Publication No. FHWA-RD-88-124
July 1988

HYDRAIN–Integrated Drainage Design Computer System

/olume V,

WSPRO–Step Backwater & Bridge Hydraulics

U S Department of Transportation
Federal Highway Administration

Research. Development. and Technology
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FOREWORD

This report (Volume V) is a technical supplement for the Water Surface Profile WSPRO) microcomputer program of the HYDRAIN integrated drainage design computer system. The HYDRAIN system which was developed under a pooled-fund study, includes a system shell and five engineering microcomputer programs for drainage design. The HYDRAIN documentation was published in 6 volumes so that there would be a separate volume for each of the engineering programs. This report will be of interest to hydraulic engineers for State highway agencies, consultants, and other Government agencies who deal with drainage design.

The HYDRAIN microcomputer programs, including WSPRO, which is the subject of this volume, have been distributed to the 25 States that participated in the pooled-fund study. Those States will evaluate the programs for a 6 to 12 month trial period after which the programs will be available through McTrans at the University of Florida, located in Gainesville, Florida and the PC-TRANS at the University of Kansas.

Sufficient copies of this report are being distributed by an FHWA transmittal memorandum to provide a minimum of one copy to each regional office, division office, and State highway agency. At least 10 copies are being distributed to those State highway agencies that participated in the study. Direct distribution is being made to the division offices. Additional copies may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

Thomas J. Pasko, Jr., Director
Office of Engineering and Highway
Operations Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-88-124		

4. Title and Subtitle HYDRAIN - INTEGRATED DRAINAGE DESIGN COMPUTER SYSTEM VOLUME V. WSPRO - STEP BACKWATER AND BRIDGE HYDRAULICS	5. Report Date November 1988
	6. Performing Organization Code
7. Author's) G. Kenneth Young and Joseph S. Krolak	8. Performing Organization Report No.
9. Performing Organization Name and Address GKY & Associates, Inc. 5411-E Backlick Road Springfield, Virginia 22151	10. Work Unit No. (TRAIS) NCP 3D3b302
	11. Contract or Grant No. DTFH61-84-C-00083
12. Sponsoring Agency Name and Address Structures Division, HNR-10 Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report September 1984 - December 1987
	14. Sponsoring Agency Code

15. Supplementary Notes
Contract Manager: J. Sterling Jones Advisors: Roy Trent, Phil Thompson, Stan Davis, Dennis Richards
Contributors: James Shearman

16. Abstract
This project report, in six volumes, documents a system of computer programs for the design of drainage components: culverts, storm drains, and open channels. The system includes an input generator to estimate design rain, hyetographs, design flow, and hydrographs. Programs are facilitated with semi-expert system shells that generate input data for engineering programs. The system is expandable and designed for personal computers that operate within an MS-DOS environment.

Volume V is a user supplement to existing, more detailed documentation for the Water-Surface Profile Computation Model Microcomputer Program (WSPRO); this code has been designed to provide a water-surface profile for six major types of flow situations: 1) unconstricted flow, 2)single-opening bridge, 3) bridge opening(s) with spur dikes, 4) single-opening embankment overflow, 5) multiple alternatives for a single job, and 6) multiple openings. WSPRO was originally developed by the United States Geologic Survey (USGS) for the Federal Highway Administration (FHWA).

This volume is one of a series. The entire series is:

FHWA No.	Vol. No.	Short Title	FHWA No.	Vol. No.	Short Title
RD-88-120	I	HYDRAIN	RD-88-123	IV	CDS
RD-88-121	II	HYDRO	RD-88-124	V	WSPRO
RD-88-122	III	PFP-HYDRA	RD-88-125	VI	HY8

To operate all the software, the user needs all six (6) volumes. To individually operate WSPRO, the user needs Volume I and Volume V.

17. Key Words	18. Distribution Statement
Backwater, Bridges, Culverts, Drainage, Expert System, Floods, Hydraulics, Hydrology, Open Channels, Sewers, Storm Drains, Personal Computers	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia, 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	53	

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METRIC (SI*) CONVERSION FACTORS

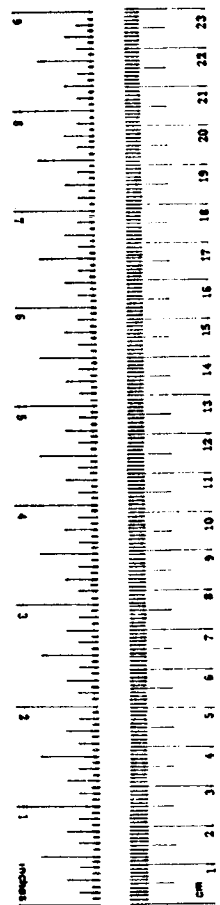
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

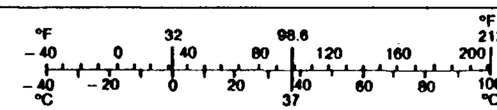
Symbol	When You Know	Multiply By	To Find	Symbol
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

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Preface

This report presents documentation for the Hydrain system. HYDRO, PFP-HYDRA, CDS, WSPRO and HY8 are five nonproprietary engineering programs incorporated in the Hydrain system. The Hydrain personal computer oriented system operates the first three of these engineering programs with an interactive program shell written in the C language. The last program, HY8, also has an interactive program interspersed with the analysis code. It is written in BASIC and FORTRAN. Each program is in turn controlled by a common system shell, also in C. The system and program shells are designed with an open architecture for expansion. Hydrain is sponsored as a Pooled Fund Project (PFP) of 23 State highway departments and is managed by the Federal Highway Administration (FHWA). The latest State to join is Texas. The system and its support are expanding.

Within the Hydrain program shell concept, the HYDRO, PFP-HYDRA and CDS program shells allow the user to easily input, edit and run input data files and to scroll through output files. With these three applications, "short" (one-line) and "long" (multiple line) help is provided within the program logic.

The other two applications are incorporated into Hydrain without the high level of help and without program shells. WSPRO has the same type of batch operations as the first three but the input file has to be created with an input file generator (word processor or line editor). Hydrain system shell allows entry to this file generator, and reentry to Hydrain, but the user must rely on hard-copy documentation for help. HY8 is a stand-alone interactive BASIC program that accepts inputs during processing and produces screen outputs that the user can capture with the print screen command. All engineering programs but HY8 are batch oriented, and three steps are built into the process of using them: input file generation, programs execution, and output file screen review or listing. HY8 accepts inputs and generates outputs as the engineering program logic is executing.

HYDRO Program

FORTRAN code for HYDRO was developed to combine existing approaches for rainfall and runoff analyses into one computerized program. Within the Hydrain system, it can be used independently or to generate input data for other engineering programs within the system.

HYDRO offers many hydrologic analysis options to the engineer. Each is site specific based on user-defined coordinates.

- Design Rain Using Digitized NWS Information - Calculates the rainfall intensity for a specific return period, duration, and site.

- Design Hyetograph using Yen and Chow's method - Calculates the rain versus time plot for a return period, duration and site.

- Intensity-Duration-Frequency Curve - Analyzes a specific site and creates two graphs: a plot of points for durations up to 24 hours, and a detail graph of the first 2 hours.

- Design Flow by Rational Method - Uses a specific return period, duration and intensity to determine the peak flow for the site.

- Design Flow by USGS Regression Method - Uses USGS three or seven parameter regression equations or user supplied equations to determine design flow.

- Design Flow by log Pearson type III - Calculates the peak flow for given data.

- Design Hydrograph by Rational Method and Snyder's Unit Graph - The rainfall intensity for a return period is used to calculate the peak flow. A hydrograph is created using Constant's modification of Snyder's method.

- Design Hydrograph by USGS Regression and Snyder's Unit Graph - Develops a hydrograph for a site based on peak flow and a unit hydrograph.

- Design Hydrograph by log Pearson type III and Snyder's Unit Graph - Develops a hydrograph for a site based on peak flow and a unit hydrograph.

- Hydrograph - Develops a hydrograph for a site based on its unit graph for a given flow.

<u>PFP-HYDRA Program</u>

FORTRAN code for PFP-HYDRA previously existed and the Pooled Fund work effort included substantial improvements. PFP-HYDRA is a storm and sanitary sewer system analysis and design program. It is used either to model an existing sewer system or to design a new system.

PFP-HYDRA generates storm flows by using either the Rational Method technique, hydrologic simulation techniques, or accepting a hydrograph generated by a HYDRO analysis. It can be used to design or analyze storm, sanitary or combined collection systems. PFP-HYDRA can handle up to 1,000 contributing drainage areas and 2,000 pipes. Additionally, PFP-HYDRA can be used for cost estimating. The Rational Method approximates the peak rate of runoff from a basin resulting from storms of a given return period. PFP-HYDRA's hydrologic simulation models the natural rainfall-runoff process. In the simulation, runoff hydrographs are generated, merged together and routed through the collection system. Inlet limitations can be analyzed: inlet overflow can be passed down a gutter system, while inlets in sumps can store water in ponds.

In the PFP-HYDRA design process, the program will select the pipe size, slope and invert elevations given certain design criteria. Additionally, PFP-HYDRA will perform analyses on an existing system of pipes (and/or ditches). When an existing system of pipes is overloaded, PFP-HYDRA will show suggested flow removal quantities as well as an increased pipe diameter size as an alternative remedy.

PFP-HYDRA requires the forming of an input file of commands to describe the sewer system. The program shell facilitates this activity. The commands are placed in a logical sequence usually from upper to lower elevation. It is possible that several command sequences can produce the same result. An input file is established for a particular collection system by the engineer and then the PFP-HYDRA program is executed. To change the characteristics of the collection system, the input file can be edited using the program shell. The input file, in itself, is a line by line command language that identifies the computation and provides the required data. Each line of data is preceded with a three-letter command. A typical command is **PDA**, indicating the line contains the design parameters for pipe analysis (PIPE DATA). PFP-HYDRA reads the command line one line (command) at a time and executes each command individually. However, PFP-HYDRA maintains a memory of information, including prior command information and results. Error checking is performed on each command.

The PFP-HYDRA program requires design criteria for the pipes: friction factor (Manning's "n"), minimum diameter, ideal depth, minimum ground cover, minimum velocity (full flow), minimum slope, and maximum diameter. The friction factor is necessary for both analysis and design, while the remaining values are needed only for design. For design, the program selects invert elevations and slope as well as the physical sizing of each link given certain design criteria. In the analysis mode, pipe alignment and sizing are predetermined and the impact of proposed flows are analyzed. Design criteria can be changed for each pipe if so desired. PFP-HYDRA is not an optimization program, thus individual case studies need to be run and analyzed by the engineer.

CDS Program

The Culvert Design System provides the user with two broad options for investigating culvert characteristics. CDS can either (1) hydraulically design a culvert or (2) analyze an existing or proposed culvert. CDS has capabilities for investigating a variety of hydrograph relationships, culvert shapes, materials, and inlet types. With CDS, the engineer can request any of six culvert types: round concrete, round metal, arch concrete, arch metal, oval concrete, and concrete box. CDS routes hydrographs and considers ponding.

The Design option selects a culvert size and number of barrels that are compatible with engineering data, environmental constraints, and site geometry. In this option, hydraulic performance data are calculated for each new culvert system design. The Review option provides hydraulic performance data for any preselected combination of culvert type and size, inlet type, slope, and number of barrels. The initial design and analysis options may be followed by up to five additional culvert types or flow frequencies so a full spectrum of risk scenarios or economic considerations can be simulated at the same time.

Two possible flow scenario methods can be selected: (1) constant flow through the culvert (steady state or irrigation), or (2) time variable drainage flow conditions (dynamic). The dynamic option can route a hydrograph through the culvert system using three hydrograph alternatives: a user input hydrograph for a given discharge, a hydrograph produced by the HYDRO program, or the use of an internally produced default hydrograph (simulating semi-arid, high plains conditions). Additionally, the dynamic flow scenario can accommodate upstream pond storage.

CDS will determine culvert size based on the design headwater, headwater/diameter ratio, inundation, outlet velocity, cover limitations, or any combination of these parameters. The program will automatically increase the number of barrels when the maximum culvert size is exceeded. There is a limit of six barrels for commercial size culverts and five for concrete box culverts. The program can also be used to assess flood hazards, environmental assessments of upstream pond coverage, downstream flooding, channel impact, inlet type and beveled inlet evaluations, and reservoir facilities which use a culvert type structure for the spillway. Based on these data the program will proceed to identify the flow type and the outlet conditions for velocity, Froude number, and brink depth.

WSPRO Program

The Water Surface Profile Computation Model Microcomputer Program has been designed to provide a water-surface profile for six major types of open channel flow situations:

- Unconstricted flow.
- Single opening bridge.
- Bridge opening(s) with spur dikes.
- Single opening embankment overflow.
- Multiple alternatives for a single job.
- Multiple openings.

The United States Geologic Survey (USGS) originally developed WSPRO for the Federal Highway Administration. The model was a batch mode mainframe program, written in FORTRAN. The members of the Pooled Fund Project decided to use WSPRO as the bridge waterways analysis element of the Integrated Computerized Drainage Design System. WSPRO was downloaded to the microcomputer by the USGS and FHWA. The microcomputer version of WSPRO, is dated August 1987. As yet, WSPRO does not have a user friendly, interactive shell to aid in data input and manipulation, although this is planned as a future Hydrain enhancement. The result is that the user must create or edit an input file on a line editor or word processor.

The input file forms a logical description of the physical characteristics of a waterway. Once the user is comfortable with this method of data setup, the program will provide a simple method for determining water surface profiles. The scheme is similar to the Corps of Engineers HEC-2 program. Both WSPRO and HEC-2 are acceptable to the Federal Emergency Management Agency. WSPRO has the advantage that it uses more recent approximation techniques for the backwater effects associated with bridge constrictions.

HY8 Program

HY8 is an interactive culvert analysis program that uses the FHWA analysis methods and information published by pipe manufacturers. The program includes modules to allow the user to interactively enter, save, and edit data. HY8 will compute the culvert hydraulics for circular, rectangular, elliptical, arch and user defined geometry. Additionally, improved inlets can be specified and the user can: analyze inlet and outlet control for full and partially full culverts, analyze the tailwater in trapezoidal and coordinate defined downstream channels, analyze flow over the roadway embankment, and balance flows through multiple parallel culverts.

The initial logic involves calculating the inlet control and outlet control headwater elevations for the given flow. These elevations are compared and the larger of the two is used as the controlling headwater elevation. Tailwater effects are taken into consideration when calculating these elevations. If the controlling headwater elevation overtops the roadway embankment, an overtopping analysis is done in which flow is balanced between the culvert discharge and the surcharge over the roadway. A balancing technique is also used for multiple barrels. If the culvert is less than full for all or part of its length, open channel computations are performed.

A series of data menus, data screens, summary screens, and output screens guides the user through the program. Each menu contains several options to match the desired culvert configuration, while the data screens prompt the user for specific dimensions and coordinates. Summary screens allow the user to edit entered data or change menu selections. Output screens display the output as calculations proceed; hard copy is only obtained using the "print screen" key.

There are three main groups of data to be entered into the program: initial culvert data, downstream channel data, and roadway data. Within the program, the user is sequentially led from one group to the next. From these sets of data, the program develops culvert performance data with or without overtopping. A performance curve can be plotted on a computer with graphics capabilities by typing a **V** for view. In addition to developing performance curves, the program generates rating curves for uniform flow, velocity, and maximum shear for the downstream channel. Culvert outlet velocities, inlet control head, and outlet control head are also calculated.

Operation

To allow the software to be used by a wide audience, Hydrain operates on an IBM XT/PC or equivalent microcomputer with 640 K RAM, a hard disk, and a monochrome monitor. A math coprocessor is recommended. Engineering programs are in FORTRAN 77. Shells are in C. The HYDRO, HYDRA, and CDS programs are equipped with a "semi-expert" system that includes extensive input shells and "short" and "long" help files. The other programs available to the experienced to expert Hydrain user, WSPRO and HY8, have received a minimum level of development under the Hydrain system.

Report Contents

The remaining section of this volume provides technical reference and user instructions for the WSPRO program. There are a total of 6 such volumes for Hydrain.

Disclaimer

FHWA, the pooled fund States and their agents have, within the limits of their resources, tested and debugged the Hydrain shells. The engineering programs derive from several varied sources and were adapted to Hydrain and also underwent testing and debugging. However, this is a very large and somewhat complicated system of logic and computer code. Errors and omissions may remain in the software. Therefore, use at your own risk. Please document problems and errors and report to FHWA. User support and technical assistance will be provided to pooled fund States. Agents of these States using the system should channel their requests for support or assistance through their sponsor State.

1. Introduction

The Water-Surface Profile Computation Model Microcomputer Program (WSPRO) has been designed to provide a water-surface profile for six major types of flow situations: 1) unconstricted flow, 2) single-opening bridge, 3) bridge opening(s) with spur dikes, 4) single-opening, embankment overflow, 5) multiple alternatives for a single job, and 6) multiple openings.

This chapter is designed to aid the user in understanding the capabilities and limitations of the model, provide an overview of terms used in model input and output, provide three examples in the preparation and review of data sets for the model and illustrate how WSPRO is applied on a microcomputer.

WSPRO was originally developed by the United States Geologic Survey (USGS) for the Federal Highway Administration (FHWA). The original model was a batch mode mainframe program, written in FORTRAN. The members of the Pooled Fund Project (PFP) decided to use WSPRO as the bridge waterways analysis element of the Integrated Computerized Drainage Design System. WSPRO was downloaded to the microcomputer by the USGS and FHWA. The microcomputer version of WSPRO, referenced in this document, is dated August 1987. As yet, WSPRO does not have a user friendly, interactive shell to aid in data collection and manipulation, although this is planned as a future enhancement. The result is that the user must currently create or edit an input file on a line editor or word processor. Therefore, one goal of this document is to assist the user in the preparation of such data sets.

Examples have been provided for creating input files for flow situations one through three above, giving explanation of terms and sample cases depicting possible data coding formats. The input file forms a logical description of the physical characteristics of a waterway, and, once the user is comfortable with this method of data setup, of the program will provide a simple method for determining water surface profiles. In the third example, bridge opening(s) with spur dikes, only a single opening will be considered.

Any questions concerning for detailed descriptions of variables or data records should be referred to the WSPRO Users Manual.[1] Any questions concerning theory should be referred to the Bridge Waterways Analysis Model, Research Report.[2]

2. **System Overview**

Capabilities and Limitations

In this section of the applications guide, several of WSPRO's capabilities and limitations will be briefly discussed. The information is a synopsis of that found in the technical reference.[2]

- Water-surface profile computations in the absence of bridges are generally consistent with the methods used in other models such as the Corps of Engineers HEC-2.
- Any combination of subcritical, critical, and supercritical flow profiles may be analyzed for one dimensional, gradually varied, steady flow.
- Discharge may be varied from cross section to cross section to account for tributary and lateral flow gains or losses.
- Up to 20 profiles for different discharges and/or initial water surface elevations may be computed at one time.
- Initial water-surface elevations for each profile may be specified by the user or computed by the model.
- Variable Manning's roughness coefficients may be specified for any cross section to reflect roughness changes both horizontally and vertically in the cross section.
- Up to three different flow lengths for left, central and right portions of a valley may be specified between any two valley cross sections.
- Users may select the friction-slope averaging technique to be used in the friction loss computations.
- Users may specify the coefficients used to compute energy losses associated with expansion or contraction of flow.
- The model will compute backwater for both free-surface and pressure flow situations at a bridge.
- The model can compute water-surface profiles through bridges for cases where road overflow occurs in conjunction with flow through the bridge opening.
- The effects of spur dikes on the water-surface profile is estimated when spur dike data are entered.
- The model can analyze multiple waterway openings for a cross section, including culverts when used as one of the multiple openings.

WSPRO Input and Output Overview

Before the three example problems are described, a brief overview of some of the terms and concepts used in WSPRO input and output will be discussed. As with the previous section, this overview is intended to provide the user with a synopsis of the user documentation.[1]

- There are approximately 40 record types; each record type performing a specific operation and identified by a one or two character name field. A listing of these record types, with a brief description of their meanings can be found in table 1.

- Records are fixed format in the first 10 characters and free format thereafter. The fields are separated by blanks, commas or asterisks.

- Many coefficients and computational control variables are assigned default values by the model and generally need not be specified. The variables can be overridden if the user desires.

- Generally, the model assumes that if data is not entered for a specific cross section, the data is identical to the previous cross section.

- It is possible to fabricate valley cross sections from a template cross section when two or more cross sections are very similar in shape.

- Bridge openings may be defined either 1) in the case of existing bridges, entirely by horizontal station and ground elevation coordinates, or 2) in terms of geometric parameters of bridge components that are combined with valley cross section data to "build" the bridge cross section.

- In a manner similar to bridge openings, spur dikes may be user defined or "built" by the model.

- Road grade data may be defined in terms of either 1) horizontal station and ground elevation coordinates, or 2) vertical curve data.

- When nonstandard conditions are encountered, many of the variable coefficients and parameters which would normally be computed by the model can be "over-ridden" with user specified values.

- The amount and type of output information can be controlled by the user (to the point where the user can define output tables). Table 2 presents output table types.

- Printer plots of cross-section data may be obtained.

Table 1. Input record types.(1)

TITLE INFORMATION

T1, T2, T3 - alphanumeric 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 of starting water-surface elevation(s)
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, and culverts, and in data propagation)

Roughness Data

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

Flow Length Data

FL - flow lengths and/or friction slope averaging technique

Table 1. Input record types (continued).

Bridge Section Data (DESIGN MODE)

BL - bridge length and location (M)
BD - bridge deck parameters (M)
AB - abutment slopes (M)
CD - opening type and configuration (M)
PW - pier or pile data (O)
KD - conveyance breakpoints (O)

Bridge Section Data (FIXED GEOMETRY MODE)

CD - opening type and configuration (M)
AB - abutment toe elevations (M)
PW - pier or pile data (O)
KD - conveyance breakpoints (O)

Approach Section Data

BP - horizontal datum correction between bridge and approach sections

Road Grade Section Data

RG - vertical curve data
BP - horizontal datum correction between bridge and road grade sections

Culvert Section Data

CG - culvert geometry
CC - culvert coefficients

Template Geometry Propagation

GT - replaces GR data when propagating template section geometry

DATA DISPLAY COMMANDS

HP - compute and print table of hydraulic properties of cross section
PX - produce printer plot of cross section

Note: (M)andatory / (O)ptional designations apply only where these routines are used.

Table 2. Output record types.(1)

WSEL - Water-surface elevation
VHD - Velocity head
Q - Discharge
SRD - Section reference distance
EGL - Energy grade line

ERR - Error in energy/discharge balance
FLEN - Flow distance
SLEN - Straight-line (SRD) distance
HF - Friction loss
HO - Other losses

VEL - Velocity
FR# - Froude number
CRWS - Critical water-surface elevation
K - Cross-section conveyance
AREA - Cross-section area

ALPHA - Velocity head correction factor
BETA - Momentum correction factor
XMAX - Maximum station in cross section
YMAX - Maximum elevation in cross section
XMIN - Minimum station in cross section

YMIN - Minimum elevation in cross section
SPLT - Stagnation point, left
SPRT - Stagnation point, right
SKEW - Skew of cross section
XSWP - Cross section wetted perimeter

XSTW - Cross section top width
LEW - Left edge of water
REW - Right edge of water
EX - Expansion loss coefficient
CK - Contraction loss coefficient

BLEN - Bridge opening length
XLAB - Abutment station, left toe
XRAB - Abutment station, right toe
LSEL - Low steel elevation
FLOW - Flow classification code

TYPE - Bridge opening type
C - Coefficient of discharge
PPCD - Pier or pile code
P/A - Pier area ratio
Q - Flow over road

WLEN - Weir length
LEW - Left edge of weir
REW - Right edge of weir
DMAX - Maximum depth of flow
CAVG - Average weir coefficient

HAVG - Average total head
DAVG - Average depth of flow
VMAX - Maximum velocity
VAVG - Average velocity
M(K) - Flow contraction ratio
KQ - Conveyance of Kq-section
XLKQ - Left edge of Kq-section
XRKQ - Right edge of Kq-section
M(G) - Geometric contraction ratio
OTEL - Road overtopping elevation

3. **User Documentation**

WSPRO and the Hydrain system shell

The first step in using WSPRO is to enter the Hydrain system shell. This is achieved by typing **HYDRAIN** and striking Enter or Carriage Return, denoted by <CR>. The preliminary screen provides the user with information on the sponsors of the Hydrain software. Strike any key to continue. The next screen appearing is a statement dealing with the responsibilities of the user and FHWA. Again, any key can be pressed to continue. After these screens, the user reaches the Hydrain Primary Menu. This menu is represented in figure 1. The primary menu allows the user to access the programs in the Pooled Fund Project. Move the cursor to the WSPRO option using the arrow keys and strike <CR> or simply strike the **W** key.

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HYDRAIN - DRAINAGE DESIGN SYSTEM → PRIMARY MENU

HYDRO   CDS   PFP-HYDRA   WSPRO   HY8   DOS   FILES   INFO PFP   QUIT

Access Bridge Waterways Design & Analysis (WSPRO/HY7) Program

                        F6-MENU  F10-HELP
```

Figure 1. Hydrain primary menu.

From within the Hydrain system shell, the user can access any of the Pooled Fund Programs. For assistance at any time within the Hydrain programs, the user can take advantage of active short helps, or, by striking <F10>, enter into long helps.

The next screen that the user will encounter is the job option menu. This is the menu that the user will employ to create or edit a WSPRO input data set as well as execute the actual WSPRO analytical program. A screen illustrating the job option menu is shown in figure 2.

Entering Input Data

Currently, WSPRO does not have an interactive input program to assist in entering data. The user must use a word processor or line editor. These programs can be accessed without "leaving" the Hydrain shell by selecting the **Input / Edit Data File** option, by either striking **I** or moving the cursor to this entry through use of the cursor keys and striking <CR>.

HYDRAIN - DRAINAGE DESIGN SYSTEM → WSPRO/HY7 PROGRAM

Access Bridge Waterways Design & Analysis (WSPRO/HY7) Program
Job Option Menu -- Select job option choice from list

Input / Edit Data File
Run Program / Review File

Quit (return to primary menu)

Create or edit data for analysis program

F6-MENU F10-HELP

Figure 2. Job option menu.

The user will be placed temporarily into DOS, getting a message to this effect. The user is now free to enter a word processor or line editor and create a input data set.

Type "EXIT" to return to Hydrain <----- How To Return To Hydrain

The IBM Personal Computer DOS
Version 3.10 (C)Copyright International Business Machines Corp 1981, 1985
(C)Copyright Microsoft Corp 1981, 1985

<C:\PFP\WSPRO> <----- At DOS Prompt, Enter the name of the line editor...

The directory in which the user is placed will be the WSPRO data directory (see the Hydrain system shell documentation for more information on disk and data directories).

Be sure when saving the file in the word processor, that a **.WSP** extension is used. Hydrain will not be able to run the input data set without this correct extension.

When finished creating or editing the input file, leave the line editor (return to the DOS prompt) and enter **EXIT** and strike <CR>. Note: the user must enter **EXIT** to return to the system shell (if this does not occur, Hydrain will remain resident in memory).

Executing WSPRO

After entering **EXIT**, the user returns to the Hydrain job option menu. To execute the WSPRO program, select the second option, **Run Program / Review File** by moving the cursor to this option and striking <CR> or simply striking **R**.

The user will be prompted for the input file name as shown in figure 3. Note that the extension is assumed to be **.WSP**. Enter the file that was just created and strike <CR> to execute WSPRO and review the results.

```
HYDRAIN - DRAINAGE DESIGN SYSTEM → WSPRO/HY7 PROGRAM

Access Bridge Waterways Design & Analysis (WSPRO/HY7) Program
Type file name (wildcard character ? or * will envoke file menu)

              Data File Name  - C:\PFP\WSPRO\*________.WSP

                 F5-CLEAR-F  F6-MENU  F10-HELP
```

Figure 3. File prompt screen.

After the program finishes executing, the output file will be placed into the Hydrain Review Program for the user to observe. There the user can decide to create another WSPRO input file or correct errors in the input data set, by again using the **Input / Edit Data File** option.

Leaving the Hydrain system shell

To depart the Hydrain system shell, return to the primary menu by moving to **Quit** and striking <CR> or simply by pressing **Q**. Once in the primary menu, move the cursor to **Quit** and press <CR> or strike **Q**. The user will be returned to DOS.

The next section will provide the user with information on how to create data sets by "building" the three simple examples mentioned in the introduction.

4. Example Problems

As mentioned in the introduction, example problems will be used to illustrate three flow situations; unconstricted flow, a single-opening bridge, and a single-opening bridge with spur dikes. Effort will be made to "build" on each previous example so that the user may get a "feel" for the necessary data required to create a more and more complicated waterway.

Example 1: Water surface profile computations without considering bridges

I. Problem Statement: Given the following site conditions, for a proposed bridge site, determine the water surface profile for the unconstricted valley. The stream reach is 3/4 mile long; is relatively straight; cross section geometry remains the same throughout; bed slope varies along the reach. Due to the uniformity of the reach, only one cross section will be required. The section is located at the center of the proposed bridge site at a section reference distance (SRD) of 2500 feet. A gauging station is located at SRD 1000 feet, providing a stage-discharge relation at that location. Figures 4 and 5 illustrate the cross sectional and channel profiles.

II. Setting Up Data Input: Input data is organized into five general groups: 1) title information; 2) job parameters; 3) profile control data; 4) cross-section definition (that includes cross-section coordinate, roughness data and cross-section information subgroups); and 5) display and execution commands. Each group may be further broken down into subgroups. The record types are defined by a one or two character identifier. Example one will be input in the following manner. The input data set will follow the group descriptions.

A. Title Information: Identifiers **T1, T2, T3** provide the user with an area in which output identification information is entered. This information can be site location data, comments, report names, etc.

B. Job Parameters: Three data records (with identifiers **J1, J2, J3**) are available to define parameters pertaining to the profile computations in their entirety.

A **J1** record is used to specify the computational control parameters shown below:

DELTAY - An elevation stepping increment, with a default value of 1.0,
YTOL - an allowable error tolerance between elevations, with a default value of 0.02,
QTOL - an allowable error tolerance between input and computed discharges, having a default value of 0.02,
FNTEST - a Froude number test value, having a 0.8 default value,

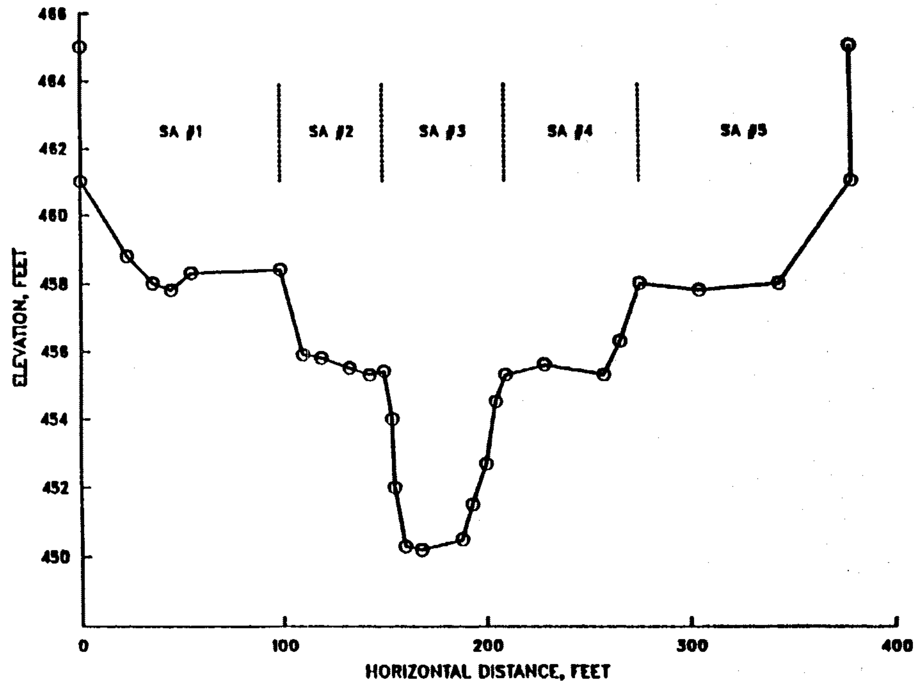

Figure 4. Example cross section.(1)

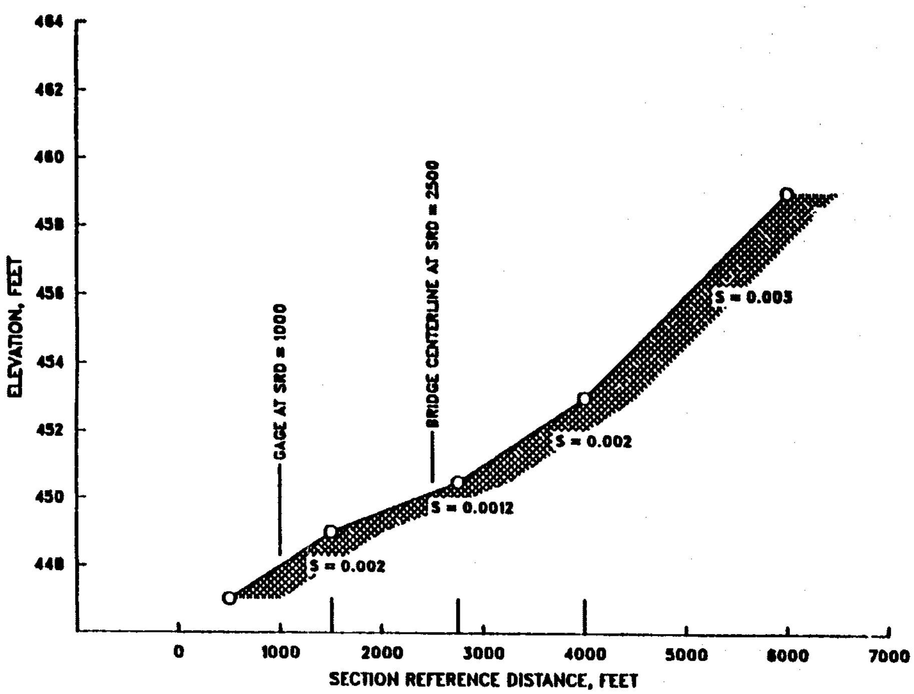

Figure 5. Example channel profile.(1)

IHFNOJ - a flag to select friction slope for all subreaches, a zero or blank is the default value.

If these values are acceptable, then ignore **J1**. Likewise, the **J2** and **J3** records are not used if using default values. Specifically, the J2 record is designed for input controls, but has not been fully implemented and should be ignored. The **J3** record can specify parameters for special output tables. Default values for **J3** indicate that no special output tables are desired. In this case of example one, default values are used.

C. Profile Control Data: For each water surface profile to be computed the following information is required: a) discharge - **Q**; b) starting elevation - **WS**, or energy slope - **SK**; and c) computation direction - **EX**. After identifying the type of data, the values may be input in a free format. Attention to spacing may make it easier for the user to re-interpret the data later on.

In the first example, five different profiles will be considered. Each profile will contain a value of discharge with its respective starting water surface elevation. For example one, the profile control data is shown in table 3.

Table 3. Example one profile control data.

Q (in ft^3/s)	**WS** (in feet)
3000	456.22
3500	456.63
4500	457.33
5500	457.92
7500	458.92

Note: For each entry on the **Q** record there must be a corresponding entry on a **WS** or **SK** and an **EX** identifier.

D. Cross-Section Definition: This data group will be separated into three subgroups; cross-section coordinates, roughness coefficients, and cross-section information.

1) Cross-Section Coordinates: In the example, assuming a uniform nature of the reach lends itself readily to the use of template sections. Horizontal geometry may be a) used without any adjustment, b) expanded or contracted by a scale factor, c) partially used by using selected portions of the section. Vertical geometry may also be a) used without adjustment, b) shifted by a constant, c) shifted by a product of valley slope and SRD difference. These parameters are entered using a **XT** record and the corresponding SRD; then, **GR** records define the horizontal and vertical cross-section data.

To fabricate a particular cross section, such as that at the gauging station, a **GT** record introduces the necessary scaling and shifting parameters. In this case, -2.2 is the shift that the Y coordinate makes from the original streambed elevation to this particular cross section.

2) Roughness Data: Figure 4 shows that a cross section may be made up of several subareas characterized by different geometry or roughness. Values of Manning's n may be specified in **N** records for each of these subareas. An n value is entered for the bottom of the subarea as well as the top. The hydraulic depths associated with these values of n are coded in **ND** records specifying first the bottom depth at and below which the bottom n is applicable. Between these depths a linear interpolation determines n. The **SA** records provide the right most X ordinate of each subarea.

3) Cross-Section Information: The user may consider unique cross sections by using the **XS** record and providing data pertinent to that particular cross section. In the example, this means entering information for a cross section at SRD 1500 and at SRD 2000 to reflect bottom slope, at SRD 2365 and SRD 2485, just prior to the bridge site, and at 2635, after the bridge site.

The values defining the cross section illustrated in figure 4 are provided in table 4.

Table 4. Cross-section definitions.

Subarea	Horizontal Distance (in ft)	Vertical Elevation (in ft)	Manning's Coefficient Range & Depth
#1	0.0	461.0	0.055 at the top (≥1) and 0.050 at the bottom (≤3).
	23.0	458.8	
	36.0	458.0	
	45.0	457.8	
	55.0	458.3	
	99.0	458.4	
#2	110.0	455.9	0.065 at the top (≥2) and 0.060 at the bottom (≤5).
	119.0	455.8	
	133.0	455.5	
	143.0	455.3	
	150.0	455.4	
#3	154.0	454.0	0.040 at the top (≥0) and 0.040 at the bottom (≤1).
	155.0	452.0	
	160.0	450.3	
	168.0	450.2	
	188.0	450.5	
	193.0	451.5	
	200.0	452.7	
	205.0	454.5	
	210.0	455.3	
#4	229.0	455.6	0.065 at the top (≥1) and 0.060 at the bottom (≤4).
	258.0	455.3	
	266.0	456.3	
	276.0	458.0	
#5	305.0	457.8	0.055 at the top (≥1) and 0.050 at the bottom (≤3).
	344.0	458.0	
	380.0	461.0	
	380.0	465.0	

E. Execution Commands: Finally, the **EX** record, corresponding to the **Q** and **WS** records, instructs the model to begin execution of the profile computations. The default direction of computation is upstream (for subcritical and/or critical flow), which is the case in this example. The **ER** record indicates the end of the run.

III. Complete Model Input Sequence: For example one, the complete input sequence is shown below. Any comments or notes to the user are in bold and should not be used in the model execution.

```
T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
T3        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICTED FLOW
J1        1.0  0.02  0.02  0.80  0          ← note: default values
J2        data input control - should be left out of input data set
J3        data output control - blank is default
Q           3000     3500     4500     5500     7500
WS        456.22   456.63   457.33   457.92   458.92
XT   SURVY  2500
GR           0.0,465.0     0.0,461.0    23.0,458.8    36.0,458.0    45.0,457.8
GR          55.0,458.3    99.0,458.4   110.0,455.9   119.0,455.8   133.0,455.5
GR         143.0,455.3   150.0,455.4   154.0,454.0   155.0,452.0   160.0,450.3
GR         168.0,450.2   188.0,450.5   193.0,451.5   200.0,452.7   205.0,454.5
GR         210.0,455.3   229.0,455.6   258.0,455.3   266.0,456.3   276.0,458.0
GR         305.0,457.8   344.0,458.0   380.0,461.0   380.0,465.0
XS    GAGE  1000
GT          -2.2
N              0.055,0.050      0.065,0.060      0.040,0.040
N              0.065,0.060      0.055,0.050
SA            99      150      210      276
ND           1,3      2,5      0,1      1,4      1,3
XS     XS2  1500     *    *    *      0.002
XS     XS3  2000     *    *    *      0.0012
XS    EXIT  2365
XS   FULLV  2485
XS    APPR  2635
EX
ER
```

Note: The asterisks in the second and third **XS** records are used to indicate that default or previously coded values for the acute angle of rotation of the channel, the expansion and contraction loss components, respectively, are to be used. The only adjustment to be made is in the valley slope - note that the 0.0012 ft/ft is assumed to be the slope for these last three **XS** records since a new slope value was not entered after XS3.

IV. Model Output: Model output, for example one, is extensive since five profiles are computed at seven cross sections. The output for a discharge of 3000 ft^3/s and the echoed input and computations for SRD 2500 and "GAGE" SRD 1000 are discussed in detail. The complete output is found in the appendix A.

A. Input Echo: Initially, data in the input data file is echoed, processed and saved. The data for the cross section "SURVY" at SRD 2500 is used to compute the X, Y coordinate pairs for the remaining cross sections. The parameter in the **GT** record identifies the shift from SRD = 2500 to SRD = 1000. The "max - min" points are calculated and all data is summarized.

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

          *** RUN DATE & TIME: 09-21-87  15:16

  T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
  T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
  T3        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICTED FLOW
  Q            3000    3500    4500    5500    7500
*** Q-DATA FOR SEC-ID, ISEQ =          1
  WS        456.22  456.63  457.33  457.92  458.92

WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICTED FLOW
          *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - "SURVY"
  XT   SURVY  2500
  GR           0.0,465.0    0.0,461.0   23.0,458.8   36.0,458.0   45.0,457.8
  GR          55.0,458.3   99.0,458.4  110.0,455.9  119.0,455.8  133.0,455.5
  GR         143.0,455.3  150.0,455.4  154.0,454.0  155.0,452.0  160.0,450.3
  GR         168.0,450.2  188.0,450.5  193.0,451.5  200.0,452.7  205.0,454.5
  GR         210.0,455.3  229.0,455.6  258.0,455.3  266.0,456.3  276.0,458.0
  GR         305.0,457.8  344.0,458.0  380.0,461.0  380.0,465.0

*** FINISH PROCESSING CROSS SECTION - "SURVY"
*** TEMPLATE CROSS SECTION "SURVY" SAVED INTERNALLY.

*** START PROCESSING CROSS SECTION - " GAGE"
  XS    GAGE  1000
  GT          -2.2
  N               0.055,0.050       0.065,0.060       0.040,0.040
  N               0.065,0.060       0.055,0.050
  SA             99      150     210      276
  ND            1,3      2,5     0,1      1,4      1,3
```

```
*** FINISH PROCESSING CROSS SECTION - " GAGE"
*** CROSS SECTION " GAGE" ADDED TO DAF, RECORD NO. =    1, IXTYPE =    1

--- DATA SUMMARY FOR SECID " GAGE" AT SRD =    1000.  ERR-CODE =      0

     SKEW      IHFNO     VSLOPE        EK         CK
       .0         0.      .0000        .50        .00

X-Y COORDINATE PAIRS  (NGP =  29):
      X       Y             X       Y             X       Y             X       Y
       .0  462.80          .0  458.80        23.0  456.60        36.0  455.80
     45.0  455.60        55.0  456.10        99.0  456.20       110.0  453.70
    119.0  453.60       133.0  453.30       143.0  453.10       150.0  453.20
    154.0  451.80       155.0  449.80       160.0  448.10       168.0  448.00
    188.0  448.30       193.0  449.30       200.0  450.50       205.0  452.30
    210.0  453.10       229.0  453.40       258.0  453.10       266.0  454.10
    276.0  455.80       305.0  455.60       344.0  455.80       380.0  458.80
    380.0  462.80

 X-Y MAX-MIN POINTS:
     XMIN       Y            X     YMIN        XMAX        Y             X     YMAX
       .0  462.80       168.0  448.00       380.0  458.80            .0  462.80

SUBAREA BREAKPOINTS (NSA =  5):
         99.     150.     210.     276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:     1.00     2.00      .00     1.00     1.00
TOP:     3.00     5.00     1.00     4.00     3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:     .055     .065     .040     .065     .055
TOP:     .050     .060     .040     .060     .050
```

B. Profile Calculations: Upon completion of the input echo and data summary, the model calculates a water-surface profile for each of the coded discharges. The output for a discharge of 3000 ft^3/s for the indicated cross sections is presented below.

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICTED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

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

GAGE:XS	******	29.	760.	.43	*****	456.65	454.16	3000.	456.22
1000.	******	349.	67119.	1.76	*****	*******	.60	3.95	
XS2:XS	500.	29.	760.	.43	1.00	457.65	*******	3000.	457.22
1500.	500.	349.	67183.	1.76	.00	.00	.60	3.95	
XS3:XS	500.	23.	880.	.33	.87	458.52	*******	3000.	458.19
2000.	500.	353.	77037.	1.84	.00	.01	.50	3.41	
EXIT:XS	365.	22.	918.	.31	.53	459.05	*******	3000.	458.74
2365.	365.	355.	80410.	1.86	.00	.00	.47	3.27	
FULLV:XS	120.	21.	932.	.30	.16	459.23	*******	3000.	458.93
2485.	120.	355.	81668.	1.87	.00	.01	.46	3.22	
APPR:XS	150.	21.	946.	.29	.20	459.44	*******	3000.	459.15
2635.	150.	356.	82880.	1.87	.00	.01	.46	3.17	

To interpret the output, the user must become familiar with the output descriptors. A brief listing of the descriptors found in the examples follows. A full listing was given earlier in table 2.

SRDL - Section distance length, the length between current section and adjacent downstream SRD. (feet)
FLEN - Flow distance between current cross-section and the adjacent downstream cross-section. (feet)
LEW - Left edge of water. (feet)
REW - Right edge of water. (feet)

AREA - Cross section area (ft^2)
K - Cross-section conveyance (ft^3/s)
VHD - Velocity head (feet)
ALPH - Velocity head correction factor, α
HF - Friction loss (feet)
HD - Other losses (expansion/contraction) (feet)
EGL - Energy gradeline elevation
ERR - Error in energy/discharge balance
CRWS - Critical water surface elevation (feet)
FR# - Froude number
Q - Discharge (ft^3/s)
VEL - Velocity (ft/s)
WSEL - Water surface elevation (feet)

Once the user becomes familiar with these terms, the output becomes more easily discernable. The resulting profiles may be used in further design processes.

Example 2: Simple Single Opening Bridge

I. Problem Statement: Now that the user is comfortable with unconstricted flow in the reach specified in example one, it is time to determine the effects of a simple, single-opening bridge on the water surface profile.

We wish to construct a bridge at SRD 2485. The bridge length between the tops of the abutments will be 120 feet; depth of the bridge deck is 1 foot; elevation of the top of the bridge deck is 463.0 feet, bridge width is 30 feet. Abutments, in this case, are vertical (without wingwalls). Figure 6 gives a plan view of the structure.

II. Setting up Data Input: Initially, the input for this example closely follows the input for example 1. The template section for SRD 2500 is unchanged. Data for gage cross-section stations at SRD 1000, 1500 and 2000 are not required since, from example one, we know the starting water-surface elevations at section "EXIT". The cross section at SRD 2365 (EXIT) has been fully described as SRD 1000 in example 1, the difference being that the slope is 0.0012 and there is no need of a Y-shifting factor in the **GT** record.

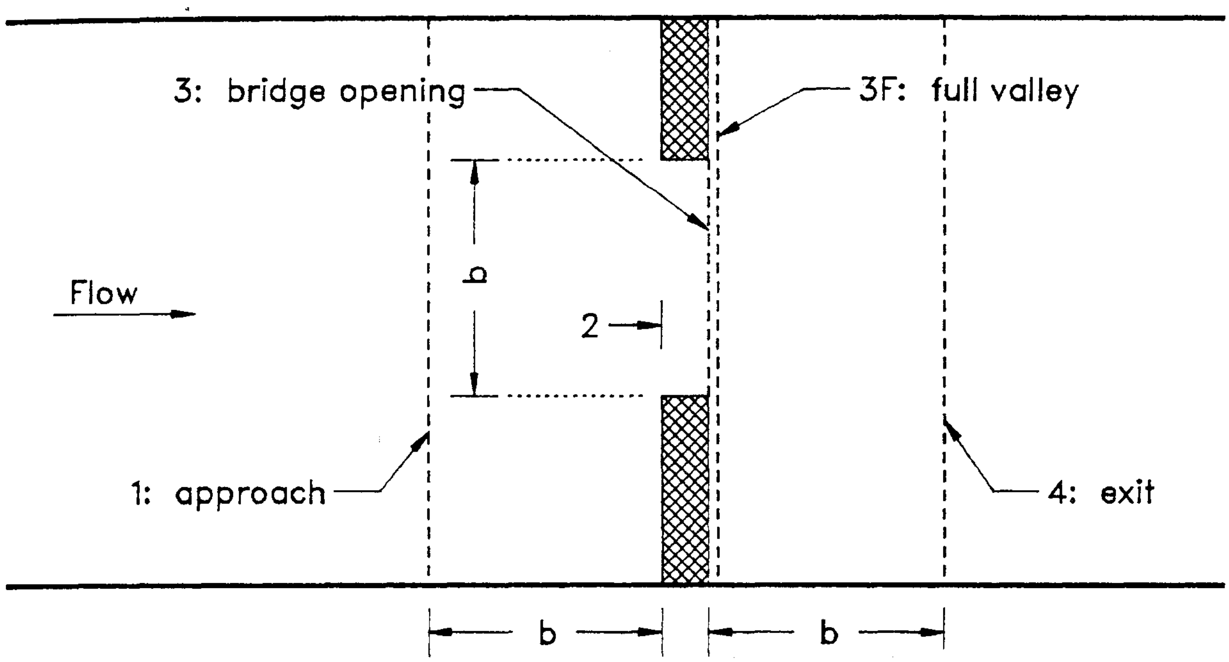

Figure 6. Plan view of structure.[2]

The user is familiar with all input coding up to the description of the bridge site; explanation of this section of input follows:

A. Cross-Section Description: The example two cross-section data will be the same as example one with the exception that only cross-section "EXIT" is considered. A slope of 0.012 ft/ft will be used as there were no earlier defined cross sections. A **GT** record without the shift parameter tells the program to use the template cross-section data without shifting the elevations. However, the template data will be adjusted based on the slope and the SRD of "EXIT". The channel roughness data will also be the same as used in example one.

B. Bridge Section: The **BR** record is the header for a bridge cross-section. The first entry in this record is a unique cross-section identification code that will be called "BRDGE". The second entry is the SRD of the cross section that in example two is equal to 2485.

A **BD** record specifies the bridge deck parameters. The first entry in this record is the depth of the bridge deck, in feet; the second is the elevation of the top of the bridge deck.

The **BL** record specifies the bridge length and the abutment constraints. The first entry for this example is a default value (blank or zero). This indicates that the bridge length is centered at the mid-point of the horizontal stations controlling the opening. The second entry in this record is the length of the bridge between the abutments, in feet. The third entry gives the right most horizontal location of the left boundary of the proposed opening; the fourth entry gives the left most location of the right boundary of the proposed opening.

The purpose of a **CD** record is to specify parameters used to compute the flow length and the coefficient of discharge for a bridge. The first of seven entries specifies the bridge opening type; A **1** (one) indicates vertical embankments and vertical abutments, with or without wingwalls. The second entry specifies the total width of the bridge deck in the direction of flow. Entry three describes the embankment side slope and the fourth entry codes the embankment elevation. Entries three and four are not applicable to a type 1 opening. Entry five is the wingwall angle - for this example, the default value of zero degrees is used. Wingwall width is the sixth entry; we will use the default value 0 for the example case. The seventh, and final **CD** entry gives the radius of the entrance rounding. Since we do not have a rounded entrance, the default value of zero is used.

Finally, the Manning's roughness values for the bridge surface are given. The records meaning are the same as were discussed earlier.

C. Approach Section: An **AS** identifier is the header record for an approach cross section. The first entry is a unique cross-section identity code; the second is the SRD of the section.

D. Execution Commands: Finally, the user codes the **EX** and **ER** records, indicating the start of calculation and end of run, respectively.

III. Complete Model Input Sequence: For example two, the complete input sequence is shown below.

```
T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
T3        <<<<< EXAMPLE PROBLEM ONE - SIMPLE BRIDGE OPENING FLOW
*
Q           3000    3500    4500    5500    7500
WS        458.74  459.16  459.87  460.48  461.50
*
XT   SURVY  2500
GR           0.0,465.0     0.0,461.0   23.0,458.8   36.0,458.0   45.0,457.8
GR          55.0,458.3    99.0,458.4  110.0,455.9  119.0,455.8  133.0,455.5
GR         143.0,455.3   150.0,455.4  154.0,454.0  155.0,452.0  160.0,450.3
GR         168.0,450.2   188.0,450.5  193.0,451.5  200.0,452.7  205.0,454.5
GR         210.0,455.3   229.0,455.6  258.0,455.3  266.0,456.3  276.0,458.0
GR         305.0,457.8   344.0,458.0  380.0,461.0  380.0,465.0
*
XS    EXIT  2365     *    *    *     0.0012
GT
*
N                0.055,0.050      0.065,0.060      0.040,0.040
N                0.065,0.060      0.055,0.050
SA            99     150     210     276
ND           1,3     2,5     0,1     1,4     1,3
*
XS   FULLV  2485
BR   BRDGE  2485
BD           1.0   463.0
BL           120     135     225
CD             1      30
N            0.040,0.050
ND           3,5
SA
AS    APPR  2635
EX
ER
```

Note: The * entered into the first column indicates a blank row, used for spacing of data.

IV. Model Output: Model output is given in two distinct forms: a) input echo, and b) computed water surface profile. The input echo section does contain some intermediate computations; the x,y - coordinate pairs of indicated cross sections are computed and displayed as well as x,y maximum and minimum points.

A. Input Echo: The input echo section of the output is very similar to that described in example 1 until the bridge section is echoed, the only difference resulting from the shifted starting elevations. A detailed explanation of the bridge and approach sections follow.

1) Bridge Section: A sample of the input echo for bridge cross-section follows. As with the cross sections in example 1, the coded input is echoed and the cross section is processed and summarized.

The cross-section information is summarized first. The skew angle, friction slope code (**IHFNO**), valley slope, expansion and contraction coefficient values were initially input at cross-section "exit" SRD 2365 and remain unchanged for the reach until a new value is coded in. The x,y - coordinate pairs are computed and displayed. X-Y maximum and minimum points are found and the roughness depths and Manning's coefficients are listed.

Finally, the bridge parameters, design data and pier data (input in records **BR**, **BD**, **BL** and **CD**) are echoed. A brief listing of data headings encountered in this example follows:

BRTYPE - Bridge opening type
BRWDTH - Bridge deck width
LSEL - Elevation of the low chord of the bridge opening, calculated by the model in design mode (feet)
USERCD - User specified discharge coefficient, calculated by the model if default option is used
WWANGL - Wingwall angle (degrees)
WWWID - Wingwall width (feet)
CRRAD - Radius of roundness of opening
BRLEN - Bridge length between abutment tops (feet)
LOCOPT - Bridge location with respect to horizontal stationing feet)
XCONLT - Horizontal stationing for left abutment constraint (feet)
XCONRT - Horizontal stationing for right abutment constraint (feet)
GIRDEP - Girder or deck depth (feet)
BDELEV - Deck elevation (feet)
BDSLP - Deck slope (ft/ft)
BDSTA - Deck slope station (feet)
NPW - Number of piers
PCODE - Pier code

An portion of example two output follows.

```
*** START PROCESSING CROSS SECTION - "BRDGE"
  BR   BRDGE  2485
  BD            1.0   463.0
  BL            120     135      225
  CD              1      30
  N                0.040,0.050
  ND            3,5
  SA

*** FINISH PROCESSING CROSS SECTION - "BRDGE"
*** CROSS SECTION "BRDGE" ADDED TO DAF, RECORD NO. =    3, IXTYPE =    2

--- DATA SUMMARY FOR SECID "BRDGE" AT SRD =   2485.  ERR-CODE =      0

     SKEW      IHFNO    VSLOPE        EK         CK
       .0         0.     .0012       .50        .00

X-Y COORDINATE PAIRS  (NGP =  18):
       X      Y              X      Y              X      Y              X      Y
    120.0  462.00       120.0  455.76       133.0  455.48       143.0  455.28
    150.0  455.38       154.0  453.98       155.0  451.98       160.0  450.28
    168.0  450.18       188.0  450.48       193.0  451.48       200.0  452.68
    205.0  454.48       210.0  455.28       229.0  455.58       240.0  455.47
    240.0  462.00       120.0  462.00

 X-Y MAX-MIN POINTS:
     XMIN       Y            X    YMIN       XMAX       Y            X    YMAX
    120.0  462.00       168.0  450.18       240.0  455.47       120.0  462.00

ROUGHNESS DEPTHS (NRD =  2):
BOT:      3.00
TOP:      5.00

ROUGHNESS COEFFICIENTS (NSA =  1):
BOT:      .040
TOP:      .050

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  WWANGL  WWWID  CRRAD
    1      30.0   462.00 ******* ******* ****** ******

DESIGN DATA:     BRLEN  LOCOPT   XABLT   XABRT
                 120.0      0.   135.0   225.0

                GIRDEP  BDELEV   BDSLP   BDSTA
                  1.00  463.00 ******* *******


PIER DATA:  NPW =  0   PCODE = **
```

2) Approach Section: The input echo for an approach station closely follows the format of a standard cross-section. The only "new" information is the bridge projection data, which is coded in the **BP** record. Since the approach is unskewed, default values are indicated. A full description of these variables is given in the users manual. The input echo for the approach section is displayed below.

```
*** START PROCESSING CROSS SECTION - " APPR"
  AS    APPR  2635
  EX

*** FINISH PROCESSING CROSS SECTION - " APPR"
*** CROSS SECTION " APPR" ADDED TO DAF, RECORD NO. =     4, IXTYPE =    5

--- DATA SUMMARY FOR SECID " APPR" AT SRD =    2635.  ERR-CODE =      0

     SKEW      IHFNO    VSLOPE        EK         CK
       .0         0.     .0012       .50        .00

X-Y COORDINATE PAIRS  (NGP =  29):
       X       Y            X      Y             X      Y             X      Y
      .0  465.16           .0  461.16         23.0  458.96         36.0  458.16
    45.0  457.96         55.0  458.46         99.0  458.56        110.0  456.06
   119.0  455.96        133.0  455.66        143.0  455.46        150.0  455.56
   154.0  454.16        155.0  452.16        160.0  450.46        168.0  450.36
   188.0  450.66        193.0  451.66        200.0  452.86        205.0  454.66
   210.0  455.46        229.0  455.76        258.0  455.46        266.0  456.46
   276.0  458.16        305.0  457.96        344.0  458.16        380.0  461.16
   380.0  465.16

 X-Y MAX-MIN POINTS:
    XMIN       Y            X    YMIN         XMAX       Y            X    YMAX
      .0  465.16        168.0  450.36        380.0  461.16           .0  465.16

SUBAREA BREAKPOINTS (NSA =  5):
         99.    150.    210.    276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:     1.00    2.00     .00    1.00    1.00
TOP:     3.00    5.00    1.00    4.00    3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055    .065    .040    .065    .055
TOP:      .050    .060    .040    .060    .050

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

B. <u>Profile Calculations:</u> Upon completion of the input echoing and data summary, the model computes a water surface profile for each discharge. The profile for a discharge of 3000 ft^3/s is presented below.

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

EXIT:XS   ******    22.     917.    .31  *****  459.05   456.20   3000.  458.74
    2365. ******   355.   80310.   1.86  ***** *******      .47    3.27

FULLV:FV    120.    21.     931.    .30    .16  459.23  *******   3000.  458.93
    2485.   120.   355.   81582.   1.87    .00     .01      .46    3.22
      <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR:AS     150.    21.     945.    .29    .20  459.44  *******   3000.  459.15
    2635.   150.   356.   82808.   1.87    .00     .01      .46    3.18
      <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRDGE:BR    120.   120.     638.    .45    .24  459.31   456.24   3000.  458.87
    2485.   120.   240.   55250.   1.30    .02     .00      .41    4.70

    TYPE PPCD FLOW      C     P/A     LSEL    BLEN    XLAB    XRAB
      1. ****   1.   .877  ******  462.00    120.    120.    240.

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

APPR:AS     120.    19.    1021.    .25    .22  459.62   456.53   3000.  459.37
    2635.   123.   359.   89862.   1.88    .09     .00      .41    2.94

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .642   .147   76494.   122.   242.  459.24

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

The user may notice that the format is the same as the format encountered in example one. The flow which is now constricted, through addition of the single opening bridge, requires additional descriptors for computational results. An explanation of new output headings follows.

TYPE - Bridge Opening Type - Same as BRtype
PPCD - Pier or Pile Code
FLOW - Flow Classification Code
C - Coefficient of Discharge

P/A - Pier Area Ratio
LSEL - Low Steel (submergence) Elevation (feet)
BLEN - Bridge Opening Length (feet)
XLAB - Abutment Station. Left Toe (feet)
XRAB - Abutment Station, Right Toe
M(G) - Geometric Contraction Ratio (Width)
M(K) - Flow Contraction Ratio (conveyance)
KQ - Conveyance of Kq section. The Kq section is the portion of the approach section that conveys discharge that can flow through the bridge opening uncontracted. (ft^3/s)
XLKQ - Left Edge of Kq Section (feet)
XRKQ - Right Edge of Kq Section (feet)
OTEL - Road Overtopping Elevation (feet)

Comparison of the results for unconstricted flow and constricted flow at SRD 2485 point out the effects of constricting the channel: area is lessened; cross-section total conveyance is lessened; velocity head increases (the alpha velocity head correction factor decreased) friction loss increased; a critical water surface elevation is indicated; and velocity increases.

Comparing the flows at the approach section illustrates the effect of backwater occurrence resulting from the constriction of flow.

Example 3: Single Opening Bridge with Spur Dikes

I. Problem Statement: Building on examples one and two, the user may want to determine the effects of spur dikes on the water profile. The same reach will be considered, with a single opening bridge equipped with spur dikes. The spur dikes are offset 20 feet horizontally from the abutments and are elliptical, the center line is parallel to flow, and the length is 50 feet. See figure 7 for a plan view of the structure.

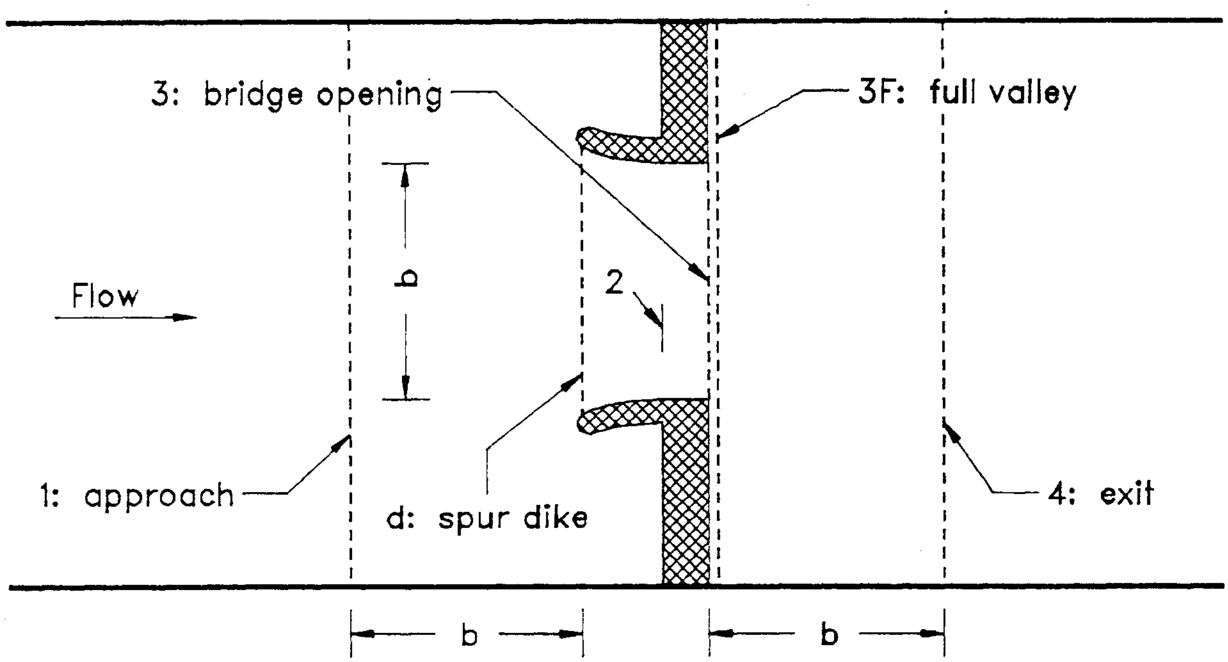

Figure 7. Plan view of spur dikes.(2)

II. Setting up Data Input: The input data set for example two is used with the addition of four lines to describe the added spur dikes. Description of the spur dike information follows.

A. Cross-Section Information: The **SD** record is the header record for the spur dike cross-section. The first entry is a unique identification code, in this case "SDIKE". The second entry is the SRD. The third, indicates the type of spur dike, coded 1-4; type 1 an elliptical spur dike, no skew, type 2 - an elliptical spur dike skewed, type 3 - straight spur dike no offset, type 4 - straight spur dike, with offset. The fourth entry refers only to a type 4 dike, so the default is used. The fifth, the horizontal offset, is the distance between the abutment and the wall of the spur dike, measured normal to the flow at the mouth of the dikes. The user is familiar with the last four entries; skew, expansion and contraction coefficients, and valley slope.

III. Partial Model Input Sequence: For example three, a partial input sequence is shown below.

```
SD   SDIKE  2535  1  *  20  *  *  *  .0012
N           0.040,0.050
ND              3,5
SA
```

IV. Model Output: Only the input echo for the spur dikes will be examined at this time - the user by now is familiar with the other input.

A. Input Echo: The input echo and data summary for cross section "SDIKE" is displayed below. It follows the same form as previously discussed with the addition of pertinent spur dike data: the type, straight dike offset and horizontal offset.

```
*** START PROCESSING CROSS SECTION - "SDIKE"
  SD   SDIKE  2535  1  *  20  *  *  *  .0012
  N           0.040,0.050
  ND              3,5
  SA

*** FINISH PROCESSING CROSS SECTION - "SDIKE"
*** CROSS SECTION "SDIKE" WRITTEN TO DISK, RECORD NO. =  4

--- DATA SUMMARY FOR SECID "SDIKE" AT SRD =   2535.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0012       .50       .00

 X-Y COORDINATE PAIRS  (NGP =  20):
       X       Y            X       Y            X       Y            X       Y

    100.0  462.06      100.0  458.21      110.0  455.94      119.0  455.84
    133.0  455.54      143.0  455.34      150.0  455.44      154.0  454.04
    155.0  452.04      160.0  450.34      168.0  450.24      188.0  450.54
    193.0  451.54      200.0  452.74      205.0  454.54      210.0  455.34
    229.0  455.64      258.0  455.34      260.0  455.59      260.0  455.53

  X-Y MAX-MIN POINTS:
     XMIN       Y            X    YMIN        XMAX       Y            X    YMAX
    100.0  462.06      168.0  450.24      260.0  455.59      100.0  462.06
```

```
ROUGHNESS DEPTHS (NRD =  2):
BOT:      3.00
TOP:      5.00

ROUGHNESS COEFFICIENTS (NSA =  1):
BOT:      .040
TOP:      .050

SPUR DIKE DATA:  SDTYPE  OFFSET  DESOFF
                     1. *******   20.00
```

B. Profile Calculations; The addition of spur dikes to the example increased the conveyance through the Kq section, as we would expect, and also increased the approach area and the friction loss. Partial output is displayed below.

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

 EXIT:XS   ******    22.     917.   .31 *****  459.05  456.20  3000.  458.74
     2365. ******   355.   80310.  1.86 ***** *******     .47   3.27

FULLV:FV     120.    21.     931.   .30   .16  459.23 *******  3000.  458.93
     2485.   120.   355.   81582.  1.87   .00     .01     .46   3.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR:AS     150.    21.     945.   .29   .20  459.44 *******  3000.  459.15
     2635.   150.   356.   82808.  1.87   .00     .01     .46   3.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRDGE:BR     120.   120.     649.   .33   .24  459.29  456.24  3000.  458.95
     2485.   120.   240.   56719.  1.00   .00     .00     .35   4.63

     TYPE PPCD FLOW      C    P/A     LSEL    BLEN    XLAB    XRAB
       1. ****   1.  1.000 ******   462.00    120.    120.    240.

===140 AT SECID "SDIKE":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =    459.20      462.1      455.5

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

SDIKE:SD      20.   100.     800.   .22   .05  459.42  456.33  3000.  459.20
     2535.    20.   260.   67690.  1.00 *****     .01     .30   3.75
```

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

APPR:AS     100.    19.     1011.    .26    .19  459.60   456.53   3000.   459.34
    2635.   103.   358.    88947.   1.88    .08     .01      .42    2.97

      M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      .642   .144    75756.   122.   242.   459.21

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

One item of interest is the "=== 140" message. This message means that the water surface level at y left or y right is below the final computed water surface elevation. If vertical extension of the end of the cross section adequately describes the cross section, no action need be taken.

A full listing of example three input data sets and a partial listing of the example one output dataset may be found in appendix A.

Appendix: Benchmark Examples

WSPRO Examples

Example One Input

```
T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
T3        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
Q           3000    3500    4500    5500    7500
WS        456.22  456.63  457.33  457.92  458.92
XT   SURVY  2500
GR            0.0,465.0    0.0,461.0   23.0,458.8   36.0,458.0   45.0,457.8
GR           55.0,458.3   99.0,458.4  110.0,455.9  119.0,455.8  133.0,455.5
GR          143.0,455.3  150.0,455.4  154.0,454.0  155.0,452.0  160.0,450.3
GR          168.0,450.2  188.0,450.5  193.0,451.5  200.0,452.7  205.0,454.5
GR          210.0,455.3  229.0,455.6  258.0,455.3  266.0,456.3  276.0,458.0
GR          305.0,457.8  344.0,458.0  380.0,461.0  380.0,465.0
XS    GAGE  1000
GT          -2.2
N              0.055,0.050      0.065,0.060      0.040,0.040
N              0.065,0.060      0.055,0.050
SA            99     150     210     276
ND           1,3     2,5     0,1     1,4     1,3
XS     XS2  1500     *   *   *     0.002
XS     XS3  2000     *   *   *     0.0012
XS    EXIT  2365
XS   FULLV  2485
XS    APPR  2635
EX
ER
```

Example Two Input

```
T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
T3        <<<<< EXAMPLE PROBLEM TWO - SIMPLE BRIDGE OPENING FLOW
*
Q           3000    3500    4500    5500    7500
WS        458.74  459.16  459.87  460.48  461.50
*
XT   SURVY  2500
GR            0.0,465.0    0.0,461.0   23.0,458.8   36.0,458.0  45.0,457.8
GR           55.0,458.3   99.0,458.4  110.0,455.9  119.0,455.8 133.0,455.5
GR          143.0,455.3  150.0,455.4  154.0,454.0  155.0,452.0 160.0,450.3
GR          168.0,450.2  188.0,450.5  193.0,451.5  200.0,452.7 205.0,454.5
GR          210.0,455.3  229.0,455.6  258.0,455.3  266.0,456.3 276.0,458.0
GR          305.0,457.8  344.0,458.0  380.0,461.0  380.0,465.0
*
XS    EXIT  2365     *   *   *     0.0012
```

```
GT
*
N             0.055,0.050       0.065,0.060       0.040,0.040
N             0.065,0.060       0.055,0.050
SA          99      150     210      276
ND         1,3      2,5     0,1      1,4      1,3
*
XS   FULLV  2485
BR   BRDGE  2485
BD         1.0    463.0
BL                  120     135      225
CD                    1      30
N             0.040,0.050
ND         3,5
SA
AS    APPR  2635
EX
ER
```

Example Three Input

```
T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
T3        <<<<< EXAMPLE PROBLEM THREE - SPUR DIKES BRIDGE FLOW
*
Q           3000     3500     4500     5500     7500
WS        458.74   459.16   459.87   460.48   461.50
*
XT   SURVY  2500
GR         0.0,465.0     0.0,461.0    23.0,458.8    36.0,458.0    45.0,457.8
GR        55.0,458.3    99.0,458.4   110.0,455.9   119.0,455.8   133.0,455.5
GR       143.0,455.3   150.0,455.4   154.0,454.0   155.0,452.0   160.0,450.3
GR       168.0,450.2   188.0,450.5   193.0,451.5   200.0,452.7   205.0,454.5
GR       210.0,455.3   229.0,455.6   258.0,455.3   266.0,456.3   276.0,458.0
GR       305.0,457.8   344.0,458.0   380.0,461.0   380.0,465.0
*
XS    EXIT  2365     *    *    *     0.0012
GT
*
N             0.055,0.050       0.065,0.060       0.040,0.040
N             0.065,0.060       0.055,0.050
SA          99      150     210      276
ND         1,3      2,5     0,1      1,4      1,3
*
XS   FULLV  2485
BR   BRDGE  2485
BD         1.0    463.0
BL         120      135     225
CD           1       30
N             0.040,0.050
ND         3,5
```

```
SA
SD   SDIKE  2535  1  *  20  *  *  *  .0012
N           0.040,0.050
ND             3,5
SA
AS    APPR  2635
EX
ER
```

Partial Example One Output

```
 WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: 09-21-87  15:16

   T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
   T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
   T3        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
   Q           3000    3500    4500    5500    7500
 *** Q-DATA FOR SEC-ID, ISEQ =           1
   WS        456.22  456.63  457.33  457.92  458.92


 WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

 *** START PROCESSING CROSS SECTION - "SURVY"
   XT   SURVY  2500
   GR          0.0,465.0    0.0,461.0   23.0,458.8   36.0,458.0   45.0,457.8
   GR         55.0,458.3   99.0,458.4  110.0,455.9  119.0,455.8  133.0,455.5
   GR        143.0,455.3  150.0,455.4  154.0,454.0  155.0,452.0  160.0,450.3
   GR        168.0,450.2  188.0,450.5  193.0,451.5  200.0,452.7  205.0,454.5
   GR        210.0,455.3  229.0,455.6  258.0,455.3  266.0,456.3  276.0,458.0
   GR        305.0,457.8  344.0,458.0  380.0,461.0  380.0,465.0

 *** FINISH PROCESSING CROSS SECTION - "SURVY"
 *** TEMPLATE CROSS SECTION "SURVY" SAVED INTERNALLY.

 WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16
```

```
*** START PROCESSING CROSS SECTION - " GAGE"
  XS    GAGE  1000
  GT          -2.2
  N               0.055,0.050       0.065,0.060       0.040,0.040
  N               0.065,0.060       0.055,0.050
  SA            99      150     210     276
  ND           1,3      2,5     0,1     1,4     1,3

*** FINISH PROCESSING CROSS SECTION - " GAGE"
*** CROSS SECTION " GAGE" ADDED TO DAF, RECORD NO. =    1, IXTYPE =    1

--- DATA SUMMARY FOR SECID " GAGE" AT SRD =   1000.  ERR-CODE =      0

     SKEW      IHFNO    VSLOPE        EK         CK
       .0         0.     .0000       .50        .00

X-Y COORDINATE PAIRS  (NGP =  29):
        X      Y            X      Y            X      Y            X      Y
       .0  462.80          .0  458.80        23.0  456.60        36.0  455.80
     45.0  455.60        55.0  456.10        99.0  456.20       110.0  453.70
    119.0  453.60       133.0  453.30       143.0  453.10       150.0  453.20
    154.0  451.80       155.0  449.80       160.0  448.10       168.0  448.00
    188.0  448.30       193.0  449.30       200.0  450.50       205.0  452.30
    210.0  453.10       229.0  453.40       258.0  453.10       266.0  454.10
    276.0  455.80       305.0  455.60       344.0  455.80       380.0  458.80
    380.0  462.80

 X-Y MAX-MIN POINTS:
     XMIN      Y            X    YMIN        XMAX      Y            X    YMAX
       .0  462.80       168.0  448.00       380.0  458.80          .0  462.80

SUBAREA BREAKPOINTS (NSA =  5):
         99.    150.    210.    276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00    2.00     .00    1.00    1.00
TOP:      3.00    5.00    1.00    4.00    3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055    .065    .040    .065    .055
TOP:      .050    .060    .040    .060    .050

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - "  XS2"
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  XS     XS2  1500     *    *    *      0.002

*** FINISH PROCESSING CROSS SECTION - "  XS2"
*** CROSS SECTION "  XS2" ADDED TO DAF, RECORD NO. =    2, IXTYPE =    1

--- DATA SUMMARY FOR SECID "  XS2" AT SRD =    1500.  ERR-CODE =       0

     SKEW      IHFNO    VSLOPE         EK         CK
       .0         0.     .0020        .50        .00

X-Y COORDINATE PAIRS  (NGP =  29):
       X      Y            X      Y            X      Y            X      Y
       .0  463.80          .0  459.80       23.0  457.60       36.0  456.80
     45.0  456.60        55.0  457.10       99.0  457.20      110.0  454.70
    119.0  454.60       133.0  454.30      143.0  454.10      150.0  454.20
    154.0  452.80       155.0  450.80      160.0  449.10      168.0  449.00
    188.0  449.30       193.0  450.30      200.0  451.50      205.0  453.30
    210.0  454.10       229.0  454.40      258.0  454.10      266.0  455.10
    276.0  456.80       305.0  456.60      344.0  456.80      380.0  459.80
    380.0  463.80

 X-Y MAX-MIN POINTS:
     XMIN        Y            X    YMIN       XMAX        Y            X    YMAX
       .0   463.80       168.0  449.00      380.0  459.80           .0  463.80

SUBAREA BREAKPOINTS (NSA =  5):
         99.     150.     210.     276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:     1.00     2.00      .00     1.00     1.00
TOP:     3.00     5.00     1.00     4.00     3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:     .055     .065     .040     .065     .055
TOP:     .050     .060     .040     .060     .050

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - "  XS3"
  XS     XS3  2000     *    *    *     0.0012

*** FINISH PROCESSING CROSS SECTION - "  XS3"
*** CROSS SECTION "  XS3" ADDED TO DAF, RECORD NO. =    3, IXTYPE =    1

--- DATA SUMMARY FOR SECID "  XS3" AT SRD =    2000.  ERR-CODE =       0
```

```
     SKEW      IHFNO    VSLOPE         EK         CK
       .0         0.     .0012        .50        .00

X-Y COORDINATE PAIRS   (NGP =  29):
       X      Y             X      Y              X      Y              X      Y
      .0  464.40           .0  460.40          23.0  458.20          36.0  457.40
    45.0  457.20         55.0  457.70          99.0  457.80         110.0  455.30
   119.0  455.20        133.0  454.90         143.0  454.70         150.0  454.80
   154.0  453.40        155.0  451.40         160.0  449.70         168.0  449.60
   188.0  449.90        193.0  450.90         200.0  452.10         205.0  453.90
   210.0  454.70        229.0  455.00         258.0  454.70         266.0  455.70
   276.0  457.40        305.0  457.20         344.0  457.40         380.0  460.40
   380.0  464.40

 X-Y MAX-MIN POINTS:
    XMIN       Y            X    YMIN        XMAX        Y              X    YMAX
      .0  464.40        168.0  449.60       380.0  460.40              .0  464.40

SUBAREA BREAKPOINTS (NSA =  5):
          99.     150.    210.    276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00    2.00     .00    1.00    1.00
TOP:      3.00    5.00    1.00    4.00    3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055    .065    .040    .065    .055
TOP:      .050    .060    .040    .060    .050

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - " EXIT"
  XS    EXIT  2365

*** FINISH PROCESSING CROSS SECTION - " EXIT"
*** CROSS SECTION " EXIT" ADDED TO DAF, RECORD NO. =    4, IXTYPE =    1

--- DATA SUMMARY FOR SECID " EXIT" AT SRD =   2365.  ERR-CODE =      0

     SKEW      IHFNO    VSLOPE         EK         CK
       .0         0.     .0012        .50        .00

X-Y COORDINATE PAIRS   (NGP =  29):
       X      Y             X      Y              X      Y              X      Y
      .0  464.84           .0  460.84          23.0  458.64          36.0  457.84
    45.0  457.64         55.0  458.14          99.0  458.24         110.0  455.74
```

```
    119.0  455.64     133.0  455.34     143.0  455.14     150.0  455.24
    154.0  453.84     155.0  451.84     160.0  450.14     168.0  450.04
    188.0  450.34     193.0  451.34     200.0  452.54     205.0  454.34
    210.0  455.14     229.0  455.44     258.0  455.14     266.0  456.14
    276.0  457.84     305.0  457.64     344.0  457.84     380.0  460.84
    380.0  464.84

 X-Y MAX-MIN POINTS:
     XMIN      Y          X    YMIN      XMAX       Y           X    YMAX
       .0  464.84     168.0  450.04     380.0  460.84          .0  464.84

SUBAREA BREAKPOINTS (NSA =  5):
         99.    150.    210.    276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00     2.00      .00     1.00     1.00
TOP:      3.00     5.00     1.00     4.00     3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055     .065     .040     .065     .055
TOP:      .050     .060     .040     .060     .050

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - "FULLV"
  XS   FULLV  2485

*** FINISH PROCESSING CROSS SECTION - "FULLV"
*** CROSS SECTION "FULLV" ADDED TO DAF, RECORD NO. =     5, IXTYPE =    1

--- DATA SUMMARY FOR SECID "FULLV" AT SRD =   2485.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0012       .50       .00

X-Y COORDINATE PAIRS  (NGP =  29):
       X      Y           X      Y            X      Y            X      Y
       .0  464.98         .0  460.98       23.0  458.78       36.0  457.98
     45.0  457.78       55.0  458.28       99.0  458.38      110.0  455.88
    119.0  455.78      133.0  455.48      143.0  455.28      150.0  455.38
    154.0  453.98      155.0  451.98      160.0  450.28      168.0  450.18
    188.0  450.48      193.0  451.48      200.0  452.68      205.0  454.48
    210.0  455.28      229.0  455.58      258.0  455.28      266.0  456.28
    276.0  457.98      305.0  457.78      344.0  457.98      380.0  460.98
    380.0  464.98
```

```
 X-Y MAX-MIN POINTS:
     XMIN        Y           X     YMIN       XMAX        Y           X     YMAX
       .0   464.98      168.0   450.18      380.0   460.98           .0   464.98

SUBAREA BREAKPOINTS (NSA =  5):
          99.     150.    210.     276.

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00     2.00      .00     1.00     1.00
TOP:      3.00     5.00     1.00     4.00     3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055     .065     .040     .065     .055
TOP:      .050     .060     .040     .060     .050

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

*** START PROCESSING CROSS SECTION - " APPR"
  XS    APPR  2635
  EX

*** FINISH PROCESSING CROSS SECTION - " APPR"
*** CROSS SECTION " APPR" ADDED TO DAF, RECORD NO. =     6, IXTYPE =    1

--- DATA SUMMARY FOR SECID " APPR" AT SRD =   2635.  ERR-CODE =      0

     SKEW      IHFNO     VSLOPE        EK         CK
       .0         0.      .0012       .50        .00

X-Y COORDINATE PAIRS  (NGP =  29):
        X        Y            X       Y            X       Y            X       Y
       .0   465.16           .0  461.16         23.0  458.96         36.0  458.16
     45.0   457.96         55.0  458.46         99.0  458.56        110.0  456.06
    119.0   455.96        133.0  455.66        143.0  455.46        150.0  455.56
    154.0   454.16        155.0  452.16        160.0  450.46        168.0  450.36
    188.0   450.66        193.0  451.66        200.0  452.86        205.0  454.66
    210.0   455.46        229.0  455.76        258.0  455.46        266.0  456.46
    276.0   458.16        305.0  457.96        344.0  458.16        380.0  461.16
    380.0   465.16

 X-Y MAX-MIN POINTS:
     XMIN        Y           X     YMIN       XMAX        Y           X     YMAX
       .0   465.16      168.0   450.36      380.0   461.16           .0   465.16

SUBAREA BREAKPOINTS (NSA =  5):
          99.     150.    210.     276.
```

```
ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00     2.00      .00     1.00     1.00
TOP:      3.00     5.00     1.00     4.00     3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:      .055     .065     .040     .065     .055
TOP:      .050     .060     .040     .060     .050

 NPROF, NQV  =       5     8

+++ BEGINNING PROFILE CALCULATIONS --       5


WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16

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

 GAGE:XS   ******     29.      760.    .43 *****  456.65   454.16    3000.   456.22
     1000. ******    349.    67119.   1.76 ***** *******      .60     3.95

  XS2:XS     500.     29.      760.    .43   1.00  457.65 *******    3000.   457.22
     1500.   500.    349.    67183.   1.76    .00     .00      .60     3.95

  XS3:XS     500.     23.      880.    .33    .87  458.52 *******    3000.   458.19
     2000.   500.    353.    77037.   1.84    .00     .01      .50     3.41

 EXIT:XS     365.     22.      918.    .31    .53  459.05 *******    3000.   458.74
     2365.   365.    355.    80410.   1.86    .00     .00      .47     3.27

FULLV:XS     120.     21.      932.    .30    .16  459.23 *******    3000.   458.93
     2485.   120.    355.    81668.   1.87    .00     .01      .46     3.22

 APPR:XS     150.     21.      946.    .29    .20  459.44 *******    3000.   459.15
     2635.   150.    356.    82880.   1.87    .00     .01      .46     3.17

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P061787             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
        <<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
           *** RUN DATE & TIME: 09-21-87  15:16
```

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
GAGE:XS	******	23.	893.	.44	*****	457.07	454.57	3500.	456.63
1000.	******	354.	78203.	1.85	*****	*******	.57	3.92	
XS2:XS	500.	23.	895.	.44	1.00	458.08	*******	3500.	457.64
1500.	500.	354.	78358.	1.85	.00	.00	.57	3.91	
XS3:XS	500.	19.	1020.	.34	.87	458.95	*******	3500.	458.61
2000.	500.	358.	89766.	1.88	.00	.01	.48	3.43	
EXIT:XS	365.	18.	1060.	.32	.53	459.48	*******	3500.	459.16
2365.	365.	360.	93650.	1.88	.00	.00	.45	3.30	
FULLV:XS	120.	17.	1074.	.31	.17	459.66	*******	3500.	459.35
2485.	120.	360.	95065.	1.88	.00	.01	.45	3.26	
APPR:XS	150.	17.	1088.	.30	.20	459.87	*******	3500.	459.57
2635.	150.	361.	96444.	1.88	.00	.01	.44	3.22	

WSPRO FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
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EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
<<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
*** RUN DATE & TIME: 09-21-87 15:16

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
GAGE:XS	******	15.	1130.	.46	*****	457.79	455.22	4500.	457.33
1000.	******	362.	100717.	1.88	*****	*******	.53	3.98	
XS2:XS	500.	15.	1131.	.46	1.00	458.79	*******	4500.	458.33
1500.	500.	362.	100796.	1.88	.00	.00	.53	3.98	
XS3:XS	500.	11.	1263.	.37	.88	459.67	*******	4500.	459.31
2000.	500.	367.	114669.	1.86	.00	.00	.45	3.56	
EXIT:XS	365.	10.	1308.	.34	.54	460.21	*******	4500.	459.87
2365.	365.	368.	119566.	1.85	.00	.00	.43	3.44	
FULLV:XS	120.	10.	1324.	.33	.17	460.39	*******	4500.	460.06
2485.	120.	369.	121301.	1.84	.00	.01	.42	3.40	
APPR:XS	150.	9.	1340.	.32	.20	460.61	*******	4500.	460.28
2635.	150.	369.	123026.	1.84	.00	.01	.42	3.36	

WSPRO FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY

P061787 MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS

EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
<<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
*** RUN DATE & TIME: 09-21-87 15:16

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
GAGE:XS	******	9.	1339.	.48	*****	458.40	456.01	5500.	457.92
1000.	******	369.	122968.	1.84	*****	*******	.51	4.11	
XS2:XS	500.	9.	1341.	.48	1.00	459.41	*******	5500.	458.92
1500.	500.	369.	123126.	1.84	.00	.00	.51	4.10	
XS3:XS	500.	5.	1479.	.39	.88	460.29	*******	5500.	459.90
2000.	500.	374.	139057.	1.81	.00	.00	.44	3.72	
EXIT:XS	365.	4.	1530.	.36	.55	460.84	*******	5500.	460.48
2365.	365.	376.	145046.	1.79	.00	.00	.42	3.60	
FULLV:XS	120.	3.	1547.	.35	.17	461.02	*******	5500.	460.67
2485.	120.	376.	147148.	1.79	.00	.01	.41	3.55	
APPR:XS	150.	3.	1565.	.34	.21	461.24	*******	5500.	460.90
2635.	150.	377.	149263.	1.78	.00	.01	.40	3.52	

WSPRO FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
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EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
<<<<< EXAMPLE PROBLEM ONE - SIMPLE UNCONSTRICITED FLOW
*** RUN DATE & TIME: 09-21-87 15:16

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
GAGE:XS	******	0.	1710.	.52	*****	459.44	457.06	7500.	458.92
1000.	******	380.	167653.	1.73	*****	*******	.48	4.38	
XS2:XS	500.	0.	1712.	.52	1.00	460.44	*******	7500.	459.92
1500.	500.	380.	167857.	1.73	.00	.00	.48	4.38	
XS3:XS	500.	0.	1859.	.42	.89	461.33	*******	7500.	460.91
2000.	500.	380.	188143.	1.67	.00	.00	.42	4.03	
EXIT:XS	365.	0.	1915.	.39	.56	461.89	*******	7500.	461.50
2365.	365.	380.	196001.	1.65	.00	.00	.40	3.92	
FULLV:XS	120.	0.	1933.	.39	.17	462.07	*******	7500.	461.69

```
    2485.    120.    380.  198628.  1.65    .00      .01      .39     3.88

APPR:XS      150.      0.    1952.   .38    .21  462.29 *******   7500.  461.92
    2635.    150.    380.  201337.  1.64    .00      .01      .38     3.84
 ER
 NORMAL  END  OF  WSPRO  EXECUTION.
```

References

1) Shearman, J., "Draft WSPRO User Document", Personal Correspondence, USGS, July, 1987.

2) Federal Highway Administration, "Bridge Waterways Analysis Model: Research Report", Report Number FHWA-RD-86-108, Washington DC, July 1986.