Modified Level II Streambed-Scour Analysis for Structure I-69-64-4767 Crossing Tippey Ditch in Grant County, Indiana

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

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INDIANA DEPARTMENT OF TRANSPORTATION

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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 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-69-64-4767 on Interstate 69 crossing Tippey Ditch in Grant County, Indiana, are presented. The site is near the town of Van Buren in the northeastern part of Grant 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 11.9 feet for the modeled discharge of 2,000 cubic feet per second and approximately 19.8 feet for the modeled discharge of 3,400 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-69-64-4767.

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 Van Buren in the northeastern part of Grant County. The drainage area for the site is approximately 5.2 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly agricultural.

Within the immediate vicinity of the bridge, Tippey Ditch has a channel-bed slope of approximately 0.00125 ft/ft. The channel-bed material is gravelly sand, and the channel banks consist of sandy gravelly silt-clay. At the time of the Level I site visit on June 16, 1993, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 69 crossing of Tippey Ditch is a 60-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping concrete spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

The methods described in this section apply to a number of bridge sites in Indiana being evaluated for scour and outline the procedures requested by INDOT for these modified Level II scour analyses. The principal modification requested by INDOT was that the input data to the model come from or be estimated from existing data sources; no additional field data were collected. Actual methods used in the scour evaluation at this particular bridge site use the most applicable method possible, given the data available.

To determine drainage area, either published values found in Hoggatt (1975) or 7.5-minute topographic maps with Hoggatt's original drainage-area delineations were used. Where there are no published data, drainage-area segments measured from the maps produced by Hoggatt were either subtracted from downstream sites or added to upstream sites published by Hoggatt (1975).

In Indiana, flood discharges are coordinated by agreement among State and Federal agencies. At sites where flood discharges officially are coordinated among State and Federal agencies in Indiana, the coordinated 100-year discharge (Q100) was modeled. INDOT also provided an additional flood discharge for these coordinated sites in excess of the Q100 to be modeled.

If a flood discharge was not coordinated, the USGS examined Federal Emergency Management Agency (FEMA) studies for Q100 determinations. Where FEMA studies did not produce a Q100, the USGS contacted IDNR for an estimated Q100 in the vicinity of the site being studied. If IDNR did not have a Q100, data from nearby USGS streamflow-gaging stations were analyzed with nearby and similar drainage basins that have been coordinated. At sites having no coordinated discharge data, the two discharges used in the model were 1) the approximated Q100 and 2) a discharge equal to 1.7 times the approximated Q100.

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1962) 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-69-64-4767 crossing Tippey Ditch in Grant County, Indiana

[--, no value]

Pier number[1]	Stationing from bridge plans[2]	Initial bed-elevation at pier (feet)	Main-channel contraction scour depth (feet)	Local scour depth (feet)	Worst-case total-scour depth[3] (feet)	Bottom elevation of pier (feet)	Worst-case bed elevation after scour[4] (feet)
Modeled discharge[5] is 2,000 cubic feet per second							
1	298+34	837	7.1	4.8	11.9	827	819.8
2	298+60	837	7.1	4.8	11.9	827	819.8
Modeled discharge is 3,400 cubic feet per second							
1	298+34	837	14.0	5.8	19.8	827	811.9
2	298+60	837	14.0	5.8	19.8	827	811.9

[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, 298+34, represents a point 29,834 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 (831.7 feet).

[5]Not a coordinated discharge.

SPECIAL CONSIDERATIONS

Model runs indicate the water-surface elevation at the bridge is lower than the low-steel elevation for the modeled discharges. Therefore, there should be no pressure flow through the bridge opening for the discharges modeled.

The piers supporting this bridge are set on the sloping concrete spill-through abutments. Therefore, even though the results shown in table 1 indicate that scour could undermine the piers, scour could only take place after the concrete abutments were removed or by erosion of bed sediment from under the protective abutments.

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, 1962, Bridge plans Interstate Route 69: Bridge File I-69-64-4767.

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-69 Over Tippey Ditch              I69-64-4767
T2        County: Grant                       Quad: Van Buren 74D
T3        11-21-96                            Bret A. Robinson
SI        0
Q         2000 3400
SK        .00125 .00125
XS   EXIT 0 0
GR        29255 850  29767 842  29813 842  29820 840  29830 835  29841 831.5
GR        29851 831.5  29860 841  29926 842  30228 850
N         .035 .034 .035
SA        29815 29860
XS   FULLV 61 0
GR        29255 850  29767 842  29813 842  29820 840  29830 835  29841 831.5
GR        29851 831.5  29860 841  29926 842  30228 850
N         .035 .034 .035
SA        29815 29860
BR   BRDGE 61 844.2 0
GR        29821 0844.1  29846 0831.6  29851 0831.7  29876 0843.9  29821 0844.1
N         .034
PD        837 3 1
CD        3 130 2 843
*          LXBr RXBr * * * TPierW
DC 0 BRDGE 29825 29871 29820 29870 * 3
*         LPierEdge RPierEdge PierWdth * * K1 K2 K3(1.1)
DP        29821 29876 1.5 * * 1 1 1.1
DP        29821 29876 1.5 * * 1 1 1.1
XS   APPR 252 0
GR        29166 850  29309 850  29759 840  29808 841  29822 841  29828 840
GR        29838 835  29841 833  29846 833  29855 835  29867 840  29887 840
GR        29894 840  30453 850
N         .045 .034 .045
SA        29820 29870
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  6:45 am     Version V050196
          Input File: 4767.dat       Output File: 4767.LST
   *-------------------------------------------------------------*
T1        I-69 OVER TIPPEY DITCH              I69-64-4767
T2        COUNTY: GRANT                       QUAD: VAN BUREN 74D
T3        11-21-96                            BRET A. ROBINSON
SI        0
Q         2000 3400

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

SK        .00125 .00125

   ************************  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-69 OVER TIPPEY DITCH            I69-64-4767
       COUNTY: GRANT                     QUAD: VAN BUREN 74D
         11-21-96                          BRET A. ROBINSON

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

XS   EXIT 0 0
GR        29255 850  29767 842  29813 842  29820 840  29830 835  29841
831.5
GR        29851 831.5  29860 841  29926 842  30228 850
N         .035 .034 .035
SA        29815 29860

 ***   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 (10 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 29255.000     850.000    29767.000     842.000    29813.000     842.000
 29820.000     840.000    29830.000     835.000    29841.000     831.500
 29851.000     831.500    29860.000     841.000    29926.000     842.000
 30228.000     850.000
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
```

WSPRO OUTPUT

```
 Minimum X-Station:   29255.000  ( associated Y-Elevation:  850.000 )
 Maximum X-Station:   30228.000  ( associated Y-Elevation:  850.000 )
 Minimum Y-Elevation:   831.500  ( associated X-Station:  29851.000 )
 Maximum Y-Elevation:   850.000  ( associated X-Station:  29255.000 )

                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .035        ---
                                        ********
                   2         .034        ---
                                        ********
                   3         .035        ---
                -------  -----------  ----------

        *-----------------------------------------------------*
        *      Finished Processing Header Record EXIT         *
        *-----------------------------------------------------*

  ************************ W S P R O ***************************
     Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
  *-------------------------------------------------------------*
        I-69 OVER TIPPEY DITCH            I69-64-4767
     COUNTY: GRANT                     QUAD: VAN BUREN 74D
       11-21-96                          BRET A. ROBINSON

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

   XS   FULLV 61 0
   GR        29255 850  29767 842  29813 842  29820 840  29830 835  29841
831.5
   GR        29851 831.5  29860 841  29926 842  30228 850
   N         .035 .034 .035
   SA        29815 29860

    ***   Completed Reading Data Associated With Header Record FULLV   ***
    ***  Storing X-Section Data In Temporary File As Record Number  2  ***

    ***              Data Summary For Header Record FULLV              ***
    SRD Location:       61.   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
   ---------  ---------    ---------  ---------    ---------  ---------
    29255.000     850.000    29767.000     842.000    29813.000     842.000
    29820.000     840.000    29830.000     835.000    29841.000     831.500
    29851.000     831.500    29860.000     841.000    29926.000     842.000
```

WSPRO OUTPUT

```
 30228.000     850.000
---------- ----------  ---------- ----------  ---------- ----------

                Minimum and Maximum X,Y-coordinates
 Minimum X-Station:   29255.000  ( associated Y-Elevation:  850.000 )
 Maximum X-Station:   30228.000  ( associated Y-Elevation:  850.000 )
 Minimum Y-Elevation:   831.500  ( associated X-Station:  29851.000 )
 Maximum Y-Elevation:   850.000  ( associated X-Station:  29255.000 )

                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .035        ---
                              ---        ********
                    2         .034        ---
                              ---        ********
                    3         .035        ---
                 -------  -----------  ----------

        *-----------------------------------------------------*
        *      Finished Processing Header Record FULLV        *
        *-----------------------------------------------------*

   ************************  W S P R O  ****************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
          I-69 OVER TIPPEY DITCH            I69-64-4767
       COUNTY: GRANT                      QUAD: VAN BUREN 74D
         11-21-96                          BRET A. ROBINSON

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

  BR   BRDGE 61 844.2 0
  GR        29821 0844.1  29846 0831.6  29851 0831.7  29876 0843.9  29821
0844.1
  N         .034
  PD        837 3 1
  CD        3 130 2 843

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

                       X,Y-coordinates ( 5 pairs)
      X          Y            X          Y            X          Y
```

WSPRO OUTPUT

29821.000	844.100	29846.000	831.600	29851.000	831.700
29876.000	843.900	29821.000	844.100		

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 29821.000 (associated Y-Elevation: 844.100)
Maximum X-Station: 29876.000 (associated Y-Elevation: 843.900)
Minimum Y-Elevation: 831.600 (associated X-Station: 29846.000)
Maximum Y-Elevation: 844.100 (associated X-Station: 29821.000)

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.034	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	130.000	2.00	843.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	844.200

Abutment Parameters

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

Pier/Pile Data (1 Group(s))
Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	837.000	3.000	1

--
* Finished Processing Header Record BRDGE *
--

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

I-69 OVER TIPPEY DITCH I69-64-4767
COUNTY: GRANT QUAD: VAN BUREN 74D
11-21-96 BRET A. ROBINSON

```
DC 0 BRDGE 29825 29871 29820 29870 * 3
DP        29821 29876 1.5 * * 1 1 1.1
DP        29821 29876 1.5 * * 1 1 1.1
```

WSPRO OUTPUT

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

XS   APPR 252 0
GR        29166 850  29309 850  29759 840  29808 841  29822 841  29828 840
GR        29838 835  29841 833  29846 833  29855 835  29867 840  29887 840
GR        29894 840  30453 850
N         .045 .034 .045
SA        29820 29870

 ***   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:      252.   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 (14 pairs)
    X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 29166.000     850.000    29309.000     850.000    29759.000     840.000
 29808.000     841.000    29822.000     841.000    29828.000     840.000
 29838.000     835.000    29841.000     833.000    29846.000     833.000
 29855.000     835.000    29867.000     840.000    29887.000     840.000
 29894.000     840.000    30453.000     850.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   29166.000  ( associated Y-Elevation:  850.000 )
  Maximum X-Station:   30453.000  ( associated Y-Elevation:  850.000 )
  Minimum Y-Elevation:   833.000  ( associated X-Station:  29846.000 )
  Maximum Y-Elevation:   850.000  ( associated X-Station:  29166.000 )

                   Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .045        ---
                                ---       ********
                      2         .034        ---
                                ---       ********
                      3         .045        ---
                   -------  -----------  ----------

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

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

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

WSPRO OUTPUT

```
        Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
     *-------------------------------------------------------------*
           I-69 OVER TIPPEY DITCH              I69-64-4767
         COUNTY: GRANT                      QUAD: VAN BUREN 74D
           11-21-96                           BRET A. ROBINSON
  EX

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

            Reach       Water Surface   Friction
       #   Discharge      Elevation      Slope          Flow Regime
      --   ---------    -------------   --------   --------------------
       1     2000.00       ********        .0013        Sub-Critical
       2     3400.00       ********        .0013        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-69 OVER TIPPEY DITCH              I69-64-4767
         COUNTY: GRANT                      QUAD: VAN BUREN 74D
           11-21-96                           BRET A. ROBINSON
 ===150 WARNING: SLOPE-CONVEYANCE CONVERGENCE FAILURE.
        Used final trial values.
        QCOMP, WSTRY:    1992.     842.69


                        WSEL     VHD        Q          AREA       SRDL       LEW
                        EGEL      HF        V           K         FLEN       REW
                        CRWS      HO      FR #         SF        ALPHA      ERR
                     ---------- ------ ---------- ---------- --------- ---------
  Section: EXIT       842.686    .423   2000.000    471.107 ********* 29723.070
  Header Type: XS     843.109 ******      4.245   56349.36 ********* 29951.910
  SRD:       .000     838.468 ******       .641     ******     1.509    ******

  Section: FULLV      842.800    .391   2000.000    497.874    61.000 29715.770
  Header Type: FV     843.192    .074      4.017   58747.60    61.000 29956.220
  SRD:     61.000     838.468    .000       .615      .0012     1.559      .009

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

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
        KRATIO:  1.44
```

WSPRO OUTPUT

```
Section: APPR      843.236   .109   2000.000   1085.475   191.000 29613.400
Header Type: AS    843.345   .154      1.843   84380.31   191.000 30074.870
SRD:    252.000    841.178   .000       .305      .0008     2.070     -.001

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

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


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     842.462   .915   2000.000    290.735    61.000 29824.280
Header Type: BR    843.377   .117      6.879   39115.89    61.000 29873.050
SRD:     61.000    839.656   .150       .554     ******     1.243     -.001

Specific Bridge Information   C      P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .8969  .056  844.200 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: APPR      843.762   .070   2000.000   1342.225    61.000 29589.720
Header Type: AS    843.831   .073      1.490  107351.50    72.363 30104.280
SRD:    252.000    841.178   .381       .231      .0008     2.014      .004

          Approach Section APPR  Flow Contraction Information
          M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
         -------- -------- --------- -------- -------- --------
             .891     .509   52635.8 ******** ********  843.762
         -------- -------- --------- -------- -------- --------

            <<< 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-69 OVER TIPPEY DITCH            I69-64-4767
       COUNTY: GRANT                     QUAD: VAN BUREN 74D
         11-21-96                          BRET A. ROBINSON

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
```

WSPRO OUTPUT

```
 Section: EXIT      844.079   .428   3400.000    888.451 ********* 29633.950
 Header Type: XS    844.507 ******      3.827   96082.66 ********* 30004.480
 SRD:       .000    840.700 ******       .597     ******     1.880    ******

 Section: FULLV     844.198   .390   3400.000    933.408    61.000 29626.300
 Header Type: FV    844.588   .073      3.643  100664.30    61.000 30008.990
 SRD:     61.000    840.700   .000       .565      .0012     1.888      .008

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:  1.53

 Section: APPR      844.623   .103   3400.000   1822.677   191.000 29550.980
 Header Type: AS    844.726   .143      1.865  153564.10   191.000 30152.410
 SRD:    252.000    842.105   .000       .261      .0007     1.911     -.005

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

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

===220 FLOW CLASS 1 ( 4 ) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
       WS3, WSIU, WS1, PFELV:   843.49     846.11     846.18     844.20

===245 ATTEMPTING FLOW CLASS 2 ( 5 ) SOLUTION.

                      WSEL    VHD       Q         AREA      SRDL      LEW
                      EGEL     HF       V           K        FLEN      REW
                      CRWS     HO      FR #        SF       ALPHA     ERR
                    --------- ------ --------- ---------- --------- ---------
 Section: BRDGE     844.100  1.467  3391.680    349.200    61.000 29821.000
 Header Type: BR    845.567 ******     9.713   54041.84 ********* 29876.000
 SRD:     61.000    841.895 ******      .680     ******     1.000    ******

 Specific Bridge Information   C     P/A   PFELEV    BLEN     XLAB     XRAB
 Bridge Type 3   Flow Type 2 ------ ----- -------- -------- -------- --------
 Pier/Pile Code  0             .4924  .057  844.200 ******** ******** ********
 --------------------------- ------ ----- -------- -------- -------- --------

                      WSEL    VHD       Q         AREA      SRDL      LEW
                      EGEL     HF       V           K        FLEN      REW
                      CRWS     HO      FR #        SF       ALPHA     ERR
                    --------- ------ --------- ---------- --------- ---------
 Section: APPR      847.100   .023  3400.000   3622.159    61.000 29439.500
 Header Type: AS    847.123   .049      .939  355168.20    77.115 30290.890
 SRD:    252.000    842.105   .709      .103      .0007     1.660     -.002

          Approach Section APPR  Flow Contraction Information
          M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
          ******** ******** ********* ******** ******** 847.100
          -------- -------- --------- -------- -------- --------
```

WSPRO OUTPUT

<<< 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-69 OVER TIPPEY DITCH I69-64-4767
COUNTY: GRANT QUAD: VAN BUREN 74D
11-21-96 BRET A. ROBINSON

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

Constants and Input Variables

Bed Material Transport Mode Factor (k1): .64
Total Pier Width Value (Pw): 3.000

#	Scour Depth	Flow Contract	Flow Approach	Width Contract	Width Approach	X-Limits Side	X-Limits Contract	X-Limits Approach
1	7.063	2000.000	978.689	43.000	50.000	Left:	********	********
	..... Approach Channel Depth:	6.902				Right:	********	********
2	13.969	2375.634	968.223	43.000	50.000	Left:	********	********
	..... Approach Channel Depth:	10.240				Right:	********	********

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

I-69 OVER TIPPEY DITCH I69-64-4767
COUNTY: GRANT QUAD: VAN BUREN 74D
11-21-96 BRET A. ROBINSON

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

Constants and Input Variables

Pier Width: 1.500

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

WSPRO OUTPUT

#	Scour Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	4.75	2000.000	842.844	11.244	8.622	.453	29821.000	29876.000
2	5.75	3391.680	844.809	13.209	12.792	.620	29821.000	29876.000

```
************************* 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-69 OVER TIPPEY DITCH          I69-64-4767
   COUNTY: GRANT                   QUAD: VAN BUREN 74D
     11-21-96                        BRET A. ROBINSON

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

                Constants and Input Variables

                    Pier Width:   1.500
            *-----------------------------------------*
              Pier Shape Factor            (K1):   1.00
              Flow Angle of Attack Factor  (K2):   1.00
              Bed Condition Factor         (K3):   1.10
              Bed Material Factor          (K4):   1.00
              Velocity Multiplier          (VM):   1.00
              Depth Multiplier             (YM):   1.00
            *-----------------------------------------*
```

#	Scour Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	4.75	2000.000	842.844	11.244	8.622	.453	29821.000	29876.000
2	5.75	3391.680	844.809	13.209	12.792	.620	29821.000	29876.000

```
  ER

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