Modified Level II Streambed-Scour Analysis for Structure I-64-108-5658 Crossing Indian Creek in Harrison County, Indiana

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

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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	U. S. Geological Survey
WSPRO	Water Surface PROfile model

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

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-64-108-5658 on Interstate 64 crossing Indian Creek in Harrison County, Indiana, are presented. The site is near the town of Corydon in the central part of Harrison 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 6.6 feet for the modeled discharge of 26,000 cubic feet per second and approximately 8.0 feet for the modeled discharge of 34,000 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-64-108-5658.

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 Corydon in the central part of Harrison County. The drainage area for the site is approximately 144 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 agricultural with some wooded land nearby.

Within the immediate vicinity of the bridge, Indian Creek has a channel-bed slope of approximately 0.000638 ft/ft. The channel-bed material is gravelly sandy silt-clay, and the channel banks consist of sandy silt-clay and bedrock. At the time of the Level I site visit on March 15, 1994, the banks were observed to have 0 to 75 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 64 crossing of Indian Creek is a 372-ft-long, multi-lane bridge consisting of four spans supported by concrete and steel piers and sloping 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, 1969) 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-64-108-5658 crossing Indian Creek in Harrison 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 26,000 cubic feet per second							
1	405+90	578	0.5	6.1	6.6	558.0	548.7
2	406+90	566	0.5	6.1	6.6	552.2	548.7
3	408+20	555	0.5	6.1	6.6	552.1	548.7
Modeled discharge is 34,000 cubic feet per second							
1	405+90	578	1.5	6.5	8.0	558.0	547.3
2	405+90	566	1.5	6.5	8.0	552.2	547.3
3	408+20	555	1.5	6.5	8.0	552.1	547.3

[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, 405+90, represents a point 40,590 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 (555.3 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, 1969, Bridge plans Interstate Route 64: Bridge File I-64-108-5658.

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-64 OVER INDIAN CREEK          I-64-108-5658
T2          COUNTY HARRISON                 QUAD CORYDON EAST
T3          11-18-96                        R L Miller
SI          0
Q            26000  34000
SK             .000638  .000638
XS   EXIT    0   48
GR         40184 590  40185 580  40725 570
GR         40749 565  40757 560  40766 559  40778 558  40791 557
GR         40811 556  40821 556  40837 557  40851 559  40854 560
GR         40875 580  40891 590  40911 605  40920 615  41323 630
N            .045  .032  .100
SA            40725  40920
XS   FULLV   379 48
GR         40184 590  40185 580  40725 570
GR         40749 565  40757 560  40766 559  40778 558  40791 557
GR         40811 556  40821 556  40837 557  40851 559  40854 560
GR         40875 580  40891 590  40911 605  40920 615  41323 630
N            .045  .032  .100
SA            40725  40920
BR   BRDGE   379    592     24
GR         40552 0593.0  40553 0592.4  40556 0592.5  40586 0578.1
GR         40623 0578.1  40648 0566.4  40776 0566.1  40781 0564.9
GR         40788 0559.9  40830 0554.6  40849 0554.9  40860 0556.1
GR         40876 0558.8  40879 0560.1  40895 0570.3  40911 0584.1
GR         40918 0590.5  40923 0590.9  40924 0591.2  40926 0591.3
GR         40927 0592.7  40926 0592.7  40810 0592.1
GR         40692 0591.5  40589 0591.2  40588 0593.1  40552 0593.0
N             .032
PD          556 2 1
PD          574 2 2
PD          574 4 3
PD          578 4 4
PD          578 6 5
CD          3    153  2  590
DC   BRDGE   40776  40935  40812  41001 *  6
DP         40552 40927  2  *  *  1.0  1.0  1.1
DP         40552 40927  2  *  *  1.0  1.0  1.1
DP         40552 40927  2  *  *  1.0  1.0  1.1
XS   APPR    911
GR         38429 650  38502 640  38609 620  38702 610  39122 610
GR         39185 610  39406 600  39787 590  40197 580  40812 572
GR         40850 570  40863 565  40869 560  40874 557  40892 556
GR         40917 556  40925 557  40937 560  40946 565  40949 570
GR         40989 610  40995 615  41001 620  41048 620
GR         41318 630  41429 630  41659 630  41899 640
N            .045  .032  .100
SA             40812  41001
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/ 6/97  8:05 am    Version V050196
          Input File: 5658.dat       Output File: 5658.LST
   *-------------------------------------------------------------*
T1          I-64 OVER INDIAN CREEK          I-64-108-5658
T2          COUNTY HARRISON              QUAD CORYDON EAST
T3          11-18-96                     R L MILLER
SI          0
Q            26000  34000

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

SK             .000638  .000638

   ************************  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-64 OVER INDIAN CREEK          I-64-108-5658
           COUNTY HARRISON              QUAD CORYDON EAST
              11-18-96                     R L MILLER

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

XS   EXIT   0   48
GR         40184 590  40185 580  40725 570
GR         40749 565  40757 560  40766 559  40778 558  40791 557
GR         40811 556  40821 556  40837 557  40851 559  40854 560
GR         40875 580  40891 590  40911 605  40920 615  41323 630
N            .045  .032  .100
SA            40725  40920

 ***   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:  48.0   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
----------  ----------   ----------  ----------   ----------  ----------
 40184.000     590.000    40185.000     580.000    40725.000     570.000
 40749.000     565.000    40757.000     560.000    40766.000     559.000
 40778.000     558.000    40791.000     557.000    40811.000     556.000
 40821.000     556.000    40837.000     557.000    40851.000     559.000
 40854.000     560.000    40875.000     580.000    40891.000     590.000
 40911.000     605.000    40920.000     615.000    41323.000     630.000
```

WSPRO OUTPUT

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

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   40184.000  ( associated Y-Elevation:  590.000 )
  Maximum X-Station:   41323.000  ( associated Y-Elevation:  630.000 )
  Minimum Y-Elevation:   556.000  ( associated X-Station:  40821.000 )
  Maximum Y-Elevation:   630.000  ( associated X-Station:  41323.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
   X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
---------- ---------- ---------- ---------- ---------- ----------
 40184.000  40394.770   40185.000  40395.430   40725.000  40756.760
 40749.000  40772.820   40757.000  40778.180   40766.000  40784.200
 40778.000  40792.230   40791.000  40800.930   40811.000  40814.310
 40821.000  40821.000   40837.000  40831.710   40851.000  40841.070
 40854.000  40843.080   40875.000  40857.130   40891.000  40867.840
 40911.000  40881.220   40920.000  40887.240   41323.000  41156.900
---------- ----------  ---------- ----------  ---------- ----------

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .045        ---
                               ---       ********
                     2         .032        ---
                               ---       ********
                     3         .100        ---
                  -------  -----------  ----------

        *-----------------------------------------------------*
        *      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-64 OVER INDIAN CREEK         I-64-108-5658
           COUNTY HARRISON              QUAD CORYDON EAST
              11-18-96                     R L MILLER

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

XS   FULLV   379 48
GR         40184 590  40185 580  40725 570
GR         40749 565  40757 560  40766 559  40778 558  40791 557
GR         40811 556  40821 556  40837 557  40851 559  40854 560
GR         40875 580  40891 590  40911 605  40920 615  41323 630
N            .045  .032  .100
SA           40725  40920
```

WSPRO OUTPUT

```
***   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:      379.   Cross-Section Skew:  48.0   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
40184.000	590.000	40185.000	580.000	40725.000	570.000
40749.000	565.000	40757.000	560.000	40766.000	559.000
40778.000	558.000	40791.000	557.000	40811.000	556.000
40821.000	556.000	40837.000	557.000	40851.000	559.000
40854.000	560.000	40875.000	580.000	40891.000	590.000
40911.000	605.000	40920.000	615.000	41323.000	630.000

Minimum and Maximum X,Y-coordinates

```
Minimum X-Station:   40184.000  ( associated Y-Elevation:  590.000 )
Maximum X-Station:   41323.000  ( associated Y-Elevation:  630.000 )
Minimum Y-Elevation:   556.000  ( associated X-Station:  40821.000 )
Maximum Y-Elevation:   630.000  ( associated X-Station:  41323.000 )
```

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
40184.000	40394.770	40185.000	40395.430	40725.000	40756.760
40749.000	40772.820	40757.000	40778.180	40766.000	40784.200
40778.000	40792.230	40791.000	40800.930	40811.000	40814.310
40821.000	40821.000	40837.000	40831.710	40851.000	40841.070
40854.000	40843.080	40875.000	40857.130	40891.000	40867.840
40911.000	40881.220	40920.000	40887.240	41323.000	41156.900

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.045	---
	---	********
2	.032	---
	---	********
3	.100	---

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

************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
```

WSPRO OUTPUT

```
          Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
 *-------------------------------------------------------------*
          I-64 OVER INDIAN CREEK          I-64-108-5658
          COUNTY HARRISON              QUAD CORYDON EAST
             11-18-96                     R L MILLER

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

BR   BRDGE   379    592     24
GR        40552 0593.0  40553 0592.4  40556 0592.5  40586 0578.1
GR        40623 0578.1  40648 0566.4  40776 0566.1  40781 0564.9
GR        40788 0559.9  40830 0554.6  40849 0554.9  40860 0556.1
GR        40876 0558.8  40879 0560.1  40895 0570.3  40911 0584.1
GR        40918 0590.5  40923 0590.9  40924 0591.2  40926 0591.3
GR        40927 0592.7  40926 0592.7  40810 0592.1
GR        40692 0591.5  40589 0591.2  40588 0593.1  40552 0593.0
N             .032
PD         556 2 1
PD         574 2 2
PD         574 4 3
PD         578 4 4
PD         578 6 5
CD         3    153  2  590

 ***   Completed Reading Data Associated With Header Record BRDGE   ***
 ***   Storing Bridge Data In Temporary File As Record Number  3    ***

 ***              Data Summary For Bridge Record BRDGE              ***
 SRD Location:      379.   Cross-Section Skew:  24.0   Error Code   0
 Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (27 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 40552.000     593.000    40553.000     592.400    40556.000     592.500
 40586.000     578.100    40623.000     578.100    40648.000     566.400
 40776.000     566.100    40781.000     564.900    40788.000     559.900
 40830.000     554.600    40849.000     554.900    40860.000     556.100
 40876.000     558.800    40879.000     560.100    40895.000     570.300
 40911.000     584.100    40918.000     590.500    40923.000     590.900
 40924.000     591.200    40926.000     591.300    40927.000     592.700
 40926.000     592.700    40810.000     592.100    40692.000     591.500
 40589.000     591.200    40588.000     593.100    40552.000     593.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   40552.000  ( associated Y-Elevation:  593.000 )
  Maximum X-Station:   40927.000  ( associated Y-Elevation:  592.700 )
  Minimum Y-Elevation:   554.600  ( associated X-Station:  40830.000 )
  Maximum Y-Elevation:   593.100  ( associated X-Station:  40588.000 )
```

WSPRO OUTPUT

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
40552.000	40576.040	40553.000	40576.950	40556.000	40579.690
40586.000	40607.090	40623.000	40640.890	40648.000	40663.730
40776.000	40780.670	40781.000	40785.230	40788.000	40791.630
40830.000	40830.000	40849.000	40847.360	40860.000	40857.410
40876.000	40872.020	40879.000	40874.770	40895.000	40889.380
40911.000	40904.000	40918.000	40910.390	40923.000	40914.960
40924.000	40915.880	40926.000	40917.700	40927.000	40918.610
40926.000	40917.700	40810.000	40811.730	40692.000	40703.930
40589.000	40609.840	40588.000	40608.920	40552.000	40576.040

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.032	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	153.000	2.00	590.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	592.000

Abutment Parameters

ABSLPL	ABSLPR	XTOELT	YTOELT	XTOERT	YTOERT
*******	*******	*********	*********	*********	*********

Pier/Pile Data (5 Group(s))
Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	556.000	2.000	1
2	574.000	2.000	2
3	574.000	4.000	3
4	578.000	4.000	4
5	578.000	6.000	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
```

WSPRO OUTPUT

```
   *-------------------------------------------------------------*
            I-64 OVER INDIAN CREEK          I-64-108-5658
            COUNTY HARRISON              QUAD CORYDON EAST
               11-18-96                     R L MILLER
DC   BRDGE   40776  40935  40812  41001 *  6
DP         40552 40927  2  *  *  1.0  1.0  1.1
DP         40552 40927  2  *  *  1.0  1.0  1.1
DP         40552 40927  2  *  *  1.0  1.0  1.1

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

XS   APPR    911
GR         38429 650  38502 640  38609 620  38702 610  39122 610
GR         39185 610  39406 600  39787 590  40197 580  40812 572
GR         40850 570  40863 565  40869 560  40874 557  40892 556
GR         40917 556  40925 557  40937 560  40946 565  40949 570
GR         40989 610  40995 615  41001 620  41048 620
GR         41318 630  41429 630  41659 630  41899 640
N            .045  .032  .100
SA             40812  41001

 ***   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:       911.   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 (28 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 38429.000     650.000    38502.000     640.000    38609.000     620.000
 38702.000     610.000    39122.000     610.000    39185.000     610.000
 39406.000     600.000    39787.000     590.000    40197.000     580.000
 40812.000     572.000    40850.000     570.000    40863.000     565.000
 40869.000     560.000    40874.000     557.000    40892.000     556.000
 40917.000     556.000    40925.000     557.000    40937.000     560.000
 40946.000     565.000    40949.000     570.000    40989.000     610.000
 40995.000     615.000    41001.000     620.000    41048.000     620.000
 41318.000     630.000    41429.000     630.000    41659.000     630.000
 41899.000     640.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   38429.000  ( associated Y-Elevation:  650.000 )
  Maximum X-Station:   41899.000  ( associated Y-Elevation:  640.000 )
  Minimum Y-Elevation:   556.000  ( associated X-Station:  40917.000 )
  Maximum Y-Elevation:   650.000  ( associated X-Station:  38429.000 )

                  Roughness Data (  3 SubAreas )
                         Roughness   Horizontal
```

WSPRO OUTPUT

```
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .045        ---
                             ---        ********
                   2         .032        ---
                             ---        ********
                   3         .100        ---
                -------  -----------  ----------

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-64 OVER INDIAN CREEK          I-64-108-5658
            COUNTY HARRISON              QUAD CORYDON EAST
               11-18-96                     R L MILLER
 EX

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

           Reach       Water Surface   Friction
     #   Discharge       Elevation       Slope          Flow Regime
    --   ---------     -------------   --------   --------------------
     1    26000.00       ********         .0006        Sub-Critical
     2    34000.00       ********         .0006        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
    *-------------------------------------------------------------*
            I-64 OVER INDIAN CREEK          I-64-108-5658
            COUNTY HARRISON              QUAD CORYDON EAST
               11-18-96                     R L MILLER

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

WSPRO OUTPUT

Section: EXIT	579.061	.769	26000.000	4916.594	*********	40235.730
Header Type: XS	579.829	******	5.288	1028468.00	*********	40874.010
SRD: .000	570.309	******	.447	******	1.767	******
Section: FULLV	579.341	.721	26000.000	5097.945	379.000	40220.570
Header Type: FV	580.063	.234	5.100	1065521.00	379.000	40874.310
SRD: 379.000	570.309	.000	.430	.0006	1.783	.000

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

Section: APPR	579.645	.927	26000.000	4625.172	532.000	40224.310
Header Type: AS	580.571	.396	5.621	852491.10	532.000	40958.640
SRD: 911.000	573.645	.103	.542	.0007	1.886	.010

<<< 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	579.602	.539	26000.000	4513.172	379.000	40582.870
Header Type: BR	580.141	.313	5.761	1186785.00	379.000	40905.790
SRD: 379.000	569.624	.000	.278	******	1.045	.016

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	.9782	.014	592.000	********	********	********
Pier/Pile Code 0						

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	579.700	.913	26000.000	4665.594	379.000	40220.090
Header Type: AS	580.612	.384	5.573	859553.10	388.663	40958.700
SRD: 911.000	573.645	.086	.537	.0007	1.890	.001

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.561	.074	795581.9	********	********	579.700

<<< End of Bridge Hydraulics Computations >>>

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

WSPRO OUTPUT

Input Units: English / Output Units: English

I-64 OVER INDIAN CREEK I-64-108-5658
COUNTY HARRISON QUAD CORYDON EAST
11-18-96 R L MILLER

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	581.139	.797	34000.000	6327.500	*********	40184.890
Header Type: XS	581.935	******	5.373	1345932.00	*********	40876.820
SRD: .000	573.350	******	.417	******	1.774	******
Section: FULLV	581.424	.743	34000.000	6524.533	379.000	40184.860
Header Type: FV	582.167	.233	5.211	1395928.00	379.000	40877.280
SRD: 379.000	573.350	.000	.397	.0006	1.760	-.002

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

Section: APPR	581.736	.874	34000.000	6277.332	532.000	40125.810
Header Type: AS	582.610	.377	5.416	1169744.00	532.000	40960.730
SRD: 911.000	576.496	.065	.482	.0007	1.915	.001

<<< 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	581.481	.773	34000.000	5125.701	379.000	40578.960
Header Type: BR	582.254	.318	6.633	1446494.00	379.000	40907.960
SRD: 379.000	571.023	.000	.315	******	1.130	-.002

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9407	.014	592.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	581.876	.841	34000.000	6394.078	379.000	40120.100
Header Type: AS	582.717	.370	5.317	1193558.00	389.731	40960.880
SRD: 911.000	576.496	.096	.470	.0007	1.913	.012

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL

WSPRO OUTPUT

```
          .606     .142 1022652.0 ******** ********  581.876
        -------- -------- --------- -------- -------- --------

              <<< 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-64 OVER INDIAN CREEK          I-64-108-5658
            COUNTY HARRISON              QUAD CORYDON EAST
               11-18-96                     R L MILLER

  ***  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):  6.000
             *-----------------------------------------------*

     Scour      -- Flow --          -- Width --         --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1    .489 18204.910 20409.290  153.000  189.000  Left:  ******** ********
    ..... Approach Channel Depth:   12.629 .....  Right: ******** ********
 2   1.489 22446.440 23426.140  153.000  189.000  Left:  ******** ********
    ..... Approach Channel Depth:   14.331 .....  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
    *-------------------------------------------------------------*
            I-64 OVER INDIAN CREEK          I-64-108-5658
            COUNTY HARRISON              QUAD CORYDON EAST
               11-18-96                     R L MILLER

       ***  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
```

WSPRO OUTPUT

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

     Scour    ---- Localized Hydraulic Properties ----      -- X-Stations --
 #   Depth     Flow       WSE     Depth  Velocity Froude #   Left       Right
--   ----- ---------- -------- ------ -------- -------- --------- ---------
 1    6.10  26000.000  579.688 25.088   7.769      .273  40552.000 40927.000
 2    6.51  34000.000  581.577 26.977   8.828      .300  40552.000 40927.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


      ************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
               Input Units: English  /  Output Units: English
      *-------------------------------------------------------------*
              I-64 OVER INDIAN CREEK          I-64-108-5658
              COUNTY HARRISON              QUAD CORYDON EAST
                 11-18-96                     R L MILLER

          ***  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    6.10  26000.000  579.688 25.088   7.769      .273  40552.000 40927.000
 2    6.51  34000.000  581.577 26.977   8.828      .300  40552.000 40927.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


      ************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
               Input Units: English  /  Output Units: English
      *-------------------------------------------------------------*
              I-64 OVER INDIAN CREEK          I-64-108-5658
              COUNTY HARRISON              QUAD CORYDON EAST
                 11-18-96                     R L MILLER

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

                       Constants and Input Variables
```

WSPRO OUTPUT

```
                    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 Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	6.10	26000.000	579.688	25.088	7.769	.273	40552.000	40927.000
2	6.51	34000.000	581.577	26.977	8.828	.300	40552.000	40927.000

```
  ER

   ****************** Normal end of WSPRO execution. ******************
   *************** Elapsed Time:   0 Minutes  6 Seconds  **************
```