Modified Level II Streambed-Scour Analysis for Structure I-69-87-4781 Crossing Wabash River in Huntington County, Indiana

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

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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	United States 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-69-87-4781 on Interstate 69 crossing Wabash River in Huntington County, Indiana, are presented. The site is near the town of Markle in the eastern part of Huntington 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 13.1 feet for the modeled discharge of 10,600 cubic feet per second and approximately 14.6 feet for the modeled discharge of 17,000 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-69-87-4781.

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 near the town of Markle in the eastern part of Huntington County. The drainage area for the site is approximately 701 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly brush covered.

Within the immediate vicinity of the bridge, Wabash River has a channel-bed slope of approximately 0.0016 ft/ft. The channel-bed material is a sand, gravel, and cobble mixture, and the channel banks consist of sandy gravelly silt. At the time of the Level I site visit on June 24, 1993, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 69 crossing of Wabash River is a 546-ft-long, multi-lane bridge consisting of six spans supported by concrete and steel piers and sloping riprap-covered 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, 1980) 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-69-87-4781 crossing Wabash River in Huntington 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 10,600 cubic feet per second							
2	739+34	757	0	13.1	13.1	749	740.9
3	740+32	754	0	13.1	13.1	749	740.9
4	741+29	756	0	13.1	13.1	749	740.9
Modeled discharge is 17,000 cubic feet per second							
2	739+34	757	0	14.6	14.6	749	739.4
3	740+32	754	0	14.6	14.6	749	739.4
4	741+29	756	0	14.6	14.6	749	739.4

[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, 739+34, represents a point 73,934 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 (754 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.

This bridge is within the flood-pool area of Huntington Reservoir. This implies that when the stage of Huntington Reservoir is approaching its flood-pool elevation, this bridge may be in back-water effect from the reservoir. Because this bridge is not always in the area of back-water effect, however, this modeling has been conducted assuming no effect from the downstream reservoir.

The model results indicate negative contraction scour (aggradation). To be consistent with the methodology outlined in the previous section, however, table 1 reports contraction scour depths of zero. This is done so that the total scour depth shown in table 1 does not lead the reader to an overly optimistic margin of safety for this bridge.

Scour calculations for this bridge were completed only at the three center-most piers; piers 1 and 5 were omitted from scour calculations. This was done for two reasons. First, the water surface profile produced from modeling the Q100 was not high enough to reach piers 1 and 5. Secondly, these piers (pier 1 and pier 5) are constructed on the sloping abutments that are protected by riprap. Therefore, it seemed appropriate to exclude these piers from the scour calculations.

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, 1980, Bridge plans Interstate Route 69: Bridge File I-69-87-4781.

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        I-69 Over Wabash River  I-69-87-4781
T2        County: Huntington      Quad: Markle 62D
T3        4-11-97                 Bret A. Robinson
SI        0
Q         10600
Q         17000
SK        .0016 .0016
XS   EXIT 0 0
GR        72071 780  73523 770  73813 760  73855 755  73877 754  73892 753
GR        73905 753  73913 754  73933 755  74015 755  74058 755  74121 755
GR        74157 753  74201 753  74209 755  74223 760  74233 765  74288 760
GR        74459 770  74622 780  75327 790  75546 800
N         .120    .034    .120
SA          73800     74300
XS   FULLV 540 0
GR        72071 780  73523 770  73813 760  73855 755  73877 754  73892 753
GR        73905 753  73913 754  73933 755  74015 755  74058 755  74121 755
GR        74157 753  74201 753  74209 755  74223 760  74233 765  74288 760
GR        74459 770  74622 780  75327 790  75546 800
N         .120    .034   .120
SA           73800   74300
BR   BRDGE 540 797 0
GR       73762 0797.3  73762 0796.1  73765 0796.0  73879 0758.1  73900 0758.9
GR       74001 0754.4  74063 0754.0  74101 0753.0  74200 0764.6  74208 0765.4
GR        74302 0797.0  74306 0797.3  74307 0798.0  73762 0797.3
N         .034
PD        754 4 1
PD        757.5 4 2
PD        757.5 6 3
PD        772 6 4
PD        772 10 5
CD        3 125 3 796
*          LXBr RXBr LXApp RXApp * TPierW
DC 0 BRDGE 73782 74282 73900 74125 * 10
*         LPierEdge RPierEdge PierWdth * * K1 K2 K3(1.1)
DP        73762 74307 2 * * 1 2.5 1.1
DP        73762 74307 2 * * 1 2.5 1.1
DP        73762 74307 2 * * 1 2.5 1.1
XS   APPR 1205 0
GR        72006 780  73553 770  73732 765  73743 760  73751 758  73774 758
GR        73850 759  73901 759  73912 755  73966 753  74110 754  74134 760
GR        74226 765  74277 770  74425 770  74610 780  75024 790  75096 800
N         .120   .034   .120
SA          73725   74200
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/ 4/97  8:24 am     Version V050196
          Input File: 4781.dat       Output File: 4781.LST
   *-------------------------------------------------------------*
T1        I-69 OVER WABASH RIVER  I-69-87-4781
T2        COUNTY: HUNTINGTON      QUAD: MARKLE 62D
T3        4-11-97                 BRET A. ROBINSON
SI        0
Q         10600
Q         17000

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

SK        .0016 .0016

   ************************  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-69 OVER WABASH RIVER  I-69-87-4781
             COUNTY: HUNTINGTON      QUAD: MARKLE 62D
             4-11-97                 BRET A. ROBINSON

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

XS   EXIT 0 0
GR        72071 780  73523 770  73813 760  73855 755  73877 754  73892 753
GR        73905 753  73913 754  73933 755  74015 755  74058 755  74121 755
GR        74157 753  74201 753  74209 755  74223 760  74233 765  74288 760
GR        74459 770  74622 780  75327 790  75546 800
N         .120    .034    .120
SA          73800     74300

 ***   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 (22 pairs)
    X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 72071.000     780.000    73523.000     770.000    73813.000     760.000
 73855.000     755.000    73877.000     754.000    73892.000     753.000
 73905.000     753.000    73913.000     754.000    73933.000     755.000
 74015.000     755.000    74058.000     755.000    74121.000     755.000
 74157.000     753.000    74201.000     753.000    74209.000     755.000
```

WSPRO OUTPUT

```
 74223.000     760.000    74233.000     765.000    74288.000     760.000
 74459.000     770.000    74622.000     780.000    75327.000     790.000
 75546.000     800.000
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   72071.000  ( associated Y-Elevation:  780.000 )
  Maximum X-Station:   75546.000  ( associated Y-Elevation:  800.000 )
  Minimum Y-Elevation:   753.000  ( associated X-Station:  74201.000 )
  Maximum Y-Elevation:   800.000  ( associated X-Station:  75546.000 )

                   Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---       ********
                     2         .034        ---
                               ---       ********
                     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
   *-------------------------------------------------------------*
             I-69 OVER WABASH RIVER  I-69-87-4781
            COUNTY: HUNTINGTON      QUAD: MARKLE 62D
            4-11-97                 BRET A. ROBINSON

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

XS   FULLV 540 0
GR        72071 780  73523 770  73813 760  73855 755  73877 754  73892 753
GR        73905 753  73913 754  73933 755  74015 755  74058 755  74121 755
GR        74157 753  74201 753  74209 755  74223 760  74233 765  74288 760
GR        74459 770  74622 780  75327 790  75546 800
N         .120    .034   .120
SA           73800   74300

 ***   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:      540.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

WSPRO OUTPUT

X,Y-coordinates (22 pairs)

X	Y	X	Y	X	Y
72071.000	780.000	73523.000	770.000	73813.000	760.000
73855.000	755.000	73877.000	754.000	73892.000	753.000
73905.000	753.000	73913.000	754.000	73933.000	755.000
74015.000	755.000	74058.000	755.000	74121.000	755.000
74157.000	753.000	74201.000	753.000	74209.000	755.000
74223.000	760.000	74233.000	765.000	74288.000	760.000
74459.000	770.000	74622.000	780.000	75327.000	790.000
75546.000	800.000				

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 72071.000 (associated Y-Elevation: 780.000)
Maximum X-Station: 75546.000 (associated Y-Elevation: 800.000)
Minimum Y-Elevation: 753.000 (associated X-Station: 74201.000)
Maximum Y-Elevation: 800.000 (associated X-Station: 75546.000)

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.120	---
	---	********
2	.034	---
	---	********
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

I-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

---
* Starting To Process Header Record BRDGE *

```
BR   BRDGE 540 797 0
GR        73762 0797.3  73762 0796.1  73765 0796.0  73879 0758.1  73900
0758.9
GR        74001 0754.4  74063 0754.0  74101 0753.0  74200 0764.6  74208
0765.4
GR        74302 0797.0  74306 0797.3  74307 0798.0  73762 0797.3
```

WSPRO OUTPUT

```
N         .034
PD        754 4 1
PD        757.5 4 2
PD        757.5 6 3
PD        772 6 4
PD        772 10 5
CD        3 125 3 796

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

  ***              Data Summary For Bridge Record BRDGE              ***
  SRD Location:      540.   Cross-Section Skew:    .0   Error Code   0
  Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (14 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 73762.000     797.300    73762.100     796.100    73765.000     796.000
 73879.000     758.100    73900.000     758.900    74001.000     754.400
 74063.000     754.000    74101.000     753.000    74200.000     764.600
 74208.000     765.400    74302.000     797.000    74306.000     797.300
 74307.000     798.000    73762.000     797.300
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   73762.000  ( associated Y-Elevation:  797.300 )
  Maximum X-Station:   74307.000  ( associated Y-Elevation:  798.000 )
  Minimum Y-Elevation:   753.000  ( associated X-Station:  74101.000 )
  Maximum Y-Elevation:   798.000  ( associated X-Station:  74307.000 )

                  Roughness Data (  1 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .034        ---
                -------  -----------  ----------

                  Discharge coefficient parameters
              BRType   BRWdth   EMBSS   EMBElv    UserCD
                3      125.000   3.00   796.000 **********

                     Pressure flow elevations
                        AVBCEL     PFElev
                     *********    797.000

                       Abutment Parameters
       ABSLPL  ABSLPR   XTOELT    YTOELT    XTOERT    YTOERT
      ******* ******* ********* ********* ********* *********


                  Pier/Pile Data (  5 Group(s) )
```

WSPRO OUTPUT

Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	754.000	4.000	1
2	757.500	4.000	2
3	757.500	6.000	3
4	772.000	6.000	4
5	772.000	10.000	5

```
        *-----------------------------------------------------*
        *      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
   *-------------------------------------------------------------*
               I-69 OVER WABASH RIVER  I-69-87-4781
              COUNTY: HUNTINGTON      QUAD: MARKLE 62D
              4-11-97                 BRET A. ROBINSON
DC 0 BRDGE 73782 74282 73900 74125 * 10
DP         73762 74307 2 * * 1 2.5 1.1
DP         73762 74307 2 * * 1 2.5 1.1
DP         73762 74307 2 * * 1 2.5 1.1

        *-----------------------------------------------------*
        *      Starting To Process Header Record APPR         *
        *-----------------------------------------------------*

XS   APPR 1205 0
GR         72006 780  73553 770  73732 765  73743 760  73751 758  73774 758
GR         73850 759  73901 759  73912 755  73966 753  74110 754  74134 760
GR         74226 765  74277 770  74425 770  74610 780  75024 790  75096 800
N          .120   .034   .120
SA           73725   74200

 ***   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:     1205.   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 (18 pairs)

X	Y	X	Y	X	Y
72006.000	780.000	73553.000	770.000	73732.000	765.000
73743.000	760.000	73751.000	758.000	73774.000	758.000
73850.000	759.000	73901.000	759.000	73912.000	755.000
73966.000	753.000	74110.000	754.000	74134.000	760.000
74226.000	765.000	74277.000	770.000	74425.000	770.000

WSPRO OUTPUT

```
  74610.000     780.000    75024.000     790.000    75096.000     800.000
 ----------  ----------  ----------  ----------  ----------  ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:   72006.000  ( associated Y-Elevation:  780.000 )
   Maximum X-Station:   75096.000  ( associated Y-Elevation:  800.000 )
   Minimum Y-Elevation:   753.000  ( associated X-Station:  73966.000 )
   Maximum Y-Elevation:   800.000  ( associated X-Station:  75096.000 )

                     Roughness Data (  3 SubAreas )
                              Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .120        ---
                                ---       ********
                      2         .034        ---
                                ---       ********
                      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
    *-------------------------------------------------------------*
               I-69 OVER WABASH RIVER  I-69-87-4781
              COUNTY: HUNTINGTON      QUAD: MARKLE 62D
              4-11-97                 BRET A. ROBINSON
  EX

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

            Reach       Water Surface   Friction
     #    Discharge       Elevation      Slope          Flow Regime
    --    ---------    -------------   --------   --------------------
     1     10600.00       ********        .0016        Sub-Critical
     2     17000.00       ********        .0016        Sub-Critical
    --    ---------    -------------   --------   --------------------

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


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

WSPRO OUTPUT

```
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
    *-------------------------------------------------------------*
              I-69 OVER WABASH RIVER  I-69-87-4781
             COUNTY: HUNTINGTON      QUAD: MARKLE 62D
             4-11-97                 BRET A. ROBINSON

                     WSEL     VHD       Q         AREA      SRDL       LEW
                     EGEL      HF       V           K        FLEN       REW
                     CRWS      HO      FR #        SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: EXIT        759.854   .410  10600.000   2063.604 ********* 73814.230
Header Type: XS      760.264 ******      5.137  264914.30 ********* 74222.590
SRD:       .000      757.419 ******       .403     ******     1.000    ******

Section: FULLV       760.667   .301  10600.000   2409.965   540.000 73793.660
Header Type: FV      760.968   .705      4.398  324727.00   540.000 74299.400
SRD:    540.000      757.419   .000       .335      .0013     1.001     -.002

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

Section: APPR        761.452   .370  10600.000   2173.589   665.000 73739.800
Header Type: AS      761.822   .813      4.877  282880.10   665.000 74160.730
SRD:   1205.000      758.282   .034       .378      .0012     1.000       .007

      <<< 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       760.810   .857  10600.000   1427.708   540.000 73870.840
Header Type: BR      761.668  1.322      7.424  177400.80   540.000 74167.660
SRD:    540.000      759.373   .081       .597     ******     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  .024  797.000 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD       Q         AREA      SRDL       LEW
                     EGEL      HF       V           K        FLEN       REW
                     CRWS      HO      FR #        SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR        763.129   .207  10600.000   2908.481   540.000 73736.120
Header Type: AS      763.336   .831      3.645  435947.50   559.441 74191.580
SRD:   1205.000      758.282   .837       .254      .0012     1.000     -.009

          Approach Section APPR  Flow Contraction Information
```

WSPRO OUTPUT

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.299	.061	410179.8	********	********	763.129

<<< 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-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	761.679	.546	17000.000	2895.391	*********	73764.300
Header Type: XS	762.226	******	5.871	424851.20	*********	74316.720
SRD: .000	758.502	******	.438	******	1.019	******
Section: FULLV	762.502	.424	17000.000	3334.519	540.000	73740.430
Header Type: FV	762.926	.712	5.098	515591.10	540.000	74330.790
SRD: 540.000	758.502	.000	.377	.0013	1.049	-.012

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

Section: APPR	763.288	.506	17000.000	2980.945	665.000	73735.770
Header Type: AS	763.794	.825	5.703	452023.50	665.000	74194.500
SRD: 1205.000	759.833	.041	.394	.0012	1.000	.002

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

<<< The Following Data Reflect The "Constricted" Profile >>>
<<< Beginning Bridge/Culvert Hydraulic Computations >>>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDGE	762.487	1.192	17000.000	1941.629	540.000	73865.800
Header Type: BR	763.679	1.325	8.756	283751.00	540.000	74181.970
SRD: 540.000	760.757	.129	.623	******	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	.023	797.000	********	********	********

WSPRO OUTPUT

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	765.065	.310	17000.000	3828.824	540.000	73729.660
Header Type: AS	765.375	.877	4.440	668726.60	562.513	74226.660
SRD: 1205.000	759.833	.818	.283	.0012	1.010	.006

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.310	.095	604322.0	********	********	765.065

<<< 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-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 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): 10.000

#	Scour Depth	Flow Contract	Flow Approach	Width Contract	Width Approach	Side	X-Limits Contract	X-Limits Approach
1	-3.074	10600.000	9546.768	490.000	225.000	Left:	********	********
	..... Approach Channel Depth:		9.156			Right:	********	********
*	Negative Scour Depth Encountered - Check If Variables Are Reasonable *							
2	-3.013	17000.000	13741.080	490.000	225.000	Left:	********	********
	..... Approach Channel Depth:		11.091			Right:	********	********
*	Negative Scour Depth Encountered - Check If Variables Are Reasonable *							

********** 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-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D

WSPRO OUTPUT

4-11-97 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):	2.50
Bed Condition Factor	(K3):	1.10
Bed Material Factor	(K4):	1.00
Velocity Multiplier	(VM):	1.00
Depth Multiplier	(YM):	1.00

#	Scour Depth	Flow	WSE	Depth	Velocity	Froude #	Left	Right
1	13.09	10600.000	761.648	8.648	7.590	.455	73762.000	74307.000
2	14.57	17000.000	763.306	10.306	9.216	.506	73762.000	74307.000

(Localized Hydraulic Properties; X-Stations)

********** 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-69 OVER WABASH RIVER I-69-87-4781

COUNTY: HUNTINGTON QUAD: MARKLE 62D

4-11-97 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):	2.50
Bed Condition Factor	(K3):	1.10
Bed Material Factor	(K4):	1.00
Velocity Multiplier	(VM):	1.00
Depth Multiplier	(YM):	1.00

#	Scour Depth	Flow	WSE	Depth	Velocity	Froude #	Left	Right
1	13.09	10600.000	761.648	8.648	7.590	.455	73762.000	74307.000
2	14.57	17000.000	763.306	10.306	9.216	.506	73762.000	74307.000

WSPRO OUTPUT

```
************************  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-69 OVER WABASH RIVER  I-69-87-4781
           COUNTY: HUNTINGTON      QUAD: MARKLE 62D
           4-11-97                 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):   2.50
                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	13.09	10600.000	761.648	8.648	7.590	.455	73762.000	74307.000
2	14.57	17000.000	763.306	10.306	9.216	.506	73762.000	74307.000

```
  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  4 Seconds  **************
```