Modified Level II Streambed-Scour Analysis for Structure I-465-139-5260 Crossing Fishback Creek in Boone County, Indiana

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

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Tables

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
square foot (ft²)	929.0	square centimeter
feet per second (ft/s)	0.3048	meters per second
cubic foot per second (ft³/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi²)	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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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-465-139-5260 on Interstate 465 crossing Fishback Creek in Boone County, Indiana, are presented. The site is near the town of Zionsville in the southeastern part of Boone County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 13.5 feet for the modeled discharge of 5,600 cubic feet per second and approximately 16.9 feet for the modeled discharge of 7,600 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-465-139-5260.

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 Zionsville in the southeastern part of Boone County. The drainage area for the site is approximately 15.2 mi^2 (Merril Dougherty, Indiana Department of Transportation, written commun., 1997). The predominant land use in the basin is rural; in the immediate vicinity of the bridge, the land is predominantly forest with some pasture land nearby.

Within the immediate vicinity of the bridge, Fishback Creek has a channel-bed slope of approximately 0.0019 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 June 20, 1991, the banks were observed to have 0 to 10 percent woody vegetative cover; and the field report noted that the banks were stable downstream from the bridge and experiencing fluvial erosion upstream from the bridge.

The Interstate 465 crossing of Fishback Creek is a 119-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, 1964) 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-465-139-5260 crossing Fishback Creek in Boone County, Indiana

Pier number[1]	Stationing from bridge plans[2]	Initial bed-elevation at pier (feet)	Main-channel contrac-tion 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 5,600 cubic feet per second							
1	169+56	860	5.7	7.8	13.5	852.3	845.4
2	170+06	860	5.7	7.8	13.5	852.6	845.4
Modeled discharge is 7,600 cubic feet per second							
1	169+56	860	8.4	8.5	16.9	852.3	842.0
2	170+06	860	8.4	8.5	16.9	852.6	842.0

[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, 169+56, represents a point 16,956 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 (858.9 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, 1964, Bridge plans Interstate Route 465: Bridge File I-465-139-5260.

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-465 OVER FISHBACK CREEK    I465-139-5260
T2          COUNTY: BOONE                QUAD: ZIONSVILLE 110B
T3          7-25-97                      JOHN T. WILSON
Q           5600    7600
SK          .0019   .0019
XS    EXIT  0
*           ***CHANNEL HAS BEEN STRAIGHTENED/MOVED--DOES NOT MATCH TOPO***
GR          16705 873   16787 872   16828 871   16935 870   16954 860   16980 859.1
GR          17005 860   17013 864   17116 863   17209 864   17319 865   17328 866
GR          17340 867   17358 868   17372 869   17390 870   17412 874
N           .100        .034        .100
SA              16935       17013
XS    FULLV 117
BR    BRDGE 117   875.0   5
*           ***BRIDGE DECK AND PIERS SKEWED 5 DEGREES***
GR          16922 875.4   16923 874.8   16926 874.8   16956 859.8   16980 858.9
GR          17006 859.9   17036 875.8   17039 875.8   17039 876.1   16922 875.4
N           .034
PD          860.0    1.5    1
PD          860.3    1.5    2
PD          860.3    3.0    3
CD          3    134    2    877
DC 0  BRDGE 16940   17021   16931   17022   *   3
*           ***APPROX. LEW & REW OF Q1 USED FOR DC LIMITS***
*           BXL      BXR     PW    *   *  K1   K2   K3
DP          16922    17039   1.5   *   *  1    1.5  1.1
DP          16922    17039   1.5   *   *  1    1.5  1.1
*           ***DP CARDS USE WHOLE BRIDGE OPENING FOR BXL/BXR***
XS    APPR  368
GR          16871 875   16892 874   16925 873   16955 860   16981 859.1
GR          17006 860   17023 871   17042 870   17062 869   17082 868
GR          17101 867   17117 866   17151 865   17186 864   17342 864
GR          17359 863   17381 863   17400 874
N           .100        .034        .100
SA              16958       17041
HP 2  BRDGE 868.4   *   868.4   5600
HP 2  BRDGE 869.5   *   869.5   7600
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  8:37 am      Version V050196
           Input File: FISHBK.DAT     Output File: FISHBK.LST
      *--------------------------------------------------------------*
T1          I-465 OVER FISHBACK CREEK    I465-139-5260
T2          COUNTY: BOONE                QUAD: ZIONSVILLE 110B
T3          7-25-97                      JOHN T. WILSON
Q           5600    7600


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


SK          .0019   .0019


       *********************** 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-465 OVER FISHBACK CREEK    I465-139-5260
        COUNTY: BOONE                QUAD: ZIONSVILLE 110B
         7-25-97                      JOHN T. WILSON


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


   XS    EXIT  0
   GR        16705 873  16787 872  16828 871  16935 870  16954 860  16980
859.1
   GR        17005 860  17013 864  17116 863  17209 864  17319 865  17328 866
   GR        17340 867  17358 868  17372 869  17390 870  17412 874
   N         .100       .034       .100
   SA              16935      17013


   ***   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 (17 pairs)

X	Y	X	Y	X	Y
16705.000	873.000	16787.000	872.000	16828.000	871.000
16935.000	870.000	16954.000	860.000	16980.000	859.100
17005.000	860.000	17013.000	864.000	17116.000	863.000
17209.000	864.000	17319.000	865.000	17328.000	866.000
17340.000	867.000	17358.000	868.000	17372.000	869.000
17390.000	870.000	17412.000	874.000		

WSPRO OUTPUT

```
                    Minimum and Maximum X,Y-coordinates
     Minimum X-Station:   16705.000  ( associated Y-Elevation:   873.000 )
     Maximum X-Station:   17412.000  ( associated Y-Elevation:   874.000 )
     Minimum Y-Elevation:   859.100  ( associated X-Station:  16980.000 )
     Maximum Y-Elevation:   874.000  ( associated X-Station:  17412.000 )


                    Roughness Data (  3 SubAreas )
                            Roughness    Horizontal
                 SubArea   Coefficient   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-465 OVER FISHBACK CREEK    I465-139-5260
        COUNTY: BOONE                 QUAD: ZIONSVILLE 110B
           7-25-97                       JOHN T. WILSON


           *-----------------------------------------------------------*
           *      Starting To Process Header Record FULLV      *
           *-----------------------------------------------------------*
XS    FULLV  117
```

```
***   Completed Reading Data Associated With Header Record FULLV   ***
***    No Roughness Data Input, Propagating From Previous Section   ***
***   Storing X-Section Data In Temporary File As Record Number  2  ***


***             Data Summary For Header Record FULLV             ***
SRD Location:       117.   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 (17 pairs)
         X           Y           X           Y           X           Y
     ----------  ----------  ----------  ----------  ----------  ----------
     16705.000    873.000    16787.000    872.000    16828.000    871.000
     16935.000    870.000    16954.000    860.000    16980.000    859.100
     17005.000    860.000    17013.000    864.000    17116.000    863.000
     17209.000    864.000    17319.000    865.000    17328.000    866.000
     17340.000    867.000    17358.000    868.000    17372.000    869.000
     17390.000    870.000    17412.000    874.000
     ----------  ----------  ----------  ----------  ----------  ----------
```

WSPRO OUTPUT

Minimum and Maximum X,Y-coordinates
```
    Minimum X-Station:    16705.000   ( associated Y-Elevation:   873.000 )
    Maximum X-Station:    17412.000   ( associated Y-Elevation:   874.000 )
    Minimum Y-Elevation:    859.100   ( associated X-Station:  16980.000 )
    Maximum Y-Elevation:    874.000   ( associated X-Station:  17412.000 )
```

```
                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-465 OVER FISHBACK CREEK    I465-139-5260
        COUNTY: BOONE                  QUAD: ZIONSVILLE 110B
            7-25-97                       JOHN T. WILSON
```

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

```
BR    BRDGE  117    875.0   5
GR        16922 875.4  16923 874.8  16926 874.8  16956 859.8  16980 858.9
GR        17006 859.9  17036 875.8  17039 875.8  17039 876.1  16922 875.4
N         .034
PD        860.0     1.5    1
PD        860.3     1.5    2
PD        860.3     3.0    3
CD        3     134    2    877
```

```
    ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 9 increased to eliminate vertical segment.
    ***   Storing Bridge Data In Temporary File As Record Number  3   ***
```

```
    ***             Data Summary For Bridge Record BRDGE             ***
    SRD Location:       117.  Cross-Section Skew:   5.0   Error Code   0
    Valley Slope: ******    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
16922.000	875.400	16923.000	874.800	16926.000	874.800
16956.000	859.800	16980.000	858.900	17006.000	859.900
17036.000	875.800	17039.000	875.800	17039.100	876.100
16922.000	875.400				

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 16922.000 (associated Y-Elevation: 875.400)
Maximum X-Station: 17039.100 (associated Y-Elevation: 876.100)
Minimum Y-Elevation: 858.900 (associated X-Station: 16980.000)
Maximum Y-Elevation: 876.100 (associated X-Station: 17039.100)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
16922.000	16922.220	16923.000	16923.220	16926.000	16926.210
16956.000	16956.090	16980.000	16980.000	17006.000	17005.900
17036.000	17035.790	17039.000	17038.780	17039.100	17038.880
16922.000	16922.220				

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.034	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	134.000	2.00	877.000	*********

Pressure flow elevations

AVBCEL	PFElev
********	875.000

Abutment Parameters

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

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

Group	Elevation	Gross Width	Number
1	860.000	1.500	1
2	860.300	1.500	2
3	860.300	3.000	3

WSPRO OUTPUT

```
*---------------------------------------------------------*
*        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-465 OVER FISHBACK CREEK    I465-139-5260
         COUNTY: BOONE                QUAD: ZIONSVILLE 110B
              7-25-97                      JOHN T. WILSON
DC 0 BRDGE  16940  17021  16931  17022  *  3
DP          16922  17039   1.5  *  *  1   1.5  1.1
DP          16922  17039   1.5  *  *  1   1.5  1.1


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


XS   APPR   368
GR         16871 875  16892 874  16925 873  16955 860  16981 859.1
GR         17006 860  17023 871  17042 870  17062 869  17082 868
GR         17101 867  17117 866  17151 865  17186 864  17342 864
GR         17359 863  17381 863  17400 874
N          .100        .034        .100
SA              16958       17041
```

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

                    X,Y-coordinates (18 pairs)

X	Y	X	Y	X	Y
16871.000	875.000	16892.000	874.000	16925.000	873.000
16955.000	860.000	16981.000	859.100	17006.000	860.000
17023.000	871.000	17042.000	870.000	17062.000	869.000
17082.000	868.000	17101.000	867.000	17117.000	866.000
17151.000	865.000	17186.000	864.000	17342.000	864.000
17359.000	863.000	17381.000	863.000	17400.000	874.000

                Minimum and Maximum X,Y-coordinates
        Minimum X-Station: 16871.000 (associated Y-Elevation: 875.000)
        Maximum X-Station: 17400.000 (associated Y-Elevation: 874.000)
        Minimum Y-Elevation: 859.100 (associated X-Station: 16981.000)
        Maximum Y-Elevation: 875.000 (associated X-Station: 16871.000)

WSPRO OUTPUT

```
                  Roughness Data (  3 SubAreas )
                         Roughness   Horizontal
                 SubArea Coefficient Breakpoint
                 ------- ----------- ----------

                    1        .100       ---
                             ---      *******
                    2        .034       ---
                             ---      *******
                    3        .100       ---
                 ------- ----------- ----------
```

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

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

```
    ************************** W S P R O **************************
        Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: English  /  Output Units: English
        *-------------------------------------------------------*
              I-465 OVER FISHBACK CREEK    I465-139-5260
            COUNTY: BOONE                QUAD: ZIONSVILLE 110B
                 7-25-97                      JOHN T. WILSON
HP 2 BRDGE   868.4  *   868.4   5600
HP 2 BRDGE   869.5  *   869.5   7600
EX
```

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

#	Reach Discharge	Water Surface Elevation	Friction Slope	Flow Regime
1	5600.00	*******	.0019	Sub-Critical
2	7600.00	*******	.0019	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-465 OVER FISHBACK CREEK    I465-139-5260
            COUNTY: BOONE                QUAD: ZIONSVILLE 110B
                 7-25-97                      JOHN T. WILSON
```

WSPRO OUTPUT

| | WSEL | VHD | Q | AREA | SRDL | LEW |
| | EGEL | HF | V | K | FLEN | REW |
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: EXIT	867.846	.494	5600.000	1792.128	********	16939.090
Header Type: XS	868.341	******	3.125	128372.80	********	17355.240
SRD: .000	866.003	******	.479	******	3.254	******
Section: FULLV	868.107	.437	5600.000	1901.127	117.000	16938.600
Header Type: FV	868.543	.207	2.946	138111.20	117.000	17359.500
SRD: 117.000	866.003	.000	.440	.0018	3.236	-.004

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

| | WSEL | VHD | Q | AREA | SRDL | LEW |
| | EGEL | HF | V | K | FLEN | REW |
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	868.501	.520	5600.000	1825.511	251.000	16935.380
Header Type: AS	869.021	.433	3.068	131752.30	251.000	17390.500
SRD: 368.000	866.407	.042	.479	.0017	3.555	.003

<<< 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	867.646	1.867	5600.000	531.661	117.000	16940.310
Header Type: BR	869.513	.376	10.533	79432.45	117.000	17020.620
SRD: 117.000	866.364	.796	.751	******	1.082	-.001

| Specific Bridge Information | C | P/A | PFELEV | BLEN | XLAB | XRAB |
Bridge Type 3 Flow Type 1	---	---	---	---	---	---
Pier/Pile Code 0	.9614	.042	875.000	********	********	********

| | WSEL | VHD | Q | AREA | SRDL | LEW |
| | EGEL | HF | V | K | FLEN | REW |
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	870.402	.222	5600.000	2636.736	117.000	16930.990
Header Type: AS	870.624	.315	2.124	199547.50	152.405	17393.790
SRD: 368.000	866.407	.798	.275	.0017	3.158	.009

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.820	.411	117386.9	********	********	870.402

<<< End of Bridge Hydraulics Computations >>>

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-465 OVER FISHBACK CREEK   I465-139-5260
        COUNTY: BOONE              QUAD: ZIONSVILLE 110B
        7-25-97                      JOHN T. WILSON
```

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: EXIT	868.999	.544	7600.000	2282.987	********	16936.900
Header Type: XS	869.543	******	3.329	174274.30	********	17371.990
SRD: .000	866.718	******	.455	******	3.155	******
Section: FULLV	869.267	.489	7600.000	2400.142	117.000	16936.390
Header Type: FV	869.756	.209	3.166	185760.90	117.000	17376.800
SRD: 117.000	866.718	.000	.424	.0018	3.138	.004

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

	WSEL	VHD	Q	AREA	SRDL	LEW
Section: APPR	869.675	.586	7600.000	2315.698	251.000	16932.670
Header Type: AS	870.261	.446	3.282	175125.30	251.000	17392.530
SRD: 368.000	867.212	.048	.467	.0018	3.496	.011

```
     <<< 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	868.556	2.869	7600.000	606.334	117.000	16938.490
Header Type: BR	871.425	.422	12.534	95884.66	117.000	17022.330
SRD: 117.000	867.790	1.459	.890	******	1.174	-.001

Specific Bridge Information		C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3	Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0		.9228	.042	875.000	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	872.539	.181	7600.000	3631.088	117.000	16926.060
Header Type: AS	872.720	.320	2.093	306744.60	155.751	17397.480
SRD: 368.000	867.212	.977	.217	.0018	2.660	.008

WSPRO OUTPUT

Approach Section APPR Flow Contraction Information
```
  M( G )    M( K )      KQ        XLKQ      XRKQ      OTEL
-------- -------- ---------- -------- -------- --------

    .812     .507  151002.1 ******** ********  872.539

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

                    <<< 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-465 OVER FISHBACK CREEK   I465-139-5260
          COUNTY: BOONE                QUAD: ZIONSVILLE 110B
             7-25-97                     JOHN T. WILSON
```

       ***   Beginning Velocity Distribution For Header Record BRDGE   ***
           SRD Location: 117.000   Header Record Number 3

       Water Surface Elevation: 868.400   Element # 1
       Flow: 5600.000 Velocity: 9.44 Hydraulic Depth: 7.128
       Cross-Section Area: 593.32   Conveyance: 92959.04
           Bank Stations -> Left: 16938.800 Right: 17022.040

X STA.	16938.8	16953.0	16957.2	16960.7	16963.8	16966.8
A(I)		50.5	34.0	30.2	27.5	27.1
V(I)		5.54	8.24	9.26	10.17	10.35
D(I)		3.55	8.08	8.71	8.83	8.95

X STA.	16966.8	16969.7	16972.5	16975.3	16978.0	16980.6
A(I)		26.4	25.7	25.7	24.8	25.1
V(I)		10.62	10.88	10.88	11.27	11.17
D(I)		9.06	9.17	9.27	9.37	9.47

X STA.	16980.6	16983.3	16986.0	16988.8	16991.6	16994.5
A(I)		25.1	24.9	25.8	25.7	26.4
V(I)		11.14	11.26	10.86	10.88	10.62
D(I)		9.42	9.32	9.22	9.11	9.00

X STA.	16994.5	16997.6	17000.8	17004.2	17008.3	17022.0
A(I)		27.0	28.3	29.4	33.6	50.1
V(I)		10.36	9.91	9.52	8.34	5.59
D(I)		8.88	8.76	8.64	8.18	3.64

WSPRO OUTPUT

```
***     Beginning Velocity Distribution For Header Record BRDGE     ***
        SRD Location:     117.000     Header Record Number  3

        Water Surface Elevation:     869.500              Element # 1
        Flow:     7600.000   Velocity: 11.06  Hydraulic Depth:   7.853
        Cross-Section Area:     687.24        Conveyance:   114590.50
             Bank Stations -> Left: 16936.600   Right:  17024.110
```

X STA.	16936.6	16952.1	16956.5	16960.1	16963.3	16966.4
A(I)		59.8	39.4	35.0	31.8	31.2
V(I)		6.35	9.64	10.86	11.97	12.17
D(I)		3.87	8.84	9.79	9.91	10.03

X STA.	16966.4	16969.4	16972.3	16975.2	16977.9	16980.6
A(I)		30.4	29.6	29.6	28.6	28.8
V(I)		12.51	12.82	12.84	13.30	13.19
D(I)		10.15	10.26	10.36	10.47	10.57

X STA.	16980.6	16983.3	16986.2	16989.0	16991.9	16994.9
A(I)		28.7	29.3	28.9	29.6	30.4
V(I)		13.22	12.96	13.14	12.84	12.52
D(I)		10.52	10.42	10.31	10.20	10.09

X STA.	16994.9	16998.0	17001.3	17004.8	17009.2	17024.1
A(I)		31.1	32.6	34.0	39.1	59.3
V(I)		12.21	11.64	11.18	9.71	6.41
D(I)		9.97	9.84	9.71	9.00	3.96

```
************************* 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-465 OVER FISHBACK CREEK   I465-139-5260
        COUNTY: BOONE                    QUAD: ZIONSVILLE 110B
              7-25-97                       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):  3.000
              *-------------------------------------------------*
```

#	Scour Depth	-- Flow -- Contract	Approach	-- Width -- Contract	Approach	Side	--- X-Limits --- Contract	Approach
1	5.684	5600.000	3420.910	78.000	91.000	Left:	*******	*******
	..... Approach Channel Depth:	8.373	.....			Right:	*******	*******
2	8.361	7600.000	4290.179	78.000	91.000	Left:	*******	*******
	..... Approach Channel Depth:	10.510	.....			Right:	*******	*******

WSPRO OUTPUT

```
     Scour   ---- Localized Hydraulic Properties ----   -- X-Stations --
  #  Depth     Flow      WSE    Depth  Velocity Froude #    Left        Right
  -- -----  ----------  --------  ------  --------  --------  ---------- ----------
  1   7.81   5600.000   868.444   9.544   11.234      .641   16922.000  17039.000
  2   8.51   7600.000   869.533  10.633   13.233      .715   16922.000  17039.000
  -- -----  ----------  --------  ------  --------  --------  ---------- ----------
```

```
************************  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-465 OVER FISHBACK CREEK    I465-139-5260
     COUNTY: BOONE                 QUAD: ZIONSVILLE 110B
        7-25-97                        JOHN T. WILSON


     ***  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):    1.50
            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	---- Localized Hydraulic Properties ----					-- X-Stations --	
		Flow	WSE	Depth	Velocity	Froude #	Left	Right
--	-----	----------	--------	------	--------	--------	---------	---------
1	7.81	5600.000	868.444	9.544	11.234	.641	16922.000	17039.000
2	8.51	7600.000	869.533	10.633	13.233	.715	16922.000	17039.000
--	-----	----------	--------	------	--------	--------	---------	---------

ER

****************** Normal end of WSPRO execution. *****************
*************** Elapsed Time: 0 Minutes 50 Seconds **************