Modified Level II Streambed-Scour Analysis for Structure (I-465)-431-49-4445 Crossing Lick Creek in Marion County, Indiana

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

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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 John T. Wilson, 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-465)-431-49-4445 on State Route 431 crossing Interstate 465 and Lick Creek in Marion County, Indiana, are presented. The site is near the city of Edgewood in the southern part of Marion County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 6.7 feet for the modeled discharge of 8,200 cubic feet per second and approximately 7.0 feet for the modeled discharge of 11,400 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-465)-431-49-4445.

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 city of Edgewood in the southern part of Marion County. The drainage area for the site is approximately 20.4 mi^2 (Merril Dougherty, Indiana Department of Transportation, written commun., 1997). The predominant land use in the basin is urban; in the immediate vicinity of the bridge, the land is predominantly interstate right-of-way with the channelized waterway of Lick Creek.

Within the immediate vicinity of the bridge, Lick Creek has a channel-bed slope of approximately 0.0025 ft/ft. The channel-bed material is a cobble gravelly sand, and the channel banks consist of concrete. At the time of the Level I site visit on July 21, 1995, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were stable.

The State Route 431 crossing of Interstate 465 and Lick Creek is a 348-ft-long, multi-lane bridge consisting of six spans supported by concrete and steel piers and sloping concrete spill-through abutments. Parts of the southern three spans cross Lick Creek, the northern three spans cross Interstate 465. 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, 1959) 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-465)-431-49-4445 crossing Lick Creek in Marion County, Indiana

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 8,200 cubic feet per second							
1	26+19	707	0	6.7	6.7	700.0	698.3
2	26+85	711	0	6.7	6.7	700.0	698.3
Modeled discharge is 11,400 cubic feet per second							
1	26+19	707	0	7.0	7.0	700.0	698.0
2	26+85	711	0	7.0	7.0	700.0	698.0

[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, 26+19, represents a point 2,619 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 (705.0 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.

Lick Creek has concrete banks in the vicinity of the bridge. The bases of the southern two piers are protected by the concrete banks. The bridge was modeled and scour was computed as if this concrete protection did not exist. Only the part of the bridge crossing Lick Creek was modeled—the spans crossing Interstate 465 were above the modeled water-surface elevations and were not included.

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, 1959, Bridge plans State Route 431: Bridge File (I-465)-431-49-4445.

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          U.S. 431 OVER LICK CREEK      (I465)431-49-4445
T2          COUNTY: MARION                QUAD: MAYWOOD  124A
T3          7-29-97                       JOHN T. WILSON
Q           8200    11400
SK          .0025   .0025
XS   EXIT   0
*           ***CHANNEL IS STRAIGHT WITH CONCRETE SLOPEWALLS***
GR          2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR          2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
N           .035        .020        .035
SA               2606        2690
XS   FULLV  140
GR         2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR         2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
BR   BRDGE  140   735
*          ***BASE OF PIERS ARE SET IN CONCRETE SLOPEWALLS***
*          ***BRIDGE SECTION WAS USED AS A TEMPLATE FOR APPR/EXIT***
GR          2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR          2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
GR          2740 734.6  2565 735.4
N          .035         .020        .035
SA               2606        2690
PD         707.3    2.0    1
PD         711.0    2.0    2
PD         711.0    4.0    3
CD         3    76    2    737
DC 0 BRDGE  2578   2699   2606   2690   *  4
*           ***DC LIMITS AT BRIDGE ARE APPROX. LEW AND REW FOR Q1***
*           BXL      BXR      PW   *  *  K1  K2  K3
DP          2565.0   2740.0   2.0  *  *  1  1   1.1
DP          2565.0   2740.0   2.0  *  *  1  1   1.1
*           ***DP CARDS USE THE WHOLE BRIDGE OPENING FOR BXL/BXR***
XS   APPR   356
GR          2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR          2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
N           .035        .020        .035
SA               2606        2690
HP 2 BRDGE  715.6  *  715.6   8200
HP 2 BRDGE  718.1  *  718.1   11400
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:  7/31/97  8:27 am     Version V050196
          Input File: LICK.DAT       Output File: LICK.LST
   *-------------------------------------------------------------*
T1         U.S. 431 OVER LICK CREEK      (I465)431-49-4445
T2         COUNTY: MARION                QUAD: MAYWOOD  124A
T3         7-29-97                       JOHN T. WILSON
Q          8200    11400

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

SK         .0025   .0025

   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
          U.S. 431 OVER LICK CREEK      (I465)431-49-4445
         COUNTY: MARION                QUAD: MAYWOOD  124A
           7-29-97                       JOHN T. WILSON

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

XS   EXIT  0
GR         2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR         2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
N          .035        .020        .035
SA              2606        2690

  ***   Completed Reading Data Associated With Header Record EXIT    ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
  ***  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 (10 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
  2565.000    735.400    2565.100    719.400    2580.000    714.800
  2606.000    713.800    2624.000    705.000    2672.000    705.000
  2690.000    713.500    2695.000    713.500    2736.000    733.000
  2740.000    733.000
----------  ----------  ----------  ----------  ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    2565.000  ( associated Y-Elevation:  735.400 )
  Maximum X-Station:    2740.000  ( associated Y-Elevation:  733.000 )
  Minimum Y-Elevation:   705.000  ( associated X-Station:   2672.000 )
  Maximum Y-Elevation:   735.400  ( associated X-Station:   2565.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .035        ---
                               ---       2606.000
                     2         .020        ---
                               ---       2690.000
                     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
   *-------------------------------------------------------------*
          U.S. 431 OVER LICK CREEK      (I465)431-49-4445
         COUNTY: MARION                QUAD: MAYWOOD  124A
           7-29-97                       JOHN T. WILSON

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

  XS   FULLV  140
  GR        2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
  GR        2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0

   ***   Completed Reading Data Associated With Header Record FULLV   ***
   ***   No Roughness Data Input, Propagating From Previous Section   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
   ***  Storing X-Section Data In Temporary File As Record Number  2  ***

   ***              Data Summary For Header Record FULLV              ***
   SRD Location:      140.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

WSPRO OUTPUT

X,Y-coordinates (10 pairs)

X	Y	X	Y	X	Y
2565.000	735.400	2565.100	719.400	2580.000	714.800
2606.000	713.800	2624.000	705.000	2672.000	705.000
2690.000	713.500	2695.000	713.500	2736.000	733.000
2740.000	733.000				

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	2565.000	(associated Y-Elevation:	735.400)
Maximum X-Station:	2740.000	(associated Y-Elevation:	733.000)
Minimum Y-Elevation:	705.000	(associated X-Station:	2672.000)
Maximum Y-Elevation:	735.400	(associated X-Station:	2565.000)

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.035	---
	---	2606.000
2	.020	---
	---	2690.000
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
   *-------------------------------------------------------------*
          U.S. 431 OVER LICK CREEK      (I465)431-49-4445
         COUNTY: MARION                QUAD: MAYWOOD  124A
           7-29-97                       JOHN T. WILSON

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

BR   BRDGE  140   735
GR         2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR         2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
GR         2740 734.6  2565 735.4
N         .035        .020        .035
SA              2606        2690
PD        707.3    2.0    1
PD        711.0    2.0    2
PD        711.0    4.0    3
CD        3    76    2    737
```

WSPRO OUTPUT

```
   ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #11 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE              ***
   SRD Location:      140.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

X,Y-coordinates (12 pairs)

X	Y	X	Y	X	Y
2565.000	735.400	2565.100	719.400	2580.000	714.800
2606.000	713.800	2624.000	705.000	2672.000	705.000
2690.000	713.500	2695.000	713.500	2736.000	733.000
2740.000	733.000	2740.100	734.600	2565.000	735.400

Minimum and Maximum X,Y-coordinates

```
  Minimum X-Station:    2565.000  ( associated Y-Elevation:  735.400 )
  Maximum X-Station:    2740.100  ( associated Y-Elevation:  734.600 )
  Minimum Y-Elevation:   705.000  ( associated X-Station:   2672.000 )
  Maximum Y-Elevation:   735.400  ( associated X-Station:   2565.000 )
```

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.035	---
	---	2606.000
2	.020	---
	---	2690.000
3	.035	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	76.000	2.00	737.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	735.000

Abutment Parameters

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

WSPRO OUTPUT

Pier/Pile Data (3 Group(s))
Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	707.300	2.000	1
2	711.000	2.000	2
3	711.000	4.000	3

```
*-------------------------------------------------*
*      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
*-----------------------------------------------------------*
        U.S. 431 OVER LICK CREEK     (I465)431-49-4445
       COUNTY: MARION               QUAD: MAYWOOD  124A
         7-29-97                     JOHN T. WILSON
DC 0 BRDGE  2578   2699   2606   2690   *  4
DP         2565.0   2740.0   2.0  *  *  1  1   1.1
DP         2565.0   2740.0   2.0  *  *  1  1   1.1

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

XS   APPR   356
GR         2565 735.4  2565 719.4  2580 714.8  2606 713.8  2624 705.0
GR         2672 705.0  2690 713.5  2695 713.5  2736 733.0  2740 733.0
N          .035        .020        .035
SA              2606        2690

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

 ***              Data Summary For Header Record APPR              ***
 SRD Location:      356.   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 (10 pairs)

X	Y	X	Y	X	Y
2565.000	735.400	2565.100	719.400	2580.000	714.800
2606.000	713.800	2624.000	705.000	2672.000	705.000
2690.000	713.500	2695.000	713.500	2736.000	733.000
2740.000	733.000				

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    2565.000  ( associated Y-Elevation:  735.400 )
  Maximum X-Station:    2740.000  ( associated Y-Elevation:  733.000 )
  Minimum Y-Elevation:   705.000  ( associated X-Station:   2672.000 )
  Maximum Y-Elevation:   735.400  ( associated X-Station:   2565.000 )

                    Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .035        ---
                               ---        2606.000
                     2         .020        ---
                               ---        2690.000
                     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
    *-------------------------------------------------------------*
           U.S. 431 OVER LICK CREEK      (I465)431-49-4445
          COUNTY: MARION                QUAD: MAYWOOD  124A
            7-29-97                       JOHN T. WILSON
  HP 2 BRDGE  715.6  *  715.6   8200
  HP 2 BRDGE  718.1  *  718.1   11400
  EX

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

           Reach      Water Surface   Friction
     #   Discharge      Elevation      Slope         Flow Regime
    --   ---------    ------------   --------   --------------------
     1     8200.00      ********        .0025        Sub-Critical
     2    11400.00      ********        .0025        Sub-Critical
    --   ---------    ------------   --------   --------------------

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

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
*-----------------------------------------------------------*
        U.S. 431 OVER LICK CREEK      (I465)431-49-4445
       COUNTY: MARION                 QUAD: MAYWOOD  124A
         7-29-97                        JOHN T. WILSON

                   WSEL     VHD       Q         AREA      SRDL      LEW
                   EGEL      HF       V           K        FLEN      REW
                   CRWS      HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
 Section: EXIT      714.087  2.827   8200.000    611.999 *********  2598.532
 Header Type: XS    716.914 ******     13.399  163881.50 *********  2696.235
 SRD:       .000    713.495 ******       .950     ******     1.013    ******

===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
       FNTEST, FR#, WSEL, CRWS:    .80      .86      715.00      713.50

===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:    713.50      735.40      .50

===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:    713.50      735.40      713.50

 Section: FULLV     714.995  2.201   8200.000    711.867   140.000  2579.368
 Header Type: FV    717.196   .286     11.519  200513.20   140.000  2698.144
 SRD:    140.000    713.495   .000       .857      .0020     1.067     -.005

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

 Section: APPR      715.656  1.847   8200.000    791.454   216.000  2577.229
 Header Type: AS    717.503   .315     10.361  229837.90   216.000  2699.532
 SRD:    356.000    713.495   .000       .755      .0015     1.106     -.009

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

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


                   WSEL     VHD       Q         AREA      SRDL      LEW
                   EGEL      HF       V           K        FLEN      REW
                   CRWS      HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
 Section: BRDGE     715.405  1.806   8200.000    760.943   140.000  2578.042
 Header Type: BR    717.211   .271     10.776  218447.00   140.000  2699.005
 SRD:    140.000    713.636   .019       .758     ******     1.000     -.011

 Specific Bridge Information   C      P/A    PFELEV     BLEN      XLAB      XRAB
 Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
 Pier/Pile Code  0           1.0000  .033  735.000 ******** ******** ********
 ------------------------- ------ ----- -------- -------- -------- --------
```

WSPRO OUTPUT

```
                    WSEL     VHD       Q          AREA       SRDL       LEW
                    EGEL      HF       V           K         FLEN       REW
                    CRWS      HO      FR #         SF        ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section: APPR      715.789  1.784   8200.000    807.865   140.000  2576.795
 Header Type: AS    717.574   .188     10.150  236036.60   140.103  2699.813
 SRD:    356.000    713.495   .178       .737      .0015     1.114     -.008

            Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
              .029     .000  236484.1 2577.911 2698.934  715.789
          -------- -------- --------- -------- -------- --------

              <<< 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
    *-------------------------------------------------------------*
           U.S. 431 OVER LICK CREEK      (I465)431-49-4445
          COUNTY: MARION                QUAD: MAYWOOD  124A
            7-29-97                       JOHN T. WILSON

                    WSEL     VHD       Q          AREA       SRDL       LEW
                    EGEL      HF       V           K         FLEN       REW
                    CRWS      HO      FR #         SF        ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section: EXIT      715.615  3.608  11400.000    786.443 *********  2577.362
 Header Type: XS    719.222 ******     14.496  227954.80 *********  2699.446
 SRD:       .000    715.428 ******      1.058     ******     1.104     ******

===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
       FNTEST, FR#, WSEL, CRWS:   .80     .85     716.83     715.43

===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   715.43     735.40     .50

===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   715.43     735.40     715.43

 Section: FULLV     716.825  2.672  11400.000    938.147   140.000  2573.441
 Header Type: FV    719.497   .278     12.152  286864.80   140.000  2701.991
 SRD:    140.000    715.428   .000       .855      .0020     1.163     -.004

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

 Section: APPR      717.515  2.279  11400.000   1028.088   216.000  2571.206
 Header Type: AS    719.794   .303     11.089  323457.40   216.000  2703.441
 SRD:    356.000    715.428   .000       .766      .0014     1.192     -.005
```

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	717.949	1.714	11400.000	1085.945	140.000	2569.802
Header Type: BR	719.662	.238	10.498	347575.60	140.000	2704.353
SRD: 140.000	715.629	.210	.651	******	1.000	.019

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 0	1.0000	.032	735.000	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	717.836	2.123	11400.000	1070.888	140.000	2570.165
Header Type: AS	719.959	.159	10.645	341257.00	140.104	2704.118
SRD: 356.000	715.428	.132	.729	.0014	1.204	.006

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.028	.000	340905.1	2569.761	2704.211	717.836

<<< 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

U.S. 431 OVER LICK CREEK (I465)431-49-4445
COUNTY: MARION QUAD: MAYWOOD 124A
7-29-97 JOHN T. WILSON

WSPRO OUTPUT

```
   ***     Beginning Velocity Distribution For Header Record BRDGE     ***
           SRD Location:     140.000        Header Record Number  3

        Water Surface Elevation:     715.600              Element # 1
        Flow:     8200.000   Velocity: 10.45  Hydraulic Depth:    6.431
        Cross-Section Area:     784.67         Conveyance:    227290.30
           Bank Stations ->  Left:    2577.409   Right:    2699.415

X STA.      2577.4     2617.5     2622.5     2626.1     2629.4     2632.6
  A( I )             87.6       43.4       37.7       34.7       34.2
  V( I )             4.68       9.44      10.89      11.83      12.00
  D( I )             2.19       8.63      10.45      10.60      10.60

X STA.      2632.6     2635.7     2638.8     2642.0     2645.0     2648.1
  A( I )             33.4       32.8       33.1       32.7       32.7
  V( I )            12.26      12.50      12.40      12.55      12.55
  D( I )            10.60      10.60      10.60      10.60      10.60

X STA.      2648.1     2651.2     2654.2     2657.3     2660.5     2663.6
  A( I )             32.4       32.4       32.8       33.2       33.4
  V( I )            12.64      12.64      12.50      12.33      12.29
  D( I )            10.60      10.60      10.60      10.60      10.60

X STA.      2663.6     2666.8     2670.1     2673.6     2678.6     2699.4
  A( I )             34.1       34.6       36.3       43.3       69.9
  V( I )            12.02      11.86      11.29       9.46       5.86
  D( I )            10.60      10.60      10.43       8.67       3.36

      ************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
      *-------------------------------------------------------------*
             U.S. 431 OVER LICK CREEK      (I465)431-49-4445
            COUNTY: MARION                 QUAD: MAYWOOD  124A
              7-29-97                        JOHN T. WILSON

   ***     Beginning Velocity Distribution For Header Record BRDGE     ***
           SRD Location:     140.000        Header Record Number  3

        Water Surface Elevation:     718.100              Element # 1
        Flow:    11400.000   Velocity: 10.30  Hydraulic Depth:    8.174
        Cross-Section Area:    1106.38         Conveyance:    356195.70
           Bank Stations ->  Left:    2569.311   Right:    2704.672

X STA.      2569.3     2611.8     2618.9     2623.5     2627.1     2630.6
  A( I )            149.6       63.3       53.9       46.7       46.1
  V( I )             3.81       9.01      10.58      12.20      12.36
  D( I )             3.52       8.88      11.74      13.08      13.10

X STA.      2630.6     2634.0     2637.4     2640.8     2644.2     2647.6
  A( I )             45.1       44.3       44.6       44.1       44.1
  V( I )            12.63      12.88      12.78      12.93      12.93
  D( I )            13.10      13.10      13.10      13.10      13.10
```

WSPRO OUTPUT

```
X STA.      2647.6     2650.9     2654.3     2657.7     2661.0     2664.4
  A( I )             44.0       44.0       44.5       44.1       43.9
  V( I )            12.96      12.97      12.81      12.91      12.98
  D( I )            13.10      13.10      13.10      13.10      13.10

X STA.      2664.4     2667.9     2671.4     2675.6     2681.2     2704.7
  A( I )             45.8       46.4       51.4       57.0      103.6
  V( I )            12.46      12.28      11.08      10.01       5.50
  D( I )            13.10      13.10      12.37      10.07       4.42

     ************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
     *-------------------------------------------------------------*
            U.S. 431 OVER LICK CREEK      (I465)431-49-4445
           COUNTY: MARION                QUAD: MAYWOOD  124A
             7-29-97                       JOHN T. WILSON

  ***  Live-Bed Contraction Scour Calculations for Header Record BRDGE  ***

                        Constants and Input Variables

              *-----------------------------------------------*
               Bed Material Transport Mode Factor (k1):    .64
               Total Pier Width Value             (Pw):  4.000
              *-----------------------------------------------*

     Scour      -- Flow --          -- Width --         --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1  -1.625  8200.000  8091.780  117.000   84.000  Left:  2578.000 2606.000
    ..... Approach Channel Depth:    8.936 .....  Right: 2699.000 2690.000
*  Negative Scour Depth Encountered - Check If Variables Are Reasonable  *

 2  -1.806 11400.000 10973.390  117.000   84.000  Left:  2578.000 2606.000
    ..... Approach Channel Depth:   10.983 .....  Right: 2699.000 2690.000
*  Negative Scour Depth Encountered - Check If Variables Are Reasonable  *
--   ------ --------- --------- -------- --------  ------ -------- --------

     ************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
     *-------------------------------------------------------------*
            U.S. 431 OVER LICK CREEK      (I465)431-49-4445
           COUNTY: MARION                QUAD: MAYWOOD  124A
             7-29-97                       JOHN T. WILSON

      ***  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    ---- Localized Hydraulic Properties ----      -- X-Stations --
 #   Depth     Flow      WSE     Depth  Velocity Froude #   Left      Right
--   ----- ---------- -------- ------ -------- -------- --------- ---------
 1    6.70   8200.000  715.582 10.582  12.631     .684   2565.000  2740.000
 2    6.98  11400.000  718.081 13.081  13.017     .634   2565.000  2740.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
*-------------------------------------------------------------*
        U.S. 431 OVER LICK CREEK      (I465)431-49-4445
       COUNTY: MARION                QUAD: MAYWOOD  124A
         7-29-97                       JOHN T. WILSON

    ***  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    6.70   8200.000  715.582 10.582  12.631     .684   2565.000  2740.000
 2    6.98  11400.000  718.081 13.081  13.017     .634   2565.000  2740.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------

  ER

  ******************  Normal end of WSPRO execution.  *****************
  **************  Elapsed Time:   0 Minutes 56 Seconds  **************
```