Modified Level II Streambed-Scour Analysis for Structure I-164-7-6974 Crossing Schlensker Ditch in Vanderburgh County, Indiana

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

Prepared in cooperation with the
INDIANA DEPARTMENT OF TRANSPORTATION

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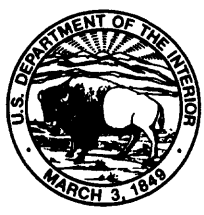

Indianapolis, Indiana
1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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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-164-7-6974 on Interstate 164 crossing Schlensker Ditch in Vanderburgh County, Indiana, are presented. The site is near the town of Daylight in the northeastern part of Vanderburgh 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 17.6 feet for the modeled discharge of 2,100 cubic feet per second and approximately 33.4 feet for the modeled discharge of 2,940 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-164-7-6974.

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 Daylight in the northeastern part of Vanderburgh County. The drainage area for the site is approximately 7.1 mi^2 (Merril Dougherty, Indiana Department of Transportation, written commun., 1997). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly agricultural.

Within the immediate vicinity of the bridge, Schlensker Ditch has a channel-bed slope of approximately 0.0012 ft/ft. The channel-bed material is gravel, and the channel banks consist of silt-clay. At the time of the Level I site visit on December 18, 1991, the banks were observed to have 0 to 40 percent woody vegetative cover; and the field report noted that the banks were experiencing fluvial erosion.

The Interstate 164 crossing of Schlensker Ditch is a 101-ft-long, multi-lane bridge consisting of three 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 USGS 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, 1985) 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-164-7-6974 crossing Schlensker Ditch in Vanderburgh 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 2,100 cubic feet per second							
1	1155+28	374	13.8	3.8	17.6	--	353.8
2	1155+66	373	13.8	3.8	17.6	--	353.8
Modeled discharge is 2,940 cubic feet per second							
1	1155+28	374	29.2	4.2	33.4	--	338.0
2	1155+66	373	29.2	4.2	33.4	--	338.0

[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, 1155+28, represents a point 115,528 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 (371.4 feet).

[5]Not a 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.

The bridge plans indicate that the piles supporting this bridge have been driven to bedrock. The plans indicate that the top of bedrock is encountered between the elevations of 319 feet and 321 feet.

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, 1985, Bridge plans Interstate Route 164: Bridge File I-164-7-6974.

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-164 OVER SCHLENSKER DITCH                    I-164-7-6974
T2        COUNTY: VANDERBURGH                            QUAD: DAYLIGHT 194C
T3        08-01-97                                       R L MILLER
SI         0
Q          2100   2940
SK         .0012  .0012
XS   EXIT  0
GR        14700 390  14701 380  15491 378  15495 376  15500 374
GR        15503 372  15507 370  15518 370  15521 372  15523 374
GR        15526 376  15531 378  16200 380  18500 380  18600 385
N          .035  .050  .035
SA            15491  15531
XS   FULLV  103
GR        14700 390  14701 380  15491 378  15495 376  15500 374
GR        15503 372  15507 370  15518 370  15521 372  15523 374
GR        15526 376  15531 378  16200 380  18500 380  18600 385
N          .035  .050  .035
SA            15491  15531
BR   BRDGE 103 388.3
GR        15486 388.3  15487 387.9  15489 387.9  15523 371.6
GR        15559 371.6  15591 387.8  15594 387.8  15595 388.3
GR        15486 388.3
N           .050
PD        372 3 1
CD        3 130 2 388
DC 0 BRDGE 15506  15574  15531 15576 * 3
DP        15486 15595 1.5 * * 1 1 1.1
XS   APPR  436
GR        14700 390  14701 380  15531 378  15536 376  15538 374
GR        15540 372  15555 370  15562 370  15565 372  15569 374
GR        15571 376  15576 378  16100 380  18050 385  18250 400
N          .035  .050  .035
SA            15531  15576
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/ 7/97  6:56 am     Version V050196
          Input File: 6974.dat       Output File: 6974.LST
   *-------------------------------------------------------------*
T1         I-164 OVER SCHLENSKER DITCH                 I-164-7-6974
T2         COUNTY: VANDERBURGH                         QUAD: DAYLIGHT 194C
T3         08-01-97                                    R L MILLER
SI          0
Q           2100   2940

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

SK          .0012  .0012

   ************************  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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                         QUAD: DAYLIGHT 194C
       08-01-97                                    R L MILLER

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

XS   EXIT  0
GR         14700 390  14701 380  15491 378  15495 376  15500 374
GR         15503 372  15507 370  15518 370  15521 372  15523 374
GR         15526 376  15531 378  16200 380  18500 380  18600 385
N           .035  .050  .035
SA             15491  15531

 ***   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 (15 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 14700.000     390.000    14701.000     380.000    15491.000     378.000
 15495.000     376.000    15500.000     374.000    15503.000     372.000
 15507.000     370.000    15518.000     370.000    15521.000     372.000
 15523.000     374.000    15526.000     376.000    15531.000     378.000
 16200.000     380.000    18500.000     380.000    18600.000     385.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   14700.000  ( associated Y-Elevation:  390.000 )
  Maximum X-Station:   18600.000  ( associated Y-Elevation:  385.000 )
  Minimum Y-Elevation:   370.000  ( associated X-Station:  15518.000 )
  Maximum Y-Elevation:   390.000  ( associated X-Station:  14700.000 )

                    Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .035        ---
                               ---        ********
                     2         .050        ---
                               ---        ********
                     3         .035        ---
                  -------  -----------  ----------

         *-----------------------------------------------------*
         *      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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                         QUAD: DAYLIGHT 194C
       08-01-97                                    R L MILLER

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

XS   FULLV  103
GR        14700 390  14701 380  15491 378  15495 376  15500 374
GR        15503 372  15507 370  15518 370  15521 372  15523 374
GR        15526 376  15531 378  16200 380  18500 380  18600 385
N          .035  .050  .035
SA            15491  15531

 ***   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:      103.   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 (15 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
 14700.000     390.000    14701.000     380.000    15491.000     378.000
 15495.000     376.000    15500.000     374.000    15503.000     372.000
```

WSPRO OUTPUT

```
 15507.000     370.000    15518.000     370.000    15521.000     372.000
 15523.000     374.000    15526.000     376.000    15531.000     378.000
 16200.000     380.000    18500.000     380.000    18600.000     385.000
----------   ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   14700.000  ( associated Y-Elevation:  390.000 )
  Maximum X-Station:   18600.000  ( associated Y-Elevation:  385.000 )
  Minimum Y-Elevation:   370.000  ( associated X-Station:  15518.000 )
  Maximum Y-Elevation:   390.000  ( associated X-Station:  14700.000 )

                   Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .035        ---
                               ---        ********
                     2         .050        ---
                               ---        ********
                     3         .035        ---
                  -------  -----------  ----------

         *-----------------------------------------------------*
         *      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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                        QUAD: DAYLIGHT 194C
       08-01-97                                   R L MILLER

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

BR   BRDGE 103 388.3
GR        15486 388.3  15487 387.9  15489 387.9  15523 371.6
GR        15559 371.6  15591 387.8  15594 387.8  15595 388.3
GR        15486 388.3
N           .050
PD        372 3 1
CD        3 130 2 388

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

WSPRO OUTPUT

X,Y-coordinates (9 pairs)

X	Y	X	Y	X	Y
15486.000	388.300	15487.000	387.900	15489.000	387.900
15523.000	371.600	15559.000	371.600	15591.000	387.800
15594.000	387.800	15595.000	388.300	15486.000	388.300

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 15486.000 (associated Y-Elevation: 388.300)
Maximum X-Station: 15595.000 (associated Y-Elevation: 388.300)
Minimum Y-Elevation: 371.600 (associated X-Station: 15559.000)
Maximum Y-Elevation: 388.300 (associated X-Station: 15486.000)

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.050	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	130.000	2.00	388.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	388.300

Abutment Parameters

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

Pier/Pile Data (1 Group(s))

Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	372.000	3.000	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-164 OVER SCHLENSKER DITCH I-164-7-6974
COUNTY: VANDERBURGH QUAD: DAYLIGHT 194C
08-01-97 R L MILLER

WSPRO OUTPUT

```
DC 0 BRDGE 15506  15574  15531 15576 * 3
DP         15486 15595 1.5 * * 1 1 1.1

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

XS   APPR  436
GR         14700 390  14701 380  15531 378  15536 376  15538 374
GR         15540 372  15555 370  15562 370  15565 372  15569 374
GR         15571 376  15576 378  16100 380  18050 385  18250 400
N           .035  .050  .035
SA             15531  15576

 ***   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:      436.   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 (15 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 14700.000     390.000    14701.000     380.000    15531.000     378.000
 15536.000     376.000    15538.000     374.000    15540.000     372.000
 15555.000     370.000    15562.000     370.000    15565.000     372.000
 15569.000     374.000    15571.000     376.000    15576.000     378.000
 16100.000     380.000    18050.000     385.000    18250.000     400.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   14700.000  ( associated Y-Elevation:  390.000 )
  Maximum X-Station:   18250.000  ( associated Y-Elevation:  400.000 )
  Minimum Y-Elevation:   370.000  ( associated X-Station:  15562.000 )
  Maximum Y-Elevation:   400.000  ( associated X-Station:  18250.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .035        ---
                                ---       ********
                      2         .050        ---
                                ---       ********
                      3         .035        ---
                   -------  -----------  ----------

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

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

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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                        QUAD: DAYLIGHT 194C
       08-01-97                                    R L MILLER
EX

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

           Reach       Water Surface   Friction
    #    Discharge       Elevation      Slope          Flow Regime
   --    ---------     -------------   --------   --------------------
    1      2100.00       ********         .0012        Sub-Critical
    2      2940.00       ********         .0012        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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                        QUAD: DAYLIGHT 194C
       08-01-97                                    R L MILLER

                    WSEL     VHD        Q         AREA       SRDL       LEW
                    EGEL      HF        V           K         FLEN       REW
                    CRWS      HO      FR #         SF        ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: EXIT       379.624   .087   2100.000   1222.229 ********* 14849.430
Header Type: XS     379.711 ******      1.718   60676.89 ********* 16074.310
SRD:       .000     379.011 ******       .417     ******     1.892    ******

Section: FULLV      379.740   .066   2100.000   1368.860   103.000 14803.720
Header Type: FV     379.806   .109      1.534   68590.64   103.000 16113.020
SRD:    103.000     379.011   .000       .356      .0011     1.806     -.014

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

Section: APPR       380.011   .041   2100.000   1693.351   333.000 14701.000
Header Type: AS     380.052   .232      1.240   92214.55   333.000 16104.270
SRD:    436.000     376.518   .000       .262      .0007     1.730      .014
```

WSPRO OUTPUT

<<< 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	379.650	.438	2100.000	421.395	103.000	15506.210
Header Type: BR	380.088	.195	4.983	40506.88	103.000	15574.900
SRD: 103.000	376.123	.182	.378	******	1.134	.000

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 0	.9390	.054	388.300	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	380.676	.012	2100.000	2713.561	203.000	14700.930
Header Type: AS	380.689	.166	.774	169598.00	240.915	16363.800
SRD: 436.000	376.518	.435	.124	.0007	1.341	.018

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.951	.736	44077.4	********	********	380.676

<<< 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-164 OVER SCHLENSKER DITCH I-164-7-6974
COUNTY: VANDERBURGH QUAD: DAYLIGHT 194C
08-01-97 R L MILLER

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: EXIT	380.087	.082	2940.000	2065.548	*********	14700.990
Header Type: XS	380.169	******	1.423	84866.94	*********	18501.740
SRD: .000	379.288	******	.549	******	2.602	******

WSPRO OUTPUT

```
Section: FULLV      380.217   .046   2940.000   2560.372   103.000 14700.980
Header Type: FV     380.264   .097      1.148  108001.90   103.000 18504.350
SRD:    103.000     379.288   .000       .371       .0009     2.255     -.003

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

Section: APPR       380.430   .036   2940.000   2315.300   333.000 14700.960
Header Type: AS     380.466   .194      1.270  137337.00   333.000 16267.610
SRD:    436.000     379.220   .000       .221       .0006     1.443       .008

       <<< 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      380.114   .757   2940.000    453.713   103.000_15505.240
Header Type: BR     380.871   .247      6.480   44950.84   103.000 15575.820
SRD:    103.000     377.126   .455       .485     ******     1.159       .000

Specific Bridge Information   C      P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .9289  .054  388.300 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                      WSEL     VHD       Q          AREA       SRDL       LEW
                      EGEL      HF       V            K        FLEN       REW
                      CRWS      HO    FR #           SF       ALPHA      ERR
                    --------- ------ ---------- ---------- --------- ---------
Section: APPR       381.693   .007   2940.000   4604.598   203.000 14700.830
Header Type: AS     381.700   .148       .638  348720.70   252.982 16760.090
SRD:    436.000     379.220   .681       .081       .0006     1.170       .003

          Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
              .955     .835   57346.9 ******** ********  381.693
          -------- -------- --------- -------- -------- --------

            <<< 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-164 OVER SCHLENSKER DITCH                 I-164-7-6974
   COUNTY: VANDERBURGH                      QUAD: DAYLIGHT 194C
       08-01-97                                  R L MILLER
```

WSPRO OUTPUT

*** 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):	3.000

#	Scour Depth	Flow Contract	Flow Approach	Width Contract	Width Approach	X-Limits Side	X-Limits Contract	X-Limits Approach
1	13.800	2100.000	484.785	65.000	45.000	Left:	********	********
	..... Approach Channel Depth:	7.876				Right:	********	********
2	29.160	2940.000	404.061	65.000	45.000	Left:	********	********
	..... Approach Channel Depth:	8.893				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-164 OVER SCHLENSKER DITCH I-164-7-6974
COUNTY: VANDERBURGH QUAD: DAYLIGHT 194C
08-01-97 R L MILLER

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

Constants and Input Variables

Pier Width: 1.500

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

#	Scour Depth	Localized Hydraulic Properties Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	3.79	2100.000	380.085	8.485	5.560	.336	15486.000	15595.000
2	4.23	2940.000	380.795	9.195	7.014	.408	15486.000	15595.000

ER

********** Normal end of WSPRO execution. **********
********** Elapsed Time: 0 Minutes 3 Seconds **********