ---        ********
                     3         .120        ---
                  -------  -----------  ----------

Bridge datum projection(s):  XREFLT  XREFRT  FDSTLT  FDSTRT
                            ******* ******* ******* *******

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

     ************************  W S P R O  ***************************
        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
  EX

          *=================================================*
          *     Summary of Boundary Condition Information   *
          *=================================================*

            Reach      Water Surface   Friction
     #   Discharge       Elevation      Slope         Flow Regime
     --  ---------    -------------   --------   --------------------
     1     7000.00       ********        .0031        Sub-Critical
     2     9870.00       ********        .0031        Sub-Critical
     --  ---------    -------------   --------   --------------------

          *=================================================*
          *        Beginning  2 Profile Calculation(s)      *
          *=================================================*


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

WSPRO OUTPUT

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

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: EXIT      714.655   .736   7000.000   2355.513 ********* 25011.620
Header Type: XS    715.391 ******       2.972  125054.80 ********* 25644.810
SRD:       .000    713.334 ******        .629     ******     5.358    ******

Section: FULLV     715.292   .722   7000.000   2378.887   200.000 25010.910
Header Type: FV    716.015   .619      2.943  126555.10   200.000 25646.540
SRD:    200.000    713.934   .000       .621      .0031     5.364       .004

       <<< 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      716.291  1.508   7000.000   1350.118   420.000 24923.480
Header Type: AS    717.800  1.393      5.185  116743.80   420.000 25326.490
SRD:    620.000    715.600   .393       .949      .0033     3.608     -.001

       <<< 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      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     715.094  1.633   7000.000    683.054   200.000 25146.480
Header Type: BR    716.727   .848     10.248   94111.67   200.000 25300.430
SRD:    200.000    715.090   .488       .858     ******     1.000       .000

Specific Bridge Information   C      P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0           1.0000  .018  723.500 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

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

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 >>>


    ************************* W S P R O ****************************
       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

                      WSEL     VHD       Q         AREA      SRDL      LEW
                      EGEL      HF       V           K        FLEN      REW
                      CRWS      HO      FR #        SF       ALPHA     ERR
                    --------- ------ ---------- ---------- --------- ---------
Section: EXIT       715.760   .843   9870.000   3082.412 ********* 24994.200
Header Type: XS     716.603 ******      3.202  176345.70 ********* 25666.170
SRD:        .000    714.222 ******       .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 ":  TRIALS 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      716.82

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      .000

        <<< 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
```

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDGE	716.252	2.067	9870.000	864.012	200.000	25144.100
Header Type: BR	718.318	******	11.423	130783.10	200.000	25302.770
SRD: 200.000	716.252	******	.871	******	1.018	******

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9909	.020	723.500	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	719.440	.922	9870.000	2758.082	200.000	24902.690
Header Type: AS	720.362	.696	3.579	245013.40	223.816	25393.930
SRD: 620.000	716.818	1.352	.573	.0036	4.630	.016

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.632	.161	204985.5	********	********	719.440

<<< 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
*-------------------------------------------------------------*
      I65 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 ---
```

WSPRO OUTPUT

#	Depth	Contract	Approach	Contract	Approach	Side	Contract	Approach
1	2.338	5669.824	5545.876	61.000	85.000	Left:	********	********
	..... Approach Channel Depth:		8.990			Right:	********	********
2	2.661	7414.086	7293.701	61.000	85.000	Left:	********	********
	..... Approach Channel Depth:		10.481			Right:	********	********

```
************************* W S P R O ***************************
   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

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

                Constants and Input Variables

                    Pier Width:   2.000
            *-----------------------------------------*
              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
            *-----------------------------------------*
```

	Scour	---- Localized Hydraulic Properties ----					-- X-Stations --	
#	Depth	Flow	WSE	Depth	Velocity	Froude #	Left	Right
1	6.02	7000.000	716.420	9.120	10.337	.603	25124.000	25322.000
2	6.52	9870.000	717.604	10.304	11.978	.658	25124.000	25322.000

```
************************* W S P R O ***************************
   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

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

                Constants and Input Variables

                    Pier Width:   2.000
            *-----------------------------------------*
```

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
                *-----------------------------------------*
```

#	Scour Depth	Localized Hydraulic Properties — Flow	WSE	Depth	Velocity	Froude #	X-Stations — Left	Right
1	6.02	7000.000	716.420	9.120	10.337	.603	25124.000	25322.000
2	6.52	9870.000	717.604	10.304	11.978	.658	25124.000	25322.000

```
 ER

  ****************** Normal end of WSPRO execution. *****************
  *************** Elapsed Time:   0 Minutes  5 Seconds **************
```