CHAPTER DR-12
COMPUTER PROGRAMS

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CHAPTER DR-12
COMPUTER PROGRAMS

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DR-12.100 FUNDAMENTALS
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DR-12.110 General

Computer software currently approved for use in the drainage design of highway projects is introduced. Detailed information should be obtained from the individual computer program users manuals and documentation provided with the software.

NOTES AND COMMENTS

DR-12.200 KTDID

Kentucky Transportation Designs In Drainage (KTDID) consists of seven hydraulic programs. It is for use with a DOS 3.0 or greater, and the instructions are contained in the program documentation. It was developed to operate on most personal computers.

To initiate the program, enter KTDID, if running from hard disk, or A:KTDID if running from the floppy drive (change drive letter as needed). The first screen is the KTDID logo. The second screen is KTDID's Main Menu, from which you can select any one of nine programs by entering the program number.

The third screen requires you to name the input and output files; and, the fourth screen is the central control screen for the whole software package.

The seven programs in the KTDID package are:

HYPACK - Culvert Design Analysis
IMPRIN - Improved Headwall Inlet Analysis for Culverts
CURBIN,
GRATIN, - Curb and Grate Programs
DITCHA - Check of Discharge or Depth in Ditches and Channels
QWAYS - Discharge Methods
KWSPRO - Kentucky's Version of FHWA "WSPRO"

A brief summary of each of the programs is given here. For more information, with details on how to use each program, the reader should consult the documentation in the KTDID software package.

State Agencies and Consulting firms which have been "Pre-Qualified" to perform work involving Kentucky's highways are officially eligible to use KTDID and receive periodic updates to the programs. County and Municipal governments may use this package of drainage programs upon request. Firms doing highway-related work for those agencies will be considered on a case-by-case basis.

DR-12.210 HYPACK, Culvert Design Analysis

This program performs the hydraulic calculations involved in the size selection of concrete or metal circular and non-circular pipe culverts and concrete box culverts. Sizes are selected by the program based on input values. An option exists in which the user can input a particular structure size and type to examine its performance. In this way, existing structures can be easily analyzed or sizes other than those chosen by the program may be studied.

HYPACK combines most of the features of FHWA's Computer Programs HY1, HY2, HY3, and uses the normal depth and critical depth routines from HY6 into a single package for culvert design. Equations for inlet and outlet con-trol can be found in Hydraulic Design Series No. 5 (HDS-5).

HYPACK also permits the design of Reinforced Concrete Elliptical Pipe and fully lined metal pipe.

Two important features of the program are:

1. "USER SELECTED SIZES": this gives the designer the input option of pre-selecting a culvert size and type to examine its performance. Existing structures can be easily evaluated.

2. Dimensionless FROUDE numbers and BRINK depths are furnished as aides in designing energy dissipators.

The details for preparing and running HYPACK are described in the HYPACK.DOC documentation in the KTDID software package.

DR-12.220 IMPRIN, Improved Headwall Inlet for Culverts

This program was developed for hydraulic design and analysis of reinforced concrete box culverts or circular pipe culverts incorporating improved inlet configurations. It was developed using techniques provided in HDS NO. 5 and published by the FHWA. The requirements for optimum design of culverts are template data and a trial conventional size.

If optimum design is not used, the program allows the user to input any one or all of the values for face width, fall, fall slope, and/or side taper to examine other improved inlet geometries.

There are some restrictions. For pipes using a side-tapered inlet, a maximum of six inches reduction in size from a conventional pipe size is allowed. See the current standard drawings for side-tapered inlets and headwalls required. Currently there is no design program available for a slope-tapered inlet for a pipe. For box culverts, both side-tapered and slope-tapered inlets may be used. There is no design procedure for box culverts with more than two barrels. The height of the improved inlet shall be the same as the conventional size box culvert barrel. The maximum improvement in width is 50% of the conventional barrel width, with the minimum width of the improved barrel being equal to the height of the box culvert. The smallest improved barrel shall be 4' x 4'. There are other dimensional restrictions. See Section 06.460 of this manual.

The methodology for using IMPRIN is outlined in detail in the IMPRIN.DOC documentation in the KTDID software package.

DR-12.230 Curb Inlet Programs

There are two inlet programs in this group. Each functions in a similar manner. The programs are used to check the spacing or design the spacing of pavement drainage inlets.

The inlets are :

CURBIN is for curb-opening inlets where the pavement slope and gutter slopes are equal or they may be unequal as in a composite gutter situation. The applicable inlets are Curb Box Inlet Types A and B, Concrete Median Barrier Box Inlet, and Slots through Bridge Railings. Grates are disregarded by this program. CURBIN can also be used for Slotted Pipe Inlet design.

GRATIN is for the spacing of Drop Box Inlet Types 1,2,3,4 without dikes and 4:1 or flatter cross slopes; Drop Box Inlet Types 5,6,7 with 4:1 or flatter cross slopes; Drop Box Inlet Types 10 and 11; and Bridge Deck Drains with Grates; and Drop Box Inlet Types 13 and 16. It may also be used where the pavement slope are equal or they may be unequal as in a composite gutter situation.

These programs are used to assist the designer in establishing an acceptable and efficient inlet spacing pattern for a continuous longitudinal grade. To determine the correct spacing in a grade-sag-grade location, determine the spacing for grade 1 down to the sag point, then for grade 2 down to the sag point using guidelines of Section 07.500.

The details about preparing and using the individual programs are described in the INLET.DOC documentation in the KTDID software package.

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DR-12.240 DITCHA, Check of Discharge or Depth of Flow in Ditches and Channels

This program may be used to determine the hydraulic properties of ditches and channels. The ditches and channels may be V-shaped or Trapezoidal. Where the depth is known, the discharge can be determined and vice versa. DITCHA is conversational in nature and does not require an input file since data is entered during the execution of the program.

DR-12.250 QWAYS, Discharge Methods

QWAYS contains three short programs which calculate the discharge for Qx year floods using the: Rational, Regional, Floods in Kentucky, and FHWA Urbanization Methods as required for the TC 61-100 forms in the drainage folders. The program is conversational and does not require an input file since data is inputed during the execution of the program.

NOTES AND COMMENTS

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DR-12.300 DISCHARGE
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DR-12.310 HEC-1

The HEC-1 Program was developed by the United States Army Corps of Engineers and is designed to simulate the surface runoff response of a river basin to precipitation by modelling interconnected subbasins. Each subbasin may represent a stream channel, a reservoir, or a runoff entity by a set of parameters included in the input which will specify the characteristics of the component.

The central part of any simulation is the stream network and this is the heart of the HEC-1 program. Included in the program are Flood Hydrograph Simulations and Flood Damage Assessment. Simulations are limited to a single storm since there is no provision for soil moisture recovery.

The model results are discharge and stage based on either historical storm data or synthetic storm data.

For more information and details on running the program, consult the HEC-1 User's Manual published by the United States Army Corps of Engineers.

NOTES AND COMMENTS

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COMPUTER PROGRAMS

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DR-12.400 WATER SURFACE PROFILES
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DR-12.410 General

There are three bridge backwater design programs that are currently approved for use by the Division of Design. These programs are capable of floodplain designation and predicting floodplain encroachment results using different methods. The programs are HEC-2, WSPRO and KWSPRO which are described below.

DR-12.420 HEC-2

HEC-2 is a computer program developed by the United States Army Corps of Engineers and includes a variety of computational capabilities for calculating water surface profiles, encroachment analysis, and friction loss, then neatly condenses the output into summary tables.

The program is intended for calculating water surface profiles for steady, gradually varied flow in natural or man-made channels. Both subcritical and supercritical flow profiles can be calculated. The effects of various obstructions such as bridges, culverts, weirs, and structures in the floodplain may be considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The program is also designed for application in floodplain management and flood insurance studies to evaluate floodway encroachments and to designate flood hazard zones. Also, the program is able to access the effects of channel improvements and levees on water surface profiles. The program provides the flexibility for use of either English or Metric units for input and output.

For more information, consult the HEC-2 User's Manual published by the United States Army Corps of Engineers.

DR-12.430 WSPRO

FHWA initiated a contract with the USGS in 1979 to develop a program that would serve as a water surface profile computational tool specifically applicable to bridge waterway design.

Super-critical and subcritical flow profiles may be analyzed for one-dimensional, gradually varied, steady flow.

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The capabilities of WSPRO, also known as HY-7, are more extensive than any of the current programs available in calculating bridge backwater and floodplain development. The model uses the standard step method to compute backwater in the unconstricted valley reaches.

The model is available for use with microcomputer. For more information and details about preparing and running the program, refer to the WSPRO User's Manual, published by USGS.

DR-12.440 KWSPRO

This introduces the initial version of the water surface profile program, KWSPRO (v. 090192). This program extends the features of the Federal Highway Administration program, WSPRO (v. 060188). KWSPRO has been developed by the Kentucky Transportation Cabinet using the original WSPRO source code.

As with most other computer models, the Kentucky Transportation Cabinet makes no claims in the results produced by KWSPRO. It is the user's responsibility to ascertain the accuracy of the results.

Input and output filenames are entered on the command line to execute the program. The two temporary files have been eliminated.

KWSPRO will allow the user to perform a floodway analysis in a manner which is similar to Encroachment Methods 1 and 4 of the Corps of Engineers' HEC-2 computer model. It also allows the user to suppress portions of normal output while performing preliminary analyses. There are other minor differences between WSPRO and KWSPRO.

Read and study the documentation incorporated into the program for the input sequence and a description of the output.

NOTES AND COMMENTS

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DR-12.500 OTHER PROGRAMS
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DR-12.510 General

All designers who employ hydraulic computer programs other than those provided by the Drainage Section shall, on a one-time basis, submit the following information which will be retained in the Drainage Section files; this includes altered versions of the Drainage Section programs:

1. Program documentation,
2. References used to develop program,
3. Flowcharts,
4. Equations used,
5. Input/output definitions,
6. Definitions and/or codes which are system specific and may appear in printouts,
7. Updates and revisions to the program;
8. Copy of the program (helpful but not required since languages vary from product to product).

If, upon review of this material and printouts in the Drainage Folder, the Chief Drainage Engineer determines that the methodology of a program produces results which are inconsistent with departmental practices, the owner of the program should be notified. That particular program will be labeled unacceptable for drainage design. Another version must be submitted for approval. Drainage folders received which: (1) do not contain the proper support documentation as outlined, and/or (2) which contain results from computer programs which are not on file in the Central Office, Drainage Section as stated above shall be rejected and held pending resolution of documentation question.

DR-12.520 DAMS2

DAMS2 is a program designed to assist the engineer in the hydraulic and hydrologic analyses of dams. The program develops inflow hydrographs and uses the storage-discharge relationships at dam sites to floodroute the hydrographs through existing or potential reservoirs. Storage-discharge relationships may be computed by the program from physical parameters or may be entered directly, if historical data is available.

This program may be used in the design and proportioning of dams. It uses SCS criterion and procedures for dams ranging from 20 acres in drainage area to over 800 square miles in drainage area. Spillways can be sized and construction quantities computed. The program is also capable of designing and analyzing a system of dams in series.

For more information, see the DAMS2 User's Manual, published by SCS.

DR-12.530 HYDRAIN

HYDRAIN integrates hydraulic and hydrologic programs into a unified system. The intent of this integration is to enable users to learn basic principles of program operation and file manipulation. The programs incorporated into the HYDRAIN shell and a brief description of each are as follows:

- HYDRO - a command line hydrology program compatible with the Rational Method, the Regional Method, and others;
- HYDRA - a command line gravity pipe network hydraulics program. Storm or sanitary sewers may be analyzed or designed with this program;
- WSPRO - a command line backwater program for natural channels with an orientation to bridge analysis and design;
- CDSV5 - a command line culvert analysis and design program;
- HY8V3 - Version 3 of the Penn State culvert program;
- EQUAT - a discharge equation program.

For more information, see the HYDRAIN User's Manual available from McTRANS, phone 904-392-0378, an authorized supplier of nonproprietary engineering computer program.

DR-12.540 Future Programs

Designers will be notified by Drainage Design Memorandums as innovative hydraulic software is approved by the Drainage Section.

NOTES AND COMMENTS

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DR-12.900 EXHIBITS

CHAPTER DR-12
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```
(INPUT)

SAMPLE HYPACK  (6' AHW)
60427
.0317 60 6 598 2.6 733 3.0 1 2 2
515
515 12 6 515 14 6
HARLAN CO. KY 38 (5' AHW)
60427
.0317 60 7 598 2.6 733 3.0 1 3 0
515
515 10 8 515 11 8 515 12 8


(OUTPUT)
                                                                  12-07-1992  09:45:25


HYPACK : KENTUCKY CULVERT DESIGN PROGRAM

************************************************************************


SAMPLE HYPACK  (6' AHW)
  STATION       S         L      AHW       DQ      DTW       CQ     CTW
 604+27.0  0.03170       60     6.00      598.     2.60      733.    3.00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

RCBC           (CODE :  515 ) -- INLET CONTROL GOVERNS
   30°-75° WING FLARE (TOP BEVEL OR ROUNDED)

   INLET CONTROL--DQ HW BRACKETS HW/D=1.0                      O.C.TEST
                   SPAN     RISE     HW     VO     YO   FROUDE  HWOC  VOOC
DQ                 12.0      6.0     6.6   27.5    1.8   3.61    4.6  11.7
DQ                 14.0      6.0     5.8   26.4    1.6   3.66    4.0  11.1
CQ                 12.0      6.0     7.9   29.5    2.1   3.60    5.6  12.5
CQ                 14.0      6.0     6.9   28.4    1.8   3.69    4.8  11.9

 THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET
 COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


RCBC           (CODE :  515 ) -- INLET CONTROL GOVERNS
   30°-75° WING FLARE (TOP BEVEL OR ROUNDED)
   SIZE SELECTED BY USER

   INLET CONTROL                                               O.C.TEST
                   SPAN     RISE     HW     VO     YO   FROUDE  HWOC  VOOC
DQ                 12.0      6.0     6.6   27.5    1.8   3.61    4.6  11.7
CQ                 12.0      6.0     7.9   29.5    2.1   3.60    5.6  12.5

 THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET
 COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


RCBC           (CODE :  515 ) -- INLET CONTROL GOVERNS
   30°-75° WING FLARE (TOP BEVEL OR ROUNDED)
```

SIZE SELECTED BY USER

INLET CONTROL

	SPAN	RISE	HW	VO	YO	FROUDE	O.C.TEST HWOC	VOOC
DQ	14.0	6.0	5.8	26.4	1.6	3.66	4.0	11.1
CQ	14.0	6.0	6.9	28.4	1.8	3.69	4.8	11.9

THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.

****

KTdid:9101

END OF RUN

****

HARLAN CO. KY 38 (5' AHW)

STATION	S	L	AHW	DQ	DTW	CQ	CTW
604+27.0	0.03170	60	7.00	598.	2.60	733.	3.00

- -

RCBC (CODE : 515) -- INLET CONTROL GOVERNS
30°-75° WING FLARE (TOP BEVEL OR ROUNDED)

INLET CONTROL--DQ HW BRACKETS HW/D=1.0

	SPAN	RISE	HW	VO	YO	FROUDE	O.C.TEST HWOC	VOOC
DQ	10.0	7.0	7.4	28.5	2.1	3.47	5.5	12.4
DQ	12.0	7.0	6.4	27.5	1.8	3.61	4.7	11.7
CQ	10.0	7.0	8.8	30.4	2.4	3.45	6.6	13.3
CQ	12.0	7.0	7.5	29.5	2.1	3.60	5.6	12.5

THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.

- -

RCBC (CODE : 515) -- INLET CONTROL GOVERNS
30°-75° WING FLARE (TOP BEVEL OR ROUNDED)
SIZE SELECTED BY USER

INLET CONTROL

	SPAN	RISE	HW	VO	YO	FROUDE	O.C.TEST HWOC	VOOC
DQ	10.0	8.0	7.2	28.5	2.1	3.47	5.6	12.4
CQ	10.0	8.0	8.5	30.4	2.4	3.45	6.5	13.3

THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.

- -

RCBC (CODE : 515) -- INLET CONTROL GOVERNS
30°-75° WING FLARE (TOP BEVEL OR ROUNDED)
SIZE SELECTED BY USER

INLET CONTROL

	SPAN	RISE	HW	VO	YO	FROUDE	O.C.TEST HWOC	VOOC
DQ	11.0	8.0	6.7	28.0	1.9	3.55	5.3	12.0
CQ	11.0	8.0	7.8	29.9	2.2	3.54	6.1	12.9

THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.

- -

RCBC (CODE : 515) -- INLET CONTROL GOVERNS
30°-75° WING FLARE (TOP BEVEL OR ROUNDED)
SIZE SELECTED BY USER

INLET CONTROL							O.C.TEST	
	SPAN	RISE	HW	VO	YO	FROUDE	HWOC	VOOC
DQ	12.0	8.0	6.3	27.5	1.8	3.61	5.0	11.7
CQ	12.0	8.0	7.3	29.5	2.1	3.60	5.7	12.5

THE SIZES OBTAINED IN THIS RUN INDICATE THAT AN IMPROVED INLET
COULD BE USED. SEE CURRENT DRAINAGE MANUAL FOR ASSISTANCE.
****

KTdid:9101

END OF RUN

IMPRIN: IMPROVED INLET HEADWALL DESIGN FOR PIPES & BOX CULVERTS

(INPUT)

```
BALKE.IN
6122.97
580.20 576.48 119 .031 0 0 585.20
1 10 5 3 .012 0 1.00 0 0 0 0
177.5 204 240 250  1.8 1.9 2.1 2.3
```

(OUTPUT)

```
                                                        05-10-1993   13:34:33

IMPRIN, IMPROVED INLET HEADWALL DESIGN FOR PIPES & BOX CULVERTS

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
PROJECT : BALKE.IN
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

STATION : 6122.97

STRUCTURE TYP : REINFORCED CONCRETE BOX CULVERT

------------------------------------------------------------------------------
ALLOWABLE HEADWATER ELEVATION :  585.2

So =  .031   SEMB =  0    SFALL =  3 :1   TAPER =  4 :1

CONVENTIONAL SIZE   (B x D) =  10  x  5  (ft x ft) ,   1  BARREL(S)

IMPROVED INLET DIMENSIONS :
        FACE    (Bf x D) = 14.0 x  5.0
        1 BARREL (B x D) =  5.0 x  5.0   (ft x ft)
        L1          (ft)  = 18.00
        L2          (ft)  =  3.00
        L3          (ft)  = 15.00
        FALL        (ft)  =  1.00
        ADJ. So           =  0.02260
        ADJ. LENGTH (ft)  =  119.00
        INLET ELEV. (ft)  =  580.200
        OUTLET ELEV.(ft)  =  576.480


              -Q-    -CONVENTIONAL-   -------------IMPROVED-------------
                         HW.IC        HW.OC     HW.TC     HW.FC       OV
              cfs         ft           ft        ft        ft        fps
        1     177.5      583.45       581.91    584.29    583.23    19.42
        2     204.0      583.78       582.47    584.79    583.53    20.15
        3     240.0      584.22       583.31    585.45    583.93    20.98
        4     250.0      584.34       583.56    585.64    584.05    21.28

==============================================================================
                                                                KTdid:9301
END OF RUN

              TRANSITION ZONE, FALL < D/4
```

DR-12.910.1 GRATED INLET SPACING

GRATIN: GRATED INLET SPACING W/NORMAL OR COMPOSITE GUTTER SLOPE

(INPUT)

```
HICKMAN CO.
13.1 2 .0108 .1667 .015 2 2 4
29500 LT
5 .8259 .013 .0208
29600 LT
5 .0224 .013 .0208
29700 LT
5 .0118 .013 .0208
29800 LT
5 .0118 .013 .0208
29900 LT
5 .0118 .013 .0208
END
```

(OUTPUT)

```
******************************************************************************
                                                       04-26-1993   10:19:51

GRATIN : GRATED INLET SPACING W/NORMAL OR COMPOSITE GUTTER SLOPE

HICKMAN CO.
```

INLET	GW ft	SW ft/ft	DPRESS ft	N	WGRATE ft	LGRATE ft	RAIN in/hr
13.1	2.00	0.011	0.167	0.015	2.00	2.00	4.000

STA ft	C	AREA ac	LS ft/ft	SX ft/ft	SW ft/ft	DEP ft	SPREAD ft	Qa cfs	Qi cfs	Qc cfs
29500 LT	0.850	0.826	0.013	0.021	0.021	0.200	9.63	2.81	1.77	1.04
29600 LT	0.850	0.022	0.013	0.021	0.021	0.142	6.82	1.12	0.89	0.23
29700 LT	0.850	0.012	0.013	0.021	0.021	0.084	4.02	0.27	0.26	0.01
29800 LT	0.850	0.012	0.013	0.021	0.021	0.045	2.15	0.05	0.05	0.00
29900 LT	0.850	0.012	0.013	0.021	0.021	0.041	1.96	0.04	0.04	0.00

KTdid:9301

END OF RUN

CURBIN: CURB-OPENING/SLOTTED PIPE INLET SPACING W/NORMAL /COMPOSITE GUTTER SLOPE

```
HICKMAN CO.
2 2 .0208 .1667 .015 4
29500 LT
5 .0259 .013 .0208
29600 LT
5 .0224 .013 .0208
29700 LT
5 .0118 .013 .0208
29800 LT
5 .0118 .013 .0208
29900 LT
5 .0118 .013 .0208
END
```

04-26-1993 10:18:08

CURBIN :
CURB-OPENING/SLOTTED PIPE INLET SPACING W/NORMAL/COMPOSITE GUTTER SLOPE

HICKMAN CO.

LENGTH ft	GW ft	SW ft/ft	DPRESS ft	N	RAIN in/hr
2.0	2.00	0.021	0.167	0.015	4.000

STA ft	C	AREA ac	LS ft/ft	SX ft/ft	SW ft/ft	DEP ft	LTI ft	SPREAD ft	Qa cfs	Qi cfs	Qc cfs
29500 LT	0.850	0.026	0.013	0.021	0.021	0.055	2.84	2.63	0.09	0.08	0.01
29600 LT	0.850	0.022	0.013	0.021	0.021	0.054	2.81	2.60	0.09	0.08	0.01
29700 LT	0.850	0.012	0.013	0.021	0.021	0.044	2.22	2.11	0.05	0.05	0.00
29800 LT	0.850	0.012	0.013	0.021	0.021	0.041	2.35	1.97	0.04	0.04	0.00
29900 LT	0.850	0.012	0.013	0.021	0.021	0.041	2.36	1.98	0.04	0.04	0.00

KTdid:9301

END OF RUN

DR-12.914.1 DITCH CALCULATIONS

```
                                                       05-02-1993   09:03:38
******************************************************************************
*

DITCHA : CHECK DEPTH OF FLOW AND DISCHARGE IN DITCHES & CHANNELS

==============================================================================

PROJECT : SAMPLE DITCHA OUTPUT FILE

DISCHARGE CALCULATIONS :

   Z = Average Side Slope (Z : 1)         =  2
   B = Bottom Width                       =  6  (ft)
   S = Channel Slope                      =  .025  (ft/ft)
   D = Channel Depth                      =  4  (ft)
   N = Manning's Roughness Coefficient    =  .042


CHANNEL HYDRAULICS :
  DISCHARGE         =   552.833   (cfs)
  AREA              =    56.000   (ft²)
  VELOCITY          =     9.872   (fps)
  HYDRAULIC RADIUS  =     2.344   (ft)
  WETTED PERIMETER  =    23.889   (ft)

******************************************************************************


DEPTH CALCULATIONS :

  Q = Discharge                           =  33  (cfs)
  B = Bottom Width                        =  6  (ft)
  Z = Average of Side Slopes (Z : 1)      =  2
  S = Channel Slope                       =  .025  (ft/ft)
  N = Manning's Roughness Coefficient     =  .042

CHANNEL HYDRAULICS :
  DEPTH             =     1.000   (ft)
  AREA              =     8.000   (ft²)
  VELOCITY          =     4.675   (fps)
  HYDRAULIC RADIUS  =     0.764   (ft)
  WETTED PERIMETER  =    10.472   (ft)

******************************************************************************
                                                       KTdid:9301
END OF RUN
```

05-13-1993 13:19:49

****
*

RATIONAL METHOD (Q = CIA)

County, Route, Item No., Stream Name :
SAMPLE QWAYS RATIONAL METHOD DISCHARGE

Zone of Influence : LEXINGTON
C-Factor : .33
Area (acres) : 183

Overland Flow Travel Time Components :

Length of Overland Flow (ft)	: LO =	280 (ft)
Overland Friction Factor	: N =	.03
2-Year, 24-Hour Precipitation	: P =	3.1
Average Overland Slope	: SO =	.02 (ft/ft)

Channel Flow Travel Time Components :

Length of Channel Flow	: LC =	2720 (ft)
Manning's Roughness Coefficient	: n =	.03
Bank Full Section Flow Area	: AC =	72 (ft^2)
Channel Slope	: SC =	.002 (ft/ft)
Wetted Perimeter	: WP =	28 (ft)

	Q	TC	Tov	Tch	I
Q 2	167.44	17.10	6.26	10.84	2.77
Q 5	219.29	17.10	6.26	10.84	3.63
Q 10	253.55	17.10	6.26	10.84	4.20
Q 25	296.53	17.10	6.26	10.84	4.91
Q 50	328.90	17.10	6.26	10.84	5.45
Q 100	361.17	17.10	6.26	10.84	5.98
Q 500	439.49	(cfs)			

===

KTdid:9301

END OF RUN

EXHIBIT DR-12.930 - Examples Of Hydraulic Design Of Bridges Using HEC-2

Introduction

This exhibit provides a brief overview of the input and output data used with HEC-2. It then provides two examples of the more common types of hydraulic analysis for bridges. Detailed information needed to use HEC-2 is found in Reference 7.

The examples only show the HEC-2 calculations for the particular bridge study. Examples of other data needed for a complete design analysis (hydrology, model calibration, etc.) is found in related chapters of this manual.

Input Data

The input data records of HEC-2 are all identified by a two-letter code at the beginning of each record. These codes are summarized in Table C.1. Many of the records described can be omitted if the options to which they apply are not required.

The location of the variables for each input record is shown by field number. Each record is divided into ten fields of eight columns each except field one. A variable in field one may only occupy record columns three through eight since record columns one and two (called field zero) are reserved for required identification characters. The values a variable may assume and the conditions for each are described in the users manual. Some variables simply call for use of program options by using the numbers -1, 0, 1, 10, and 15. Other variables contain numbers which express the magnitude of the variable. For these a plus or minus sign is shown in the description under "value" and the numerical value of the variable is entered as input. Where the value of a variable is to be zero, the variable may be left blank since a blank field is read as zero.

Any number without a decimal point must be right justified in its field. Any number without a sign is considered positive.

The location of variables on records is often referred to by an abbreviated designation; for example, J1.5 refers to the fifth field of the J1 card.

Output Data

The user can identify certain types of data output, but of more interest for this manual is a definition of the output variables which appear in the computer printouts shown herein. These definitions are summarized in Table C.2. In general, the output consists of an echo of input data and cross-section computations for each succeeding cross section followed by the water surface profile results.

TABLE C.1
FUNCTIONAL USE INDEX

Records Used	Task
T1, T2, T3, J1.4 - J1.9, NC, X1.1 - X1.9, GR, EJ, ER	Basic Applications
AC	Archival Option
C	Data Comment Cards
J2.1, J3	Multiple Profiles, Summary Printout
J5	Printout Control
J1.1, J2.10, X2.10	Traces & Input Data Printout
J4	Storage-Discharge Output
J2.2 - J2.5, X1.10	Printer Plots of Cross Sections and Profiles
J6.1	Optional Friction Loss Equations
J2.10, X2.10	Flow Distribution
J2.7	Critical Depth Option
J1.3, X2.2	Direct Solution for Manning's 'n'
J2.6, NH, NV	Optional Cards for Specifying Manning's 'n'
J1.2, J1.8, J1.10, X2.1, QT	Options for Specifying Discharge
X3, ET	Specifications of Ineffective Flow Areas & Encroachments
X4	Additional Ground Points
J2.8, J2.9, CI	Channel Modification Due to Excavation
X2.3 - X2.6, BT, SB, X5	Bridge Losses

TABLE C.2
OUTPUT DATA DESCRIPTION

This table contains a description of all output variables that apply to any cross section. Many of these variables can be selected for summary printout display.

Variable	Description
ACH	Cross section area of the channel.
ALOB	Cross section area of the left overbank.
ALPHA	Velocity head coefficient.
AREA	Cross section area.
AROB	Cross section area of the right overbank.
BANK ELEV LEFT/RIGHT	Left and right bank elevations
BAREA	Net area of the bridge opening below the low chord. Entered on SB card.
BW	The bottom width of the trapezoidal excavation.
CASE	A variable indicating how the water surface elevation was computed. Values of 11, -2, -3, and 0 indicate assumptions of critical depth, minimum difference, a fixed change (X5 card), or a balance between the computed and assumed water surface elevations, respectively.
CCHV	Contraction coefficient.
CEHV	Expansion coefficient.
CHSLOP	Channel slope
CLASS	Identification number for following types of bridge flow.

CLASS	TYPE OF FLOW
1	Low Flow - Class A
2	Low Flow - Class B
3	Low Flow - Class C
10	Pressure Flow Alone
11,15	Weir and Low Flow - Class A
12	Weir and Low Flow - Class B
13	Weir and Low Flow - Class C
30	Pressure Flow and Weir Flow
59	Special Bridge Reverts to Normal Bridge Method

67 For Encroachment Methods 3 through 6

Variable	Description
CLSTA	The centerline station of the trapezoidal excavation.
CORAR	Area of the bridge deck subtracted from the total cross sectional area in the normal bridge method.
CRIWS	Critical water surface elevation.
CWSEL	Computed water surface elevation.
DEPTH	Depth of flow.
DIFEG	Difference in energy elevation for each profile.
DIFKWS	Difference in water surface elevation between known and computed.
DIFWSX	Difference in water surface elevation between sections.
EG	Energy gradient elevation for a cross section which is equal to the computed water surface elevation CWSEL plus the velocity head HV.
EGLWC	The energy grade line elevation computed assuming low flow.
EGPRS	The energy grade line elevation computed assuming pressure flow.
ELENCL	Elevation of left encroachment.
ELENCR	Elevation of right encroachment.
ELLC	Elevation of the bridge low chord. Equals ELLC entered on the X2 card if used, otherwise it equals the maximum low chord in the BT table.
ELMIN	Minimum elevation in the cross section.
ELTRD	Elevation oft he top of roadway. Equals ELTRD entered on the X2 card if used, otherwise it equals the minimum top of the road in the BT table.
ENDST	Ending station where the water surface intersects the ground on the right side.
H3	Drop in water surface elevation from upstream to downstream sides of the bridge computed using Yarnell's equation assuming Class A low flow.

HL	Energy loss due to friction.
HV	Discharge-weighted velocity head for a cross section.
IDC	Number of trials required to determine critical depth
ICONT	Number of trials to determine the water surface elevation by the slope area method, or the number of trials to balance the energy gradient by the special bridge method, or the number of trials required to calculate encroachment stations by encroachment methods 5 and 6.
IHLEQ	Friction loss equation index.
ITRIAL	Number of trials required to balance the assumed and computed water surface elevations.
KRATIO	Ratio of the upstream to downstream conveyance.
OLOSS	Energy loss due to minor losses such as transition losses.
PERENC	The target of encroachment requested on the ET card.
Q	Total flow in the cross section 1.
QCH	Amount of flow in the channel.
QCHP	Percent of flow in the channel.
QLOB	Amount of flow in the left overbank.
QLOBP	Percent of flow in the left overbank.
QPR	Total pressure or low flow at the bridge.
QROB	Amount of flow in the right overbank.
QROBP	Percent of flow in the right overbank.
QWEIR	Total weir flow at the bridge.
RBEL	Right bank elevation.
SECNO	Identifying cross section number. Equal to the number in the first field of the X1 card.
SLOPE	Slope of the energy grade line for the current section.
SSTA	Starting station where the water surface intersects the ground.

STENCL	The station of the left encroachment.
STENCR	The station of the right encroachment.
STCHL	Station of the left bank.
STCHR	Station of the right bank.
TELMX	Elevation of the lower of the end points of the cross section.
TIME	Travel time from the first cross section to the current cross section in hours.
TOPWID	Width at the calculated water surface elevation.
TRAPEZOID AREA	Net area of the bridge opening up to the low chord as defined by SS, BWP and BWC on the SB card. Should be close to BAREA on the SB card.
TWA	Cumulative surface area (acres or 1000 square meters) of the stream from the first cross section.
VCH	Mean velocity in the channel.
VLOB	Mean velocity in left overbank.
VOL	Cumulative volume (acre-feet or 1000 cubic meters) of water in the stream from the first cross section.
VROB	Mean velocity in the right overbank.
WSELK	Known water surface elevation; for example, a high water mark.
WTN	Length weighted value of Manning's 'n' for the channel. Used when computing Manning's 'n' from high water marks.
XLBEL	Left bank elevation.
XLCH	Distance in the channel between the previous cross section and the current cross section.
XLOBL	Distance in the left overbank between the previous cross section and the current cross section.
XLOBR	Distance in the right overbank between the previous cross section and the current cross section.
XNCH	Manning's 'n' for the channel area.
XNL	Manning's 'n' for the left overbank area.

XNR — Manning's 'n' for the right overbank area.

.01K — The total discharge (index Q) carried with $S^{1/2}$=.01 (equivalent to .01 times conveyance).

Example Problems

The use of HEC-2 for modeling a bridge crossing is similar that of WSPRO. There are, however, some significant differences that must be recognized. This list is not all inclusive but does identify some of those differences.

Task	HEC-2	WSPRO
Profile Control	J, QT	J, Q, WS, SK
Cross Section Header	X-1,X-2, etc.	XS, XR, XT
Terrain Data	GR (elev.,sta.)	GR(sta., elev.)
Bridge	SB, BT	BR, BD, BL, etc.

Example 1 in Appendix B (WSPRO) is used to demonstrate HEC-2 modeling of a simple (normal) bridge crossing using the Special Bridge routine. By employing the same example for both modeling techniques, the user can readily compare the similarities and differences in the models.

Example 2 demonstrates the use of the "Floodway Routines" contained in HEC-2. These routines are used extensively by FEMA in its flood insurance studies.

Example 1 - Single Opening Bridge

Given: A normal, single-opening bridge is to be constructed at this stream crossing. The average stream slope in the vicinity of the bridge is 0.00052 ft./ft. The bridge opening begins at station 230 ft and ends at station 430 ft for a total bridge opening length of 200 ft. It has vertical abutments and bridge deck elevation of 35.0 ft with a low steel elevation of 32.0 ft. There are three bridge piers with a spacing of 50 ft and a width of 3 ft. No overtopping is allowed.

Find: For discharges of 5000, 10000, 15000, 20000, and 25000 cfs, calculate the upstream flood stage caused by the bridge and the mean velocity at the bridge section.

Soln: The input data records are shown in Table C.3 All five discharges are shown on the QT record. The profile is started using a known water surface elevation (WSELK, J1, field 9) obtained from the WSPRO run in example B1. This WSELK is used rather than starting by using the slope-area method employed in the WSPRO example to ensure that both runs begin at exactly the same elevation. Thus, any differences in the computed water surface elevations at subsequent stations is due to the inherent calculation methods of each program.

The most downstream cross section is located at station 1000 (X1, field one) and the ground points are entered in the accompanying GR records. This cross section is propagated upstream to the bridge and approach section location. The bridge data is entered on the SB record and the roadway profile (weir) is entered on the BT records.

The output data is shown in Table C.4 for Q=2000 cfs. Forty items of information are shown for each section. Since the flood stage for this discharge did not inundate the low chord or overtop the roadway, the program computed the hydraulic performance of the bridge as Class A Low Flow.

Summary printout Table No. 150 is generated because a summary was requested (J2, field 1) and no J3 was supplied. The user may specify a user defined summary by using the J3 record.

The total flood stage upstream of the bridge is 28.9 ft (CWSEL at SECNO 1440). The velocity through the bridge is 8.86 ft/s.

Table C.3

```
T1       EXAMPLE 1
T2       BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3       NORMAL BRIDGE CROSSING;      THREE 3-FT PIERS
J1           0        5        0        0    0.000        0        0        0    27.99        0
J2           1        0       -1        5        0        0        0        0        0        0
J6           3
NC        0.07    0.045    0.035     0.01      0.3
NH           4    0.045      200     0.07      300    0.035      430    0.045      730        0
QT           5     5000    10000    15000    20000    25000
X1        1000       21      230      430        0        0        0        0        0        0
GR          35        0       28        0     23.5      140     21.5      200       21      230
GR        20.5      250     20.4      280       20      300       19      310       10      330
GR           3      360        8      380       18      400       21      430       20      450
GR          17      475     17.5      500       18      550       20      600       28      730
GR          35      730
NC           0        0        0       .3       .5
NH           4    0.045      200     0.07      300    0.035      430    0.045      730        0
X1        1200       21      230      430      200      200      200        0       .1        0
X3          10        0        0        0        0        0        0       28       31        0
GR          35        0       28        0     23.5      140     21.5      200       21      230
GR        20.5      250     20.4      280       20      300       19      310       10      330
GR           3      360        8      380       18      400       21      430       20      450
GR          17      475     17.5      500       18      550       20      600       28      730
GR          35      730
SB          .9     1.56        3        0     28.4        9     3312     2.96        3        3
NC           0        0        0       .1       .3
NH           4    0.045      200     0.07      300    0.035      430    0.045      730        0
X1        1240        0        0        0       40       40       40        0        0        0
X2           0        0        1       32       35        0        0        0        0        0
X3          10        0        0        0        0        0        0       28       31        0
BT           6        0       35       28      229       35       21      230       35       32
BT         430       35       32      431       35       21      730       35       35
X1        1440        0        0        0      200      200      200        0        0        0
EJ
ER
```

Table C.4

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 1
IHLEQ = 3. THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF THE GEOMETRIC MEAN FRICTION SLOPE. THAT IS

HL = WLEN*(S*SLOPE)**.5

WHERE WLEN = DISCHARGE-WEIGHTED REACH LENGTH, S = FRICTION SLOPE AT CURRENT CROSS SECTION, SLOPE = FRICTION SLOPE AT PRECEDING CROSS SECTION.
0

CCHV= .100 CEHV= .300
1490 NH CARD USED
*SECNO 1000.000

1000.000	24.99	27.99	.00	27.99	28.26	.27	.00	.00	21.00
20000.	1478.	12249.	6273.	845.	2531.	21.6	0.	0.	21.00
.00	1.75	4.84	2.94	.051	.036	.045	.000	3.00	.31
.000488	.0	.0	.0	0	0	0	.00	729.53	729.84

0
CCHV= .300 CEHV= .500
1490 NH CARD USED
*SECNO 1200.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = .59

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 28.00 ELREA= 31.00

1200.000	24.68	27.78	.00	.00	28.80	1.02	.17	.38	21.10
20000.	0.	20000.	0.	0.	2468.	0.	18.	2.	21.10
.01	.00	8.10	.00	.000	.036	.000	.000	3.10	230.00
.001400	200.	200.	200.	6	0	0	.00	200.00	430.00

0
1

SPECIAL BRIDGE

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
.90	1.56	3.00	.00	28.40	9.00	3312.00	2.96	3.00	3.00

CCHV= .100 CEHV= .300
1490 NH CARD USED
*SECNO 1240.000
CLASS A LOW FLOW

3420 BRIDGE W.S.= 27.53 BRIDGE VELOCITY = 8.86 CALCULATED CHANNEL AREA = 2257.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD	WEIRLN
.00	28.90	.12	0.	20000.	3312.	3052.	32.00	35.00	0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 28.00 ELREA= 31.00

1240.000	24.80	27.90	.00	.00	28.90	1.00	.10	.00	21.10
20000.	0.	20000.	0.	0.	2492.	0.	21.	2.	21.10
.01	.00	8.03	.00	.000	.036	.000	.000	3.10	230.00
.001362	40.	40.	40.	0	0	0	.00	200.00	430.00

*SECNO 1440.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.91

1440.000	25.80	28.90	.00	.00	29.12	.22	.14	.08	21.10
20000.	1756.	11772.	6472.	1033.	2694.	2380.	40.	4.	21.10
.02	1.70	4.37	2.72	.050	.037	.045	.000	3.10	.00
.000374	200.	200.	200.	2	0	0	.00	730.00	730.00

0
1

ERROR CORR - 01,02,03
MODIFICATION -
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

NORMAL BRIDGE CROSSING;

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10*KS	VCH	AREA	.01K
	1000.000	.00	.00	.00	3.00	20000.00	27.99	.00	28.26	4.88	4.84	5511.45	9053.65
*	1200.000	200.00	.00	.00	3.10	20000.00	27.78	.00	28.80	14.00	8.10	2468.46	5345.21
	1240.000	40.00	35.00	32.00	3.10	20000.00	27.90	.00	28.90	13.62	8.03	2491.79	5419.88
*	1440.000	200.00	.00	.00	3.10	20000.00	28.90	.00	29.12	3.74	4.37	6106.55	10336.36

1

NORMAL BRIDGE CROSSING;

SUMMARY PRINTOUT TABLE 150

SECNO		Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPSID	XLCH	
	1000.000		20000.00	27.99	.00	.00	.00	729.53	.00
	1200.000		20000.00	27.78	.00	-.21	.00	200.00	200.00
	1240.000		20000.00	27.90	.00	.12	.00	200.00	40.00
	1440.000		20000.00	28090	.00	1.01	.00	730.00	200.00

1

Example 2 - Single Opening Bridge/Floodway Boundaries

Given: The same data used in example 1 with the addition of floodway stations at distances of 180 ft and 450 ft on each cross section.

Find: For a discharge of 20000 cfs, calculate the flood stage upstream of the bridge and the mean velocity through the bridge when floodways are used.

Soln: The input data is shown in Table C.5.

The floodway data is entered on an ET record inserted immediately prior to each X1 record. The field number specified on INQ (J1, field 2) directs the program to the appropriate discharge on the QT record and the field of the ET record that specifies the Xth and the Xth +1 fields containing the encroachment stations. The code **8**.11 in field seven of the ET record signifies fields 8 and 9 will contain the encroachment stations; 8.**1**1 indicates method one option will be used, and 8.1**1** indicates flow through a bridge.

The output data is shown in Table C.6. The 270-ft wide floodway causes approximately a 3.5 ft increase in the CWSEL at SECNO 1000, causes the water surface to contact the low steel at the bridge resulting in pressure flow, and causes approximately 3.4 ft increase in the CWSEL at SECNO 1440.

The total flood stage upstream of the bridge is 32.3 ft (CWSEL at SECNO 1440). The velocity through the bridge is 6 ft/s.

Table C.5

```
T1      EXAMPLE 2
T2      BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3      ENCROACHMENT TYPE 1     NORMAL BRIDGE CROSSING;     THREE 3-FT PIERS
J1            0       7       0       0 0.00052       0       0       0   27.99       0
J2            1       0      -1       5       0       0       0       0       0       0
NC         0.07   0.035   0.045     0.1     0.3
NH            4   0.045     200    0.07     300   0.035     430   0.045     730       0
QT            6    5000   10000   15000   20000   25000   20000
ET                                         8.11     180     450
X1         1000      21     300     430       0       0       0       0       0       0
GR           35       0      28       0    23.5     140    21.5     200      21     230
GR         20.5     250    20.4     280      20     300      19     310      10     330
GR            3     360       8     380      18     400      21     430      20     450
GR           17     475    17.5     500      18     550      20     600      28     730
GR           35     730
NC            0       0       0      .3      .5
NH            4   0.045     200    0.07     300   0.035     430   0.045     730       0
ET                                                         8.11     180     450
X1         1200      21     230     430     200     200     200       0      .1       0
X3           10       0       0       0       0       0       0      28      31       0
GR           35       0      28       0    23.5     140    21.5     200      21     230
GR         20.5     250    20.4     280      20     300      19     310      10     330
GR            3     360       8     380      18     400      21     430      20     450
GR           17     475    17.5     500      18     550      20     600      28     730
GR           35     730
SB           .9    1.56       3       0    28.4       9    3312    2.96       3       3
NC            0       0       0      .1      .3
NH            4   0.045     200    0.07     300   0.035     430   0.045     730       0
ET                                                         8.11     180     450
X1         1240       0       0       0      40      40      40       0       0       0
X2            0       0       1      32      35       0       0       0       0       0
X3           10       0       0       0       0       0       0      28      31       0
BT            6       0      35      28     229      35      21     230      35      32
BT          430      35      32     431      35      21     730      35      35
NH            4   0.045     200    0.07     300   0.035     430   0.045     730       0
ET                                                         8.11     180     450
X1         1440       0       0       0     200     200     200       0       0       0
EJ
ER
```

Table C.6

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 1

CCHV= .100 CEHV= .300
1490 NH CARD USED
*SECNO 1000.000

3470 ENCROACHMENT STATIONS= 180.0 450.0 TYPE= 1 TARGET= 270.000

1000.000	28.45	31.45	.00	.00	32.03	.58	.00	.00	20.00
20000.	3045.	16353.	601.	1267.	2453.	219.	0.	0.	21.00
.00	2.40	6.67	2.75	.066	.035	.045	.000	3.00	180.00
.000520	0.	0.	0.	0	0	4	.00	270.00	450.00

0
CCHV= .300 CEHV= .500
1490 NH CARD USED
*SECNO 1200.000

3470 ENCROACHMENT STATIONS= 180.0 450.0 TYPE= 1 TARGET= 270.000

1200.000	28.62	31.72	.00	.00	32.17	.45	.10	.04	21.10
20000.	1217.	18178.	604.	507.	3257.	222.	18.	1.	21.10
.01	2.40	5.58	2.72	.059	.038	.045	.000	3.10	180.00
.000503	200.	200.	200.	2	0	0	.00	270.00	450.00

0
SPECIAL BRIDGE

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
.90	1.56	3.00	.00	28.40	9.00	3312.00	2.96	3.00	3.00

CCHV= .100 CEHV= .300
1490 NH CARD USED
*SECNO 1240.000
BTCARD BRIDGE STENCL= 180.00 STENCR= 450.00
PRESSURE FLOW

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD	WEIRLN
.00	28.90	.12	0.	20000.	3312.	3052.	32.00	35.00	0.

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	TRAPEZOID AREA	ELLC	ELTRD	WEIRLN
32.61	32.20	.03	0.	20000.	3312.	3052.	32.00	35.00	0.

3470 ENCROACHMENT STATIONS= 180.0 450.0 TYPE= 1 TARGET= 270.000 1240.000 29.09 32.19 .00 .00
32.61 .42 .43 .00 21.10

20000.	1248.	18139.	.00	.00	32.61	.42	.43	.00	21.10
.01	2.35	5.42	2.64	.060	.038	.045	.000	3.10	180.00
.000459	40.	40.	40.	2	0	0	.00	270.00	450.00

0
1

1490 NH CARD USED
*SECNO 1440.000

3470 ENCROACHMENT STATIONS= 180.0 450.0 TYPE= 1 TARGET= 270.00

1440.000	29.18	32.28	.00	.00	32.70	.42	.09	.00	21.10
20000.	1254.	18132.	614.	535.	3369.	234.	41.	3.	21.10
.02	2.34	5.38	2.63	.060	.038	.045	.000	3.10	180.00
.000451	200.	200.	200.	0	0	0	.00	270.00	450.00

0
1

ERROR CORR - 01,02,03
MODIFICATION -
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

ENCROACHMENT TYPE 1

SUMMARY PRINTOUT TABLE 150

SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG
10*KS	VCH	AREA	.01K					
1000.000	.00	.00	.00	3.00	20000.00	31.45	.00	32.03
5.20	6.67	3939.70	8767.35					
1200.000	200.00	.00	.00	3.10	20000.00	31.72	.00	32.17
5.03	5.58	3986.97	8920.64					
1240.000	40.00	35.00	32.00	3.10	20000.00	32.19	.00	32.61
4.59	5.42	4111.72	9330.79					
1440.000	200.00	.00	.00	3.10	20000.00	32.28	.00	32.70
4.51	5.38	4137.56	9416.68					

1

ENCROACHMENT TYPE 1

SUMMARY PRINTOUT TABLE 150

SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
1000.000	20000.00	31.45	.00	.00	.00	270.00	.00
1200.000	20000.00	31.72	.00	.27	.00	270.00	200.00
1240.000	20000.00	32.19	.00	.46	.00	270.00	40.00
1440.000	20000.00	32.28	.00	.10	.00	270.00	200.00

EXHIBIT DR-12.940.01 Examples Of Hydraulic Design Of Bridges Using WSPRO

Introduction

This appendix provides a brief overview of the input and output data used with WSPRO. It then provides several examples of the more common types of hydraulic analysis for bridges. Detailed information needed to use WSPRO is found in Reference 6.

The example only shows the WSPRO calculations for the particular bridge study. Examples of other data needed for a complete design analysis (hydrology, model calibration, etc.) is found in related chapters of this manual.

Input Data

The input data records for WSPRO (6) are all identified by a two-letter code at the beginning of each record. These codes are summarized in Table B.1 and can be divided into four groups: (l) title; (2) job parameters (optional); (3) profile control data; and (4) cross-section definition. The record identification codes must appear in the first two columns of each input record. Data values are entered in free format beginning in column 11 and can be separated by commas or blanks. Default values of certain parameters can be used by entering an asterisk or double commas. The input data records are easily created by using word-processing software which has a text-file creation feature.

Output Data

The user can identify certain types of data output, but of more interest for this manual is a definition of the output variables which appear in the computer printouts shown herein. These definitions are summarized in Table B.2. In general, the output consists of an echo of input data and cross-section computations for each succeeding cross section followed by the water surface profile results.

WSPRO Examples

B.1 Input Data Records

Profile control data include Q, WS, SK, and EX records. The Q-record allows a whole series of discharges to be analyzed in a single computer run. The starting water surface elevation can be specified directly for each Q with a WS record, or the critical water surface elevation will be assumed if WS has a value less than this such as the lowest ground elevation. Alternatively, a slope of the energy grade line can be entered on an SK record to obtain a starting water surface elevation by the slope-area method. The EX record is used to specify a computation in the downstream direction (supercritical) with a value of unity or an upstream (subcritical) computation with a value of zero (default).

Cross-section data comprise the bulk of the input data and include ground elevations and locations, roughness coefficients, and bridge and spur dike geometry. Header codes for cross section data are:

(1) XS - unconstricted valley sections
(2) BR - bridge opening section
(3) SD - spur dike section
(4) XR - road grade section
(5) AS - approach section
(6) CV - culvert section
(7) XT - template section

The actual x-y coordinate data for each cross section are entered on GR records and must be referenced to a common datum. Roughness data are entered on N records and must correspond to the subsection definitions given by SA records. The SA record gives the right-hand boundary as an x-value for each subsection going from left to right except the last one which is the limiting right boundary. The N values then correspond to each subsection. The N values can vary with elevation within each subsection by using an ND record which gives the vertical breakpoints for the additional values of N entered on the N record.

In what is called design mode, specific bridge parameters can be varied on the following records:

(1) BL - parameters defining bridge length and horizontal location of the opening
(2) BD - bridge deck parameters
(3) AB - abutment parameters

Other bridge records defining bridge and embankment configuration (CD), pier or pile data (PW), spur dikes (SD), and road grades (XR) are discussed in more detail in the user's instructions. Four bridge types are possible in design mode as shown previously in Table 10-2. As an alternative, the bridge opening geometry can be entered as GR data in the fixed geometry mode.

Data propagation is a very convenient feature of WSPRO which avoids re-entering data that do not change from one cross section to the next. Data on N, ND, and SA records, for example, can be coded only once and propagated from one section to the next until they change. A single cross section defined by GR records can also be propagated by specifying only the slope and longitudinal distance to each succeeding section. A more flexible propagation of geometric cross section data can be achieved with a template cross section (XT) described in more detail in the user's instructions.

B.2 Output Data

The user can specify certain types of data output, but of more interest for this manual is a definition of the output variables which appear in the computer printouts shown herein. These definitions are summarized in Table B.2.

B.3 Methodology

For a complete understanding of WSPRO methodology and procedures, the user of this manual consult References 6 and 12.

Table B.1 - Input Data Records

TITLE INFORMATION

T1, T2, T3 - Alphanumeric title data for identification of output

JOB PARAMETERS

J1 - error tolerances, test values, etc.
J2 - input and output control parameters
J3 - special tabling parameters

PROFILE CONTROL DATA

Q - discharge(s) for profile computation(s)
WS - starting water surface elevation(s)
SK - energy gradient(s) for slope-conveyance computation
EX - execution instruction and computation direction(s)
ER - indicates end of input (end of run)

CROSS-SECTION DEFINITION

Header Records

XS - regular valley section
BR - bridge-opening section
SD - spur dike section
XR - road grade section
AS - approach section
CV - culvert section
XT - template section

Cross-sectional Geometry Data

GR - x,y coordinates of ground points in a cross section (some exceptions at bridges, spur dikes, roads, culverts, and in data propagation)

Roughness Data

N - roughness coefficients (Manning's n-values)
SA - x-coordinates of subarea breakpoints in a cross section
ND - depth breakpoints for vertical variation of N values

Flow Length Data

FL - flow lengths and/or friction slope averaging technique

Bridge Section Data (M-mandatory: O-optional)

DESIGN MODE (no GR data)	FIXED GEOMETRY MODE (GR data)
BL - bridge length, location(M)	CD - bridge opening type (M)
BD - bridge deck parameters M)	AB-abutment toe elev. (M-Type 2)
AB - abutment slopes (M-Type 3)	PW - pier or pile data (0)
CD - bridge opening type (M)	KD - conveyance breakpoints (0)
PW - pier or pile data (0)	

KD - conveyance breakpoints (0)

Approach Section Data

BP - horizontal datum correction between bridge and approach sections

Template Geometry Propagation

GT - replaces GR data when propagating template section geometry

Table B.2 - Definition of Output Variables

VARIABLE	DEFINITION
ALPH	Velocity head correction factor
AREA	Cross-section area
BETA	Momentum correction factor
BLEN	Bridge opening length
C	Coefficient of discharge
CAVG	Average weir coefficient
CK	Contraction loss coefficient (0.0 default)
CRWS	Critical water-surface elevation
DAVG	Average depth of flow over roadway
DMAX	Maximum depth of flow over roadway
EGL	Energy grade line
EK	Expansion loss coefficient (0.5 default)
ERR	Error in energy/discharge balance
FLEN	Flow distance
FLOW	Flow classification code
FR#	Froude number
HAVG	Average total head
HF	Friction head loss
HO	Minor head losses (expansion/contraction)
K	Cross-section conveyance
KQ	Conveyance of Kq-section
LEW	Left edge of water or left edge of weir
LSEL	Low steel (submergence) elevation
M(K)	Flow contraction ratio (conveyance)
M(G)	Geometric contraction ratio (width)
OTEL	Road overtopping elevation
PPCD	Pier or pile code
P/A	Pier area ratio
Q	Discharge
REW	Right edge of water or right edge of weir
SKEW	Skew of cross section
SLEN	Straight-line distance
SPLT	Stagnation point, left
SPRT	Stagnation point, right
SRD	Section reference distance
TYPE	Bridge opening type
VAVG	Average velocity
VMAX	Maximum velocity
VEL	Velocity
VHD	Velocity head
WLEN	Weir length
WSEL	Water-surface elevation
XLAB	Abutment station, left toe
XRAB	Abutment station, right toe

XLKQ	Left edge of Kq-section
XRKQ	Right edge of Kq-section
XMAX	Maximum station in cross section
XMIN	Minimum station in cross section
XSTW	Cross-section top width
XSWP	Cross-section wetted perimeter
YMAX	Maximum elevation in cross section
YMIN	Minimum elevation in cross section

B.3 Example 1 - Single Opening Bridge

Given: A normal, single-opening bridge is to be constructed at the cross section shown in Figure B.1 which shows the subsections and roughnesses. The average stream slope in the vicinity of the bridge is 0.00052 ft/ft. The bridge opening begins at station 230 and ends at station 430 for a total bridge opening length of 200 ft. It has vertical abutments and embankments (Type 1) and a bridge deck elevation of 35.0 ft with a low steel elevation of 32.0 ft. There are three bridge piers with a spacing of 50 ft and a width of 3 ft. No overtopping is allowed.

Find: For discharges of 5000, 10000, 15000, 20000, and 25000 cfs, calculate the backwater caused by the bridge and the mean velocity at the bridge section.

Soln.: The input data records are shown in Table B.3. All five discharges are entered in the Q record for a single computer run. The starting water surface elevation is obtained by the slope-area method which is indicated by the slope of 0.00052 on the SK record. The exit cross section is located at station 1000 ft, and the ground points shown in Figure B.1 are entered in the GR records. This single cross section is propagated upstream in this example. The BD record inputs a bridge girder depth of 3.0 ft and a bridge deck elevation of 35 ft to give a low steel elevation (LSE) of 32 ft. The bridge length of 200 ft beginning at x-230 ft and ending at x-430 ft is given in the BL record. The elevations at the bottom of the piers and their cumulative widths are shown in the PW record. Finally, the CD record indicates a Type 1 bridge opening and a 40-ft bridge width.

Sample output is shown in Table B.4 for Q-20000 cfs. Input data echo has been suppressed for brevity. First, the water surface elevations for the unconstricted flow are given at the exist, full-valley, and approach sections. These results are followed by the water surface elevations at the bridge section and the approach section for constricted flow. The critical water surface elevations and Froude numbers at the bridge and approach sections both indicate subcritical flow at these sections. Therefore, the flow is Type I as shown in Figure 10-2. The backwater of 1.09 ft is obtained by subtracting the unconstricted water surface elevation at the approach section from the corresponding constricted value (29.33-28.24). The bridge opening velocity is 8.36 ft/s, and the approach velocity is 3.17 ft/s. Note that the flow is Class 1 which is free surface flow through the bridge opening without embankment overtopping.

Figure B.1 Example 1 Cross Section

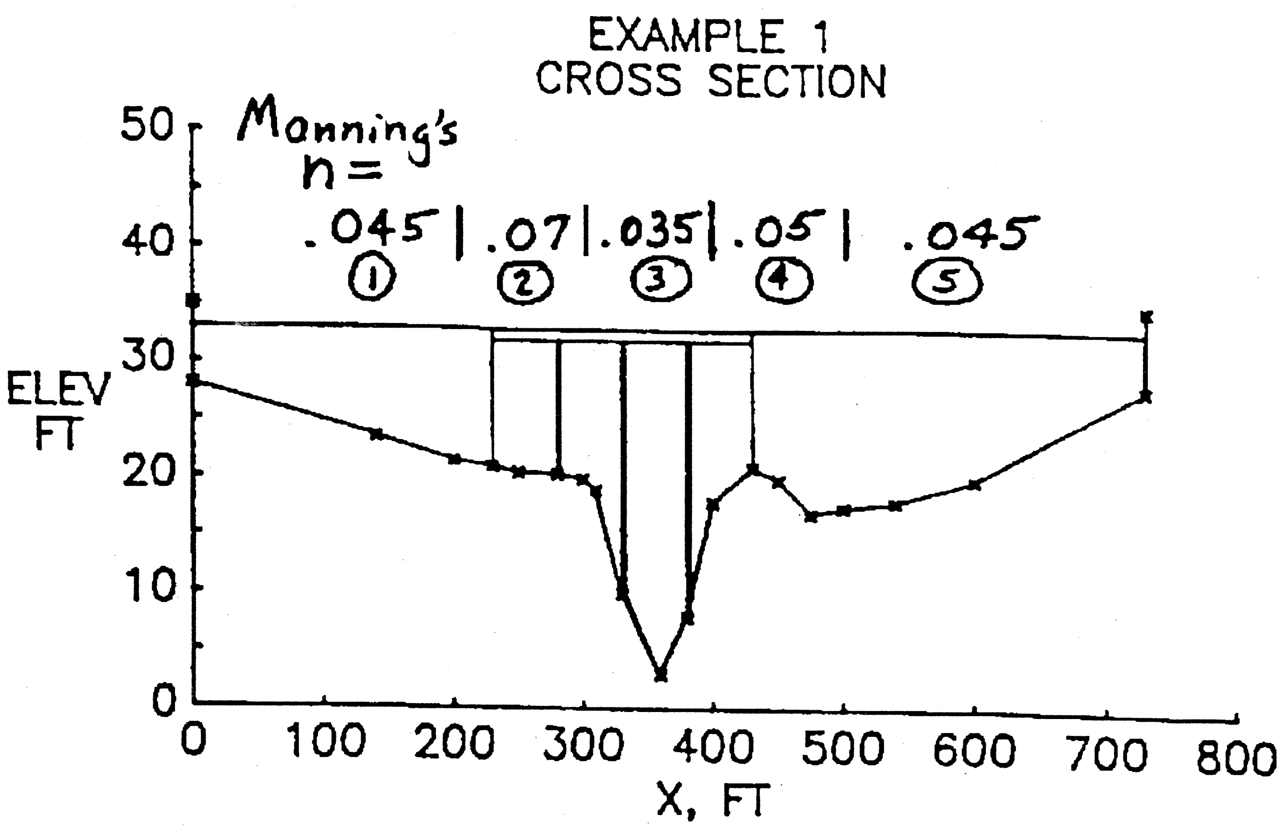


TABLE B.3 - INPUT DATA FOR EXAMPLE 1

```
T1        EXAMPLE 1 - NORMAL BRIDGE CROSSING
T2     BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3     BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS *
Q         5000   10000 15000  20000   25000
SK     .00052 .00052      .00052 .00052 .00052
*
XS   EXIT 1000
GR       0,35.0 0,28.0 140,23.5 200,21.5
GR       230,21.0 250,20.5 280,20.4 300,20.0
GR       310,19.0 330,10.0 360,3.0  380,8.0
GR       400,18.0 430,21.0 450,20.0 475,17.0
GR       500,17.5 540,18.0 600,20.0 730,28.0
GR       730,35.0
N        0.045 0.07 0.035 0.045
SA          200   300   430
XS   FULV 1200   *     *     * 0.00052
*
BR   BRGE 1200
BD       3.0   35.0
BL       200    230    430
PW        8.0,3.0     10.0,3.0     10.0,6.0     20.4,6.0     20.4,9.0
CD             1         40
N        0.035
*
AS   APPR 1440
EX
ER
```

TABLE B.4 - OUTPUT FOR EXAMPLE 1

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1 - NORMAL BRIDGE CROSSING
        BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-04-90  08:31

 XSID:CODE   SRDL    LEW      AREA X-X EGL    CRWS       Q   WSEL
       SRD   FLEN    REW         K X-X ERR     FR#     VEL

EXIT :XS   ******     0.    5500.   28.34   21.89  20000.  27.99
     1000. ******   730.  876788. *******     .31    3.64
FULV :FV     200.     0.    5509.   28.46 *******  20000.  28.11
     1200.   200.   730.  878463.    .01      .30    3.63
   <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     240.     0.    5517.  28.59 *******  20000.   28.24
     1440.   240.   730.  880145.    .01     .30    3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

         <<<<<RESULTS THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW      AREA X-X EGL    CRWS      Q   WSEL
       SRD   FLEN    REW         K X-X ERR     FR#     VEL

BRGE :BR     200.   230.    2394.  29.36   22.55  20000.   27.41
     1200.   200.   430.  502576.  .00      .57    8.36

     TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
       1.   0.   1.    .746    .055    32.00    200.    230.    430.

 XSID:CODE   SRDL    LEW      AREA X-X EGL    CRWS      Q   WSEL
       SRD   FLEN    REW         K X-X ERR     FR#     VEL

APPR :AS     200.     0.    6311.   29.59   22.12  20000. 29.33
     1440.   219.   730. 1055081.    .00      .24    3.17

       M(G)   M(K)       KQ   XLKQ    XRKQ    OTEL
       .726   .396  636504.   245.    445.    29.26

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

B.4 Examples 1A, 1B - Adjusted Bridge Lengths

Given: The bridge length in Example 1 has been changed first to 250 ft and then to 150 ft with 4 piers and 2 piers, respectively, to maintain the 50-ft pier spacing. The abutment stations are XLAB-230 ft; XRAB-480 ft for the 250-ft opening length and XLAB-280 ft; XRAB-430 ft for the 150-ft length. All other parameters are the same as in Example 1.

Find: Bridge backwater and constriction velocity for Q-5000, 10000, 15000, 20000, and 25000 cfs.

Soln.: The input data records and output are shown for Q-20000 cfs in Tables B.5 and B.6 for L-250 ft and in Tables B.7 and B.8 for L-150 ft. The only changes in the input are in the BL and PW records, and in the longitudinal stations for the full-valley, bridge, and approach sections according to the definitions in Figure 10-3.

The backwater h1* for the five discharges and bridge opening lengths of 150, 200, and 250 ft are compared in Figure B.2. It can be observed that the backwater values increase at an increasing rate as the head losses become substantial at the higher discharges. The mean velocity in the bridge section for the same three bridge opening lengths is shown in Figure B.3 The velocities range generally between 5 and 10 ft/s for the discharges shown. It can be observed in Table B.6 that the flow is to Type I for all three opening lengths because the water surface elevation (WSEL) at each cross section is above the critical water surface elevation (CRWS). The flow through the bridge opening can also be categorized as Class 1 because it is free surface flow with no overtopping at the bridge section.

TABLE B.5 - INPUT DATA FOR EXAMPLE 1A

```
T1      EXAMPLE 1A - NORMAL BRIDGE CROSSING
T2      BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-480 FT; FOUR 3-FT PIERS
*
Q       5000   10000  15000  20000  25000
SK       .00052 .00052 .00052 .00052  .00052
*
XS   EXIT 1000
GR       0,35.0 0,28.0 140,23.5 200,21.5
GR        230,21.0 250,20.5       280,20.4 300,20.0
GR        310,19.0 330,10.0       360,3.0  380,8.0
GR        400,18.0 430,21.0       450,20.0 475,17.0
GR        500,17.5 540,18.0       600,20.0 730,28.0
GR        730,35.0
N       0.045  0.07 0.035 0.045
SA           200   300   430
*
XS   FULV 1250   *     *     * 0.00052
*
BR   BRGE 1250
BD        3.0   35.0
BL       250   230   480
PW        8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
PW        21.0,9.0   21.0,12.0
CD        1   40
N       0.035
*
AS   APPR 1540
EX
ER
```

TABLE B.6 - OUTPUT FOR EXAMPLE 1A

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1A - NORMAL BRIDGE CROSSING
        BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-480 FT; FOUR 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  07:06

 XSID:CODE   SRDL    LEW     AREA X-X EGL    CRWS     Q   WSEL
      SRD    FLEN    REW        K X-X ERR     FR#    VEL

EXIT :XS   ******     0.    5500.   28.34   21.89 20000.   27.99
     1000. ******   730.  876788. *******     .31   3.64

FULV :FV     250.     0.    5508.  28.48 ******* 20000.   28.13
     1250.   250.   730.  878425.   .01      .30   3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     290.     0.    5516.  28.64 ******* 20000.   28.29
     1540.   290.   730.  880046.  .01      .30    3.63
     <<<<<THE ABOVE RESULTS  "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<RESULTS  THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA X-X EGL    CRWS     Q     WSEL
      SRD    FLEN    REW        K X-X ERR     FR#    VEL

BRGE :BR     250.   230.    2853.   28.98   22.33 20000.   27.64
     1250.   250.   480.  580455.  .00      .48    7.01

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN   XLAB   XRAB
       1.   0.   1.   .756    .054   32.00    250.   230.   480.

 XSID:CODE   SRDL    LEW     AREA X-X EGL    CRWS     Q     WSEL
      SRD    FLEN    REW        K X-X ERR     FR#    VEL

APPR :AS     250.     0.    5973.   29.21   22.18  20000.  28.92
     1540.   265.   730.  978713.  .02      .27    3.35

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .658   .303  680086.   240.   490.    28.82

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

TABLE B.7 - INPUT DATA FOR EXAMPLE 1B

```
T1      EXAMPLE 1B - NORMAL BRIDGE CROSSING
T2      BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-280-430 FT; TWO 3-FT PIERS
*
Q       5000    10000   15000    20000  25000
SK      .00052  .00052  .00052   .00052 .00052
*
XS   EXIT 1000
GR      0,35.0 0,28.0 140,23.5 200,21.5
GR      230,21.0 250,20.5      280,20.4 300,20.0
GR      310,19.0 330,10.0      360,3.0  380,8.0
GR      400,18.0 430,21.0      450,20.0 475,17.0
GR      500,17.5 540,18.0 600,20.0 730,28.0
GR      730,35.0
N       0.045 0.07 0.035 0.045
SA         200  300   430
*
XS   FULV 1150   *     *     * 0.00052
*
BR   BRGE 1150
BD      3.0   35.0
BL      150    280   430
PW      8.0,3.0    10.0,3.0    10.0,6.0
CD      1   40
N       0.035
*
AS   APPR 1340
EX
ER
```

TABLE B.8 - OUTPUT FOR EXAMPLE 1B

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1B - NORMAL BRIDGE CROSSING
        BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-280-430 FT; TWO 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  07:13

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS        Q     WSEL
       SRD   FLEN    REW         K X-XERR     FR#      VEL

EXIT :XS    ******    0.     5500. 28.34   21.89  20000.   27.99
     1000. ******   730.  876788.*******     .31     3.64

FULV :FV     150.     0.     5509. 28.43 *******  20000.   28.08
     1150.   150.   730.  878492. .01      .30     3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     190.     0.     5517.  28.54 *******  20000.   28.19
     1340.   190.   730.  880224. .01      .30     3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW      AREAX-XEGL    CRWS        Q     WSEL
       SRD   FLEN    REW         K X-XERR     FR#      VEL

BRGE :BR     150.   280.     2022. 29.87   22.29  20000.   27.15
     1150.   150.   430.  450837.  .00      .64     9.89

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
       1.   0.   1.   .748   .054   32.00   150.    280.    430.

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS        Q     WSEL
       SRD   FLEN    REW         K X-XERR     FR#      VEL

APPR :AS     150.     0.     6734. 30.08   22.07  20000.   29.86
     1340.   169.   730. 1154573. .01      .22     2.97

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .795   .452  632135.   291.   441.   29.81

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

Figure B.2 Backwater For Examples 1, 1A, 1B With Varying Bridge Opening Length L

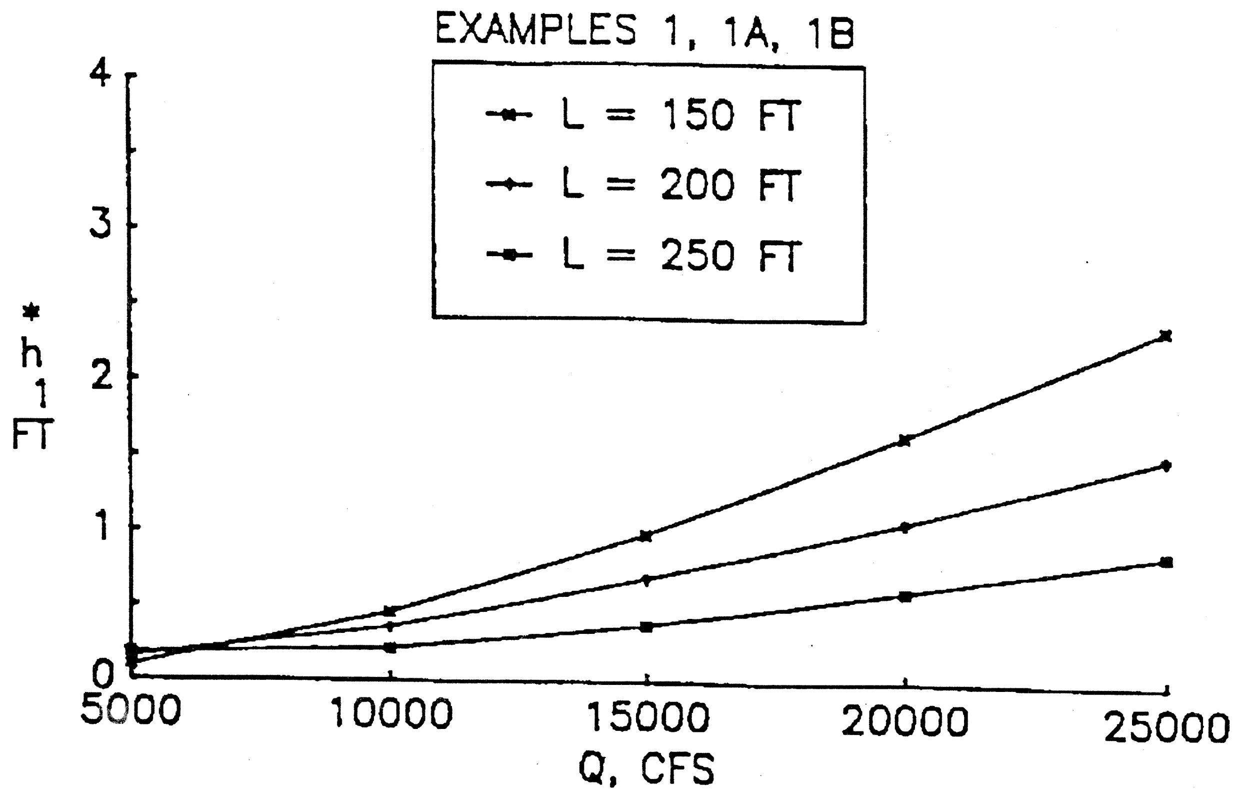
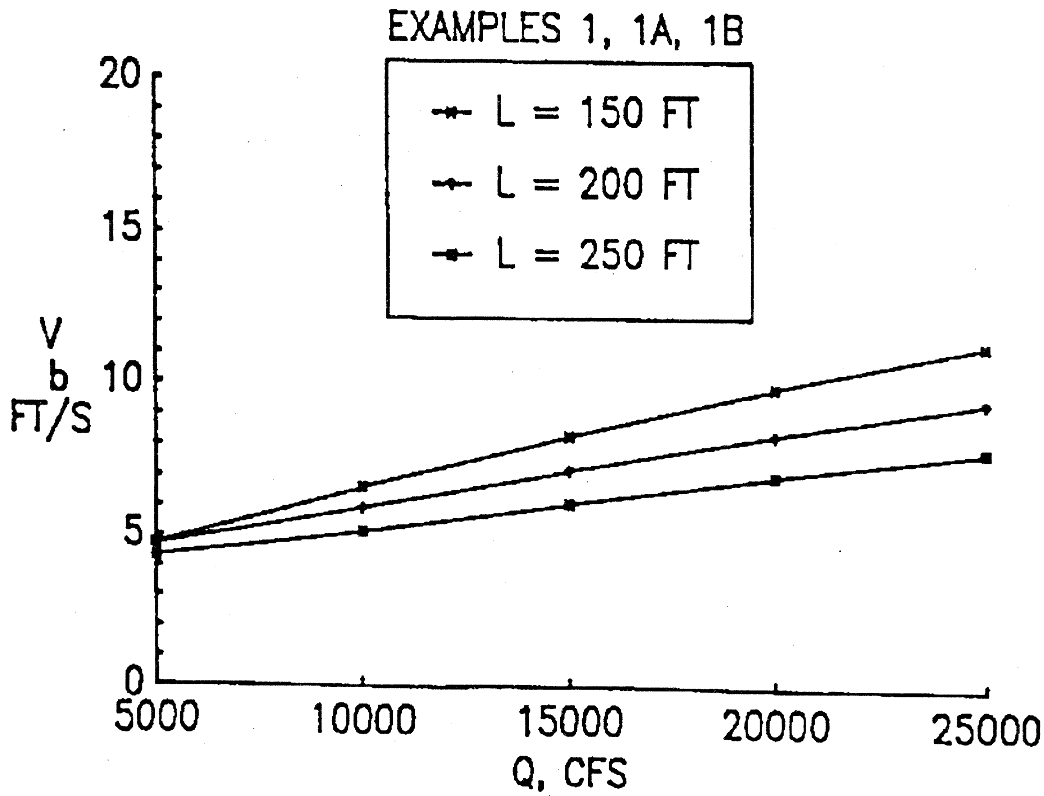


Figure B.3 Bridge Velocity For Examples 1, 1A, 1B With Varying Bridge Opening Length L



B.5 Examples 1C, 1D - Adjusted Valley Slope

Given: For purposes of illustration of flow types, assume that the bed slope has steeper values of 0.0035 ft/ft and 0.0045 ft/ft compared with the previous value of 0.00052 ft/ft. The bridge opening length is 200 ft, and all other variables are the same.

Find: Bridge backwater and constriction velocity for Q-5000, 10000, 15000, 20000, and 25000 cfs.

Soln: The input data records and computer output for Q-20000 cfs are shown in Tables B.9 and B.10, respectively, for slope S-0.0035 and in Tables B.11 and B.12 for S-0.0045. The only changes in the input data occur in the slopes in the SK record to obtain the starting water surface elevation at the EXIT section, and in the slope given in the FULV for data propagation.

The computer results given in Tables B.10 and B.12 clearly show that a greater value of bed slope decreases the normal water surface elevation in comparison to its value in Example 1. The computer output further shows a series of three warning messages for the unconstricted flow computations. These messages are associated with the numerical root search used to computer water surface elevations. The Froude number given in the output FR is not the true Froude number but only a Froude number criterion because it is computed by ignoring the variation of the kinetic energy correction coefficient (alpha) with depth. When FR# exceeds 0.8, WSEL found from the energy balance is rejected and a new root search is started with a reduced increment in depth y (DELTAY) and with a lower limit given by the critical water surface elevation (CRWS) found as the point of minimum specific energy. This is the meaning of messages 125, 110, and 115 which do no invalidate the results for unconstricted flow. They simply warn in this case that the slope is approaching critical slope.

The constricted flow results in Tables B.10 and B.12 indicate the assumption of critical flow at the bridge (BRGE) section because no solution could be found for the energy balance. In this case, choked flow is the reason and critical depth is the correct value in the constricted section. The difference between Examples 1C and 1D can be seen by comparing the normal water surface elevation (WSEL) at the full-valley (FULV) section with the critical water surface elevation (CRWS) at the bridge (BRGE) section. In Table B.10, CRWS < WSEL for a slope of 0.0035 and we have Type IIA flow. The results in Table B.12 for S-0.0045, however, show that CRWS < WSEL and the flow type is IIB. Choked flow and critical depth at the bridge section occur in both cases.

The backwater for Examples 1C and 1D is compared with that in Example 1 in Figure B.4. Choking does not occur for Q-5000 and 10000 cfs but does occur for the higher flows and results in a dramatic increase in the backwater at these flows compared with Example 1. The bridge velocity is shown in Figure B.5 and it is larger at all discharges because of the increased slope.

TABLE B.9 - INPUT DATA FOR EXAMPLE 1C

```
T1      EXAMPLE 1C - NORMAL BRIDGE CROSSING
T2      BED SLOPE -0.0035; LSE-32.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
*
Q       5000   10000   15000    20000   25000
SK       .0035  .0035   .0035    .0035   .0035
*
XS   EXIT 1000
GR       0,35.0 0,28.0 140,23.5 200,21.5
GR       230,21.0 250,20.5 280,20.4 300,20.0
GR       310,19.0 330,10.0 360,3.0  380,8.0
GR       400,18.0 430,21.0 450,20.0 475,17.0
GR       500,17.5 540,18.0 600,20.0 730,28.0
GR       730,35.0
N       0.045 0.07 0.035 0.045
SA          200  300   430
XS   FULV 1200   *     *     * 0.0035
*
BR   BRGE 1200
BD       3.0   35.0
BL       200    230   430
PW       8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
CD       1   40
N       0.035
*
AS   APPR 1440
EX
ER
```

TABLE B.10 - OUTPUT FOR EXAMPLE 1C

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1C - NORMAL BRIDGE CROSSING
        BED SLOPE -0.0035; LSE-32.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  07:24

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K X-XERR     FR#     VEL

EXIT :XS   ******   157.    2413.  24.64   21.89  20000.   22.93
     1000. ******   648.  337991.*******     .83    8.29

 ===125 FR# EXCEEDS FNTEST AT SECID "FULV ":  TRIALS CONTINUED.
       FNTEST,FR#,WSEL,CRWS =   .80     .83     23.65      22.59

 ===110 WSEL NOT FOUND AT SECID "FULV ":  REDUCED DELTAY.
        WSLIM1,WSLIM2,DELTAY =    22.43      35.70     .50

 ===115 WSEL NOT FOUND AT SECID "FULV ":  USED WSMIN = CRWS.
        WSLIM1,WSLIM2,CRWS =    22.43      35.70      22.59

FULV :FV     200.   157.    2421. 25.34   22.59  20000.   23.64
     1200.   200.   648.  339115. .01      .83    8.26
   <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR ":  TRIALS CONTINUED.
        FNTEST,FR#,WSEL,CRWS =.80     .83      24.50      23.43

 ===110 WSEL NOT FOUND AT SECID "APPR ":  REDUCED DELTAY.
        WSLIM1,WSLIM2,DELTAY =    23.14      36.54     .50

 ===115 WSEL NOT FOUND AT SECID "APPR ":  USED WSMIN = CRWS.
        WSLIM1,WSLIM2,CRWS =    23.14      36.54      23.43

APPR :AS     240.   156.    2426. 26.19   23.43  20000.   24.49
     1440.   240.   648.  339910. .01      .83    8.24
    <<<<<ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A_S_S_U_M_E_D !!!!!
       SECID "BRGE "     Q,CRWS =   20000.        23.18
```

```
              <<<<<RESULTS THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW        K X-XERR     FR#     VEL

BRGE :BR      200.    230.    1429. 26.86   23.18  20000.   23.18
     1200.    200.    430.  219119.*******    1.02   14.00

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
       1.   0.   1.   .910    .065   32.00    200.    230.    430.

 XSID:CODE    SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW        K X-XERR     FR#     VEL

APPR :AS      200.    74.     3905. 27.85   23.43  20000.   27.16
     1440.    211.    691.  584413..01       .47    5.12

       M(G)    M(K)       KQ   XLKQ   XRKQ    OTEL
       .593    .295  411701.   234.   434.   26.93

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

TABLE B.11 - INPUT DATA FOR EXAMPLE 1D

```
T1      EXAMPLE 1D - NORMAL BRIDGE CROSSING
T2      BED SLOPE -0.0045; LSE-32.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
*
Q       5000   10000   15000   20000  25000
SK      .0045  .0045   .0045   .0045  .0045
*
XS   EXIT 1000
GR      0,35.0 0,28.0 140,23.5 200,21.5
GR      230,21.0 250,20.5 280,20.4 300,20.0
GR      310,19.0 330,10.0 360,3.0  380,8.0
GR      400,18.0 430,21.0 450,20.0 475,17.0
GR      500,17.5 540,18.0 600,20.0 730,28.0
GR      730,35.0
N       0.045 0.07 0.035 0.045
SA         200  300   430
*
XS   FULV 1200   *     *     * 0.0045
*
BR   BRGE 1200
BD      3.0  35.0
BL      200    230   430
PW      8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
CD      1   40
N       0.035
*
AS   APPR 1440
EX
ER
```

TABLE B.12 - OUTPUT FOR EXAMPLE 1D

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1D - NORMAL BRIDGE CROSSING
        BED SLOPE -0.0045; LSE-32.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  07:28

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

EXIT :XS   ******   174.    2150. 24.48   21.89  20000.   22.38
     1000. ******   639.  297888.*******     .95    9.30

 ===125 FR# EXCEEDS FNTEST AT SECID "FULV ":  TRIALS CONTINUED.
        FNTEST,FR#,WSEL,CRWS = .80     .94      23.33       22.79

 ===110 WSEL NOT FOUND AT SECID "FULV ":  REDUCED DELTAY.
        WSLIM1,WSLIM2,DELTAY =    21.88      35.90     .50

 ===115 WSEL NOT FOUND AT SECID "FULV ":  USED WSMIN = CRWS.
        WSLIM1,WSLIM2,CRWS =    21.88      35.90      22.79

FULV :FV     200.   173.    2158. 25.38   22.79  20000.   23.29
     1200.   200.   639.  299046. .01      .95    9.27
  <<<<<THE ABOVE RESULTS  "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR ":  TRIALS CONTINUED.
        FNTEST,FR#,WSEL,CRWS = .80     .95      24.38       23.87

 ===110 WSEL NOT FOUND AT SECID "APPR ":  REDUCED DELTAY.
        WSLIM1,WSLIM2,DELTAY =    22.79      36.98     .50

 ===115 WSEL NOT FOUND AT SECID "APPR ":  USED WSMIN = CRWS.
        WSLIM1,WSLIM2,CRWS =    22.79      36.98      23.87

APPR :AS     240.   173.    2158. 26.46   23.87  20000.   24.37
     1440.   240.   639.  299046. .01      .95    9.27
      <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A_S_S_U_M_E_D !!!!!
        SECID "BRGE "     Q,CRWS =    20000.       23.39
```

```
         <<<<<RESULTS THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL     LEW      AREA X-XEGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K X-XERR      FR#      VEL

BRGE :BR      200.    230.     1431.  27.02    23.39   20000.    23.39
     1200.    200.    430.   219647. *******    1.01    13.98

     TYPE PPCD FLOW      C      P/A     LSEL     BLEN    XLAB     XRAB
       1.   0.   1.   .915     .067    32.00     200.    230.     430.

 XSID:CODE    SRDL     LEW      AREA X-XEGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K X-XERR      FR#      VEL

APPR :AS      200.     84.     3712. 28.05    23.87   20000.    27.29
     1440.    210.    686.   550811.  .01      .50     5.39

       M(G)   M(K)         KQ    XLKQ    XRKQ     OTEL
       .571   .285    393505.    233.    433.     27.02

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

Figure B.4 Backwater For Flow Types I, IIA, IIB

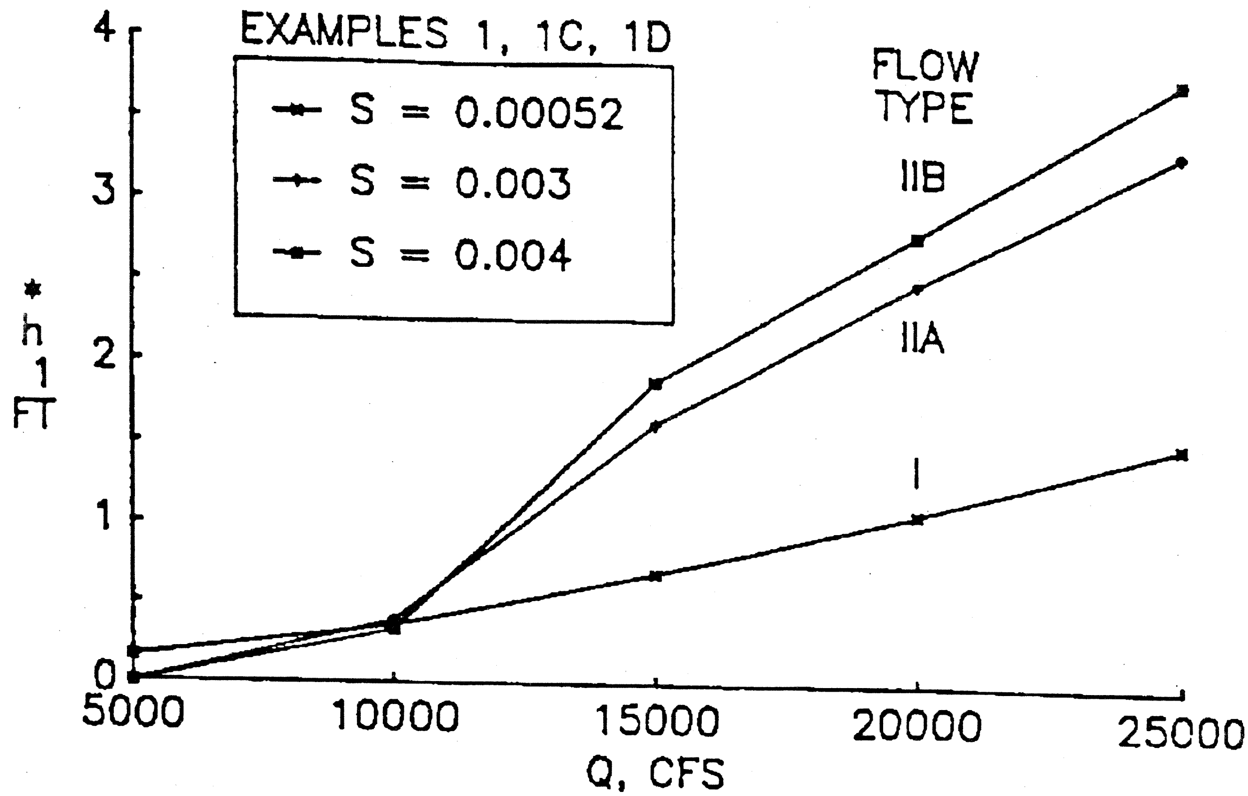
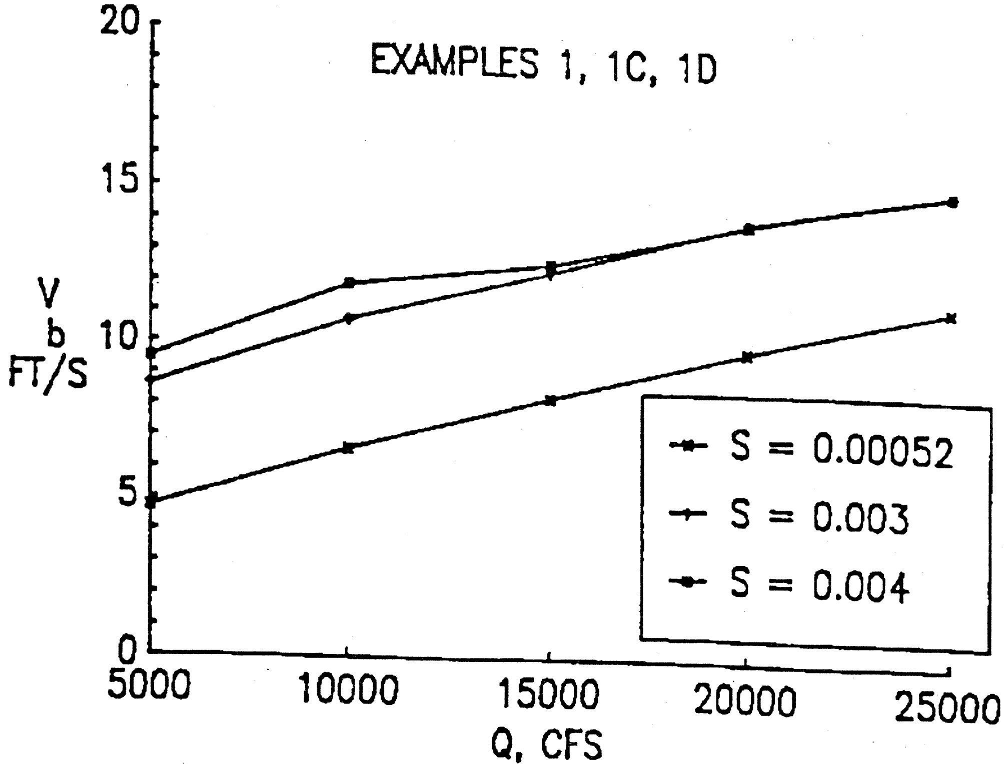


Figure B.5 Bridge Velocity For Flow Types I, IIA, IIB



B.6 Example 1E - Pressure Flow

Given: The low steel elevation (LSE) of the bridge deck has been lowered from 32 ft to 28 ft. The Type 1 bridge opening length is 200 ft and the bed slope is 0.00052 ft as in Example 1.

Find: Bridge backwater and construction velocity for Q = 5000, 10000, 15000, 20000, and 25000 cfs.

Soln.: The input data are given in Table B.13, and the output is shown in Table B. 14. Discharges of 5000 and 10000 cfs are not included in the input data in Table B.13 because it was apparent that no change would occur in the results for these discharges. No road embankment data (XR) are included so overtopping is not allowed. The results for 20000 cfs in Table B.14 show that the flow regime changes from free surface flow (Class 1) to submerged orifice flow (Class 3). The same is true for Q = 25000 cfs but not for Q = 15000 cfs as shown in Figure B.6. The backwater for submerged orifice flow is obviously considerably greater than for free surface flow, and the situation becomes worse as the discharge increases. The effect on bridge velocities is less noticeable as shown in Figure B.7 because the bridge opening has completely filled.

TABLE B.13 - INPUT DATA FOR EXAMPLE 1E

```
T1      EXAMPLE 1E - NORMAL BRIDGE CROSSING
T2      BED SLOPE -0.00052;LSE-28.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
*
Q       5000    10000    15000    20000   25000
SK      .00052  .00052   .00052   .00052  .00052
*
XS   EXIT 1000
GR      0,35.0 0,28.0 140,23.5 200,21.5
GR      230,21.0 250,20.5 280,20.4 300,20.0
GR      310,19.0 330,10.0 360,3.0 380,8.0
GR      400,18.0 430,21.0 450,20.0 475,17.0
GR      500,17.5 540,18.0 600,20.0 730,28.0
GR      730,35.0
N       0.045 0.07 0.035 0.045
SA         200  300   430
XS   FULV 1200   *    *    * 0.00052
*
BR   BRGE 1200
BD      3.0   31.0
BL      200    230   430
PW      8.0,3.0 10.0,3.0 10.0,6.0  20.4,6.0 20.4,9.0
CD      1   40
N       0.035
*
AS   APPR 1440
EX
ER
```

TABLE B.14 - OUTPUT FOR EXAMPLE 1E

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1E - NORMAL BRIDGE CROSSING
        BED SLOPE -0.00052;LSE-28.0 FT; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  08:24

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K X-XERR     FR#     VEL

EXIT :XS    ******    0.     5500.  28.34   21.89  20000.   27.99
     1000. ******   730.   876788. *******    .31    3.64

FULV :FV     200.     0.     5509. 28.46 ******* 20000.   28.11
     1200.   200.   730.   878463.  .01      .30    3.63
      <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     240.     0.     5517. 28.59 ******* 20000.   28.24
     1440.   240.   730.   880145. .01      .30    3.63
     <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                          WS3N,LSEL =    28.11        28.00

              <<<<<RESULTS THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K X-XERR     FR#     VEL

BRGE :BR     200.   230.     2375. 29.15   22.64  20379.   28.00
     1200. ******   430.   352447.******     .44    8.58

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
       1.   0.   3.   .800   .054   28.00   200.    230.    430.

 XSID:CODE   SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K X-XERR     FR#     VEL

APPR :AS     200.     0.     6717. 30.11   22.12  20000.   29.89
     1440.   219.   730.  1150572. .02      .22    2.98

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******    29.83

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

Figure B.6 Backwater Effects Of Low Steel

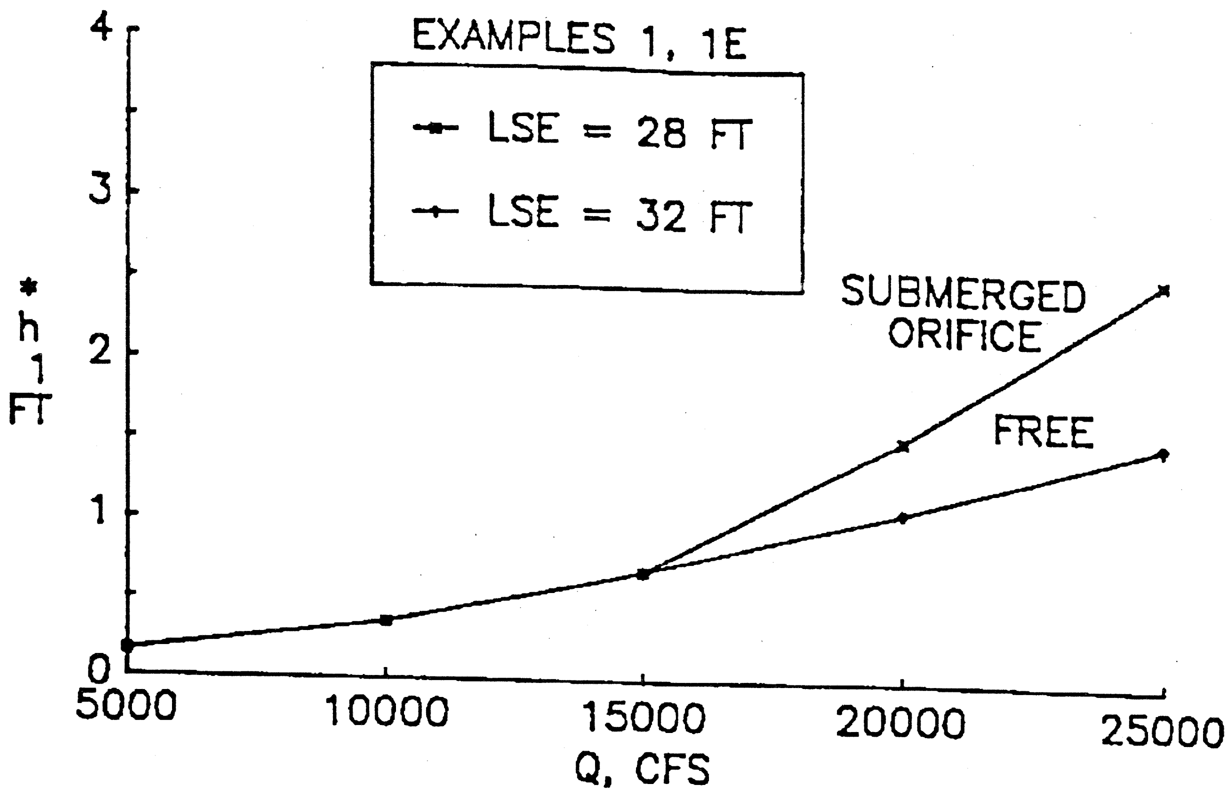
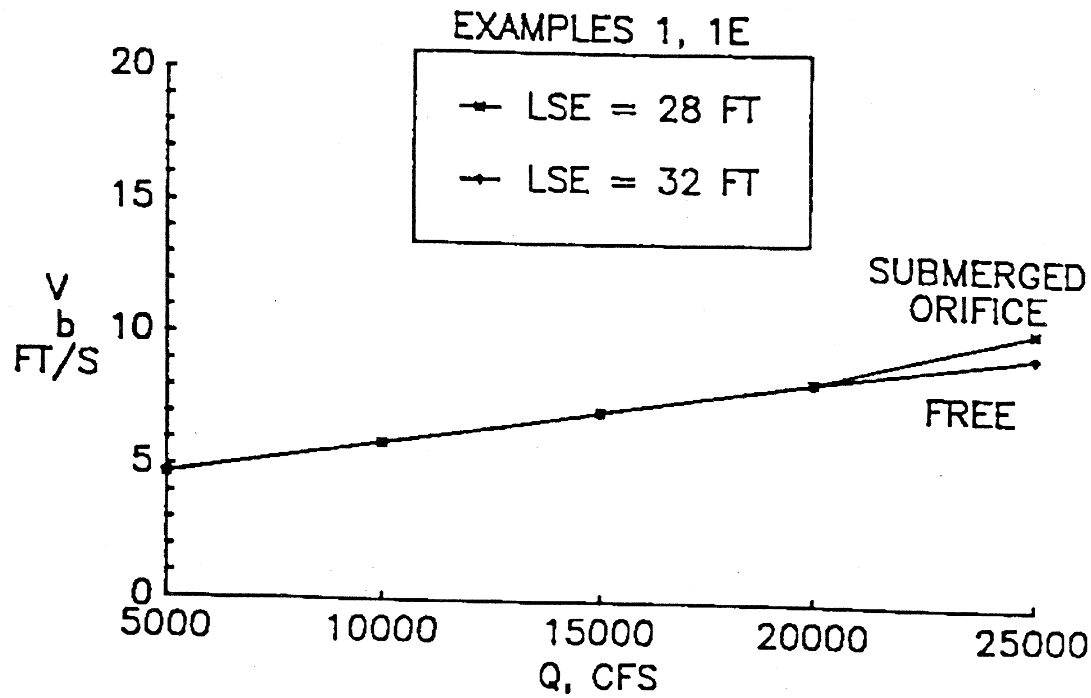


Figure B.7 Bridge Velocity Effects Of Low Steel



B.7 Example 1F - Multiple Openings

<u>Given:</u> An additional bridge opening is proposed from x-475 ft to 525 ft to augment the 200 ft length of Example 1. The bridge is still Type 1 with vertical embankments and abutments and no overflow for each opening, but it is classified now as a multiple-opening bridge and is shown in Figure B.8.

<u>Find:</u> Backwater for Q-5000, 10000, 15000, 20000, and 25000 cfs.

<u>Soln:</u> The input data shown in Table B.15 have an additional set of bridge data records (BRGR) immediately following the main bridge records (BRGM) and at the same longitudinal station. Note that the approach section is located at station 1440 ft as before in order to satisfy the requirement of being one bridge width upstream for the largest opening width. The output in Table B.16 is somewhat more extensive than in previous examples because of the trail-and-error process of splitting the flow between the two openings. Iterations are continued until the apportioned discharge between the two openings agrees with the conveyance-weighted water surface elevation at the upstream approach section within an acceptable tolerance on two successive iterations. Table B.16 gives a final result, for example, of 16949 cfs through the main opening and 3051 cfs through the auxiliary opening for a total Q of 20000 cfs and a conveyance-weighted water surface elevation of 28.60 ft at the approach (APPR) section. In Figure B.9 the complete backwater results are compared with the equivalent single-opening results of Example 1A which had a single-opening width of 250 ft. There is some reduction in the backwater values for all discharges for the multiple-opening bridge presumably because of a more uniform flow distribution and less contraction in the approach flow.

Figure B.8 Example 1F Cross Section For Multiple Bridge Opening

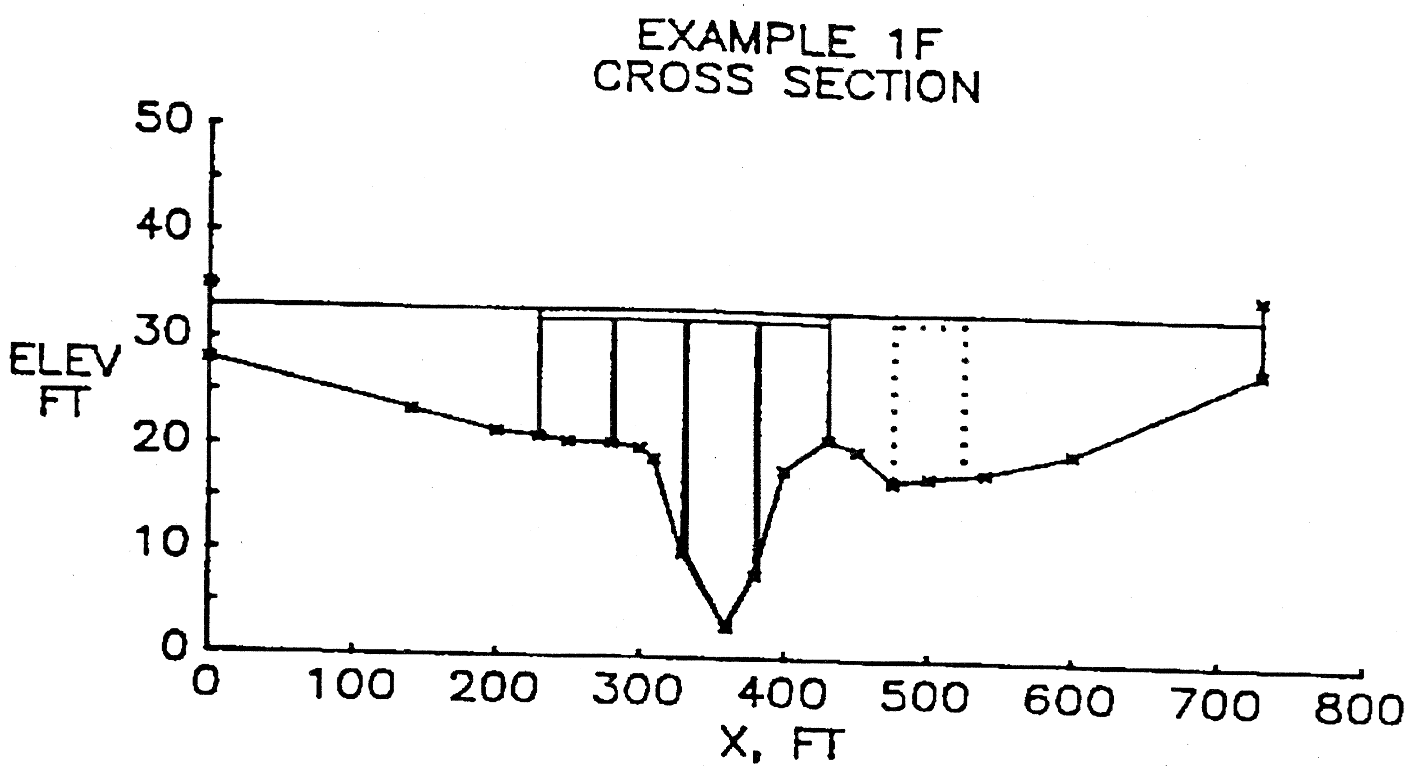


Figure B.9 Backwater For Multiple vs. Single Bridge Opening

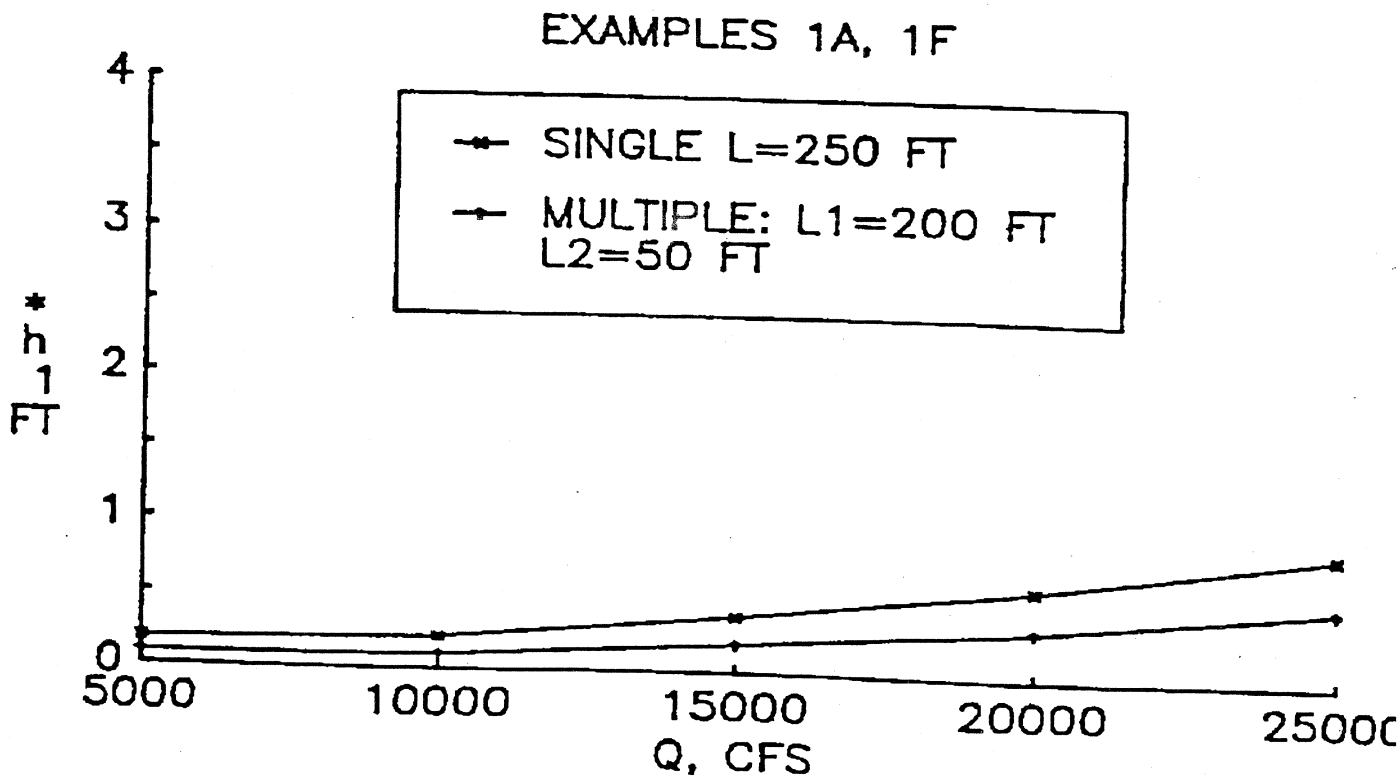


TABLE B.15 - INPUT DATA FOR EXAMPLE 1F

```
T1      EXAMPLE 1F - NORMAL BRIDGE CROSSING
T2      SLOPE -0.00052;MULTIPLE OPENINGS; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-430 FT; 475-525 FT
*
Q       20000  25000
SK      .00052  .00052
*
XS   EXIT 1000
GR      0,35.0 0,28.0 140,23.5 200,21.5
GR      230,21.0 250,20.5 280,20.4 300,20.0
GR      310,19.0 330,10.0 360,3.0 380,8.0
GR      400,18.0 430,21.0 450,20.0 475,17.0
GR      500,17.5 540,18.0 600,20.0 730,28.0
GR      730,35.0
N       0.045 0.07 0.035 0.045
SA          200  300   430
*
XS   FULV 1200   *     *     * 0.00052
*
BR   BRGM 1200
BD      3.0   35.0
BL      200    230   430
PW      8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
CD      1   40
N       0.035
*
BR   BRGR 1200
BD      3.0   35.0
BL      50    475    525
CD      1     40
N       0.035
*
AS   APPR 1440
EX
ER
```

TABLE B.16 - OUTPUT DATA FOR EXAMPLE 1F

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1F - NORMAL BRIDGE CROSSING
        SLOPE -0.00052;MULTIPLE OPENINGS; NO OVERTOPPING
        BRIDGE OPENING (TYPE 1): X-230-430 FT; 475-525 FT
           *** RUN DATE & TIME: 06-01-90  08:31

 XSID:CODE    SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW         K X-XERR     FR#     VEL

EXIT :XS    ******     0.     5500. 28.34   21.89  20000.   27.99
     1000. ******    730.  876788. *******     .31    3.64

FULV :FV      200.     0.     5509. 28.46 ******* 20000.   28.11
     1200.    200.   730.  878463. .01       .30    3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS      240.     0.     5517. 28.59 ******* 20000.   28.24
     1440.    240.   730.  880145.  .01       .30     3.63
   <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 XSID:CODE    SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW         K X-XERR     FR#     VEL

BRGM :BR      200.   230.     2470. 28.84   21.82  16937.   27.79
     1200.    200.   430.  528407. .00       .41    6.86

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       1.   0.    1.   .836   .055   32.00    200.    230.    430.

 XSID:CODE    SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW         K X-XERR     FR#     VEL

SLICE:AS      200.     0.     3819. 29.02   21.36  16937.   28.51
     1440.    206.   467.  777117.  .01       .35     4.43

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
       .572   .164  648503.   231.   431.    28.42

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>


         <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW         K X-XERR     FR#     VEL

BRGR :BR       50.   475.      514. 28.75   22.44   3063.   27.84
     1200.     50.   525.   82166. .00       .42    5.96

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       1. ****    1.   .780 ******   32.00     50.    475.    525.

 XSID:CODE    SRDL    LEW      AREA X-XEGL    CRWS       Q    WSEL
       SRD    FLEN    REW         K X-XERR     FR#     VEL



SLICE:AS       50.   467.     1960. 28.87   22.44   3063.   28.84
     1290.     60.   730.  151774.  .00       .10     1.56

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
       .810   .665   50853.   512.   562.    28.82

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

```
===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                "APPR "     KRATIO =  1.67

 XSID:CODE    SRDL     LEW      AREA X-XEGL    CRWS        Q    WSEL
       SRD    FLEN     REW         K X-XERR     FR#      VEL

APPR :XS      150.    467.     1990. 28.91 *******   3063.   28.87
     1440.    150.    730.   253522. .00       .10    1.54

 XSID:CODE    SRDL     LEW      AREA X-XEGL    CRWS        Q    WSEL
       SRD    FLEN     REW         K X-XERR     FR#      VEL

APPR :XS    ******      0.     5779. 28.92 *******  20000.   28.60
     1440. ******     730.   936265. .36       .28    3.46
```

B.8 Example 1G - Bridge With Embankment Overtopping

Given: The roadway and embankment profile shown in Figure B.10 has been suggested for which some overtopping is expected at higher discharges. From left to right, the roadway profile slopes upward from an elevation of 28 ft to the bridge deck elevation of 31 ft with a low steel elevation of 28 ft. It then slopes back downward to an elevation of 28 ft. The bridge opening is Type 2 with sloping embankments having 3:1 side slopes and vertical abutments. The bridge opening length is 200 ft, and the bed slope is 0.00052 ft/ft as in Example 1.

Find: Backwater for Q-5000, 10000, 15000, 20000, and 25000 cfs.

Soln: The input data in Table B.17 show the addition of an XR and GR data record. The XR record locates the centerline of the roadway at Station 1220 ft with a width of 40 ft. GR record provides stations and corresponding elevations for the roadway profile. These roadway data records immediately follow the bridge data records. Note that the bridge is Type 2 in the CD record with sloping embankments (3:1) and vertical abutments.

The output given in Table B.18 indicates the embankment overflow occurs for a total discharge of 20000 cfs with approximately 900 cfs of overflow. The embankment and bridge deck are treated as a broad-crested weir divided into crest segments with a mean discharge coefficient for each segment. The division of flow between orifice flow (or free-surface flow) and weir flow is determined by iteration. Iteration continues until the approach head satisfies the head-discharge relation for orifice flow (or free-surface flow) through the bridge opening and weir flow over the roadway. The resulting flow in this example is Class 6: submerged orifice flow with embankment overflow.

The results for backwater are given in Figure B.11 and compared with the same bridge (LSE-28 ft) for which no overflow is allowed by eliminating the XR record. Embankment overflow begins at Q-20000 cfs and causes a slight decrease in backwater. In both cases, submerged orifice flow through the bridge opening begins at this discharge. At Q-25000 cfs, however, the backwater is considerably smaller with overflow than without overflow because of the larger proportion of discharge occurring as weir flow as opposed to orifice flow.

Figure B.10 Example 1G Cross Section With Embankment Overtopping

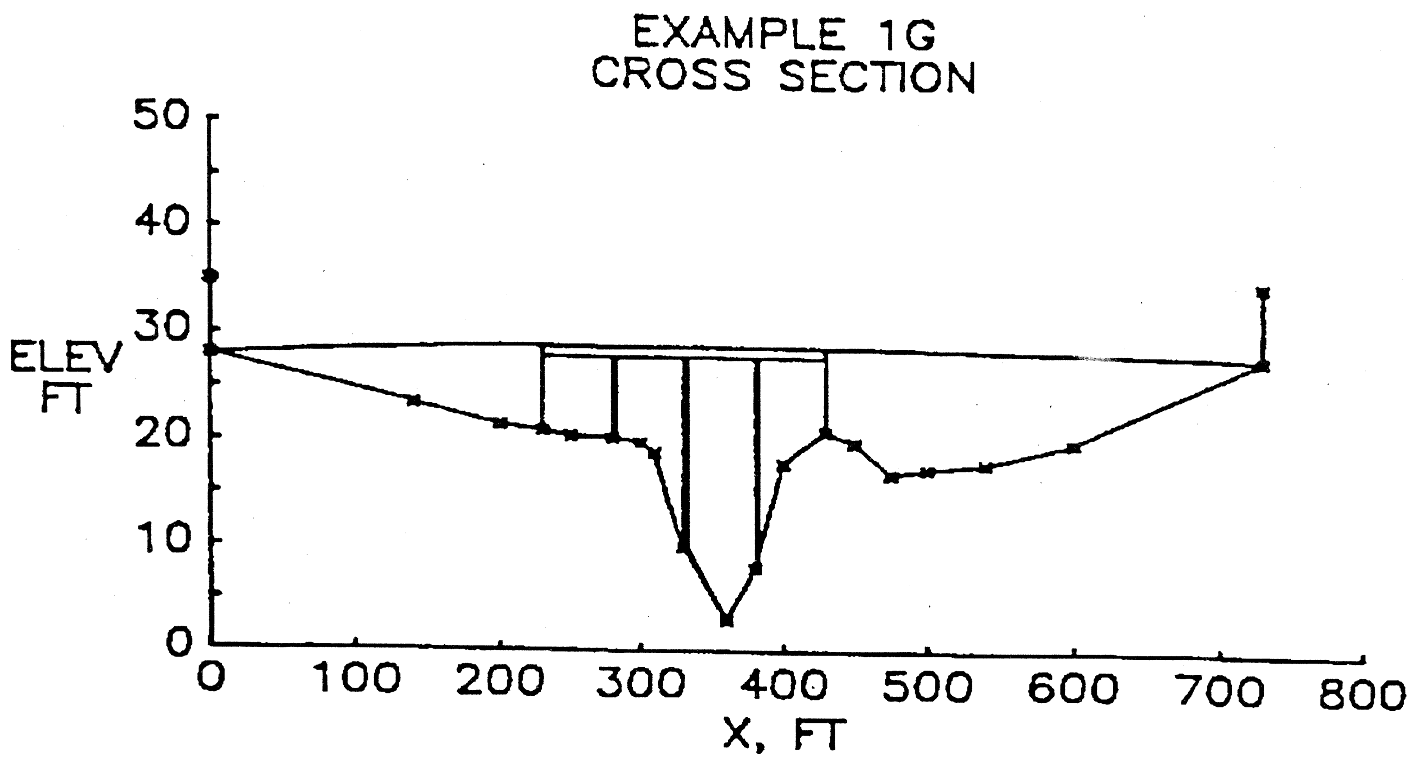


Figure B.11 Backwater Effects Of Embankment Overtopping

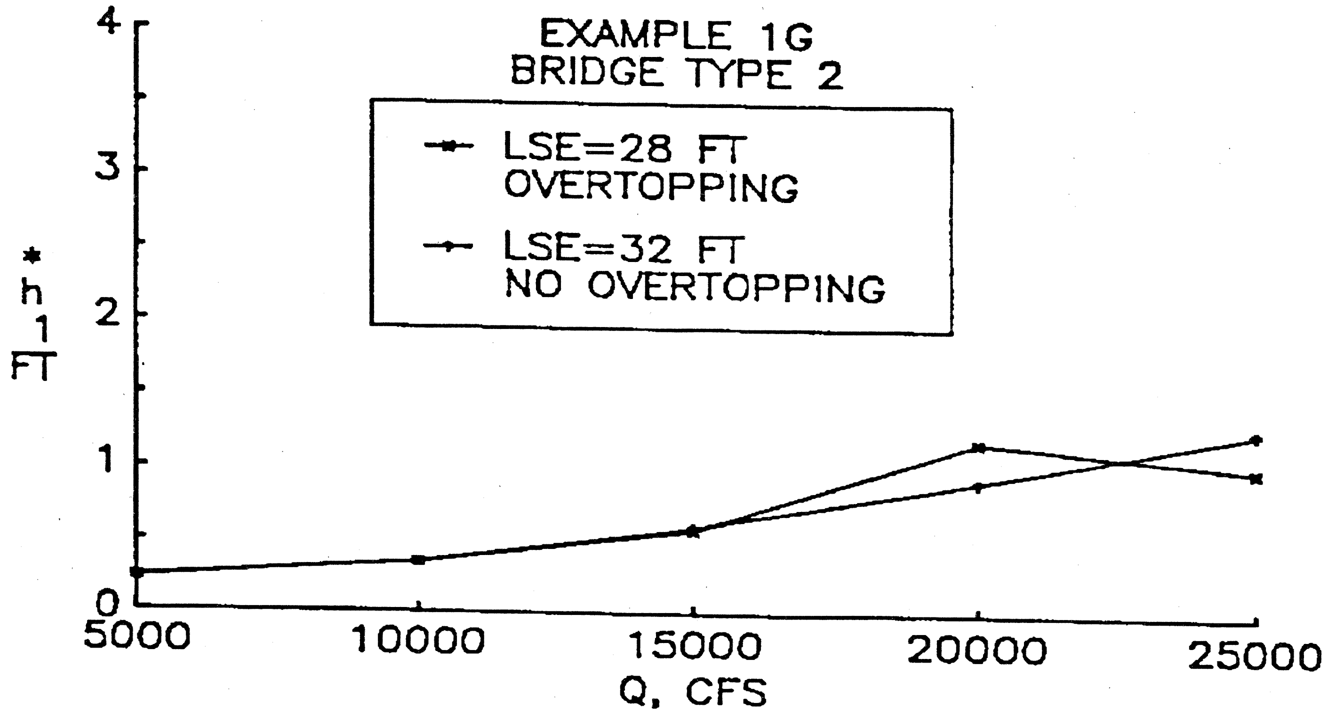


TABLE B.17 - INPUT DATA FOR EXAMPLE 1G

```
T1      EXAMPLE 1G - NORMAL BRIDGE CROSSING
T2      SLOPE -0.00052; EMBANKMENT OVERTOPPING; LSE-28.0 FT
T3      BRIDGE OPENING (TYPE 2): X-230-430 FT; THREE 3-FT PIERS
*
Q       20000  25000
SK       .00052  .00052
*
XS   EXIT 1000
GR       0,35.0 0,28.0 140,23.5 200,21.5
GR       230,21.0 250,20.5 280,20.4 300,20.0
GR       310,19.0 330,10.0 360,3.0 380,8.0
GR       400,18.0 430,21.0 450,20.0 475,17.0
GR       500,17.5 540,18.0 600,20.0 730,28.0
GR       730,35.0
N        0.045 0.07 0.035 0.045
SA           200  300   430
*
XS   FULV 1200   *     *     * 0.00052
*
BR   BRGE 1200
BD       3.0   31.0
BL       200    230   430
PW        8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
CD       2   40     3.0  31
N        0.035
*
XR   ROAD 1220        40
GR       0,28        230,31        430,31      730,28
*
AS   APPR 1440
EX
ER
```

TABLE B.18 - OUTPUT DATA FOR EXAMPLE 1G

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1G - NORMAL BRIDGE CROSSING
        SLOPE -0.00052; EMBANKMENT OVERTOPPING; LSE-28.0 FT
        BRIDGE OPENING (TYPE 2): X-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  08:38

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

EXIT :XS   ******     0.     5500. 28.34   21.89  20000.   27.99
     1000. ******   730.  876788.*******     .31    3.64

FULV :FV     200.     0.     5509. 28.46 *******  20000.   28.11
     1200.   200.   730.  878463. .01       .30     3.63
<<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  APPR :AS     240.     0.    5517. 28.59 *******  20000.   28.24
     1440.   240.   730.  880145.  .01       .30    3.63
<<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =     28.11       28.00

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

BRGE :BR     200.   230.     2375. 29.01   22.36  19161.   28.00
     1200. ******   430.  352447.*******     .41    8.07

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       2.   0.   6.   .800   .054   28.00   200.   230.   430.

    XSID:CODE     SRD   FLEN     HF X-XEGL    ERR       Q    WSEL
   ROAD :RG    1220.   200.   .06 X-X29.84  .00     909.   29.53

               Q    WLEN     LEW    REWX-XVMAX  VAVG  HAVG  CAVG
   LT:     395.   117.      0.    117. 4.7    4.4   1.1   3.0
   RT:     515.   153.    577.    730. 4.7    4.4   1.1   3.0

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

APPR :AS     200.     0.     6555. 29.90   22.12  20000.   29.67
     1440.   219.   730. 1111915.  .00       .23    3.05
```

B.9 Example 1H - Spur Dikes

Given: Spur dikes have been added to the 200-ft single bridge opening. The bridge is Type 3 with sloping embankments and sloping abutments. Embankment side slope is 3:1 while the abutment slope and spur dike side slope are 2:1. The spur dike is 150 ft long and is elliptical with a 60-ft horizontal offset (2). The roadway profile used in Example 1G has been raised by one foot to avoid overtopping. As a result the bridge deck elevation is 32 ft and the low steel elevation is 29 ft. The bed slope is 0.00052 ft as in Example 1.

Find: Backwater and bridge velocity for Q-20000 cfs with and without spur dikes.

Soln: The first difference to note in the input data in Table B.19 is the change in longitudinal stations that results from the sloping abutments. In this case the bridge opening width for the purpose of locating the bridge cross section relative the exit section is defined as the width at mid-depth in the bridge opening and has been found to be 214 ft. In addition, the opening width as given in the BL record is at the top of the abutments and is expected to be greater than or equal to 232 ft. The stations of 230 ft and 430 ft locate the toes of the left and right abutments, respectively. The AB record inputs the abutment and spur dike side slopes as 2:1.

The spur dike data are given in the SD data record following the BR record but preceding the roadway (XR) record. The spur dike is Type 1 (elliptical with no skew) and has a 60-ft lateral offset from the abutment to the mouth of the dikes. The length of the dikes is 150 ft measured from the upstream edge of the 40-ft wide bridge; therefore, the mouth of the dikes has a longitudinal station of 1404 ft. The approach section is 214 ft upstream of the mouth of the dikes at station 1618 ft.

The results given in Table B.20 show a backwater at the approach section of 0.51 ft (28.84-28.34). The spur dike section was then removed from the input data records and the resulting backwater was 0.86 ft. Thus, the spur dike reduces the backwater by improving the approach flow conditions, but its main purpose is reduction of erosion.

TABLE B.19 - INPUT DATA FOR EXAMPLE 1H

```
T1      EXAMPLE 1H - NORMAL BRIDGE CROSSING
T2      SLOPE -0.00052; LSE-29.0 FT; ELLIPTICAL SPUR DIKES (L-150 FT)
T3      BRIDGE (TYPE 3)OPENING: XABUT-230-430 FT; THREE 3-FT PIERS
*
Q       20000
SK      .00052
*
XS   EXIT 1000
GR       0,35.0 0,28.0 140,23.5 200,21.5
GR       230,21.0 250,20.5 280,20.4 300,20.0
GR       310,19.0 330,10.0 360,3.0 380,8.0
GR       400,18.0 430,21.0 450,20.0 475,17.0
GR       500,17.5 540,18.0 600,20.0 730,28.0
GR       730,35.0
N        0.045 0.07 0.035 0.045
SA           200  300   430
*
XS   FULV 1214    *     *     * 0.00052
*
BR   BRGE 1214
BD       3.0   32.0
BL       232   230   430
PW        8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0 20.4,9.0
CD       3   40     3.0  32.0
AB       2
N        0.035
*
SD   SPUR 1404      1      *       60
*
XR   ROAD 1234       40
GR       0,29      230,32        430,32        730,29
*
AS   APPR 1618
EX
ER
```

TABLE B.20 - OUTPUT FOR EXAMPLE 1H

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLE 1H - NORMAL BRIDGE CROSSING
        SLOPE -0.00052; LSE-29.0 FT; ELLIPTICAL SPUR DIKES (L-150 FT)
        BRIDGE (TYPE 3)OPENING: XABUT-230-430 FT; THREE 3-FT PIERS
           *** RUN DATE & TIME: 06-01-90  08:41

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

EXIT :XS   ******     0.    5500. 28.34   21.89  20000.   27.99
     1000. ******   730.  876788. *******     .31    3.64

FULV :FV     214.     0.    5509. 28.46 ******* 20000.   28.11
     1214.   214.   730.  878453.  .01      .30    3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR :AS     404.     0.    5515. 28.68 ******* 20000.   28.33
     1618.   404.   730.  879893. .01      .30    3.63
    <<<<<THE ABOVE RESULTS "NORMAL" (UNCONSTRICTED) FLOW>>>>>
              <<<<<RESULTS THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

BRGE :BR     214.   216.    2561. 28.74   22.62  20000.   27.79
     1214.   214.   444.  534134. .00      .41    7.81

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       3.   0.   1.  1.000   .053   29.00    232.    230.    430.

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

SPUR :SD     150.   155.    3793. 28.96   22.08  20000.   28.53
     1404.   150.   506.  763092.  .01      .28    5.27

    XSID:CODE    SRD   FLEN    HF X-XEGL     ERR       Q    WSEL
   ROAD :RG    1234.   <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA X-XEGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K X-XERR     FR#     VEL

APPR :AS     214.     0.    5884. 29.14   22.22  20000.   28.84
     1618.   233.   730.  959094.  .01      .27    3.40

       M(G)   M(K)       KQ  XLKQ   XRKQ    OTEL
       .687   .355  617602.  238.   459.   28.68
```

B.10 Example 2H - Contraction And Bridge Scour

Given: Consider the single opening bridge (Type 1) with opening length of 200 ft from x-230 ft to x-430 ft as in Example 1 and Q-25000 cfs. There are three bridge piers each 3 ft wide located at x-280, 330, and 380 ft. The bridge piers have a zero skew relative to the direction of flow and the river bed is medium sand with D50-0.4 mm.

Find: Estimate the contraction scour and bridge pier scour for Q-25000 cfs.

Soln: The HP record can be used with WSPRO to obtain the detailed velocity and conveyance values needed to compute the scour as shown in Table B.21. The code of 1 in Col. 4 causes the subsection conveyance data to be printed in this case for the approach section, and a code of 2 provides the velocity distribution data in the bridge opening section. The beginning water surface elevation, the increment in the water surface elevation, and the ending water surface elevation at which output is desired can all be specified for a given discharge. A portion of the output is shown in Table B.22.

The local scour and contraction scour are calculated independently as suggested by Method 2 in HEC-18 (9) and added. (Alternatively, the contraction scour is estimated and the hydraulics are adjusted accordingly in an iterative procedure before calculating local scour.)

The contraction scour in this example is Case 1 (overbank flow on the flood plain being forced through the main channel) and is computed according to Laursen's formula (9). Other formulae are also presented in HEC-18.

$$(y_s/y_1) = (Q_t/Q_c)^{6/7}(W_1W_2)^{K1}(n_2/n_1)^{K2}\text{-}1.0$$

in which y_s,-contraction scour depth; y_1-average depth in the approach main channel; Q_t-total discharge through the contracted section; Qc-discharge in the approach main channel; W_1-width of the main channel; W_2-width of the contracted section; n_1-Manning's n for the main channel; n_2-Manning's n for the contracted section; and K_1 and K_2 are empirical constants.

From the results of Example 1, the water surface elevation in the approach section for Q-25000 cfs is 31.14 ft. Then from Table B.22 for WSEL-31.14 ft, the main channel is subsection 3 and we have:

$$y_1 = \text{AREA/TOPW} = 2383/130 = 18.3 \text{ ft}$$

$$Q_t/Q_c = K_t/K_c = 1.38E6/0.68E6 = 2.0$$

$$W_1/W_2 = 130/200 = 0.65$$

To obtain K_1 and K_2 , we need the shear velocity:

$$V_* = (gy_1S)^{1/2} = (32.2*18.3*.00052)^{1/2} = 0.55 \text{ ft/s}$$

and the fall velocity w for D50 = 0.4 mm is 0.2 ft/s. Therefore, $V_*/w>2$ which gives K_1-0.69 and K_2-0.37. Finally, assuming n_1/n_2-1, we have:

$$y_s = 18.3 * [(2.0)^{6/7} * (0.65)^{.69} - 1.0] = 6.3 \text{ ft}$$

Local bridge pier scour is computed by the CSU formula as recommended by HEC-18 (5):

$$y_s/y_1 = 2.0\ K_1K_2\ (a/y_1)^{.65}\ Fr_1^{.43}$$

in which y_8 = scour depth; y_1 = flow depth just upstream of bridge pier; K_1 = pier shape correction coefficient; K_2 = correction for angle of attack; a = pier width; and Fr_1 = Froude no. = $V_1/(gy_1)^{1/2}$.

The local scour is computed around the deepest bridge pier at x-380 ft where the ground elevation is approximately 8.0 ft. From Example 1, the water surface elevation in the bridge opening for Q-25000 cfs is 28.54. Then from Table B.22, the velocity at the bridge pier is approximately 11.8 ft/s and the depth is approximately 20.5 ft (28.54-8.0). For a round nose pier, K_1-1.0, and K_2-1.0 for zero skew. Therefore:

y_8=20.5*2.0*$(3.0/20.5)^{.65}$8$[11.8/(32.2*20.5)^{1/2}]^{.43}$=8.4 ft

The maximum scour using Method 2 is then approximately 15 ft (6.3+8.4).

TABLE B.21 - INPUT DATA FOR EXAMPLE 2

```
T1      EXAMPLE 2-NORMAL BRIDGE CROSSING - SCOUR COMPUTATIONS
T2      BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
T3      BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
*
Q       25000
SK      .00052
*
XS  EXIT 1000
GR      0,35.0 0,28.0 140,23.5 200,21.5
GR      230,21.0 250,20.5 280,20.4 300,20.0
GR      310,19.0 330,10.0 360,3.0 380,8.0
GR      400,18.0 430,21.0 450,20.0 475,17.0
GR      500,17.5 540,18.0 600,20.0 730,28.0
GR      730,35.0
N       0.045 0.07 0.035 0.045
SA          200  300   430
XS  FULV 1200  *    *    * 0.00052
*
BR  BRGE 1200
BD      3.0  35.0
BL      200   230   430
PW      8.0,3.0 10.0,3.0 10.0,6.0 20.4,6.0  20.4,9.0
CD      1  40
N       0.035
*
AS  APPR 1440
HP 1 APPR 30.14    1.0   32.14     25000
HP 2 BRGE 27.54    1.0   29.54     25000
EX
ER
```

TABLE B.22 - OUTPUT FOR EXAMPLE 2

```
     EXAMPLE 2 - NORMAL BRIDGE CROSSING - SCOUR COMPUTATIONS
     BED SLOPE -0.00052;LSE-32.0 FT; NO OVERTOPPING
     BRIDGE OPENING (TYPE 1): X-230-430 FT; THREE 3-FT PIERS
        *** RUN DATE & TIME: 06-01-90  08:44

 CROSS-SECTION :  ISEQ =  4;  SECID = APPR ;  SRD =    1440.

  WSEL   SA#X-X  K    TOPW   WETP  ALPH     LEW     REW      QCR
           1 100578.  200.   202.                          13211.
           2 86147.   100.   100.                          15864.
           3 623771.  130.   136.                          53239.
           4 384667.  300.   302.                          45954.
 30.14      1195163.  730.   740.  1.60      0.    730.   95217.

  WSEL   SA#X-X K    TOPW   WETP  ALPH     LEW     REW      QCR
           1 134845.  200.   203.                          17251.
           2 102292.  100.   100.                          18516.
           3 684892.  130.   136.                          57912.
           4 457511.  300.   303.                          53823.
 31.14      1379541.  730.   742.  1.55      0.    730.  112483.

  WSEL   SA#X-X K    TOPW   WETP  ALPH     LEW     REW      QCR
           1 172859.  200.   204.                          21635.
           2 119527.  100.   100.                          21301.
           3 748277.  130.   136.                          62714.
           4 535113.  300.   304.                          62096.
 32.14      1575776.  730.   744.  1.51      0.    730.  130847.

HP 2 BRGE 27.54      1.0    29.54      25000
  VELOCITY DIST:  ISEQ =  3;  SECID = BRGE ;  SRD =    1200.

      WSEL     LEW     REW    AREA       K        Q     VEL
     28.54   230.0   430.0  2619.7  580155.   25000.   9.54

X STA.   230.0  270.5  297.7  316.8  325.4 331.4
  A(I)      316.9  221.5  183.6  123.5  106.2
  V(I)       3.94   5.64   6.81  10.12  11.77

X STA.   331.4  336.5 341.1 345.6 349.7 353.3
  A(I)       99.7   94.2  96.7  92.7  85.0
  V(I)      12.54  13.26 12.93 13.49 14.70

X STA.   353.3 357.2 361.1 365.2 369.3 373.8
 A(I)        94.7  97.9  100.5 97.3  100.9
  V(I)      13.20 12.76  12.44 12.84 12.39

X STA.   373.8 378.4 383.7 390.4 401.3 430.0
  A(I)       98.5  106.0 112.5 136.3  255.1
  V(I)      12.69  11.79 11.11  9.17   4.90
```

SAMPLE KWSPRO INPUT FILE DR-12-950.0

```
T1        Butler County
T2        KY 1038 Over Neils Creek
T3        Floodway Analysis
*         100 Year, 100 Year + 1'
Q         1959 1959
WS        523.18 524.18
J1        * .10 .10 1.5  *
J3         6 10 5 3
*         Cross Section 130' Downstream (Taken Lt. To Rt.)
XS   Exit  100
FL        0 215 0 253 0
GR        0,543.6 41,539.5 87,533.4 125,527.7 146,522.5 182,520.2
GR        195,518.9 215,519.0 217,517.6 225,515.9 241,515.9 243,516.8
GR        248,518.7 253,521.7 269,522.1 318,523.4 350,524.4 386,528.9
GR        422,532.3 436,533.7 448,534.0 456,531.5 466,536.3 504,538.2
GR        509,536.8 513,540.0 544,545.1
N         .05 .045 .045 .05 .05
SA        215 253 269 436
HP 1      523.18 1 524.18 1959
FW        1.2 1 1 192 253
*         Cross Section At Proposed Alignment
XS   Fullv 130
FL        30 237 30 277 30
GR        0,541.8 49,536.4 89,531.4 127,527.4 158,525.4 203,523.0
GR        237,521.4 244,516.6 256,515.1 259,517.1 268,517.3 277,520.9
GR        300,524.7 330,529.1 371,532.5 403,535.3 439,536.6 479,534.8
GR        527,533.5 572,537.1 580.7,537.65 668,540.80 732,543.9
N         .05 .045 .05 .05
SA        237 277 479
FW        1.2 1 1 237 277
*         Existing Bridge Section
BR   Brdge 130 522.25
FL        30 237 30 277 30
BD        1.9 524.15 -0.0033445 263
BL        26.89 249.71 276.6
CD        4 22 2 524 30
KD        * * * 249.71 276.6
*         Existing Roadway Section
XR   Road  141 22
FL        11 237 11 277 11
GR        10,537.65 100,534.5 145,531.1 165,529.2 190,526.8
GR        200,525.8 232,524.2 233.7,522.4 233.71,517.6 242,516.9
GR        250,517.0 252.4,516.8 260.6,518.0 260.61,522.3 261.9,524.1
GR        300,524.2 350,525.8 385.0,528.8
BP        225
FW        1.2 1 1 237 277
*         Cross Section 30' Upstream
AS   Appr  182
FL        52 243 52 277 52
GR        0,541.1 44,536.6 99,528.9 160,522.6 219,520.0
GR        243,520.3 245,518.0 261,517.3
GR        264,518.3 269,519.2 277,521.1 304,523.8 333,528.7 386,534.4
GR        434,537.3 442,537.6 451,539.3 459,540.1
N         .05 .045 .045 .05 .05
SA        160 243 277 304
BP        327
FW        1.2 1 1 212 277
*
EX
ER
```

```
         KWSPRO : KENTUCKY TRANSPORTATION CABINET VERSION - WSPRO (HY-7)
Ky9301                     FLOODWAY  ANALYSIS  MODEL

                 Run Date & Time :  7-30-1993   14:56

  T1         Butler County

  T2         KY 1038 Over Neils Creek

  T3         Floodway Analysis

  *          100 Year, 100 Year + 1'

-------------------------------------------------------------------------------
                            === Q-WS-SK-J_ DATA ===
-------------------------------------------------------------------------------
  Q          1959 1959

  WS         523.18 524.18

  J1         * .10 .10 1.5  *

J1 RECORD PARAMETERS:
DELTAY = 1.00   YTOL =  .10   QTOL =  .10   FNTEST = 1.50   IHFNOJ = -1

  J3          6 10 5 3

  *

  *          Cross Section 130' Downstream (Taken Lt. To Rt.)

  *

-------------------------------------------------------------------------------
                         === CROSS SECTION === "Exit "
-------------------------------------------------------------------------------
  XS    Exit  100

  FL         0 215 0 253 0

  GR         0,543.6 41,539.5 87,533.4 125,527.7 146,522.5 182,520.2

  GR         195,518.9 215,519.0 217,517.6 225,515.9 241,515.9 243,516.8

  GR         248,518.7 253,521.7 269,522.1 318,523.4 350,524.4 386,528.9

  GR         422,532.3 436,533.7 448,534.0 456,531.5 466,536.3 504,538.2

  GR         509,536.8 513,540.0 544,545.1

  N          .05 .045 .045 .05 .05

  SA         215 253 269 436

  HP 1       523.18 1 524.18 1959

<-- Cross Section "Exit " Written to Disk, Record No. =  1

=== DATA SUMMARY FOR SECID : "Exit ", SRD =   100.00 ft , ERR-CODE=    0
```

SKEW	IHFNO	VSLOPE	EK	CK
deg		ft/ft		
.0	0.	*********	.50	.00

X-Y COORDINATE PAIRS (NGP = 27):

X	Y	X	Y	X	Y	X	Y
ft	ft	ft	ft	ft	ft	ft	ft
.00	543.60	41.00	539.50	87.00	533.40	125.00	527.70
146.00	522.50	182.00	520.20	195.00	518.90	215.00	519.00
217.00	517.60	225.00	515.90	241.00	515.90	243.00	516.80
248.00	518.70	253.00	521.70	269.00	522.10	318.00	523.40
350.00	524.40	386.00	528.90	422.00	532.30	436.00	533.70
448.00	534.00	456.00	531.50	466.00	536.30	504.00	538.20
509.00	536.80	513.00	540.00	544.00	545.10		

X-Y MAX-MIN POINTS:

XMIN	Y	X	YMIN	XMAX	Y	X	YMAX
ft	ft	ft	ft	ft	ft	ft	ft
.00	543.60	225.00	515.90	544.00	545.10	544.00	545.10

SUBAREA BREAKPOINTS (NSA = 5):
215.00 ft 253.00 ft 269.00 ft 436.00 ft

ROUGHNESS COEFFICIENTS (NSA = 5):
.050 .045 .045 .050 .050

FLOW LENGTH DATA (NFL = 3):

FLEN	XSTA	FLEN	XSTA	FLEN
ft	ft	ft	ft	ft
.00	215.00	.00	253.00	.00

PROPERTIES - SECTION SUB-AREAS : Exit Section. SRD = 100.00 ft Rec# = 1

WSEL = 523.18

X1	TO X2	AREA	K	TOPW	WETP	VEL	ALPH	LEW	REW	QSUB
ft		ft²	cfs	ft	ft	fps		ft	ft	cfs
143.	215.	199.	11644.	72.	72.	3.03				601.
215.	253.	233.	25049.	38.	40.	5.54				1294.
253.	269.	20.	799.	16.	16.	2.02				41.
269.	310.	22.	434.	41.	41.	1.02				22.
		474.	37926.	166.	169.	4.13	1.36	143.	310.	1959.

WSEL = 524.18

X1	TO X2	AREA	K	TOPW	WETP	VEL	ALPH	LEW	REW	QSUB
ft		ft²	cfs	ft	ft	fps		ft	ft	cfs
139.	215.	272.	18987.	76.	76.	2.45				667.
215.	253.	271.	32209.	38.	40.	4.17				1131.
253.	269.	36.	2092.	16.	16.	2.01				73.
269.	343.	80.	2501.	74.	74.	1.10				88.
		660.	55788.	204.	206.	2.97	1.39	139.	343.	1959.

```
FW        1.2 1 1 192 253
  *
  *        Cross Section At Proposed Alignment
```

```
*

---------------------------------------------------------------------------
                         === CROSS SECTION === "Fullv"
---------------------------------------------------------------------------
 XS   Fullv 130

 FL        30 237 30 277 30

 GR        0,541.8 49,536.4 89,531.4 127,527.4 158,525.4 203,523.0

 GR        237,521.4 244,516.6 256,515.1 259,517.1 268,517.3 277,520.9

 GR        300,524.7 330,529.1 371,532.5 403,535.3 439,536.6 479,534.8

 GR        527,533.5 572,537.1 580.7,537.65 668,540.80 732,543.9

 N         .05 .045 .05 .05

 SA        237 277 479

 FW        1.2 1 1 237 277

<-- Cross Section "Fullv" Written to Disk, Record No. =  2

=== DATA SUMMARY FOR SECID : "Fullv", SRD =   130.00 ft , ERR-CODE=    0

     SKEW     IHFNO    VSLOPE        EK        CK
      deg               ft/ft
       .0        0. *********       .50       .00

X-Y COORDINATE PAIRS  (NGP =  23):
       X       Y         X       Y          X       Y          X       Y
      ft      ft        ft      ft         ft      ft         ft      ft
      .00  541.80     49.00  536.40      89.00  531.40     127.00  527.40
   158.00  525.40    203.00  523.00     237.00  521.40     244.00  516.60
   256.00  515.10    259.00  517.10     268.00  517.30     277.00  520.90
   300.00  524.70    330.00  529.10     371.00  532.50     403.00  535.30
   439.00  536.60    479.00  534.80     527.00  533.50     572.00  537.10
   580.70  537.65    668.00  540.80     732.00  543.90

 X-Y MAX-MIN POINTS:
     XMIN       Y         X    YMIN       XMAX       Y          X    YMAX
      ft       ft        ft      ft         ft      ft         ft      ft
      .00  541.80    256.00  515.10     732.00  543.90     732.00  543.90

SUBAREA BREAKPOINTS (NSA =  4):
      237.00 ft  277.00 ft  479.00 ft

ROUGHNESS COEFFICIENTS (NSA =  4):
         .050     .045     .050     .050

FLOW LENGTH DATA (NFL = 3):
           FLEN       XSTA       FLEN       XSTA       FLEN
             ft         ft         ft         ft         ft
          30.00     237.00      30.00     277.00      30.00
 *

 *         Existing Bridge Section

 *
```

```
------------------------------------------------------------------------------
                       === CROSS SECTION === "Brdge"
------------------------------------------------------------------------------
   BR   Brdge 130 522.25

   FL        30 237 30 277 30

   BD        1.9 524.15 -0.0033445 263

   BL        26.89 249.71 276.6

   CD        4 22 2 524 30

   KD        * * * 249.71 276.6

   *

   *         Existing Roadway Section

   *

 <-- No Roughness Data INPUT. Will use "N" record from previous cross section.
 <-- Cross Section "Brdge" Written to Disk, Record No. =  3

 === DATA SUMMARY FOR SECID : "Brdge", SRD =   130.00 ft , ERR-CODE=    0

      SKEW     IHFNO    VSLOPE        EK        CK
       deg               ft/ft
        .0        0. *********       .50       .00

 X-Y COORDINATE PAIRS  (NGP =   8):
        X       Y          X       Y          X       Y          X       Y
       ft      ft         ft      ft         ft      ft         ft      ft
    249.71  522.29    249.71  515.89    256.00  515.10    259.00  517.10
    268.00  517.30    276.60  520.74    276.60  522.20    249.71  522.29

  X-Y MAX-MIN POINTS:
      XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
       ft      ft         ft      ft         ft      ft         ft      ft
    249.71  522.29    256.00  515.10    276.60  520.74    249.71  522.29

 SUBAREA BREAKPOINTS (NSA =  4):
       237.00 ft  277.00 ft  479.00 ft

 ROUGHNESS COEFFICIENTS (NSA =  4):
          .050    .045    .050    .050

 FLOW LENGTH DATA (NFL = 3):
            FLEN       XSTA       FLEN       XSTA       FLEN
              ft         ft         ft         ft         ft
           30.00     237.00      30.00     277.00      30.00

 BRIDGE PARAMETERS:
  BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  WWANGL
              ft       ft           x : 1      ft     deg
     4     22.00   522.25 *******   2.00   524.00   30.00

 DESIGN DATA:     BRLEN  LOCOPT  XCONLT  XCONRT
                     ft           ft      ft
                  26.89     .00   249.71  276.60
```

```
               GIRDEP  BDELEV   BDSLP   BDSTA
                 ft      ft     ft/ft     ft
                1.90  524.15  -.0033  263.00

PIER DATA:  NPW =  0    PPCD = ****
-------------------------------------------------------------------------------
                          === CROSS SECTION === "Road "
-------------------------------------------------------------------------------
  XR   Road  141 22

  FL         11 237 11 277 11

  GR         10,537.65 100,534.5 145,531.1 165,529.2 190,526.8

  GR         200,525.8 232,524.2 233.7,522.4 233.71,517.6 242,516.9

  GR         250,517.0 252.4,516.8 260.6,518.0 260.61,522.3 261.9,524.1

  GR         300,524.2 350,525.8 385.0,528.8

  BP         225

  FW         1.2 1 1 237 277

<-- No Roughness Data INPUT. Will use "N" record from previous cross section.
<-- Cross Section "Road " Written to Disk, Record No. =  4

=== DATA SUMMARY FOR SECID : "Road ", SRD =   141.00 ft , ERR-CODE=    0

     SKEW     IHFNO    VSLOPE        EK         CK
      deg              ft/ft
       .0        0. *********       .50        .00

X-Y COORDINATE PAIRS  (NGP =  18):
       X       Y          X       Y          X       Y          X       Y
      ft      ft         ft      ft         ft      ft         ft      ft
    10.00  537.65     100.00  534.50     145.00  531.10     165.00  529.20
   190.00  526.80     200.00  525.80     232.00  524.20     233.70  522.40
   233.71  517.60     242.00  516.90     250.00  517.00     252.40  516.80
   260.60  518.00     260.61  522.30     261.90  524.10     300.00  524.20
   350.00  525.80     385.00  528.80

 X-Y MAX-MIN POINTS:
     XMIN      Y          X     YMIN       XMAX      Y          X     YMAX
      ft      ft         ft      ft         ft      ft         ft      ft
    10.00  537.65     252.40  516.80     385.00  528.80      10.00  537.65

SUBAREA BREAKPOINTS (NSA =  4):
      237.00 ft  277.00 ft  479.00 ft

ROUGHNESS COEFFICIENTS (NSA =  4):
         .050    .045    .050    .050

FLOW LENGTH DATA (NFL = 3):
           FLEN      XSTA      FLEN      XSTA      FLEN
            ft        ft        ft        ft        ft
          11.00    237.00     11.00    277.00     11.00

ROAD GRADE DATA:  IPAVE  RDWID  USERCF
                           ft
               *******   22.00 *******
```

```
BRIDGE PROJECTION DATA:  XREFLT  XREFRT    FDSTLT  FDSTRT
                             ft      ft        ft      ft
                        225.00 ******** ******** ********
  *

  *         Cross Section 30' Upstream

  *
------------------------------------------------------------------------------
                        === CROSS SECTION === "Appr "
------------------------------------------------------------------------------
  AS   Appr  182

  FL         52 243 52 277 52

  GR         0,541.1 44,536.6 99,528.9 160,522.6 219,520.0

  GR         243,520.3 245,518.0 261,517.3

  GR         264,518.3 269,519.2 277,521.1 304,523.8 333,528.7 386,534.4

  GR         434,537.3 442,537.6 451,539.3 459,540.1

  N          .05 .045 .045 .05 .05

  SA         160 243 277 304

  BP         327

  FW         1.2 1 1 212 277

<-- Cross Section "Appr " Written to Disk, Record No. =  5

=== DATA SUMMARY FOR SECID : "Appr ", SRD =   182.00 ft , ERR-CODE=    0

     SKEW     IHFNO    VSLOPE        EK        CK
      deg               ft/ft
       .0       0. *********       .50       .00

X-Y COORDINATE PAIRS  (NGP =  18):
       X       Y          X       Y          X       Y          X       Y
      ft      ft         ft      ft         ft      ft         ft      ft
     .00  541.10      44.00  536.60      99.00  528.90     160.00  522.60
  219.00  520.00     243.00  520.30     245.00  518.00     261.00  517.30
  264.00  518.30     269.00  519.20     277.00  521.10     304.00  523.80
  333.00  528.70     386.00  534.40     434.00  537.30     442.00  537.60
  451.00  539.30     459.00  540.10

 X-Y MAX-MIN POINTS:
     XMIN        Y          X    YMIN       XMAX        Y          X    YMAX
      ft        ft         ft      ft         ft       ft         ft      ft
     .00  541.10     261.00  517.30     459.00  540.10        .00  541.10

SUBAREA BREAKPOINTS (NSA =  5):
      160.00 ft  243.00 ft  277.00 ft  304.00 ft

ROUGHNESS COEFFICIENTS (NSA =  5):
         .050     .045     .045     .050     .050

FLOW LENGTH DATA (NFL = 3):
            FLEN      XSTA      FLEN      XSTA      FLEN
```

```
            ft         ft         ft         ft         ft
         52.00     243.00      52.00     277.00      52.00

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT   FDSTLT  FDSTRT
                            ft      ft       ft      ft
                        327.00 ******** ******** ********
   *

   *

   EX


==============================================================================

                    <<=== NORMAL PROFILE ==== NO. 1 ===>>

==============================================================================


       KWSPRO : KENTUCKY TRANSPORTATION CABINET VERSION - WSPRO (HY-7)
                          FLOODWAY  ANALYSIS  MODEL

        Butler County
        KY 1038 Over Neils Creek
        Floodway Analysis
               Run Date & Time :  7-30-1993   14:56


------------------------------------------------------------------------------
  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q     WSEL
               ft      ft      ft²    ft     ft     ft      ft    cfs      ft
        SRD   FLEN    REW       K   ALPH    HO     ERR     FR#     VEL
         ft    ft      ft   cfs             ft                     fps
------------------------------------------------------------------------------

 Exit :XS   ******   143.     474.   .36 *****  523.54  521.14   1959.  523.18
       100. ******   310.   37926.  1.36 ***** *******     .50    4.13

  <--135 Conveyance Ratio Outside Recommended Limits.
                                "Fullv"     KRATIO =    .60

 Fullv:FV      30.   204.     257.  1.08   .13  524.03 *******   1959.  522.94
       130.    30.   289.   22594.  1.20   .36    -.01     .85    7.61

  <--135 Conveyance Ratio Outside Recommended Limits.
                                "Appr "     KRATIO =   1.64

 Appr :AS      52.   147.     480.   .31   .24  524.25 *******   1959.  523.94
       182.    52.   305.   37010.  1.20   .00    -.02     .45    4.08

                    <<== END OPEN CHANNEL FLOW ==>>

  <--255 Attempting Flow CLASS 3 (6) Solution.
                          WS3N,LSEL =    522.94     522.25

                    <<== BEGIN CONSTRICTED FLOW ==>>

------------------------------------------------------------------------------
  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q     WSEL
```

```
             ft       ft        ft²     ft      ft        ft        ft    cfs          ft
     SRD   FLEN      REW         K    ALPH      HO       ERR       FR#     VEL
      ft     ft       ft      cfs               ft                       fps
-------------------------------------------------------------------------------------

 Brdge:BR     30.    250.      134.    .25 *****  522.55  519.40     543.  522.29
      130. ******    277.     7355.   1.00 ***** *******     .32     4.05

     TYPE PPCD FLOW      C      P/A     LSEL    BLEN    XLAB    XRAB
                                          ft      ft      ft      ft
       4. ****   6.   .800    .000   522.25     27.    250.    277.

    XSID:CODE     SRD   FLEN     HF    VHD     EGL      ERR       Q      WSEL
                   ft     ft     ft     ft      ft               cfs       ft
   Road :RG      141.    30.    .13    .42  523.80     -.02    1370.   522.64

               Q    WLEN     LEW     REW   DMAX   DAVG   VMAX   VAVG   HAVG   CAVG
             cfs      ft      ft      ft     ft     ft    fps    fps     ft
   LT:       40.      1.    233.    235.    5.1    4.0   10.9    9.4    5.2    3.2
   RT:     1330.     26.    235.    261.    5.8    5.4   11.5    9.3    6.6    3.0

---------------------------------------------------------------------------------------
 XSID:CODE    SRDL      LEW      AREA    VHD      HF       EGL      CRWS        Q     WSEL
                ft       ft       ft²     ft      ft        ft        ft    cfs         ft
      SRD     FLEN      REW         K   ALPH      HO       ERR       FR#     VEL
       ft       ft       ft      cfs              ft                         fps
---------------------------------------------------------------------------------------

 Appr :AS     30.    151.      414.    .42     .59  523.93  522.42    1959.  523.51
      182.     81.    301.    30078.   1.21     .00    -.02     .55    4.73

      M(G)    M(K)        KQ    XLKQ    XRKQ    OTEL
                         cfs      ft      ft      ft
    ****** ****** ******** ****** ****** ********

                                                                         - 523.94
                                                                         ---------
                                                    BRIDGE BACKWATER =        .00

                              <<== END CONSTRICTED FLOW ==>>

      FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    SLEN       Q      WSEL

                   ft      ft      cfs       ft
   Exit :XS      100.*******    1959.   523.18
   Fullv:FV      130.     30.    1959.   522.94
   Brdge:BR      130.     30.     543.   522.29
   Road :RG      141.     41.    1370.   522.64
   Appr :AS      182.     30.    1959.   523.51

=======================================================================================

                          <<=== FLOODWAY PROFILE ==== NO. 2 ===>>

=======================================================================================
```

KWSPRO SAMPLE ANALYSIS **DR-12.950.9**

FLOODWAY ANALYSIS MODEL

```
        Butler County
        KY 1038 Over Neils Creek
        Floodway Analysis
               Run Date & Time :  7-30-1993   14:56

 ------------------------------------------------------------------------------
  XSID:CODE    SRDL     LEW     AREA    VHD    HF     EGL    CRWS      Q     WSEL
                 ft      ft      ft2     ft    ft      ft      ft    cfs       ft
        SRD    FLEN     REW        K   ALPH    HO     ERR     FR#     VEL
         ft      ft      ft    cfs            ft                      fps
 ------------------------------------------------------------------------------

 Exit :XS    ******    192.     391.    .42 *****  524.60  521.14   1959.  524.18
       100.  ******    253.   41637.   1.08 ***** *******     .36    5.01

 Fullv:FV       30.    237.     273.    .80   .09  524.88 *******   1959.  524.08
       130.     30.    277.   29338.   1.00   .19    -.00     .48    7.16

 Appr :AS       52.    212.     341.    .54   .21  525.12  522.42   1959.  524.58
       182.     52.    277.   33111.   1.05   .00     .03     .45    5.75

                            <<== END OPEN CHANNEL FLOW ==>>

  <--255 Attempting Flow CLASS 3 (6) Solution.
                           WS3N,LSEL =   524.08     522.25

                            <<== BEGIN CONSTRICTED FLOW ==>>

 ------------------------------------------------------------------------------
  XSID:CODE    SRDL     LEW     AREA    VHD    HF     EGL    CRWS      Q     WSEL
                 ft      ft      ft2     ft    ft      ft      ft    cfs       ft
        SRD    FLEN     REW        K   ALPH    HO     ERR     FR#     VEL
         ft      ft      ft    cfs            ft                      fps
 ------------------------------------------------------------------------------

 Brdge:BR       30.    250.     134.    .29 *****  522.59  519.50    582.  522.29
       130.  ******    277.    7355.   1.00 ***** *******     .34    4.34

      TYPE PPCD FLOW      C      P/A     LSEL    BLEN    XLAB    XRAB
                                           ft      ft      ft      ft
        4. ****   6.   .800    .000   522.25     27.    250.    277.

     XSID:CODE      SRD    FLEN     HF    VHD      EGL      ERR       Q      WSEL
                     ft      ft     ft     ft       ft               cfs       ft
    Road :RG       141.     30.    .10    .53   525.04      .09    1559.   523.66

                 Q    WLEN     LEW     REW    DMAX   DAVG   VMAX   VAVG   HAVG   CAVG
               cfs      ft      ft      ft      ft     ft    fps    fps     ft
    LT:         0. ****** ****** ****** ***** ***** ***** ***** ***** *****
    RT:     1559.     25.    237.    262.     6.9    6.3   12.4   10.1    7.7    3.0

 ------------------------------------------------------------------------------
  XSID:CODE    SRDL     LEW     AREA    VHD    HF     EGL    CRWS      Q     WSEL
                 ft      ft      ft2     ft    ft      ft      ft    cfs       ft
        SRD    FLEN     REW        K   ALPH    HO     ERR     FR#     VEL
         ft      ft      ft    cfs            ft                      fps
 ------------------------------------------------------------------------------
```

```
Appr :AS      30.    212.     342.   .53    .60  525.14  522.56   1959.  524.61
       182.   106.   277.   33349.  1.05    .00     .09     .45    5.73


        M(G)    M(K)        KQ   XLKQ   XRKQ    OTEL
                           cfs     ft     ft      ft
      ****** ****** ******** ****** ****** ********

                                                                     - 524.58
                                                                     ---------
                                                 BRIDGE BACKWATER =       .02
```

<<== END CONSTRICTED FLOW ==>>

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	SLEN	Q	WSEL
	ft	ft	cfs	ft
Exit :XS	100.	*******	1959.	524.18
Fullv:FV	130.	30.	1959.	524.08
Brdge:BR	130.	30.	582.	522.29
Road :RG	141.	41.	1559.	523.66
Appr :AS	182.	30.	1959.	524.61

KWSPRO FLOODWAY TABLE

7-30-1993 14:56

SECID	DIST ft	FLDWAY WIDTH ft	STATIONS LTLIM ft	CHAN ft	RTLIM ft	MEAN VEL. fps	ELEVATIONS W/O-FW ft	WITH-FW ft	RISE ft
Exit	100.0	61.0	192.0	234.0	253.0	5.01	523.18	524.18	1.00
Fullv	130.0	40.0	237.0	257.0	277.0	5.75	522.94	524.08	1.14
Brdge	130.0	26.9	249.7	257.0	276.6	4.34	522.29	522.29	.00
Road	141.0	40.0	237.0	257.0	277.0	1.00	522.64	523.66	1.03
Appr	182.0	65.0	212.0	260.0	277.0	5.73	523.51	524.61	1.10

ER

NORMAL END OF KWSPRO RUN.