Modified Level II Streambed-Scour Analysis for Structure I-65-85-5527 Crossing Sugar Creek in Johnson 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:

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

Modified Level II Streambed-Scour Analysis for Structure I-65-85-5527 Crossing Sugar Creek in Johnson County, Indiana

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-65-85-5527 on Interstate 65 crossing Sugar Creek in Johnson County, Indiana, are presented. The site is near the town of Amity in the southeastern part of Johnson 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 26.8 feet for the modeled discharge of 26,000 cubic feet per second and approximately 30.8 feet for the modeled discharge of 34,100 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-65-85-5527.

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 Amity in the southeastern part of Johnson County. The drainage area for the site is approximately 346 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 forest with some pasture land nearby.

Within the immediate vicinity of the bridge, Sugar Creek has a channel-bed slope of approximately 0.00077 ft/ft. The channel-bed material is gravelly sandy silt/clay, and the channel banks consist of gravelly sandy silt/clay. At the time of the Level I site visit on June 22, 1994, the banks were observed to have 0 to 50 percent woody vegetative cover; and the field report noted that the banks were fairly stable but subject to some mass wasting.

The Interstate 65 crossing of Sugar Creek is a 403-ft-long, multi-lane bridge consisting of five 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, 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-65-85-5527 crossing Sugar Creek in Johnson 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	435+31	683	9.8	17.0	26.8	664	645.7
2	436+17	680	9.8	17.0	26.8	664	645.7
3	437+01	676	9.8	17.0	26.8	664	645.7
4	437+92	676	9.8	17.0	26.8	664	645.7
Modeled discharge is 34,100 cubic feet per second							
1	435+31	683	12.4	18.4	30.8	664	641.7
2	436+17	680	12.4	18.4	30.8	664	641.7
3	437+01	676	12.4	18.4	30.8	664	641.7
4	437+92	676	12.4	18.4	30.8	664	641.7

[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, 435+31, represents a point 43,531 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 (672.5 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 65: Bridge File I-65-85-5527.

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-65 Over Sugar Creek                    I65-85-5527
T2        County: Johnson                          Quad: Marietta 138A
T3        11-01-96                                 Bret A. Robinson
SI        0
Q         26000   34100
SK        .00077 .00077
XS   EXIT 0 20
GR        42128 700  42168 690  42992 680  43106 680  43451 682  43472 681
GR        43489 680  43516 680  43550 681  43576 681  43585 675  43590 672
GR        43600 671  43631 671  43639 672  43648 673  43651 675  43659 676
GR        43725 676  43737 675  43750 675  43761 676  43772 677  43775 678
GR        43788 683  43814 682  43820 682  43834 683  43883 683  43927 682
GR        44060 682  44177 690  44229 700
N         .100    .034   .100
SA           43550    43910
XS   FULLV 410 20
GR        42128 700  42168 690  42992 680  43106 680  43451 682  43472 681
GR        43489 680  43516 680  43550 681  43576 681  43585 675  43590 672
GR        43600 671  43631 671  43639 672  43648 673  43651 675  43659 676
GR        43725 676  43737 675  43750 675  43761 676  43772 677  43775 678
GR        43788 683  43814 682  43820 682  43834 683  43883 683  43927 682
GR        44060 682  44177 690  44229 700
N         .100     .034   .100
SA           43250      43695
BR   BRDGE 410 694 20
GR       43462 0693.8  43462 0693.3  43491 0682.8  43545 0682.6  43560 0680.3
GR       43600 0679.5  43624 0679.7  43632 0675.0  43635 0673.6  43646 0672.5
GR       43656 0672.7  43664 0673.3  43685 0673.3  43693 0673.9  43694 0675.8
GR       43750 0675.9  43752 0675.6  43761 0675.2  43773 0675.9  43820 0676.0
GR        43858 0693.1  43862 0693.1  43862 0695.0  43462 0693.8
N         .032
PD        676 4 3
PD        680 4 4
PD        680 6 2
PD        683 6 2
PD        683 8 1
CD        3 144 2 692
DC 0 BRDGE 43623 43693 43680 43920 * 8
DP        43462 43862 2 * * 1 2.8 1.1
DP        43462 43862 2 * * 1 2.8 1.1
DP        43462 43862 2 * * 1 2.8 1.1
DP        43462 43862 2 * * 1 2.8 1.1
AS   APPR 964
GR        42716 700  42771 690  43675 682  43731 683  43797 683  43803 675
GR        43833 673  43871 673  43876 675  43879 678  43910 679  43934 680
GR        43948 681  43985 683  44059 680  44377 690  46383 698
N         .035 .032 .035
SA        43550 43900
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  0:28 pm     Version V050196
          Input File: 5527.dat       Output File: 5527.LST
   *-------------------------------------------------------------*
T1         I-65 OVER SUGAR CREEK              I65-85-5527
T2         COUNTY: JOHNSON                    QUAD: MARIETTA 138A
T3         11-01-96                           BRET A. ROBINSON
SI         0
Q          26000   34100

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

SK         .00077 .00077

   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
          I-65 OVER SUGAR CREEK              I65-85-5527
       COUNTY: JOHNSON                    QUAD: MARIETTA 138A
         11-01-96                           BRET A. ROBINSON

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

XS   EXIT 0 20
GR         42128 700  42168 690  42992 680  43106 680  43451 682  43472 681
GR         43489 680  43516 680  43550 681  43576 681  43585 675  43590 672
GR         43600 671  43631 671  43639 672  43648 673  43651 675  43659 676
GR         43725 676  43737 675  43750 675  43761 676  43772 677  43775 678
GR         43788 683  43814 682  43820 682  43834 683  43883 683  43927 682
GR         44060 682  44177 690  44229 700
N          .100    .034   .100
SA            43550    43910

 ***   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:  20.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (33 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
 42128.000     700.000    42168.000     690.000    42992.000     680.000
 43106.000     680.000    43451.000     682.000    43472.000     681.000
 43489.000     680.000    43516.000     680.000    43550.000     681.000
```

WSPRO OUTPUT

43576.000	681.000	43585.000	675.000	43590.000	672.000
43600.000	671.000	43631.000	671.000	43639.000	672.000
43648.000	673.000	43651.000	675.000	43659.000	676.000
43725.000	676.000	43737.000	675.000	43750.000	675.000
43761.000	676.000	43772.000	677.000	43775.000	678.000
43788.000	683.000	43814.000	682.000	43820.000	682.000
43834.000	683.000	43883.000	683.000	43927.000	682.000
44060.000	682.000	44177.000	690.000	44229.000	700.000

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 42128.000 (associated Y-Elevation: 700.000)
Maximum X-Station: 44229.000 (associated Y-Elevation: 700.000)
Minimum Y-Elevation: 671.000 (associated X-Station: 43631.000)
Maximum Y-Elevation: 700.000 (associated X-Station: 42128.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
42128.000	42218.640	42168.000	42256.230	42992.000	43030.540
43106.000	43137.660	43451.000	43461.860	43472.000	43481.590
43489.000	43497.560	43516.000	43522.930	43550.000	43554.890
43576.000	43579.320	43585.000	43587.770	43590.000	43592.470
43600.000	43601.870	43631.000	43631.000	43639.000	43638.520
43648.000	43646.980	43651.000	43649.790	43659.000	43657.310
43725.000	43719.330	43737.000	43730.610	43750.000	43742.820
43761.000	43753.160	43772.000	43763.500	43775.000	43766.320
43788.000	43778.530	43814.000	43802.960	43820.000	43808.600
43834.000	43821.760	43883.000	43867.800	43927.000	43909.150
44060.000	44034.130	44177.000	44144.070	44229.000	44192.940

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.100	---
	---	********
2	.034	---
	---	********
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-65 OVER SUGAR CREEK I65-85-5527
COUNTY: JOHNSON QUAD: MARIETTA 138A

WSPRO OUTPUT

11-01-96 BRET A. ROBINSON

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

```
XS   FULLV 410 20
GR        42128 700  42168 690  42992 680  43106 680  43451 682  43472 681
GR        43489 680  43516 680  43550 681  43576 681  43585 675  43590 672
GR        43600 671  43631 671  43639 672  43648 673  43651 675  43659 676
GR        43725 676  43737 675  43750 675  43761 676  43772 677  43775 678
GR        43788 683  43814 682  43820 682  43834 683  43883 683  43927 682
GR        44060 682  44177 690  44229 700
N         .100     .034   .100
SA           43250      43695
```

```
 ***   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:      410.   Cross-Section Skew:  20.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

X,Y-coordinates (33 pairs)

X	Y	X	Y	X	Y
42128.000	700.000	42168.000	690.000	42992.000	680.000
43106.000	680.000	43451.000	682.000	43472.000	681.000
43489.000	680.000	43516.000	680.000	43550.000	681.000
43576.000	681.000	43585.000	675.000	43590.000	672.000
43600.000	671.000	43631.000	671.000	43639.000	672.000
43648.000	673.000	43651.000	675.000	43659.000	676.000
43725.000	676.000	43737.000	675.000	43750.000	675.000
43761.000	676.000	43772.000	677.000	43775.000	678.000
43788.000	683.000	43814.000	682.000	43820.000	682.000
43834.000	683.000	43883.000	683.000	43927.000	682.000
44060.000	682.000	44177.000	690.000	44229.000	700.000

Minimum and Maximum X,Y-coordinates

```
 Minimum X-Station:   42128.000  ( associated Y-Elevation:  700.000 )
 Maximum X-Station:   44229.000  ( associated Y-Elevation:  700.000 )
 Minimum Y-Elevation:   671.000  ( associated X-Station:  43631.000 )
 Maximum Y-Elevation:   700.000  ( associated X-Station:  42128.000 )
```

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
42128.000	42218.640	42168.000	42256.230	42992.000	43030.540
43106.000	43137.660	43451.000	43461.860	43472.000	43481.590
43489.000	43497.560	43516.000	43522.930	43550.000	43554.890
43576.000	43579.320	43585.000	43587.770	43590.000	43592.470
43600.000	43601.870	43631.000	43631.000	43639.000	43638.520

WSPRO OUTPUT

```
 43648.000   43646.980    43651.000   43649.790    43659.000   43657.310
 43725.000   43719.330    43737.000   43730.610    43750.000   43742.820
 43761.000   43753.160    43772.000   43763.500    43775.000   43766.320
 43788.000   43778.530    43814.000   43802.960    43820.000   43808.600
 43834.000   43821.760    43883.000   43867.800    43927.000   43909.150
 44060.000   44034.130    44177.000   44144.070    44229.000   44192.940
----------  ----------   ----------  ----------   ----------  ----------

                  Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .100        ---
                              ---       ********
                    2         .034        ---
                              ---       ********
                    3         .100        ---
                 -------  -----------  ----------

        *-----------------------------------------------------*
        *      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-65 OVER SUGAR CREEK              I65-85-5527
      COUNTY: JOHNSON                   QUAD: MARIETTA 138A
        11-01-96                          BRET A. ROBINSON

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

   BR   BRDGE 410 694 20
   GR        43462 0693.8  43462 0693.3  43491 0682.8  43545 0682.6  43560
0680.3
   GR        43600 0679.5  43624 0679.7  43632 0675.0  43635 0673.6  43646
0672.5
   GR        43656 0672.7  43664 0673.3  43685 0673.3  43693 0673.9  43694
0675.8
   GR        43750 0675.9  43752 0675.6  43761 0675.2  43773 0675.9  43820
0676.0
   GR        43858 0693.1  43862 0693.1  43862 0695.0  43462 0693.8
   N         .032
   PD        676 4 3
   PD        680 4 4
   PD        680 6 2
   PD        683 6 2
   PD        683 8 1
   CD        3 144 2 692
```

WSPRO OUTPUT

```
   ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #23 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE              ***
   SRD Location:      410.   Cross-Section Skew:  20.0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

X,Y-coordinates (24 pairs)

X	Y	X	Y	X	Y
43462.000	693.800	43462.100	693.300	43491.000	682.800
43545.000	682.600	43560.000	680.300	43600.000	679.500
43624.000	679.700	43632.000	675.000	43635.000	673.600
43646.000	672.500	43656.000	672.700	43664.000	673.300
43685.000	673.300	43693.000	673.900	43694.000	675.800
43750.000	675.900	43752.000	675.600	43761.000	675.200
43773.000	675.900	43820.000	676.000	43858.000	693.100
43862.000	693.100	43862.100	695.000	43462.000	693.800

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	43462.000	(associated Y-Elevation:	693.800)
Maximum X-Station:	43862.100	(associated Y-Elevation:	695.000)
Minimum Y-Elevation:	672.500	(associated X-Station:	43646.000)
Maximum Y-Elevation:	695.000	(associated X-Station:	43862.100)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
43462.000	43473.100	43462.100	43473.190	43491.000	43500.350
43545.000	43551.090	43560.000	43565.190	43600.000	43602.770
43624.000	43625.330	43632.000	43632.840	43635.000	43635.660
43646.000	43646.000	43656.000	43655.400	43664.000	43662.910
43685.000	43682.650	43693.000	43690.160	43694.000	43691.110
43750.000	43743.730	43752.000	43745.610	43761.000	43754.070
43773.000	43765.340	43820.000	43809.510	43858.000	43845.210
43862.000	43848.970	43862.100	43849.070	43462.000	43473.100

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.032	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	144.000	2.00	692.000	**********

Pressure flow elevations

WSPRO OUTPUT

```
                    AVBCEL      PFElev
                  *********    694.000

                        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      676.000      4.000       3
                   2      680.000      4.000       4
                   3      680.000      6.000       2
                   4      683.000      6.000       2
                   5      683.000      8.000       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
    *-------------------------------------------------------------*
           I-65 OVER SUGAR CREEK              I65-85-5527
        COUNTY: JOHNSON                    QUAD: MARIETTA 138A
          11-01-96                           BRET A. ROBINSON
  DC 0 BRDGE 43623 43693 43680 43920 * 8
  DP         43462 43862 2 * * 1 2.8 1.1
  DP         43462 43862 2 * * 1 2.8 1.1
  DP         43462 43862 2 * * 1 2.8 1.1
  DP         43462 43862 2 * * 1 2.8 1.1

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

  AS   APPR 964
+++078 NOTICE:  AS Record Replaced With XS Record (See Users Manual).
  GR         42716 700  42771 690  43675 682  43731 683  43797 683  43803 675
  GR         43833 673  43871 673  43876 675  43879 678  43910 679  43934 680
  GR         43948 681  43985 683  44059 680  44377 690  46383 698
  N          .035 .032 .035
  SA         43550 43900

   ***   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:      964.   Cross-Section Skew:    .0   Error Code   0
```

WSPRO OUTPUT

```
 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
---------- ----------   ---------- ----------   ---------- ----------
 42716.000    700.000    42771.000    690.000    43675.000    682.000
 43731.000    683.000    43797.000    683.000    43803.000    675.000
 43833.000    673.000    43871.000    673.000    43876.000    675.000
 43879.000    678.000    43910.000    679.000    43934.000    680.000
 43948.000    681.000    43985.000    683.000    44059.000    680.000
 44377.000    690.000    46383.000    698.000
---------- ----------   ---------- ----------   ---------- ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   42716.000  ( associated Y-Elevation:  700.000 )
  Maximum X-Station:   46383.000  ( associated Y-Elevation:  698.000 )
  Minimum Y-Elevation:   673.000  ( associated X-Station:  43871.000 )
  Maximum Y-Elevation:   700.000  ( associated X-Station:  42716.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .035        ---
                                ---       ********
                      2         .032        ---
                                ---       ********
                      3         .035        ---
                   -------  -----------  ----------

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-65 OVER SUGAR CREEK              I65-85-5527
        COUNTY: JOHNSON                   QUAD: MARIETTA 138A
          11-01-96                          BRET A. ROBINSON
  EX

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

            Reach       Water Surface   Friction
      #   Discharge       Elevation       Slope          Flow Regime
```

WSPRO OUTPUT

```
--    ---------    -------------   --------   --------------------
 1     26000.00       ********         .0008        Sub-Critical
 2     34100.00       ********         .0008        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-65 OVER SUGAR CREEK              I65-85-5527
       COUNTY: JOHNSON                    QUAD: MARIETTA 138A
         11-01-96                           BRET A. ROBINSON

                     WSEL     VHD        Q          AREA       SRDL       LEW
                     EGEL      HF        V            K         FLEN       REW
                     CRWS      HO      FR #          SF        ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: EXIT       687.293   .308  26000.000  10198.290 ********* 42391.050
Header Type: XS     687.601 ******      2.549  936131.40 ********* 44137.410
SRD:       .000     683.241 ******       .325     ******     3.044    ******

Section: FULLV      687.654   .240  26000.000  10835.420   410.000 42361.290
Header Type: FV     687.894   .295      2.400 1005190.00   410.000 44142.700
SRD:    410.000     682.986   .000       .281      .0007     2.680      -.001

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

Section: APPR       688.041   .339  26000.000   6198.063   554.000 42992.420
Header Type: AS     688.379   .435      4.195  857020.60   554.000 44314.690
SRD:    964.000     684.798   .049       .380      .0008     1.238      .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      687.304  1.408  26000.000   3386.958   410.000 43478.600
Header Type: BR     688.713   .447      7.677  684795.90   410.000 43845.120
SRD:    410.000     683.295   .664       .552     ******     1.537      -.002

Specific Bridge Information   C      P/A    PFELEV     BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ------ --------- --------- --------- ---------
Pier/Pile Code  0             .8067  .020  694.000 ******** ******** ********
```

WSPRO OUTPUT

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

                    WSEL     VHD       Q         AREA      SRDL       LEW
                    EGEL      HF       V           K        FLEN       REW
                    CRWS      HO     FR #         SF       ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: APPR       689.140   .220  26000.000   7739.675   410.000 42868.160
Header Type: AS     689.360   .424      3.359 1140439.00   473.389 44349.660
SRD:    964.000     684.798   .225       .290       .0008    1.254     -.003

            Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
             .721     .420  661907.5 ******** ********  689.140
          -------- -------- --------- -------- -------- --------

              <<< End of Bridge Hydraulics Computations >>>


    ************************* W S P R O ****************************
       Federal Highway Administration - U. S. Geological Survey
             Model for Water-Surface Profile Computations.
            Input Units: English / Output Units: English
    *-----------------------------------------------------------*
          I-65 OVER SUGAR CREEK              I65-85-5527
       COUNTY: JOHNSON                    QUAD: MARIETTA 138A
         11-01-96                           BRET A. ROBINSON

                    WSEL     VHD       Q         AREA      SRDL       LEW
                    EGEL      HF       V           K        FLEN       REW
                    CRWS      HO     FR #         SF       ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: EXIT       688.652   .355  34100.000  12661.180 ********* 42279.070
Header Type: XS     689.007 ******      2.693 1228186.00 ********* 44157.290
SRD:       .000     683.990 ******       .324     ******     3.143    ******

Section: FULLV      689.017   .281  34100.000  13353.820   410.000 42248.960
Header Type: FV     689.299   .293      2.554 1326449.00   410.000 44162.630
SRD:    410.000     683.893   .000       .284       .0007    2.775       .000

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

Section: APPR       689.387   .346  34100.000   8109.037   554.000 42840.320
Header Type: AS     689.732   .401      4.205 1210820.00   554.000 44357.490
SRD:    964.000     685.568   .032       .360       .0007    1.257       .000

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

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


                    WSEL     VHD       Q         AREA      SRDL       LEW
                    EGEL      HF       V           K        FLEN       REW
```

WSPRO OUTPUT

	CRWS	HO	FR #	SF	ALPHA	ERR
Section: BRDGE	688.546	1.950	34100.000	3845.760	410.000	43475.190
Header Type: BR	690.495	.474	8.867	836355.50	410.000	43847.880
SRD: 410.000	684.470	1.015	.615	******	1.595	.000

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 0	.7919	.020	694.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	690.947	.209	34100.000	10702.250	410.000	42765.790
Header Type: AS	691.155	.407	3.186	1651881.00	473.664	44614.390
SRD: 964.000	685.568	.253	.268	.0007	1.321	.001

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.753	.454	902240.7	********	********	690.947

<<< End of Bridge Hydraulics Computations >>>

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

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

I-65 OVER SUGAR CREEK I65-85-5527
COUNTY: JOHNSON QUAD: MARIETTA 138A
11-01-96 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): 8.000

#	Scour Depth	-- Flow -- Contract	Approach	-- Width -- Contract	Approach	--- X-Limits --- Side	Contract	Approach
1	9.806	9350.915	11627.730	62.000	240.000	Left:	********	********
	..... Approach Channel Depth:		10.053			Right:	********	********
2	12.405	11621.600	13867.230	62.000	240.000	Left:	********	********
	..... Approach Channel Depth:		11.860			Right:	********	********

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-65 OVER SUGAR CREEK              I65-85-5527
    COUNTY: JOHNSON                    QUAD: MARIETTA 138A
      11-01-96                           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):   2.80
               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  17.00  26000.000  687.529 15.029   9.003     .409  43462.000 43862.000
 2  18.36  34100.000  688.799 16.299  10.504     .459  43462.000 43862.000
--  ----- ---------- -------- ------ -------- -------- --------- ---------


************************** 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-65 OVER SUGAR CREEK              I65-85-5527
    COUNTY: JOHNSON                    QUAD: MARIETTA 138A
      11-01-96                           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):   2.80
               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 Depth	Flow	WSE	Localized Hydraulic Properties Depth	Velocity	Froude #	X-Stations Left	Right
1	17.00	26000.000	687.529	15.029	9.003	.409	43462.000	43862.000
2	18.36	34100.000	688.799	16.299	10.504	.459	43462.000	43862.000

```
************************* 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-65 OVER SUGAR CREEK              I65-85-5527
    COUNTY: JOHNSON                    QUAD: MARIETTA 138A
      11-01-96                           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):   2.80
              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	Localized Hydraulic Properties Depth	Velocity	Froude #	X-Stations Left	Right
1	17.00	26000.000	687.529	15.029	9.003	.409	43462.000	43862.000
2	18.36	34100.000	688.799	16.299	10.504	.459	43462.000	43862.000

```
************************* 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-65 OVER SUGAR CREEK              I65-85-5527
    COUNTY: JOHNSON                    QUAD: MARIETTA 138A
      11-01-96                           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):   2.80
  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	17.00	26000.000	687.529	15.029	9.003	.409	43462.000	43862.000
2	18.36	34100.000	688.799	16.299	10.504	.459	43462.000	43862.000

```
ER

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