Modified Level II Streambed-Scour Analysis for Structure I-74-4-4415DRA Crossing Spring Creek in Vermillion County, Indiana

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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 (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-74-4-4415DRA, the southwest ramp crossing Spring Creek at the intersection of Interstate 74 and State Road 63 in Vermillion County, Indiana, are presented. The site is in northern Vermillion County near the town of Foster, which is in southern Warren 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 8.8 feet for the modeled discharge of 4,500 cubic feet per second and approximately 9.8 feet for the modeled discharge of 6,600 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-74-4-4415DRA.

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 in northern Vermillion County near the town of Foster, which is just across the county line in southern Warren County. The drainage area for the site is approximately 22.6 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.

Within the immediate vicinity of the bridge, Spring Creek has a channel-bed slope of approximately 0.0026 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 11, 1991, the banks were observed to have 10 to 90 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 74 ramp crossing of Spring Creek is a 112-ft-long, two-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, 1979) 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-74-4-4415DRA crossing Spring Creek in Vermillion 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 4,500 cubic feet per second							
1	11+78	544	0	8.8	8.8	536.0	534.0
2	12+22	544	0	8.8	8.8	536.0	534.0
Modeled discharge is 6,600 cubic feet per second							
1	11+78	544	0.1	9.7	9.8	536.0	533.0
2	12+22	544	0.1	9.7	9.8	536.0	533.0

[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, 11+78, represents a point 1,178 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 (542.8 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.

Based on the bridge plans (Indiana State Highway Commission, 1979) and the field report from the Level I assessment, the piers appear to be protected by the riprap cover of the slopewall. The upstream side of pier 1 is protected by a concrete guidewall. The bridge was modeled and scour was computed as if these protective measures did not exist.

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, 1979, Bridge plans Interstate Route 74: Bridge File I-74-4-4415DRA.

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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
T2         COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
T3         7-30-97                       JOHN T. WILSON
Q          4500    6600
SK         .0026   .0026
XS    EXIT  0
GR        1043 570  1053 560  1145 550  1159 542.8  1190 542.8  1204 550
GR        1310 560
N         .100      .040      .100
SA             1145      1204
XS    FULLV  126
BR    BRDGE  126  560.0   20
*         ***BRIDGE DECK IS SKEWED 20 DEGREES (FROM BRIDGE PLANS)***
*         ***BASE OF PIERS ARE SET IN RIPRAP SLOPEWALLS***
*         ***PIER 1 IS PROTECTED BY CONCRETE GUIDE WALL***
GR        1138 560.0  1182 542.8  1219 542.8
GR        1264 561.5  1138 560.0
N         .038
PD        544.0    1.5    1
PD        544.0    1.5    2
PD        544.4    3.0    3
CD        3    40    2    558
DC 0 BRDGE  1153   1247   1206   1265    *  3
*         ***DC LIMITS AT BRIDGE ARE APPROX. LEW AND REW FOR Q1***
*          BXL       BXR       PW    *  *  K1   K2   K3
DP         1138.0    1264.0    1.5   *  *  1    2.0  1.1
DP         1138.0    1264.0    1.5   *  *  1    2.0  1.1
*          ***DP CARDS USE THE WHOLE BRIDGE OPENING FOR BXL/BXR***
XS    APPR   292
GR        1137 570  1151 560  1206 550  1219 542.8  1251 542.8  1265 550
GR        1394 550  1458 565
N         .100      .040      .100
SA             1206      1265
HP 2 BRDGE  554.4  *  554.4   4500
HP 2 BRDGE  556.4  *  556.4   6600
EX
ER
```

WSPRO OUTPUT

```
  *************************  W S P R O  **************************
     Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
        Run Date & Time:  8/ 6/97 11:29 am     Version V050196
          Input File: spring.dat     Output File: spring.LST
  *-------------------------------------------------------------*
T1          I-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
T2          COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
T3          7-30-97                       JOHN T. WILSON
Q           4500    6600

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

SK          .0026   .0026

  *************************  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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
        COUNTY: VERMILLION             QUAD: PERRYSVILLE  93C
            7-30-97                         JOHN T. WILSON

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

XS   EXIT  0
GR         1043 570  1053 560  1145 550  1159 542.8  1190 542.8  1204 550
GR         1310 560
N          .100       .040      .100
SA              1145      1204

 ***   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 ( 7 pairs)
     X           Y            X           Y            X           Y
----------  ----------   ----------  ----------   ----------  ----------
  1043.000     570.000     1053.000     560.000     1145.000     550.000
  1159.000     542.800     1190.000     542.800     1204.000     550.000
  1310.000     560.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                     Minimum and Maximum X,Y-coordinates
  Minimum X-Station:     1043.000  ( associated Y-Elevation:   570.000 )
  Maximum X-Station:     1310.000  ( associated Y-Elevation:   560.000 )
  Minimum Y-Elevation:    542.800  ( associated X-Station:    1190.000 )
  Maximum Y-Elevation:    570.000  ( associated X-Station:    1043.000 )

                        Roughness Data (  3 SubAreas )
                                Roughness   Horizontal
                      SubArea  Coefficient  Breakpoint
                      -------  -----------  ----------
                         1         .100        ---
                                   ---       1145.000
                         2         .040        ---
                                   ---       1204.000
                         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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
           COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
               7-30-97                        JOHN T. WILSON

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

XS    FULLV  126

 ***    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:       126.   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 ( 7 pairs)
     X           Y            X           Y            X           Y
 ----------  ----------  ----------  ----------  ----------  ----------
   1043.000    570.000     1053.000    560.000     1145.000    550.000
   1159.000    542.800     1190.000    542.800     1204.000    550.000
   1310.000    560.000
 ----------  ----------  ----------  ----------  ----------  ----------
```

WSPRO OUTPUT

```
                    Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    1043.000  ( associated Y-Elevation:  570.000 )
  Maximum X-Station:    1310.000  ( associated Y-Elevation:  560.000 )
  Minimum Y-Elevation:   542.800  ( associated X-Station:   1190.000 )
  Maximum Y-Elevation:   570.000  ( associated X-Station:   1043.000 )

                      Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                    SubArea  Coefficient  Breakpoint
                    -------  -----------  ----------
                       1         .100        ---
                                 ---       1145.000
                       2         .040        ---
                                 ---       1204.000
                       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-74 RAMP OVER SPRING CREEK    I74-4-4415DRA
       COUNTY: VERMILLION              QUAD: PERRYSVILLE  93C
           7-30-97                        JOHN T. WILSON

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

BR   BRDGE  126   560.0   20
GR        1138 560.0  1182 542.8  1219 542.8
GR        1264 561.5  1138 560.0
N         .038
PD        544.0    1.5    1
PD        544.0    1.5    2
PD        544.4    3.0    3
CD        3    40    2    558

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

WSPRO OUTPUT

X,Y-coordinates (5 pairs)

X	Y	X	Y	X	Y
1138.000	560.000	1182.000	542.800	1219.000	542.800
1264.000	561.500	1138.000	560.000		

Minimum and Maximum X,Y-coordinates

```
Minimum X-Station:     1138.000  ( associated Y-Elevation:  560.000 )
Maximum X-Station:     1264.000  ( associated Y-Elevation:  561.500 )
Minimum Y-Elevation:    542.800  ( associated X-Station:   1219.000 )
Maximum Y-Elevation:    561.500  ( associated X-Station:   1264.000 )
```

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
1138.000	1142.885	1182.000	1184.231	1219.000	1219.000
1264.000	1261.286	1138.000	1142.885		

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.038	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	40.000	2.00	558.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	560.000

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	544.000	1.500	1
2	544.000	1.500	2
3	544.400	3.000	3

```
*---------------------------------------------------*
*      Finished Processing Header Record BRDGE      *
*---------------------------------------------------*
```

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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
      COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
          7-30-97                       JOHN T. WILSON
DC 0 BRDGE  1153   1247   1206   1265   *  3
DP          1138.0   1264.0   1.5  *  *  1   2.0  1.1
DP          1138.0   1264.0   1.5  *  *  1   2.0  1.1

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

XS   APPR   292
GR        1137 570  1151 560  1206 550  1219 542.8  1251 542.8  1265 550
GR        1394 550  1458 565
N         .100      .040      .100
SA             1206      1265

 ***   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:      292.   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 ( 8 pairs)
     X           Y             X           Y             X           Y
----------  ----------   ----------  ----------   ----------  ----------
  1137.000     570.000     1151.000     560.000     1206.000     550.000
  1219.000     542.800     1251.000     542.800     1265.000     550.000
  1394.000     550.000     1458.000     565.000
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    1137.000   ( associated Y-Elevation:  570.000 )
  Maximum X-Station:    1458.000   ( associated Y-Elevation:  565.000 )
  Minimum Y-Elevation:   542.800   ( associated X-Station:   1251.000 )
  Maximum Y-Elevation:   570.000   ( associated X-Station:   1137.000 )

                    Roughness Data (  3 SubAreas )
                          Roughness    Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .100        ---
                               ---       1206.000
                     2         .040        ---
                               ---       1265.000
                     3         .100        ---
                  -------  -----------  ----------
```

WSPRO OUTPUT

```
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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
          COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
              7-30-97                       JOHN T. WILSON
  HP 2 BRDGE  554.4  *  554.4   4500
  HP 2 BRDGE  556.4  *  556.4   6600
  EX

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

          Reach       Water Surface    Friction
   #    Discharge      Elevation        Slope          Flow Regime
   --   ---------    ------------    --------    -------------------
   1     4500.00       ********        .0026         Sub-Critical
   2     6600.00       ********        .0026         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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
          COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
              7-30-97                       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      553.706   .963   4500.000    678.665 *********  1110.902
Header Type: XS    554.670 ******      6.631   88218.39 *********  1243.287
SRD:       .000    550.168 ******       .613     ******     1.409    ******

Section: FULLV     554.112   .864   4500.000    733.942   126.000  1107.174
Header Type: FV    554.975   .303      6.131   95533.58   126.000  1247.583
SRD:    126.000    550.168   .000       .575      .0024     1.477      .003

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

Section: APPR      554.829   .409   4500.000   1349.381   166.000  1179.439
Header Type: AS    555.238   .265      3.335  132959.70   166.000  1414.605
SRD:    292.000    550.722   .000       .377      .0016     2.364     -.002

      <<< 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     554.272   .661   4500.000    751.118   126.000  1152.654
Header Type: BR    554.932   .266      5.991  113871.00   126.000  1246.606
SRD:    126.000    549.586   .000       .406     ******     1.184      .017

Specific Bridge Information   C     P/A   PFELEV    BLEN     XLAB     XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0            .9192  .041  560.000 ******** ******** ********
---------------------------- ------ ----- -------- -------- -------- --------

                    WSEL     VHD        Q        AREA       SRDL      LEW
                    EGEL     HF         V         K         FLEN      REW
                    CRWS     HO       FR #        SF        ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: APPR      554.825   .410   4500.000   1348.319   126.000  1179.464
Header Type: AS    555.234   .218      3.337  132837.10   156.209  1414.585
SRD:    292.000    550.722   .079       .378      .0016     2.364     -.015

           Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
              .604     .171  110492.2 1193.381 1287.249  554.825
          -------- -------- --------- -------- -------- --------

             <<< 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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
      COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
          7-30-97                        JOHN T. WILSON

                          WSEL     VHD        Q          AREA       SRDL       LEW
                          EGEL      HF        V            K        FLEN       REW
                          CRWS      HO      FR #          SF        ALPHA      ERR
                       --------- ------ ---------- ---------- --------- ---------
Section: EXIT            555.777  1.209   6600.000    995.248 *********  1091.851
Header Type: XS          556.986 ******      6.632  129407.80 *********  1265.237
SRD:          .000       552.024 ******       .649     ******     1.768    ******

Section: FULLV           556.197  1.090   6600.000   1069.781   126.000  1087.989
Header Type: FV          557.287   .305      6.169  138960.20   126.000  1269.687
SRD:      126.000        552.024   .000       .608      .0024     1.842     -.004

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:  1.45

Section: APPR            557.082   .462   6600.000   1903.820   166.000  1167.052
Header Type: AS          557.544   .259      3.467  201253.90   166.000  1424.215
SRD:      292.000        552.220   .000       .353      .0016     2.472     -.002

       <<< 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           556.296   .968   6600.000    951.475   126.000  1147.475
Header Type: BR          557.264   .281      6.937  157513.50   126.000  1251.477
SRD:      126.000        551.251   .000       .460     ******     1.294      .014

Specific Bridge Information    C     P/A    PFELEV    BLEN     XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0            .8793  .038  560.000 ******** ******** ********
------------------------- ------ ----- -------- -------- -------- --------
```

WSPRO OUTPUT

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	557.112	.458	6600.000	1911.686	126.000	1166.883
Header Type: AS	557.571	.223	3.452	202276.40	156.998	1424.345
SRD: 292.000	552.220	.080	.351	.0016	2.473	-.006

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.597	.206	160753.7	1190.453	1294.387	557.112

<<< 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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
     COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
        7-30-97                         JOHN T. WILSON
```

*** Beginning Velocity Distribution For Header Record BRDGE ***
SRD Location: 126.000 Header Record Number 3

Water Surface Elevation: 554.400 Element # 1
Flow: 4500.000 Velocity: 5.90 Hydraulic Depth: 8.069
Cross-Section Area: 763.22 Conveyance: 116403.60
Bank Stations -> Left: 1152.326 Right: 1246.915

X STA.	1152.3	1171.0	1176.5	1180.5	1183.5	1186.5
A(I)		68.3	45.8	40.7	35.3	33.9
V(I)		3.30	4.91	5.53	6.38	6.63
D(I)		3.65	8.38	10.22	11.45	11.60

X STA.	1186.5	1189.3	1192.1	1194.8	1197.5	1200.2
A(I)		32.9	32.5	31.4	31.1	31.1
V(I)		6.83	6.92	7.16	7.24	7.24
D(I)		11.60	11.60	11.60	11.60	11.60

X STA.	1200.2	1202.9	1205.6	1208.3	1211.1	1213.9
A(I)		31.3	31.3	31.7	32.1	33.0
V(I)		7.19	7.19	7.11	7.02	6.82
D(I)		11.60	11.60	11.60	11.60	11.60

X STA.	1213.9	1216.8	1219.8	1223.6	1228.8	1246.9
A(I)		33.1	35.5	39.3	45.3	67.9
V(I)		6.81	6.34	5.73	4.97	3.31
D(I)		11.60	11.55	10.48	8.60	3.76

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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
     COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
         7-30-97                        JOHN T. WILSON

  ***   Beginning Velocity Distribution For Header Record BRDGE     ***
        SRD Location:    126.000       Header Record Number  3

     Water Surface Elevation:    556.400            Element # 1
     Flow:    6600.000   Velocity:  6.86  Hydraulic Depth:   9.207
     Cross-Section Area:    962.33       Conveyance:   159975.40
        Bank Stations ->  Left:   1147.209   Right:   1251.727

X STA.       1147.2      1168.3      1174.5      1178.9      1182.4      1185.5
  A( I )                  86.9        58.8        50.8        45.5        42.4
  V( I )                  3.80        5.61        6.50        7.26        7.78
  D( I )                  4.12        9.46       11.53       13.07       13.60

X STA.       1185.5      1188.5      1191.5      1194.4      1197.3      1200.1
  A( I )                  41.2        40.6        39.3        38.8        38.8
  V( I )                  8.02        8.12        8.40        8.50        8.50
  D( I )                 13.60       13.60       13.60       13.60       13.60

X STA.       1200.1      1203.0      1205.9      1208.8      1211.7      1214.7
  A( I )                  39.1        39.1        39.5        39.2        41.9
  V( I )                  8.45        8.45        8.35        8.41        7.87
  D( I )                 13.60       13.60       13.60       13.60       13.60

X STA.       1214.7      1217.8      1221.1      1225.4      1231.4      1251.7
  A( I )                  41.3        44.8        50.2        58.0        86.1
  V( I )                  8.00        7.36        6.58        5.69        3.83
  D( I )                 13.60       13.31       11.83        9.70        4.23
```

```
************************* 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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
     COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
         7-30-97                        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
          *------------------------------------------------*
```

WSPRO OUTPUT

```
      Scour     -- Flow --          -- Width --         --- X-Limits ---
 #    Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1    -.694  4500.000  3523.816   91.000   59.000  Left:  1153.000 1206.000
    ..... Approach Channel Depth:   10.377 .....  Right: 1247.000 1265.000
*  Negative Scour Depth Encountered - Check If Variables Are Reasonable  *

 2     .078  6600.000  4730.451   91.000   59.000  Left:  1153.000 1206.000
    ..... Approach Channel Depth:   12.665 .....  Right: 1247.000 1265.000
--   ------ --------- --------- -------- --------  ------ -------- --------

     *************************  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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA4415DRA
          COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
              7-30-97                        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):   2.00
                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    8.85  4500.000  554.351 11.551    7.236     .375   1138.000   1264.000
 2    9.70  6600.000  556.376 13.576    8.526     .408   1138.000   1264.000
--   ----- --------- -------- ------ -------- --------  ---------  ---------

     *************************  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-74 RAMP OVER SPRING CREEK   I74-4-4415DRA
          COUNTY: VERMILLION            QUAD: PERRYSVILLE  93C
              7-30-97                        JOHN T. WILSON
```

WSPRO OUTPUT

```
***  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):   2.00
           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    8.85    4500.000  554.351 11.551    7.236      .375  1138.000  1264.000
 2    9.70    6600.000  556.376 13.576    8.526      .408  1138.000  1264.000
--   -----  ---------- -------- ------ -------- -------- --------- ---------

ER

  ******************  Normal end of WSPRO execution.  *****************
  ***************  Elapsed Time:   0 Minutes 33 Seconds  **************
```