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User's Manual for WSPRO

A Computer Model for Water Surface Profile Computations

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16. Abstract

WSPRO, a water-surface profile computation model, can be used to analyze one-dimensional, gradually-varied, steady flow in open channels. WSPRO also can be used to analyze flow through bridges and culverts, embankment overflow, and multiple-opening stream crossings.

This user's manual provides guidance for using the WSPRO model and updates a previous edition dated September, 1990. It presents a general overview of input data requirements, uses conceptual examples to illustrate typical data sequences for various model applications, and provides detailed instructions for preparation of input data. Several example problems are included to illustrate both input data and model output. Analysis and interpretation of model output is discussed in detail.

Two additional appendices have been added. Section 10 documents operation of the HYDRAIN WSPRO Input/Output Program. Section 11 discusses the operation of the SMS WSPRO interface. Both programs automate user interaction with the computer model.

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SECTION 1 - INTRODUCTION

This manual presents data preparation instructions for WSPRO, a water-surface profile computation model. Version numbers are used to identify the various modifications and enhancements of the model. The version number consists of the letter V followed by the six-digit date (month, day, year). This manual corresponds with version V061698 of the program. Before studying these instructions, one should be aware of the basic computer resources and the user experience level required for WSPRO applications.

The WSPRO model consists of about 25,000 lines of Fortran source code. The code conforms to the American National Standards Institute (ANSI) Fortran 90 Standards. The program can be implemented on mainframe computers and microcomputers. Execution of the program requires 400 kilobytes of memory on microcomputers. Standard card reader logic is used for data input. A printer-compatible output file is created with successful model execution. Section 8 of this report presents additional information regarding implementation of the model on different computer systems.

Successful application of the model and proper interpretation of output from the model requires that the user have a background in surface-water hydraulics. Even with sufficient experience, however, it is not always easy to determine what data are necessary to adequately define the physical system for numerical analysis. Similarly, determining whether or not the output from a model adequately represents the real-world situation can be very difficult. The computational theory incorporated into this model is summarized in a previous report (Shearman and others, 1986)[1]. References cited in that report and in this manual provide additional detail on theory and methodology. Many users also may find it helpful to consult references that deal more directly with data requirements. Field-survey procedures are discussed by Benson and Dalrymple (1967)[2]. Roughness coefficients are discussed in most standard hydraulics texts, such as those by Chow (1959)[3] and Henderson (1966)[4]. Barnes (1967)[5] presents color photos of sites for which roughness coefficients have been computed for measured discharges. Davidian (1984)[6] discusses proper location and subdivision of cross-sections as well as additional topics related to water-surface profile computations. Matthai (1967)[7] discusses measurement of peak discharge at width contractions by indirect methods. Hydraulic analysis of flow through culverts is discussed in detail in several miscellaneous FHWA publications.[8,9,10,11] Shearman (1976)[12] discusses computer applications for step-backwater and floodway analysis and Schneider and others (1977)[13] discusses computation of backwater and discharge at width constrictions of heavily vegetated flood plains.

This manual attempts to simplify the instructions by prefacing detailed coding instructions with: (1) an overview of input data requirements without regard to actual data arrangement, and (2) a discussion of typical data sequences without detailed discussion of each pertinent parameter. These input data discussions are followed by an overview of model output and discussion of messages that may be generated during model execution. Detailed examples are then presented to illustrate specific input/output features of the model.

Section 2 presents an overview of all input data and discusses the individual data records in general terms without specifically defining the parameters within each data record. Section 3 presents typical data sequences for various model applications. These examples are conceptual inasmuch as they concentrate on the data sequences and not the individual parameters. These conceptual model applications, presented in order of progressively increased data requirements, are: (1) water-surface profile computations without considering bridges; (2) analysis of a basic, single-opening bridge situation; (3) analysis of a bridge with guidebanks; (4) single-opening analysis with consideration of embankment overflow; (5) analysis of several bridge design alternatives in a single model execution; and (6) analysis of a multiple-opening bridge situation. The objective of the overview and conceptual examples is to provide a background for the detailed coding instructions. Section 4 discusses the general rules and conventions for coding and then presents, in alphabetical order, detailed coding instructions for individual data records. Section 5 discusses the various forms of output that can be generated by the model. Section 6 summarizes all messages that may be generated during model execution. Several examples, complete with input data and model output, are presented in Section 7 to demonstrate model applications. Stand alone operation of the WSPRO executable is discussed in Section 8, Computer Considerations. A discussion on the operation of the HYDRAIN WSPRO Input/Output Program is presented in Appendix B. Appendix C contains a discussion of the Surface Water Modeling System's (SMS) graphical user interface for WSPRO.

SECTION 2 - INPUT DATA OVERVIEW

It is convenient to categorize the input data into five general groups as follows: (1) title information; (2) job parameters; (3) profile control data; (4) cross-section definition; and (5) data display commands. Within each of these groups, the various parameters are further classified into subgroups, based on either their similarity to each other or the need to separate them from the others for ease of data modifications. These subgroups are allocated to different data records. The record types are defined by a one- or two-character identifier. These record identifiers were chosen with the intent that they be indicative of the data coded in that data record and (or) the purpose of that data record. A general discussion of the individual data records pertaining to each of the above groups follows. This information is summarized in Table 2-1.

2.1 TITLE INFORMATION

Title information is used only for output identification. No other data (with the exception of the * or *F command) can precede the title information. Up to three title information records may be input (with identifiers of T1, T2, and T3), but it is permissible to use none. Except for column restrictions, there are no specific coding requirements. Therefore, the user has great flexibility to provide unique identification for individual jobs.

2.2 JOB PARAMETERS

Two data records (with identifiers of J1 and UT) are available to define parameters that pertain to the entirety of the profile computations. The J1 record can be used to define such things as error tolerances, parameter test values and computational increments. Reasonable default values are provided for each of the parameters, thus negating the need for J1 data for many relatively standard applications. The UT record (which replaces the J3 record used in previous releases of the program) can be used to select parameters to be included in optional user-defined output tables.

2.3 PROFILE CONTROL DATA

For each water-surface profile to be computed, up to 20 profiles per run, the model requires information regarding (1) discharge, (2) starting water-surface elevation, and (3) computation direction. Discharge data are coded in one or more Q records, one discharge value for each water-surface profile to be computed. A starting water-surface elevation for each of the discharges must be specified by the user or computed by the model. User-specified water-surface elevations are coded on one or more WS records.

Table 2-1. Tabulation of data records by group.

TITLE INFORMATION	T1, T2, T3	-	Alphanumeric data for identification of output.
JOB PARAMETERS	J1	-	Error tolerances, test values, and computational increments.
	UT	-	User defined 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, computation direction(s), and floodways.
	ER	-	Indicates end of input (end-of-run).
CROSS-SECTION DEFINITION			
Header Records	XS	-	Unconstricted valley section.
	BR	-	Bridge-opening section.
	GB	-	Guidebank section (SD record still recognized).
	XR	-	Road-grade section.
	AS	-	Approach section (no longer required but still recognized).
	CV	-	Culvert section.
	XT	-	Template section.
Cross-Sectional Geometry Data	GR	-	x,y-coordinates of ground points in a cross-section with exceptions at bridges, guidebanks, and culverts; and for data propagation.
Roughness Data	N	-	Roughness coefficients ('n'-values).
	SA	-	x-coordinates of subarea breakpoints in cross-section.
	ND	-	Hydraulic-depth breakpoints for vertical variation of roughness.
Flow Length Data	FL	-	Flow lengths and (or) friction slope averaging technique.
Component Mode Bridge Data	BL	-	Bridge length and location.
	BC	-	Bridge low-chord parameters (BD record is still recognized).
	AB	-	Abutment slopes.
	CD	-	Opening type and configuration.
	PD	-	Pier or pile data (PW record is still recognized).
	KQ	-	Conveyance breakpoints (KD record is still recognized).
Coordinate Mode Bridge Data	AB	-	Abutment toe elevations.
	CD	-	Opening type and configuration.
	PD	-	Pier or pile data (PW record is still recognized).
	KQ	-	Conveyance breakpoints (KD record is still recognized).
Approach/Road-grade Section Data	BP	-	Horizontal datum correction between bridge and approach and/or bridge and road-grade sections.
Culvert Section Data	CG	-	Culvert geometry.
	CC	-	Culvert coefficients.
OTHER RECORDS			
Scour Computation Data	DA	-	Abutment scour data.
	DC	-	Contraction scour data.
	DP	-	Local pier scour data.
Effective Flow Data	EF	-	Effective flow input.
Floodway Computation Data	FW	-	Mandatory record for floodway analysis to specify encroachment method, surcharge, and left and right encroachment limits.
	FS	-	Optional control record to vary surcharge for a range of flows.
Metric/English Units	SI	-	Metric/English input/output
Template Geometry Propagation	GT	-	Replaces GR data when propagating template section geometry.
Channel Hydraulic Properties	HP	-	Produce tables of cross-sectional properties or velocity and conveyance distribution.
Comments/Remarks	*	-	Insert comments and (or) blank lines in the input data sequence.
Free Format Input Dataset	*F	-	Allows free-format input (must be first record).

The user may choose to have the model compute the starting water-surface elevation. The model can compute either a "normal" water-surface elevation (by slope-conveyance method) or a critical water-surface elevation (based on minimum specific energy). A slope-conveyance computation can be obtained by specifying an energy gradient rather than a water-surface elevation. Energy gradients are specified in one or more SK records and take precedence over specified water-surface elevations. Specifying an elevation in the WS record that is less than the critical water-surface elevation for the initial cross-section (this is easily assured by coding a value below channel bottom) will cause the model to default to the critical-flow computation when no (or a negative) energy gradient is specified. The model is designed to compute profiles in both an upstream direction (for subcritical and (or) critical flow) and in a downstream direction (for supercritical and (or) critical flow). Computation direction for each profile to be computed is specified in an EX record whenever any downstream computations are involved (upstream is the default direction). The EX record also instructs the model to begin the profile computations. If the EX record is absent, the model will input and check the data but will not compute profiles. Obviously, a Q record must be coded for any job. Depending on the user's choice of options, one or both or neither of the WS and SK data records are required. Care must be taken to provide a consistent number of entries and maintain a one-to-one correspondence between the entries in the Q, WS, SK, and EX records. This will be illustrated in later examples.

2.4 CROSS-SECTION DEFINITION

The majority of the input data is the cross-section data required to describe the physical system. Water-surface profile computations may require several different types of cross-sections. Regardless of the type of cross-section, the user must define the location, geometry, and roughness of each cross-section and perhaps other coefficients and parameters associated with the cross-section which influence the profile computations. The model is limited to a total of 100 cross-sections in a single job.

2.4.1 Header Information

Header information is required for each cross-section. Unique record identifiers for the various header records serve to identify the different cross-section types. Certain coefficients and parameters associated with each cross-section are coded in the header record.

The header record identifiers and the cross-sections to which they apply are:

(1) XS - All unconstricted valley sections.
(2) BR - Bridge-opening section.
(3) GB - Guidebank section.
(4) XR - Road-grade section.
(5) CV - Culvert section.
(6) XT - Template section.

A cross-section identification code and a section reference distance are required in every header record. The section reference distance defines the location of the cross-section in the study reach relative to other cross-sections. It also provides one method of defining subreach flow lengths. Optional parameters common to the first five header records are cross-section skew, expansion and contraction coefficients, and valley slope. The BR, GB, XR, and CV records provide for additional parameters unique to bridges, guidebanks, road-grades, and culvert sections, respectively. The model provides reasonable default values for many of these optional and additional parameters.

2.4.2 Cross-Sectional Geometry

Cross-sectional geometry is defined for most cross-sections using GR records. Pairs of x,y-coordinates representing the horizontal station and ground elevation of each ground point are coded on one or more GR records. Horizontal stationing is measured from any arbitrary datum on the left bank except at bridges where certain cross-sections must be referenced to a common horizontal datum. The model uses left to right as a positive direction and assumes that left and right are defined by looking downstream. Ground elevations at all cross-sections must be referenced to a common vertical datum. GR data are not coded for most bridge design applications (unless using coordinate mode to specify the shape of the bridge opening), some guidebank situations, culvert cross-sections, and when propagating cross-sectional geometry.

2.4.3 Roughness Data

Manning's roughness coefficients may be specified in N records for all cross-sections except culverts. When a cross-section is subdivided for roughness or geometry, the x-coordinates of the subdivision points are coded in SA records. Hydraulic-depth breakpoints for vertical variation of roughness are coded in ND records. When propagating roughness data, only the data that has changed from that of the downstream cross-section is required. It is not necessary that x-coordinates for subdivision points correspond to x-coordinates for points defining the shape of the cross-section.

2.4.4 Flow Lengths

Two options exist for defining flow length between successive cross-sections. The default option uses the difference between the section reference distances of successive header records. However, some users prefer a reference distance tied into a datum that does not necessarily reflect flow length (for example, centerline distance along a meandering stream). Another problem with using a cumulative distance is that a revision or error in one cross-section influences additional cross-sections. Sometimes it also is desirable to vary the flow length across the valley between two cross-sections. Therefore, the user may choose to use FL records to define from one to three flow lengths between successive cross-sections.

2.4.5 Bridge-Opening Cross-Sections

Two conventions are available for coding bridge-opening cross-sections. The first method (referred to as *component mode*) uses easy to define *components* to describe the shape of the bridge opening. The second method (referred to as *coordinate mode*) allows the user to describe the actual shape of the opening using *coordinate* points similar to how cross-section shapes are defined. The advantage of the *component mode* lies in the ability to easily alter the bridge type, length, and shape which allows convenient analysis of different design alternatives. The advantage of the *coordinate mode* is in the ability to model unusual bridge opening shapes or openings that don't conform to the coordinate mode guidelines.

2.4.5.1 Component Mode

The component mode minimizes input data requirements for definition of (and subsequent modifications) bridge geometry by using information specified on records to define specific components of the bridge geometry. Component mode simply provides the user with the flexibility to easily analyze different design alternatives or bridge configurations. The model itself has no design capabilities. The record identifiers and the data contained in the additional records are:

(1) BL - parameters defining bridge length and horizontal location of the opening.
(2) BC - parameters defining bottom chord information for the bridge.
(3) AB - parameters defining abutment slopes for the bridge.

In component mode, a bridge-opening cross-section is created by combining the data from the BL, BC, and AB records with the GR data of the full-valley cross-section (input immediately prior to the bridge-opening cross-section). An AB record is required in component mode only for spill-through type abutments (Type III bridge). The BL and BC records are always required in component mode for initial definition of the bridge opening. Subsequent bridge geometry modifications (i.e., for alternative designs in a single model execution) require recoding only those record type(s) pertaining to the parameter(s) being changed.

2.4.5.2 Coordinate Mode

Some bridge geometries, such as arched openings, defy adequate definition by the component mode. Also, for existing bridges it is highly preferable to not have to break down the geometry into components if nothing is going to be modified. The coordinate mode permits coding a bridge opening as a closed polygon using GR data. With left and right defined relative to looking downstream, the minimum (leftmost) horizontal station and its elevation must be the first x,y-coordinate coded. If the left edge of the bridge is vertical, the coordinate pair for the highest elevation must be coded first. The remaining x,y-coordinates for the ground, abutments, and low steel must be coded in counter-clockwise order. The first coordinate pair must be repeated as the last coordinate pair in the GR data.

Whichever of the above procedures is followed, other applicable data records are:

(1) CD - parameters defining bridge and embankment configuration.
(2) KQ - parameters for user override of stationing related to conveyance breakpoints in the approach section.
(3) PD - parameters defining piers or piles.

The CD record is mandatory, the KQ and PD records are optional.

2.4.6 Guidebanks

Two conventions are also available for defining guidebank geometry. One of the parameters in the GB header record is the horizontal offset of the guidebank relative to the bridge abutments (measured normal to the flow at the mouth of the guidebank). In component mode, if the user codes a value for this parameter, the model will construct a cross-section at the mouth of the guidebank. The top width of that section will be equal to the top width of the bridge opening plus twice the offset value coded. The side slopes will equal the bridge abutment slopes and the channel bottom geometry is propagated from the full-valley section at the bridge. The coordinate mode requires defining guidebank section geometry with GR data. Defining the shape of the guidebank cross-section using coordinate mode is often necessary when the guidebanks are not symmetrical. The guidebank cross-section should be constructed at the location of the mouth of the guidebanks.

2.4.7 Road Grades

The geometry of a road-grade section is defined by x,y-coordinates in GR records in a manner similar to other cross-sections. The x,y-coordinates should define a transect along whatever part of the embankment will act as the weir crest (perhaps the centerline (crown) in a rural situation and sidewalk (or curb) in an urban situation). Roughness data are not input for road-grade sections (the model output reflects propagated roughness data for the road grade but the original purpose for that was never implemented in the model). Cautions that need to be exercised in coding road-grade sections are discussed in Section 4.3.9.

2.4.8 Approach Sections

The only difference between an approach cross-section and any other unconstricted valley cross-section is that the model assumes that the first unconstricted valley cross-section (defined with an XS header record) upstream of the bridge opening is the approach section. Cautions to be exercised in coding approach sections are presented in Section 4.3.8.

2.4.9 Culverts

Culvert hydraulics are analyzed using FHWA methodology (U.S. Federal Highway Administration, 1982; 1980; 1979). Shearman and others (1986) present a full summary of the culvert computations. Culverts may be analyzed both in multiple-opening situations, as stand-alone (single- or multi-barrel) installations, and as an intermediate structure in a continuous water-surface profile computation. A culvert can be defined with: (1) a CV header record; (2) a CG record to define culvert geometry; and (3) a CC record to define applicable coefficients. Default values are provided for all of the parameters in the CC record.

2.4.10 Datum Corrections

All cross-sections must be referenced to a common vertical datum. An individual cross-section surveyed to an incorrect datum could be adjusted using the template section features of the model (see Section 2.4.12). The field-survey data could be coded as a template section and the YSHIFT parameter of the GT record applied to make the appropriate elevation adjustment. This procedure could also be used to change the datum for all cross-sections (e.g., to convert an arbitrary datum to mean sea level datum). This would be somewhat cumbersome since it would require coding each cross-section as a template section to apply the necessary adjustment.

One-dimensional models generally do not require a common horizontal datum from cross-section to cross-section. However, WSPRO's analysis of single-opening bridge hydraulics requires common horizontal datums for: (1) bridge-opening and approach sections (for effective flow length computations); and (2) bridge-opening and road-grade sections (for determining correct location of left and right road overflow segments). The user may choose to make such horizontal datum corrections by coding a BP record in conjunction with road-grade and (or) approach section data (instead of adjusting field-survey or design data prior to input). BP record input data for this purpose is the horizontal station on the road-grade and (or) approach section(s) that coincide with certain reference points on the bridge section. The reference points depend on whether component mode or coordinate mode is being used. Horizontal stationing of the bridge opening may vary for different alternatives in component mode. Therefore, the location constraining stations (XCONLT and XCONRT in the BL record) are the logical reference points if using component mode. In coordinate mode, the minimum and maximum horizontal stations of the bridge-opening section are used as reference points. The horizontal station on the road-grade section that coincides with the intercept of a vertical projection from the appropriate left reference point of the bridge is sufficient to relate the horizontal data of the bridge-opening and road-grade sections. The horizontal station at the approach section that coincides with the intercept of a line projected parallel to the flow from the appropriate left reference point of the bridge is sufficient to relate the horizontal data of the bridge and approach sections, except for cases of curvilinear flow.

If curvilinear flow exists, a BP record should be included with the approach section data to assure an adequate estimate of effective flow length, even if there is no horizontal datum problem. For this purpose, lines parallel to the flow are projected from both the left and right reference points of the bridge section to the approach section. The horizontal stations at the approach section of both flow-line intercepts and the length of both flow lines are coded in the BP record.

Multiple-opening analysis involve projections of horizontal stationing from section to section to define valley strips and to fabricate intermediate exit and approach cross-sections. Therefore, all cross-sections, from the downstream match section through the upstream match section, inclusive, must be referenced to a common horizontal datum. The user must make all necessary adjustments to field-survey or design data prior to input to the model.

2.4.11 Data Propagation

WSPRO is designed to minimize coding of repetitive data. Data applicable to successive cross-sections are automatically propagated by the model. That is, once values are established (by specification or default) for certain parameters, those values will be used at each succeeding cross-section until new values are specified. The changed value will then be propagated until another value is specified. Three parameters in the header records (expansion and contraction coefficients and valley slope) are automatically propagated. When fabricating a series of cross-sections from one known cross-section it is quite likely that all of the data in the N, ND, and SA records are identical for all of the fabricated sections. Coding N, ND, and SA data for the first (most downstream) section of such a series of cross-sections is sufficient and appropriate. Even when not fabricating cross-sections, it is fairly common for the N and ND data to be identical for successive cross-sections but for the SA data (subdivision points) to vary. In such cases, coding the N and ND data for the downstream section and coding only the SA data for succeeding sections is sufficient. A change in the number of subdivisions nullifies the propagation of all roughness data. However, a change of magnitude of values in one record type does not require recoding all roughness data. For example, if the roughness coefficients change but the vertical breakpoints remain applicable, only the N data need recoding and the ND data can be propagated.

It also is possible to repetitively apply geometry data. Omitting GR data from the cross-section definition will cause the model to propagate GR data from the preceding (downstream) section with no changes. Coding valley slope in the header record and omitting GR data will result in geometry with x-coordinates identical to the preceding section and y-coordinates equal to those of the preceding section plus the product of valley slope and the difference in section reference distances of the two cross-sections.

2.4.12 Template Sections

Additional flexibility for repetitive use of geometric data is possible using template sections. A template section is defined with an XT header record and GR records. Once defined, the template section is retained in its original form until replaced with a new template section. There are no limits to the number or location of cross-sections that may be fabricated using the template-section geometry. The horizontal geometry of the template section can be: (1) used unadjusted; (2) expanded or contracted by a scale factor; or (3) partially used by "chopping off" portions of the left and (or) right sides of the section. Vertical geometry of the template section may be: (1) used unadjusted; (2) shifted by a constant; or (3) shifted by the product of valley slope and section reference distance difference. Use of the template section to fabricate a cross-section is implemented using a GT record instead of GR records for a section. The GT record introduces the desired scaling and shifting parameters.

The roughness coefficients (N records) and hydraulic-depth breakpoints (ND records) must not be included with the template section data but with the data of the section(s) being fabricated. SA records (subarea breakpoint stations) may appear with either the template section or the section(s) being fabricated. However, when the scale factor option is to be applied, the subarea breakpoints are not scaled by the model. Therefore, the SA data must be included with each fabricated section and the breakpoints adjusted to be consistent with the scaled x,y-coordinate data.

2.5 OTHER RECORDS

2.5.1 Floodway

The data requirements for a floodway analysis are accomplished using FW and FS data records. The FW record allows the user to complete a floodway analysis for individual cross-sections or for part of or all of the cross-sections in a reach. Parameters associated with the FW record are an option code, a surcharge limit, left horizontal encroachment station, and right horizontal encroachment station. With the exception of the option code, the remaining parameters can be left blank to allow default computations to occur. Each FW record can have a separate surcharge value as a parameter. However, when a surcharge value is provided on the first FW record encountered in the input data set, WSPRO will automatically propagate this value to subsequent FW records. An optional, separate FS record allows introduction of global surcharge values that are associated with each discharge on the Q record. The FS record must be grouped with the profile control information before any header records are encountered.

2.5.2 Scour

The data requirements for scour computations are dependent on the type of analysis desired. Pier scour analysis requires coding of the necessary parameters and constants for use with a pier scour prediction equation. This information is input by using a DP record. Estimates of contraction scour are dependent on estimation equation parameters which are input on the DC record. Abutment scour is computed using parameters coded on a DA record. Detailed information on the theory and application of the pier, contraction, and abutment scour computation methodologies can be found in HEC-18, Evaluating Scour at Bridges, Richardson and Davis (1995)[14]. Multiple DP, DC, and DA scour records can be used in a separate program execution.

2.5.3 HP Records

Tables of cross-sectional properties and (or) velocity and conveyance distribution are optional forms of model output. Tables of cross-sectional properties and (or) velocity and conveyance distribution can be obtained using HP records. The appropriate command record(s) must be input for each cross-section for which such output is desired.

SECTION 3 - TYPICAL DATA SEQUENCES

This section presents examples of data sequences for various model applications. The primary objective is to illustrate data sequences with little attention to individual parameters within each record. Generally, only three parameters in the cross-section header records are shown. These parameters are the record identifier (columns 1-2), the section identification code (columns 6-10), and the section reference distance (first parameter after column 10). Parameters are indicated only if they provide additional clarity to the example, and then they are indicated by name rather than actual numerical value. Figure 3-1 illustrates all record types required to describe an unconstricted, valley cross-section. The header record (an XS record in this example) must be the first record in a cross-section data group. The GR records must always be in a contiguous group and in sequence of ascending horizontal stationing. There are no other restrictions as to the ordering of the record types illustrated. The following sections describe various arrangements of these data, first without consideration of bridges, then with additional data to describe both single- and multiple-opening bridge situations and to obtain results for alternative designs.

```
-----------------------------------------80 character record ---------------------------------------------

1-2  4  6-10                                    11-80

ID#   SECID                                   User's Format

XS   secid  srd  [,other variables as needed]
GR          x,y-coordinates ...
GR                              ... continued ...
GR                                                ... last x,y-coordinate
N           Manning's roughness coefficients
ND          hydraulic-depth breakpoints for vertical roughness variation
SA          station breakpoints for horizontal subdivisions
FL          flow length/friction-loss computation data
```

Figure 3-1. Record types for defining unconstricted valley cross-sections.

3.1 REACHES WITH NO BRIDGES

The first example is a curvilinear stream reach with variable land cover and a slightly meandering main channel (Figure 3-2). The data sequence in Figure 3-3 reflects assumptions as follows: (1) four cross-sections (three subreaches) are needed to define the total reach; (2) a rating curve (relation of water-surface elevation and discharge) is known at the downstream cross-section (XSEC1); (3) cross-sectional geometry varies significantly (thus GR data are

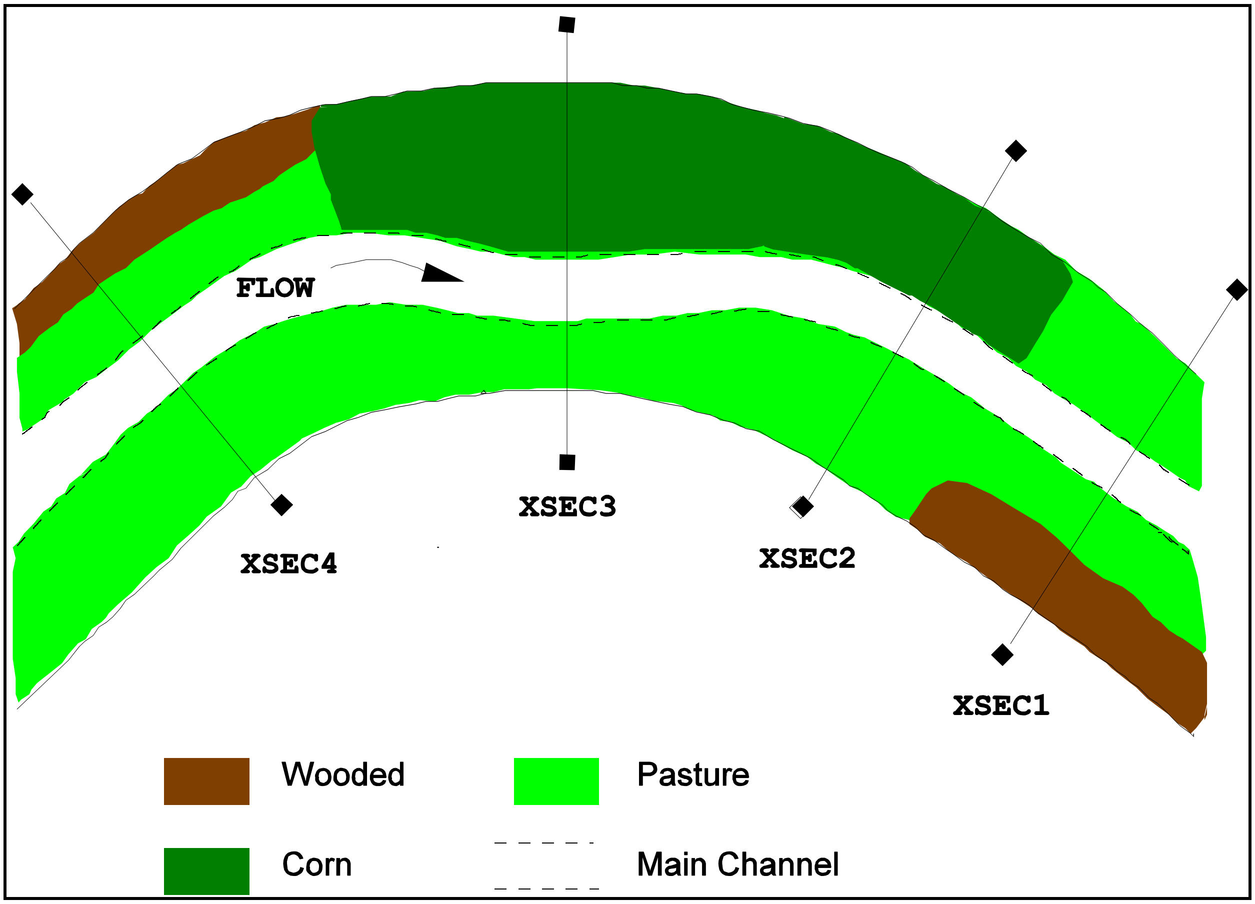


Figure 3-2. Definition sketch: curvilinear reach with variable land cover.

needed for each section); (4) roughness is to be varied both horizontally and vertically at each cross-section; and (5) overbank and main-channel flow lengths are significantly different in both the second and third subreaches. The user should note the cross-section locations in Figure 3-2. A cross-section should describe average geometry and roughness for a subreach. The computational procedure assumes that a subreach extends half the distance to adjacent cross-sections in both the upstream and downstream directions.

--80 character record --		
1-2 4 6-10	11-80	
ID# SECID	User's Format	

```
T_        T1, T2, T3 records as desired
J1        J1 record [as needed]
UT        UT record [as needed]
Q         q1, q2, q3, . . .
WS        ws1, ws2, ws3, . . .
XS   XSEC1 srd1, [as needed]
GR        x1,y1  x2,y2 . . .
GR          . . . last x,y-coordinate
N         nbot1, ntop1, . . . nbot4, ntop4
ND        botd1, topd1, . . . botd4, topd4
SA        xsa1, xsa2, xsa3
XS   XSEC2 srd2, [as needed]
N         nbot1, ntop1, . . . nbot3, ntop3
GR        x1,y1  x2,y2 . . .
GR          . . . last x,y-coordinate
SA        xsa1, xsa2
ND        botd1, topd1, . . . botd3, topd3
XS   XSEC3 srd3, [as needed]
FL        flen1, xlb, flen2, xrb, flen3
SA        xsa1, xsa2
GR        x1,y1  x2,y2 . . .
GR          . . . last x,y-coordinate
XS   XSEC4 srd4, [as needed]
GR        x1,y1  x2,y2 . . .
GR          . . . last x,y-coordinate
SA        xsa1, xsa2, xsa3
ND        botd1, topd1, . . . botd4, topd4
N         nbot1, ntop1, . . . nbot4, ntop4
FL        flen1, xlb, flen2, xrb, flen3
EX
ER
```

Figure 3-3. Input data sequence: curvilinear reach of Figure 3-2.

The title information (T1, T2, and T3 records) and job parameters (J1 and UT records) must precede all other data (with the exception of the * and *F command). All job-parameter data may be omitted if all default values are satisfactory and no special tables are desired. Because a rating curve exists for XSEC1, a WS record is used to specify a beginning water-surface elevation for each discharge specified in the Q record. In addition to the header record and GR data, a complete description of roughness (N, ND, and SA records) is required for each of the first two sections. Because the number of subareas and the roughness values differ from XSEC1 to XSEC2 (pasture, main channel, pasture and woods versus corn, main channel and pasture), roughness data cannot be propagated from XSEC1 to XSEC2. However, the N and ND data for XSEC2 can be propagated to XSEC3. SA data are required at XSEC3 because the subdivision stations are different than those at XSEC2. XSEC4 also requires complete roughness data because of four versus three subareas and different roughness coefficients than XSEC3. FL data are never required at the most downstream cross-section because friction-loss computations for the downstream subreach rely on the upstream FL data. FL data are not required for XSEC2 in this example because the lengths along the overbanks and main channel are equal, thus the difference between the section reference distances of XSEC2 and XSEC1 is used for flow length. FL data are used at XSEC3 and XSEC4 to account for the different flow lengths in the overbanks and main channel. The EX record instructs the model to compute profiles for the preceding data; one profile is computed for each discharge specified in the Q record.

The second example reach (rather idealistic) has uniform geometry and the same roughness characteristics throughout. Cross-sectional geometry for XS1 was obtained by field survey. Channel slope varies as shown in Figure 3-4 and the stage-discharge relation is unknown.

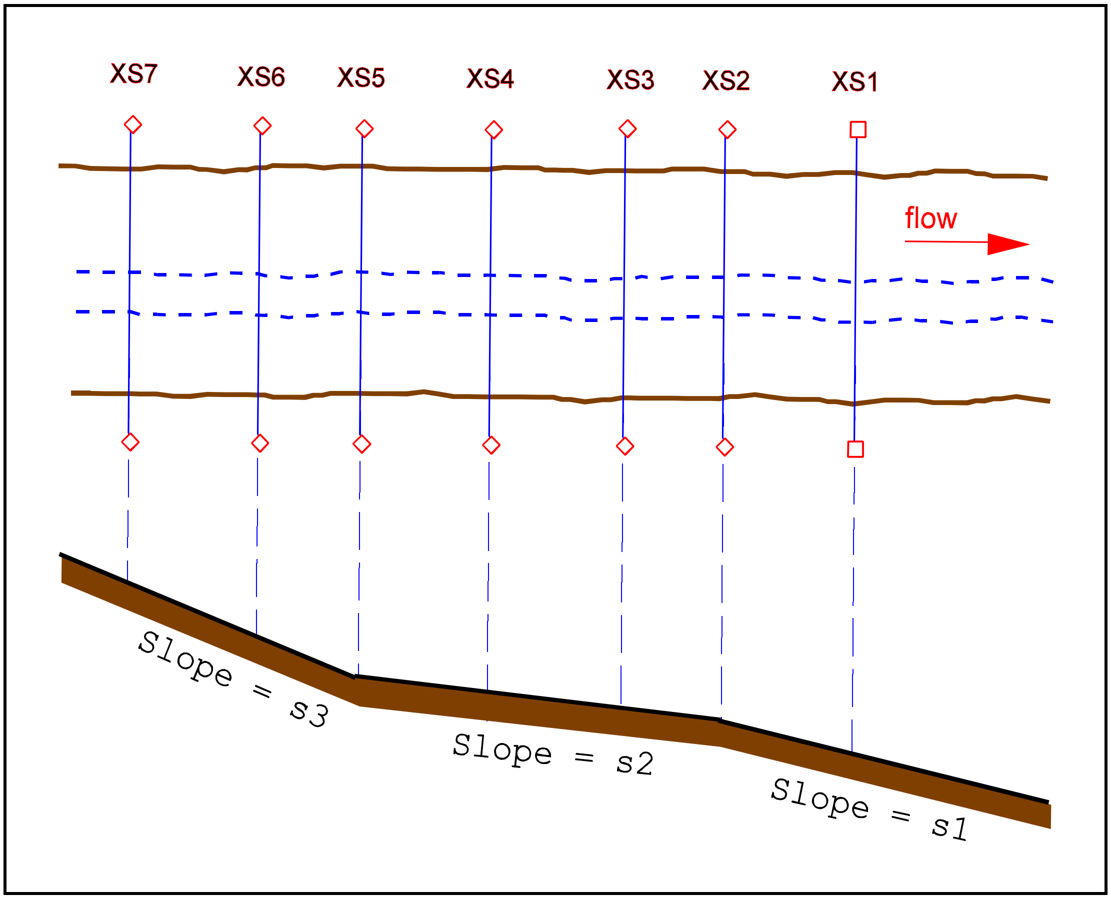


Figure 3-4. Definition sketch: idealistic reach; data propagation.

Figure 3-5 illustrates the data sequence. An SK record (rather than a WS record) is appropriate to define the starting conditions for profile computations if one assumes that the slope, s1, extends a significant distance down- stream and there are no downstream controls to affect the water-surface profile. In that case normal flow can be assumed at XS1. Thus, slope-conveyance is appropriate for computing the starting water-surface elevation at XS1. Complete description of the geometry and roughness is required for the first section; note that both horizontal and vertical variations of roughness are used. Subsequent cross-sections require only a header record because the uniform reach permits propagation of all geometry and roughness data. Valley slope specified in a header record is applicable to the subreach extending to the adjacent downstream cross-section, as well as to successive upstream subreaches until a different valley slope is specified. Therefore, coding the three slopes (s1, s2, s3) in the header record of the first section where each slope is applicable is sufficient to adjust the cross-section elevations. The [as needed] entry in the header records indicate additional variables that might be coded in a header record.

```
-------------------------------------------80 character record ---------------------------------------------

1-2  4  6-10                                    11-80

ID#   SECID                                 User's Format
```

```
T_        T1, T2, T3 records as desired
J1        J1 record [as needed]
UT        UT record [as needed]
Q         q1, q2, q3, . . .
SK        s1, s1, s1, . . .
XS   XS1  srd1, [as needed]
GR        x1,y1  x2,y2 . . .
GR              . . . etc., etc., . . .
GR                             . . . last x,y-coordinate
N         nbot1, ntop1, nbot2, ntop2, nbot3, ntop3
ND        botd1, topd1, botd2, topd2, botd3, topd3
SA        xsa1, xsa2
XS   XS2  srd2, [as needed], s1
XS   XS3  srd3, [as needed], s2
XS   XS4  srd4, [as needed]
XS   XS5  srd5, [as needed]
XS   XS6  srd6, [as needed], s3
XS   XS7  srd7, [as needed]
```

Figure 3-5. Input data sequence: data propagation for reach of Figure 3-4.

The third example illustrates use of a template cross-section. The three cross-sections (XSEC7, XSEC8, XSEC9) shown in Figure 3-6 were obtained by field survey After initial analyses it was judged that the shaded area is ineffective flow area and that two additional sections are needed to adequately model the flow expansion and contraction in the reach. Truncation of the middle section (XSEC8) to better model the effective flow area could be accomplished by discarding data left of the effective-flow cutoff point and coding a vertical wall at that point. Also, one could fabricate the intermediate sections (XS8-A and XS8-C) using x,y-coordinate data from XSEC8 (with elevations adjusted for valley slope, if necessary) and coding a vertical wall at the appropriate cutoff point.

WSPRO can perform this truncation and fabrication by means of the template cross-section feature. This is especially convenient when the need for modified and (or) additional cross-sections is discovered after the data have already been coded. In this case the surveyed XSEC8 can serve as a template cross-section. A template section can be placed anywhere in the data sequence prior to its first use. The template section follows XSEC7 in the data sequence in Figure 3-7. The section reference distance and valley slope coded in the XT header record are used to adjust elevations of any cross-section fabricated from the template section. XS8-A is

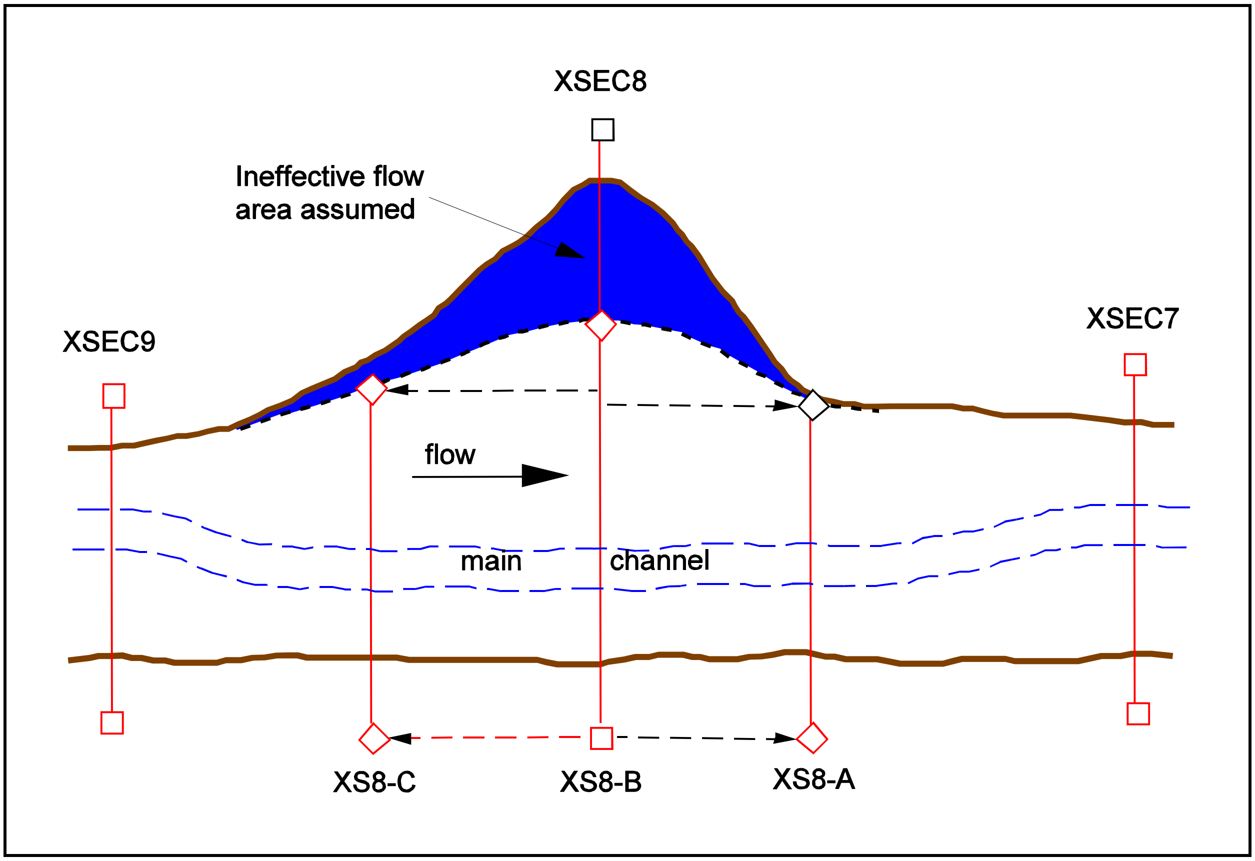


Figure 3-6. Definition sketch: example application of a template cross-section.

defined by an XS header record, a GT record, and an SA record. The horizontal station of the cutoff point (at the tail-end of the arrow pointing to XS8-A) is coded as the XLIML parameter, the second parameter in a GT record. The null value (*) is coded because the first parameter is not being used but proper parameter positioning must be maintained. The coefficients and vertical variation of roughness at XSEC7 are assumed applicable and propagated to XS8-A. SA data are recoded to reflect XSEC8 subarea breakpoints. Assuming that subarea stations would be the same for all sections fabricated from the template section, XS8-B and XS8-C require only XS and GT records. As it was for XS8-A, the XLIML parameter on the GT record for XS8-B and XS8-C is used to specify the horizontal station of the appropriate cutoff point on the left overbank (at the diamond for XS8-B and at the tail-end of the arrow pointing to XS8-C).

```
-------------------------------------------80 character record -----------------------------------------------
1-2  4  6-10                                   11-80
ID#   SECID                                 User's Format
```

```
XS   XSEC7 srd7, [as needed]
__          [ GR, N, ND, and SA data, as appropriate ]
*
XT   XSEC8 srd8, vslope
GR         x1,y1  x2,y2 . . .
GR                 . . . last x,y-coordinate
*
XS   XS8-A srd8-A, [as needed]
GT         *, xliml
SA         xsa1, xsa2
*
XS   XS8-B srd8, [as needed]
GT               *, xliml
*
XS   XS8-C srd8-C, [as needed]
GT         *, xliml
*
XS   XSEC9 srd9, [as needed]
__          [ GR, N, ND, and SA data, as appropriate ].
```

Figure 3-7. Input data sequence: template section application for Figure 3-6.

3.2 SINGLE-OPENING BRIDGE SITUATIONS

Computations for bridges having a single opening require definition of a minimum of four cross-sections. These sections consist of three unconstricted valley sections in addition to the bridge-opening section. Presence of guidebanks and (or) possible road overflow introduces the possibility for an additional one or two optional cross-sections.

3.2.1 Basic Bridge Situation, Component Mode

Figure 3-8 is a sketch of a typical single-opening bridge situation.

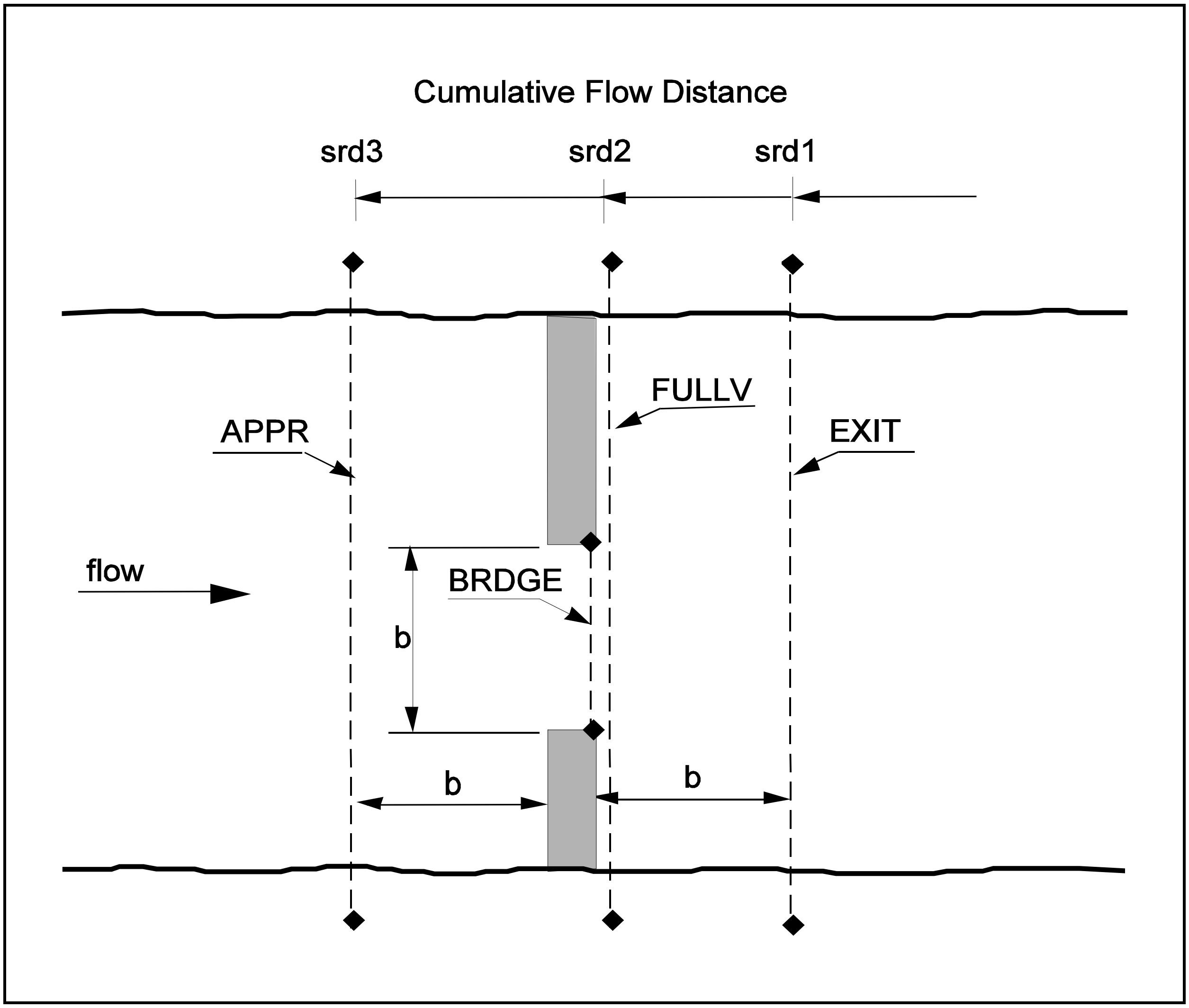


Figure 3-8. Definition sketch: cross-section locations, single-opening bridge.

Figure 3-9 illustrates a data sequence for a case where: (1) component mode is being used for the bridge opening (i.e., bridge design data are to be superimposed on the full-valley section geometry); (2) there are no guidebanks; and (3) there is no chance of overtopping the embankment (thereby eliminating the need to code a road-grade section).

---80 character record ---		
1-2 4 6-10		11-80
ID# SECID		User's Format

```
XS   EXIT srd1 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
XS   FULLV srd2 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
BR   BRDGE srd2 [,as needed]
__         [ N, ND, and SA data, if appropriate ]
BL        brlen, xconlt, xconrt
BC        girdep, bdelev [,as needed]
CD        brtype, brwdth [,as needed]
AB                              - - - - - - - - - - -
PD                               optional  records
KQ                              - - - - - - - - - - -
*
XS   APPR  srd3 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
```

Figure 3-9. Input data sequence: single-opening bridge of Figure 3-8, component mode.

This sequence begins with definition of the exit section which is one bridge length downstream from the bridge-opening cross-section. Data defining title information, job parameters, and profile control data are not illustrated. Also, additional cross-sections could be defined, if desired, both downstream from the exit cross-section and upstream from the approach cross-section. The exit and full-valley sections are each illustrated in Figure 3-9 with an XS header record followed by GR data to describe geometry and N, ND, and SA data to define roughness. The bridge section is introduced with a BR header record which is followed by roughness data (if different from the full-valley section roughness) and the bridge parameter data. The BL and BC records are mandatory in component mode to define the size and location of the opening. The bridge length (distance between the tops of the abutments) and the horizontal constraints for the location of the abutment toes must be specified in the BL record to define the horizontal dimension of the bridge and the extent of the full-valley section geometry to be used, respectively. The BC record supplies data required to place the "top" on the opening. Girder depth and deck elevation are required and, for sloping decks, the slope and the x-coordinate corresponding the specified deck elevation (y-coordinate) must be coded. The CD record also is mandatory and provides data required for determining the coefficient of discharge and the flow length through the bridge. The type of bridge opening and the bridge width (dimension in direction of flow) are always required and other parameter requirements depend on the bridge type. The remaining records are required only under certain circumstances or are entirely optional. A brief summary of data requirements for the bridge opening using component mode follows.

(1) In component mode the AB record is only required to specify abutment slopes for a type 3 opening (all other opening types have vertical abutments).
(2) Only when there are piers or piles to be defined is it necessary to code PD data.
(3) The KQ record is required only when it is necessary to override the default determination of the computed boundaries of the K_q segment of the approach cross-section which influences the computation of the flow-contraction ratio. These requirements are further defined in the KQ record explanation in Section 4.

Because there are no guidebanks nor road-grade sections involved, definition of the approach section immediately follows the definition of the bridge-opening section. An unconstricted valley cross-section record (XS record) and the appropriate GR, N, ND, and SA data are required to define the approach section.

3.2.2 Basic Bridge Situation, Coordinate Mode

Existing bridges, or bridges that do not conform to the component mode data requirements (e.g., arch bridges), can be defined using the coordinate mode. This convention requires using GR data to describe the opening as an irregular polygon. Very rigid rules apply to the specification of x,y-coordinates around this polygon. The minimum (leftmost) horizontal station and its elevation must be the first x,y-coordinate specified. If the left abutment is vertical, x,y-coordinates for the highest elevation must be coded first. Subsequent coordinates for points along the abutments, ground surface, and low chord must be specified in a counter-clockwise direction. The last x,y-coordinates must be an exact duplicate of the first x,y-coordinates. Subdivision station(s) (SA record) for unconstricted valley cross-sections do not have to coincide with any station(s) in the GR records. However, if a bridge-opening cross-section must be subdivided because of geometry and (or) variations in roughness, there must be a distinct relation between the SA and GR data. GR data must include x,y-coordinates at each subarea breakpoint along the bottom of the bridge-opening polygon.

Figure 3-10 illustrates the coordinate mode data sequence for the preceding example. The BL and BC data are not used because the GR data defines the bridge-opening geometry. As is the case for component mode, the CD record is mandatory and the PD and KQ records are optional for the coordinate mode. The AB record is again optional but is used to satisfy a different requirement. The AB record is required in coordinate mode only to specify elevations at the toes of the abutments for a type 2 opening. These elevations (determined by the model in the component mode) are needed to compute one of the adjustment factors for the coefficient of discharge.

--80 character record ---	
1-2 4 6-10	11-80
ID# SECID	User's Format

```
XS   EXIT  srd1 [,as needed]
__          [GR, N, ND, and SA data, as appropriate]
*
XS   FULLV srd2 [,as needed]
__          [GR, N, ND, and SA data, as appropriate]
*
BR   BRDGE srd2 [,as needed]
__          [GR, N, ND, and SA data, as appropriate]
CD         brtype, brwdth [,as needed]
AB                                 - - - - - - - - - - -
PD                                  optional  records
KQ                                 _ _ _ _ _ _ _ _ _ _ _
*
XS   APPR  srd3 [,as needed]
__          [GR, N, ND, and SA data, as appropriate]
```

Figure 3-10. Input data sequence: single-opening bridge of Figure 3-8, coordinate mode.

3.2.3 Addition of Guidebank Data

Figure 3-11 is a definition sketch of a bridge with guidebanks. As with bridge sections, there are two conventions applicable to definition of a guidebank section. Component mode permits superimposing guidebanks on the full-valley section. This is only applicable when component mode is also being used for the bridge-opening section. The GBOFF parameter (horizontal offset) on the GB header record initiates component mode for guidebanks (see Table 4-25). Side slopes of the guidebanks are equal to the slope(s) of the bridge abutments. These data, combined with the appropriate segment of the full-valley section, define guidebank geometry. Coordinate mode requires GR data to define guidebank section geometry. In either mode, roughness data are specified in N, ND, and SA records as appropriate for the situation and parameters for determining the guidebank adjustment factor applied to the coefficient of discharge are coded in the GB header record.

Figure 3-12 illustrates a data sequence for the sketch of Figure 3-11, including GR data to define guidebank geometry. Guidebank section data are always input immediately following the input data for the bridge opening to which the guidebanks are attached.

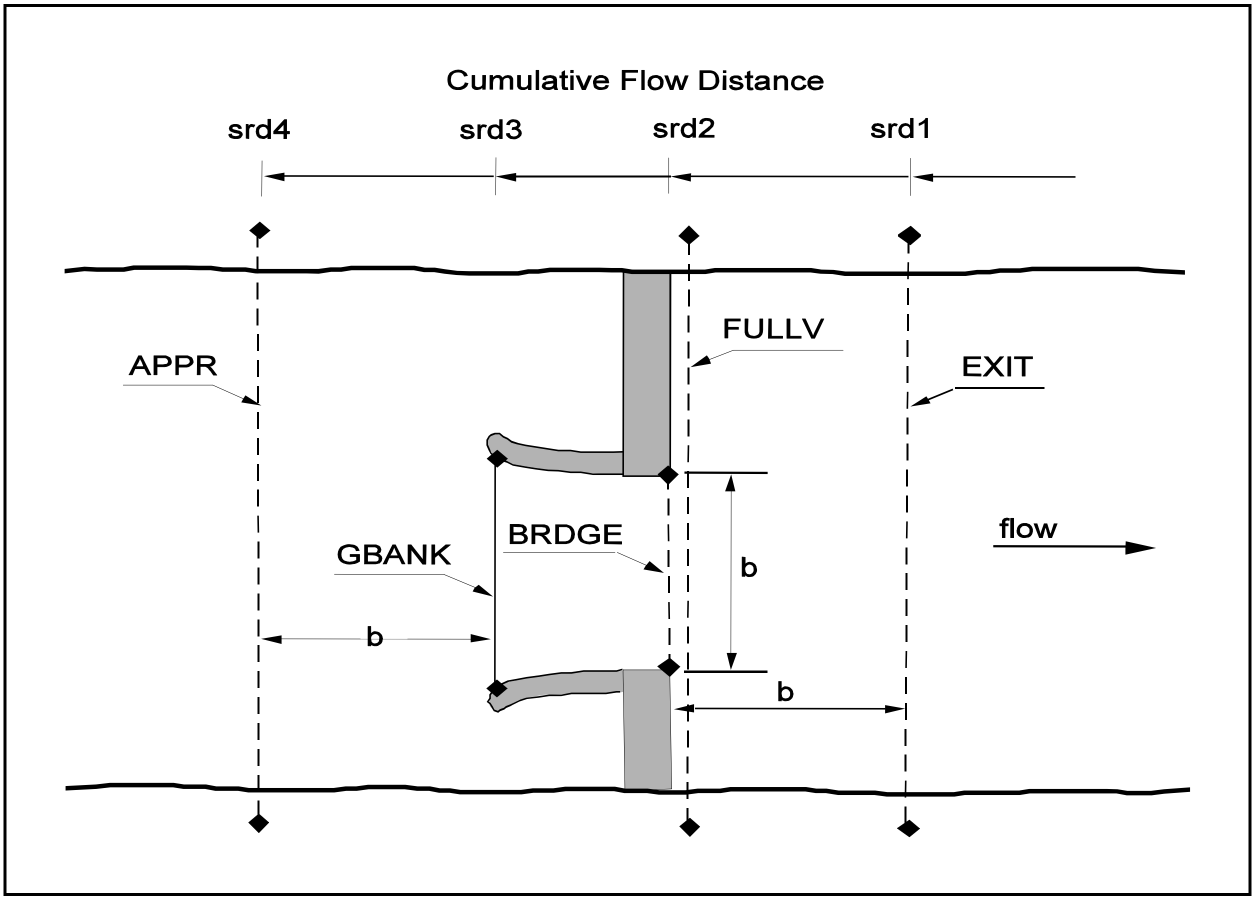


Figure 3-11. Definition sketch: cross-section locations, single-opening bridge with guidebanks.

--80 character record ---	
1-2 4 6-10	11-80
ID# SECID	User's Format

```
XS   EXIT  srd1 [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
XS   FULLV srd2 [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
BR   BRDGE srd2 [,as needed]
__         [BL and BC data or GR data, and
__              N, ND, and SA data, as appropriate]
CD         brtype, brwdth  [,as needed]
__         [AB, PD, and KQ data as appropriate]
GB   GDBNK srd3, gbtype, bsubd  [,as needed]
__          [GR, N, ND, and SA data, as appropriate]
```

```
XS   APPR  srd4  [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
```

Figure 3-12. Input data sequence: single-opening bridge with guidebanks as shown in Figure 3-11.

3.2.4 Addition of Road-Grade Data

Figure 3-13 illustrates the addition of a road-grade cross-section to a data sequence for a basic bridge situation. The road-grade cross-section data immediately precede the data describing the approach cross-section. A default value is provided within the model for each of the parameters in the road-grade header record except for section reference distance. Explanation of each of these default values is presented in the detailed coding instructions for the XR header record. When these default values are not sufficient, they can be overridden with appropriate user-specified values. Geometry of the top of the embankment defining the "potential" weir crest are described by specifying x,y-coordinates in GR records in the same manner that unconstricted valley sections are defined.

```
-------------------------------------------80 character record ----------------------------------------------
1-2  4  6-10                                  11-80
ID#  SECID                                 User's Format
```

```
XS   EXIT  srd1  [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
*
XS   FULLV srd2  [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
*
BR   BRDGE srd2  [,as needed]
__         [BL and BC data or GR data, and
__               N, ND, and SA data, as appropriate]
CD        brtype, brwdth  [,as needed]
__         [AB, PD, and KQ data as appropriate]
*
XR   ROAD  srdrd  [,as needed]
__         [GR data]
*
XS   APPR  srd4  [,as needed]
__         [GR, N, ND, and SA data, as appropriate]
```

Figure 3-13. Input data sequence: single-opening bridge with road-grade (no definition sketch).

3.2.5 Alternative Design Data

Figure 3-14 illustrates a data sequence for obtaining computations for alternative designs. Profiles are required for every combination of three alternative bridge lengths (brlen1, brlen2, and brlen3) and two road-grade alternatives (a "high" embankment and a "low" embankment) for a range of five discharges (q1, q2, q3, q4, and q5). When varying both road-grade and bridge data, it will normally be prudent to hold the road-grade data constant for all bridge alternatives because usually it takes less coding for bridge modifications; to modify a road grade all data must be recoded. The first EX record (after the approach section data) will initiate profile computations for each of the five discharges for the brlen1 and "high" embankment combination. The next two four-record sequences (T3, BR, BL, and EX records) will result in two additional sets of five profiles for combinations of brlen2 and brlen3 with the "high" embankment. The next part of the sequence (T3, XR, GR, and EX records) will result in (1) the "high" embankment data being replaced by the "low" embankment data and (2) computation of five profiles for the brlen3 and "low" embankment combination. The next two four-record sequences (T3, BR, BL, and EX records) will result in profiles for the combinations of brlen2 and brlen1 with the "low" embankment alternative.

---80 character record --		
1-2 4 6-10		11-80
ID# SECID		User's Format

```
T1   RISK ANALYSIS FOR HWY-77 BRIDGE
T2   HYPOTHETICAL CREEK NEAR NOWHERE, USA
T3   LENGTH = brlen1 / "high" EMBANKMENT
*
WS   ws1, ws2, ws3, ws4, ws5
Q    q1,  q2,  q3,  q4,  q5
*
XS   EXIT  srd1[,as needed]
__         [exit section data]
*
XS   FULLV srd2 [,as needed]
__         [full-valley section data]
*
BR   BRDGE srd2 [,as needed]
BL         brlen1, xconlt, xconrt
__         [remaining bridge data]
*
XR   ROAD  srdrd [,as needed]
__         [road-grade data, "high" embankment]
*
XS   APPR  srd3  [,as needed]
__         [approach section data]
EX
*
T3   LENGTH = brlen2/"high" EMBANKMENT
BR   BRDGE
BL         brlen2
```

```
EX
*
T3   LENGTH = brlen3/"high" EMBANKMENT
BR   BRDGE
BL         brlen3
EX
*
T3   LENGTH = brlen3/"low" EMBANKMENT
XR   ROAD
__         [road-grade data, "low" embankment]
EX
*
T3   LENGTH = brlen2/"low" EMBANKMENT
BR   BRDGE
BL   brlen2
EX
*
T3   LENGTH = brlen1/"low" EMBANKMENT
BR   BRDGE
BL         brlen1
EX
ER
```

Figure 3-14. Input data sequence: alternative designs (no definition sketch).

To revise or replace data the SECID in subsequent header records must be identical to the original SECID for that cross-section, including the position of any blank characters. In this example the T3 record was revised for each alternative to provide unique output identification. Any or all of the title information records may be modified for this purpose. This example generates a total of thirty profiles, thus, users may wish to be prudent in the number of alternatives input and (or) the amount of output requested for each alternative to avoid an "overwhelming" volume of results.

3.3 MULTIPLE-OPENING BRIDGE SITUATION

Figure 3-15 is a definition sketch of a long, flood-plain crossing.

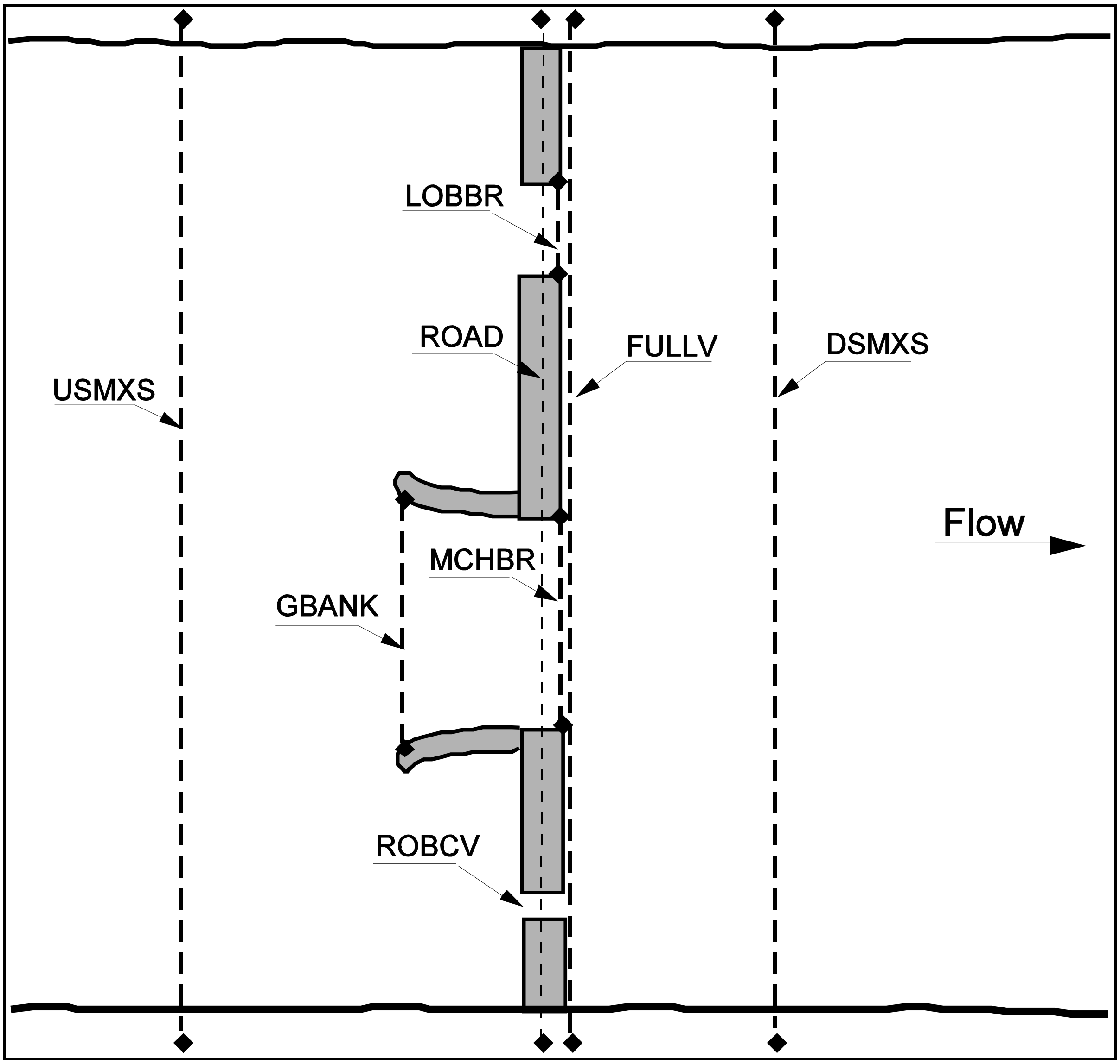


Figure 3-15. Definition sketch: multiple-opening stream crossing.

The crossing consists of three openings as follows: (1) a primary bridge spanning the main channel; (2) a relief bridge on the left overbank spanning a secondary channel; and (3) a culvert on the right overbank, primarily to provide low-flow passage for a wide, shallow drainage ditch, but large enough to pass a significant portion of the total flow at higher discharges. The primary bridge also has elliptical guidebanks. Figure 3-16 illustrates the data sequence required to define this situation from the downstream match section through the upstream match section, inclusive. The sections are defined in the following order: (1) downstream match section (analogous to the exit section of single-opening bridges); (2) full-valley section; (3) bridge section for the relief bridge on left overbank; (4) bridge section for the primary bridge; (5) guidebank section; (6) culvert section for the culvert on right overbank; (7) road-grade section; and (8) upstream match section (analogous to the approach section of single-opening bridges and requires an XS header record).

--80 character record --	
1-2 4 6-10	11-80
ID# SECID	User's Format

```
XS   DSMXS
__        [downstream match section data]
*
XS   FULLV
__         [full-valley section data]
*
BR   LOBBR
__         [bridge section data]
*
BR   MCHBR
__         [bridge section data]
*
GB   GDBNK
__         [guidebank data]
*
CV   ROBCV
__         [culvert data]
*
XR   ROAD
__         [road-grade data]
*
XS   USMXS
__         [upstream match section data]
```

Figure 3-16. Input data sequence: multiple-opening stream crossing of Figure 3-15.

3.4 CULVERT HYDRAULICS

Figure 3-17 shows a typical series of input data for a reach of a stream where culvert hydraulics are to be computed. A continuous water surface profile can be generated by placing a CV header record at the location shown in Figure 3-17. The culvert header record (CV record) is placed at the same section reference distance as the full valley cross-section. The xctr variable on the CV record locates the culvert laterally in the flood plain. The culvert geometry is entered on a CG record and if desired default culvert coefficients can be overridden through the use of a CC record.

---80 character record --	
1-2 4 6-10	11-80
ID# SECID	User's Format

```
XS   EXIT srd1 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
XS   FULLV srd2 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
CV   CULV  srd2, xctr, cvleng, dsinv, usinv, [, as needed]
CG         icode, rise, [ as needed ]
CC         [ optional as needed ]
*
XS   APPR  srd3 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
```

Figure 3-17. Input data sequence: continuous profile culvert computations .

3.5 SCOUR COMPUTATIONS

Figure 3-18 shows a conceptual data file that uses the DC, DP, and DA records to compute local scour at a bridge opening. The records are located after the last cross-section has been defined and before the EX record. The DC record is used to compute live-bed and clear-water contraction scour. The DP record is used to compute local scour at piers and the DA record is used to compute local scour at abutments. Multiple DC, DP, and DA records can be used to analyze different scour conditions or to examine scour sensitivity.

```
-------------------------------------------80 character record ----------------------------------------------
1-2  4  6-10                                    11-80
ID#  SECID                                      User's Format

XS   EXIT srd1 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
XS   FULLV srd2 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
BR   BRDGE srd2 [,as needed]
__         [ N, ND, and SA data, if appropriate ]
BL        brlen, xconlt, xconrt
BC        girdep, bdelev [,as needed]
CD        brtype, brwdth [,as needed]
AB                            - - - - - - - - - - -
PD                             optional  records
KQ                            - - - - - - - - - - -_ _ _ _ _ _ _ _ _ _
*
XS   APPR  srd3 [,as needed]
__         [ GR, N, ND, and SA data, as appropriate ]
*
DC   BRDGE [ as needed]
__         [ additional DC records as desired ]
*
DP   BRDGE [ as needed]
__         [ additional DP records as desired ]
*
DA   BRDGE [ as needed]
__         [ additional DA records as desired ]
*
EX
ER
```

Figure 3-18. Input data sequence: single-opening bridge of Figure 3-8, scour analysis.

3.6 FLOODWAY RECORDS

Floodway computations can be accomplished through the use of FS and/or FW records. The example shown in Figure 3-19 uses FW records to specify the desired surcharge on a cross-section by cross-section basis. The encroachment method, the desired surcharge, and encroachment constraints can be specified on the FW record for each of the cross-sections where and encroachment is to be analyzed.

----------------80 character record ----------------	
1-2 4 6-10	11-80
ID# SECID	User's Format

```
T1          - - - - - - - - - - - -
T2            Title Information
T3          - - - - - - - - - - - -
*
Q           discharge information
WS          starting water surface elevation information
*
XS    XS#1  srd1 [,as needed]
__           [ GR, N, ND, and SA data, as appropriate ]
FW           [ surcharge ]
*
XS    XS#2  srd2 [,as needed]
__           [ GR, N, ND, and SA data, as appropriate ]
FW           [ surcharge ]
*
XS    XS#3  srd3 [,as needed]
__           [ GR, N, ND, and SA data, as appropriate ]
FW           [ surcharge ]
*
EX
ER
```

Figure 3-19. Input data sequence: floodway computations.

SECTION 4 - DETAILED INPUT DATA CODING INSTRUCTIONS

4.1 GENERAL

WSPRO input data preparation has been greatly simplified by minimizing the use of fixed-field formats. The title information records (T1, T2, T3) are the only data records read with an 80-column fixed-field format. Only three data items in the remaining input data are constrained by fixed-field formats. They are a record identifier in columns 1 and 2, an option code in column 4, and a cross-section identification code in columns 6 through 10. Therefore, columns 1 through 10 of each record are reserved in fixed-field format to specify these three data items in accordance with the specifications shown in Table 4-1. When the option code and (or) the section identification code are not required in a data record, columns 3 through 5 and (or) 6 through 10 of that data record should be blank. Columns 11 through 80 are available to use as a free-format area for coding the remaining data.

Table 4-1. Fixed-field input format for columns 1 through 10 of all data records.

Card Column(s)	Input Format	Data
1-2	A2	Alphanumeric record identifier
3	1x	Blank space
4	I1	Integer option code
5	1x	Blank space
6-10	A5	Alphanumeric cross-section identification code, SECID

The record identifier, consisting of one or two characters, was introduced in the previous two sections. Table 4-2 summarizes, in alphabetical order, all of the valid record identifiers and the purpose of each data record. The model relies on the record identifier to determine the type of incoming data. Obviously, incorrect coding of a record identifier will result in some degree of job failure. The option code is a single-digit entry which is used in a few of the data records to select certain input/output options or optional computational techniques. The section identification, SECID, may consist of from one to five alphanumeric characters. The model uses SECID to identify cross-sections, both internally and in model output. Because of the alternative design features of the model, any data associated with a repeated SECID will replace data that were previously input with that SECID. Therefore, each cross-section must be identified with a unique SECID.

Primary objectives in adopting free-format input were to: (1) provide a "user-friendly" input scheme and; (2) eliminate many common coding errors that frequently occur when restricted by rigidly formatted input schemes. Free-format coding can be used to input a continuous string of numbers with appropriate data-field delimiters. Such input is usually objectionable to most users, however, because it is very difficult to visually interpret and (or) check such data strings. Most users will find it convenient to space the entries within the free-format area to enhance visual scanning of the data. Enough flexibility exists for users to tailor input patterns to suit the type and quantity of data and the users' individual tastes.

Free-format input eliminates fixed column requirements, yet there are certain coding conventions that must be followed. Also, unlike the flexibility in the ordering of data records, the individual data items in each data record must be coded in the specified order. The following conventions apply to coding data in the free-format area.

(1) Individual data items must be separated by either: a comma; one or more blanks; or any combination of a comma and one or more blanks.

(2) When a data item is not required (or it is to be assigned a default value) a null value may have to be specified, depending on the location of the data item within the parameter list. A null value must be specified for an omitted data item in the middle of a list. A null value in the middle of a list may be indicated by either two successive commas (with or without intervening blanks), or an asterisk (*). A null value must be indicated (with either a single comma or an asterisk) when omitting the first item in a list. Missing items at the end of a list are automatically assigned default values and need not be indicated at all, although the appropriate number of either successive commas or asterisks is generally allowed. The exception to this rule is in the Q, WS, and SK records where the last entry **must not** be a null value. When commas are used to indicate null values, they may be preceded and (or) followed by one or more blanks. When asterisks are used, they may be separated from adjacent data items (default or specified) as per rule number 1, above.

(3) Data values may be coded to whatever precision is appropriate for the type of data and the situation. Any number with a decimal fraction must be coded with a decimal point. Any value coded without a decimal point is input as a whole number.

A few examples should clarify application of rules 1 and 2, above. Assume a data list contains four variables (var1, var2, var3, and var4). Equivalent coding sequences (not all inclusive) for several situations follow.

Example 1. All four variables are required by the model.

(a) `var1,var2,var3,var4`
(b) `var1  var2  var3  var4`
(c) `var1  ,var2 , var3  var4`

Example 2. Default values are sufficient for the second and third variables.

(a) `var1,,,var4`
(b) `var1  *  *  var4`
(c) `var1,*,* var4`

Example 3. Only var1 is required.

(a) `var1`
(b) `var1  *  *  *`

Example 4. Only var2 and var3 are required.

(a) `,  var2  var3`
(b) `*  var2  var3  *`
(c) `*,var2,var3`

The input examples in later sections should provide additional understanding of the free-format coding conventions.

An alternative method of providing input has been provided. By placing a *F as the first record in an input data string the entire data file format can be considered free format. However, the user needs to be aware that of the fact that if the *F coding convention is followed that all input in columns 1-10 must be provided.

Table 4-2. Record identifiers and purpose of data record.

Record identifier	Purpose of data record
AB	Specifying (1) abutment slopes for type 3 openings **in component mode or** (2) abutment toe elevations for type 2 openings **in coordinate mode**.
BC	Specifying bridge low-chord parameters (**component mode only**).
BL	Specifying bridge length and abutment location constraints (**component mode only**).
BP	Specifying relation of bridge-opening horizontal datum to the horizontal datum of road and (or) approach sections.
BR	Header record for bridge-opening cross-section.
CC	Specifying culvert coefficients.
CD	Specifying parameters used for computing the flow length and the coefficient of discharge for a bridge opening.
CG	Specifying culvert section geometry.
CV	Header record for culvert cross-section.
DA	Specifying parameters used for computing local scour at abutments.
DC	Specifying parameters used for computing contraction scour.
DP	Specifying parameters used for computing local pier scour.
EF	Specifying effective flow input.
ER	Specifying end of run.
EX	Instructing model to begin execution of profile computations and specifying computation directions.
FL	Specifying friction slope averaging technique and (or) variable flow length(s) between sections.
FS	Specifying parameters for global floodway analysis.
FW	Specifying parameters for floodway analysis.
GB	Header record for guidebank cross-section.
GR	Specifying x,y-coordinates to define cross-section geometry.

Table 4-2. Record identifiers and purpose of data record (continued).

Record identifier	Purpose of data record
GT	Replaces GR data for sections being fabricated from template section.
HP	Requesting tables of cross-sectional properties and (or) velocity and conveyance distribution.
J1	Specifying parameters for computational control.
KQ	Specifying user-selected breakpoints to override the default location of the Kq segment of the approach cross-section.
N	Specifying roughness (Manning's "n") coefficients.
ND	Specifying hydraulic-depth breakpoints for vertical variation of roughness.
PD	Specifying pier or pile data.
Q	Specifying discharge for each profile to be computed.
SA	Specifying x-coordinates of breakpoints for subdivision of cross-sections for roughness and (or) geometry variation.
SI	Specifying metric or English input/output.
SK	Specifying energy gradient(s) for computing starting water-surface elevation(s) by slope conveyance.
T1,T2,T3	Specifying title information for identification of model output.
UT	Specifying user defined special tabling parameters.
WS	Specifying starting water-surface elevation(s) for profile computations.
XR	Header record for road-grade cross-section.
XS	Header record for unconstricted valley and approach cross-sections.
XT	Header record for template cross-section.
*	Inserting comments and (or) blank lines into the input data sequence.
*F	Specifying free-format input mode.

4.2 INDIVIDUAL DATA RECORDS

The following tables present coding details for each of the individual data records, including (1) the variables to be coded, (2) definition of the variables, and (3) default values (where applicable). Variables listed outside of brackets are mandatory. Variables listed between brackets are optional but some or all of those optional variables may be required under certain circumstances. The tables are arranged in alphabetized order of the record identifiers.

Table 4-3. Description of format and contents of AB record.

AB — AB Record — AB

Purpose: **Mandatory** record to specify abutment slope(s) **for type 3 openings in component mode** (**not used** for other opening types in component mode). **Mandatory** record to specify abutment toe elevations **for type 2 openings in coordinate mode (not used** for other opening types in coordinate mode model).

Format:		
Columns:	Format:	Contents:
1-2	A2	**AB**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**ABSLPL, [ABSLPR]** or **YABLT, YABRT**

Definition of variables:

ABSLPL, **ABSLPR** Slope (horizontal distance per meter change in elevation) of the left and right abutments, respectively. **Required only for type 3 openings when using COMPONENT MODE** for defining a bridge section. If both abutments have the same slope, only **ABSLPL** is required. See Figure 4-9 for illustration of these parameters.

YABLT, YABRT Ground elevation at the toe of the left and right abutments, respectively. **Required only for type 2 openings when using COORDINATE mode** (in component mode the model determines these elevations). The depths of water at the toes of the abutments are used to compute an adjustment factor for the coefficient of discharge. See Figure 4-8 for illustration of these parameters.

Note:

1) See **Table 4-11** for an explanation of bridge opening types.

Table 4-4. Description of format and contents of AS record.

AS — AS Record — AS

Purpose: Optional header record for approach cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**AS**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, [SKEW,EK,CK,VSLOPE]**

Definition of variables:

SECID Unique cross-section identification code (see **Section 5.1** for additional discussion of **SECID**).

SRD Section reference distance. A cumulative distance, in meters, along the stream measured from any arbitrary zero reference point (**SRD** may be negative). Unless an **FL** record is coded for the approach section, the difference in the full-valley section **SRD** and the approach section **SRD** is used as the flow length to compute friction losses in the unconstricted profile computations. The effective flow length (Schneider, et al., 1977) is used for friction-loss computations for bridge backwater regardless of **SRD** or **FL** data. The **SRD** value for the approach section should be approximately equal to the **SRD** value of the full-valley section plus the bridge width plus the bridge length (plus the length of guidebanks if they exist).

SKEW The acute angle that the section must be rotated to orient the section normal to the flow direction. The model applies the cosine of **SKEW** to the horizontal dimension of the section to compute cross-sectional properties. Default is zero degrees.

EK, CK	Coefficients used to compute expansion and contraction losses, respectively, for the energy equation balance. These coefficients do not apply to bridge-backwater computations, but are used for computing the unconstricted profile in the full-valley to approach section subreach in upstream computations and are used in the approach to bridge section subreach in downstream computations. Default values are either **EK** = 0.5 and **CK** = 0.0 or the current values being propagated from downstream data.
VSLOPE	Valley slope, in meters per meter. Used to adjust elevations of propagated geometry data. Also used to adjust elevations of approach section data used to fabricate intermediate approach cross-sections in a multiple-opening situation. Default value is either zero or the current value being propagated from downstream data.

Note:

1) The AS Header Record has been replaced by a regular full valley cross-section (as defined by an XS Header Record) in the current version of WSPRO. For purposes of bridge hydraulic computations, the program assumes that the first cross-section upstream of the bridge is the approach cross-section. WSPRO still recognizes an AS Header Record but will prompt the user with a message in the input data summary stating that the AS Header Record has been replaced with a XS Header Record.

Table 4-5. Description of format and contents of BC record.

BC — BC Record — BC

Purpose: Specifying bridge deck parameters. **Mandatory for component mode, not used for coordinate mode.**

Format:		
Columns:	Format:	Contents:
1-2	A2	**BC**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BCELEV, [BCSLP, BCSTA]**

Definition of variables:

BCELEV Low bridge-chord elevation. If bridge deck is not horizontal, **BCSLP** and **BCSTA** also are required.

BCSLP Bridge deck slope, in meters per meter; left to right fall is negative.

BCSTA The x-coordinate corresponding to the y-coordinate of **BCELEV**.

The above data provide the information necessary to connect the tops of the abutments to the low chord. Figure 4-1 illustrates the **BC** record parameters.

Note:

1) The BC Record replaces the BD Record used in earlier versions of WSPRO. The program still recognizes a BD Record but will prompt the user with a message in the input data summary stating that the BD Record has been replaced with the BC Record.

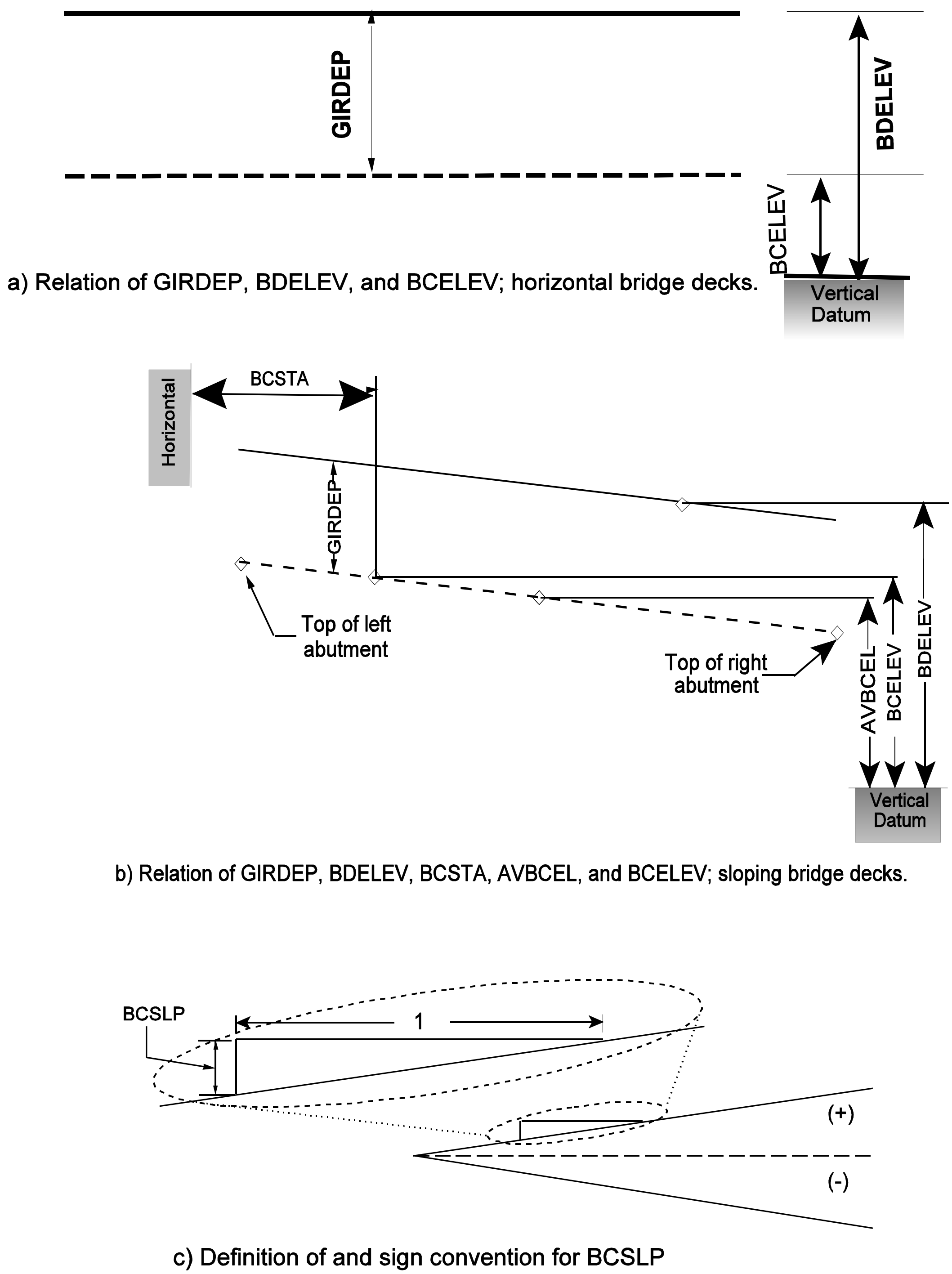


Figure 4-1. Definition sketch: BC parameters.

Table 4-6. Description of format and contents of BL record.

BL — BL Record — BL

Purpose: Specifying bridge length and abutment location constraints (COMPONENT MODE ONLY).

Format:		
Columns:	Format:	Contents:
1-2	A2	**BL**
3	1X	Blank
4	1X	**LOCOPT**
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BRLEN, XCONLT, XCONRT**

Definition of variables:

LOCOPT Bridge-location option to specify location of the specified bridge length (**BRLEN**) with respect to the specified horizontal stationing (**XCONLT**, **XCONRT**). Three choices are available as follows:

0 **BRLEN** is centered at the midpoint of the minimum bridge length (i.e., the midpoint between the tops of the abutments with the abutment toes located at the constraining points, **XCONLT** and **XCONRT**). **LOCOPT** = 0 is the default option.

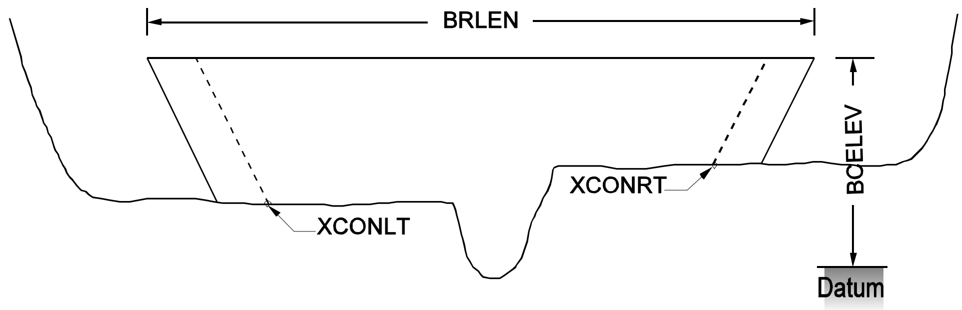
1 The toe of the right abutment is placed at the location specified by **XCONRT**.

2 The toe of the left abutment is placed at the location specified by **XCONLT**.

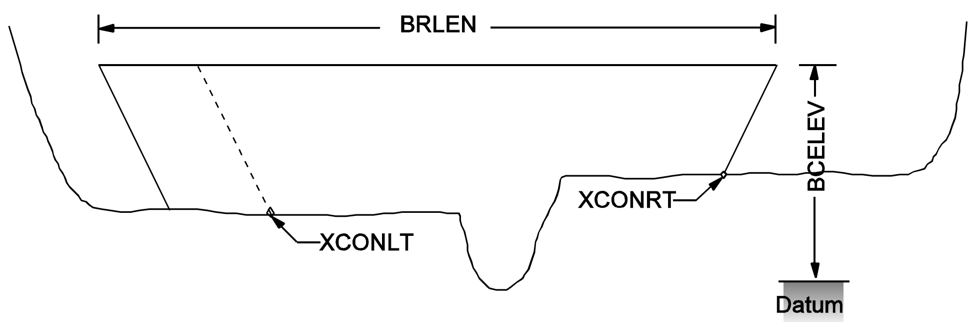
Figure 4-2 illustrates the effect of **LOCOPT** on the location of the bridge opening in COMPONENT MODE. Figure 4-3 illustrates the determination of the minimum bridge length in COMPONENT MODE's "bridge-building" process.

BRLEN The length of the bridge (between the tops of the abutments) in meters. Must be specified for the first alternative of a series, but is optional on subsequent alternative designs.

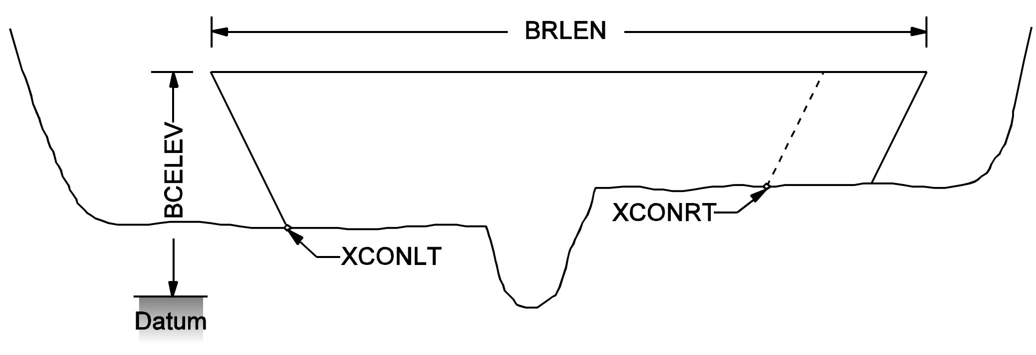
XCONLT, **XCONRT** Horizontal stationing controlling the location of the bridge opening. These values serve as constraints on the abutment locations and bridge length. **The model will not locate the toe of either abutment between XCONLT and XCONRT**. Any specified **BRLEN** which would result in such a situation is not analyzed. It is mandatory to specify these variables for the first alternative of a series, but optional on subsequent alternative designs.



a) LOCOPT = 0, bridge opening centered at midpoint of tops of abutments



b) LOCOPT= 1, right abutment toe fixed at XCONRT



c) LOCOPT = 2, left abutment toe fixed at XCONLT

Figure 4-2. Definition sketch: effect of LOCOPT on bridge-opening location.

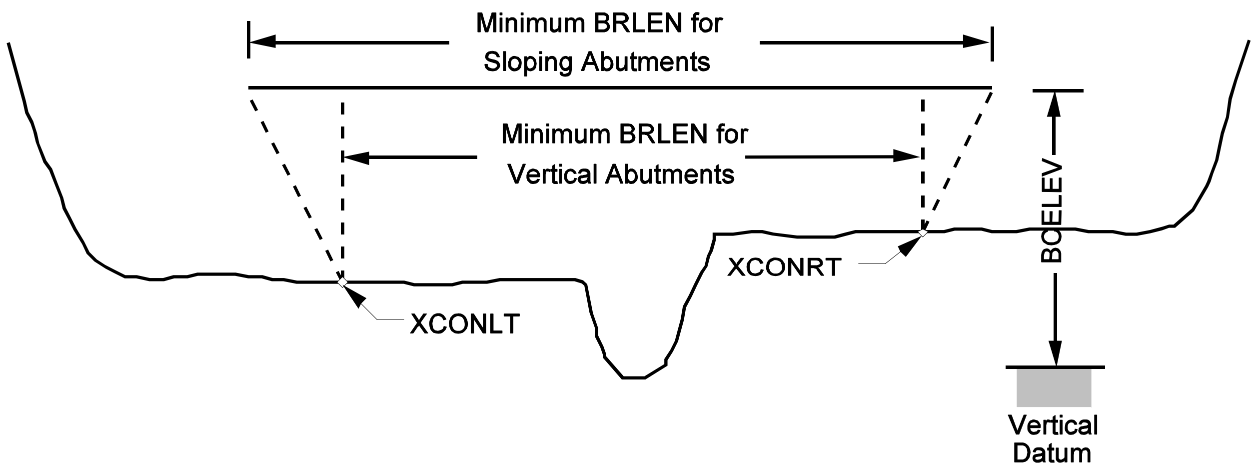


Figure 4-3. Definition sketch: BL record parameters.

Table 4-7. Description of format and contents of BP record.

BP — BP Record — BP

Purpose: Specifying relation of the horizontal datum of the bridge opening to the horizontal datum of road-grade and (or) approach section(s) (**only applicable to single-opening situations**).

Format:		
Columns:	Format:	Contents:
1-2	A2	**BP**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**XREFLT, [XREFRT**, **FDSTLT, FDSTRT]**

Definition of variables:

XREFLT x-coordinate on the road-grade or the approach section that coincides with the projection from a reference point in the bridge section. The left reference point is either (1) **XCONLT** (in **BL** record) for COMPONENT MODE or (2) the minimum x-coordinate of the bridge section for COORDINATE MODE. The projection is made vertically to the road-grade section and along a line parallel to the flow to the approach section. **XREFLT** is the only parameter needed in the **BP** record to provide a common horizontal datum for bridge and road-grade sections (see Figure 4-4). **XREFLT** is also the only parameter needed in the **BP** record to provide a common horizontal datum for bridge and approach sections if their horizontal stationing is not aligned properly and (or) if either (or both) of those sections are skewed to the direction of flow (see Figure 4-5)

Curvilinear flow requires three additional parameters. A typical situation is illustrated in Figure 4-6. The bridge and approach sections must be aligned normal to the flow. The variable flow length due to nonparallel sections is described by the additional parameters.

XREFRT x-coordinate of the approach section which coincides with the projection (parallel to the flow) of a right-hand reference point in the bridge section, which is either (1) **XCONRT** (in **BL** record) for COMPONENT MODE or (2) maximum x-coordinate of the bridge section for COORDINATE MODE.

FDSTLT, **FDSTRT** The flow distances measured along the left and right projection lines, respectively.

A **BP** record for datum correction between the road grade and the bridge is **included with the road-grade data**. A **BP** record for datum correction (or to account for curvilinear flow) between the bridge and the approach section is **included with the approach-section data**.

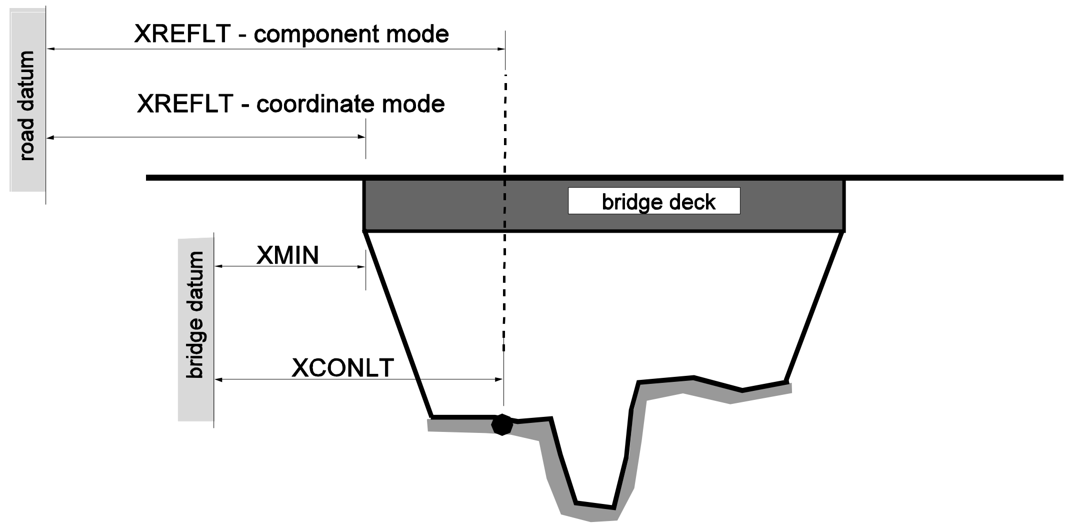


Figure 4-4. Definition sketch: application of BP record for datum correction between bridge-opening and road-grade sections.

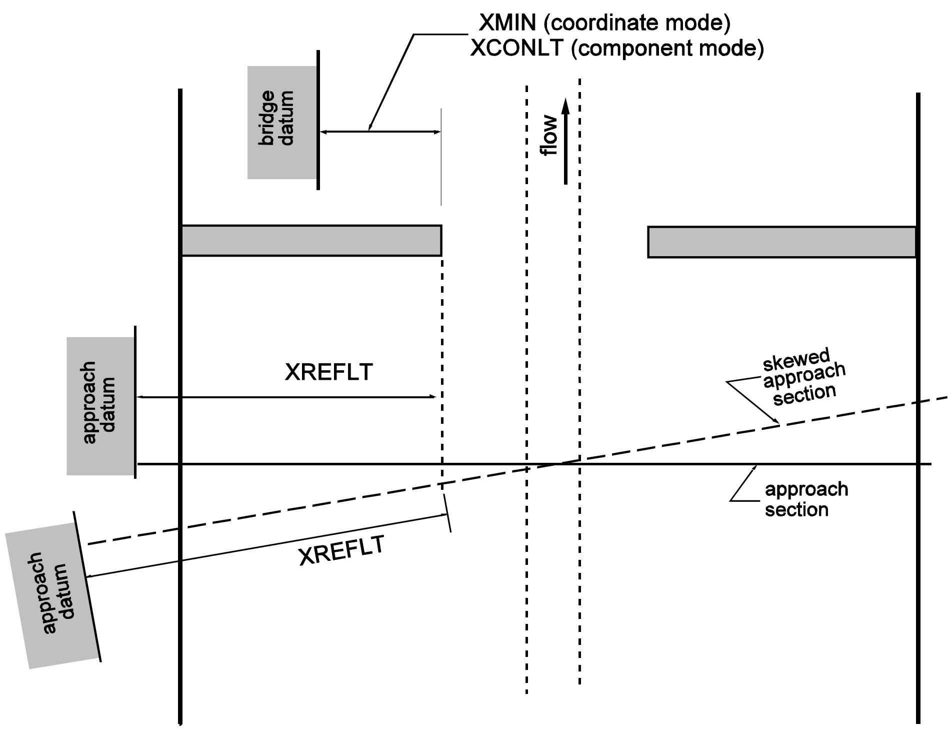


Figure 4-5. Definition sketch: application of BP record for datum correction between bridge-opening and approach sections.

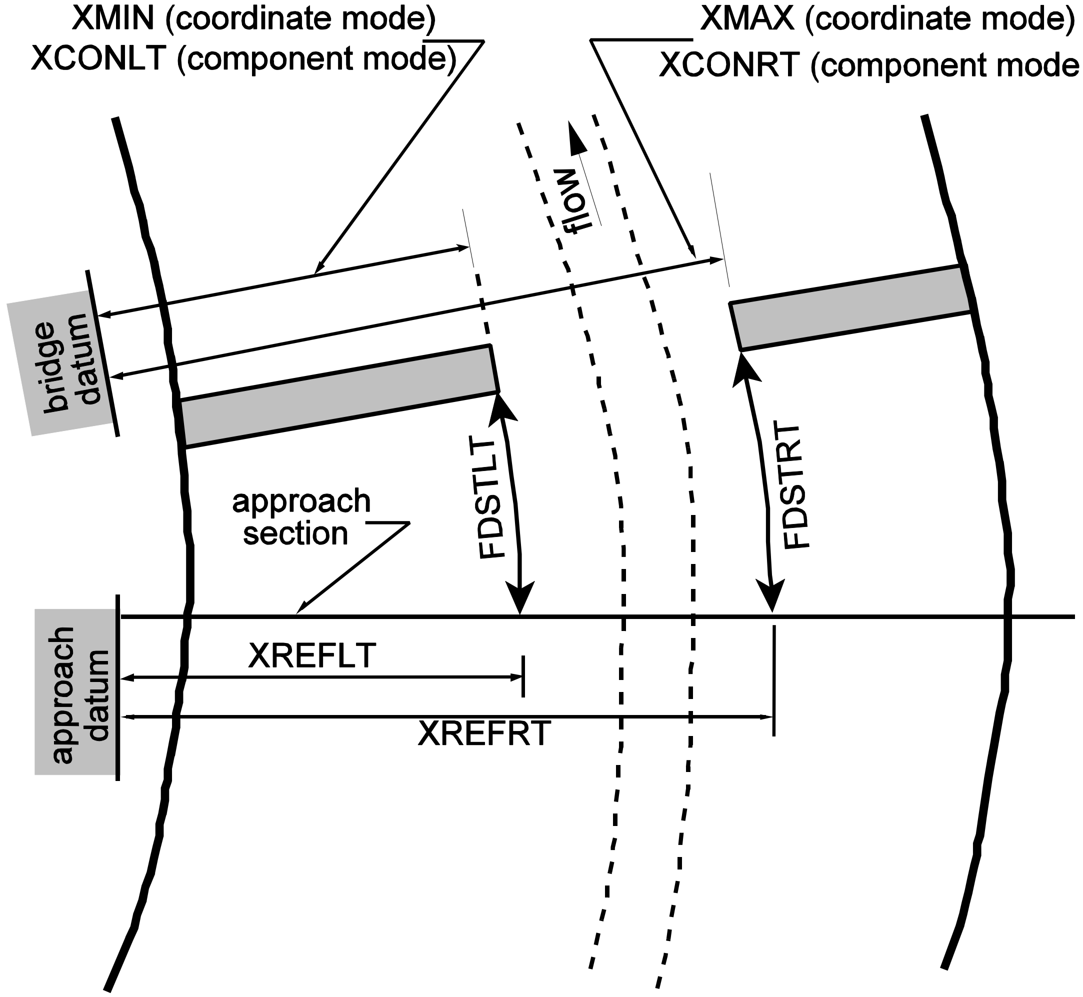


Figure 4-6. Definition sketch: application of BP record for curvilinear flow between approach and bridge.

Table 4-8. Description of format and contents of BR record.

BR — BR Record — BR

Purpose: Header record for bridge cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**BR**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, [PFELEV,SKEW,EK,CK,USERCD]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance; must be assigned the same value as the full-valley section.

PFELEV Elevation of the low chord of the bridge opening. Should be coded for **COORDINATE** mode if there is any chance for pressure flow. **WSPRO cannot check for (nor compute) pressure flow without this elevation.** The model computes a low chord elevation in **COMPONENT MODE**. An average elevation is computed for sloping decks. Users may **override** the **COMPONENT MODE** computed value by coding **PFELEV** in the **BR** header record. See Section 4.3.7 and Figure 4-1 for additional information on **PFELEV**.

SKEW The acute angle that the section must be rotated to orient the section normal to the flow direction. The model applies the cosine of **SKEW** to the horizontal dimension of the section to compute cross-sectional properties. Default is zero degrees. See Section 4.3.6 for additional information.

EK, CK	Coefficients used to compute expansion and contraction losses, respectively, for the energy equation balance. These coefficients are not used in bridge-backwater computations. They are used for supercritical flow computations from the bridge section to the exit section. Default values are either **EK** = 0.5 and **CK** = 0.0 or the current values being propagated from downstream data.
USERCD	User-specified coefficient of discharge for a bridge. WSPRO uses this override value instead of the computed value.

Table 4-9. Description of format and contents of CC record.

CC CC Record CC

Purpose: Specifying culvert coefficients. This record is not required if all of the default values are considered acceptable.

Format:		
Columns:	Format:	Contents:
1-2	A2	**CC**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**IEQNO, [CKE**,**CVALPH**,**CN]**

Definition of variables:

IEQNO The inlet equation number.

CKE The culvert entrance-loss coefficient, k_e.

CVALPH The velocity head correction coefficient, a, for the culvert.

CN Manning's roughness coefficient, n, for the culvert.

Default values for **CKE**, **CVALPH**, and **CN** are based on the value **ICODE** in the **CG** record. Default values for **CKE** are tabulated in the last column of Table 4-13. Default values for **CVALPH** and **CN** are tabulated in Table 4-10.

Table 4-10. Default values for roughness coefficient, n, and velocity head correction coefficient, a, for culverts.

	n	a		
Shape	-----	Box	Circle	Arch
Material				
Concrete	0.012	1.00	1.04	1.05
Corrugated metal	0.035	----	1.12	1.16

Table 4-11. Description of format and contents of CD record.

CD — CD Record — CD

Purpose: **Mandatory record for ALL bridge openings** to specify parameters used for computing the flow length and the coefficient of discharge for a bridge.

Format:		
Columns:	Format:	Contents:
1-2	A2	**CD**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BRTYPE, BRWDTH, EMBSS, EMBELV, WWANGL, WWWID, ENTRND**

Definition of variables:

BRTYPE Indicates the type of bridge opening, as follows:

1 Vertical embankments AND vertical abutments, with or without wingwalls (Figure 4-7).
2 Sloping embankments AND vertical abutments without wingwalls (Figure 4-8).
3 Sloping embankments AND sloping spillthrough abutments (Figure 4-9).
4 Sloping embankments AND vertical abutments with wingwalls (Figure 4-10).

BRWDTH Total width (in direction of flow) of the bridge deck. For type 1 openings **BRWDTH** should include the length of the upstream wing-walls. For the other types **BRWDTH** should reflect only the deck dimension. The model computes the x-components using the values coded for **EMBSS** and **EMBELV**.

EMBSS Embankment side slope, expressed in the horizontal change in meters per meter change of elevation (e.g., 3 to 1 is expressed as 3.0 OR 2½ to 1 is expressed as 2.5). Default value is zero. **Must be specified for BRTYPE 2, 3, and 4**.

EMBELV	Embankment elevation **must be provided for BRTYPE 2, 3, and 4**. A representative elevation in the vicinity of the bridge opening should be used when the top of the embankment is not horizontal. **EMBELV** and **EMBSS** are used to compute x-component(s) of flow length through bridge (see Figure 4-11).
WWANGL	Wingwall angle, in degrees. Required **only** for **type 1** openings with wingwalls (Figure 4-7) and **type 4** openings (Figure 4-10). Default is zero degrees.
WWWID	Wingwall width, in meters. Required **only** for **type 1** openings with wingwalls (see Figure 4-7). Default is zero.
ENTRND	Radius of entrance rounding, in meters. Required **only** for **type 1** openings with rounded entrance corners. Default is zero.

Table 4-11. Description of format and contents of CD record (continued).

CD	CD Record	CD

Notes:

1) **BRTYPE** and **BRWDTH must be coded** for **all** opening types.
2) For **BRTYPE 1**, additional parameters may be applicable as follows:
   a) **WWANGL** and **WWWID -** both parameters must be specified when wingwalls are present.
   b) **ENTRND -** wingwalls are not present and entrance corners are rounded.
   c) **No** additional parameters when neither wingwalls nor entrance rounding exists.
3) For **BRTYPE 1**, **EMBSS** and **EMBELV** should be allowed to default.
4) **EMBSS** and **EMBELV must be coded** for **BRTYPE 2, 3, and 4**.
5) There are **NO** additional parameters for **BRTYPE 2 and 3**.
6) **WWANGL** should be coded for **BRTYPE 4**.
7) A complete explanation of the variables presented in Figures 4-8, 4-9, 4-10, and 4-11 can be found in the Bridge Waterways Analysis Model, Research Report (Shearman and others, 1986).

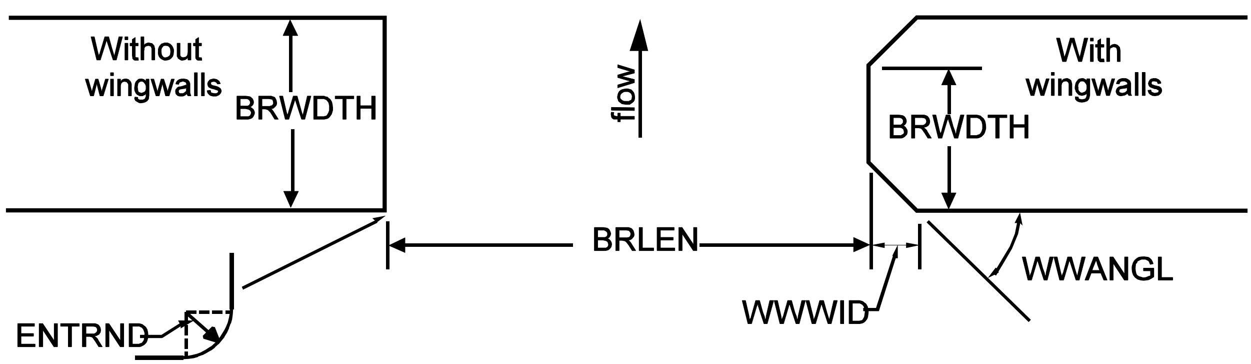
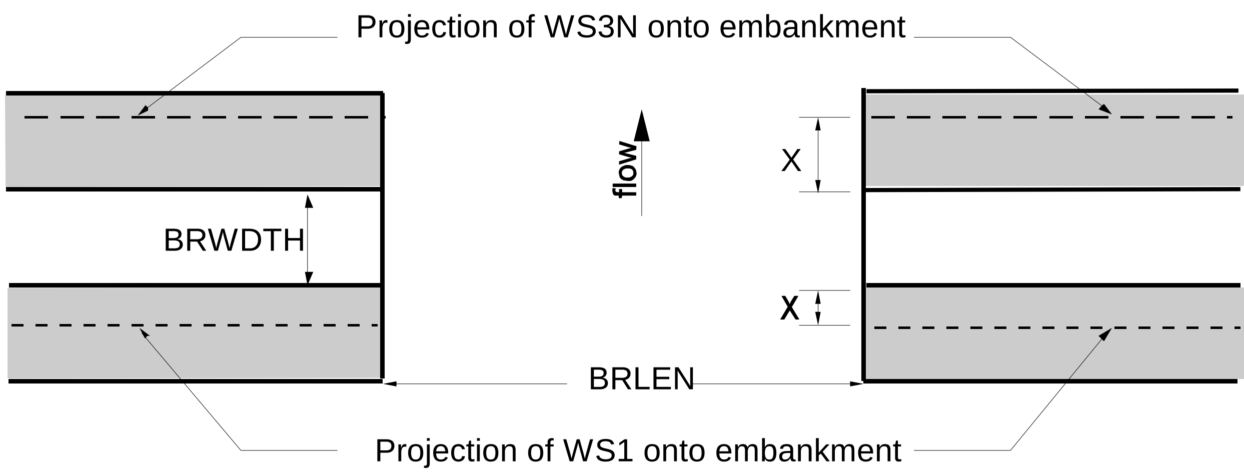
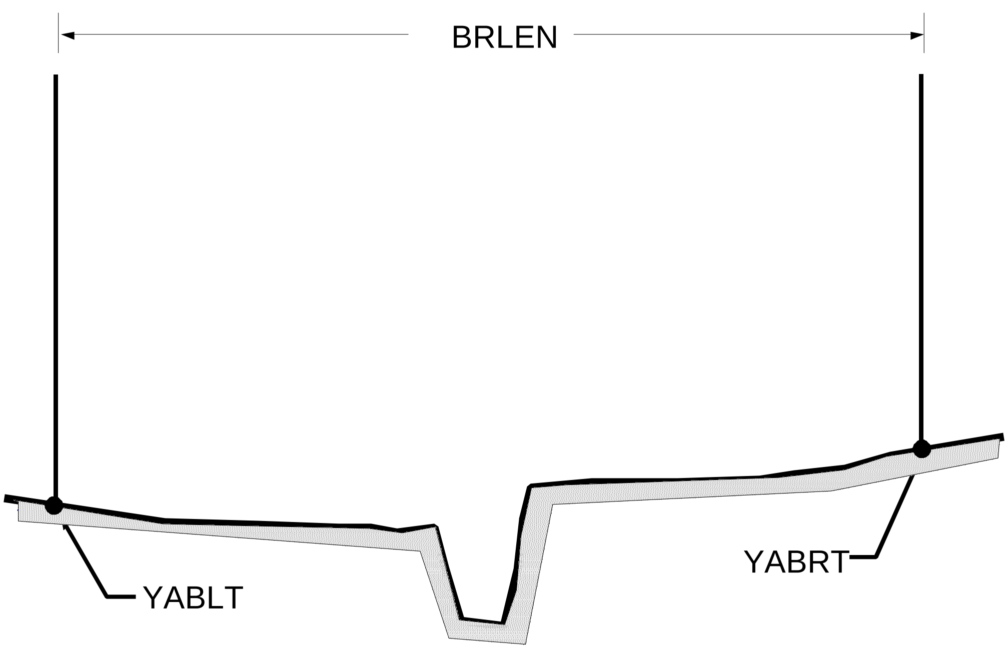


Figure 4-7. Definition sketch: type 1 bridge opening (BRTYPE = 1).



a) Plan view



b) Elevation view, upstream side of bridge

Figure 4-8. Definition sketch: type 2 bridge opening (BRTYPE = 2).

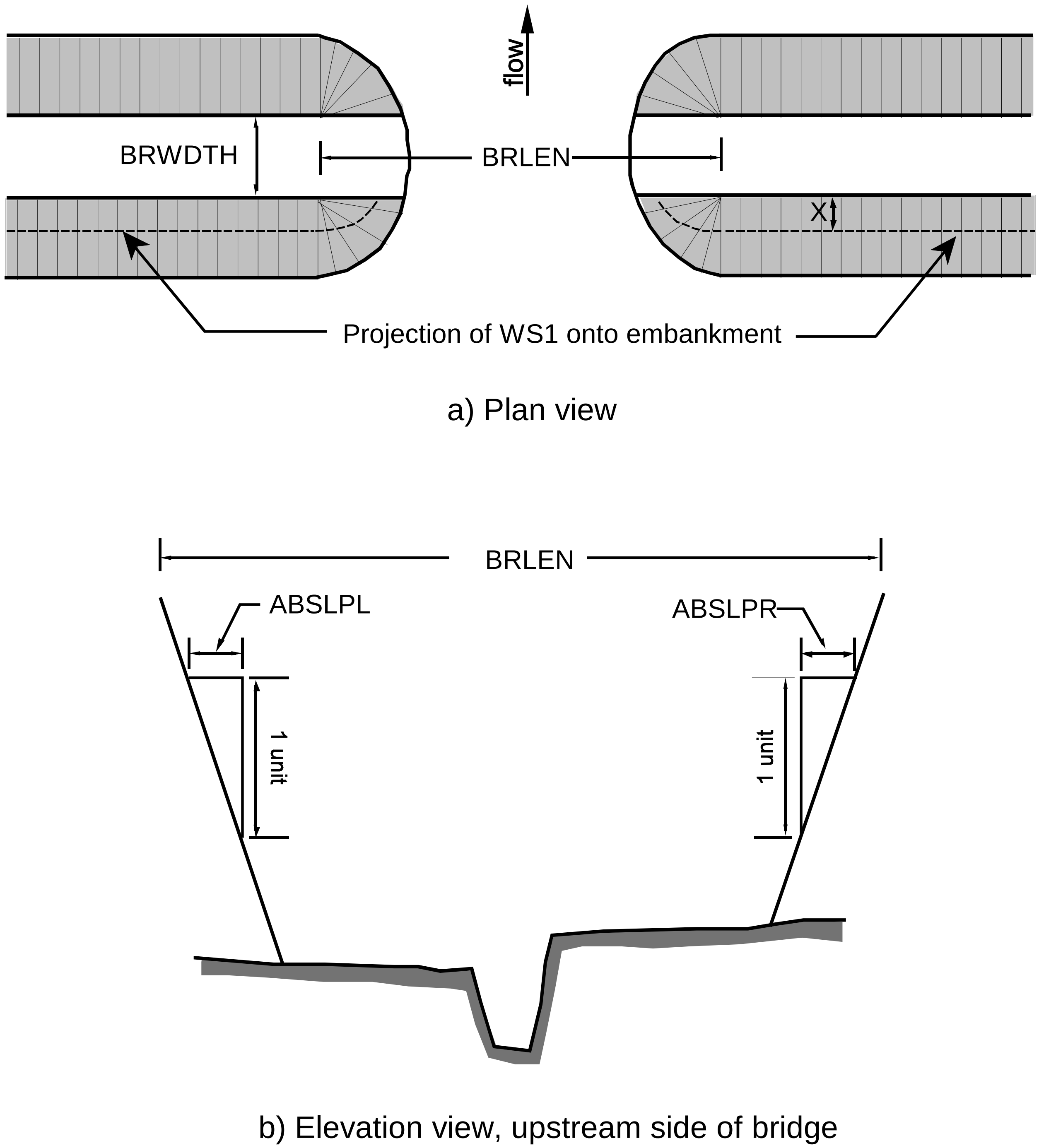


Figure 4-9. Definition sketch: type 3 bridge opening (BRTYPE = 3).

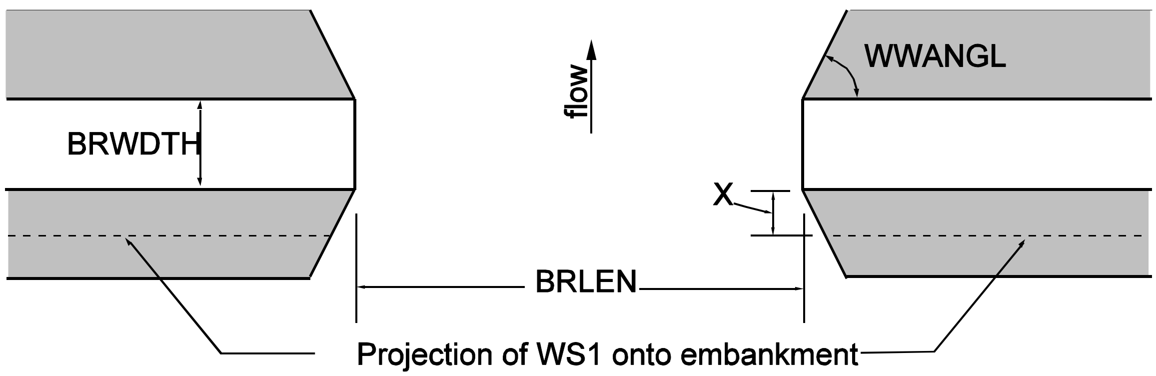


Figure 4-10. Definition sketch: type 4 bridge opening (BRTYPE = 4).

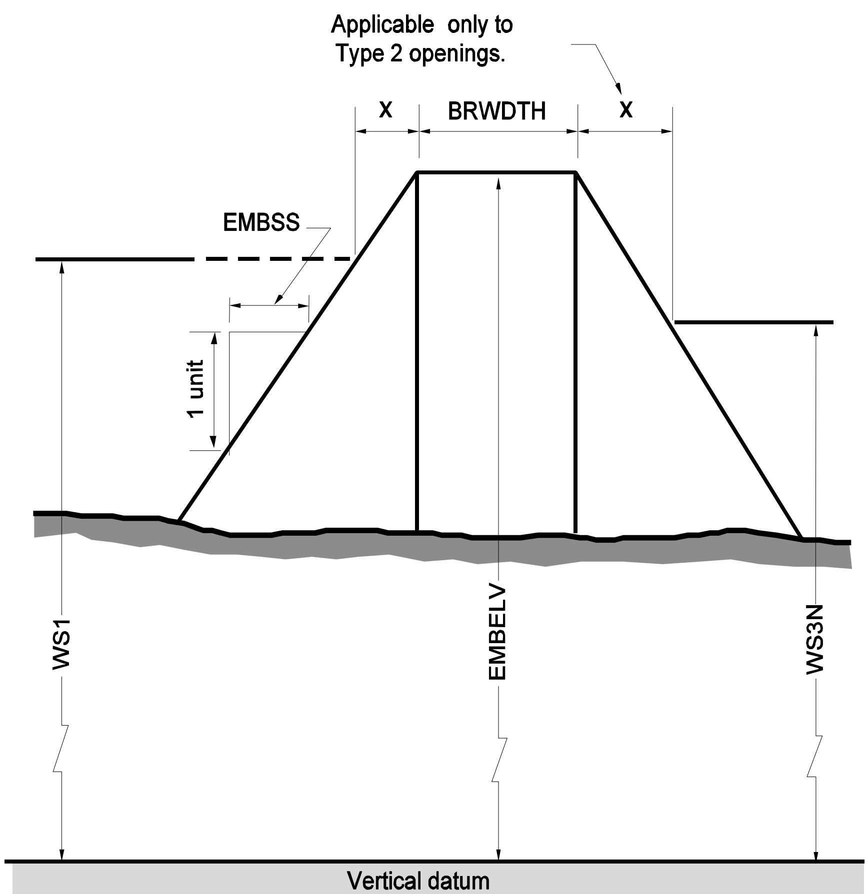


Figure 4-11. Definition sketch: embankment parameters (BRTYPE 2,3, and 4)

Table 4-12. Description of format and contents of CG record.

CG — CG Record — CG

Purpose: Specifying culvert section geometry.

Format:		
Columns:	Format:	Contents:
1-2	A2	**CG**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**ICODE, RISE, [SPAN, BOTRAD, TOPRAD, CORRAD]**

Definition of variables:

ICODE Three digit culvert code (i.e., IJK) in which the individual digits indicate the following:

I Shape code: 1 = BOX; 2 = CIRCULAR; and 3 = ARCH.
J Material code: 1 = CONCRETE; 2 = CORRUGATED METAL PIPE (steel); and 3 = ALUMINUM.
K Inlet code (type of inlet column in Table 4-13).

Table 4-13 lists valid combinations of I, J, and K. **ICODE** also controls default values for **CKE**, **CVALPH**, and **CN** (see Tables 4-9, 4-10, and 4-13).

RISE The maximum vertical dimension, **in millimeters**, of the culvert barrel. The rise equals the diameter for circular culverts.

SPAN The maximum horizontal dimension of the culvert barrel, **in millimeters**. **SPAN must be** coded for box and pipe-arch culverts but **should not be** coded for circular culverts.

BOTRAD Bottom radii of pipe-arch culvert barrel, **in millimeters**. Appropriate values are tabulated in CDS-4 (FHWA, 1982). If not specified, approximate values of this,

	and following two parameters will be computed on the basis of **ICODE**, **SPAN**, and **RISE** using the equations tabulated in Table 4-14.
TOPRAD	Top radii of pipe-arch culvert barrel, **in millimeters**.
CORRAD	Corner radii of pipe-arch culvert barrel, **in millimeters**.

Table 4-13. Coefficients used in the analysis of culverts.

I J K	Type of inlet	Ke
BOX Culverts		
1 1 1	WINGWALLS: 30E - 75E flare; square top edge	0.4
1 1 2	HEADWALL: (a) normal or (b) 45E skew; square edge	0.5
1 1 3	WINGWALLS: 15E flare with square edges	0.5
1 1 4	WINGWALLS: extended with 0E flare; square top edge	0.7
1 1 5	HEADWALL: (a) normal or (b) 45E skew; 1:1 bevels	0.2
1 1 6	WINGWALLS: (a) 18E - 33.7E flare with 1.5:1 top bevel; or (b) 45E flare with 1:1 top bevel	0.2
1 1 7	HEADWALL: normal with 1.5:1 bevel on three sides	0.2
CIRCULAR Culverts		
2 1 1	PROJECTING: socket end	0.2
2 1 2	HEADWALL: socket end	0.2
2 1 3	PROJECTING: square edge	0.5
2 1 4	HEADWALL: square edge	0.5
2 1 5	END SECTION: concrete	0.5
2 2 5	END SECTION: corrugated metal	0.5
2 1 6	BEVEL: concrete with 1:1 bevels	0.2
2 2 6	BEVEL: corrugated metal with 1:1 bevels	0.2
2 1 7	BEVEL: concrete with 1.5:1 bevels	0.2
2 2 7	BEVEL: corrugated metal with 1.5:1 bevels	0.2
2 2 1	PROJECTING: corrugated metal	0.9
2 2 2	MITERED: corrugated metal	0.7
2 2 3	HEADWALL: corrugated metal	0.5
ARCH Culverts		
3 1 1	HEADWALL: square edge	0.5
3 1 2	HEADWALL: grooved end	0.2
3 1 3	PROJECTING: grooved end	0.2
3 2 1	PROJECTING: corner radius of pipe-arch culvert < 457 mm (18.0 in)	0.9
3 2 2	PROJECTING: corner radius of pipe-arch culvert = 787 mm (31.0 in)	0.9
3 2 3	PROJECTING: corner radius of pipe-arch culvert = 1194 mm (47.0 in)	0.9
3 2 4	MITERED: corner radius of pipe-arch culvert < 457 mm (18.0 in)	0.7
3 3 1	PROJECTING: corner radius of pipe-arch culvert = 808 mm (31.8 in)	0.9
3 2 4	MITERED: corner radius of pipe-arch culvert < 457 mm (18.0 in)	0.7
3 2 5	MITERED: corner radius of pipe-arch culvert = 787 mm (31.0 in)	0.7
3 2 6	MITERED: corner radius of pipe-arch culvert = 1194 mm (47.0 in)	0.7
3 3 2	MITERED: corner radius of pipe-arch culvert = 808 mm (31.8 in)	0.7
3 2 7	HEADWALL: corner radius of pipe-arch culvert < 457 mm (18.0 in)	0.5
3 2 8	HEADWALL: corner radius of pipe-arch culvert = 787 mm (31.0 in)	0.5
3 2 9	HEADWALL: corner radius of pipe-arch culvert = 1194 mm (47.0 in)	0.5
3 3 3	HEADWALL: corner radius of pipe-arch culvert = 808 mm (31.8 in)	0.5

Table 4-14. Approximate formulas for pipe-arch auxiliary dimensions.

NOTE: All Dimensions in millimeters.

R = rise
B = span
r_t = top radius
r_b = bottom radius
r_c = corner radius

REINFORCED CONCRETE PIPE ARCH
$r_c = 15.19 + 0.243\mathbf{R}$
$r_t = 30.73 + 0.499\mathbf{B}$
$r_b = -1527.3 + 2.106\mathbf{R} + 0.583(\,|\,\mathbf{B} - 2413\,|\,)$

CORRUGATED METAL PIPE ARCH, Corner Radius of pipe-arch culvert < 457 mm (18.0 in)
$r_c = 29.0 + 0.205\mathbf{R}$ if **R** < 1400 mm
$r_c = 457.0$ if **R** > 1400 mm
$r_t = 15.09 + 0.498\mathbf{B}$
$r_b = 177.8 - 2.036\mathbf{R} + 2.741\mathbf{B}$

CORRUGATED METAL PIPE ARCH, Corner Radius of pipe-arch culvert = 787 mm (31.0 in)
$r_t = -8.79 + 0.505\mathbf{B}$
$r_b = -24300 + 29.39\mathbf{R} - 13.49\mathbf{B}$

CORRUGATED METAL PIPE ARCH, Corner Radius of pipe-arch culvert = 1194 mm (47.0 in)
$r_t = -83.06 + 0.521\mathbf{B}$
$r_b = -23579 + 18.44\mathbf{R} - 7.81\mathbf{B}$

ALUMINUM PIPE ARCH, Corner Radius of pipe-arch culvert = 808 mm (31.8 in)
$r_t = -17.68 + 0.522\mathbf{B}$
$r_b = 9220 - 9.64\mathbf{R} + 6.38\mathbf{B}$

Table 4-15. Description of format and contents of CV record.

CV — CV Record — CV

Purpose: Header record for culvert cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**CV**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, XCTR, CVLENG, DSINV, USINV, [NBBL]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance. The SRD for the culvert should reflect the location of the downstream end of the barrel and should be the same as the **SRD** of the full-valley cross-section when none of sections are skewed to the flow.

XCTR The horizontal stationing of the center of the culvert measured relative to an arbitrary origin on the left bank. This stationing must be consistent with the stationing defining a multiple-opening situation.

CVLENG Length of the culvert barrel(s), in meters.

DSINV Elevation of downstream invert, in meters above the common elevation datum.

USINV Elevation of upstream invert, in meters above the common elevation datum.

NBBL Number of culvert barrels (default is one barrel).

For a stand-alone culvert analysis, **SRD** and **XCTR** have no useful purpose but should be assigned some arbitrary value to prevent input problems.

Table 4-16. Description of format and contents of DA record.

DA — DA Record — DA

Purpose: Specifying parameters for the computation of abutment scour.

Format:		
Columns:	Format:	Contents:
1-2	A2	**DA**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**[K1, K2, YAL, YAR, Q, FS]**

Definition of variables:

SECID Unique cross-section identification code. SECID is optional (depending on placement in the data stream as with the Q and HP Records.

K1, K2 K1 and K2 are the two correction/adjustment factors for abutment shape and embankment skew (default value is 1.0 for both factors).

YAL, YAR User-specified overrides for the left and right abutment depth, y_a , in meters. Use these parameters for cases when an average overbank depth may not be realistic for scour computations (e.g., if the abutment location is within the main channel, some weighted average value of y_a may yield more meaningful estimates of scour depths).

Q Discharge through the bridge opening (cubic meters per second).

FS Factor of safety (default = 1.0).

The standard/default mode of WSPRO computations will consist of:

1) Compute the length of embankment projected normal to flow, a', for the left abutment as LEW(bridge) - LEW(approach) and for the right abutment as REW(approach) - REW(bridge).

2) Compute left/right abutment obstructed flow areas, A_e, for left/right a' segments at the approach section.
3) Compute left/right y_a values by dividing left/right flow areas, A_e, by the right/left a' values.
4) Compute left/right abutment obstructed flow, Q_e, based on ratio of the left/right a' segment conveyances to the total approach section conveyance.
5) Compute left/right abutment index velocities, V_e, by dividing left/right values of Q_e by left/right values of A_e.
6) Compute Froude number as a function of V_e and y_a.

Notes:

1) A message will be generated when $a'/y_a > 25$ so the user can decide if an alternate methodology should be attempted.

2) Definition and explanation of the variables used in the abutment scour equation can be found in Hydraulic Engineering Circular 18, Evaluating Scour At Bridges (Richardson and Davis, 1995).

3.) The current version of WSPRO does not support abutment scour computations in coordinate mode. This capability is to be added at a future date.

Table 4-17. Description of format and contents of DC record.

DC — DC Record — DC

Purpose: Specifying parameters to perform live-bed and clear-water contraction scour depth computations.

Format:		
Columns:	Format:	Contents:
1-2	A2	**DC**
3	1X	Blank
4	1X	**0,** *(live-bed contraction scour)*
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**[BXL, BXR, AXL, AXR, K1, PW, YB, YA]**

--- or ---

Format:		
Columns:	Format:	Contents:
1-2	A2	**DC**
3	1X	Blank
4	1X	**1,** *(clear-water contraction scour)*
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**[BXL, BXR, AXL, AXR, D_{50}, PW, YB, YA]**

Definition of variables:

SECID — Unique cross-section identification code. SECID is optional (depending on placement in the data stream as with the Q and HP Records.

BXL, BXR, AXL, AXR — BXL, BXR, AXL, AXR are the left and right horizontal limits of the bridge (BX section) and approach (AX section) channel segments, respectively. Defaults for these limits are the left and right edges of water for the bridge and approach sections. AX and BX will be limited, of course, to the difference between left- and right-edges of water.

K1 — The k_1 exponent in the contraction scour estimation equation (default 0.64).

PW — Cumulative pier width. Without a value for this parameter, the value of W_2 used in either the clear-water or live-bed contraction scour equations will be reduced by gross pier width based on PD record input data. If a PD record is not used this value must be coded on the DC record.

YB — Depth of flow in bridge opening.

YA — Depth of flow in channel or floodplain.

D_{50} — Median diameter of bed material in bridge opening or in the floodplain, mm. This value is required when using the DC record to compute clear-water contraction scour.

Notes:

1) Multiple DC records can be used to evaluate different combinations of left and right horizontal limits and/or different values of k_1.

2) It is also possible to add variables YB (water-surface elevation in contracted section), QB (flow through bridge opening), WS1 (water-surface elevation at approach section), QT (total flow at the approach section) to permit contraction scour computations 'divorced' from profile computations.

3) Samples of how BXL, BXR, AXL, and AXR are located are demonstrated in Figures 7-26 and 7-27.

4) Definition and explanation of the variables used in the contraction scour equations can be found in Hydraulic Engineering Circular 18, Evaluating Scour At Bridges (Richardson and Davis, 1995).

Table 4-18. Description of format and contents of DP record.

DP — DP Record — DP

Purpose: Specifying parameters to perform local pier scour computations.

Format:		
Columns:	Format:	Contents:
1-2	A2	**DP**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**[BXL, BXR, PW, YB, QB, K1, K2, K3, K4, V1M, Y1M]**

Definition of variables:

SECID Unique cross-section identification code.

BXL Left horizontal limit of channel segment to be examined for pier scour computations.

BXR Right horizontal limit of channel segment to be examined for pier scour computations.

PW Individual pier width.

YB User-specified override for the water-surface elevation in the bridge opening.

QB Discharge through the bridge opening.

K1,K2, K3,K4 Correction/adjustment factors applied to the scour estimation equation (default values are 1.1, 1.0, 1.0, and 1.0 for K1, K2, K3, and K4 respectively).

V1M Velocity multiplier.

Y1M Depth multiplier.

Notes:

1) The **V1M** and **Y1M** parameters are multipliers to increase or decrease the maximum velocity and depth values. These parameters could be used as safety factors and/or to perform fundamental sensitivity analyses to show variation in scour depth for different combinations of velocity and depth. Multiple DP records can be used to specify different **V1M** and **Y1M** values for sensitivity analyses.

2) Pier scour computations can be divorced from the profile computations by coding the **YB** and **QB** parameters. This feature is useful when it is deemed necessary to adjust computed elevations and/or in complex flow situations where water-surface elevations are not determined by WSPRO computations. Velocity and depth values are determined as per the above discussion. These computations could be accomplished by inputting only the bridge section.

3) Definition and explanation of the variables used in the pier scour equation can be found in Hydraulic Engineering Circular 18, Evaluating Scour At Bridges (Richardson and Davis, 1995).

Table 4-19. Description of format and contents of EF record.

EF EF Record EF

Purpose: Allows user to set effective flow limits and user-defined stagnation points.

Format:		
Columns:	Format:	Contents:
1-2	A2	**EF**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**XLEF, YLEF, XREF, YREF**

Definition of variables:

XLEF Left station for effective flow calculations, in meters.

YLEF Depth at left station where flow limits no longer take effect.

XREF Right station for effective flow calculations, in meters.

YREF Depth at right station where flow limits no longer take effect.

Table 4-20. Description of format and contents of ER record.

ER ER Record ER

Purpose: Specifying end of input data. (Begin computations.)

Format:		
Columns:	Format:	Contents:
1-2	A2	**ER**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	No Parameters

A harmless message about input end-of-file occurs if this record is missing.

Table 4-21. Description of format and contents of EX record.

EX — EX Record — EX

Purpose: Instructing model to execute profile computations and specifying computation direction. **No profiles are computed if an EX record is not coded.**

Format:		
Columns:	Format:	Contents:
1-2	A2	**EX**
3	1X	Blank
4	1X	**IEX**
5	1X	Blank
6-10	A5	Blank
11-80	Free	**IDIR(1), IDIR(2) ... , IDIR (NPROF)**

The parenthetical notation indicates the order number, i, assigned by the model to each profile to be computed; i = 1 and i = **NPROF** for the first and last profiles to be computed with **NPROF** $\leq$ 20.

Definition of variables:

IEX — If all profiles are to be computed in the downstream direction, coding **IEX** = 1 is equivalent to coding **IDIR** = 1 for each profile

IDIR(i) — Computation-direction code for i^{th} profile. **IDIR** = 0 for upstream (subcritical and/or critical) computations. **IDIR** = 1 for downstream (supercritical and/or critical) computations. No entries are required if all profiles are to be computed in the upstream direction. Any combination of upstream and downstream computations requires that **IDIR** be specified for each discharge in **Q** record. See Sections 4.3.2 and 4.3.3 and Figure 4-12 for additional information.

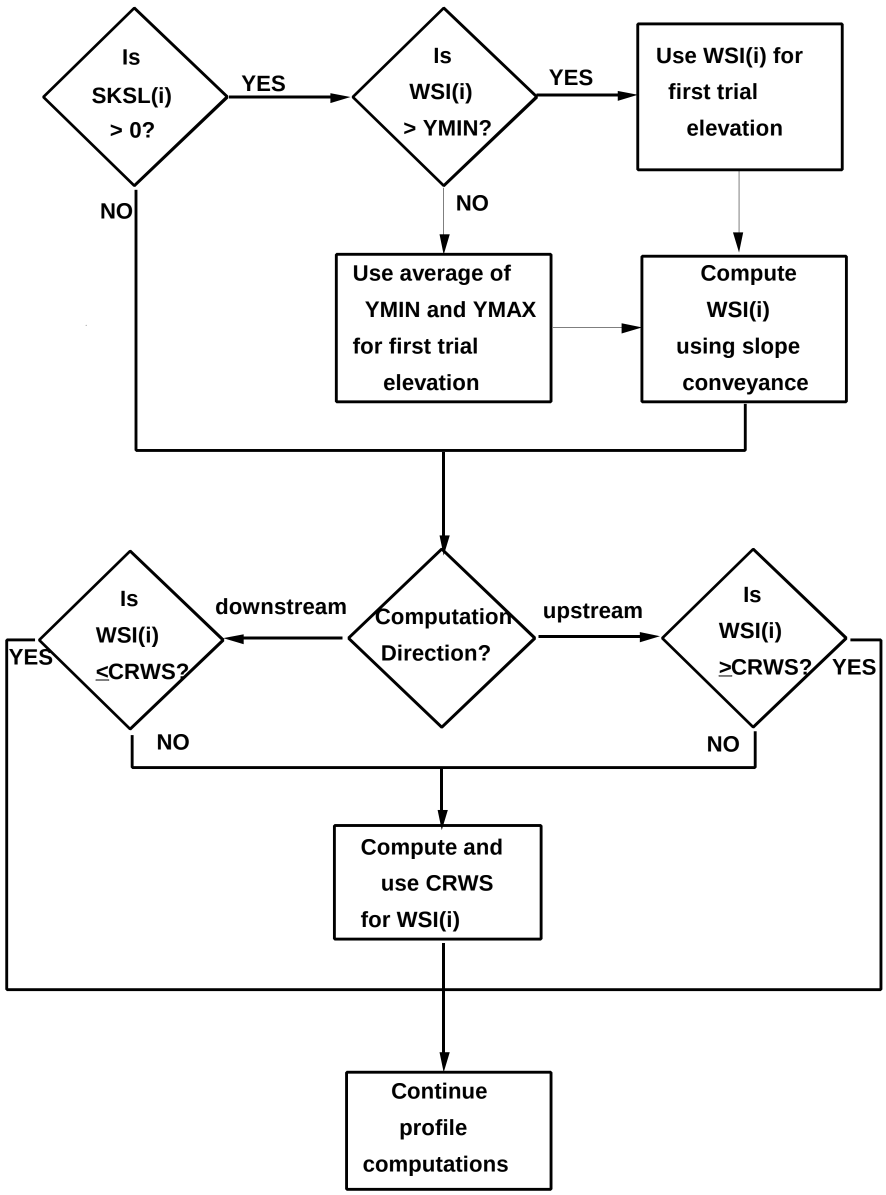


Figure 4-12. Flow chart: computational path for various combinations of WS, SK, and EX data.

Table 4-22. Description of format and contents of FL record.

FL — FL Record — FL

Purpose: Specifying friction slope averaging technique and (or) variable flow length(s) between sections.

Format:		
Columns:	Format:	Contents:
1-2	A2	**FL**
3	1X	Blank
4	1X	**IHFNO**
5	1X	Blank
6-10	A5	Blank
11-80	Free	**[FLEN(1) [, XFL (1), FLEN (2)] [, XFL (2), FLEN (3)]**

Definition of variables:

IHFNO Code to select the friction slope (or conveyance) averaging technique in the friction-loss computations. Valid entries are:

0 Uses geometric mean of conveyance.
1 Uses arithmetic average of conveyance.
2 Uses arithmetic average of friction slope.
3 Uses harmonic mean of friction slope.

IHFNO is propagated from section to section until a different value is introduced. **IHFNO** does not apply to bridge backwater computations (geometric mean of conveyance is always used). **IHFNO** is overridden if **IHFNOJ** is coded on the **J1** record.

FLEN Flow length between the current cross-section and the adjacent downstream cross-section. Up to three values may be specified, and these lengths override **SRD** values except in bridge backwater computations. When more than one **FLEN** value is specified, each length applies to a segment of the cross-section (which does not have to bear any relation to the subdivisions specified on **SA**

records). The conveyance of the segments are used to compute a conveyance-weighted average flow length.

XFL x-coordinate of breakpoints between the segments of the cross-section for which multiple **FLEN** values are to be applied. Figure 4-13 illustrates the **FLEN** and **XFL** parameters.

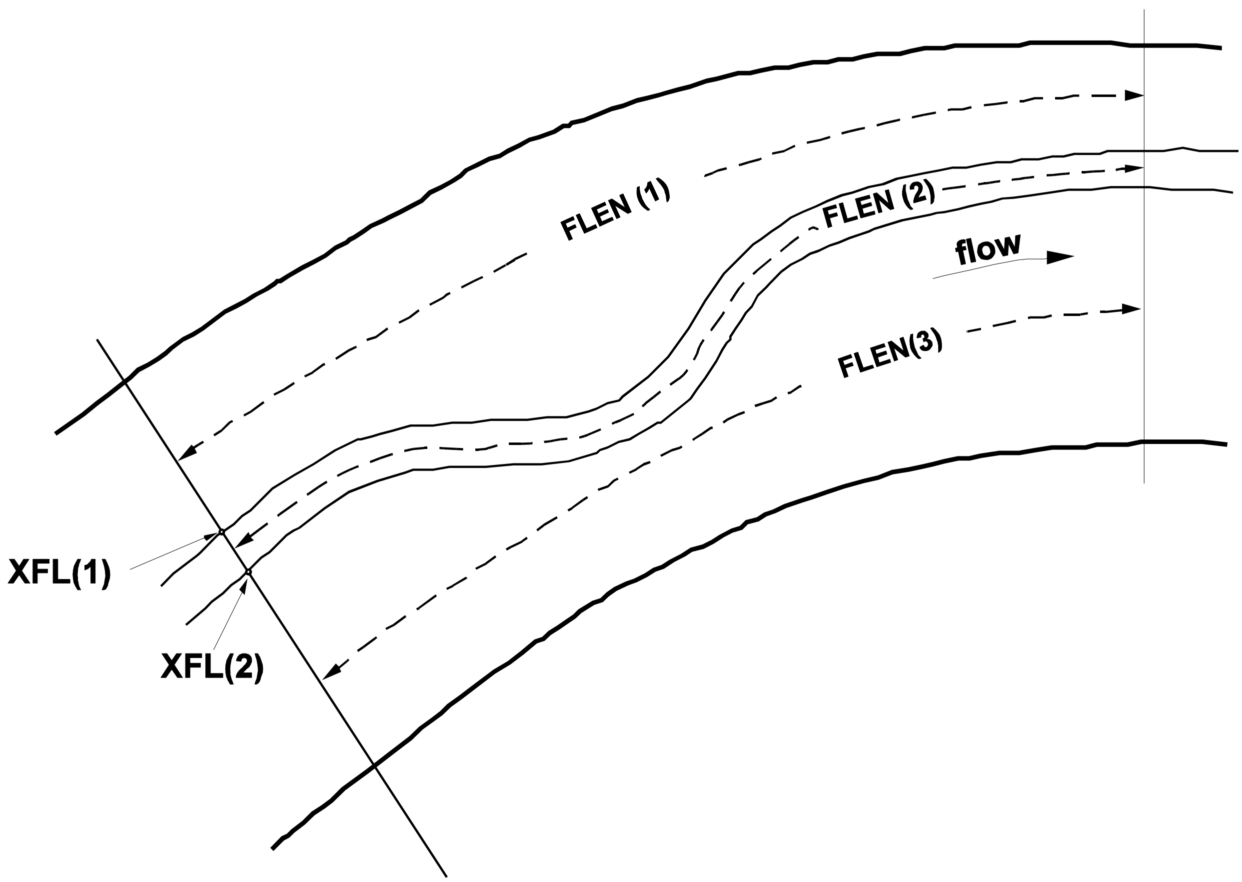


Figure 4-13. Definition sketch: FL record parameters.

Table 4-23. Description of format and contents of FS record.

FS — FS Record — FS

Purpose: Optional record for floodway analysis to specify global surcharges that vary based on some corresponding flow on the Q record.

Format:		
Columns:	Format:	Contents:
1-2	A2	**FS**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**FS**(1), **FS**(2), **...**, **FS**(**NPROF**)

The parenthetical notation indicates the order number, i, assigned by the model to each profile to be computed; i = 1 and i = **NPROF** for the first and last profiles to be computed with **NPROF** $\leq$ 20.

Definition of variables:

FS(i) — Floodway surcharge, in meters, representing the allowable surcharge to be calculated at each section with a corresponding FW record. If a **FS** record is used, a surcharge **must be provided** for **FS** for each discharge specified in the **Q** record. Values on the FW record can override these surcharges for a specific cross-section.

Table 4-24. Description of format and contents of FW record.

FW **FW Record** FW

Purpose: Mandatory record for floodway analysis to specify the encroachment method, desired surcharge, and left and right encroachment limits.

Format:		
Columns:	Format:	Contents:
1-2	A2	**FW**
3	1X	Blank
4	1X	**MTHD**
5	1X	Blank
6-10	A5	Blank
11-80	Free	**TARGET, [XENCLT, XENCRT**]

Definition of variables:

MTHD Encroachment method option code. Valid values are:

- 0 Equal encroachment.
- 1 Fixed limits on left bank.
- 2 Fixed limits on right bank.
- 3 Fixed limits on both left and right banks (no TARGET surcharge).

TARGET The desired surcharge, in meters. (This value overrides all surcharges that may be specified on the FS record.)

XENCLT The x-station of the encroachment constraint on left bank. (Not used for option code 0.)

XENCRT The x-station of the encroachment constraint on right bank. (Not used for option code 0.)

Table 4-25. Description of format and contents of GB record.

GB GB Record GB

Purpose: Header record for guidebanks cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**GB**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, GBTYPE, [BSUBD, GBOFF, SKEW, EK, CK, VSLOPE]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance.

GBTYPE Code to indicate the type of guidebanks. Valid entries are:
1 Elliptical guidebanks, no skew.
2 Elliptical guidebanks, skewed.
3 Straight guidebanks, no offset.
4 Straight guidebanks, with offset.

BSUBD Distance, in meters, that straight banks are offset from the bridge abutments (not to be confused with **GBOFF** below). Only relevant when **GBTYPE** = 4; for all other guide bank types, place asterisk (*****) in field as a place holder.

GBOFF Measured normal to flow at the guidebank mouths, the horizontal offset, in meters, between guidebanks and bridge abutments. Use an average value if left and right offsets are not equal. WSPRO places base of the guidebanks at this distance from the abutment stations (see Figure 4-14). Guidebank side slopes are equal to bridge abutment slopes. Remaining ground points are obtained from the full-valley cross-section.

SKEW	The acute angle that section must be rotated to orient the section normal to the flow direction. WSPRO applies the cosine of **SKEW** to horizontal dimension of section to compute cross-sectional properties. Default is zero degrees.
EK, **CK**	Expansion and contraction loss coefficients, respectively, for the energy equation balance. Coefficients would apply only to downstream computations from the guidebank to bridge opening. Default values are either **EX** = 0.5 and **CK** = 0.0 or the current values being propagated from downstream data.
VSLOPE	Valley slope. Used to adjust elevations of x,y-coordinates for the guidebank when geometric data are propagated. Default value is zero or the current value being propagated from downstream data.

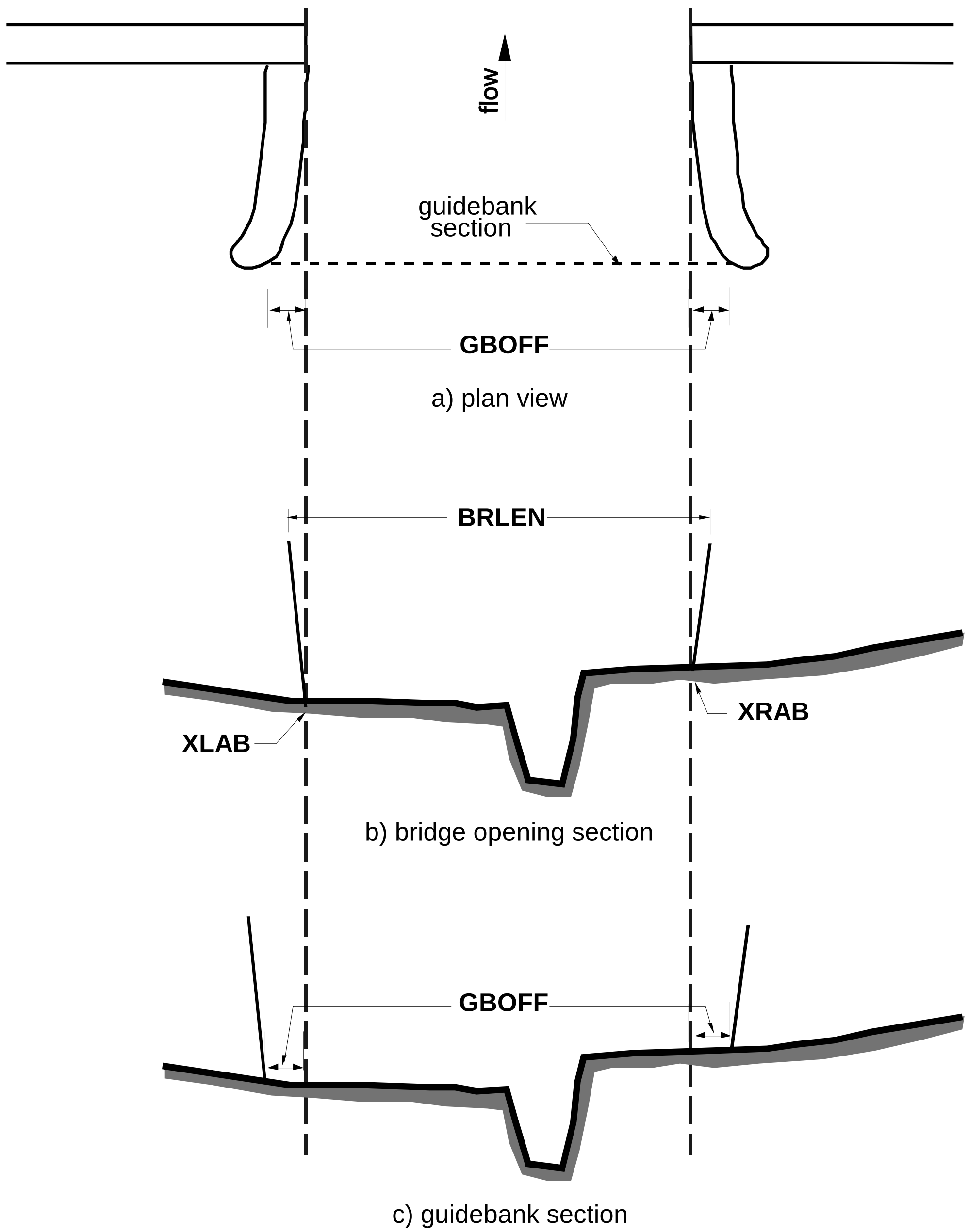


Figure 4-14. Definition sketch: Guidebank section from component mode.

Table 4-26. Description of format and contents of GR record.

GR — GR Record — GR

Purpose: Specifying x,y-coordinates to define cross-sectional geometry.

Format:		
Columns:	Format:	Contents:
1-2	A2	**GR**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**X(1), Y(1), X(2), Y(2), ... X(NGP), Y(NGP)**

The parenthetical notation indicates the order number, i, assigned by the model to each x,y-coordinate pair; i = 1 and i = **NGP** for the first and last coordinate pairs with **NGP** $\leq$ 100.

Definition of variables:

X(i) x-coordinate, in meters from an arbitrary datum on the left bank, of the i^{th} ground point (left and right defined by facing downstream.

Y(i) y-coordinate of the i^{th} ground point, in meters above elevation datum.

Successive coordinates are coded from left to right (counterclockwise) and each x-coordinate must be equal to or greater than the previous x-coordinate (except for closing bridge openings). There is no limit on the number of **GR** records used. Figure 4-15 illustrates the x,y-coordinate system and its interrelation with roughness data.

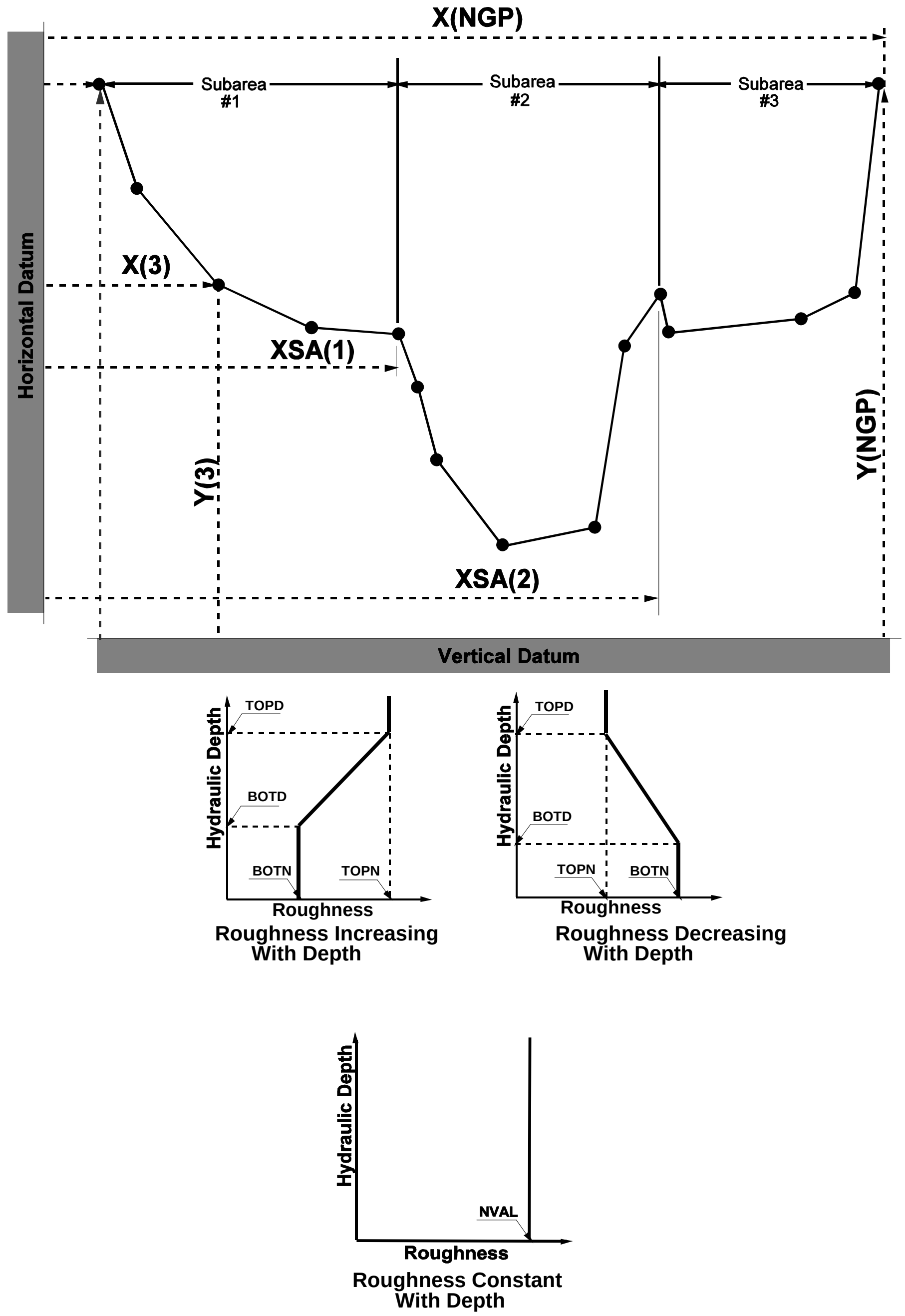


Figure 4-15. Definition sketch: GR, N, ND, and SA parameters.

Table 4-27. Description of format and contents of GT record.

GT — GT Record — GT

Purpose: Replaces GR data for cross-sections being fabricated from template section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**GT**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**YSHIFT, XLIML, XLIMR, SCALE, XORIG**

Definition of variables:

YSHIFT Vertical distance, in meters, to apply to template section elevations to obtain desired elevations for the fabricated cross-section.

XLIML, **XLIMR** x-coordinates of the left and right limits of the segment of the template cross-section to be retained for the fabricated cross-section. Neither value needs to coincide with x,y-coordinates specified in **GR** records. The model places vertical walls that extend to the maximum elevation of the cross-section at **XLIML** and (or) **XLIMR.**

SCALE Scale factor use to expand (stretch) or contract (shrink) the template section horizontally; **SCALE** = 1.1 stretches a section by 10 percent and **SCALE** = 0.9 shrinks a section by 10 percent).

XORIG x-coordinate in the template section which is held constant when the **SCALE** factor is used. This maintains cross-section alignment if so desired; **SCALE** alters the x-coordinates on either side of **XORIG**.

Table 4-28. Description of format and contents of HP record.

HP — HP Record — HP

Purpose: Instructs the model to produce tables of cross-sectional properties and (or) velocity and conveyance distribution.

Format:		
Columns:	Format:	Contents:
1-2	A2	**HP**
3	1X	Blank
4	1X	**IHP**
5	1X	Blank
6-10	A5	**[SECID]**
11-80	Free	**[ELMIN, YINC, ELMAX, Q]**

Definition of variables:

IHP Option code indicating: (1) table of cross-sectional properties for the entire cross-section (**IHP** = 0); (2) table of cross-sectional properties for each subarea as well as the entire section (**IHP** = 1); or (3) table(s) of velocity and conveyance distribution (**IHP** = 2).

SECID Section identification code, not required if **HP** record included with the section data.

ELMIN The minimum elevation in the cross-section for which computations are desired. Default value is one-fourth of the difference between the maximum and minimum ground elevations above channel bottom, rounded to the nearest whole meter.

YINC The elevation increment between successive elevations for which computations are desired. Defaults to **DELTAY** (**J1** record).

ELMAX The maximum elevation for which computations are desired. Default value is the maximum elevation in the cross-section.

Q Discharge (coded only for **IHP** = 2) is required to compute the velocity and conveyance distribution.

Multiple **HP** records may be coded for a section to obtain properties and (or) distribution computations (for one or more discharges) at one time. See Sections 4.3.3 and 7.6 for additional information.

Table 4-29. Description of format and contents of J1 record.

J1 — J1 Record — J1

Purpose: Specifying computational control parameters.

Format:		
Columns:	Format:	Contents:
1-2	A2	**J1**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**[DELTAY, YTOL, QTOL, FNTEST, IHFNOJ]**

Definition of variables:

DELTAY Stepping increment, in meters, for successive trial water-surface elevations to balance the energy equation. Default value is 1.0.

YTOL Allowable tolerance (error), in meters, between successive computed elevations for acceptable energy equation balance. Default value is 0.006 meters.

QTOL Allowable tolerance (error), in hundredths, between the input discharge (**Q** record) and the total computed discharge for bridge flow and road overflow. Default value is 2 percent (entered as 0.02).

FNTEST Froude number test value. A computed water-surface elevation with a computed Froude number greater than **FNTEST** is (at least temporarily) considered an invalid solution. Default value is 0.8.

IHFNOJ

Code for the friction slope (or conveyance) averaging technique used in friction-loss computations. Valid entries are: 0 for geometric mean conveyance (default value); 1 for arithmetic average conveyance; 2 for arithmetic average friction slope; and 3 for harmonic mean friction slope. **IHFNOJ** is applicable for all subreaches except for bridge computations which use geometric mean conveyance. To vary the averaging technique within a job requires use of **FL** records. **IHFNOJ** overrides all **IHFNO** values coded on **FL** records.

Table 4-30. Description of format and contents of KQ record.

KQ — KQ Record — KQ

Purpose: Specifying user-selected breakpoints of the KQ segment of the approach section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**KQ**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**XLKQ, XRKQ**

Definition of variables:

XLKQ x-coordinate of the left limit of the conveyance (flow) distribution for the KQ-section.

XRKQ x-coordinate of the right limit of conveyance (flow) distribution for the KQ-section.

Notes:

1) Figure 4-16 illustrates application of the KQ record.
2) The model, unless overridden by some combination of **XLKQ** and **XRKQ**, will place the KQ-section based on the location of the computed centroid of conveyance.

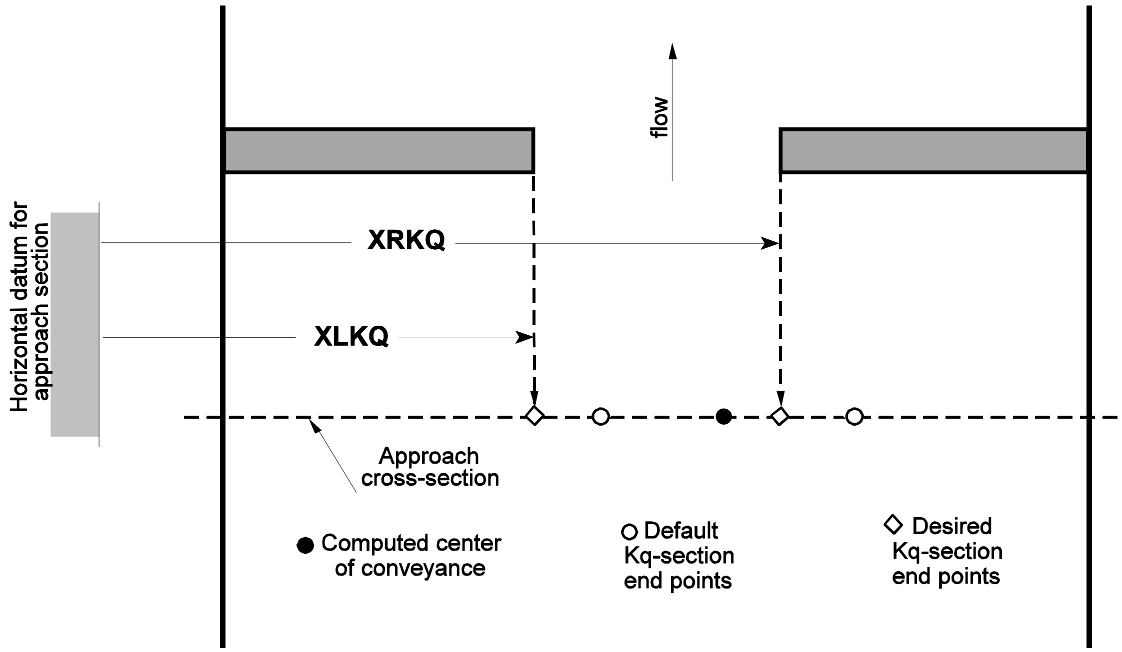


Figure 4-16. Definition sketch: KQ record parameters.

Table 4-31. Description of format and contents of N record.

N N Record N

Purpose: Specifying roughness (Manning's "n") coefficients.

Format:		
Columns:	Format:	Contents:
1-2	A2	**N**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BOTN (1) [, BOTN (2) , . . . , BOTN (NSA)] Option 1**

-- or --

Format:		
Columns:	Format:	Contents:
1-2	A2	**N**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BOTN(1), TOPN(1) [, . . . , BOTN(NSA) , TOPN(NSA)] Option 2**

Definition of variables:

BOTN(i) N-value for the i^{th} subarea. In the absence of **ND** record data, this coefficient is applied over the entire range of depths. If **ND** command data are applicable, **BOTN**(i) is applied for the range of hydraulic depth, d of 0 < d **BOTD**(i).

TOPN(i)	When **ND** command data are applicable, **TOPN**(i) is applied for the range of hydraulic depth, d of d **TOPD**(i). **TOPD**(i) values must not be coded when **ND** command data are not applicable.

Notes:

1) See Figure 4-14 and Tables 4-32 and 4-35 for additional information.
2) NSA is the number of subareas in the channel cross-section.

Table 4-32. Description of format and contents of ND record.

ND — ND Record — ND

Purpose: Specifying depth breakpoints for vertical variation of roughness.

Format:		
Columns:	Format:	Contents:
1-2	A2	**ND**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**BOTD(1),TOPD(1),BOTD(2),TOPD(2) ..., BOTD(NSA),TOPD(NSA)**

The parenthetical notation indicates the subarea number, i, assigned by the model to each subarea in a cross-section; i = 1 and i = **NSA** for the leftmost and rightmost subareas with **NSA** $\leq$ 20.

Definition of variables:

BOTD(i) Hydraulic depth (area divided by top width) in the i^{th} subarea at or below which **BOTN** (specified for the i^{th} subarea in the **N** record) is applicable.

TOPD(i) Hydraulic depth in the i^{th} subarea at or above which **TOPN** (specified for the i^{th} subarea in the **N** record) is applicable.

Roughness coefficients for hydraulic depths between **BOTD** and **TOPD** are computed by straight-line interpolation. Values of **BOTD**, **TOPD**, **BOTN**, and **TOPN** must be supplied for each subarea when **ND** data are coded. Code equal top and bottom values for any subarea(s) with constant roughness. See Figure 4-15 and Tables 4-31 and 4-35 for additional information.

Table 4-33. Description of format and contents of PD record.

PD — PD Record — PD

Purpose: Specifying pier or pile data.

Format:		
Columns:	Format:	Contents:
1-2	A2	**PD**
3	1X	Blank
4	1X	**PPCD**
5	1X	Blank
6-10	A5	Blank
11-80	Free	**PELV**(1), **PDTH**(1), **PNUM**(1), ..., **PELV**(**NPD**), **PDTH**(**NPD**), **PNUM**(**NPD**)

The parenthetical notation indicates the order number, i, assigned by the model to each **PELV**, **PDTH**, and **PNUM** data pair; i = 1 and i = **NPD** for the lowest and highest **PELV** values with **NPD** $\leq$ 25.

Definition of variables:

PPCD — Code to identify piers (**PPCD** = 0) or piles (**PPCD** = 1); affects the pier adjustment to the coefficient of discharge.

PELV(i) — The elevation, in meters above the common elevation datum, of the i^{th} pair of elevation-width data.

PDTH(i) — The **gross** width, in meters, of **all** piers (and/or pile bents) for the i^{th} pair of elevation-width data.

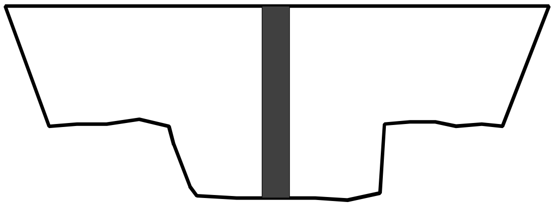
PNUM(i) — The number of piers/piles at the specific elevation **PELV**(i).

Figure 4-16 illustrates pier data requirements. An elevation-area relation is computed from the elevation-width data. Areas between specified elevations are based on straight-line interpolation. Constant width is assumed between the highest **PELV** and the maximum bridge-opening elevation. Coding a **PELV** value lower than the minimum bridge-opening elevation is an abortive error.

The minimum data requirement is an elevation-width pair at the minimum elevation at which piers (piles) begins. No additional data are required if the gross width is constant between the specified **PELV** and maximum bridge-opening elevation (see Figure 4-17a).

If the gross pier (pile) width varies uniformly between the minimum **PELV** and maximum bridge-opening elevation, a second elevation-width pair is needed for the maximum elevation (see Figure 4-17b).

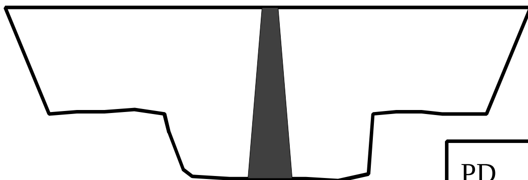
Non-uniform variation of gross width requires two elevation-width pairs at each elevation that gross width changes abruptly. An abrupt change can be: (1) additional piers coming into effect with increasing elevation; (2) changes in pier dimensions; and (3) loss of piers with increasing elevation (sloping low chord). Figures 5-17c and 5-17d illustrate the latter cases.



Constant pier width (1.52 m) from channel bottom (elevation 30.48 m) to horizontal low chord

```
PD     30.48, 1.52, 1
```

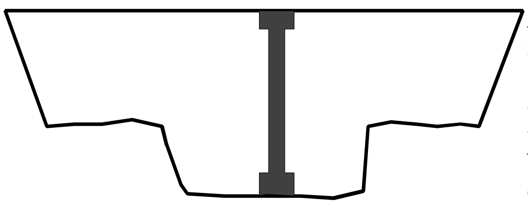
a) constant pier width



Uniformly varying pier width: 1.83 m at channel bottom (elevation 30.48) to 1.22 m at horizontal low chord (elevation 38.10)

```
PD     30.48, 1.83, 1   38.10, 1.22, 1
```

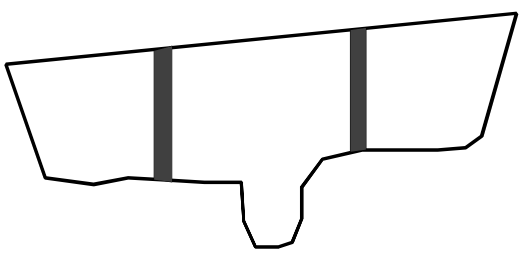
b) uniformly varying pier width



Abrupt variation in pier width due to shape: channel bottom elevation is 30.48 m; horizontal low chord elevation is 38.10 m; 0.91 m wide footer extends 0.61m above channel bottom; 0.91m wide pier cap extends 0.61 m below low chord; 0.46 m pier

```
PD   30.48, 0.91, 1  31.09, 0.91, 1  31.09, 0.46, 1  37.49, 0.46, 1  37.49, 0.91, 1
```

c) abruptly varying pier width with shape



Abrupt variation in pier width due to elevation: each pier is 0.61 m wide. Elevations: left pier -at ground 30.78, at low chord 36.58 m; right pier - at ground 31.55 m, at low chord 36.88 m

```
PD   30.78, 0.61, 1  31.55, 0.61, 1  31.55, 1.22, 2  36.58, 1.22, 2
PD   36.58, 0.61, 1  36.88, 0.61, 1  36.88, 0, 0
```

d) abrupt changes in pier width with elevation

Figure 4-17. Definition sketch: PD record parameters.

Table 4-34. Description of format and contents of Q record.

Q — Q Record — Q

Purpose: Specifying discharge for each profile to be computed.

Format:		
Columns:	Format:	Contents:
1-2	A2	**Q**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**Q(1), Q(2), . . . , Q(NPROF)**

The parenthetical notation indicates the order number, i, assigned by the model to each profile to be computed; i = 1 and i = **NPROF** for the first and last profiles to be computed with **NPROF** $\leq$ 20.

Definition of variables:

Q(i) Discharge, in cubic meters per second, for each water-surface profile to be computed. The final value of **NPROF** is determined by the model based on the total number (specified or default) of corresponding, valid entries in the **Q**, **WS**, **SK**, and **EX** records. All entries in the **Q** record must be positive values (no zero or default values are permitted). See Sections 4.3.2, 4.3.3, and 7.6 for additional information.

Table 4-35. Description of format and contents of SA record.

SA — SA Record — SA

Purpose: Specifying horizontal breakpoints for subdivision of cross-section for roughness and (or) geometry variations.

Format:		
Columns:	Format:	Contents:
1-2	A2	**SA**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**XSA(1), XSA(2) . . . , XSA(NSA-1)**

The parenthetical notation indicates the subarea number, i, assigned by the model to each subarea in a cross-section; i = 1 and i = **NSA** for the leftmost and rightmost subareas with **NSA** $\leq$ 19.

Definition of variables:

XSA(i) — x-coordinate of the rightmost limit of the i^{th} subdivision. The last **XSA** value coded is the horizontal station of the subdivision point between the last two subareas. **XSA** values are not required to match with any x-coordinates in the **GR** data **except in bridge-opening cross-sections**.

Table 4-36. Description of format and contents of SI record.

SI — SI Record — SI

Purpose: Allows user the option of specifying the unit system for both input and output.

Format:		
Columns:	Format:	Contents:
1-2	A2	**SI**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**(code number, 0, 1, 2, or 3)**

Definition of variables:

		Input	Output
code number:	0	ENGLISH	ENGLISH
	1	METRIC	METRIC
	2	ENGLISH	METRIC
	3	METRIC	ENGLISH

Table 4-37. Description of format and contents of SK record.

SK — SK Record — SK

Purpose: Specifying friction slope(s) (energy gradient(s)) for computing starting water-surface elevation(s) by slope conveyance.

Format:		
Columns:	Format:	Contents:
1-2	A2	**SK**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**SKSL(1), SKSL(2) . . . , SKSL(NPROF)**

The parenthetical notation indicates the order number, i, assigned by the model to each profile to be computed; i = 1 and i = **NPROF** for the first and last profiles to be computed with **NPROF** $\leq$ 20.

Definition of variables:

SKSL(i) Friction slope (energy gradient), in meters per meter, to compute the initial water-surface elevation for the i^{th} profile by slope conveyance. Computations **are not** made for any **SKSL** with a zero, negative, or null value. The number of entries (specified or default) in the **SK** record must be identical to the number of entries in the **Q** record. The last entry in an **SK** record must not be a null value; instead code a negative slope. See Section 4.3.2 and Figure 4-12 for additional information.

Table 4-38. Description of format and contents of T1, T2, and T3 records.

T1[,T2,T3] T1[,T2,T3] Record T1[,T2,T3]

Purpose: To present title information for identification of model input dataset.

Format:		
Columns:	Format:	Contents:
1-2	A2	**T1[,T2,T3]**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	70A1	**Any alphanumeric character string**

Format: **T1** [up to 70 alphanumeric characters to provide first title line]
T2 [optional - up to 70 alphanumeric characters to provide second title line]
T3 [optional - up to 70 alphanumeric characters to provide third title line]

Notes:

1) This record is used in conjunction with the T2 and T3 commands.
2) The information in the free-format area of the T1, T2, and T3 command are printed on essentially every page of printed output, along with the date and time of job execution. When analyzing a series of alternative designs, it is possible to change some of the title information for each alternative without recoding all three commands. Depending on the amount of information to be changed, the user may choose to provide a new T2 and T3 command or just a new T3 command for each alternative. If a new T2 command is coded without a new T3 command, a blank line is printed for T3 command information.

Table 4-39. Description of format and contents of UT record.

UT — UT Record — UT

Purpose: Specifying parameters for user-defined output tables. (Up to three tables can be obtained).

Format:		
Columns:	Format:	Contents:
1-2	A2	**UT**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**VARNOS (list 1), VARNOS (list 2), VARNOS (list 3)**

Definition of variables:

VARNOS Code numbers of stored output variables. The total number of variables in the three lists cannot exceed 50. Up to 3 tables containing no more than 50 total variables can be printed. An asterisk in the data field on the UT record separates the user-defined tables. The number of variables in each individual list is constrained only by printer line length (80 columns maximum). The model automatically uses 12 columns, thus leaving a maximum of 68 columns for the user. Table 5.1 provides a listing of variables from which user-defined tables can be developed.

Table 4-40. Description of format and contents of WS record.

WS WS Record WS

Purpose: Specifying starting water-surface elevations for profile computations.

Format:		
Columns:	Format:	Contents:
1-2	A2	**WS**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**WSI(1), WSI(2), . . . , WSI(NPROF)**

The parenthetical notation indicates the order number, i, assigned by the model to each profile to be computed; i = 1 and i = **NPROF** for the first and last profiles to be computed with **NPROF** $\leq$ 20.

Definition of variables:

WSI(i) Elevation, in meters, above the common elevation datum, representing the water-surface elevation to be used at the first cross-section for the i^{th} profile computation. If a **WS** record is used, an elevation or a null value (*) **must be provided** for **WSI** for each discharge specified in the **Q** record. A null value **must not** be specified for **WSI** for the **last** profile; instead code an elevation lower than the minimum elevation in the initial section. See Section 4.3.2 and Figure 4-11 for additional information.

Table 4-41. Description of format and contents of XR record.

XR XR Record XR

Purpose: Header record for road-grade cross-section parameters.

Format:		
Columns:	Format:	Contents:
1-2	A2	**XR**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, EMBWID, [IPAVE, USERCF, SKEW, EK, CK, VSLOPE]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance. Should reflect the location of the centerline of the road near the center of the bridge.

EMBWID Embankment top width, in meters. This distance should reflect the breadth (measured in the direction of flow) of the broad-crested weir that the embankment becomes when overtopped. Default value is **BRWDTH** (**CD** record) which is frequently narrower than most of the embankment width.

IPAVE Code to indicate the road surface material. Default is paved (IPAVE = 1); graveled (or otherwise rough) is indicated by IPAVE = 2.

USERCF User-specified coefficient for unsubmerged weir flow. This value will override the coefficient computed by the model. The model will apply an adjustment factor for submerged weir flow for either a user-specified or computed coefficient.

SKEW The acute angle that the section must be rotated to orient the section normal to the flow direction. The model applies the cosine of **SKEW** to the horizontal dimension of the section to compute the weir length perpendicular to the flow. Sometimes it is more correct to use the default of zero degrees for a skewed cross-section because upstream ponding causes the overflow to cross the road at a 90-degree angle, thus the skewed length is the more appropriate weir length to be used.

EK, CK Coefficients used to compute expansion and contraction losses, respectively, for the energy equation balance. Default values are either **EK** = 0.5 and **CK** = 0.0 or the current values being propagated from downstream data.

VSLOPE Valley slope, meters per meter. Used for adjusting elevations of propagated geometry data. (Default value is either 0.0 or the last valley slope that was input for a previous cross-section).

Table 4-42. Description of format and contents of XS record.

XS — XS Record — XS

Purpose: Header record for unconstricted valley cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**XS**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, [SKEW, EK, CK, VSLOPE]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance, in meters. Cumulative distance along the stream measured from an arbitrary zero reference point (**SRD** may be negative). Unless overridden by **FL** data, the difference between the **SRD** values of successive cross-sections is assumed to represent the flow distance between those sections and is used to compute friction losses for the energy equation balance.

SKEW The acute angle that the section must be rotated to orient the section normal to the flow direction. The model applies the cosine of **SKEW** to the horizontal dimension of the section to compute cross-sectional properties. Default is zero degrees. See Section 4.3.6 for additional information.

EK, CK Coefficients used to compute expansion and contraction losses, respectively, for the energy equation balance. Default values are either **EK** = 0.5 and **CK** = 0.0 or the current values being propagated from downstream data.

VSLOPE Valley slope, in meters per meter, used for adjusting cross-section elevations when the geometry data for the section are being propagated from a template section or from a previously input section. Default value is either zero or the current value being propagated from downstream data.

Table 4-43. Description of format and contents of XT record.

XT — XT Record — XT

Purpose: Header record for template cross-section.

Format:		
Columns:	Format:	Contents:
1-2	A2	**XT**
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	**SECID**
11-80	Free	**SRD, [VSLOPE]**

Definition of variables:

SECID Unique cross-section identification code.

SRD Section reference distance, in meters. This provides the reference point for elevation adjustments by valley slope.

VSLOPE Valley slope, in meters per meter. Alternatively, the valley slope may be specified in the header record of the cross-section being fabricated.

Only geometry data (**GR** records) are input for a template section. Roughness data (**SA**, **N**, and **ND** records) are included with the input data for the cross-section(s) fabricated from the template section.

Table 4-44. Description of format and contents of * record.

* * Record *

Purpose: Inserting comments (or blank lines) in the input data sequence.

Format:		
Columns:	Format:	Contents:
1-2	A2	|
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**[up to 70 alphanumeric characters to insert comments]**

Note: The free-format area can be used to code notes that may help the user keep track of the input data, or simply left blank to separate different input data (e.g., between cross-sections) to improve readability of printouts.

Table 4-45. Description of format and contents of *F record.

*F *F Record *F

Purpose: To allow data to be entered in free format.

Format:		
Columns:	Format:	Contents:
1-2	A2	• F
3	1X	Blank
4	1X	Blank
5	1X	Blank
6-10	A5	Blank
11-80	Free	**(no parameters)**

Note: This command should be the first command in the data file if the data following are in free format.

4.3 SPECIAL CONSIDERATIONS

The purpose of this section is to somewhat consolidate several aspects of data input that appear to cause the majority of problems in WSPRO applications. The intent of the following subsections is to highlight potential problems and discuss preventative action(s). Much of the discussion consists of cross references to applicable sections, figures, and tables.

4.3.1 Data Record Continuation

Continuation of some data records would be totally illogical (e.g., T1, T2, and T3 records). There would never be a logical need for continuation of many of the data record types because of the limited number of parameters (e.g., header records, data display commands, and others). Cross-section data (GR, N, ND, and SA records) are easily continued by simply providing a sufficient number of records with the same record identifier to contain all the data items. There are no rules as to the number of data items per record nor where in the sequence of data items the switch is made to the next record. However, a special rule exists for Q, WS, SK, and UT records which often require more than a single record. To use more than a single record for these data types, the last entry in all but the last record of the group must be a comma. The model will not recognize the intended continuation of the data if this rule is not followed.

4.3.2 Profile Control Data

A discharge must be specified in the Q record(s) for each profile to be computed. In addition to discharge the model must be provided information, either explicitly or implicitly, regarding boundary condition(s) (i.e., water-surface elevation or energy gradient at the initial section and computational direction) for each profile. No default values are permitted in the discharge data; if multiple profiles are to be computed for the same discharge for different initial water-surface elevations, that discharge must be coded for each profile to be computed.

With one exception there must be either a WS or an SK record in the data sequence, in some cases both are necessary. An SK record is not required when the user does not want the initial water-surface elevation for any profile(s) to be determined by slope-conveyance computations. A WS record is required when the user wants to explicitly assign the initial water-surface elevation for any profile(s). If a combination of energy gradient(s) and explicitly assigned water-surface elevation(s) are to be used for initial conditions, both WS and SK records are required. Neither WS nor SK data are required if all profiles are to be computed using critical water-surface elevation at the initial cross-section. For any profile that the user does not provide a "valid" entry for either energy gradient or water-surface elevation, the model defaults to using critical water-surface elevation at the initial cross-section. A "valid" entry for slope is any number greater than zero (no check is made as to reasonable magnitude). A "valid" entry for water-surface elevation is: (1) an elevation that is within the range of the minimum and maximum ground elevations at the initial cross-section; and (2) in the correct flow regime (subcritical or critical for upstream computations; supercritical or critical for downstream computations). Figure 4-12 illustrates the computational path for various combinations of data in the WS, SK, and EX records. A "valid" entry in the SK record takes precedence over a specified water-surface elevation and will be used for slope-conveyance computation of the initial water-surface elevation (WSI). If a corresponding "valid" entry is coded in the WS record, it will be used as the "first guess" in the trial-and-error slope-conveyance solution. This feature was designed to speed up the trial-and-error solution. However, the solution is efficient enough that the user should not be too greatly concerned with making such "guesses." In the absence of a "valid" entry in the SK record, a "valid" entry in the WS record will be used directly for WSI. As stated above, in the absence of any "valid" entry in either WS or SK record(s), WSI is set equal to the critical-flow water-surface elevation, CRWS, which is based on minimum specific energy.

The model initially assumes the total number of profiles to be computed is equal to the number of discharges coded in the Q record(s). However, the model reduces that number if it does not find corresponding data (specified or default) in the WS and (or) SK and EX records. A complicating factor is that "trailing" default values (those appearing after the last specified numerical value) are not "counted." Therefore, do not allow a default value for the last profile in either SK or WS records. If SK data are being used, but slope conveyance is not applicable to the last profile, code a negative value for the energy gradient for the last profile. Likewise, if WS data are being used, but an explicitly assigned water-surface elevation is not applicable to the last profile, code a value that is less than the minimum ground elevation in the initial cross-section. The rules for providing appropriate corresponding entries in the EX record (by specification or default) are explained in Table 4-21.

4.3.3 Placement of Q and HP Records in Data Sequence

There are alternate means of specifying discharges and requesting plots and properties of cross-sections. Also, unlike most of the data types, these data records require specific ordering within the overall data sequence. Refer to Section 7.6 for an example that illustrates these rules.

4.3.4 Section Reference Distance

Section reference distance (SRD) must be coded in each header record (can never accept a default value in this field). Most of the cross-sections are input in downstream to upstream order (except if both guidebank and road-grade sections are coded at a bridge, and in some multiple-opening situations). Therefore, each SRD should be equal to (for full-valley and bridge-opening sections and for some multiple-opening situations) or greater than the preceding SRD (except in some multiple-opening situations). No internal check (error trap) exists for SRD coding mistakes. Therefore, the profile computations output should be scanned to detect such errors; the SRDL variable should reflect positive (negative) values of reasonable magnitude for upstream (downstream) computations.

The SRD generally reflects points located along the main channel. In multiple-opening situations data are input for each opening from left to right across the valley. SRD for each opening should reflect the location along the valley. A multiple-opening crossing that is not skewed would have the same SRD value for all bridge-opening (and culvert) sections. However, for a skewed crossing having its right end further downstream than its left end, the SRD of each opening should be unequal and in descending order.

4.3.5 Elevation Limits for Computing Profiles

WSPRO's chances of successfully balancing (1) the energy equation for both open-channel and bridge-backwater computations and (2) the discharge for combined flow through the bridge and over the road are constrained by both the input data and flow regime.

For upstream computations in open channels, WSPRO is limited to a range of elevation bounded by a minimum of the water-surface elevation for critical flow (CRWS) and a maximum of the highest ground elevation (YMAX) coded for the cross-section. If YMAX is the elevation of the leftmost (rightmost) point in the cross-section, WSPRO "builds" a wall at the rightmost (leftmost) point in the cross-section extending vertically to YMAX. If YMAX occurs at an interior point in a cross-section, both banks will be extended vertically to YMAX. **It follows that the user should attempt to code any open-channel cross-section to include at least one ground point higher than any computed water-surface elevation that can reasonably be expected.**

For upstream computations of bridge hydraulics, the lower elevation limit for any cross-section is the water-surface elevation for critical flow. The upper limit is governed by YMAX of the approach cross-section. **Not coding the approach section to a sufficiently high elevation is a frequent cause for termination of computations.**

4.3.6 Skewed Cross-Sections

The model requires cross-sectional properties (e.g., area, conveyance, wetted perimeter, etc.) that reflect a plane normal to the direction of flow. Normally this should be accomplished when the section is surveyed. In the simplest cases, a single straight line across the valley can be surveyed normal to the flow. If such a section is later determined to be actually skewed to the direction of flow (or field conditions dictate surveying along a line skewed to the flow), the skew angle can be coded in the header record and the model will use the cosine of the angle to convert the surveyed plane to a plane normal to the flow. However, this "rotation" of the cross-section is strictly horizontal (i.e., there is no accounting for elevation differences between the points in the surveyed cross-section relative to "true" ground elevations along the plane normal to the flow). Thus, if valley slope is significant, the "corrected" cross-section does not truly represent the physical field conditions. Sometimes more than one straight-line segment (or perhaps a curvilinear line) is required to obtain a plane normal to the flow. In such cases the section must be surveyed (or a surveyed section modified) to directly reflect the appropriate plane in the coded x,y-coordinates. Cross-sections that are corrected for skew have their x-coordinates adjusted about the minimum y-coordinate (YMIN) in the cross-section.

Bridge openings can also be easily corrected for skew. Logically, one would usually survey the full valley cross-section with the same orientation to the floodplain as the bridge cross-section. However, this is not a requirement. The user must be aware that there is no assumed relationship between values of skew coded on the full valley cross-section and values of skew coded on the bridge cross-section. If both the full valley and bridge cross-sections are skewed to the floodplain, then the user would code a value of skew on each cross-sections header record.

The user should seriously question the applicability of WSPRO for severely skewed stream crossings. In addition to the "rotation" versus true elevations alluded to above, a skewed bridge situation (either single or multiple openings) may create complex flow patterns that in order to analyze may require a two-dimensional (2-D) analyses. Any bridge flow exhibits some degree of 2-D flow. WSPRO can use one-dimensional (1-D) computational techniques to successfully analyze the hydraulics of bridges that are not terribly complex. This is accomplished by use of certain coefficients, effective flow length (which reflects a quasi-2-D component), and cross-sections located close to, but not in, the definite 2-D flow zones. A skewed crossing, however, introduces increased opportunity for 2-D flow to the extent that the flow patterns assumed for the WSPRO computations may be totally invalidated. Two significant problems (relative to 1-D flow) occur at the upstream side of a skewed crossing: (1) the water tends to pond (stagnate) along the segment of the embankment that is furthest downstream; and (2) the segment of the embankment that is furthest upstream tends to intercept the flow and "funnel" the intercepted flow (especially if there is a cleared right-of-way) along the embankment to the bridge opening. The resulting flow pattern is far different from that which occurs at a perpendicular crossing. Similar problems can be caused by complex topography and (or) complex patterns of roughness distribution.

Another problem that may arise at skewed crossings is cross-section location (which is a moot point if flow pattern is a problem). For larger skew angles, the exit and (or) approach sections may intersect with the embankment when an attempt is made to locate them normal to the flow at the prescribed distance from the bridge opening. If the "rotational" problem is not severe, it is probably best to survey all bridge-related sections parallel to each other, code the appropriate skew angle, and let the model adjust them accordingly. If that is not considered appropriate, sound engineering judgment must be exercised in locating the cross-sections.

Surveying all bridge-related cross-sections parallel to each other should also be considered for skewed multiple-opening stream crossings. In some instances when making a multiple-opening analysis, the model has trouble making the various projections for the needed intermediate exit and approach sections when there is a combination of skewed and unskewed cross-sections. The above discussion pertaining to 2-D versus 1-D analyses is also strongly applicable to multiple-opening situations.

4.3.7 Bridge-Backwater Computations

See Section 4.3.5 for elevation limits for the backwater computations.

See Figures 3-8 through 3-13 and related discussion in Section 3.2 for cross-section data requirements for bridge-backwater computations.

See Section 4.3.8 for information pertaining to approach sections.

The parameter that controls whether or not the model will check for the possibility of and compute pressure flow is the low-steel elevation (PFELEV), which may be coded in the BR header record. In component mode the model computes a value of PFELEV (average of the elevations of abutment tops) and the user is not required to assign a value on the BR record. However, in coordinate mode the model does not have sufficient information to compute PFELEV. Therefore, the user must code PFELEV in the BR record for coordinate mode if there is any possibility of pressure flow. Without a value for PFELEV, either computed (in component mode) or specified (in coordinate mode), the model cannot test for the possibility of pressure flow and thus will not compute pressure flow regardless of the degree of submergence of the opening.

The PFELEV parameter can also be used to control the type of solution obtained (i.e., pressure versus free surface). Because the bridge opening is completely described in the form of a polygon, the PFELEV is not tied into the computation of the bridge-opening properties. Thus the user may "mislead" the model by coding a PFELEV value that is higher or lower than the actual low-chord elevation to dictate the flow class that is computed. This is possible in both component and coordinate modes. For example, the user may wish to obtain a free-surface flow solution to compare with a borderline submerged orifice flow situation. The model is a slave to precision. If PFELEV (computed in component mode or specified by the user for coordinate mode) is 100.000 and the computed tailwater elevation is 100.010 or 100.001), the model will compute submerged pressure flow which is obviously a very borderline case. By specifying a value of PFELEV that is higher than the tailwater elevation, the user can force a free-surface solution. Sometimes it is also possible to vary PFELEV to dictate free-surface versus unsubmerged pressure flow computations.

WSPRO is not universally applicable to dual bridges or other closely-spaced bridge situations. Typical dual bridges do not usually pose a major problem inasmuch as the flow is essentially continuous through the two structures. Even if the abutments of the two structures are not continuous, the distance between the structures is generally too short to permit expansion of the flow between the two structures to a degree that the flow must undergo significant contraction to pass through the downstream structure. Under such conditions the dual bridges can be treated as an extra-wide bridge (BRWDTH in the CD record). Water may actually be flowing into any gap between the embankments associated with each structure. Such flow is not, however, flowing in the direction that the flow is being modeled. If the quantity of such flow between the embankments is significant and (or) the multi-directional flow pattern is thought to have significant effect on the bridge backwater, a one-dimensional model such as WSPRO is not the appropriate model for analyzing that flow situation.

Some dual bridges are too far apart to satisfy the above assumption of essentially continuous flow through the two structures. In some cases, especially urban situations, bridges are so closely spaced that cross-section location requirements for WSPRO's computational techniques cannot be strictly satisfied. The most important question to be considered under such circumstances is whether or not the true physical system can be adequately described for 1-D analysis. If the situation is obviously a 2-D flow situation, WSPRO is not applicable to the problem. When attempting to describe closely spaced bridges for 1-D analysis, consideration must be given as to how much of the valley width will actually be flowing effectively. It may be prudent to arbitrarily (using engineering judgment) decrease the width of the approach section of the downstream bridge by constructing walls at the boundaries of the assumed effective flow width (likewise, the exit section of the upstream bridge). In some cases of very closely-spaced bridges, it is probably best to abandon "bridge hydraulics" and attempt to model the flow situation using straight step-backwater computations with appropriate expansion and contraction coefficients.

4.3.8 Approach Sections

See Section 4.3.5 for discussion regarding the effect of the maximum ground elevation in the approach section on bridge-backwater computations.

If a BR Header Record is coded, the program recognizes the first cross-section upstream as the approach cross-section.

The approach cross-section should be located at a distance upstream from the bridge opening that is approximately equal to the sum of the BRWDTH and BRLEN (plus the distance from the upstream face of the bridge to the dike section if guidebanks are present). Some latitude is permitted on this requirement; misplacement by as much as 20 percent of the BRLEN will usually have insignificant effect on the results. A major problem can arise if the approach section is too close to the bridge. The effective flow length computations may encounter a "divide by zero" or a "square root of a negative number" computational problem, thus terminating the model computations. The user should check for possible datum problems between, or perhaps x,y-coordinate coding problems in, the bridge and approach sections. Two parameters in the profile output for the constricted results at the approach section provide a means for this check. If FLEN (the effective flow length) is drastically different than the SRD difference (SRDL), a problem exists. The BP record provides a solution for datum problems for single-opening situations.

4.3.9 Road-Grade Sections

Care should be taken to provide consistent data for the approach, road-grade, and exit sections; do not describe a situation that is hydraulically impossible. If the road-grade is to act as a weir, the flow must have access from the approach section and egress to the exit section for the entire length of the road-grade that the model is using for a weir. Frequently a road-grade will exit the flooded width of the valley through a "cut" section in the side hill(s). The inundated length of roadway can thus be much greater than the effective flow width of the valley. However, the coded road-grade section should reflect only that part of the road-grade that can act as a weir; slack-water segments outside of the effective flow width of the approach and (or) exit sections must be excluded.

Road-grades may not always act as weirs, especially when the embankment height is very small and (or) depths of water over the road are quite high. Instead of acting as a weir, the road-grade is essentially a vertical contraction of a section of the valley. In such cases it sometimes becomes necessary to abandon the "bridge and weir" hydraulics in favor of the "composite-section" method described by Shearman and others (1986).

4.3.10 Multiple-Opening Situations

The upstream match section is analogous to the approach section of single-opening bridges and must be coded with an XS header record. The maximum ground elevation influences bridge backwater computations (see Section 4.3.5).

See Section 4.3.4 for discussion related to section reference distances.

The requirement of a common horizontal datum for all related cross-sections (downstream match section through upstream match section, inclusive) cannot be overstressed. There is no opportunity to correct datum problems with BP records in multiple-opening situations. All cross-sections must be aligned or computations related to the projection of data between and among sections will fail.

All openings must have flow through them or the model will experience computational problems and will either run forever or terminate. For situations where one or more openings are "dry" for lower discharges of interest, the analysis must be segmented such that all openings have flow for the discharges being analyzed.

SECTION 5 - MODEL OUTPUT OVERVIEW

WSPRO automatically generates rather detailed output describing the processing of the input data and the results of all profile computations. This output, depending on the user's system and mode of operation, may be automatically printed and (or) stored in a "print" file for viewing on the screen of a terminal or microcomputer. The model offers no options to suppress any of this output, but users can edit out unwanted segments of the file before printing. Output generated for cross-sectional properties and user-defined tables also are directed to this "print" file. WSPRO uses a temporary direct-access file for storage and retrieval of cross-section data. Another temporary direct-access file stores computed results and key input parameters. Additional detail is presented in the following paragraphs and examples of model output are presented in Section 7. A glossary in the appendix contains definitions and (or) cross references for the many acronyms that appear in the output.

5.1 INPUT-DATA-PROCESSING INFORMATION

This output echoes each input data record and provides detailed information on how WSPRO has interpreted and processed each data record. This information includes messages related to possible input data problems; these messages are discussed in Section 6.1. A header record indicates the end of input data for the current section being processed (or the beginning of input data for the next section). Upon encountering a header record while processing cross-section data, WSPRO determines how much (if any) data are needed from previously input section data to provide complete section definition. After determining that a section has been completely defined, the current section is output to file 13 for subsequent retrieval for profile computations.

5.2 CROSS-SECTIONAL PROPERTIES

HP records can be used to generate tables of cross-sectional properties and (or) velocity and conveyance distribution for any section(s) except road grades and culverts. Properties can be obtained for the total cross-section, with or without a subarea breakdown. Cross-sectional geometry errors may be revealed by inconsistencies (and (or) absurd values) of properties, either within a cross-section or from section to section in a reach. Velocity and conveyance distribution can be obtained for one or more discharges at one or more elevations. Coding strategies for HP records are discussed in Section 4.3.3 with examples in Section 7.

5.3 STANDARD TABLE OF COMPUTED PROFILE RESULTS

This output, also directed to the "print" file, contains a section-by-section tabular summary of a considerable number of parameters from the profile computations. It also may contain messages pertaining to the profile computations; these messages are discussed in Section 6.2. Thorough examination of this output to evaluate the adequacy of the analysis should be considered an integral part of any modeling effort. There is generally sufficient information in this output for the user to readily determine if there are any significant problems in the hydraulic computations. However, it may be necessary to generate supplemental output, such as properties computations, to determine corrective action(s) required (e.g., perhaps more (or better) section data). Although the headings for the various parameters were intended to be descriptive, the infrequent or less experienced user may not find all of them meaningful. The appendix provides a glossary containing brief definitions and (or) cross references for input/output acronyms.

5.4 USER-DEFINED TABLES

Tables of selected parameters can be generated in the print file by coding a sequence of variable code numbers on UT record(s). Table 5-1 lists the variables that can be printed in table format along with the headings used and variable parameter code numbers. User-defined tables cannot be generated for multiple-opening analyses. As can be seen in the table, up to 80 variables can be printed in tables. Up to 3 tables with no more than 50 total variables can be printed. An asterisk in the data field on the UT record separates the user-defined tables.

Table 5-1. Variables available for user-defined tables (UT record).

	Variable code number	Heading
Cross-section conveyance	1	K
Cross-section area	2	AREA
Velocity head correction factor, a	3	ALPH
Momentum correction factor, ß	4	BETA
Water-surface elevation	5	WSEL
Velocity head	6	VHD
Discharge	7	Q
Section reference distance	8	SRD
Maximum station in cross-section	9	XMAX
Maximum elevation in cross-section	10	YMAX
Minimum station in cross-section	11	XMIN
Minimum elevation in cross-section	12	YMIN
Boundary cross-section conveyance	13	K
Boundary cross-section area	14	AREA

(CONTINUED ON NEXT PAGE)

Table 5-1. Variables available for user-defined tables (UT record) (continued).

	Variable code number	Heading
Boundary velocity head correction factor, a	15	ALPH
Boundary momentum correction factor, ß	16	BETA
Boundary water-surface elevation	17	WSEL
Boundary velocity head	18	VHD
Boundary discharge	19	Q
Boundary section reference distance	20	SRD
Boundary maximum station in cross-section	21	XMAX
Boundary maximum elevation in cross-section	22	YMAX
Boundary minimum station in cross-section	23	XMIN
Boundary minimum elevation in cross-section	24	YMIN
Energy grade line	25	EGL
Velocity	26	VEL
Froude number	27	FR#
Critical water-surface elevation	28	CRWS
Minimum flow depth	29	DMIN
Friction loss	30	HF
Other losses (expansion/contraction)	31	HO
Expansion loss coefficient	32	EK
Contraction loss coefficient	33	CK
Friction slope	34	SF
Error in energy/discharge balance	35	ERR
Flow distance	36	FLEN
Straight-line (SRD) distance	37	SRDL
Stagnation point, left	38	SPLT
Stagnation point, right	39	SPRT
Skew of cross-section	40	SKEW
Cross-section wetted perimeter	41	XSWP
Cross-section top width	42	XSTW
Left edge of water	43	LEW
Right edge of water	44	REW
Low steel (submergence) elevation	45	PFELEV
Bridge opening length	46	BLEN
Bridge opening type	47	TYPE
Flow classification code	48	FLOW
Abutment station, left toe	49	XLAB
Abutment station, right toe	50	XRAB
Coefficient of discharge	51	C
Pier or pile code	52	PPCD
Pier area ratio	53	P/A
Road overtopping elevation	54	OTEL
Left Road Section		
Flow over road	55	Q

(CONTINUED ON NEXT PAGE)

Table 5-1. Variables available for user-defined tables (UT record) (continued).

	Variable code number	Heading
Weir length	56	WLEN
Left edge of water	57	LEW
Right edge of water	58	REW
Maximum depth of flow	59	DMAX
Average depth of flow	60	DAVG
Average total head	61	HAVG
Average weir coefficient	62	CAVG
Maximum velocity	63	VMAX
Average velocity	64	VAVG
Right Road Section		
Flow over road	65	Q
Weir length	66	WLEN
Left edge of water	67	LEW
Right edge of water	68	REW
Maximum depth of flow	69	DMAX
Average depth of flow	70	DAVG
Average total head	71	HAVG
Average weir coefficient	72	CAVG
Maximum velocity	73	VMAX
Average velocity	74	VAVG
Approach Section Information		
Flow contraction ratio (conveyance)	75	M(K)
Geometric contraction ratio (width)	76	M(G)
Conveyance of Kq-section	77	KQ
Left edge of Kq-section	78	XLKQ
Right edge of Kq-section	79	XRKQ

Table 5-2. Alphabetized list of output headings and associated parameter code numbers for user-defined tables.

Heading	Code number[1]
ALPH	3, 15
AREA	2, 14
BETA	4, 16
BLEN	46
C	51
CAVG	62, 72
CK	33
CRWS	28
DAVG	60, 70
DMAX	59, 69
DMIN	29
EGL	25
EK	32
ERR	35
FLEN	36
FLOW	48
FR#	27
HAVG	61, 71
HF	30
HO	31
K	1, 13
KQ	77
LEW	43, 57, 67
M(G)	76
M(K)	75
OTEL	54
P/A	53
PFELEV	45
PPCD	52
Q	7, 19, 55, 65
REW	44, 58, 68
SF	34
SKEW	40
SPLT	38
SPRT	39
SRD	8, 20

Table 5-2. Alphabetized list of output headings and associated parameter code numbers for user-defined tables (continued).

Heading	Code number[1]
SRDL	37
TYPE	47
VAVG	64, 74
VEL	26
VHD	6, 18
VMAX	63, 73
WLEN	56, 66
WSEL	5, 17
XLAB	49
XLKQ	78
XMAX	9, 21
XMIN	11, 23
XRAB	50
XRKQ	79
XSTW	42
XSWP	41
YMAX	10, 22
YMIN	12, 24

1 Parameter code numbers in Table 5-1.

5.5 CROSS-SECTION DATA

A direct-access file (logical unit 13) is used as a "work" file for storage and retrieval of the cross-section data. The model determines the definition of each cross-section from the input data sequence and constructs this file for subsequent input of cross-section data for profile computations. Each record in this file defines a single cross-section and contains supplemental data pertaining to that cross-section.

5.6 SUMMARY OF PARAMETERS

Certain key input parameters and results from profile computations are stored in a direct-access file (logical unit 14) and are accessed for producing user-defined tables. The parameters currently available are discussed with user-defined tables (Section 5.4).

SECTION 6 - MESSAGES

WSPRO generates two types of messages during execution; one for those messages related to input data and the second for those concerning profile computations. Each set of messages has a separate numbering sequence.

6.1 INPUT DATA MESSAGES

Messages related to input data are tabulated in Table 6-1. Each message begins with `+++xxx` where `xxx` is a three-digit sequence number for table look-up convenience. The three leading plus signs provide a convenient method for scanning the output for input data messages, especially when interactively previewing the output on a terminal or microcomputer. The lower-case acronyms to the right of or on the line below the message represent variables that are output to aid the user in understanding the message and (or) solving the problem for those cases that the message indicates that a problem exists. When a problem does exist, the message attempts to explain the problem and, when possible, indicate possible user action to remedy the situation.

Table 6-1. Input Data Messages.

```
+++xxx  MESSAGE:
                    ---- pertinent discussion ----
```

```
+++001    WARNING:  Record Type "XX" Out Of Order, Data Not
          Used.
+++002    FATAL ERROR:  Record "XX" Has Invalid Format (See
          Users Manual).
+++003    CAUTION:  Profile Control Data Changes After EX
          Record Ignored.
+++004    CAUTION:  Unexpected continuation - record
          skipped.
+++005    WARNING:  Ignoring Unrecognized Record "XX".
+++006    ERROR:  Invalid Characters "xxx" in Columns 3
          through 5.
+++010    WSi below YMIN at SECID "":  Used WSi = CRWS.
          YMIN, WSi, CRWS =       .0        .00        .00
+++011    WSi in wrong flow regime at secid "":  Used WSi =
          CRWS.
          WSi,CRWS =      .00        .00
+++014    WARNING:  Excess data items ignored.
```

Table 6-1. Input Data Messages (Continued).

+++xxx	MESSAGE: ---- pertinent discussion ----
+++015	WARNING: Too many data items on J3 record; Only 99 items used.
+++016	CAUTION: Ignoring extraneous option/secid.
+++017	ERROR: Data count (99) inconsistent with profile count (88).
+++018	ERROR: Unknown Secid "XXXXX" (Ignoring This Data Element).
+++019	ERROR: Invalid option code ignored (X).
+++020	ERROR: Computation direction established by EX Record.
+++021	ERROR: Data count (99) inconsistent with profile count (88).
+++022	ERROR: Profile count (99) reduced to data count (88).
+++023	ERROR: Discharge data #99 invalid or missing.
+++024	WARNING: Profile computations may be incomplete as a result of inconsistent profile control data.
+++025	FATAL ERROR: Profile computations bypassed as a result of inconsistent profile control data.
+++026	FATAL ERROR: Invalid continuation or redefinition for record "XX".
+++027	FATAL: Data count (88) for Record "XX" exceeds maximum (99).
+++028	FATAL ERROR: Mismatch between Header Record (XX) and Data Record (YY).
+++029	ERROR: Missing flow length or breakpoint station - 99
+++030	ERROR: Invalid friction loss option code "*".
+++031	FATAL ERROR: No X/Y-Coordinates for SECID "XXXXX".
+++032	FATAL ERROR: Major reversal at X-coordinate #99.
+++033	FATAL ERROR: Total number of X and Y values is an odd value (99).
+++034	WARNING: No input data for section reference distance (assuming a value of zero).
+++035	FATAL ERROR: Bridge opening cross-section must be closed. X(1): 88.000 Y(1): 12345.000 X(99): 67890.000 Y(99): 24680.000

Table 6-1. Input Data Messages (Continued).

```
+++xxx  MESSAGE:
                        ---- pertinent discussion ----

     +++036    ERROR:  Culvert code (  99 ) invalid for shape
               code *.
     +++037    ERROR:  Problem with either culvert length (
               ******** ) or  upstream/downstream inverts (
               ******* / ******* ).
     +++038    ERROR:  Invalid culvert pipe-arch auxiliary
               dimensions:
                         12345.0  67890.0  24680.0
     +++039    ERROR:  Culvert rise ( ******** ) and/or span (
               ******** )
               invalid for shape code *
     +++040    FATAL ERROR:  Full Valley Section Not On File.
               Program Ending.
     +++041    ERROR:  Top of abutment ( 12345.000 ) outside
               valley limits
               ( 67890.000 to  24680.000 ).
     +++042    ERROR:  Top of abutment ( 12345.000 ) below ground
               surface
               ( 67890.000 to  24680.000 ).
     +++044    ERROR:  Bridge length ( ******** ) too short for
               the selected abutment stations ( ********,
               ******** ).
     +++045    ERROR:  Template Expansion Error; Negative Scale
               Factor
               ( ******* ).
     +++046    ERROR:  12345.000 (from the GT Record) is greater
               than the maximum template X-coordinate ( 67890.000
               ).  The program will delete all ground points.
     +++047    ERROR:  Inconsistency with number of values ( 99,
               88 ) in the roughness data.
     +++048    ERROR:  Cannot Propagate Required Roughness data.
     +++049    WARNING:  Section Reference Distance Changed (
               12345.0 ->   67890.0 ).
     +++050    ERROR:  Section Type Code Changed ( 99 -> 88 ).
     +++051    ERROR:  Q Record Out of Order - Ignored by
               Program.
     +++052    ERROR:  Q Record Ignored (No Room to Store It).
```

Table 6-1. Input Data Messages (Continued).

+++xxx MESSAGE:
---- pertinent discussion ----

+++054	ERROR: Inconsistency between number of pier/piles entered (99)and the number actually encountered (88).
+++055	ERROR: First pier/pile elevation (12345.000) is below minimum elevation (67890.000). Replacing the input value with the minimum.
+++056	ERROR: Pier/pile #99 has a negative width (******).
+++057	ERROR: Pier/pile group #99 has a negative value (****).
+++058	ERROR: Elevation reversal (12345.000 to 67890.000) encountered (starting at pier/pile #99).
+++060	FATAL ERROR: First X-coordinate (12345.000) is not equal to minimum X-coordinate (67890.000).
+++061	FATAL ERROR: Last X-coordinate (12345.000) is not equal to maximum X-coordinate (67890.000).
+++062	FATAL ERROR: Successive X-reversals or X-reversal followed by vertical segment beginning at X-coordinate #99 cannot be adjusted.
+++063	FATAL ERROR: Cross-section "XXXXX" must be preceded by at least one other open-channel (i.e., XS Header Record) cross-section.
+++064	FATAL ERROR: Section reference distance reversal between sections "XXXXX" (at srd 12345.000) and "XXXXX" (at srd 67890.000).
+++065	CAUTION: Only limited SRD and cross-section sequence checking performed on "XXXXX" for multiple-openings.
+++066	FATAL ERROR: Full-valley section "XXXXX" (at srd 12345.000) and bridge-opening section "YYYYY" (at srd 67890.000) should be at the same location.
+++067	FATAL ERROR: Guide Bank "XXXXX" must be preceded by a bridge-opening.
+++068	FATAL ERROR: Road-grade "XXXXX" must be preceded by either a bridge-opening, guide-bank, or culvert.
+++069	FATAL ERROR: Road-grade "XXXXX" must be preceded by either a bridge-opening, guide-bank, or culvert.

Table 6-1. Input Data Messages (Continued).

+++xxx MESSAGE: ---- pertinent discussion ----	
+++070	FATAL ERROR: Full-valley section "XXXXX" (at srd 12345.000) and culvert section "CCCCC" (at srd 67890.000) should be at the same location.
+++072	NOTICE: X-coordinate #99 increased to eliminate vertical segment.
+++073	NOTICE: X-coordinate #99 increased to eliminate negligible reversal.
+++074	NOTICE: X-coordinates #99 and #** replaced with "averaged" input values to eliminate minor X-reversal. Also adjusted associated Y-coordinates using linear interpolation.
+++075	NOTICE: PW Record Replaced With PD Record (See Users Manual).
+++076	NOTICE: KD Record Replaced With KQ Record (See Users Manual).
+++077	NOTICE: BD Record Replaced With BC Record (See Users Manual).
+++078	NOTICE: AS Record Replaced With XS Record (See Users Manual).
+++079	NOTICE: SD Record Replaced With GB Record (See Users Manual).
+++081	NOTICE: PX Record Ignored. Graphics and Plotting Supported Using WSSHL Program (See Users Manual).
+++082	NOTICE: J3 Record Replaced With UT Record (See Users Manual).
+++095	ERROR: Pier Scour Analysis Missing Pier Width (DP Record).

WSPRO uses two integer variables and the record type to trace the input data flow. These two variables, which appear as itype and jtype in some of the above messages, may be helpful in diagnosing some input problems. Table 6-2 cross references itype and jtype to the record type.

Table 6-2. Cross-reference table for record type versus itype and jtype.

Record Type	itype	jtype	Record Type	itype	jtype	Record Type	itype	jtype
T1	1	1	HP	4	2	GR	7	1
T2		2				N		2
T3		3				SA		3
			WS	5	1	ND		4
UT	2	1	SK	2		FL		5
J3		3	Q		3	GT		6
						BP		8
XS	3	1	EX	6	1	BL	1	1
BR		2	ER		0	PD		12
GB		3				AB		13
XR		4				BC		14
XS		5				CD		16
CV		6				KQ		17
XT		7				CG		18
						CC		28
						“*”		29

6.2 PROFILE COMPUTATION MESSAGES

Table 6-3 is a tabulation of messages associated with profile computations. Each message begins with ===xxx where xxx is the three-digit reference number for Table 6-3. The upper-case acronyms on the line(s) immediately below the message represent intermediate results that are output to provide assistance in understanding the message.

The existence of one or more messages does not necessarily indicate invalid results. Some messages are simply intended to alert the user that a potential problem exists. It is up to the user to assess the severity of such problems and to judge whether additional and (or) alternate analyses and (or) input data are warranted.

Sometimes a series of messages is printed to indicate what assumptions were made within the model and the resultant computational path followed by the model. Again, it is the user's responsibility to assess the end result and judge whether or not the assumptions and computational procedures were appropriate. If not, the user may wish to alter the input so that the model will arrive at a more appropriate solution.

Table 6-3. Profile Computation Messages.

```
===xxx MESSAGE
                         ---- pertinent variables ----

Comments
```

```
===010 WSI BELOW YMIN AT SECID "aaaaa":  USED WSI = CRWS.
           YMIN,WSI,CRWS = xxxxxx.x   xxxxx.xx   xxxxx.xx
```

Starting water-surface elevation (WSI) specified on WS record is lower than the minimum ground elevation (YMIN) at the initial cross-section. Critical water-surface elevation (CRWS) is used for WSI.

```
===015 WSI IN WRONG FLOW REGIME AT SECID "aaaaa":  USED WSI = CRWS.
              WSI,CRWS = xxxxx.xx   xxxxx.xx
```

WSI, the starting water-surface elevation specified in the WS record is invalid. For upstream (subcritical) profile computations, WSI cannot be lower than CRWS, the critical water-surface elevation. For downstream (supercritical) profile computations, WSI cannot be higher than CRWS. WSI is set equal to CRWS.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                              ---- pertinent variables ----

Comments
```

```
===020 SLOPE-CONVEYANCE CONVERGENCE FAILURE:  USED FINAL TRIAL WS.
              QCOMP,WS = xxxxxxx.   xxxxx.xx
```

The iterative solution for determining the starting water-surface elevation by slope-conveyance did not converge in 20 iterations with the conveyance-error tolerance equal to one-tenth of one percent. The last trial elevation, WS, is used for the starting elevation. This problem may arise due to the convergence criteria being too stringent. In that case the computed discharge, QCOMP, will be essentially equal to the specified discharge and the computed profile should be acceptable. Otherwise there are probably cross-section coding errors that require correction.

```
===025 SLOPE-CONVEYANCE DISCHARGE OUT OF RANGE.
           WSMIN,QMIN,WSMAX,QMAX = xxxxx.xx   xxxxxxx.   xxxxx.xx   xxxxxxx.
```

The user-specified discharge in the Q record is outside the possible range of discharges at the initial cross-section. Discharge limits are computed using the user-specified slope in the SK record. The upper and lower discharge limits, QMIN and QMAX, are computed for water-surface elevations WSMIN, 0.076 m above channel bottom, and WSMAX, 0.006 m below the maximum cross-section elevation. Message **===010** will follow because the model arbitrarily defaults to an elevation lower than minimum ground elevation.

```
===105 WSMIN BELOW YMIN AT SECID "aaaaa":  USED WSMIN = CRWS.
                       YMIN,WSMIN,CRWS = xxxxxx.x   xxxxx.xx   xxxxx.xx
```

WSMIN is the lower limit of trial water-surface elevations to be used in the attempt to balance the energy equation. During upstream (subcritical) profile computations, the initial WSMIN is based on the water-surface elevation of the previous cross-section. When the initial WSMIN is below the minimum ground elevation of the cross-section the model defaults to using CRWS, the critical water-surface elevation, for WSI.

```
===110 WSEL NOT FOUND AT SECID "aaaaa":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY = xxxxx.xx   xxxxx.xx   xx.xx
```

No sign change found in the energy-balance error between elevation limits WSLIM1 and WSLIM2. A smaller value of DELTAY, the elevation increment, might yield a sign change. A new DELTAY equal to half of the original (specified or default) value is used. For downstream computations the same elevation range will be investigated; see message **===115** for upstream computations.

```
===115 WSEL NOT FOUND AT SECID "aaaaa":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS = xxxxx.xx   xxxxx.xx   xxxxx.xx
```

For upstream computations, in addition to reducing DELTAY, the lower elevation limit, WSMIN, will be set equal to the critical water-surface elevation, CRWS.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                        ---- pertinent variables ----

Comments
```

```
===120 YTOL NOT SATISFIED AT SECID "aaaaa":  TRIALS CONTINUED.
                       YTOL,WSLIM1,WSLIM2 = xx.xx   xxxxx.xx   xxxxx.xx
```

A sign change in the energy-balance error occurred between WSLIM1 and WSLIM2. However, the iterative solution (method of false position) failed to find an energy balance meeting the elevation tolerance, YTOL, for any elevation between WSLIM1 and WSLIM2. For upstream [downstream] computations, the old upper [lower] limit becomes the new lower [upper] limit for continuing trials for a solution at higher [lower] elevations. A larger YTOL value may be required for high-gradient, high-velocity, or not-so-gradually-varied flow situations.

```
===125 FR# EXCEEDS FNTEST AT SECID "aaaaa":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS = xx.xx   xx.xx   xxxxx.xx   xxxxx.xx
```

WSEL, a water-surface elevation which balances the energy equation, has a computed Froude number, FR#, greater than FNTEST, the Froude number test value (default value of 0.8 or user-specified on the J1 record). WSPRO rejects WSEL and attempts to find a valid solution at a higher elevation. The model uses a new lower elevation limit which is the higher of 1) WSEL plus five times the tolerance, YTOL; or 2) the critical water-surface elevation, CRWS.

```
===130 CRITICAL WATER-SURFACE ELEVATION  ASSUMED  !!!!!
              ENERGY EQUATION  NOT BALANCED  AT SECID "aaaaa"
                   WSBEG, WSEND, CRWS = xxxxx.xx   xxxxx.xx   xxxxx.xx
```

No satisfactory solution for WSEL was found between elevation limits WSBEG and WSEND at the section with SECID aaaaa. Instead of aborting profile computations completely, WSPRO assumes critical water-surface elevation, CRWS, at that section and attempts to perform profile computations for subsequent sections. The user must decide what further action (if any) is needed to obtain meaningful profile results.

```
===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            SECID "aaaaa"     KRATIO = xx.xx
```

KRATIO is the conveyance of the section with SECID aaaaa divided by the conveyance of the preceding section in the profile computations. This section-to-section conveyance ratio should be between 0.7 and 1.4 to ensure reliable profile computations. Additional cross-sections should be considered if the ratio significantly violates the recommended criteria, especially if friction losses between the two sections are significant.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                        ---- pertinent variables ----

Comments
```

```
===140 AT SECID "aaaaa":  END OF Cross-section EXTENDED VERTICALLY.
                            WSEL,YLT,YRT = xxxxx.xx   xxxxxx.x   xxxxxx.x
```

Either YLT or YRT (ground elevations at the section end points) was lower than the computed water-surface elevation, WSEL. No action is required if vertical extension of the section adequately defines cross-sectional geometry.

```
===195 PROFILE COMPUTATIONS  TERMINATED !!!!!
             IPR =  nn     CHECK INPUT ERROR MESSAGES FOR SECID "aaaaa"
```

An input data problem has caused an error flag to be set for the cross-section with SECID aaaaa. If profile computations were allowed to proceed, severe (possibly irrecoverable) computational problems might occur. Therefore, the profile computations are terminated at the previous section. Check the input data interpretation output for that section (and perhaps adjacent sections) for input data error messages (also consult Table 7-1). IPR indicates the number of the profile being computed.

```
===210 QUESTIONABLE CRITICAL-FLOW SOLUTION.
                  SECID "aaaaa"     Q,CRWS = xxxxx.xx   xxxxx.xx
```

The elevation of minimum specific energy coincides (within tolerance YTOL) with the maximum elevation in the cross-section with SECID aaaaa. Thus, it is highly unlikely that CRWS is a valid critical water-surface elevation for the discharge, Q. Computations continue and subsequent assumptions and actions within the model may yield a valid solution. However, the user should carefully scrutinize the results (if any) to determine their validity.

```
===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN = xxxxx.xx   xxxxx.xx   xxxxx.xx   xxxxx.xx
```

WS1, WSSD, and WS3 are the computed water-surface elevations for flow class 1 at the approach, grade-bank (if any), and bridge-opening sections. WS1 is higher than minimum road elevation, RGMIN. A flow class 4 solution will be attempted (message ===**265** will follow).

```
===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL = xxxxx.xx   xxxxx.xx   xxxxx.xx   xxxxx.xx
```

For free-surface flow (flow class 1 or 4), the water-surface elevation immediately upstream from the bridge, WSIU, is higher than the low-steel elevation, LSEL. WSPRO assumes that pressure flow (flow class 2 or 5) might occur. The flow class 1 or 4 elevations at the tailwater and approach sections, WS3 and WS1, are printed for evaluation. Message ===**245** will follow unless LSEL is undefined, in which case the flow class 1 or 4 results will be used.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                        ---- pertinent variables ----
Comments
```

```
===225 NO ENERGY BALANCE IN 15 ITERATIONS.
                        FLOW,Q =    n   xxxxxxx.
                  WS1,WSSD,WS3 = xxxxx.xx   xxxxx.xx   xxxxx.xx
```

The iterative, simultaneous solution of the energy balance for free-surface bridge flow failed to converge. The variables printed indicate the flow class, FLOW, flow through the bridge, Q, and water-surface elevations at the approach, grade-bank (if any), and bridge-opening sections, WS1, WSSD, and WS3, computed on the last iteration. Further action(s) by the model are indicated by additional **===xxx** messages.

```
===230 REJECTED FLOW CLASS 1 SOLUTION.
             WS1,WSSD,WS3 = xxxxx.xx   xxxxx.xx   xxxxx.xx
                     CRWS = xxxxx.xx   xxxxx.xx   xxxxx.xx
                     YMAX = xxxxx.xx   xxxxx.xx   xxxxx.xx
```

All efforts to compute free-surface flow without road overflow failed. Subsequent **===xxx** messages will indicate actions taken by the model. Low-steel elevation and road-grade data influence the action(s) taken. The three lines of variables printed indicate the final trial water-surface elevations, critical water-surface elevations, and maximum ground elevations at (from left to right) the approach, grade-bank and bridge-opening sections. One common cause of this problem is that YMAX of the approach section (which is the upper elevation limit for bridge computations) is too low to permit a solution.

```
===235 CONTINUE FLOW CLASS 4 COMPUTATIONS.
                        ITER,QRD =   nn   xxxxxxx.
                  WS,WSMIN,WSMAX = xxxxx.xx   xxxxx.xx   xxxxx.xx
```

When an energy balance failure (see message **===225**) for the free-surface bridge flow occurs during class 4 flow computations, the model assumes that too much flow is being put through the bridge and that more road overflow is needed. Therefore, iterations are continued using the last trial elevation WS, as the new lower limit. The other variables are: ITER, the current iteration number; QRD, the computed flow over the road; and WSMIN and WSMAX, the previous elevation limits.

===**240** NO DISCHARGE BALANCE IN 15 ITERATIONS.
WS,QBO,QRD = xxxxx.xx xxxxxxx. xxxxxxx.

Variables printed are the water-surface elevation for the last iteration, WS, and computed flows through the bridge, QBO, and over the road, QRD. The problem could be that the discharge tolerance is too stringent (in which case the sum of QBO and QRD would compare favorably with the specified discharge). In that case, increase QTOL (in the J1 record) and recompute. Otherwise it is likely that data input or design problems must be overcome. Further action(s) by the model are indicated by additional **===xxx** messages.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                        ---- pertinent variables ----
Comments
```

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

Indicates that WSPRO will attempt to find a solution for flow class 2 or 5. If a satisfactory solution is not found, message ===**270** will follow.

```
===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS1 = x.xx   xxxxx.xx   xxxxx.xx
```

YU/Z, the ratio of mean depths in the approach and bridge-opening sections, is less than 1.10 (arbitrary lower limit of assumed pressure flow). WSPRO assumes that flow class 1 or 4 results (if any) are applicable. Flow class 2 or 5 elevations immediately upstream of the bridge, WSIU, and at the approach section, WS1, are printed for user evaluation (see message ===**270**).

```
===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL = xxxxx.xx   xxxxx.xx
```

The tailwater elevation, WS3N, is higher than the low-steel elevation, LSEL. WSPRO assumes that flow class 3 or 6 will occur (submerged pressure flow). A flow class 1 or 4 solution may be forced by coding LSEL higher than actual low-steel elevation. It may be advisable to obtain both pressure and free-surface solutions for border line cases. A comparison of results can be used to select the most appropriate solution.

===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

This message follows ===**225** if road-grade data have been input, the assumption being that free-surface flow may occur in conjunction with road overflow. It is also printed after class 1 flow solutions if those results indicate possible road overflow.

```
===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,QRATIO = xxxxxxx.   xxxxxxx.   xx.xx
```

QRATIO is QRD, the computed road overflow, divided by QRDMAX, an estimated maximum road overflow. QRDMAX is the total discharge multiplied by the conveyance of the horizontal slice of water in the approach section that is higher than minimum road-grade elevation and divided by the total approach-section conveyance. Consideration should be given to treating the road grade and bridge as a composite section since weir flow may not actually occur.

===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

Flow class 2 or 5 results are either unacceptable, as per message ===**250**, or a solution is not obtained. In the former case, if flow class 1 or 4 results have been obtained, those results are assumed most applicable and are reflected in profile output and subsequent profile computations. In the latter case, or if flow class 1 or 4 results were not obtained, message ===**295** will follow.

(CONTINUED ON NEXT PAGE)

Table 6-3. Profile Computation Messages (Continued).

```
===xxx MESSAGE
                        ---- pertinent variables ----

Comments
```

===275 REJECTED FLOW CLASS 3 (6) SOLUTION.

Similar to message ===**280** except that class 3 or 6 computations have failed and the preceding successful computations may be either class 1 or 4 flow.

===280 REJECTED FLOW CLASS 4 SOLUTION.

Class 4 flow computations were unsuccessful (see message ===**240**). Preceding computations for class 1 flow were successful but indicated probable road overflow (see message ===**225**). The model will continue profile computations using the class 1 flow results instead of terminating computations. The user should scrutinize such results very closely because it is very possible that data input or design problems are causing the computational problems.

```
===285 CRITICAL WATER-SURFACE ELEVATION  ASSUMED  !!!!!
                  SECID "aaaaa"     Q,CRWS = xxxxxxx.   xxxxx.xx
```

At the section with SECID of aaaaa, for the discharge, Q, a solution could not be found in the subcritical flow regime. Critical water-surface elevation, CRWS, is assumed so that computations may continue. If CRWS is reflected in the final solution, the results should be given very close scrutiny to determine the validity of the analyses. Downstream profile computations may be advisable to determine if supercritical flow occurs at such sections.

```
===295 PROFILE COMPUTATIONS  TERMINATED  !!!!!
          IPR =  nn    BRIDGE FLOW COMPUTATIONS  FAILED !!!!!
```

All attempts to obtain acceptable bridge results have failed and the profile computations are terminated. IPR is the number of the profile being computed.

SECTION 7 - EXAMPLES OF MODEL INPUT AND OUTPUT

Examples of various WSPRO applications are presented in this section. The examples do not provide much background detail about the input data (e.g., maps, cross-section plots, etc.) nor do they present in-depth discussions of all aspects of the related hydraulic analyses. The primary intent of the examples is to illustrate WSPRO input-data sequences and output.

The illustrations in this section show sample input and output data. To reduce the bulk of this manual, many listings have been shortened by deleting parts of the output. Generally, a note has been inserted to indicate where a deletion has been made.

7.1 EXAMPLE #1: SIMPLE, OPEN-CHANNEL REACH

Figure 7-1 illustrates input data for five sections which describe a stream reach in which there are no bridges or culverts. An XS header record must be coded for each section. The geometry of each section is defined by GR data. Each section is subdivided into three subareas for horizontal variation of roughness. The three roughness coefficients specified in the N record are propagated to each of the other sections because no other N and (or) ND data are coded. The x-coordinates of the subdivision breakpoints do vary from section to section as reflected in the SA records. A single profile is computed for the discharge specified in the Q record. The initial water-surface elevation is computed by slope conveyance using the energy gradient coded in the SK record.

```
T1        Example 1 - Some Creek Near Anywhere, USA
T2        Simple Open-Channel Profile Example
T3        Constant Discharge Subcritical Flow
*
SI 1
*
Q           283.168
SK          0.0023
*
XS   SEC-A  30.480
GR          32.614,189.829  40.234,186.263  51.816,183.429  57.912,181.051
GR          75.590,179.984  82.601,179.984  89.306,179.862  94.488,179.984
GR          96.926,180.777 103.022,181.630 106.680,183.032 112.166,184.038
GR          115.824,184.404  121.920,184.465
N           0.065    0.027     0.065
SA              51.816   112.166
*
XS   SEC-B 64.008
GR         43.891,189.616   55.474,184.556  62.484,181.508  66.751,180.929
GR         67.666,180.960   83.820,179.802  90.526,179.771  96.317,179.832
GR         105.156,180.015 108.814,180.960 117.043,184.130 117.348,184.465
GR         121.920  184.587
SA         55.474  117.043
*
XS   SEC-C 114.300
GR         60.046,188.793  68.275,185.440  75.286,181.661  83.515,180.289
GR         84.125,179.680  89.611,179.619  92.964,179.375  96.622,179.253
```

```
GR        99.670,179.375 107.594,179.741 108.204,180.685 113.995,181.722
GR        119.786,183.916 121.006,184.282 121.920,184.313
SA        68.275  121.006
*
XS   SEC-D 152.400
GR        67.056,188.702  73.152,184.008  77.114,180.899  83.210,180.807
GR        84.125,180.076  89.916,180.015  95.098,180.015  96.012,179.527
GR        99.974,179.558 103.632,179.588 103.937,180.076 113.386,181.295
GR        118.567,183.916 121.920,184.008
SA        73.152  117.043
*
XS   SEC-E 195.072
GR        62.179,188.671  73.152,180.777  78.638,180.807  84.125,180.533
GR        89.306,180.472  94.793,180.472 100.279,180.381 105.766,180.746
GR        111.252,180.685 117.043,183.185 121.920,183.490 122.225,185.318
SA        75.895  111.343
*
EX
ER
```

Figure 7-1. Input data for the simple, open-channel reach of example #1.

Figure 7-2 illustrates the output for this example. The output summarizes the input data with an echo of each input data records. After finding a section header record, WSPRO continues input of subsequent records until a record type other than GR, N, ND, SA, FL, or * is found. WSPRO suspends input at that point to process the section input data. Any missing data are obtained from the previous section. Data for the current section are then summarized in a neat, tabular format. WSPRO's subsequent actions depend on the record type that initiated processing of the section data. The possibilities are: (1) another header record will cause it to repeat the above procedure; (2) a display command (HP record) will result in generation of the output requested by that command; (3) a Q record would indicate that discharge is to be changed at this section and the values would be stored accordingly; (4) an EX record will result in profile computation and output; and (5) an ER record would cause the model to come to a normal stop. Any other record type would be invalid at this point and would cause generation of an error message. Part of the desired output may be obtained despite the error, the amount depending on where the problem occurs.

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
        Run Date & Time:  9/ 9/97  9:07 am    Version V070197
         Input File: EX1.DAT        Output File: EX1.LST
   *-----------------------------------------------------------------*
T1         EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
T2         SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
T3         CONSTANT DISCHARGE SUBCRITICAL FLOW
SI 1
                     Metric (SI) Units Used in WSPRO

               Quantity    SI Unit              Precision
             ------------ -------------------- -----------
              Length       meters                 0.001
              Depth        meters                 0.001
              Elevation    meters                 0.001
              Widths       meters                 0.001
              Velocity     meters/second          0.001
              Discharge    cubic meters/second    0.001
              Slope        meter/meter            0.001
              Angles       degrees                0.01
             ------------ -------------------- -----------

Q            283.168

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

SK           0.0023
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
             EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
                SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
                CONSTANT DISCHARGE SUBCRITICAL FLOW

         *----------------------------------------------------*
         *      Starting To Process Header Record SEC-A       *
         *----------------------------------------------------*

XS   SEC-A  30.480
GR          32.614,189.829  40.234,186.263  51.816,183.429  57.912,181.051
GR        75.590,179.984  82.601,179.984  89.306,179.862  94.488,179.984
GR        96.926,180.777 103.022,181.630 106.680,183.032 112.166,184.038
GR        115.824,184.404  121.920,184.465
N           0.065    0.027     0.065
SA              51.816   112.166

 ***   Completed Reading Data Associated With Header Record SEC-A   ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***             Data Summary For Header Record SEC-A               ***
 SRD Location:       30.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (14 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
    32.614     189.829       40.234     186.263       51.816     183.429
    57.912     181.051       75.590     179.984       82.601     179.984
    89.306     179.862       94.488     179.984       96.926     180.777
   103.022     181.630      106.680     183.032      112.166     184.038
   115.824     184.404      121.920     184.465
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      32.614  ( associated Y-Elevation:  189.829 )
  Maximum X-Station:     121.920  ( associated Y-Elevation:  184.465 )
  Minimum Y-Elevation:   179.862  ( associated X-Station:     89.306 )
  Maximum Y-Elevation:   189.829  ( associated X-Station:     32.614 )

                    Roughness Data (  3 SubAreas )
                            Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .065         ---
                               ---        51.816
                     2         .027         ---
                               ---       112.166
                     3         .065         ---
                  -------  -----------  ------------

         *----------------------------------------------------*
         *      Finished Processing Header Record SEC-A       *
         *----------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *----------------------------------------------------------------*
           EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
              SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
              CONSTANT DISCHARGE SUBCRITICAL FLOW

       *----------------------------------------------------*
       *      Starting To Process Header Record SEC-B       *
       *----------------------------------------------------*

XS   SEC-B 64.008
GR         43.891,189.616   55.474,184.556  62.484,181.508  66.751,180.929
GR       67.666,180.960   83.820,179.802  90.526,179.771  96.317,179.832
GR       105.156,180.015 108.814,180.960 117.043,184.130 117.348,184.465
GR       121.920  184.587
SA         55.474  117.043

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

 ***              Data Summary For Header Record SEC-B              ***
 SRD Location:       64.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (13 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
    43.891     189.616       55.474     184.556       62.484     181.508
    66.751     180.929       67.666     180.960       83.820     179.802
    90.526     179.771       96.317     179.832      105.156     180.015
   108.814     180.960      117.043     184.130      117.348     184.465
   121.920     184.587
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      43.891  ( associated Y-Elevation:  189.616 )
  Maximum X-Station:     121.920  ( associated Y-Elevation:  184.587 )
  Minimum Y-Elevation:   179.771  ( associated X-Station:     90.526 )
  Maximum Y-Elevation:   189.616  ( associated X-Station:     43.891 )

                    Roughness Data (  3 SubAreas )
                           Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .065         ---
                               ---         55.474
                     2         .027         ---
                               ---        117.043
                     3         .065         ---
                  -------  -----------  ------------

       *----------------------------------------------------*
       *      Finished Processing Header Record SEC-B       *
       *----------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
           EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
              SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
              CONSTANT DISCHARGE SUBCRITICAL FLOW

       *---------------------------------------------------*
       *      Starting To Process Header Record SEC-C      *
       *---------------------------------------------------*

XS   SEC-C 114.300
GR         60.046,188.793  68.275,185.440  75.286,181.661  83.515,180.289
GR       84.125,179.680  89.611,179.619  92.964,179.375  96.622,179.253
GR       99.670,179.375 107.594,179.741 108.204,180.685 113.995,181.722
GR       119.786,183.916 121.006,184.282 121.920,184.313
SA         68.275  121.006

 ***   Completed Reading Data Associated With Header Record SEC-C   ***
 ***  Storing X-Section Data In Temporary File As Record Number  3  ***

 ***             Data Summary For Header Record SEC-C              ***
 SRD Location:      114.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (15 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
    60.046     188.793       68.275     185.440       75.286     181.661
    83.515     180.289       84.125     179.680       89.611     179.619
    92.964     179.375       96.622     179.253       99.670     179.375
   107.594     179.741      108.204     180.685      113.995     181.722
   119.786     183.916      121.006     184.282      121.920     184.313
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      60.046  ( associated Y-Elevation:  188.793 )
  Maximum X-Station:     121.920  ( associated Y-Elevation:  184.313 )
  Minimum Y-Elevation:   179.253  ( associated X-Station:     96.622 )
  Maximum Y-Elevation:   188.793  ( associated X-Station:     60.046 )

                    Roughness Data (  3 SubAreas )
                            Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1        .065          ---
                              ---          68.275
                     2        .027          ---
                              ---         121.006
                     3        .065          ---
                  -------  -----------  ------------

       *---------------------------------------------------*
       *      Finished Processing Header Record SEC-C      *
       *---------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
           EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
              SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
              CONSTANT DISCHARGE SUBCRITICAL FLOW

       *----------------------------------------------------*
       *      Starting To Process Header Record SEC-D       *
       *----------------------------------------------------*

XS   SEC-D 152.400
GR         67.056,188.702  73.152,184.008  77.114,180.899  83.210,180.807
GR       84.125,180.076  89.916,180.015  95.098,180.015  96.012,179.527
GR       99.974,179.558 103.632,179.588 103.937,180.076 113.386,181.295
GR       118.567,183.916 121.920,184.008
SA         73.152  117.043

 ***   Completed Reading Data Associated With Header Record SEC-D   ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***              Data Summary For Header Record SEC-D              ***
 SRD Location:      152.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (14 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
    67.056     188.702       73.152     184.008       77.114     180.899
    83.210     180.807       84.125     180.076       89.916     180.015
    95.098     180.015       96.012     179.527       99.974     179.558
   103.632     179.588      103.937     180.076      113.386     181.295
   118.567     183.916      121.920     184.008
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      67.056  ( associated Y-Elevation:  188.702 )
  Maximum X-Station:     121.920  ( associated Y-Elevation:  184.008 )
  Minimum Y-Elevation:   179.527  ( associated X-Station:     96.012 )
  Maximum Y-Elevation:   188.702  ( associated X-Station:     67.056 )

                    Roughness Data (  3 SubAreas )
                            Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .065         ---
                               ---        73.152
                     2         .027         ---
                               ---       117.043
                     3         .065         ---
                  -------  -----------  ------------

       *----------------------------------------------------*
       *      Finished Processing Header Record SEC-D       *
       *----------------------------------------------------*
```

```
  *************************  W S P R O  ***************************
     Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
            Input Units: Metric  /  Output Units: Metric
  *-----------------------------------------------------------------*
            EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
               SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
               CONSTANT DISCHARGE SUBCRITICAL FLOW

        *---------------------------------------------------*
        *      Starting To Process Header Record SEC-E      *
        *---------------------------------------------------*

XS   SEC-E 195.072
GR         62.179,188.671  73.152,180.777  78.638,180.807  84.125,180.533
GR       89.306,180.472  94.793,180.472 100.279,180.381 105.766,180.746
GR       111.252,180.685 117.043,183.185 121.920,183.490 122.225,185.318
SA         75.895  111.343

 ***   Completed Reading Data Associated With Header Record SEC-E   ***
 ***  Storing X-Section Data In Temporary File As Record Number  5  ***

 ***              Data Summary For Header Record SEC-E              ***
 SRD Location:      195.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (12 pairs)
     X          Y             X          Y             X          Y
----------  ----------    ----------  ----------    ----------  ----------
    62.179     188.671       73.152     180.777       78.638     180.807
    84.125     180.533       89.306     180.472       94.793     180.472
   100.279     180.381      105.766     180.746      111.252     180.685
   117.043     183.185      121.920     183.490      122.225     185.318
----------  ----------    ----------  ----------    ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      62.179  ( associated Y-Elevation:  188.671 )
  Maximum X-Station:     122.225  ( associated Y-Elevation:  185.318 )
  Minimum Y-Elevation:   180.381  ( associated X-Station:    100.279 )
  Maximum Y-Elevation:   188.671  ( associated X-Station:     62.179 )

                     Roughness Data (  3 SubAreas )
                             Roughness    Horizontal
                   SubArea  Coefficient   Breakpoint
                   -------  -----------  ------------
                      1         .065         ---
                                ---         75.895
                      2         .027         ---
                                ---        111.343
                      3         .065         ---
                   -------  -----------  ------------

        *---------------------------------------------------*
        *      Finished Processing Header Record SEC-E      *
        *---------------------------------------------------*
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
              EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
                 SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
                 CONSTANT DISCHARGE SUBCRITICAL FLOW
EX

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

           Reach      Water Surface   Friction
     #   Discharge      Elevation      Slope        Flow Regime
    --   ---------    -------------   --------   --------------------
     1      283.17      ********        .0023        Sub-Critical
    --   ---------    -------------   --------   --------------------

         *====================================================*
         *        Beginning  1 Profile Calculation(s)         *
         *====================================================*
```

```
*************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*----------------------------------------------------------------*
          EXAMPLE 1 - SOME CREEK NEAR ANYWHERE, USA
             SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
             CONSTANT DISCHARGE SUBCRITICAL FLOW

             << Beginning Computations for Profile  1 >>

                WSEL    VHD      Q          AREA      SRDL      LEW
                EGEL     HF      V           K        FLEN      REW
                CRWS     HO     FR #         SF       ALPHA     ERR
             --------- ------ ---------- ---------- --------- ---------
Section: SEC-A   182.532   .395   283.168    101.763 *********    54.112
Header Type: XS  182.928 ******     2.782    5902.40 *********   105.378
SRD:     30.480  181.963 ******      .631     ******     1.000    ******

Section: SEC-B   182.704   .283   283.168    120.176    33.528    59.731
Header Type: XS  182.988   .060     2.356    7551.27    33.528   113.343
SRD:     64.008  181.804   .000      .503      .0018     1.000     -.001

Section: SEC-C   182.738   .370   283.168    105.062    50.291    73.285
Header Type: XS  183.109   .077     2.695    6864.35    50.291   116.679
SRD:    114.300  181.858   .043      .553      .0015     1.000      .000

Section: SEC-D   182.776   .440   283.168     96.356    38.099    74.720
Header Type: XS  183.217   .073     2.938    6080.87    38.099   116.315
SRD:    152.399  182.092   .035      .617      .0019     1.000     -.001

Section: SEC-E   182.820   .566   283.168     93.073    42.672    70.311
Header Type: XS  183.386   .106     3.042    5278.85    42.672   116.198
SRD:    195.072  182.393   .062      .747      .0025     1.199     -.001

             << Completed Computations of Profile  1 >>

 ER

  ******************  Normal end of WSPRO execution.  *****************
  ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-2. Output data.

The user should look for input data messages identified by "+++" and consult Table 6-1 for explanation(s) and possible solution(s) for any problem(s) that might exist. When previewing output on a terminal or microcomputer screen, it is convenient to use a "search" command to detect any +++ string(s).

Output for profile computation headings are defined in Section 5 and (or) Appendix A. As previously discussed, any modeling effort should include a thorough review of this output. Inconsistencies from section to section, unreasonable and (or) unexpected parameter values, results not in agreement with pre-conceived notions and (or) sound engineering judgment, etc., may indicate that additional and (or) modified input data are needed for the analysis. The final lines reflect the end of run with normal termination.

7.2 EXAMPLE #2: SINGLE-OPENING BRIDGE (COORDINATE MODE)

Figure 7-3 illustrates input data for a simple, single-opening bridge analysis. The minimum number of sections (see Figure 3-8) are shown in this example. Optional grade-bank and road-grade sections are not required if grade banks are not present and there is no possibility of road overflow.

```
T1        Example 2:  Dry  Creek  Near  Barren  Hills
T2        Simple  Bridge  Example  Fixed-geometry  Mode
*
SI 1
*
Q         147.248
WS        336.621
*
* Exit Cross-Section - GR Data From X,Y Coordinates
*
XS   EXIT  14554.200
GR          0.000,337.597   21.336,337.078   44.196,336.652   49.073,335.128
GR         56.998,334.183   67.970,334.701   71.018,334.518   74.066,334.396
GR         78.638,333.634   83.210,333.329   87.782,333.329   93.878,333.512
GR         99.974,333.573  104.851,334.335  106.680,334.609  111.862,334.457
GR        118.872,334.274  124.054,333.939  131.978,333.939  136.246,333.543
GR        141.732,333.390  148.133,334.335  149.047,334.975  156.972,335.128
GR        167.335,335.890  172.822,337.718
N         0.040
*
* Full-Valley Cross-Section - All Data Propagated From Exit Cross-Section
*
XS   FULLV  14599.920
*
*  Bridge Section - Component Mode
*
BR   BRIDG  14599.920  337.810  30.000
GR         0.000,337.810   0.000,336.956   4.877,335.036  15.240,333.177
GR        20.726,333.238  28.956,333.299  35.662,334.396  41.758,336.591
GR        41.758,337.383   0.000,337.810
PD        333.451,0.701,1  336.895,0.701,1  336.895,1.829,2  337.810,1.829,2
CD        2  18.410  1.000  338.785
AB        *  *  336.956  336.591
*
XS   APPRO 14660.880
GR          0.000,337.322   22.860,337.017   42.672,336.743   50.292,335.311
GR         56.388,334.244   68.580,334.762   71.628,334.518   74.676,334.488
GR         79.248,333.665   83.820,333.360   88.392,333.360   94.488,333.573
GR        100.584,333.573  105.156,334.396  106.680,334.670  112.776,334.518
GR        118.872,334.335  123.444,334.000  132.588,334.000  137.160,333.604
GR        141.732,333.451  147.828,334.396  149.352,335.036  156.972,335.280
GR        167.640,335.890  175.260,338.023
*
* BP Record Used To Adjust Horizontal Datum Between Bridge and Approach
BP        68.580
*
EX
ER
```

Figure 7-3. Input data.

A single profile is computed for the specified discharge (shown in the Q record) using the water-surface elevation in the WS record. Exit-section geometry and roughness are propagated to the full-valley section. Because valley slope is not coded in either XS header record, elevations are projected horizontally. Bridge-opening data begins with the required BR header record. WSPRO recognizes coordinate mode because GR data are used instead of BL and BC records and data to define bridge geometry. Missing roughness data are propagated from the full-valley section. Because it is a type 2 opening (BRTYPE = 2 in the CD record), an AB record is required to specify abutment toe elevations (see Table 4-3). In the PD data note that: (1) the PPCD value of 0 indicates pier data; and (2) the last data pair is redundant (see Table 4-33 and Figure 4-16). Although the PW record is obsolete (replaced by the PD record), a PW record has been coded in this example to illustrate WSPRO's ability to detect and handle obsolete records. Approach-section data begins with the required XS header record and geometry is defined by GR data. Missing roughness data are propagated from the full-valley section (bridge data are never propagated). The first x-coordinate in both the bridge and the approach section is zero, which is only possible if the bridge opening is fully eccentric to the left. Assuming that is not the case here, a horizontal-datum problem exists. A BP record located with the approach section data provides the correction. A line projected parallel to the flow, from the minimum x-coordinate in the bridge (zero in this case), intersects the approach section at x-coordinate 68.580 (see Table 4-7 and Figure 4-5). Figure 7-4 shows a portion of the input-data-processing output for the bridge opening. Profile output is shown in Figure 7-5.

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *----------------------------------------------------------------*
              EXAMPLE 2:  DRY  CREEK  NEAR  BARREN  HILLS
             SIMPLE  BRIDGE  EXAMPLE  FIXED-GEOMETRY  MODE

           *----------------------------------------------------*
           *      Starting To Process Header Record BRIDG       *
           *----------------------------------------------------*

  BR   BRIDG  14599.920  337.810  30.000
  GR         0.000,337.810   0.000,336.956   4.877,335.036  15.240,333.177
  GR  2    0.726,333.238  28.956,333.299  35.662,334.396  41.758,336.591
  GR  4    1.758,337.383   0.000,337.810
  PD        333.451,0.701,1  336.895,0.701,1  336.895,1.829,2  337.810,1.829,2
  CD        2  18.410  1.000  338.785
  AB        *  *  336.956  336.591

   ***   Completed Reading Data Associated With Header Record BRIDG   ***
   ***   No Roughness Data Input, Propagating From Previous Section   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 9 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRIDG              ***
   SRD Location:    14600.   Cross-Section Skew:  30.0   Error Code   0
   Valley Slope:  *******   Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (10 pairs)
       X          Y             X          Y             X          Y
  ----------  ----------   ----------  ----------   ----------  ----------
        .000     337.810         .100     336.956        4.877     335.036
      15.240     333.177       20.726     333.238       28.956     333.299
      35.662     334.396       41.758     336.591       41.858     337.383
```

```
      .000     337.810
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  337.810 )
  Maximum X-Station:      41.858  ( associated Y-Elevation:  337.383 )
  Minimum Y-Elevation:   333.177  ( associated X-Station:     15.240 )
  Maximum Y-Elevation:   337.810  ( associated X-Station:       .000 )

      X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
      .000       2.042         .100       2.128        4.877       6.265
    15.240      15.240       20.726      19.991       28.956      27.118
    35.662      32.926       41.758      38.205       41.858      38.292
      .000       2.042
----------  ----------   ----------  ----------   ----------  ----------

                    Roughness Data (  1 SubAreas )
                            Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .040         ---
                  -------  -----------  ------------

                  Discharge coefficient parameters
              BRType   BRWdth   EMBSS   EMBElv    UserCD
                2       18.410   1.00   338.785 **********

                      Pressure flow elevations
                         AVBCEL     PFElev
                      *********    337.810

                        Abutment Parameters
       ABSLPL  ABSLPR   XTOELT    YTOELT    XTOERT    YTOERT
      ******* ******* *********   336.956 *********   336.591


                  Pier/Pile Data (  4 Group(s) )
                Code Indicates Bridge Uses Piers
               Group  Elevation  Gross Width  Number
              ------  ---------  -----------  ------
                 1      333.451        .701       1
                 2      336.895        .701       1
                 3      336.895       1.829       2
                 4      337.810       1.829       2
              ------  ---------  -----------  ------

        *----------------------------------------------------*
        *      Finished Processing Header Record BRIDG      *
        *----------------------------------------------------*
```

Figure 7-4. Summary of bridge section data for the single-opening bridge (coordinate mode) of example #2.

```
 ************************  W S P R O  **************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-------------------------------------------------------------*
          EXAMPLE 2:  DRY  CREEK  NEAR  BARREN  HILLS
         SIMPLE  BRIDGE  EXAMPLE  FIXED-GEOMETRY  MODE

               << Beginning Computations for Profile  1 >>

                   WSEL    VHD       Q          AREA      SRDL      LEW
                   EGEL     HF       V           K        FLEN      REW
                   CRWS     HO      FR #        SF        ALPHA     ERR
                --------- ------ ---------- ---------- --------- ---------
Section: EXIT      336.621   .013   147.247    287.057 *********    44.294
Header Type: XS    336.634 ******      .512   12416.24 *********   169.529
SRD:  14554.200    334.608 ******      .108     ******     1.000    ******

Section: FULLV     336.627   .013   147.247    287.882    45.720    44.273
Header Type: FV    336.640   .006      .511   12472.93    45.720   169.549
SRD:  14599.920    334.608   .000      .108      .0001     1.000      .000

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

Section: APPRO     336.636   .014   147.247    280.319    60.960    43.238
Header Type: AS    336.650   .008      .525   11828.16    60.960   170.305
SRD:  14660.880    334.667   .000      .113      .0001     1.000      .000

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

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


                   WSEL    VHD       Q          AREA      SRDL      LEW
                   EGEL     HF       V           K        FLEN      REW
                   CRWS     HO      FR #        SF        ALPHA     ERR
                --------- ------ ---------- ---------- --------- ---------
Section: BRIDG     336.546   .283   147.247     84.819    45.720     3.010
Header Type: BR    336.829   .021     1.736    3744.85    45.720    38.097
SRD:  14599.920    335.169   .173      .484     ******     1.844      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 2   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code  0           .7365  .026  337.809 ******** ********* *********
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:    336.627
    Downstream Bridge Section Water Surface Elevation:             336.546
    Bridge DrawDown Distance:                                         .081
---------------------------------------------------------------------------

                   WSEL    VHD       Q          AREA      SRDL      LEW
                   EGEL     HF       V           K        FLEN      REW
                   CRWS     HO      FR #        SF        ALPHA     ERR
                --------- ------ ---------- ---------- --------- ---------
Section: APPRO     336.878   .011   147.247    311.999    42.550    32.849
Header Type: AS    336.889   .023      .471   13362.86    52.638   171.171
SRD:  14660.880    334.667   .036      .100      .0001     1.000      .000

        ** Change in Approach Section Water Surface Elevation:  .242 **

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

```
        .722     .604    5289.1    83.379   118.467  336.878
    -------- -------- --------- --------- --------- --------

        <<< End of Bridge Hydraulics Computations >>>

          << Completed Computations of Profile  1 >>

ER

 ******************  Normal end of WSPRO execution.  *****************
 ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-5. Computed profile output for the single-opening bridge (coordinate mode) of example #2, first analysis.

7.3 EXAMPLE #3: BRIDGE-BACKWATER COMPUTATIONS USING TEMPLATE SECTION

A common practice is to design a bridge using only one valley cross-section, usually surveyed along the centerline of the proposed stream crossing. Slope-conveyance is generally used to determine the unconstricted (pre-bridge) water-surface elevation which subsequently serves as the base to determine the amount of backwater that may be created by the proposed bridge. It is not within the scope of this report to present an in-depth discussion of the potential problems associated with this "one-section" analytical procedure. However, a brief discussion is in order to establish a foundation for the following example. The most obvious constraint in this "one-section" method is the selection of an applicable energy gradient for the slope-conveyance computations. Assuming subcritical flow (the most frequent case), the applicable energy gradient depends on downstream conditions. The first question that must be addressed is: "Is the surveyed section truly representative of the valley geometry for a significant reach length downstream from the bridge site?" If that question cannot be answered in the affirmative, then obviously the "one-section" method is probably inadequate. The only reasonable alternative in that case is to survey a sufficient number of sections to adequately define the variable geometry and use step-backwater computation techniques to define the unconstricted water-surface profile. An affirmative answer still raises additional questions. The next question may be "Is there significant variation in roughness and (or) stream slope downstream from the bridge site?" Another logical question is "Are there any human induced influences on the water-surface profile downstream from the bridge site?" If responses to the last two questions are negative, using slope-conveyance and the "one-section" method can be quite adequate. If either or both of the latter two questions indicate a problem, but uniform (or uniformly varying) geometry is reasonably approximated, the template-section feature of WSPRO might be used to great advantage. This feature permits the user (within limits) to fabricate additional sections so that step-backwater computations can be used instead of slope-conveyance computations. Also, even though many agencies desire to apply WSPRO's bridge-backwater computational techniques, they are restricted by policy and (or) economics to surveying a single valley section. Assuming that slope-conveyance determination of the unconstricted water-surface elevation is applicable, such agencies could utilize the template-section feature to fabricate the additional sections required for the WSPRO analysis and use slope conveyance to determine the water-surface elevation at the exit section.

The following two sections illustrate use of the template-section feature subject to the following assumptions: (1) the surveyed section adequately represents the geometry of the entire length of reach being considered; (2) there are significant changes in valley slope in the stream reach downstream from the bridge site; (3) roughness varies both vertically and horizontally within each section but does not vary from section to section along the reach; and (4) a gaging station provides a known stage-discharge relation at a point downstream from the bridge site. The third and fourth assumptions shorten the illustrations and discussion. The analysis could easily include variation of roughness along the reach. Without a known stage-discharge relation, a similar data setup could be used to take advantage of the "self-correcting" and "converging profile" characteristics of step-backwater analyses discussed by Davidian (1984).

The example is separated into two logical steps: (1) transfer the known stage-discharge relation from the downstream point to the bridge-related sections; and (2) compute the bridge backwater (in this case for only one design alternative). A third step, not illustrated in this example, is computing step-backwater upstream from the bridge to determine the extent of the backwater effects (logically performed after reducing the number of feasible alternative designs).

7.3.1 Transfer Known Stage-Discharge Relation to Bridge Site

A plot of the surveyed section is presented in Figure 7-6 and the stream-bed profile plot is shown in Figure 7-7.

The section was surveyed along the centerline of the proposed stream crossing (SRD = 762). The known stage-discharge relation is available from a streamflow-gaging station at SRD = 304.8. The input data for transferring this known relation to the bridge site are illustrated in Figure 7-8. Profiles are computed for five discharges (Q record) using water-surface elevations (WS record) from the known stage-discharge relation. Because the surveyed section is located upstream from where section data is first needed, that section must be initially introduced as a template section. Template-section data consist of an XT header record and GR data. The required XS header record for the section needed at SRD = 304.800. The GT record in instructs the model to get the geometry for that section from the template section. The -0.671 coded in the GT record is the elevation difference from SRD = 762 to SRD = 304.8. That value is used to lower the template-section elevations to fabricate the section at SRD = 304.8. If a uniform valley slope exists between two points, the slope can be coded in either header record (XT or XS) to accomplish the necessary elevation adjustment. The roughness data for this most downstream section follows the header record. Each of the upstream sections require only an XS header record due to the assumptions of uniform geometry and constant roughness from section to section. Elevation adjustments are accomplished by valley slope propagation. Roughness data are also propagated. The SRD values of the last three sections reflect appropriate locations for the subsequent bridge-backwater analysis.

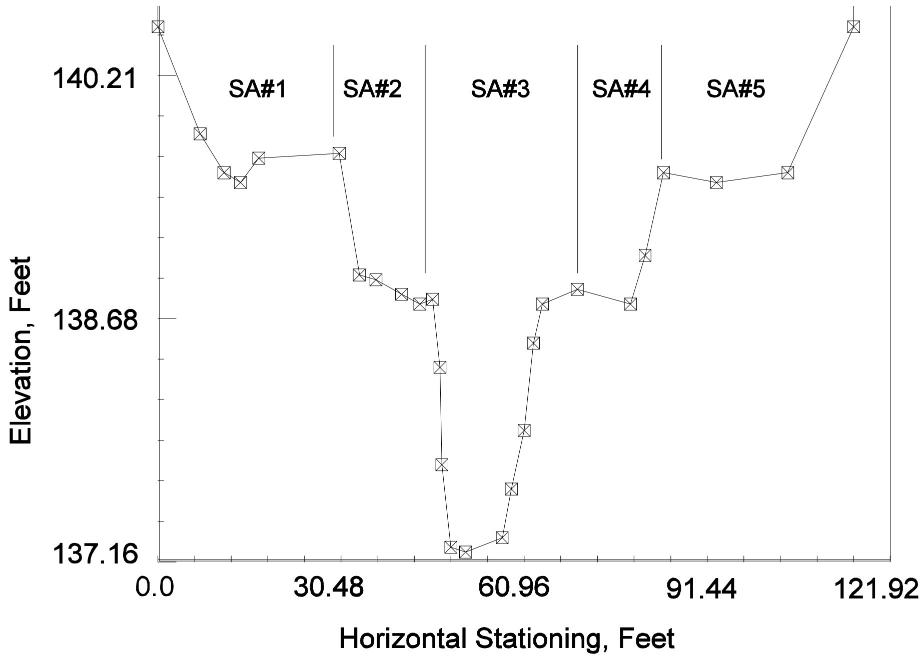


Figure 7-6. Plot of surveyed cross-section for example #3.

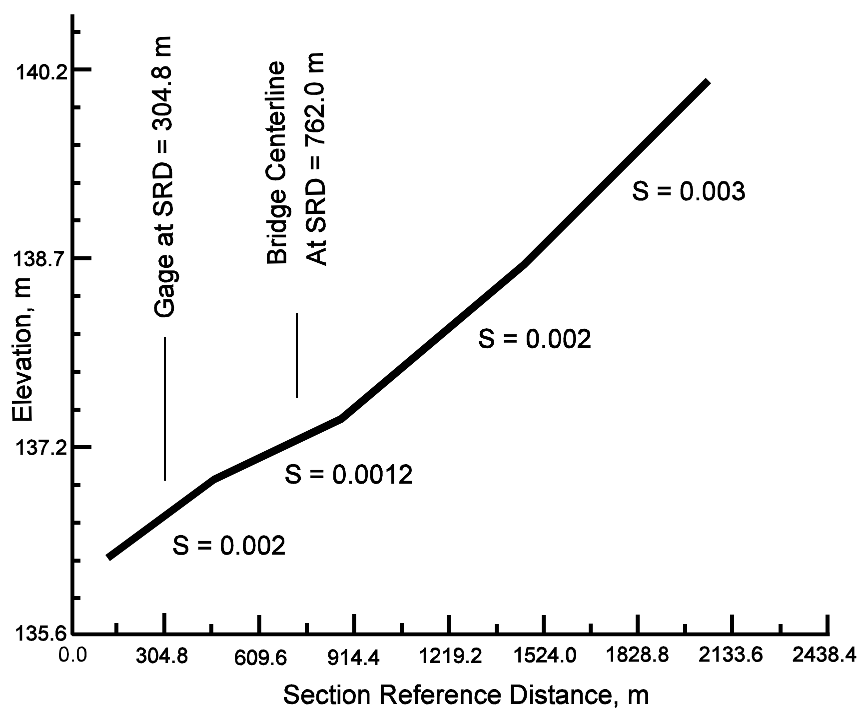


Figure 7-7. Plot of streambed profile for example #3.

```
T1        Example 3:  Examples  of  Input & Output  for  WSPRO Computer Model
T2        FHWA/USGS  Model  for  Water-surface  Profile  Computations
T3        <<<<<  Transfer  Known  Rating  to  Upstream  Sections  >>>>>
*
SI 1
*
Q           84.951   99.109  127.426  155.743  212.376
WS         139.056  139.181  139.394  139.574  139.879
*
XT   SURVY 762.000
GR           0.000,141.732    0.000,140.513    7.010,139.842    10.973,139.598
GR          13.716,139.537   16.764,139.690   30.175,139.720    33.528,138.958
GR          36.271,138.928   40.538,138.836   43.586,138.775    45.720,138.806
GR          46.939,138.379   47.244,137.770   48.768,137.251    51.206,137.221
GR          57.302,137.312   58.826,137.617   60.960,137.983    62.484,138.532
GR          64.008,138.775   69.799,138.867   78.638,138.775    81.077,139.080
GR          84.125,139.598   92.964,139.537  104.851,139.598   115.824,140.513
GR         115.824,141.732
*
XS    GAGE 304.800
GT         -0.671
N          0.055,0.050  0.065,0.060  0.040,0.040
N                0.065,0.060  0.055,0.050
SA           30.175  45.720  64.008  84.125
ND         0.305,0.914  0.610,1.524  0.000,0.305
ND               0.305, 1.219  0.305, 0.914
*
XS     XS2 457.200   *   *   *  0.0020
XS     XS3 609.600   *   *   *  0.0012
XS    EXIT 720.852
XS   FULLV 757.428
XS    APPR 803.148
*
EX
ER
```

Figure 7-8. Input data for transferring stage-discharge relation to the bridge site, example #3.

The WSPRO generated output for the input data file shown in Figure 7-8 is presented in Figure 7-9.

```
   *************************  W S P R O  **************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
        Run Date & Time:  9/10/97  7:31 am     Version V070197
         Input File: EX3.DAT        Output File: EX3.LST
   *----------------------------------------------------------------*
T1         EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
T2         FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
T3         <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>
SI 1
                    Metric (SI) Units Used in WSPRO

               Quantity    SI Unit              Precision
             ------------ -------------------- -----------
              Length       meters                 0.001
              Depth        meters                 0.001
              Elevation    meters                 0.001
              Widths       meters                 0.001

              Velocity     meters/second          0.001
              Discharge    cubic meters/second    0.001
              Slope        meter/meter            0.001

              Angles       degrees                0.01
             ------------ -------------------- -----------

Q           84.951   99.109  127.426  155.743  212.376

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

WS         139.056  139.181  139.394  139.574  139.879
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
  EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
    <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

          *----------------------------------------------------*
          *      Starting To Process Header Record SURVY      *
          *----------------------------------------------------*

  XT   SURVY 762.000
  GR        0.000,141.732   0.000,140.513   7.010,139.842    10.973,139.598
  GR       13.716,139.537  16.764,139.690  30.175,139.720    33.528,138.958
  GR       36.271,138.928  40.538,138.836  43.586,138.775    45.720,138.806
  GR       46.939,138.379  47.244,137.770  48.768,137.251    51.206,137.221
  GR       57.302,137.312  58.826,137.617  60.960,137.983    62.484,138.532
  GR       64.008,138.775  69.799,138.867  78.638,138.775    81.077,139.080
  GR       84.125,139.598  92.964,139.537 104.851,139.598   115.824,140.513
  GR      115.824,141.732

   ***   Completed Reading Data Associated With Header Record SURVY   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #29 increased to eliminate vertical segment.
   ***          Storing Template Header Record Data In Memory          ***


   ***               Data Summary For Header Record SURVY              ***
   SRD Location:      762.    Valley Slope:  *******     Error Code   0

                     X,Y-coordinates (29 pairs)
      X          Y             X          Y            X          Y
  ----------  ----------   ----------  ----------   ----------  ----------
        .000     141.732         .100     140.513        7.010     139.842
      10.973     139.598       13.716     139.537       16.764     139.690
      30.175     139.720       33.528     138.958       36.271     138.928
      40.538     138.836       43.586     138.775       45.720     138.806
      46.939     138.379       47.244     137.770       48.768     137.251
      51.206     137.221       57.302     137.312       58.826     137.617
      60.960     137.983       62.484     138.532       64.008     138.775
      69.799     138.867       78.638     138.775       81.077     139.080
      84.125     139.598       92.964     139.537      104.851     139.598
     115.824     140.513      115.924     141.732
  ----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
    Minimum X-Station:        .000  ( associated Y-Elevation:  141.732 )
    Maximum X-Station:     115.924  ( associated Y-Elevation:  141.732 )
    Minimum Y-Elevation:   137.221  ( associated X-Station:     51.206 )
    Maximum Y-Elevation:   141.732  ( associated X-Station:       .000 )

          *----------------------------------------------------*
          *      Finished Processing Header Record SURVY      *
          *----------------------------------------------------*
```

```
   ************************  W S P R O  **************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

         *---------------------------------------------------*
         *      Starting To Process Header Record  GAGE      *
         *---------------------------------------------------*

XS    GAGE 304.800
GT         -0.671
N          0.055,0.050  0.065,0.060  0.040,0.040
N              0.065,0.060  0.055,0.050
SA           30.175  45.720  64.008  84.125
ND         0.305,0.914  0.610,1.524  0.000,0.305
ND             0.305, 1.219  0.305, 0.914

 ***   Completed Reading Data Associated With Header Record  GAGE   ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***             Data Summary For Header Record  GAGE               ***
 SRD Location:      305.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.061         .100     139.842        7.010     139.171
    10.973     138.927       13.716     138.866       16.764     139.019
    30.175     139.049       33.528     138.287       36.271     138.257
    40.538     138.165       43.586     138.104       45.720     138.135
    46.939     137.708       47.244     137.099       48.768     136.580
    51.206     136.550       57.302     136.641       58.826     136.946
    60.960     137.312       62.484     137.861       64.008     138.104
    69.799     138.196       78.638     138.104       81.077     138.409
    84.125     138.927       92.964     138.866      104.851     138.927
   115.824     139.842      115.924     141.061
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.061 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.061 )
  Minimum Y-Elevation:   136.550  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.061  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
       SubArea    Point    Coefficient    Depth    Breakpoint
       -------  ---------- -----------  ---------  ----------
          1       Bottom       .055         .305      ---
                   Top         .050         .914      ---
                   --          ---         ---        30.175
          2       Bottom       .065         .610      ---
                   Top         .060        1.524      ---
                   --          ---         ---        45.720
          3       Bottom       .040         .000      ---
                   Top         .040         .305      ---
                   --          ---         ---        64.008
          4       Bottom       .065         .305      ---
                   Top         .060        1.219      ---
                   --          ---         ---        84.125
          5       Bottom       .055         .305      ---
                   Top         .050         .914      ---


         *---------------------------------------------------*
         *      Finished Processing Header Record  GAGE      *
         *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *---------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

         *---------------------------------------------------*
         *      Starting To Process Header Record   XS2      *
         *---------------------------------------------------*

XS      XS2 457.200  *  *  *  0.0020

 ***   Completed Reading Data Associated With Header Record   XS2   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  2  ***

 ***              Data Summary For Header Record   XS2              ***
 SRD Location:      457.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00200    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (29 pairs)
     X          Y             X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.366         .100     140.147        7.010     139.476
    10.973     139.232       13.716     139.171       16.764     139.324
    30.175     139.354       33.528     138.592       36.271     138.562
    40.538     138.470       43.586     138.409       45.720     138.440
    46.939     138.013       47.244     137.404       48.768     136.885
    51.206     136.855       57.302     136.946       58.826     137.251
    60.960     137.617       62.484     138.166       64.008     138.409
    69.799     138.501       78.638     138.409       81.077     138.714
    84.125     139.232       92.964     139.171      104.851     139.232
   115.824     140.147      115.924     141.366
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.366 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.366 )
  Minimum Y-Elevation:   136.855  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.366  ( associated X-Station:       .000 )

                   Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
       SubArea    Point    Coefficient    Depth    Breakpoint
       -------  ----------  -----------  ---------  ----------
          1       Bottom        .055        .305       ---
                   Top          .050        .914       ---
                   --           ---         ---       30.175
          2       Bottom        .065        .610       ---
                   Top          .060       1.524       ---
                   --           ---         ---       45.720
          3       Bottom        .040        .000       ---
                   Top          .040        .305       ---
                   --           ---         ---       64.008
          4       Bottom        .065        .305       ---
                   Top          .060       1.219       ---
                   --           ---         ---       84.125
          5       Bottom        .055        .305       ---
                   Top          .050        .914       ---


         *---------------------------------------------------*
         *      Finished Processing Header Record   XS2      *
         *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *----------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

         *----------------------------------------------------*
         *      Starting To Process Header Record   XS3      *
         *----------------------------------------------------*

XS      XS3 609.600  *  *  *  0.0012

 ***   Completed Reading Data Associated With Header Record   XS3   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  3  ***

 ***              Data Summary For Header Record   XS3              ***
 SRD Location:      610.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.549         .100     140.330        7.010     139.659
    10.973     139.415       13.716     139.354       16.764     139.507
    30.175     139.537       33.528     138.775       36.271     138.745
    40.538     138.653       43.586     138.592       45.720     138.623
    46.939     138.196       47.244     137.587       48.768     137.068
    51.206     137.038       57.302     137.129       58.826     137.434
    60.960     137.800       62.484     138.349       64.008     138.592
    69.799     138.684       78.638     138.592       81.077     138.897
    84.125     139.415       92.964     139.354      104.851     139.415
   115.824     140.330      115.924     141.549
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.549 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.549 )
  Minimum Y-Elevation:   137.038  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.549  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
                Transition   Roughness   Hydraulic  Horizontal
       SubArea     Point    Coefficient    Depth    Breakpoint
       -------  ----------  -----------  ---------  ----------
          1       Bottom        .055         .305      ---
                   Top          .050         .914      ---
                    --          ---          ---       30.175
          2       Bottom        .065         .610      ---
                   Top          .060        1.524      ---
                    --          ---          ---       45.720
          3       Bottom        .040         .000      ---
                   Top          .040         .305      ---
                    --          ---          ---       64.008
          4       Bottom        .065         .305      ---
                   Top          .060        1.219      ---
                    --          ---          ---       84.125
          5       Bottom        .055         .305      ---
                   Top          .050         .914      ---


         *----------------------------------------------------*
         *      Finished Processing Header Record   XS3      *
         *----------------------------------------------------*
```

```
    ************************  W S P R O  **************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

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

XS    EXIT 720.852

 ***   Completed Reading Data Associated With Header Record  EXIT   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***             Data Summary For Header Record  EXIT               ***
 SRD Location:      721.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (29 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.682         .100     140.463        7.010     139.792
    10.973     139.548       13.716     139.487       16.764     139.640
    30.175     139.670       33.528     138.908       36.271     138.878
    40.538     138.786       43.586     138.725       45.720     138.756
    46.939     138.329       47.244     137.720       48.768     137.201
    51.206     137.171       57.302     137.262       58.826     137.567
    60.960     137.933       62.484     138.482       64.008     138.725
    69.799     138.817       78.638     138.725       81.077     139.030
    84.125     139.548       92.964     139.487      104.851     139.548
   115.824     140.463      115.924     141.682
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.682 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.682 )
  Minimum Y-Elevation:   137.171  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.682  ( associated X-Station:       .000 )

                     Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
        SubArea   Point    Coefficient    Depth    Breakpoint
        -------  ---------- -----------  ---------  ----------
           1      Bottom        .055        .305       ---
                   Top          .050        .914       ---
                   --           ---         ---       30.175
           2      Bottom        .065        .610       ---
                   Top          .060       1.524       ---
                   --           ---         ---       45.720
           3      Bottom        .040        .000       ---
                   Top          .040        .305       ---
                   --           ---         ---       64.008
           4      Bottom        .065        .305       ---
                   Top          .060       1.219       ---
                   --           ---         ---       84.125
           5      Bottom        .055        .305       ---
                   Top          .050        .914       ---


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

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

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

XS   FULLV 757.428

 ***   Completed Reading Data Associated With Header Record FULLV   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  5  ***

 ***              Data Summary For Header Record FULLV              ***
 SRD Location:      757.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (29 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.726         .100     140.507        7.010     139.836
    10.973     139.592       13.716     139.531       16.764     139.684
    30.175     139.714       33.528     138.952       36.271     138.922
    40.538     138.830       43.586     138.769       45.720     138.800
    46.939     138.373       47.244     137.764       48.768     137.245
    51.206     137.215       57.302     137.306       58.826     137.611
    60.960     137.977       62.484     138.526       64.008     138.769
    69.799     138.861       78.638     138.769       81.077     139.074
    84.125     139.592       92.964     139.531      104.851     139.592
   115.824     140.507      115.924     141.726
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.726 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.726 )
  Minimum Y-Elevation:   137.215  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.726  ( associated X-Station:       .000 )

                   Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
       SubArea    Point    Coefficient    Depth    Breakpoint
       -------  ----------  -----------  ---------  ----------
          1       Bottom        .055        .305      ---
                   Top          .050        .914      ---
                   --           ---         ---      30.175
          2       Bottom        .065        .610      ---
                   Top          .060       1.524      ---
                   --           ---         ---      45.720
          3       Bottom        .040        .000      ---
                   Top          .040        .305      ---
                   --           ---         ---      64.008
          4       Bottom        .065        .305      ---
                   Top          .060       1.219      ---
                   --           ---         ---      84.125
          5       Bottom        .055        .305      ---
                   Top          .050        .914      ---


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

```
   ************************  W S P R O  **************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

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

XS    APPR 803.148

 ***   Completed Reading Data Associated With Header Record  APPR   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  6  ***

 ***             Data Summary For Header Record  APPR               ***
 SRD Location:      803.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.781         .100     140.562        7.010     139.891
    10.973     139.647       13.716     139.586       16.764     139.739
    30.175     139.769       33.528     139.007       36.271     138.977
    40.538     138.885       43.586     138.824       45.720     138.855
    46.939     138.428       47.244     137.819       48.768     137.300
    51.206     137.270       57.302     137.361       58.826     137.666
    60.960     138.032       62.484     138.581       64.008     138.824
    69.799     138.916       78.638     138.824       81.077     139.129
    84.125     139.647       92.964     139.586      104.851     139.647
   115.824     140.562      115.924     141.781
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.781 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.781 )
  Minimum Y-Elevation:   137.270  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.781  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
      SubArea     Point    Coefficient    Depth    Breakpoint
      -------  ----------  -----------  ---------  ----------
         1       Bottom        .055        .305       ---
                  Top          .050        .914       ---
                  --           ---         ---        30.175
         2       Bottom        .065        .610       ---
                  Top          .060       1.524       ---
                  --           ---         ---        45.720
         3       Bottom        .040        .000       ---
                  Top          .040        .305       ---
                  --           ---         ---        64.008
         4       Bottom        .065        .305       ---
                  Top          .060       1.219       ---
                  --           ---         ---        84.125
         5       Bottom        .055        .305       ---
                  Top          .050        .914       ---


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

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *----------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>
EX

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

          Reach      Water Surface   Friction
    #   Discharge      Elevation      Slope        Flow Regime
   --   ---------    -------------   --------   --------------------
    1       84.95       139.056       ******        Sub-Critical
    2       99.11       139.181       ******        Sub-Critical
    3      127.43       139.394       ******        Sub-Critical
    4      155.74       139.574       ******        Sub-Critical
    5      212.38       139.879       ******        Sub-Critical
   --   ---------    -------------   --------   --------------------

        *====================================================*
        *        Beginning  5 Profile Calculation(s)         *
        *====================================================*
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *---------------------------------------------------------------*
  EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

                  << Beginning Computations for Profile  1 >>

                     WSEL    VHD       Q          AREA      SRDL      LEW
                     EGEL     HF       V           K        FLEN      REW
                     CRWS     HO      FR #         SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section:  GAGE     139.056   .129     84.951     70.654 *********     8.875
Header Type: XS    139.185 ******      1.202    1897.59 *********   106.398
SRD:    304.799    138.430 ******       .598     ******     1.757    ******

Section:   XS2     139.361   .129     84.951     70.733   152.400     8.861
Header Type: XS    139.490   .305      1.201    1899.47   152.400   106.408
SRD:    457.200    138.735   .000       .597      .0020     1.758      .001

Section:   XS3     139.655   .101     84.951     81.727   152.399     7.059
Header Type: XS    139.757   .266      1.039    2175.65   152.399   107.738
SRD:    609.599    138.918   .000       .500      .0017     1.845      .000

Section:  EXIT     139.825   .093     84.951     85.403   111.252     6.666
Header Type: XS    139.919   .162       .994    2273.79   111.252   108.174
SRD:    720.852    139.049   .000       .472      .0015     1.861     -.001

Section: FULLV     139.879   .091     84.951     86.424    36.576     6.563
Header Type: XS    139.971   .050       .982    2301.54    36.576   108.295
SRD:    757.428    139.093   .000       .465      .0014     1.865      .005

Section:  APPR     139.944   .089     84.951     87.465    45.719     6.458
Header Type: XS    140.034   .061       .971    2330.06    45.719   108.417
SRD:    803.147    139.150   .000       .458      .0013     1.868      .005

                  << Completed Computations of Profile  1 >>
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
 EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
    <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

                 << Beginning Computations for Profile  2 >>

                    WSEL    VHD      Q          AREA      SRDL      LEW
                    EGEL     HF      V           K        FLEN      REW
                    CRWS     HO     FR #         SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  GAGE     139.181  .134     99.109     83.065 *********     6.904
Header Type: XS    139.315 ******     1.193    2211.05 *********   107.897
SRD:    304.799    138.551 ******      .572     ******     1.851    ******

Section:   XS2     139.487  .134     99.109     83.220   152.400     6.888
Header Type: XS    139.621  .305      1.190    2215.18   152.400   107.916
SRD:    457.200    138.856  .000       .570      .0020     1.852      .001

Section:   XS3     139.782  .105     99.109     94.690   152.399     5.734
Header Type: XS    139.887  .266      1.046    2534.38   152.399   109.261
SRD:    609.599    139.039  .000       .479      .0017     1.881     -.002

Section:  EXIT     139.953  .097     99.109     98.549   111.252     5.351
Header Type: XS    140.050  .162      1.005    2647.68   111.252   109.706
SRD:    720.852    139.172  .000       .454      .0015     1.883     -.001

Section: FULLV     140.007  .095     99.109     99.635    36.576     5.244
Header Type: XS    140.102  .050       .994    2680.13    36.576   109.830
SRD:    757.428    139.216  .000       .447      .0014     1.883      .005

Section:  APPR     140.072  .092     99.109    100.734    45.719     5.136
Header Type: XS    140.165  .061       .983    2713.19    45.719   109.956
SRD:    803.147    139.271  .000       .440      .0014     1.882      .005

                 << Completed Computations of Profile  2 >>
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
 EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
    <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

                  << Beginning Computations for Profile  3 >>

                     WSEL    VHD       Q         AREA      SRDL      LEW
                     EGEL     HF       V          K        FLEN      REW
                     CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section:  GAGE     139.393   .140    127.425    105.081 *********     4.711
Header Type: XS    139.534 ******      1.212    2846.26 *********   110.451
SRD:    304.799    138.750 ******       .532     ******     1.879    ******

Section:   XS2     139.700   .140    127.425    105.229   152.400     4.697
Header Type: XS    139.840   .304      1.210    2850.87   152.400   110.468
SRD:    457.200    139.055   .000       .531      .0020     1.878      .003

Section:   XS3     139.996   .111    127.425    117.420   152.399     3.524
Header Type: XS    140.108   .267      1.085    3240.40   152.399   111.834
SRD:    609.599    139.238   .000       .454      .0018     1.857      .000

Section:  EXIT     140.170   .103    127.425    121.775   111.252     3.112
Header Type: XS    140.273   .164      1.046    3384.60   111.252   112.314
SRD:    720.852    139.372   .000       .430      .0015     1.847      .002

Section: FULLV     140.225   .101    127.425    122.966    36.576     3.000
Header Type: XS    140.326   .051      1.036    3424.56    36.576   112.445
SRD:    757.428    139.417   .000       .424      .0014     1.845      .005

Section:  APPR     140.290   .099    127.425    124.143    45.719     2.889
Header Type: XS    140.389   .062      1.026    3464.28    45.719   112.574
SRD:    803.147    139.470   .000       .418      .0014     1.842      .003

                  << Completed Computations of Profile  3 >>
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
 <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

             << Beginning Computations for Profile  4 >>

                  WSEL     VHD       Q          AREA      SRDL      LEW
                  EGEL      HF       V           K        FLEN      REW
                  CRWS      HO      FR #         SF       ALPHA     ERR
               --------- ------ ---------- ---------- --------- ---------
Section:  GAGE   139.574   .147    155.742    124.477 *********     2.858
Header Type: XS  139.721 ******      1.251    3475.58 *********   112.610
SRD:    304.799  138.989 ******       .509     ******     1.841    ******

Section:   XS2   139.880   .146    155.742    124.632   152.400     2.843
Header Type: XS  140.026   .305      1.249    3480.84   152.400   112.627
SRD:    457.200  139.294   .000       .508      .0020     1.840      .001

Section:   XS3   140.178   .118    155.742    137.488   152.399     1.652
Header Type: XS  140.297   .270      1.132    3929.59   152.399   114.015
SRD:    609.599  139.477   .000       .439      .0018     1.805      .000

Section:  EXIT   140.353   .109    155.742    142.169   111.252     1.225
Header Type: XS  140.463   .167      1.095    4099.20   111.252   114.513
SRD:    720.852  139.610   .000       .418      .0015     1.790     -.003

Section: FULLV   140.407   .107    155.742    143.328    36.576     1.119
Header Type: XS  140.515   .052      1.086    4141.67    36.576   114.635
SRD:    757.428  139.654   .000       .413      .0014     1.787      .000

Section:  APPR   140.474   .105    155.742    144.664    45.719      .998
Header Type: XS  140.579   .063      1.076    4190.90    45.719   114.776
SRD:    803.147  139.709   .000       .407      .0014     1.783      .002

             << Completed Computations of Profile  4 >>
```

```
     ************************  W S P R O  **************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *------------------------------------------------------------------*
  EXAMPLE 3:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

                  << Beginning Computations for Profile  5 >>

                     WSEL     VHD       Q         AREA      SRDL      LEW
                     EGEL      HF       V          K        FLEN      REW
                     CRWS      HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section:  GAGE    139.879   .157    212.376    158.973 *********      .096
 Header Type: XS   140.036 ******      1.335    4739.04 *********   115.826
 SRD:    304.799   139.307 ******       .479     ******     1.733    ******

 Section:   XS2    140.186   .157    212.376    159.281   152.400      .096
 Header Type: XS   140.343   .305      1.333    4751.54   152.400   115.826
 SRD:    457.200   139.612   .000       .478      .0020     1.732      .005

 Section:   XS3    140.486   .128    212.376    172.846   152.399      .087
 Header Type: XS   140.615   .271      1.228    5320.61   152.399   115.836
 SRD:    609.599   139.795   .000       .415      .0018     1.671      .000

 Section:  EXIT    140.665   .119    212.376    178.137   111.252      .083
 Header Type: XS   140.785   .169      1.192    5548.59   111.252   115.840
 SRD:    720.852   139.929   .000       .394      .0015     1.651      .001

 Section: FULLV    140.720   .117    212.376    179.426    36.576      .082
 Header Type: XS   140.838   .053      1.183    5604.11    36.576   115.841
 SRD:    757.428   139.973   .000       .390      .0015     1.647      .000

 Section:  APPR    140.788   .115    212.376    180.863    45.719      .081
 Header Type: XS   140.903   .064      1.174    5666.34    45.719   115.842
 SRD:    803.147   140.027   .000       .384      .0014     1.642      .000

                  << Completed Computations of Profile  5 >>

  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-9. Output for transferring stage-discharge relation to the bridge site, example #3.

7.3.2 Bridge-Backwater Analysis (Component Mode) with Road Grade

Figure 7-10 illustrates the input data for analysis of a bridge to be located at SRD = 762. The results of the analysis in the preceding section provide known water-surface elevations at the exit section. Again the surveyed section is introduced as a template section (XT record). The exit section (XS record) is fabricated from the template-section geometry (GT record). Elevation adjustments are made using the product of the valley slope (which could alternatively been coded in the XT record) and the difference in section reference distances (i.e., 762.000-720.852). Roughness data for the exit section are coded in the following N, SA, and ND records. Missing geometry and roughness data for the full-valley section are propagated from the exit section with elevation adjustments again made using valley slope. Bridge data, in component form (no GR data) for component mode, is shown in the BR record section. Had roughness data not been coded for the bridge opening, it would have been obtained from the full-valley section. The road-grade section is coded in the XR and GR records which follow. Bridge data are never propagated, and even in component mode the bridge section does not interfere with upstream propagation of data from the full-valley section. Therefore, missing geometry and roughness data for the approach section (XS header record) are propagated from the full-valley section, with elevations adjusted for the specified valley slope.

```
T1         Example 3A:  Examples  of  Input & Output  for  WSPRO Computer Model
T2         FHWA/USGS  Model  for  Water-surface  Profile  Computations
T3         <<<<<  Additional  Bridge  Backwater  Computations  >>>>>
*
SI 1
*
Q           84.951   99.109  127.426  155.743  212.376
WS         139.824  139.952  140.168  140.354  140.665
*
XT    SURVY 762.000
GR            0.000,141.732    0.000,140.513    7.010,139.842   10.973,139.598
GR           13.716,139.537   16.764,139.690   30.175,139.720   33.528,138.958
GR           36.271,138.928   40.538,138.836   43.586,138.775   45.720,138.806
GR           46.939,138.379   47.244,137.770   48.768,137.251   51.206,137.221
GR           57.302,137.312   58.826,137.617   60.960,137.983   62.484,138.532
GR           64.008,138.775   69.799,138.867   78.638,138.775   81.077,139.080
GR           84.125,139.598   92.964,139.537  104.851,139.598  115.824,140.513
GR          115.824,141.732
*
XS     EXIT 720.852  *  *  *  0.0012
GT          -0.671
N            0.055,0.050  0.065,0.060  0.040,0.040
N                  0.065,0.060  0.055,0.050
SA             30.175  45.720  64.008  84.125
ND           0.305,0.914  0.610,1.524  0.000,0.305
ND                 0.305,1.219  0.305,0.914
*
XS    FULLV 757.428
*
BR    BRDGE 757.428
BC          140.818
BL          36.576  41.148  68.580
CD          1  9.144
N           0.040  0.050
ND          0.914  1.524
*
XR     ROAD 762.000  9.144
GR          0.000,140.818  36.576,141.122  73.152,141.122  115.824,140.818
*
XS     APPR 803.148
*
EX
ER
```

Figure 7-10. Input data for single-opening bridge (component mode) and road grade, example #3.

Figure 7-11 presents parts of the output for the bridge-backwater computations. The output for the fifth profile includes a series of ===xxx messages. Such messages are documented in Table 6-3. Following is a brief discussion of this particular series of messages.

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
           Run Date & Time:  9/10/97 10:58 am     Version V070197
            Input File: EX3A.DAT       Output File: EX3A.LST
      *----------------------------------------------------------------*
   T1        EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
   T2        FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
   T3        <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>
   SI 1
                       Metric (SI) Units Used in WSPRO

                  Quantity    SI Unit              Precision
                ------------ -------------------- -----------
                 Length       meters                 0.001
                 Depth        meters                 0.001
                 Elevation    meters                 0.001
                 Widths       meters                 0.001

                 Velocity     meters/second          0.001
                 Discharge    cubic meters/second    0.001
                 Slope        meter/meter            0.001

                 Angles       degrees                0.01
                ------------ -------------------- -----------

   Q          84.951   99.109  127.426  155.743  212.376

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

   WS        139.824  139.952  140.168  140.354  140.665
```

```
     ************************  W S P R O  **************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
  EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
       <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

           *---------------------------------------------------*
           *      Starting To Process Header Record SURVY      *
           *---------------------------------------------------*

  XT   SURVY 762.000
  GR         0.000,141.732    0.000,140.513    7.010,139.842   10.973,139.598
  GR        13.716,139.537   16.764,139.690   30.175,139.720   33.528,138.958
  GR        36.271,138.928   40.538,138.836   43.586,138.775   45.720,138.806
  GR        46.939,138.379   47.244,137.770   48.768,137.251   51.206,137.221
  GR        57.302,137.312   58.826,137.617   60.960,137.983   62.484,138.532
  GR        64.008,138.775   69.799,138.867   78.638,138.775   81.077,139.080
  GR        84.125,139.598   92.964,139.537  104.851,139.598  115.824,140.513
  GR       115.824,141.732

   ***   Completed Reading Data Associated With Header Record SURVY   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #29 increased to eliminate vertical segment.
   ***         Storing Template Header Record Data In Memory          ***


   ***              Data Summary For Header Record SURVY              ***
   SRD Location:      762.    Valley Slope:  *******     Error Code   0

                              X,Y-coordinates (29 pairs)
       X          Y             X          Y             X          Y
  ----------  ----------    ----------  ----------    ----------  ----------
        .000     141.732          .100     140.513         7.010     139.842
      10.973     139.598        13.716     139.537        16.764     139.690
      30.175     139.720        33.528     138.958        36.271     138.928
      40.538     138.836        43.586     138.775        45.720     138.806
      46.939     138.379        47.244     137.770        48.768     137.251
      51.206     137.221        57.302     137.312        58.826     137.617
      60.960     137.983        62.484     138.532        64.008     138.775
      69.799     138.867        78.638     138.775        81.077     139.080
      84.125     139.598        92.964     139.537       104.851     139.598
     115.824     140.513       115.924     141.732
  ----------  ----------    ----------  ----------    ----------  ----------

                     Minimum and Maximum X,Y-coordinates
    Minimum X-Station:        .000  ( associated Y-Elevation:  141.732 )
    Maximum X-Station:     115.924  ( associated Y-Elevation:  141.732 )
    Minimum Y-Elevation:   137.221  ( associated X-Station:     51.206 )
    Maximum Y-Elevation:   141.732  ( associated X-Station:       .000 )

           *---------------------------------------------------*
           *      Finished Processing Header Record SURVY      *
           *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

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

XS    EXIT 720.852  *  *  *  0.0012
GT         -0.671
N           0.055,0.050  0.065,0.060  0.040,0.040
N               0.065,0.060  0.055,0.050
SA            30.175  45.720  64.008  84.125
ND          0.305,0.914  0.610,1.524  0.000,0.305
ND              0.305,1.219  0.305,0.914

 ***   Completed Reading Data Associated With Header Record  EXIT   ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***              Data Summary For Header Record  EXIT              ***
 SRD Location:      721.   Cross-Section Skew:    .0  Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.061         .100     139.842        7.010     139.171
    10.973     138.927       13.716     138.866       16.764     139.019
    30.175     139.049       33.528     138.287       36.271     138.257
    40.538     138.165       43.586     138.104       45.720     138.135
    46.939     137.708       47.244     137.099       48.768     136.580
    51.206     136.550       57.302     136.641       58.826     136.946
    60.960     137.312       62.484     137.861       64.008     138.104
    69.799     138.196       78.638     138.104       81.077     138.409
    84.125     138.927       92.964     138.866      104.851     138.927
   115.824     139.842      115.924     141.061
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.061 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.061 )
  Minimum Y-Elevation:   136.550  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.061  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
      SubArea     Point     Coefficient    Depth    Breakpoint
      -------  ----------  -----------  ---------  ----------
         1       Bottom        .055        .305       ---
                  Top          .050        .914       ---
                  --           ---         ---       30.175
         2       Bottom        .065        .610       ---
                  Top          .060       1.524       ---
                  --           ---         ---       45.720
         3       Bottom        .040        .000       ---
                  Top          .040        .305       ---
                  --           ---         ---       64.008
         4       Bottom        .065        .305       ---
                  Top          .060       1.219       ---
```

```
         --          ---         ---        84.125
 5      Bottom       .055        .305       ---
         Top         .050        .914       ---


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

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-------------------------------------------------------------*
EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

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

XS   FULLV 757.428

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

 ***             Data Summary For Header Record FULLV             ***
 SRD Location:      757.   Cross-Section Skew:    .0  Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50  Contraction:   .00

                    X,Y-coordinates (29 pairs)
     X          Y             X          Y             X          Y
----------  ----------    ----------  ----------   ----------  ----------
      .000     141.105          .100     139.886        7.010     139.215
    10.973     138.971        13.716     138.910       16.764     139.063
    30.175     139.093        33.528     138.331       36.271     138.301
    40.538     138.209        43.586     138.148       45.720     138.179
    46.939     137.752        47.244     137.143       48.768     136.624
    51.206     136.594        57.302     136.685       58.826     136.990
    60.960     137.356        62.484     137.905       64.008     138.148
    69.799     138.240        78.638     138.148       81.077     138.453
    84.125     138.971        92.964     138.910      104.851     138.971
   115.824     139.886       115.924     141.105
----------  ----------    ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.105 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.105 )
  Minimum Y-Elevation:   136.594  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.105  ( associated X-Station:       .000 )

                   Roughness Data (  5 SubAreas )
               Transition   Roughness   Hydraulic  Horizontal
      SubArea     Point    Coefficient    Depth    Breakpoint
      -------  ----------  -----------  ---------  ----------
         1       Bottom        .055        .305       ---
                  Top          .050        .914       ---
                  --           ---         ---      30.175
         2       Bottom        .065        .610       ---
                  Top          .060       1.524       ---
                  --           ---         ---      45.720
         3       Bottom        .040        .000       ---
                  Top          .040        .305       ---
                  --           ---         ---      64.008
         4       Bottom        .065        .305       ---
                  Top          .060       1.219       ---
                  --           ---         ---      84.125
         5       Bottom        .055        .305       ---
                  Top          .050        .914       ---
```

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

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *----------------------------------------------------------------*
 EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

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

 BR   BRDGE 757.428
 BC         140.818
 BL         36.576  41.148  68.580
 CD         1  9.144
 N          0.040  0.050
 ND         0.914  1.524

  ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #17 increased to eliminate vertical segment.
  ***   Storing Bridge Data In Temporary File As Record Number  3    ***

  ***              Data Summary For Bridge Record BRDGE              ***
  SRD Location:      757.   Cross-Section Skew:    .0   Error Code   0
  Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                         X,Y-coordinates (18 pairs)
      X          Y            X          Y            X          Y
 ---------- ----------   ---------- ----------   ---------- ----------
     36.576    140.818       36.676    138.294       40.538    138.209
     43.586    138.148       45.720    138.179       46.939    137.752
     47.244    137.143       48.768    136.624       51.206    136.594
     57.302    136.685       58.826    136.990       60.960    137.356
     62.484    137.905       64.008    138.148       69.799    138.240
     73.152    138.205       73.252    140.818       36.576    140.818
 ---------- ----------   ---------- ----------   ---------- ----------

                     Minimum and Maximum X,Y-coordinates
   Minimum X-Station:      36.576  ( associated Y-Elevation:  140.818 )
   Maximum X-Station:      73.252  ( associated Y-Elevation:  140.818 )
   Minimum Y-Elevation:   136.594  ( associated X-Station:     51.206 )
   Maximum Y-Elevation:   140.818  ( associated X-Station:     36.576 )

                        Roughness Data (  1 SubAreas )
                         Transition    Roughness
               SubArea     Point     Coefficient    Depth
               -------  ----------   -----------  ---------
                  1       Bottom         .040         .914
                           Top           .050        1.524
               -------  ----------   -----------  ---------

                      Discharge coefficient parameters
         BRType   BRWdth   WWAngl   WWWdth   EntRnd    UserCD
           1       9.144  ******  ******** ******** **********

                          Pressure flow elevations
                             AVBCEL     PFElev
                            140.818    140.818

                            Abutment Parameters
         ABSLPL  ABSLPR   XTOELT    YTOELT    XTOERT    YTOERT
```

```
    ******* *******    36.576   138.294    73.152   138.205

         Bridge Length and Bottom Chord component input data
BRLEN    LOCOPT   XCONLT    XCONRT    BCELEV   BCSLP   BCXSTA
36.576    0       41.148    68.580   140.818   .0000    54.864

             ** No Pier/Pile Data Encountered **


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

```
     *************************  W S P R O  ****************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
  EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
       <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

           *---------------------------------------------------*
           *      Starting To Process Header Record  ROAD      *
           *---------------------------------------------------*

  XR    ROAD 762.000  9.144
  GR         0.000,140.818  36.576,141.122  73.152,141.122  115.824,140.818

   ***   Completed Reading Data Associated With Header Record  ROAD   ***
    ***   Storing Roadway Data In Temporary File As Record Number  4    ***

   ***              Data Summary For Roadway Record  ROAD             ***
   SRD Location:      762.   Cross-Section Skew:    .0   Error Code   0
   Roadway Width:    9.144   User-Specified Weir Coefficient:  ******
   Input Code Indicates Roadway Surface Consists of a Paved Material.

                     X,Y-coordinates ( 4 pairs)
       X          Y           X          Y            X          Y
  ----------  ----------   ----------  ----------   ----------  ----------
        .000     140.818       36.576     141.122       73.152     141.122
     115.824     140.818
  ----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
    Minimum X-Station:        .000  ( associated Y-Elevation:  140.818 )
    Maximum X-Station:     115.824  ( associated Y-Elevation:  140.818 )
    Minimum Y-Elevation:   140.818  ( associated X-Station:    115.824 )
    Maximum Y-Elevation:   141.122  ( associated X-Station:     36.576 )

Bridge datum projection:  XREFLT = *******

           *---------------------------------------------------*
           *      Finished Processing Header Record  ROAD      *
           *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
    FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

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

XS     APPR 803.148

 ***   Completed Reading Data Associated With Header Record  APPR   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  5  ***

 ***              Data Summary For Header Record  APPR              ***
 SRD Location:      803.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y             X          Y             X          Y
----------  ----------    ----------  ----------    ----------  ----------
      .000     141.160          .100     139.941         7.010     139.270
    10.973     139.026        13.716     138.965        16.764     139.118
    30.175     139.148        33.528     138.386        36.271     138.356
    40.538     138.264        43.586     138.203        45.720     138.234
    46.939     137.807        47.244     137.198        48.768     136.679
    51.206     136.649        57.302     136.740        58.826     137.045
    60.960     137.411        62.484     137.960        64.008     138.203
    69.799     138.295        78.638     138.203        81.077     138.508
    84.125     139.026        92.964     138.965       104.851     139.026
   115.824     139.941       115.924     141.160
----------  ----------    ----------  ----------    ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.160 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.160 )
  Minimum Y-Elevation:   136.649  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.160  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
               Transition  Roughness   Hydraulic  Horizontal
       SubArea    Point    Coefficient   Depth    Breakpoint
       -------  ---------- -----------  --------- ----------
          1       Bottom        .055        .305      ---
                   Top          .050        .914      ---
                   --           ---         ---       30.175
          2       Bottom        .065        .610      ---
                   Top          .060       1.524      ---
                   --           ---         ---       45.720
          3       Bottom        .040        .000      ---
                   Top          .040        .305      ---
                   --           ---         ---       64.008
          4       Bottom        .065        .305      ---
                   Top          .060       1.219      ---
                   --           ---         ---       84.125
          5       Bottom        .055        .305      ---
                   Top          .050        .914      ---
```

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

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

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *----------------------------------------------------------------*
   EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
        <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>
   EX

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

             Reach      Water Surface   Friction
       #   Discharge      Elevation      Slope        Flow Regime
      --   ---------    -------------   --------   --------------------
       1       84.95       139.824       ******       Sub-Critical
       2       99.11       139.952       ******       Sub-Critical
       3      127.43       140.168       ******       Sub-Critical
       4      155.74       140.354       ******       Sub-Critical
       5      212.38       140.665       ******       Sub-Critical
      --   ---------    -------------   --------   --------------------

           *====================================================*
           *        Beginning  5 Profile Calculation(s)         *
           *====================================================*
```

```
    ************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-------------------------------------------------------------*
 EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

                 << Beginning Computations for Profile  1 >>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO     FR #         SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  EXIT    139.824   .027     84.951    152.611 *********      .284
Header Type: XS   139.851 ******       .556    4488.66 *********   115.608
SRD:    720.852   138.430 ******       .205     ******     1.758    ******

Section: FULLV    139.836   .029     84.951    149.025    36.576      .605
Header Type: FV   139.866   .013       .570    4353.38    36.576   115.234
SRD:    757.428   138.472   .000       .212      .0004     1.769      .000

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

Section:  APPR    139.853   .031     84.951    144.729    45.719      .992
Header Type: AS   139.885   .018       .586    4193.28    45.719   114.783
SRD:    803.147   138.529   .001       .222      .0004     1.783      .001

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

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


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO     FR #         SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: BRDGE    139.809   .091     84.951     80.045    36.576    36.615
Header Type: BR   139.901   .023      1.061    2529.21    36.576    73.213
SRD:    757.428   138.439   .026       .229     ******     1.600      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .7907 .000  140.817   36.576    36.576    73.152
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:    139.836
    Downstream Bridge Section Water Surface Elevation:            139.809
    Bridge DrawDown Distance:                                        .027
----------------------------------------------------------------------------

             *** Roadway Section Located at SRD   762.000 ***

                  Section:   ROAD     Header Type: XR
                  <<< Embankment Is Not Overtopped >>>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO     FR #         SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  APPR    139.908   .028     84.951    150.974    36.575      .430
Header Type: AS   139.937   .024       .562    4426.88    38.544   115.438
SRD:    803.147   138.529   .010       .208      .0004     1.763      .001
```

```
** Change in Approach Section Water Surface Elevation:  .055 **

      Approach Section  APPR Flow Contraction Information
    M( G )   M( K )     KQ       XLKQ      XRKQ     OTEL
   -------- -------- --------- --------- --------- --------
       .678     .274    3211.7    37.298    73.895  139.895
   -------- -------- --------- --------- --------- --------

       <<< End of Bridge Hydraulics Computations >>>

         << Completed Computations of Profile  1 >>
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
 EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

                 << Beginning Computations for Profile  2 >>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  EXIT     139.951  .030     99.109    167.420 *********      .090
Header Type: XS    139.982 ******      .591    5089.29 *********   115.832
SRD:    720.852    138.551 ******      .205     ******     1.695    ******

Section: FULLV     139.965  .031     99.109    163.895    36.576      .093
Header Type: FV    139.997  .014       .604    4941.29    36.576   115.830
SRD:    757.428    138.597  .000       .212      .0004     1.711      .000

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

Section:  APPR     139.983  .034     99.109    159.652    45.719      .096
Header Type: AS    140.017  .019       .620    4766.64    45.719   115.827
SRD:    803.147    138.650  .001       .222      .0004     1.730      .001

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

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


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     139.929  .116     99.109     84.432    36.576    36.611
Header Type: BR    140.045  .025      1.173    2753.53    36.576    73.218
SRD:    757.428    138.527  .037       .247     ******     1.651      .000

Specific Bridge Information   C     P/A  PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .7784 .000 140.817   36.576    36.576    73.152
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:    139.965
    Downstream Bridge Section Water Surface Elevation:            139.929
    Bridge DrawDown Distance:                                        .036
---------------------------------------------------------------------------

             *** Roadway Section Located at SRD   762.000 ***

                  Section:   ROAD     Header Type: XR
                  <<< Embankment Is Not Overtopped >>>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  APPR     140.054  .030     99.109    167.876    36.575      .090
Header Type: AS    140.084  .027       .590    5108.66    38.831   115.833
SRD:    803.147    138.650  .011       .204      .0004     1.693      .001
```

```
** Change in Approach Section Water Surface Elevation:  .071 **

      Approach Section  APPR Flow Contraction Information
    M( G )   M( K )     KQ       XLKQ      XRKQ     OTEL
   -------- -------- --------- --------- --------- --------
       .684     .307    3539.2    37.338    73.944  140.040
   -------- -------- --------- --------- --------- --------

       <<< End of Bridge Hydraulics Computations >>>

         << Completed Computations of Profile  2 >>
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
 EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

                 << Beginning Computations for Profile  3 >>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  EXIT    140.168   .035   127.425    192.424 *********      .073
Header Type: XS   140.203 ******      .662    6178.91 *********   115.850
SRD:    720.852   138.750 ******      .208     ******     1.605    ******

Section: FULLV    140.183   .037   127.425    189.099    36.576      .075
Header Type: FV   140.220   .015      .673    6029.31    36.576   115.848
SRD:    757.428   138.796   .000      .214      .0004     1.616      .000

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

Section:  APPR    140.203   .039   127.425    185.076    45.719      .078
Header Type: AS   140.242   .021      .688    5850.63    45.719   115.845
SRD:    803.147   138.849   .000      .222      .0005     1.629      .000

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

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


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: BRDGE    140.129   .167   127.425     91.732    36.576    36.603
Header Type: BR   140.296   .030     1.389    3141.05    36.576    73.225
SRD:    757.428   138.693   .061      .280     ******     1.697      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .7676  .000  140.817   36.576    36.576    73.152
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:    140.183
    Downstream Bridge Section Water Surface Elevation:            140.129
    Bridge DrawDown Distance:                                        .054
----------------------------------------------------------------------------

             *** Roadway Section Located at SRD   762.000 ***

                  Section:   ROAD     Header Type: XR
                  <<< Embankment Is Not Overtopped >>>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  APPR    140.309   .033   127.425    197.346    36.575      .069
Header Type: AS   140.343   .031      .645    6403.53    39.392   115.854
SRD:    803.147   138.849   .015      .199      .0005     1.590      .001
```

```
** Change in Approach Section Water Surface Elevation:  .106 **

      Approach Section  APPR Flow Contraction Information
    M( G )   M( K )     KQ       XLKQ      XRKQ     OTEL
   -------- -------- --------- --------- --------- --------
       .684     .353    4142.3    37.407    74.029  140.294
   -------- -------- --------- --------- --------- --------

       <<< End of Bridge Hydraulics Computations >>>

         << Completed Computations of Profile  3 >>
```

```
    *************************  W S P R O  ***************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *----------------------------------------------------------------*
 EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
     FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

                 << Beginning Computations for Profile  4 >>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  EXIT     140.354   .041    155.742    213.962 *********      .057
Header Type: XS    140.395 ******       .727    7189.39 *********   115.865
SRD:     720.852   138.989 ******       .212     ******     1.544    ******

Section: FULLV     140.371   .043    155.742    210.854    36.576      .060
Header Type: FV    140.414   .017       .738    7039.24    36.576   115.863
SRD:     757.428   139.031   .000       .218      .0005     1.552      .001

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

Section:  APPR     140.393   .045    155.742    207.058    45.719      .062
Header Type: AS    140.438   .022       .752    6857.77    45.719   115.860
SRD:     803.147   139.088   .000       .225      .0005     1.563      .000

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

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


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     140.297   .222    155.742     97.879    36.576    36.596
Header Type: BR    140.520   .035      1.591    3480.61    36.576    73.232
SRD:     757.428   138.849   .088       .311     ******     1.726      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .7611  .000  140.817   36.576    36.576    73.152
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:    140.371
    Downstream Bridge Section Water Surface Elevation:            140.297
    Bridge DrawDown Distance:                                        .074
-----------------------------------------------------------------------------

             *** Roadway Section Located at SRD   762.000 ***

                   Section:   ROAD     Header Type: XR
                   <<< Embankment Is Not Overtopped >>>

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  APPR     140.536   .037    155.742    223.698    36.575      .051
Header Type: AS    140.574   .036       .696    7669.17    39.761   115.872
SRD:     803.147   139.088   .018       .197      .0005     1.519      .002
```

```
** Change in Approach Section Water Surface Elevation:  .143 **

      Approach Section  APPR Flow Contraction Information
    M( G )   M( K )     KQ       XLKQ      XRKQ     OTEL
   -------- -------- --------- --------- --------- --------
       .684     .385    4714.0    37.466    74.102  140.521
   -------- -------- --------- --------- --------- --------

        <<< End of Bridge Hydraulics Computations >>>

          << Completed Computations of Profile  4 >>
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *----------------------------------------------------------------*
  EXAMPLE 3A:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
       <<<<<  ADDITIONAL  BRIDGE  BACKWATER  COMPUTATIONS  >>>>>

                  << Beginning Computations for Profile  5 >>

                     WSEL     VHD       Q         AREA      SRDL      LEW
                     EGEL      HF       V          K        FLEN      REW
                     CRWS      HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section:  EXIT    140.665   .053   212.376    249.987 *********      .032
 Header Type: XS   140.718 ******      .849    9033.11 *********   115.891
 SRD:    720.852   139.307 ******      .223     ******     1.461    ******

 Section: FULLV    140.685   .055   212.376    247.240    36.576      .034
 Header Type: FV   140.740   .020      .858    8885.99    36.576   115.889
 SRD:    757.428   139.351   .000      .227      .0006     1.466      .001

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

 Section:  APPR    140.711   .057   212.376    243.874    45.719      .036
 Header Type: AS   140.768   .026      .870    8707.19    45.719   115.887
 SRD:    803.147   139.406   .000      .233      .0006     1.473      .000

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

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

===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
       WS1, WS2, WS3, RGMIN:    140.94        .00     140.57     140.82

===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

===220 FLOW CLASS 1 ( 4 ) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
       WS3, WSIU, WS1, PFELV:   140.57     140.89     140.94     140.82

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

===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
       YU/Z, WSIU, WS:  1.06     141.02     141.07

===270 REJECTED FLOW CLASS 2 ( 5 ) SOLUTION.


                     WSEL     VHD       Q         AREA      SRDL      LEW
                     EGEL      HF       V          K        FLEN      REW
                     CRWS      HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section: BRDGE    140.570   .343   211.006    107.906    36.576    36.585
 Header Type: BR   140.913   .044     1.955    4059.12    36.576    73.242
 SRD:    757.428   139.124   .150      .364     ******     1.759      .000

 Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
 Bridge Type 1  Flow Type 4 ------ ----- -------- -------- --------- ---------
 Pier/Pile Code **          .7539  .000  140.817   36.576    36.576    73.152
 -------------------------- ------ ----- -------- -------- --------- ---------
     Unconstricted Full Valley Section Water Surface Elevation:    140.685
     Downstream Bridge Section Water Surface Elevation:            140.570
     Bridge DrawDown Distance:                                        .115
```

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

                    WSEL     VHD       Q          AREA      FLEN      LEW
                    EGEL      HF       V           ERR      SRD       REW
                 --------- ------ ---------- ---------- --------- ---------
 Section:  ROAD    140.938   .044      1.369      1.881    36.575      .000
 Header Type: XR   140.966   .016       .727       .000   762.000   115.823

        Hydraulic Characteristics of Left and Right Roadway Sections

                                   Left Weir           Right Weir
        Weir Flow          (Q)           .63                  .74
        Weir Length      (WLEN)       14.457               16.867
        Weir LEW          (LEW)         .000               98.956
        Weir REW          (REW)       14.457              115.823
        Maximum Depth    (DMAX)         .120                 .120
        Average Depth    (DAVG)         .060                 .060
        Maximum Velocity (VMAX)         .737                 .737
        Average Velocity (VAVG)         .727                 .727
        Average Head     (HAVG)         .088                 .088
        Weir Coefficient (CAVG)        2.987                2.987

                    WSEL     VHD       Q          AREA      SRDL      LEW
                    EGEL      HF       V           K        FLEN      REW
                    CRWS      HO      FR #         SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
 Section:  APPR    140.937   .044    212.376    270.121    36.575      .018
 Header Type: AS   140.982   .043       .786   10142.84    40.308   115.905
 SRD:    803.147   139.406   .024       .196      .0006     1.423      .000

         ** Change in Approach Section Water Surface Elevation:  .226 **

               Approach Section  APPR Flow Contraction Information
            M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
           -------- -------- --------- --------- --------- --------
               .684     .428    5797.1    37.543    74.199 ********
           -------- -------- --------- --------- --------- --------

               <<< End of Bridge Hydraulics Computations >>>

                 << Completed Computations of Profile  5 >>

  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-11. Output for single-opening bridge (component mode) and road grade, example #3.

With one exception, WSPRO first attempts to compute free-surface flow with the entire flow passing through the bridge (class 1). The exception occurs when the tailwater is higher than the low-chord elevation, in which case WSPRO assumes submerged pressure flow, with or without road overflow (class 6 or 3). In this example, message ===215 appears because the class 1 solution has a water-surface elevation at the approach section higher than the minimum road-grade elevation (RGMIN = 140.82). Message ===260 indicates that a class 4 solution (free-surface bridge flow with road overflow) is attempted. The class 4 solution generates message ===220 because the water-surface elevation immediately upstream from the bridge (WSIU = 140.90) is higher than the low-chord elevation (PFELV = 14-.82). Message ===245 indicates that an unsubmerged pressure flow solution, with or without road overflow (class 2 or 5) is attempted. When no more such messages are generated, the appropriate flow type has been selected and computation continues. This is a good illustration that the messages do not always indicate problems. Frequently they simply indicate the assumptions and actions taken by the model.

7.4 EXAMPLE #4: UPSTREAM/DOWNSTREAM PROFILE COMPUTATIONS

WSPRO is designed to accommodate profile computations in both upstream and downstream directions during a single model execution. It is not always obvious that downstream computations are required; the need may not be recognized until upstream computations have been attempted. However, Figure 7-12 illustrates input data for a case where profiles are required for two discharges in a reach where it is quite certain there is a combination of subcritical and supercritical subreaches. Upstream profiles are computed with a starting water-surface elevation determined by slope conveyance; downstream profiles are computed with a critical-flow water-surface elevation at the initial section. This is reflected by the corresponding entries in the Q, SK, and EX records. The entries for the first profile reflect a discharge of 362.456 m^3/s (cubic meters per second), an energy gradient of 0.0037, and upstream computations (0 in the EX record). Likewise, the second set of entries reflect: (1) the same discharge; (2) critical flow to be computed at the initial section (negative slope, no water-surface elevation); and (3) downstream computations (1 in the EX record).

```
T1         Example 4:  Steep Creek near Nowhere, USA
*
*          SRD  SRDL  Q  YMIN  FR#  CRWS  WSEL  EGL
UT          8    37   7   11   27    28     5    25
*
SI 1
*
Q           362.456  362.456  396.436  396.436
SK           0.0037       -1   0.0037       -1
*
XS   XSEC1 30.480
GR          32.614,189.829   40.234,186.263   51.816,183.429   57.912,181.051
GR          75.590,179.984   82.601,179.984   89.306,179.862   94.488,179.984
GR          96.926,180.777  103.022,181.630  106.680,183.032
N           0.065   0.027   0.065
SA             51.816   112.166
*
XS   XSEC2 60.960
GR           43.891,189.616   55.474,184.556   62.484,181.508   66.751,180.929
GR           67.666,180.960   83.820,179.802   90.526,179.771   96.317,179.832
GR          105.156,180.015  108.814,180.960  117.043,184.130
SA          55.474   117.043
*
XS   XSEC3 91.440
GR           60.046,188.793   68.275,185.745   75.286,181.935   83.515,180.594
GR           84.125,179.984   89.611,179.923   92.964,179.680   96.622,179.558
GR           99.670,179.680  107.594,180.045  108.204,180.990  113.995,182.027
GR          119.786,184.221
SA          68.275   121.006
*
XS   XSEC4 121.920
GR           67.056,188.702   73.152,184.617   77.114,181.508   83.210,181.417
GR           84.125,180.685   89.916,180.624   95.098,180.624   96.012,180.137
GR           99.974,180.167  103.632,180.198  103.937,180.685  113.386,181.905
GR          118.567,184.526
SA          73.152   117.043
*
XS   XSEC5 165.811
GR           62.179,188.671   75.895,181.844   78.638,181.874   84.125,181.600
GR           89.611,181.539   95.098,181.539  100.279,181.447  105.766,181.813
GR          111.252,181.752  117.348,184.709
```

```
SA         75.895   111.343
*
XS   XSEC6 215.494
GR          66.142,189.555   71.018,186.995   75.286,185.136   81.382,182.514
GR          84.430,182.088   87.173,181.844   93.878,181.691   97.231,181.539
GR         101.498,181.539  105.766,181.844  114.910,182.088  115.824,185.440
SA         75.286   114.910
*
XS   XSEC7 245.974
GR          69.494,189.860   78.638,184.861   85.039,182.606   85.039,182.148
GR          88.392,182.057   90.830,181.722   97.231,181.600  100.279,181.478
GR         104.242,181.569  107.290,181.905  117.958,182.088  118.872,185.654
SA         78.638   117.958
*
EX         0  1  0  1
ER
```

Figure 7-12. Input data for upstream/downstream profile computations.

Figure 7-13 shows the output for the subcritical and supercritical profile computations for the 362.456 m^3/s discharge. The energy equation was successfully balanced at a subcritical water-surface elevation at XSEC2 and at XSEC3. When WSPRO cannot obtain a subcritical result at a section, it assumes that perhaps that section is a critical-flow section with supercritical flow between the critical-flow section and the next section downstream where subcritical flow was successfully computed. Thus WSPRO assumes a critical water-surface elevation (CRWS) at the section in question and attempts to balance the energy equation for a subcritical water-surface elevation at the next upstream section. The preceding was the case for XSEC4 through XSEC7 with the only success (subcritical result) occurring at XSEC7. The output for downstream computations (supercritical result) is presented on pages 213 through 215. When computing in the downstream direction, at any section where the energy equation cannot be balanced for supercritical flow, WSPRO again assumes the possibility of a critical-flow section. That is, it assumes CRWS at the section in question and attempts to balance the energy equation at the next downstream section. In this example, for CRWS at XSEC7, a supercritical result could not be obtained at XSEC6. However, for CRWS at XSEC6 a supercritical result could be obtained at XSEC5. WSPRO was also able to successfully balance the energy equation for supercritical flow from XSEC5 to XSEC4, XSEC4 to XSEC3, and XSEC3 to XSEC2. A supercritical water-surface elevation could not be computed at XSEC1.

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
        Run Date & Time:  9/10/97 12:54 pm     Version V070197
         Input File: EX4.DAT        Output File: EX4.LST
   *-----------------------------------------------------------------*
T1        EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA
UT         8    37   7   11   27    28     5    25
SI 1
                    Metric (SI) Units Used in WSPRO

               Quantity    SI Unit              Precision
             ------------ -------------------- -----------
              Length       meters                 0.001
              Depth        meters                 0.001
              Elevation    meters                 0.001
              Widths       meters                 0.001

              Velocity     meters/second          0.001
              Discharge    cubic meters/second    0.001
              Slope        meter/meter            0.001

              Angles       degrees                0.01
             ------------ -------------------- -----------

Q          362.456  362.456  396.436  396.436

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

SK          0.0037       -1   0.0037       -1
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
             EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

         *----------------------------------------------------*
         *      Starting To Process Header Record XSEC1      *
         *----------------------------------------------------*

XS   XSEC1 30.480
GR         32.614,189.829   40.234,186.263   51.816,183.429   57.912,181.051
GR       75.590,179.984   82.601,179.984   89.306,179.862   94.488,179.984

GR       96.926,180.777  103.022,181.630  106.680,183.032
N          0.065   0.027   0.065
SA            51.816   112.166

 ***   Completed Reading Data Associated With Header Record XSEC1   ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***              Data Summary For Header Record XSEC1              ***
 SRD Location:       30.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (11 pairs)
     X          Y             X          Y            X          Y
----------  ----------    ----------  ----------   ----------  ----------
    32.614     189.829       40.234     186.263       51.816     183.429
    57.912     181.051       75.590     179.984       82.601     179.984
    89.306     179.862       94.488     179.984       96.926     180.777
   103.022     181.630      106.680     183.032
----------  ----------    ----------  ----------   ----------  ----------

                    Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      32.614  ( associated Y-Elevation:  189.829 )
  Maximum X-Station:     106.680  ( associated Y-Elevation:  183.032 )
  Minimum Y-Elevation:   179.862  ( associated X-Station:     89.306 )
  Maximum Y-Elevation:   189.829  ( associated X-Station:     32.614 )

                      Roughness Data (  3 SubAreas )
                              Roughness    Horizontal
                    SubArea  Coefficient   Breakpoint
                    -------  -----------  ------------
                       1         .065         ---
                                 ---         51.816
                       2         .027         ---
                                 ---        112.166
                       3         .065         ---
                    -------  -----------  ------------

         *----------------------------------------------------*
         *      Finished Processing Header Record XSEC1      *
         *----------------------------------------------------*
```

```
************************* W S P R O ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*----------------------------------------------------------------*
          EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

      *---------------------------------------------------*
      *      Starting To Process Header Record XSEC2      *
      *---------------------------------------------------*

XS   XSEC2 60.960
GR          43.891,189.616   55.474,184.556   62.484,181.508   66.751,180.929
GR        67.666,180.960   83.820,179.802   90.526,179.771   96.317,179.832

GR       105.156,180.015  108.814,180.960  117.043,184.130
SA         55.474   117.043

 ***   Completed Reading Data Associated With Header Record XSEC2   ***
 ***  Storing X-Section Data In Temporary File As Record Number  2  ***

 ***             Data Summary For Header Record XSEC2               ***
 SRD Location:       61.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (11 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
    43.891     189.616       55.474     184.556       62.484     181.508
    66.751     180.929       67.666     180.960       83.820     179.802
    90.526     179.771       96.317     179.832      105.156     180.015
   108.814     180.960      117.043     184.130
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      43.891  ( associated Y-Elevation:  189.616 )
  Maximum X-Station:     117.043  ( associated Y-Elevation:  184.130 )
  Minimum Y-Elevation:   179.771  ( associated X-Station:     90.526 )
  Maximum Y-Elevation:   189.616  ( associated X-Station:     43.891 )

                   Roughness Data (  3 SubAreas )
                          Roughness    Horizontal
                 SubArea  Coefficient   Breakpoint
                 -------  -----------  ------------
                    1         .065         ---
                              ---          55.474
                    2         .027         ---
                              ---         117.043
                    3         .065         ---
                 -------  -----------  ------------

      *---------------------------------------------------*
      *      Finished Processing Header Record XSEC2      *
      *---------------------------------------------------*
```

```
*************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*-----------------------------------------------------------------*
          EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

      *---------------------------------------------------*
      *      Starting To Process Header Record XSEC3      *
      *---------------------------------------------------*

XS   XSEC3 91.440
GR         60.046,188.793   68.275,185.745   75.286,181.935   83.515,180.594
GR       84.125,179.984   89.611,179.923   92.964,179.680   96.622,179.558

GR       99.670,179.680  107.594,180.045  108.204,180.990  113.995,182.027

GR      119.786,184.221
SA        68.275   121.006

 ***   Completed Reading Data Associated With Header Record XSEC3   ***
 ***  Storing X-Section Data In Temporary File As Record Number  3  ***

 ***             Data Summary For Header Record XSEC3               ***
 SRD Location:       91.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (13 pairs)
     X          Y            X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
    60.046     188.793       68.275     185.745       75.286     181.935
    83.515     180.594       84.125     179.984       89.611     179.923
    92.964     179.680       96.622     179.558       99.670     179.680
   107.594     180.045      108.204     180.990      113.995     182.027
   119.786     184.221
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      60.046  ( associated Y-Elevation:  188.793 )
  Maximum X-Station:     119.786  ( associated Y-Elevation:  184.221 )
  Minimum Y-Elevation:   179.558  ( associated X-Station:     96.622 )
  Maximum Y-Elevation:   188.793  ( associated X-Station:     60.046 )

                    Roughness Data (  3 SubAreas )
                          Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .065         ---
                               ---         68.275
                     2         .027         ---
                               ---        121.006
                     3         .065         ---
                  -------  -----------  ------------

      *---------------------------------------------------*
      *      Finished Processing Header Record XSEC3      *
      *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
             EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

         *---------------------------------------------------*
         *      Starting To Process Header Record XSEC4      *
         *---------------------------------------------------*

XS   XSEC4 121.920
GR         67.056,188.702   73.152,184.617   77.114,181.508   83.210,181.417
GR       84.125,180.685   89.916,180.624   95.098,180.624   96.012,180.137

GR       99.974,180.167  103.632,180.198  103.937,180.685  113.386,181.905

GR      118.567,184.526
SA        73.152   117.043

 ***   Completed Reading Data Associated With Header Record XSEC4   ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***              Data Summary For Header Record XSEC4              ***
 SRD Location:      122.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (13 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
    67.056     188.702       73.152     184.617       77.114     181.508
    83.210     181.417       84.125     180.685       89.916     180.624
    95.098     180.624       96.012     180.137       99.974     180.167
   103.632     180.198      103.937     180.685      113.386     181.905
   118.567     184.526
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      67.056  ( associated Y-Elevation:  188.702 )
  Maximum X-Station:     118.567  ( associated Y-Elevation:  184.526 )
  Minimum Y-Elevation:   180.137  ( associated X-Station:     96.012 )
  Maximum Y-Elevation:   188.702  ( associated X-Station:     67.056 )

                    Roughness Data (  3 SubAreas )
                           Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .065         ---
                               ---         73.152
                     2         .027         ---
                               ---        117.043
                     3         .065         ---
                  -------  -----------  ------------

         *---------------------------------------------------*
         *      Finished Processing Header Record XSEC4      *
         *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
             EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

         *---------------------------------------------------*
         *      Starting To Process Header Record XSEC5      *
         *---------------------------------------------------*

XS   XSEC5 165.811
GR          62.179,188.671   75.895,181.844   78.638,181.874   84.125,181.600
GR        89.611,181.539   95.098,181.539  100.279,181.447  105.766,181.813

GR       111.252,181.752  117.348,184.709
SA         75.895   111.343

 ***   Completed Reading Data Associated With Header Record XSEC5   ***
 ***  Storing X-Section Data In Temporary File As Record Number  5  ***

 ***              Data Summary For Header Record XSEC5              ***
 SRD Location:      166.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (10 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
    62.179     188.671       75.895     181.844       78.638     181.874
    84.125     181.600       89.611     181.539       95.098     181.539
   100.279     181.447      105.766     181.813      111.252     181.752
   117.348     184.709
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      62.179  ( associated Y-Elevation:  188.671 )
  Maximum X-Station:     117.348  ( associated Y-Elevation:  184.709 )
  Minimum Y-Elevation:   181.447  ( associated X-Station:    100.279 )
  Maximum Y-Elevation:   188.671  ( associated X-Station:     62.179 )

                    Roughness Data (  3 SubAreas )
                          Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1        .065         ---
                              ---         75.895
                     2        .027         ---
                              ---        111.343
                     3        .065         ---
                  -------  -----------  ------------

         *---------------------------------------------------*
         *      Finished Processing Header Record XSEC5      *
         *---------------------------------------------------*
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *-----------------------------------------------------------------*
             EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

         *----------------------------------------------------*
         *      Starting To Process Header Record XSEC6      *
         *----------------------------------------------------*

XS   XSEC6 215.494
GR          66.142,189.555   71.018,186.995   75.286,185.136   81.382,182.514
GR        84.430,182.088   87.173,181.844   93.878,181.691   97.231,181.539

GR       101.498,181.539  105.766,181.844  114.910,182.088  115.824,185.440

SA         75.286   114.910

 ***   Completed Reading Data Associated With Header Record XSEC6   ***
 ***  Storing X-Section Data In Temporary File As Record Number  6  ***

 ***              Data Summary For Header Record XSEC6              ***
 SRD Location:      215.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (12 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
    66.142     189.555       71.018     186.995       75.286     185.136
    81.382     182.514       84.430     182.088       87.173     181.844
    93.878     181.691       97.231     181.539      101.498     181.539
   105.766     181.844      114.910     182.088      115.824     185.440
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      66.142  ( associated Y-Elevation:  189.555 )
  Maximum X-Station:     115.824  ( associated Y-Elevation:  185.440 )
  Minimum Y-Elevation:   181.539  ( associated X-Station:    101.498 )
  Maximum Y-Elevation:   189.555  ( associated X-Station:     66.142 )

                     Roughness Data (  3 SubAreas )
                             Roughness    Horizontal
                   SubArea  Coefficient   Breakpoint
                   -------  -----------  ------------
                      1         .065         ---
                                ---         75.286
                      2         .027         ---
                                ---        114.910
                      3         .065         ---
                   -------  -----------  ------------

         *----------------------------------------------------*
         *      Finished Processing Header Record XSEC6      *
         *----------------------------------------------------*
```

```
     ************************  W S P R O  **************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
               EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

           *---------------------------------------------------*
           *      Starting To Process Header Record XSEC7      *
           *---------------------------------------------------*

  XS   XSEC7 245.974
  GR          69.494,189.860   78.638,184.861   85.039,182.606   85.039,182.148
  GR        88.392,182.057   90.830,181.722   97.231,181.600  100.279,181.478

  GR       104.242,181.569  107.290,181.905  117.958,182.088  118.872,185.654

  SA         78.638   117.958

   ***   Completed Reading Data Associated With Header Record XSEC7   ***
+++072 NOTICE:  X-coordinate # 4 increased to eliminate vertical segment.
   ***  Storing X-Section Data In Temporary File As Record Number  7  ***

   ***             Data Summary For Header Record XSEC7              ***
   SRD Location:      246.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                       X,Y-coordinates (12 pairs)
       X          Y             X          Y            X          Y
  ----------  ----------   ----------  ----------   ----------  ----------
      69.494     189.860       78.638     184.861       85.039     182.606
      85.139     182.148       88.392     182.057       90.830     181.722
      97.231     181.600      100.279     181.478      104.242     181.569
     107.290     181.905      117.958     182.088      118.872     185.654
  ----------  ----------   ----------  ----------   ----------  ----------

                   Minimum and Maximum X,Y-coordinates
    Minimum X-Station:      69.494  ( associated Y-Elevation:  189.860 )
    Maximum X-Station:     118.872  ( associated Y-Elevation:  185.654 )
    Minimum Y-Elevation:   181.478  ( associated X-Station:    100.279 )
    Maximum Y-Elevation:   189.860  ( associated X-Station:     69.494 )

                      Roughness Data (  3 SubAreas )
                          Roughness    Horizontal
                    SubArea  Coefficient   Breakpoint
                    -------  -----------  ------------
                       1        .065          ---
                                ---          78.638
                       2        .027          ---
                                ---         117.958
                       3        .065          ---
                    -------  -----------  ------------

           *---------------------------------------------------*
           *      Finished Processing Header Record XSEC7      *
           *---------------------------------------------------*
```

```
        *************************  W S P R O  ***************************
           Federal Highway Administration  -  U. S. Geological Survey
                  Model for Water-Surface Profile Computations.
                  Input Units: Metric  /  Output Units: Metric
        *----------------------------------------------------------------*
                  EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA
    EX          0  1  0  1

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

               Reach      Water Surface   Friction
         #   Discharge      Elevation      Slope        Flow Regime
        --   ---------    -------------   --------   --------------------
         1      362.46      ********        .0037       Sub-Critical
         2      362.46      ********       ******      Super-Critical
         3      396.44      ********        .0037       Sub-Critical
         4      396.44      ********       ******      Super-Critical
        --   ---------    -------------   --------   --------------------

             *====================================================*
             *        Beginning  4 Profile Calculation(s)         *
             *====================================================*
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
               EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

                  << Beginning Computations for Profile  1 >>

                     WSEL    VHD       Q         AREA      SRDL      LEW
                     EGEL     HF       V          K        FLEN      REW
                     CRWS     HO      FR #        SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section: XSEC1    182.544   .639    362.456    102.372 *********    54.082
 Header Type: XS   183.184 ******      3.540    5956.34 *********   105.409
 SRD:     30.480   182.249 ******       .801     ******     1.000    ******

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "XSEC2".
       KRATIO:  1.40

 Section: XSEC2    182.858   .406    362.456    128.469    30.480    59.377
 Header Type: XS   183.264   .080      2.821    8356.57    30.480   113.742
 SRD:     60.960   182.086   .000       .586      .0026     1.000     -.001

===125 FR# EXCEEDS FNTEST AT SECID "XSEC3":  TRIALS CONTINUED.
       FNTEST, FR#, WSEL, CRWS:   .80     .84     182.76     182.49

===110 WSEL NOT FOUND AT SECID "XSEC3":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   182.49     188.79     .05

===115 WSEL NOT FOUND AT SECID "XSEC3":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   182.49     188.79     182.49

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "XSEC3".
       KRATIO:   .68

 Section: XSEC3    182.757   .774    362.456     93.019    30.479    73.771
 Header Type: XS   183.532   .083      3.896    5719.86    30.479   115.924
 SRD:     91.440   182.488   .184       .838      .0027     1.000      .000

===110 WSEL NOT FOUND AT SECID "XSEC4":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   183.02     188.70     .05

===115 WSEL NOT FOUND AT SECID "XSEC4":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   183.02     188.70     183.02

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC4".
       WSBEG, WSEND, CRWS:   183.02     188.70     183.02

 Section: XSEC4    183.022  1.010    362.456     81.438    30.480    75.183
 Header Type: XS   184.033 ******      4.450    4695.78    30.480   115.594
 SRD:    121.920   183.022 ******      1.001      .0005     1.000    ******

===110 WSEL NOT FOUND AT SECID "XSEC5":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   183.82     188.67     .05

===115 WSEL NOT FOUND AT SECID "XSEC5":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   183.82     188.67     183.82

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC5".
       WSBEG, WSEND, CRWS:   183.82     188.67     183.82

 Section: XSEC5    183.822  1.047    362.456     85.384    43.891    71.918
```

```
 Header Type: XS    184.870 ******       4.244    4920.27    43.891   115.521
 SRD:    165.811    183.822 ******       1.034      .0008     1.139    ******

===110 WSEL NOT FOUND AT SECID "XSEC6":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   184.11     189.55     .05

===115 WSEL NOT FOUND AT SECID "XSEC6":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   184.11     189.55     184.11

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC6".
       WSBEG, WSEND, CRWS:   184.11     189.55     184.11

 Section: XSEC6     184.111  1.061     362.456     79.928    49.682    77.668
 Header Type: XS    185.172 ******       4.534    4838.67    49.682   115.461
 SRD:    215.493    184.111 ******       1.002      .0006     1.012    ******

 Section: XSEC7     184.587   .711     362.456     97.768    30.480    79.413
 Header Type: XS    185.298   .126       3.707    6563.61    30.480   118.598
 SRD:    245.974    184.119   .000        .755      .0041     1.014      .000

                 << Completed Computations of Profile  1 >>
```

```
************************  W S P R O  **************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*---------------------------------------------------------------*
          EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA
```

=== User Defined Table 1 of 1 ===

	SRD	SRDL	Q	XMIN	FR #	CRWS	WSEL
1 XSEC1	30.480	*********	362.456	32.613	.801	182.249	182.544
2 XSEC2	60.960	30.480	362.456	43.890	.586	182.086	182.858
3 XSEC3	91.440	30.479	362.456	60.045	.838	182.488	182.757
4 XSEC4	121.920	30.480	362.456	67.056	1.001	183.022	183.022
5 XSEC5	165.811	43.891	362.456	62.178	1.034	183.822	183.822
6 XSEC6	215.493	49.682	362.456	66.141	1.002	184.111	184.111
7 XSEC7	245.974	30.480	362.456	69.493	.755	184.119	184.587

	EGL
1 XSEC1	183.184
2 XSEC2	183.264
3 XSEC3	183.532
4 XSEC4	184.033
5 XSEC5	184.870
6 XSEC6	185.172
7 XSEC7	185.298

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
               EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

                  << Beginning Computations for Profile  2 >>
===100 WSI BELOW YMIN AT SECID "XSEC7":  SETTING WSI = CRWS.
       YMIN, WSI, CRWS:    181.5   ********     184.12


                      WSEL    VHD       Q         AREA      SRDL      LEW
                      EGEL     HF       V          K        FLEN      REW
                      CRWS     HO      FR #        SF       ALPHA     ERR
                   --------- ------ ---------- ---------- --------- ---------
 Section: XSEC7     184.119  1.065    362.456     79.762 *********   80.742
 Header Type: XS    185.185 ******      4.544    4802.12 *********  118.478
 SRD:    245.974    184.119 ******      1.004     ******     1.011   ******

===115 WSEL NOT FOUND AT SECID "XSEC6":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   184.11     181.60     184.11

===110 WSEL NOT FOUND AT SECID "XSEC6":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   184.11     181.60    -.05

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC6".
       WSBEG, WSEND, CRWS:  184.11     181.60     184.11

 Section: XSEC6     184.111  1.061    362.456     79.928   -30.480   77.668
 Header Type: XS    185.172 ******      4.534    4838.67    30.480  115.461
 SRD:    215.493    184.111 ******      1.002     ******     1.012   ******

===115 WSEL NOT FOUND AT SECID "XSEC5":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   183.82     181.51     183.82

 Section: XSEC5     183.730  1.146    362.456     81.351   -49.682   72.105
 Header Type: XS    184.876   .295      4.455    4569.79    49.682  115.330
 SRD:    165.811    183.822   .000      1.104      .0059     1.132     .003

===115 WSEL NOT FOUND AT SECID "XSEC4":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   183.02     180.20     183.02

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "XSEC4".
       KRATIO:   .61

 Section: XSEC4     182.428  1.992    362.456     58.002   -43.891   75.940
 Header Type: XS    184.420   .455      6.248    2768.52    43.891  114.420
 SRD:    121.920    183.022   .000      1.625      .0104     1.000     .001

===115 WSEL NOT FOUND AT SECID "XSEC3":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   182.49     179.62     182.49

 Section: XSEC3     181.871  2.029    362.456     57.475   -30.480   75.672
 Header Type: XS    183.901   .519      6.306    2784.20    30.480  113.129
 SRD:     91.440    182.488   .000      1.626      .0170     1.000     .001

===115 WSEL NOT FOUND AT SECID "XSEC2":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   182.09     179.83     182.09

 Section: XSEC2     181.653  1.515    362.456     66.501   -30.479   62.149
 Header Type: XS    183.168   .475      5.450    3026.55    30.479  110.613
 SRD:     60.960    182.086   .256      1.486      .0156     1.000     .001
```

```
===115 WSEL NOT FOUND AT SECID "XSEC1":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   182.25     179.92     182.25

===110 WSEL NOT FOUND AT SECID "XSEC1":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   182.25     179.92    -.05

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC1".
       WSBEG, WSEND, CRWS:   182.25     179.92     182.25

 Section: XSEC1     182.249   .877    362.456     87.418   -30.480    54.840
 Header Type: XS    183.126 ******      4.146    4676.89    30.480   104.637
 SRD:     30.480    182.249 ******       .999     ******     1.000    ******

                  << Completed Computations of Profile  2 >>
```

```
  ************************  W S P R O  **************************
     Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
            Input Units: Metric  /  Output Units: Metric
  *-------------------------------------------------------------*
            EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA

                     === User Defined Table 1 of 1 ===

               SRD      SRDL        Q        XMIN      FR #      CRWS      WSEL
            --------- --------- --------- --------- --------- --------- ---------
 1 XSEC7     245.974 *********   362.456    69.493     1.004   184.119   184.119
 2 XSEC6     215.493   -30.480   362.456    66.141     1.002   184.111   184.111
 3 XSEC5     165.811   -49.682   362.456    62.178     1.104   183.822   183.730
 4 XSEC4     121.920   -43.891   362.456    67.056     1.625   183.022   182.428
 5 XSEC3      91.440   -30.480   362.456    60.045     1.626   182.488   181.871
 6 XSEC2      60.960   -30.479   362.456    43.890     1.486   182.086   181.653
 7 XSEC1      30.480   -30.480   362.456    32.613      .999   182.249   182.249

               EGL
            ---------
 1 XSEC7     185.185
 2 XSEC6     185.172
 3 XSEC5     184.876
 4 XSEC4     184.420
 5 XSEC3     183.901
 6 XSEC2     183.168
 7 XSEC1     183.126
```

Figure 7-13. Output for upstream/downstream profile computations.

The appropriate segments of each profile must be pieced together to form a hydraulically valid profile for the reach. It can be assumed that the subcritical initial water-surface elevation at XSEC1 is valid inasmuch as it yielded successful subcritical computations upstream and a supercritical result could not be obtained in the downstream computations. An assumption that XSEC6 is a critical-flow section can be supported based on the fact that for CRWS it yielded successful computations in both upstream and downstream directions (i.e., supercritical result at XSEC5 and subcritical result at XSEC7). Perhaps further proof of this should be obtained by attempting lower (supercritical) starting conditions at XSEC7 in downstream computations to disprove the possibility of supercritical flow at XSEC6. If XSEC6 is a critical-flow section, the subcritical result at XSEC7 appears valid. It also seems quite certain, based on the "failure" of upstream computations and the "success" of downstream computations, that a supercritical profile is valid for XSEC5 and XSEC4.

A choice must then be made between two "valid" answers at both XSEC2 and XSEC3. Based on the highest energy-grade-line elevation, it can be assumed that subcritical flow occurs at XSEC2 and supercritical flow occurs at XSEC3. Based on the relatively low Froude numbers at these sections, it could further be assumed that the transition from supercritical flow at XSEC3 and subcritical flow at XSEC2 is in the form of a relatively weak hydraulic jump.

7.5 EXAMPLE #5: USER-DEFINED TABLES

Figure 7-14 shows the user-defined tables generated with the computed profiles of the previous section. User-defined tables are requested using the UT record. These tables are output immediately following their associated profile output. They were separated from that output and placed in Figure 7-14 to facilitate discussion. User-defined tables are created by using one (or more) UT record(s) as explained in Table 4-39 and Section 5. The series of numbers in the free-format area of the UT record represents a single "list" of parameter numbers (PARNOS) to generate one user-defined table. A second user-defined table could have been generated for each profile by coding an asterisk and another "list" of PARNOS following the existing "list" of PARNOS (and a third user-defined table by coding another asterisk and a third "list" of PARNOS following the second "list" of PARNOS).

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
           Run Date & Time:  9/10/97 12:54 pm     Version V070197
            Input File: EX4.DAT        Output File: EX4.LST
      *---------------------------------------------------------------*
   T1        EXAMPLE 4:  STEEP CREEK NEAR NOWHERE, USA
   UT         8    37   7   11   27    28     5    25


---------------------Section of output deleted------------------------------


                         === User Defined Table 1 of 1 ===

                SRD      SRDL        Q       XMIN      FR #      CRWS      WSEL
            --------- --------- --------- --------- --------- --------- ---------
 1 XSEC1      30.480 *********  362.456    32.613      .801   182.249   182.544
 2 XSEC2      60.960    30.480  362.456    43.890      .586   182.086   182.858
 3 XSEC3      91.440    30.479  362.456    60.045      .838   182.488   182.757
 4 XSEC4     121.920    30.480  362.456    67.056     1.001   183.022   183.022
 5 XSEC5     165.811    43.891  362.456    62.178     1.034   183.822   183.822
 6 XSEC6     215.493    49.682  362.456    66.141     1.002   184.111   184.111
 7 XSEC7     245.974    30.480  362.456    69.493      .755   184.119   184.587

                EGL
            ---------
 1 XSEC1     183.184
 2 XSEC2     183.264
 3 XSEC3     183.532
 4 XSEC4     184.033
 5 XSEC5     184.870
 6 XSEC6     185.172
 7 XSEC7     185.298


---------------------Section of output deleted------------------------------
```

```
                       === User Defined Table 1 of 1 ===

                SRD      SRDL        Q       XMIN      FR #      CRWS      WSEL
             --------- --------- --------- --------- --------- --------- ---------
 1 XSEC7     245.974 *********   362.456    69.493     1.004   184.119   184.119
 2 XSEC6     215.493   -30.480   362.456    66.141     1.002   184.111   184.111
 3 XSEC5     165.811   -49.682   362.456    62.178     1.104   183.822   183.730
 4 XSEC4     121.920   -43.891   362.456    67.056     1.625   183.022   182.428
 5 XSEC3      91.440   -30.480   362.456    60.045     1.626   182.488   181.871
 6 XSEC2      60.960   -30.479   362.456    43.890     1.486   182.086   181.653
 7 XSEC1      30.480   -30.480   362.456    32.613      .999   182.249   182.249

                EGL
             ---------
 1 XSEC7     185.185
 2 XSEC6     185.172
 3 XSEC5     184.876
 4 XSEC4     184.420
 5 XSEC3     183.901
 6 XSEC2     183.168
 7 XSEC1     183.126


----------------------Remainder of output deleted-----------------------------
```

Figure 7-14. User-defined tables.

User-defined tables summarize results in downstream to upstream progression regardless of computational direction. The second parameter selected, SRDL, is the section reference distance (SRD) difference between adjacent sections. Thus, positive values indicate upstream computations and negative values indicate downstream computations. The other parameters selected are pertinent to desirable plotting variables or otherwise associated with determining the "valid" segments of the upstream/downstream profile computations.

7.6 EXAMPLE #6: CODING OF DISCHARGE DATA AND DISPLAY COMMANDS

Placement of additional Q data to account for changing discharge(s) along a reach and HP record to obtain properties and (or) plots of sections is subject to specific rules of "order dependence" (unlike most of the record types for this model). However, despite the "order dependence," alternative coding schemes exist. The following illustrations are considerably shortened by eliminating most of the detail of associated record types.

The following examples are based on a reach of stream having five sections with SECID's of XSECA through XSECE. A tributary stream enters the stream reach being modeled between XSECB and XSECC. Hydrologic analyses indicate that for discharges of 141.6 and 99.12 m^3/s at XSECA, the tributary stream contributes 28.32 and 19.82 m^3/s, thus dictating the need to specify discharges of 113.28 and 79.30 m^3/s at XSECC.

Figure 7-15a illustrates one alternative for coding the necessary discharge data. Q data that precede all cross-section data are assigned to the most downstream section. New discharge data may be coded with the cross-section data for the section at which the discharge changes. When coded in this fashion, no SECID is required in the Q record(s) that reflect the new discharge data. However, this Q data must follow all cross-section data (GR, N, ND, SA, and FL records) section at which the new discharge data are introduced.

Figure 7-15b presents a second alternative for coding the appropriate Q data. Q data for the initial section is coded as in the preceding discussion. The Q record(s) for the new discharge data required at XSECC (with the SECID) may be introduced any time after XSECC has been input (but not interspersed with any cross-section data). Most logically this would be immediately prior to the EX record as shown.

Figure 7-15c indicates that all Q data, appropriately identified with the applicable SECID, can be introduced after the involved cross-section data have been input. Again, the most logical placement would be immediately prior to the EX record. This latter alternative permits "grouping" of the Q data so that if any modification(s) and (or) additions/deletions are required, all Q data are readily displayed for revision(s). This can be highly advantageous because, of course, each "set" of Q data must have a consistent number of corresponding entries.

```
Q         141.60  99.12
XS  XSECA  srd_A, [,as needed]
__             [ GR, N, ND, and SA data as appropriate ]
XS  XSECB  srd_B, [,as needed]
__            [  GR, N, ND, SA, and FL data as appropriate ]
XS  XSECC  srd_C, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
Q         113.28  79.30
XS  XSECD  srd_D, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
XS  XSECE  srd_E, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
EX

      a) new discharge data coded with cross-section data

Q         141.60  99.12
XS  XSECA  srd_A, [,as needed]
__             [ GR, N, ND, and SA data as appropriate ]
XS  XSECB  srd_B, [,as needed]
__            [  GR, N, ND, SA, and FL data as appropriate ]
XS  XSECC  srd_C, [as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
XS  XSECD  srd_D, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
XS  XSECE  srd_E, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
Q   XSECC 113.28  79.30
EX

      b) new discharge data coded with cross-section data

XS  XSECA  srd_A, [,as needed]
__             [ GR, N, ND, and SA data as appropriate ]
XS  XSECB  srd_B, [,as needed]
__            [  GR, N, ND, SA, and FL data as appropriate ]
XS  XSECC  srd_C, [as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
XS  XSECD  srd_D, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
XS  XSECE  srd_E, [,as needed]
__            [ GR, N, ND, SA, and FL data as appropriate ]
Q   XSECA  141.60  99.12
Q   XSECC  113.28  79.30
EX
      c) all discharge data coded after all cross-section data
```

Figure 7-15. Alternatives for coding discharge data.

HP records placement follows the same rules as Q record placement, except there is no analogy for an "unidentified" HP record preceding all cross-section data as there is with Q data. HP records may be included with the data of the section(s) of interest, with no SECID required but following all GR, N, ND, SA, and FL data associated with the individual section(s). Alternatively, they may be "grouped," with SECID's, any time after the data for the pertinent section(s) have been input (again, most logically placed immediately prior to the EX record as per the Q records in Figure 7-15c). This latter convention permits ready display of all such records for: (1) any required modification(s); and (or) (2) deletion of some or all of such records if and when the user no longer needs that particular output.

7.7 EXAMPLE #7: CROSS-SECTIONAL PROPERTIES

Three different forms of cross-sectional properties are available as optional WSPRO output. Two forms of hydraulic-properties (e.g., area, conveyance, wetted perimeter, etc.) tables are available for a range of elevations with a specified (or default) elevation increment. One of these tables summarizes hydraulic properties for the total section; the second table provides a subarea breakdown of the same hydraulic properties. A third variation of cross-sectional properties can be obtained in the form of velocity and conveyance distribution in any section (except road-grade sections). All of these optional outputs can be obtained along with profile computations or generated separately with abbreviated input data. The following examples use the latter option.

7.7.1 Hydraulic Properties for Total Section

Data from the surveyed section in example #3 are used to illustrate the hydraulic-properties output that can be obtained using HP records. Table 4-28 should be consulted for HP record details. Figure 7-16 shows hydraulic-properties output for the total section for a range of elevations from 138.25 to 140.5 in increments of 0.15 m as reflected by the HP record. IHP has been assigned a value of zero.

```
T1        Example 3:  Examples  of  Input & Output  for  WSPRO Computer Model
T2        FHWA/USGS  Model  for  Water-surface  Profile  Computations
T3        <<<<<  Transfer  Known  Rating  to  Upstream  Sections  >>>>>
*
SI 1
*
Q           127.426
WS          139.394
*
XT   SURVY 762.000
GR           0.000,141.732    0.000,140.513    7.010,139.842    10.973,139.598
GR          13.716,139.537   16.764,139.690   30.175,139.720    33.528,138.958
GR          36.271,138.928   40.538,138.836   43.586,138.775    45.720,138.806
GR          46.939,138.379   47.244,137.770   48.768,137.251    51.206,137.221
GR          57.302,137.312   58.826,137.617   60.960,137.983    62.484,138.532
GR          64.008,138.775   69.799,138.867   78.638,138.775    81.077,139.080
GR          84.125,139.598   92.964,139.537  104.851,139.598   115.824,140.513
GR         115.824,141.732
*
XS    GAGE 304.800
GT         -0.671
N          0.055,0.050  0.065,0.060  0.040,0.040
N                0.065,0.060  0.055,0.050
SA           30.175  45.720  64.008  84.125
ND         0.305,0.914  0.610,1.524  0.000,0.305
ND               0.305, 1.219  0.305, 0.914
*
XS     XS2 457.200  *  *  *  0.0020
XS     XS3 609.600  *  *  *  0.0012
XS    EXIT 720.852
XS   FULLV 757.428
XS    APPR 803.148
*
HP 0 FULLV 138.379  0.3048  140.818
HP 1 FULLV 138.379  0.3048  140.818
HP 2 FULLV 138.379  0.3048  140.818  127.426
```

```
*
EX
ER

-------------------------Section of output deleted-------------------------

      *************************  W S P R O  ****************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *---------------------------------------------------------------*
   EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

    ***    Compute Cross-Section Properties For Header Record FULLV   ***
            SRD Location:    757.428       Header Record Number  5

  Water     Cross      Cross                       Bank Station
  Surface   Section    Section  Top    Wetted   ------------  Hydrlic  Critical
  Elevation Conveyance Area(s) Width    Pmtr     Left  Right   Depth     Flow
  --------- ---------- ------- ------ ------- ------ ------ ------- ---------
    138.379     320.60     14.   15.2   15.75   46.9   62.1    .919     41.81
    138.684     483.93     19.   17.4   18.11   46.1   63.5   1.082     61.41
    138.989     738.96     29.   47.0   47.76   33.4   80.4    .611     62.11
    139.293    1133.98     44.   50.3   51.13   32.0   82.4    .866    102.82
    139.598    1639.75     60.   78.4   79.27   10.9  104.9    .769    129.54
    139.903    2368.13     89.  102.3  103.15    6.3  108.6    .869    189.61
    140.208    3360.19    121.  109.1  109.97    3.2  112.2   1.110    293.80
    140.512    4592.25    155.  115.7  116.68     .1  115.8   1.342    426.20
    140.817    6096.56    191.  115.8  117.29     .1  115.8   1.646    603.61
    140.818    6099.71    191.  115.8  117.29     .1  115.8   1.647    603.99
  --------- ---------- ------- ------ ------- ------ ------ ------- ---------


-------------------------Section of output deleted-------------------------
```

Figure 7-16. Table of hydraulic properties; total cross-section (IHP=0).

7.7.2 Hydraulic Properties by Subarea

By coding IHP = 1, the same data will generate an expanded table that includes a breakdown of the hydraulic properties by subarea. Figure 7-17 shows parts of this expanded table.

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *-----------------------------------------------------------------*
   EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

    ***    Compute Cross-Section Properties For Header Record FULLV    ***
            SRD Location:    757.428       Header Record Number  5

 Water     S  Cross      Cross                  Bank Station
 Surface   A  Section    Section  Top   Wetted  ------------  Hydrlic  Critical
 Elevation #  Conveyance Area(s) Width   Pmtr    Left  Right   Depth     Flow
 --------- -- ---------- ------- ------ ------- ------ ------ ------- ---------
            3     320.60     14.   15.2  15.75                   .919     41.81
   138.379        320.60     14.   15.2  15.75   46.9   62.1     .919     41.81
            Velocity Head Correction Factor (alpha): 1.000

            3     483.93     19.   17.4  18.11                  1.082     61.41
   138.684        483.93     19.   17.4  18.11   46.1   63.5   1.082     61.41
            Velocity Head Correction Factor (alpha): 1.000

            2       6.54      2.   12.4  12.36                   .132      1.87
            3     719.69     24.   18.3  19.00                  1.333     88.18
            4      12.73      3.   16.4  16.40                   .167      3.50
   138.989        738.96     29.   47.0  47.76   33.4   80.4     .611     62.11
            Velocity Head Correction Factor (alpha): 1.285

            2      47.46      6.   13.7  13.73                   .409     11.24
            3    1014.37     30.   18.3  19.00                  1.638    120.09
            4      72.15      8.   18.4  18.40                   .438     16.69
   139.293       1133.98     44.   50.3  51.13   32.0   82.4     .866    102.82
            Velocity Head Correction Factor (alpha): 1.529

            1        .28      0.    4.2   4.18                   .035       .08
            2     117.08     10.   15.0  15.11                   .664     25.49
            3    1348.13     36.   18.3  19.00                  1.943    155.13
            4     172.75     14.   20.1  20.18                   .692     36.26
            5       1.52      1.   20.8  20.80                   .036       .45
   139.598       1639.75     60.   78.4  79.27   10.9  104.9     .769    129.54
            Velocity Head Correction Factor (alpha): 1.638

            1      35.82      5.   23.9  23.87                   .224      7.92
            2     223.22     15.   15.5  15.63                   .945     44.75
            3    1718.79     41.   18.3  19.00                  2.247    193.03
            4     326.08     20.   20.1  20.18                   .997     62.70
            5      64.22      8.   24.5  24.47                   .313     13.42
   139.903       2368.13     89.  102.3 103.15    6.3  108.6     .869    189.61
            Velocity Head Correction Factor (alpha): 1.872

            1     150.91     13.   27.0  27.02                   .485     28.57
            2     365.31     19.   15.5  15.63                  1.250     68.06
            3    2124.61     47.   18.3  19.00                  2.552    233.61
            4     519.03     26.   20.1  20.18                  1.301     93.56
            5     200.34     16.   28.1  28.14                   .557     36.64
   140.208       3360.19    121.  109.1 109.97    3.2  112.2   1.110    293.80
            Velocity Head Correction Factor (alpha): 1.849

            1     340.83     22.   30.1  30.12                   .725     58.14
            2     538.65     24.   15.5  15.63                  1.555     94.42
            3    2564.11     52.   18.3  19.00                  2.857    276.68
            4     737.07     32.   20.1  20.18                  1.606    128.29
            5     411.59     25.   31.7  31.74                   .782     68.68
```

```
  140.512       4592.25    155.  115.7  116.68     .1  115.8   1.342    426.20
          Velocity Head Correction Factor (alpha): 1.749
--------- -- ---------- ------- ------ ------- ------ ------ ------- ---------
```

```
      ************************  W S P R O  **************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *-------------------------------------------------------------*
   EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

    ***    Compute Cross-Section Properties For Header Record FULLV   ***
            SRD Location:    757.428       Header Record Number  5

 Water     S  Cross      Cross                     Bank Station
 Surface   A  Section    Section  Top   Wetted  ------------  Hydrlic  Critical
 Elevation #  Conveyance Area(s) Width   Pmtr    Left  Right   Depth     Flow
 --------- -- ---------- ------- ------ ------- ------ ------ ------- ---------
            1     626.70     31.   30.1   30.43                  1.029     98.41
            2     725.90     29.   15.5   15.63                  1.860    123.50
            3    3036.06     58.   18.3   19.00                  3.162    322.12
            4     984.64     38.   20.1   20.18                  1.911    166.49
            5     723.26     34.   31.7   32.05                  1.086    112.50
   140.817       6096.56    191.  115.8  117.29     .1  115.8   1.646    603.61
            Velocity Head Correction Factor (alpha): 1.611

            1     627.31     31.   30.1   30.43                  1.029     98.50
            2     726.30     29.   15.5   15.63                  1.860    123.56
            3    3037.03     58.   18.3   19.00                  3.162    322.21
            4     985.16     38.   20.1   20.18                  1.912    166.57
            5     723.92     34.   31.7   32.05                  1.087    112.59
   140.818       6099.71    191.  115.8  117.29     .1  115.8   1.647    603.99
            Velocity Head Correction Factor (alpha): 1.611
 --------- -- ---------- ------- ------ ------- ------ ------ ------- ---------
```

Figure 7-17. Table of hydraulic properties; subarea breakdown (IHP=1).

7.7.3 Velocity and Conveyance Distribution

Velocity and conveyance distribution(s) for the same data can be obtained by coding IHP = 2. Sample results are illustrated in Figure 7-18.

```
     *********************** W S P R O ************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------*
  EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

   ***     Beginning Velocity Distribution For Header Record FULLV    ***
           SRD Location:    757.428       Header Record Number  5

        Water Surface Elevation:    138.379            Element # 1
        Flow:     127.426   Velocity:  9.15  Hydraulic Depth:    .919
        Cross-Section Area:      13.92        Conveyance:      320.60
           Bank Stations ->  Left:     46.922   Right:     62.076

 X STA.        46.9       48.4       49.0       49.6       50.1       50.6
   A( I )             1.0         .7         .6         .6         .6
   V( I )            6.45       9.00       9.91      10.44      10.44
   D( I )             .69       1.09       1.14       1.15       1.15

 X STA.        50.6       51.2       51.7       52.2       52.7       53.2
   A( I )              .6         .6         .6         .6         .6
   V( I )           10.52      10.63      10.65      10.47      10.54
   D( I )            1.16       1.16       1.15       1.15       1.14

 X STA.        53.2       53.8       54.3       54.9       55.5       56.1
   A( I )              .6         .6         .6         .6         .7
   V( I )           10.42      10.17      10.29      10.03       9.75
   D( I )            1.13       1.12       1.11       1.10       1.10

 X STA.        56.1       56.7       57.3       58.1       59.2       62.1
   A( I )              .7         .7         .8         .9        1.2
   V( I )            9.46       9.27       8.27       7.42       5.26
   D( I )            1.09       1.08        .99        .81        .42

        Water Surface Elevation:    138.684            Element # 2
        Flow:     127.426   Velocity:  6.76  Hydraulic Depth:   1.082
        Cross-Section Area:      18.85        Conveyance:      483.93
           Bank Stations ->  Left:     46.051   Right:     63.473

 X STA.        46.1       48.3       49.0       49.6       50.2       50.7
   A( I )             1.5        1.0         .9         .8         .8
   V( I )            4.24       6.70       7.21       7.65       7.72
   D( I )             .66       1.39       1.45       1.45       1.46

 X STA.        50.7       51.3       51.8       52.4       52.9       53.5
   A( I )              .8         .8         .8         .8         .8
   V( I )            8.01       7.99       8.16       8.01       8.06
   D( I )            1.47       1.46       1.46       1.45       1.44

 X STA.        53.5       54.0       54.6       55.2       55.8       56.4
   A( I )              .8         .8         .8         .8         .9
   V( I )            7.95       7.75       7.83       7.62       7.40
   D( I )            1.43       1.42       1.41       1.40       1.40

 X STA.        56.4       57.0       57.7       58.6       59.7       63.5
   A( I )              .9         .9        1.0        1.2        1.7
   V( I )            7.17       6.92       6.15       5.45       3.65
   D( I )            1.39       1.35       1.21       1.02        .46
```

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *-------------------------------------------------------------------*
   EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

    ***     Beginning Velocity Distribution For Header Record FULLV     ***
            SRD Location:    757.428       Header Record Number  5

         Water Surface Elevation:    138.989              Element # 3
         Flow:     127.426   Velocity:  4.43  Hydraulic Depth:    .611
         Cross-Section Area:     28.75        Conveyance:     738.96
            Bank Stations ->  Left:     33.367   Right:     80.394

 X STA.        33.4       47.9       48.8       49.4       50.1       50.7
   A( I )              3.3        1.4        1.1        1.1        1.1
   V( I )             1.92       4.61       5.55       5.55       5.92
   D( I )              .23       1.60       1.75       1.76       1.76

 X STA.        50.7       51.3       51.9       52.5       53.1       53.7
   A( I )              1.1        1.0        1.0        1.1        1.1
   V( I )             5.86       6.08       6.08       5.97       6.00
   D( I )             1.77       1.77       1.76       1.75       1.74

 X STA.        53.7       54.4       55.0       55.6       56.3       57.0
   A( I )              1.1        1.1        1.1        1.1        1.2
   V( I )             5.85       5.88       5.84       5.68       5.51
   D( I )             1.73       1.72       1.71       1.70       1.69

 X STA.        57.0       57.7       58.5       59.5       61.0       80.4
   A( I )              1.2        1.2        1.4        1.7        4.3
   V( I )             5.40       5.10       4.54       3.82       1.48
   D( I )             1.66       1.52       1.35       1.13        .22

         Water Surface Elevation:    139.293              Element # 4
         Flow:     127.426   Velocity:  2.92  Hydraulic Depth:    .866
         Cross-Section Area:     43.61        Conveyance:    1133.98
            Bank Stations ->  Left:     32.026   Right:     82.368

 X STA.        32.0       46.6       48.2       49.0       49.8       50.5
   A( I )              6.2        2.2        1.7        1.5        1.5
   V( I )             1.03       2.85       3.82       4.19       4.23
   D( I )              .42       1.43       1.98       2.06       2.07

 X STA.        50.5       51.2       51.9       52.6       53.3       54.0
   A( I )              1.5        1.5        1.4        1.5        1.4
   V( I )             4.39       4.37       4.46       4.38       4.40
   D( I )             2.07       2.07       2.06       2.05       2.04

 X STA.        54.0       54.7       55.5       56.2       57.0       57.8
   A( I )              1.5        1.5        1.5        1.5        1.6
   V( I )             4.34       4.37       4.19       4.17       4.10
   D( I )             2.03       2.02       2.01       2.00       1.96

 X STA.        57.8       58.7       59.8       61.3       67.3       82.4
   A( I )              1.7        1.8        2.0        3.7        6.4
   V( I )             3.79       3.48       3.13       1.70        .99
   D( I )             1.80       1.61       1.37        .63        .43
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
  EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

   ***    Beginning Velocity Distribution For Header Record FULLV    ***
          SRD Location:    757.428       Header Record Number  5

       Water Surface Elevation:    139.598              Element # 5
       Flow:     127.426   Velocity:  2.11  Hydraulic Depth:    .641
       Cross-Section Area:     60.33         Conveyance:     1639.75
          Bank Stations ->  Left:     10.874   Right:    104.924

 X STA.        10.9        42.4        47.4        48.5        49.4        50.2
   A( I )              7.4         4.7         2.3         2.1         1.9
   V( I )              .86        1.35        2.72        3.03        3.31
   D( I )              .24         .94        2.08        2.35        2.37

 X STA.        50.2        51.1        51.9        52.6        53.5        54.3
   A( I )              1.9         1.9         1.9         1.9         1.9
   V( I )             3.28        3.39        3.39        3.33        3.35
   D( I )             2.38        2.38        2.37        2.36        2.34

 X STA.        54.3        55.1        55.9        56.8        57.7        58.7
   A( I )              1.9         1.9         1.9         2.0         2.1
   V( I )             3.28        3.30        3.28        3.21        2.97
   D( I )             2.33        2.32        2.31        2.28        2.12

 X STA.        58.7        59.8        61.3        65.0        72.9       104.9
   A( I )              2.2         2.5         3.8         6.0         7.8
   V( I )             2.83        2.55        1.69        1.06         .81
   D( I )             1.91        1.68        1.02         .77         .24

       Water Surface Elevation:    139.903              Element # 6
       Flow:     127.426   Velocity:  1.43  Hydraulic Depth:    .869
       Cross-Section Area:     88.84         Conveyance:     2368.13
          Bank Stations ->  Left:      6.319   Right:    108.579

 X STA.         6.3        38.0        44.5        47.8        48.9        49.9
   A( I )             11.7         7.0         4.6         2.9         2.6
   V( I )              .55         .91        1.37        2.20        2.43
   D( I )              .37        1.08        1.43        2.51        2.67

 X STA.        49.9        50.9        51.8        52.7        53.7        54.6
   A( I )              2.6         2.5         2.5         2.5         2.5
   V( I )             2.47        2.55        2.55        2.51        2.52
   D( I )             2.68        2.68        2.67        2.66        2.64

 X STA.        54.6        55.6        56.6        57.6        58.7        60.0
   A( I )              2.5         2.5         2.6         2.8         2.9
   V( I )             2.50        2.51        2.42        2.32        2.17
   D( I )             2.63        2.62        2.59        2.43        2.20

 X STA.        60.0        61.8        65.8        72.3        78.7       108.6
   A( I )              3.3         5.0         6.9         7.0        11.8
   V( I )             1.94        1.28         .92         .91         .54
   D( I )             1.90        1.24        1.07        1.10         .39
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
  EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
      FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
     <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

   ***    Beginning Velocity Distribution For Header Record FULLV    ***
          SRD Location:    757.428       Header Record Number  5

       Water Surface Elevation:    140.208              Element # 7
       Flow:     127.426   Velocity:  1.05  Hydraulic Depth:   1.110
       Cross-Section Area:    121.04         Conveyance:     3360.19
          Bank Stations ->  Left:      3.181   Right:    112.234

 X STA.         3.2       32.3       39.3       45.4       48.0       49.2
   A( I )            14.6        8.9        8.5        5.1        3.5
   V( I )             .44        .71        .75       1.25       1.80
   D( I )             .50       1.26       1.40       1.93       2.89

 X STA.        49.2       50.4       51.5       52.6       53.7       54.9
   A( I )             3.4        3.3        3.3        3.3        3.3
   V( I )            1.88       1.91       1.94       1.91       1.92
   D( I )            2.98       2.99       2.98       2.96       2.95

 X STA.        54.9       56.0       57.2       58.4       59.9       61.7
   A( I )             3.4        3.3        3.5        3.8        4.1
   V( I )            1.89       1.90       1.82       1.67       1.57
   D( I )            2.93       2.91       2.80       2.54       2.23

 X STA.        61.7       65.6       71.6       77.4       88.0      112.2
   A( I )             6.0        8.3        8.1       10.0       13.2
   V( I )            1.06        .77        .79        .64        .48
   D( I )            1.56       1.37       1.40        .94        .55

       Water Surface Elevation:    140.512              Element # 8
       Flow:     127.426   Velocity:   .82  Hydraulic Depth:   1.342
       Cross-Section Area:    155.32         Conveyance:     4592.25
          Bank Stations ->  Left:       .100   Right:    115.824

 X STA.          .1       22.0       34.9       41.2       46.4       48.5
   A( I )            15.2       12.7       10.3        9.0        5.5
   V( I )             .42        .50        .62        .71       1.15
   D( I )             .69        .98       1.63       1.74       2.63

 X STA.        48.5       49.8       51.1       52.4       53.7       55.0
   A( I )             4.4        4.3        4.2        4.3        4.3
   V( I )            1.44       1.49       1.51       1.49       1.50
   D( I )            3.26       3.29       3.29       3.27       3.25

 X STA.        55.0       56.4       57.7       59.2       61.1       64.0
   A( I )             4.3        4.3        4.6        4.9        6.0
   V( I )            1.48       1.50       1.39       1.29       1.06
   D( I )            3.23       3.20       2.98       2.68       2.05

 X STA.        64.0       69.8       75.5       81.8       94.4      115.8
   A( I )             9.8        9.7       10.3       12.4       14.9
   V( I )             .65        .66        .62        .51        .43
   D( I )            1.70       1.68       1.63        .98        .70
```

```
      *************************  W S P R O  ***************************
         Federal Highway Administration  -  U. S. Geological Survey
                Model for Water-Surface Profile Computations.
                Input Units: Metric  /  Output Units: Metric
      *-----------------------------------------------------------------*
   EXAMPLE 7:  EXAMPLES  OF  INPUT & OUTPUT  FOR  WSPRO COMPUTER MODEL
       FHWA/USGS  MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
      <<<<<  TRANSFER  KNOWN  RATING  TO  UPSTREAM  SECTIONS  >>>>>

    ***    Beginning Velocity Distribution For Header Record FULLV    ***
           SRD Location:    757.428       Header Record Number  5

        Water Surface Elevation:    140.817              Element # 9
        Flow:     127.426   Velocity:   .67  Hydraulic Depth:   1.646
        Cross-Section Area:    190.60          Conveyance:     6096.56
           Bank Stations ->  Left:       .075   Right:    115.849

 X STA.          .1       16.9       29.4       37.3       43.3       47.6
   A( I )            16.1       14.1       12.9       11.9        9.5
   V( I )             .40        .45        .49        .53        .67
   D( I )             .96       1.12       1.64       1.98       2.22

 X STA.        47.6       49.2       50.7       52.2       53.7       55.2
   A( I )             5.7        5.3        5.3        5.4        5.3
   V( I )            1.12       1.19       1.21       1.19       1.20
   D( I )            3.43       3.59       3.60       3.58       3.55

 X STA.        55.2       56.7       58.3       60.1       62.6       67.4
   A( I )             5.3        5.5        5.8        6.7        9.8
   V( I )            1.21       1.16       1.09        .96        .65
   D( I )            3.53       3.45       3.14       2.66       2.06

 X STA.        67.4       73.4       78.9       88.2       98.8      115.8
   A( I )            11.8       11.3       13.6       13.4       16.0
   V( I )             .54        .57        .47        .47        .40
   D( I )            1.98       2.02       1.47       1.27        .93

        Water Surface Elevation:    140.818              Element #10
        Flow:     127.426   Velocity:   .67  Hydraulic Depth:   1.647
        Cross-Section Area:    190.67          Conveyance:     6099.71
           Bank Stations ->  Left:       .074   Right:    115.849

 X STA.          .1       16.9       29.4       37.3       43.3       47.6
   A( I )            16.1       14.1       12.9       11.9        9.5
   V( I )             .40        .45        .49        .53        .67
   D( I )             .96       1.12       1.64       1.98       2.23

 X STA.        47.6       49.2       50.7       52.2       53.7       55.2
   A( I )             5.7        5.3        5.3        5.4        5.3
   V( I )            1.12       1.19       1.21       1.19       1.20
   D( I )            3.43       3.59       3.60       3.58       3.55

 X STA.        55.2       56.7       58.3       60.1       62.6       67.3
   A( I )             5.3        5.5        5.8        6.6        9.8
   V( I )            1.21       1.16       1.10        .96        .65
   D( I )            3.53       3.46       3.15       2.67       2.06

 X STA.        67.3       73.3       79.1       88.2       98.8      115.8
   A( I )            11.7       11.7       13.4       13.4       16.0
   V( I )             .54        .55        .48        .47        .40
   D( I )            1.98       2.02       1.46       1.27        .94
```

Figure 7-18. Table of velocity and conveyance distribution (IHP=2).

7.8 EXAMPLE #8: MULTIPLE-OPENING BRIDGE

Figure 7-19 shows the input data for a simple, multiple-opening bridge problem. A definition sketch for the problem is shown in Figure 7-20. The valley is 152.4 m wide with two 15.24 m low-flow channels. Each channel bridge is 33.528-m long. Component mode is used for both bridges (BL, BC, and CD records). The geometry (GR records) and roughness (N record) of the downstream match section, DNSTM, is assumed representative of the entire reach. Those data are thus propagated to the full valley, FULLV, and upstream match, UPSTM, sections with elevation adjustments for a valley slope of 0.002 (XS DNSTM record). DNSTM and UPSTM are located at SRDs that satisfy exit and approach section locations for the longest opening. One profile is computed for a discharge of 226.535 m^3/s using an energy gradient (SK record) equal to the valley slope (assuming uniform flow downstream from DNSTM).

```
T1         Example 8:  Multiple Opening Bridge Example
T2         Symmetrical  Valley
T3         33.5 And 27.4 Meter Long Bridges
*
SI 1
*
Q          226.535
SK          0.0020
*
XS   DNSTM 0.000  *  *  *  0.0020
GR           0.000,6.096   0.000,1.524   30.480,1.524   30.480,0.000
GR          45.720,0.000  45.720,1.524  106.680,1.524  106.680,0.000
GR         121.920,0.000 121.920,1.524  152.400,1.524  152.400,6.096
N          0.040
*
XS   FULLV 33.528
*
* Left Channel Bridge (33.5 Meter Bridge)
BR    LTBO 33.528
BL         33.528  30.480  45.720
BC          3.658
CD              1  15.240
*
* Right Channel Bridge (27.4 Meter Bridge)
BR    RTBO  33.528
BL         27.432  106.680  121.920
BC          3.658
CD              1  15.240
*
XS   UPSTM 82.296
*
EX
ER
```

Figure 7-19. Input data for multiple-opening bridge of example #8.

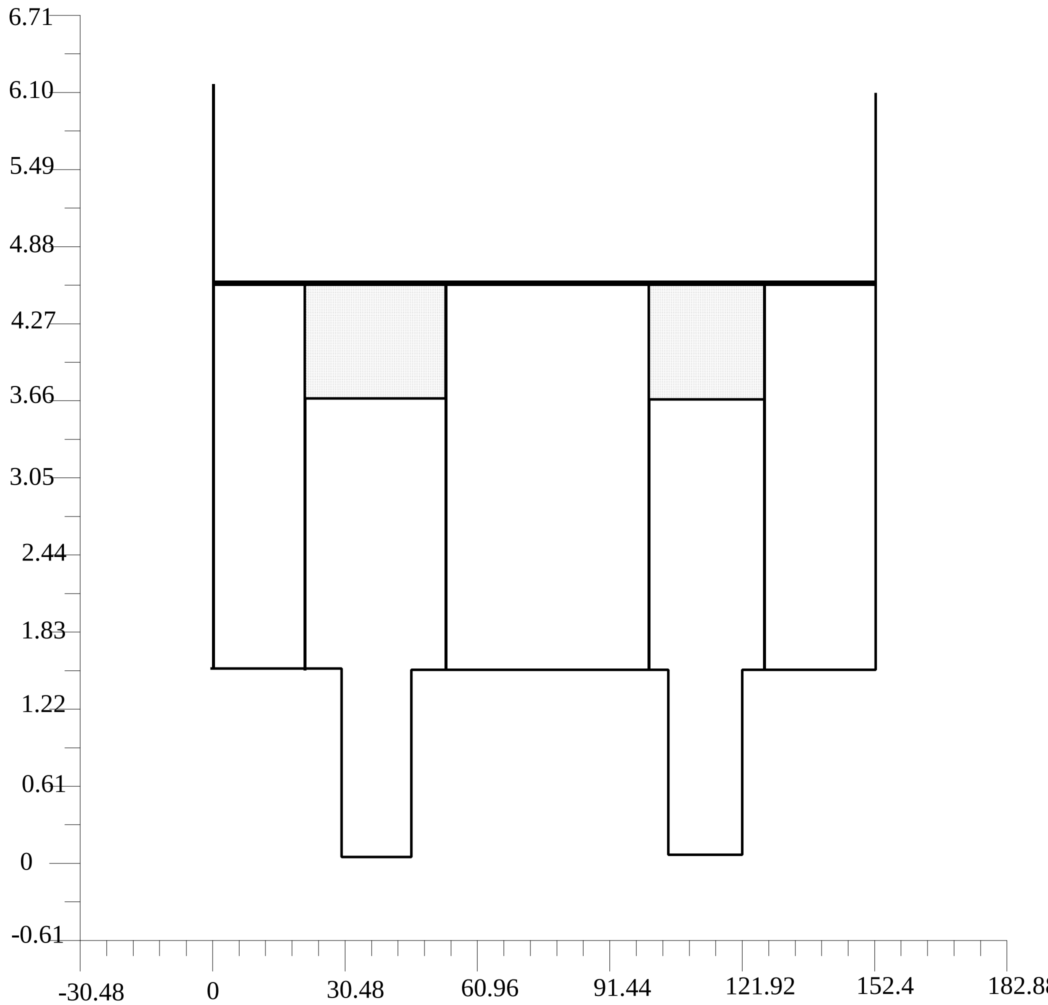


Figure 7-20. Definition sketch: multiple-opening bridge of example #8

Figure 7-21 is part of the profile output. The first lines show the unconstricted profile results. These results are used to make the initial estimates of the valley strips and their properties shown in the next lines. First shown are the first iteration backwater computations. A step-backwater computation is made to determine the elevation at UPSTM for that strip. The valley-strip elevation and conveyance at UPSTM for each opening are then used to compute the conveyance-weighted elevation at UPSTM.

```
-------------------------Section of output deleted--------------------------

     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *----------------------------------------------------------------*
              EXAMPLE 8:  MULTIPLE OPENING BRIDGE EXAMPLE
                          SYMMETRICAL  VALLEY
                    33.5 AND 27.4 METER LONG BRIDGES

                  << Beginning Computations for Profile  1 >>

                     WSEL    VHD       Q          AREA       SRDL      LEW
                     EGEL     HF       V           K         FLEN      REW
                     CRWS     HO      FR #         SF        ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
  Section: DNSTM       2.428   .077    226.535    184.220 *********      .080
  Header Type: XS      2.505 ******      1.229    5063.46 *********   152.419
  SRD:        .000     1.826 ******       .357     ******     1.000    ******

  Section: FULLV       2.496   .076    226.535    184.448    33.528      .080
  Header Type: FV      2.573   .066      1.228    5073.87    33.528   152.419
  SRD:      33.528     1.893   .000       .356      .0020     1.000      .005

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

  Section: UPSTM       2.595   .076    226.535    184.635    48.767      .080
  Header Type: AS      2.672   .097      1.226    5082.34    48.767   152.419
  SRD:      82.295     1.993   .000       .356      .0020     1.000      .005

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

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

```
 ************************  W S P R O  **************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
          EXAMPLE 8:  MULTIPLE OPENING BRIDGE EXAMPLE
                      SYMMETRICAL  VALLEY
                33.5 AND 27.4 METER LONG BRIDGES

  Multiple Bridge Opening Calculations             Iteration  1
  --------------------------------------------------------------
  Stagnation Point *********
  Bridge  1           A3      BOLEW      CA3     CDF     CDFn
  Section  LTBO       QS      BOREW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ---------------
  AS     94.829      53.548    21.392    46.860 1.031      1.027
  KS     2597.8      119.43    54.908      .875 2.300     118.90

  Stagnation Point    79.017
  Bridge  2           A3      BOLEW      CA3     CDF     CDFn
  Section  RTBO       QS      BOREW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ---------------
  AS     89.807      48.024   100.640    42.334  .967       .972
  KS     2484.7      107.11   128.060      .882 2.305     107.63

  Stagnation Point *********
  Total Values        A3      BOREW      CA3     CDF     CDFn
  All Sections        QS      BOLEW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ----- ----------
  AS    184.635  ********** *********    89.194 ***** **********
  KS     5082.5  ********** ********* ********* ***** **********
  --------------------------------------------------------------


                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  LTBO      2.356   .392   118.902     48.854    33.528    21.398
Header Type: BR     2.749   .123     2.433    1448.88    33.528    54.900
SRD:     33.528     1.985   .117      .644     ******     1.299      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .8773  .000    3.657   33.528    21.336    54.863
---------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:      2.496
    Downstream Bridge Section Water Surface Elevation:              2.356
    Bridge DrawDown Distance:                                        .140
----------------------------------------------------------------------------

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V          K        FLEN      REW
                    CRWS     HO      FR #        SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: SLICE      2.893   .051   118.902    118.349    33.528      .073
Header Type: AS     2.944   .092     1.004    3850.08    36.672    79.017
SRD:     82.295     2.008   .102      .262      .0020     1.000      .001

              Approach Section SLICE Flow Contraction Information
            M( G )   M( K )     KQ      XLKQ      XRKQ     OTEL
           -------- -------- --------- --------- --------- --------
               .575     .384    2369.8    21.834    55.336    2.893
           -------- -------- --------- --------- --------- --------
```

```
               <<< End of Bridge Hydraulics Computations >>>

Section: UPSTM       2.894   .051    118.902    118.406       .000      .073
Header Type: XS      2.945   .000      1.004    3853.15       .000    79.017
SRD:     82.295      2.008   .000       .262      .0010      1.000      .002


                     WSEL    VHD       Q          AREA       SRDL      LEW
                     EGEL     HF       V           K         FLEN      REW
                     CRWS     HO      FR #         SF        ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section:  RTBO       2.343   .395    107.632     43.826     27.432   100.647
Header Type: BR      2.738   .097      2.455    1360.02     27.432   128.052
SRD:     33.528      1.907   .127       .620     ******      1.284      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **           .8824 .000    3.657   27.432   100.584   128.016
--------------------------- ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:      2.496
    Downstream Bridge Section Water Surface Elevation:              2.343
    Bridge DrawDown Distance:                                        .153
----------------------------------------------------------------------------

                     WSEL    VHD       Q          AREA       SRDL      LEW
                     EGEL     HF       V           K         FLEN      REW
                     CRWS     HO      FR #         SF        ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: SLICE       2.876   .047    107.632    111.348     33.528    79.017
Header Type: AS      2.924   .090       .966    3446.77     36.485   152.426
SRD:     76.199      1.962   .095       .251      .0020      1.000      .001

              Approach Section SLICE Flow Contraction Information
            M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
           -------- -------- --------- --------- --------- --------
               .626     .403    2058.3  100.851   128.256    2.876
           -------- -------- --------- --------- --------- --------

               <<< End of Bridge Hydraulics Computations >>>

Section: UPSTM       2.882   .048    107.632    110.901      6.096    79.017
Header Type: XS      2.930   .005       .970    3423.93      6.096   152.425
SRD:     82.295      1.974   .000       .252      .0010      1.000      .001

Section: UPSTM       2.888   .049    226.535    229.327 *********      .073
Header Type: XS      2.938 ******       .987    7276.23 *********   152.426
SRD:     82.295      1.993 ******       .257     ******      1.000      .005
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
          EXAMPLE 8:  MULTIPLE OPENING BRIDGE EXAMPLE
                      SYMMETRICAL  VALLEY
                33.5 AND 27.4 METER LONG BRIDGES

  Multiple Bridge Opening Calculations              Iteration  2
  --------------------------------------------------------------
  Stagnation Point *********
  Bridge  1          A3      BOLEW      CA3     CDF     CDFn
  Section  LTBO      QS      BOREW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ---------------
  AS    118.947      48.855   21.399    42.661 1.024      1.023
  KS     3674.2      119.43   54.901      .873 2.301     118.82

  Stagnation Point    79.015
  Bridge  2          A3      BOLEW      CA3     CDF     CDFn
  Section  RTBO      QS      BOREW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ---------------
  AS    112.239      43.826  100.648    38.616  .975       .976
  KS     3492.4      107.11  128.052      .881 2.304     107.71

  Stagnation Point *********
  Total Values       A3      BOREW      CA3     CDF     CDFn
  All Sections       QS      BOLEW       CJ     CRF      QSn
  -------------  ---------- --------- --------- ----- ----------
  AS    231.185  ********** *********    81.277 ***** **********
  KS     7166.6  ********** ********* ********* ***** **********
  --------------------------------------------------------------


                 WSEL    VHD       Q         AREA      SRDL      LEW
                 EGEL     HF       V          K        FLEN      REW
                 CRWS     HO      FR #        SF       ALPHA     ERR
              --------- ------ ---------- ---------- --------- ---------
Section:  LTBO     2.357  .392   118.822     48.872    33.528    21.398
Header Type: BR    2.749  .123     2.431    1449.72    33.528    54.900
SRD:     33.528    1.985  .117      .643     ******     1.300      .000

Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
Bridge Type 1   Flow Type 1 ------ ----- -------- -------- --------- ---------
Pier/Pile Code **            .8771  .000    3.657   33.528    21.336    54.863
---------------------------  ------ ----- -------- -------- --------- ---------
    Unconstricted Full Valley Section Water Surface Elevation:      2.496
    Downstream Bridge Section Water Surface Elevation:              2.357
    Bridge DrawDown Distance:                                        .139
----------------------------------------------------------------------------

                 WSEL    VHD       Q         AREA      SRDL      LEW
                 EGEL     HF       V          K        FLEN      REW
                 CRWS     HO      FR #        SF       ALPHA     ERR
              --------- ------ ---------- ---------- --------- ---------
Section: SLICE     2.893  .051   118.822    118.338    33.528      .073
Header Type: AS    2.944  .093     1.004    3835.20    36.672    79.015
SRD:     82.295    2.008  .102      .262      .0020     1.000      .001

              Approach Section SLICE Flow Contraction Information
            M( G )   M( K )     KQ      XLKQ      XRKQ     OTEL
           -------- -------- --------- --------- --------- --------
              .575     .384   2360.8    21.833    55.335    2.893
           -------- -------- --------- --------- --------- --------
```

```
               <<< End of Bridge Hydraulics Computations >>>

  Section: UPSTM       2.894   .051    118.822    118.395      .000      .073
  Header Type: XS      2.945   .000      1.003    3838.26      .000    79.015
  SRD:     82.295      2.008   .000       .262      .0010     1.000      .002


                       WSEL    VHD       Q          AREA      SRDL      LEW
                       EGEL     HF       V           K        FLEN      REW
                       CRWS     HO      FR #         SF       ALPHA     ERR
                    --------- ------ ---------- ---------- --------- ---------
  Section:  RTBO       2.343   .395    107.712     43.812    27.432   100.647
  Header Type: BR      2.739   .096      2.458    1359.33    27.432   128.052
  SRD:     33.528      1.907   .127       .621     ******     1.284      .000

  Specific Bridge Information   C     P/A   PFELEV    BLEN      XLAB      XRAB
  Bridge Type 1  Flow Type 1 ------ ----- -------- -------- --------- ---------
  Pier/Pile Code **            .8826  .000    3.657   27.432   100.584   128.016
  -------------------------- ------ ----- -------- -------- --------- ---------
      Unconstricted Full Valley Section Water Surface Elevation:      2.496
      Downstream Bridge Section Water Surface Elevation:              2.343
      Bridge DrawDown Distance:                                        .153
  ----------------------------------------------------------------------------

                       WSEL    VHD       Q          AREA      SRDL      LEW
                       EGEL     HF       V           K        FLEN      REW
                       CRWS     HO      FR #         SF       ALPHA     ERR
                    --------- ------ ---------- ---------- --------- ---------
  Section: SLICE       2.876   .047    107.712    111.360    33.528    79.015
  Header Type: AS      2.924   .090       .967    3460.98    36.485   152.426
  SRD:     76.199      1.963   .095       .251      .0020     1.000      .001

              Approach Section SLICE Flow Contraction Information
            M( G )   M( K )     KQ       XLKQ      XRKQ     OTEL
           -------- -------- --------- --------- --------- --------
               .626     .403    2066.6   100.850   128.255    2.876
           -------- -------- --------- --------- --------- --------

               <<< End of Bridge Hydraulics Computations >>>

  Section: UPSTM       2.882   .048    107.712    110.911     6.096    79.015
  Header Type: XS      2.931   .005       .971    3437.92     6.096   152.425
  SRD:     82.295      1.975   .000       .252      .0010     1.000      .001

  Section: UPSTM       2.888   .049    226.535    229.322 *********      .073
  Header Type: XS      2.938 ******       .987    7275.96 *********   152.426
  SRD:     82.295      1.993 ******       .257     ******     1.000      .005

                 << Completed Computations of Profile  1 >>

   ER

    ******************  Normal end of WSPRO execution.  *****************
    ***************  Elapsed Time:   0 Minutes  1 Seconds  **************

-------------------------Remainder of output deleted-------------------------
```

Figure 7-21. Computed profile output for multiple-opening bridge of example #8.

7.9 EXAMPLE #9: CULVERTS

WSPRO was originally designed to perform culvert computations only in multiple-opening analyses but was later "patched" to analyze "stand-alone" culverts (both single- and multi-barrel installations). This version of WSPRO removes the limitations of previous versions in computing continuous culvert profiles.

A culvert installation is required for a design discharge of 135.94 m^3/s. Site characteristics and other factors suggest a battery of six 2.7-m, circular-concrete pipes might suffice. Parts of the culvert analysis output are shown in Figure 7-22.

```
T1        CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
T2        METRIC
*
SI 1
*
Q             22.6536
WS           139.2140
*
XT   SURVY 762.000
GR           0.000,141.732    0.000,140.513    7.010,139.842    10.973,139.598
GR          13.716,139.537   16.764,139.690   30.175,139.720    33.528,138.958
GR          36.271,138.928   40.538,138.836   43.586,138.775    45.720,138.806
GR          46.939,138.379   47.244,137.770   48.768,137.251    51.206,137.221
GR          57.302,137.312   58.826,137.617   60.960,137.983    62.484,138.532
GR          64.008,138.775   69.799,138.867   78.638,138.775    81.077,139.080
GR          84.125,139.598   92.964,139.537  104.851,139.598   115.824,140.513
GR         115.824,141.732
*
XS    EXIT 720.852 * * * 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           30.175  45.720  64.008  84.125
ND         0.305,0.914  0.610,1.524  0.000,0.305
ND               0.305,1.219  0.305,0.914
*
XS   FULLV 757.428
*
CV   BOXCV 757.428  51.206  30.48  137.21  137.24  1
CG         115  3048  3658
*
XS    APPR 803.148
*
EX
ER
```

Figure 7-22. Input data for culvert analysis.

A convenient way to estimate the road overflow is to substitute an "equivalent" bridge opening for the culvert. This should not be considered as an alternative for culvert analysis (culvert hydraulics and bridge hydraulics are different) but can be used to obtain a valid "rating" for the road overflow. This example uses a bridge opening having an area equivalent to a battery of culverts.

Part of the profile output is shown in Figure 7-23. It should be noted that the headwater elevation from culvert computations is for a point immediately upstream from the culvert, 19.8 m downstream from the approach section. The water-surface elevation difference between these points is less than 0.03 m for "normal" flow. If adjustment is made for total loss of velocity head for ponded conditions the difference may be about 0.06 m. The elevation immediately upstream from the embankment used for road-overflow computations in WSPRO is the approach elevation minus an "estimated" friction loss. Thus, we have a road overflow of 3.716 m^3/s at a 183.279 HWE.

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
          Run Date & Time:  9/11/97  8:30 am     Version V070197
           Input File: EX9M.DAT       Output File: EX9M.LST
     *-----------------------------------------------------------------*
  T1        CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
  T2        METRIC
  SI 1
                      Metric (SI) Units Used in WSPRO

                 Quantity    SI Unit              Precision
                ------------ -------------------- -----------
                 Length      meters                 0.001
                 Depth       meters                 0.001
                 Elevation   meters                 0.001
                 Widths      meters                 0.001

                 Velocity    meters/second          0.001
                 Discharge   cubic meters/second    0.001
                 Slope       meter/meter            0.001

                 Angles      degrees                0.01
                ------------ -------------------- -----------

  Q              22.6536

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

  WS            139.2140
```

```
 ************************  W S P R O  **************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *---------------------------------------------------------------*
     CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                              METRIC

       *---------------------------------------------------*
       *      Starting To Process Header Record SURVY      *
       *---------------------------------------------------*

 XT   SURVY 762.000
 GR         0.000,141.732    0.000,140.513    7.010,139.842    10.973,139.598
 GR        13.716,139.537   16.764,139.690   30.175,139.720    33.528,138.958
 GR        36.271,138.928   40.538,138.836   43.586,138.775    45.720,138.806
 GR        46.939,138.379   47.244,137.770   48.768,137.251    51.206,137.221
 GR        57.302,137.312   58.826,137.617   60.960,137.983    62.484,138.532
 GR        64.008,138.775   69.799,138.867   78.638,138.775    81.077,139.080
 GR        84.125,139.598   92.964,139.537  104.851,139.598   115.824,140.513
 GR       115.824,141.732

  ***   Completed Reading Data Associated With Header Record SURVY   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #29 increased to eliminate vertical segment.
  ***         Storing Template Header Record Data In Memory          ***


  ***              Data Summary For Header Record SURVY              ***
  SRD Location:      762.    Valley Slope:  *******     Error Code   0

                      X,Y-coordinates (29 pairs)
      X          Y            X          Y            X          Y
 ----------  ----------   ----------  ----------   ----------  ----------
       .000     141.732         .100     140.513        7.010     139.842
     10.973     139.598       13.716     139.537       16.764     139.690
     30.175     139.720       33.528     138.958       36.271     138.928
     40.538     138.836       43.586     138.775       45.720     138.806
     46.939     138.379       47.244     137.770       48.768     137.251
     51.206     137.221       57.302     137.312       58.826     137.617
     60.960     137.983       62.484     138.532       64.008     138.775
     69.799     138.867       78.638     138.775       81.077     139.080
     84.125     139.598       92.964     139.537      104.851     139.598
    115.824     140.513      115.924     141.732
 ----------  ----------   ----------  ----------   ----------  ----------

                   Minimum and Maximum X,Y-coordinates
   Minimum X-Station:        .000  ( associated Y-Elevation:  141.732 )
   Maximum X-Station:     115.924  ( associated Y-Elevation:  141.732 )
   Minimum Y-Elevation:   137.221  ( associated X-Station:     51.206 )
   Maximum Y-Elevation:   141.732  ( associated X-Station:       .000 )

       *---------------------------------------------------*
       *      Finished Processing Header Record SURVY      *
       *---------------------------------------------------*
```

```
    *************************  W S P R O  **************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *-----------------------------------------------------------------*
        CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                                METRIC

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

 XS    EXIT 720.852 * * * 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          30.175  45.720  64.008  84.125
 ND        0.305,0.914  0.610,1.524  0.000,0.305
 ND            0.305,1.219  0.305,0.914

  ***   Completed Reading Data Associated With Header Record  EXIT   ***
  ***  Storing X-Section Data In Temporary File As Record Number  1  ***

  ***              Data Summary For Header Record  EXIT              ***
  SRD Location:      721.   Cross-Section Skew:    .0   Error Code   0
  Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                          X,Y-coordinates (29 pairs)
      X          Y            X          Y             X          Y
 ----------  ----------   ----------  ----------   ----------  ----------
       .000     141.683         .100     140.464        7.010     139.793
     10.973     139.549       13.716     139.488       16.764     139.641
     30.175     139.671       33.528     138.909       36.271     138.879
     40.538     138.787       43.586     138.726       45.720     138.757
     46.939     138.330       47.244     137.721       48.768     137.202
     51.206     137.172       57.302     137.263       58.826     137.568
     60.960     137.934       62.484     138.483       64.008     138.726
     69.799     138.818       78.638     138.726       81.077     139.031
     84.125     139.549       92.964     139.488      104.851     139.549
    115.824     140.464      115.924     141.683
 ----------  ----------   ----------  ----------   ----------  ----------

                      Minimum and Maximum X,Y-coordinates
   Minimum X-Station:        .000  ( associated Y-Elevation:  141.683 )
   Maximum X-Station:     115.924  ( associated Y-Elevation:  141.683 )
   Minimum Y-Elevation:   137.172  ( associated X-Station:     51.206 )
   Maximum Y-Elevation:   141.683  ( associated X-Station:       .000 )

                     Roughness Data (  5 SubAreas )
                Transition   Roughness   Hydraulic  Horizontal
        SubArea    Point    Coefficient    Depth    Breakpoint
        -------  ----------  -----------  ---------  ----------
           1       Bottom        .055         .305      ---
                    Top          .050         .914      ---
                    --           ---          ---      30.175
           2       Bottom        .065         .610      ---
                    Top          .060        1.524      ---
                    --           ---          ---      45.720
           3       Bottom        .040         .000      ---
                    Top          .040         .305      ---
                    --           ---          ---      64.008
           4       Bottom        .065         .305      ---
                    Top          .060        1.219      ---
                    --           ---          ---      84.125
```

```
 5       Bottom        .055          .305       ---
          Top          .050          .914       ---


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

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *----------------------------------------------------------------*
     CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                             METRIC

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

XS   FULLV 757.428

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

 ***              Data Summary For Header Record FULLV              ***
 SRD Location:      757.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (29 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.727         .100     140.508        7.010     139.837
    10.973     139.592       13.716     139.532       16.764     139.685
    30.175     139.715       33.528     138.952       36.271     138.923
    40.538     138.831       43.586     138.770       45.720     138.801
    46.939     138.374       47.244     137.765       48.768     137.246
    51.206     137.216       57.302     137.307       58.826     137.612
    60.960     137.978       62.484     138.527       64.008     138.770
    69.799     138.862       78.638     138.770       81.077     139.075
    84.125     139.592       92.964     139.532      104.851     139.592
   115.824     140.508      115.924     141.727
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.727 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.727 )
  Minimum Y-Elevation:   137.216  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.727  ( associated X-Station:       .000 )

                    Roughness Data (  5 SubAreas )
             Transition   Roughness   Hydraulic  Horizontal
    SubArea    Point     Coefficient    Depth    Breakpoint
    -------  ----------  -----------  ---------  ----------
       1       Bottom        .055        .305       ---
                Top          .050        .914       ---
                 --          ---         ---       30.175
       2       Bottom        .065        .610       ---
                Top          .060       1.524       ---
                 --          ---         ---       45.720
       3       Bottom        .040        .000       ---
                Top          .040        .305       ---
                 --          ---         ---       64.008
       4       Bottom        .065        .305       ---
                Top          .060       1.219       ---
                 --          ---         ---       84.125
       5       Bottom        .055        .305       ---
                Top          .050        .914       ---


       *----------------------------------------------------*
```

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

```
 ************************* W S P R O ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *---------------------------------------------------------------*
      CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                              METRIC

       *---------------------------------------------------*
       *      Starting To Process Header Record BOXCV      *
       *---------------------------------------------------*

CV   BOXCV 757.428  51.206  30.48  137.21  137.24  1
CG         115  3048  3658

 ***   Completed Reading Data Associated With Header Record BOXCV   ***
 ***      Notice - Program Assuming All Culvert Input Complete      ***
  ***   Storing Culvert Data In Temporary File As Record Number  3    ***

 ***             Data Summary For Header Record BOXCV               ***
 SRD Location:      757.       Culvert Code:  115       Error Code   0

 Culvert Information:

     Shape:  Box        Material:  Concrete
     Inlet Code: 5   Length:   30.480
     Rise:  3048.000   Span:  3658.000   # Barrel(s):  1
     Roughness:   .0120   Horizontal Stationing:    51.206
     Entrance Loss Coefficient:   .20   Alpha:  1.0000
     Invert Elevations -> Upstream:    137.240
                          Downstream:  137.210

       *---------------------------------------------------*
       *      Finished Processing Header Record BOXCV      *
       *---------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
     CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                             METRIC

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

XS    APPR 803.148

 ***   Completed Reading Data Associated With Header Record  APPR   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***              Data Summary For Header Record  APPR              ***
 SRD Location:      803.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00120    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                       X,Y-coordinates (29 pairs)
     X          Y             X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000     141.781         .100     140.562        7.010     139.891
    10.973     139.647       13.716     139.586       16.764     139.739
    30.175     139.769       33.528     139.007       36.271     138.977
    40.538     138.885       43.586     138.824       45.720     138.855
    46.939     138.428       47.244     137.819       48.768     137.300
    51.206     137.270       57.302     137.361       58.826     137.666
    60.960     138.032       62.484     138.581       64.008     138.824
    69.799     138.916       78.638     138.824       81.077     139.129
    84.125     139.647       92.964     139.586      104.851     139.647
   115.824     140.562      115.924     141.781
----------  ----------   ----------  ----------   ----------  ----------

                   Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:  141.781 )
  Maximum X-Station:     115.924  ( associated Y-Elevation:  141.781 )
  Minimum Y-Elevation:   137.270  ( associated X-Station:     51.206 )
  Maximum Y-Elevation:   141.781  ( associated X-Station:       .000 )

                      Roughness Data (  5 SubAreas )
               Transition   Roughness    Hydraulic  Horizontal
      SubArea     Point    Coefficient    Depth     Breakpoint
      -------  ----------  -----------  ---------  ----------
         1       Bottom        .055        .305       ---
                  Top          .050        .914       ---
                  --           ---         ---        30.175
         2       Bottom        .065        .610       ---
                  Top          .060       1.524       ---
                  --           ---         ---        45.720
         3       Bottom        .040        .000       ---
                  Top          .040        .305       ---
                  --           ---         ---        64.008
         4       Bottom        .065        .305       ---
                  Top          .060       1.219       ---
                  --           ---         ---        84.125
         5       Bottom        .055        .305       ---
                  Top          .050        .914       ---


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

```
                  ******* ******* ******* *******

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

```
 *************************  W S P R O  **************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *----------------------------------------------------------------*
     CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                               METRIC
EX

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

        Reach      Water Surface   Friction
 #    Discharge      Elevation      Slope         Flow Regime
--    ---------    -------------   --------   --------------------
 1       22.65        139.214       ******        Sub-Critical
--    ---------    -------------   --------   --------------------

      *===================================================*
      *        Beginning  1 Profile Calculation(s)        *
      *===================================================*
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
         CONTINUOUS WATER SURFACE PROFILE WITH CULVERT IN REACH
                                METRIC

                  << Beginning Computations for Profile  1 >>

                     WSEL    VHD       Q          AREA      SRDL      LEW
                     EGEL     HF       V           K        FLEN      REW
                     CRWS     HO      FR #         SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section:  EXIT    139.213   .022     22.653     41.806 *********    32.183
 Header Type: XS   139.236 ******       .541    1081.61 *********    82.156
 SRD:    720.852   138.000 ******       .233     ******     1.513    ******

 Section: FULLV    139.229   .024     22.653     40.414    36.576    32.305
 Header Type: FV   139.253   .016       .560    1041.91    36.576    81.991
 SRD:    757.428   138.044   .000       .243      .0005     1.499      .000

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

 Section:  APPR    139.251   .025     22.653     38.784    45.719    32.450
 Header Type: AS   139.277   .022       .584     996.29    45.719    81.798
 SRD:    803.147   138.098   .000       .256      .0005     1.481      .001

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

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

                     WSEL     TWD      Q/BL        AIN      OTFULL
                     HWic      Dc     VELIN        AOUT      Ac
                     HWoc      Dn     VELOUT      CVSLPE     An
                  --------- ------ ---------- ---------- ---------
 Section: BOXCV    139.844  2.020     22.654      7.469     -.069
 Header Type: CV     2.456  1.575      3.033      7.389     5.761
 SRD:    757.428     2.604  2.334      3.066      .0010     8.539
                  --------- ------ ---------- ---------- ---------

                     WSEL    VHD       Q          AREA      SRDL      LEW
                     EGEL     HF       V           K        FLEN      REW
                     CRWS     HO      FR #         SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section:  APPR    139.849   .007     22.653     77.845    45.719     7.692
 Header Type: AS   139.857   .005       .291    2074.98    45.719   107.274
 SRD:    803.147   138.098   .000       .142      .0001     1.821      .000

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

                <<< End of Culvert Hydraulics Computations >>>

                  << Completed Computations of Profile  1 >>
  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-23. Output for "culvert" analysis.

7.10 EXAMPLE #10: SCOUR COMPUTATIONS

Estimates of contraction scour, pier scour, and abutment scour can be computed with WSPRO by using the DC, DP, and DA records. The methods used in WSPRO to compute scour are presented in HEC-18, Evaluating Scour at Bridges (add reference here). If more information is required about the techniques used to evaluate scour at bridges, the user should refer to HEC-18. The following example illustrates the procedure that is used to compute scour with WSPRO.

7.10.1 Estimating Scour at Bridges - Computer Solution

A 198.12 meter long type 3 (spill-through abutments and sloping embankments) bridge is to be constructed over a channel that has an estimated design flow of 849.51 m^3/s. The right abutment is to be fixed at the right bank of the main channel and the left abutment extends into the overbank area. The elevation of the bridge deck is 6.71 meters and the girder depth is 1.22 meters. Six round nose piers that are 1.52 meters thick and 12.19 meters long will be placed in the channel. Four piers are in the main channel and two are in the overbank area. The abutments are on 1V:2H slopes. The abutments and piers are designed to be aligned with the flow. Long term aggradation and degradation have been considered and are assumed to be negligible. Using the scour computing functions in WSPRO, estimate the contraction scour and the local scour depths at the abutments and piers. The D_{50} of the bed material is 1 millimeter. Assume that the main channel is stable laterally and will not migrate into the overbank area of the bridge opening. This implies that pier scour can be estimated with reduced depths and velocities in the overbank area. Also, assume that clear-water contraction scour occurs in the overbank area of the bridge opening. Figures 7-24 and 7-25 show the geometry and configuration of the bridge and approach cross-sections. Figures 7-26 and 7-27 show the left and right locations of the bridge opening and approach cross-section live-bed and clear-water contraction scour boundaries that have been assumed. Figure 7-28 shows the input data file that can be used to accomplish the scour computations. Once the magnitude of each of the scour components is determined, the magnitude of total scour can be computed and plotted on a figure similar to Figure 7-29.

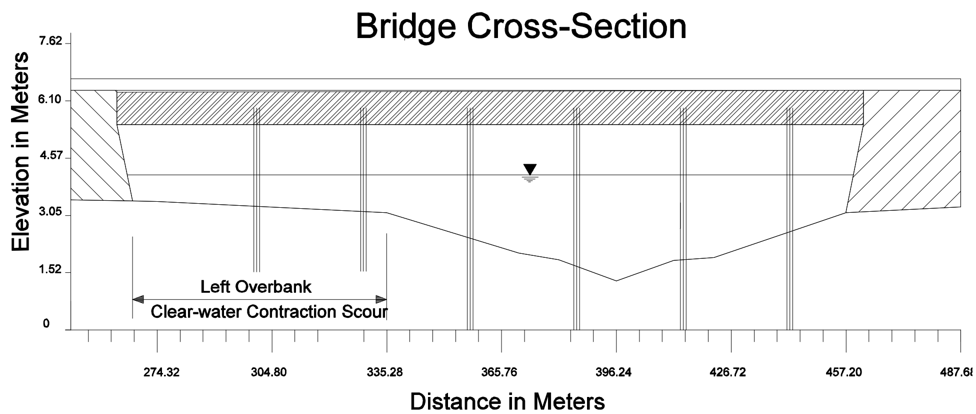


Figure 7-24. Bridge Cross-Section Configuration

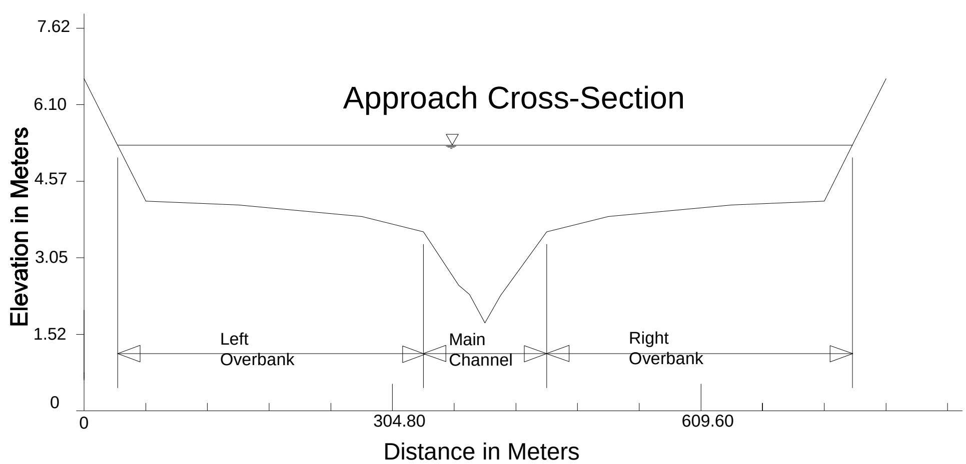


Figure 7-25. Approach Cross-Section Configuration.

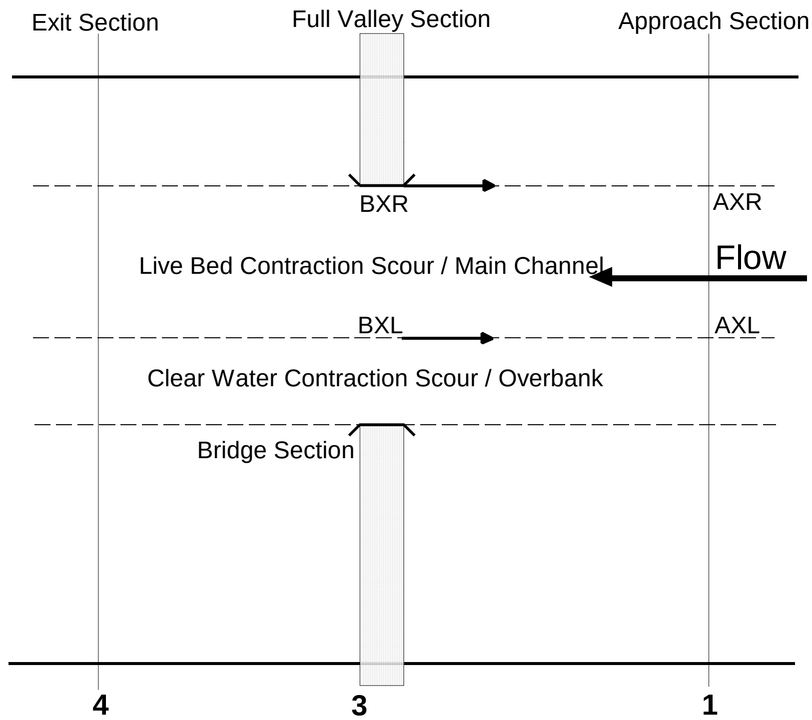


Figure 7-26. Live-Bed Contraction Scour Channel Computation Limits.

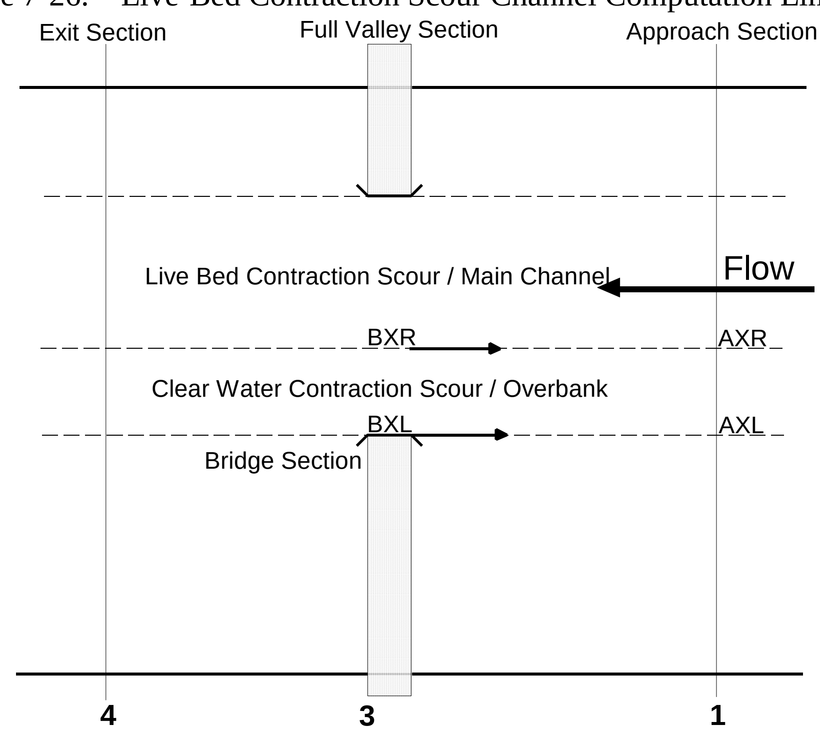


Figure 7-27. Clear-Water Contraction Scour Channel Computation Limits.

```
T1        WORKSHOP PROBLEM - SCOUR CREEK - METRIC
T2        ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
T3        CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS
*
SI 1
Q         849.51
SK        0.002
*
XS   EXIT  228.60 * * * .002
GR          0.00,5.79   30.48,4.57   60.96,3.35  152.40,3.28  274.32,3.05
GR        335.28,2.74  370.33,1.68  381.00,1.49  396.24,0.93  411.48,1.48
GR        422.15,1.55  457.20,2.74  518.16,3.05  640.08,3.28  731.52,3.35
GR        762.00,4.57  792.48,5.79
N            0.042    0.032    0.042
SA               335.28    457.20
*
XS   FULLV 426.72
*
BR   BRDG  426.72
BL 1       198.12   335.28   457.20
BC         5.49
CD         3  15.24  2  6.71
AB         2
PD         1.72  9.14  6
N          0.042   0.032
SA             335.28
*
XS   APPR  640.08
*
*    SECID  K1   K2   YL    YR     Q     FS
DA   BRDG  .55
*
*    SECID  BXL   BXR   PW    YB   QB   K1   K2   K3   K4   V1M   D1M
DP   BRDG   335.28 *   1.52
*
*    SECID  BXL  BXR    PW    YB   QB   K1   K2   K3   K4   V1M   D1M
DP   BRDG    *  335.28 1.52
*
*  0 SECID  BXL   BXR   AXL   AXR   K1    PW   YB   YA
DC 0 BRDG  335.28  *     *     *     *   6.10
*
*  1 SECID  BXL   BXR   AXL   AXR   D50   PW   YB   YA
DC 1 BRDG    *  335.28   *     *    1.0  3.05
*
EX
ER
```

Figure 7-28. WSPRO Input Data File For “Scour Computation” Example.

7.10.2 Abutment Scour Computations

The abutment scour computations are accomplished by using the DA record. The program is allowed to default in all data fields except for the K1 value where the assumed default is 1.00. Since K1 for spill through abutments is 0.55, this value is placed in the field where the K1 value is read. Figure 7-30 presents the WSPRO output for the abutment scour computations.

7.10.3 Pier Scour Computations

Since the assumption is made that over time the main channel will not migrate into the overbank portion of the bridge opening, pier scour is be computed for the piers in the main channel using hydraulic properties for flow in that portion of the bridge opening. Using similar logic, pier scour in the overbank portion of the bridge opening is computed using hydraulic properties for the flow in that portion of the opening. By default, WSPRO will compute worst case (by using maximum depths and velocities) pier scour for the opening using hydraulic properties based on equal conveyance "tubes" computed using the entire opening. Since in this example we are to compute scour in the main channel and overbank portions of the bridge openings using their respective hydraulic properties, the user needs to use multiple DP records. The first DP record is used to compute pier scour in the main channel. Since the defaults for BXL and BXR are the left and right edges of water in the bridge cross-section, overrides are necessary. Because the main channel begins at station 335.28 and ends where water intersects the right abutment, an override is necessary for BXL. The second DP record works similarly except that an override is required for BXR which will limit the calculations to the portion of the bridge opening between the intersection of the water surface and the left abutment and the boundary between the overbank and the main channel which occurs at station 335.28. If the user desires, overrides can be input on the DP record for velocities and depths. These values will be used in the scour computations. Figures 7-31 and 7-32 present the WSPRO output for the main channel and overbank pier scour computations.

7.10.4 Contraction Scour Computations

The contraction scour computations are made assuming that clear-water contraction scour will occur in the overbank and live-bed contraction scour will occur in the main channel portion of the bridge opening. The boundary between clear-water contraction scour and live-bed contraction scour is assumed to occur at station 335.28 in the bridge opening. By using multiple DC records an estimate of contraction scour can be computed for each portion of the bridge opening. The live-bed contraction scour is computed using a DC record with the option code set equal to 0. The default value of BXL is overwritten with the value 335.28 which is the left boundary of the portion of the bridge opening where live-bed sediment transport occurs. All other values with the exception of PW are allowed to default. The cumulative pier width (PW) is equal to 6.10 meters (4 piers each 1.52 meters wide), with is equal to the summed width of piers in the portion of the main channel.

Clear-water contraction scour is computed by setting the option code on the DC record equal to 1 and allowing the value of BXL to default to the intersection of the left edge of water in the bridge opening. The default value of BXR is overwritten with 335.28 which is the right boundary of the portion of the bridge opening where clear-water sediment transport occurs. Since clear-water contraction scour is estimated using different variables than live-bed contraction scour, the format of the DC record is different when estimating clear-water contraction scour. The D_{50} value of the bed material is assumed to be 1 millimeter and the cumulative pier width is 3.05 meters (2 piers each 1.52 meters wide). Figures 7-33 and 7-34 present the WSPRO output for the live-bed and clear-water contraction scour computations.

7.10.5 Summary

Once the estimates of local scour at the piers and abutments have been determined, they need to be added to the contraction scour and long term aggradation or degradation to produce a total scour depth. The estimate of scour at the left abutment (5.86 meters) is added to the clear-water contraction scour (-0.63 meters) to produce the total scour. Note that if the estimated contraction scour is negative it should be assumed equal to zero. If this is the case, the user should re-examine their assumption of clear-water contraction scour. The local scour at the piers in the overbank (2.18 meters) is added to the clear-water contraction scour (-0.63) to produce the total scour at the piers in the overbank (2.18 meters). The total scour at the piers the main channel is estimated by adding the local scour at the piers (3.57 meters) to the live-bed contraction scour (2.08 meters) to obtain a value of 5.65 meters. The total scour at the right abutment is obtained by adding the estimate of scour at the right abutment (6.77 meters) to the live-bed contraction scour (2.08 meters) to obtain a value of 8.85 meters. In all of the above computations the long aggradation or degradation was assumed negligible. Once the various estimates of scour have obtained, the user can plot them on a figure similar to Figure 7-29.

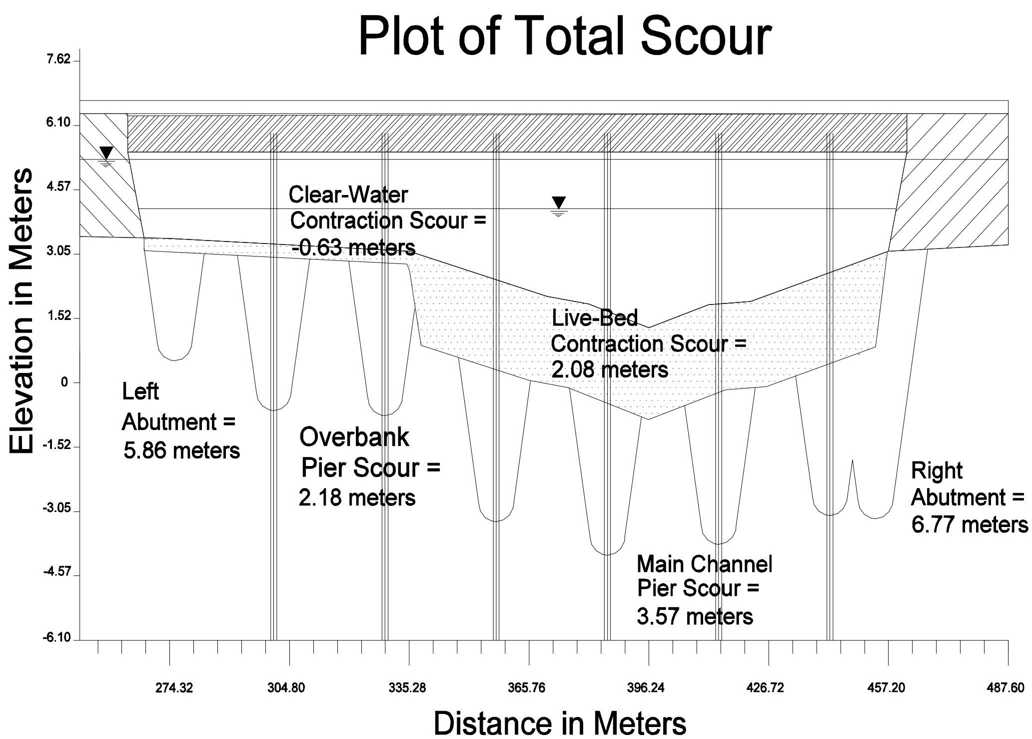


Figure 7-29. Schematic Plot of Scour Components.

```
*************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*----------------------------------------------------------------*
           WORKSHOP PROBLEM - SCOUR CREEK - METRIC
      ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
      CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS

   ***  Abutment Scour Calculations for Header Record BRDG   ***

                 Constants and Input Variables

          *------------------------------------------*
           Adjustment Factor            (K1):    .55
           Flow Angle of Attack Factor  (K2):   1.00
           Factor of Safety             (FS):   1.00
          *------------------------------------------*

    Abtmnt Scour                                        Overbank
 #   Side  Depth   X-Statn  A-Prime    Ya        Qe     Froude #
--  ------ ------ --------- -------- --------- --------- ---------
 1  Left    5.858  268.077  268.077    1.029   152.256      .174
    Right   6.768  457.200  335.280    1.140   221.506      .173
--  ------ ------ --------- -------- --------- --------- ---------
```

Figure 7-30. Printed Output From Abutment Scour Computations.

```
************************  W S P R O  **************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*--------------------------------------------------------------*
           WORKSHOP PROBLEM - SCOUR CREEK - METRIC
      ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
      CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS

    ***  Pier Scour Calculations for Header Record BRDG   ***

                 Constants and Input Variables

                     Pier Width:   1.520
         *--------------------------------------------*
           Pier Shape Factor            (K1):   1.10
           Flow Angle of Attack Factor  (K2):   1.00
           Bed Condition Factor         (K3):   1.00
           Bed Material Factor          (K4):   1.00
           Velocity Multiplier          (VM):   1.00
           Depth Multiplier             (YM):   1.00
         *--------------------------------------------*

    Scour   ---- Localized Hydraulic Properties ----     -- X-Stations --
 #  Depth    Flow      WSE    Depth  Velocity Froude #   Left      Right
--  ----- ---------- -------- ------ -------- -------- --------- ---------
 1   3.57    759.074    4.261  2.935   3.647     .679   335.280   459.450
--  ----- ---------- -------- ------ -------- -------- --------- ---------
```

Figure 7-31.   Printed Output From Main Channel Pier Scour Computations.

```
************************  W S P R O  *************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*-------------------------------------------------------------*
           WORKSHOP PROBLEM - SCOUR CREEK - METRIC
      ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
      CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS

    ***  Pier Scour Calculations for Header Record BRDG   ***

                  Constants and Input Variables

                      Pier Width:   1.520
         *-------------------------------------------*
           Pier Shape Factor            (K1):   1.10
           Flow Angle of Attack Factor  (K2):   1.00
           Bed Condition Factor         (K3):   1.00
           Bed Material Factor          (K4):   1.00
           Velocity Multiplier          (VM):   1.00
           Depth Multiplier             (YM):   1.00
         *-------------------------------------------*

     Scour   ---- Localized Hydraulic Properties ----     -- X-Stations --
 #   Depth    Flow      WSE    Depth  Velocity Froude #   Left      Right
--   ----- ---------- -------- ------ -------- -------- --------- ---------
 1    2.18     90.436    4.261  1.125   1.566     .471    266.381   335.280
--   ----- ---------- -------- ------ -------- -------- --------- ---------
```

Figure 7-32. Printed Output From Overbank Pier Scour Computations.

```
     ************************  W S P R O  **************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
                WORKSHOP PROBLEM - SCOUR CREEK - METRIC
           ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
           CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS

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

                      Constants and Input Variables

             *-----------------------------------------------*
              Bed Material Transport Mode Factor (k1):    .64
              Total Pier Width Value             (Pw):  6.100
             *-----------------------------------------------*

      Scour     -- Flow --         -- Width --        --- X-Limits ---
  #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
 --  ------ --------- --------- -------- --------  ------ -------- --------
  1   2.079   770.268   406.497  115.820  121.920  Left:   335.280  335.280
     ..... Approach Channel Depth:    2.664 .....  Right:  457.200  457.200
 --  ------ --------- --------- -------- --------  ------ -------- --------
```

Figure 7-33. Printed Output From Live-Bed Contraction Scour Computations.

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
                WORKSHOP PROBLEM - SCOUR CREEK - METRIC
           ESTIMATING SCOUR AT BRIDGES - COMPUTER SIMULATION
           CONTRACTION, PIER, AND ABUTMENT SCOUR CALCULATIONS

      ***  Clear-Water Contraction Scour for Header Record BRDG   ***

                      Constants and Input Variables

                 *------------------------------------*
                  Bed Material D50 Value (D50): 1.0000
                  Pier Width Value       (Pw):  3.050
                 *------------------------------------*

     Scour     -- Flow --         -- Width --        --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--  ------ --------- --------- -------- --------  ------ -------- --------
 1   -.633    83.192    71.425   64.153   67.203  Left:   268.077  268.077
    ..... Approach Channel Depth:    1.579 .....  Right:  335.280  335.280
*  Negative Scour Depth Encountered - Check If Variables Are Reasonable  *
--  ------ --------- --------- -------- --------  ------ -------- --------
```

Figure 7-34.   Printed Output From Overbank Contraction Scour Computations.

7.11 EXAMPLE #11: FLOODWAY COMPUTATIONS

A floodway encroachment analysis is required for a simple channel. It is desired that the encroachment occur equally from both sides of the channel. Figure 35 illustrates input data for a simple reach. A surcharge of 0.3048 m has been applied throughout the reach by using a FW record at each cross-section. The results of the analysis are presented in Figure 36.

```
T1        WORKSHOP PROBLEM - FLOOD CREEK - METRIC
T2        FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
T3        HYPOTHETICAL CHANNEL
*
SI 1
*
Q         849.51
SK        0.002
*
XS    XS#1 0  *  *  *  .002
GR          0.00,5.79   30.48,4.57   60.96,3.35  152.40,3.28  274.32,3.05
GR         335.28,2.74  370.33,1.68  381.00,1.49  396.24,0.93  411.48,1.48
GR         422.15,1.55  457.20,2.74  518.16,3.05  640.08,3.28  731.52,3.35
GR         762.00,4.57  792.48,5.79
N             0.042    0.032    0.042
SA                335.28    457.20
FW         0.3048
*
XS    XS#2 457.20
FW         0.3048
*
XS    XS#3 685.80
FW         0.3048
*
XS    XS#4 914.40
FW         0.3048
*
EX
ER
```

Figure 7-35. WSPRO Input Data File For Floodway Computation Example.

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
        Run Date & Time:  9/15/97 11:30 am     Version V070197
         Input File: EX11.DAT       Output File: EX11.LST
   *-----------------------------------------------------------------*
T1         WORKSHOP PROBLEM - FLOOD CREEK - METRIC
T2         FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
T3         HYPOTHETICAL CHANNEL
SI 1
                     Metric (SI) Units Used in WSPRO

                Quantity    SI Unit              Precision
               ------------ -------------------- -----------
                Length      meters                  0.001
                Depth       meters                  0.001
                Elevation   meters                  0.001
                Widths      meters                  0.001

                Velocity    meters/second           0.001
                Discharge   cubic meters/second     0.001
                Slope       meter/meter             0.001

                Angles      degrees                 0.01
               ------------ -------------------- -----------

Q          849.51

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

SK         0.002
```

```
   *************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: Metric  /  Output Units: Metric
   *----------------------------------------------------------------*
              WORKSHOP PROBLEM - FLOOD CREEK - METRIC
        FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                        HYPOTHETICAL CHANNEL

         *----------------------------------------------------*
         *      Starting To Process Header Record  XS#1       *
         *----------------------------------------------------*

XS    XS#1 0  *  *  *  .002
GR           0.00,5.79   30.48,4.57   60.96,3.35  152.40,3.28  274.32,3.05
GR       335.28,2.74  370.33,1.68  381.00,1.49  396.24,0.93  411.48,1.48
GR       422.15,1.55  457.20,2.74  518.16,3.05  640.08,3.28  731.52,3.35
GR       762.00,4.57  792.48,5.79
N             0.042    0.032    0.042
SA                335.28    457.20
FW          0.3048

 ***   Completed Reading Data Associated With Header Record  XS#1   ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***              Data Summary For Header Record  XS#1              ***
 SRD Location:        0.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00200   Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

         ** Floodway Computations Selected for this Section **
            Details: Encroachment from left and right banks
                     Initial floodway boundary section
                     Maximum Surcharge:   .305


                     X,Y-coordinates (17 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000       5.790       30.480       4.570       60.960       3.350
   152.400       3.280      274.320       3.050      335.280       2.740
   370.330       1.680      381.000       1.490      396.240        .930
   411.480       1.480      422.150       1.550      457.200       2.740
   518.160       3.050      640.080       3.280      731.520       3.350
   762.000       4.570      792.480       5.790
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:    5.790 )
  Maximum X-Station:     792.480  ( associated Y-Elevation:    5.790 )
  Minimum Y-Elevation:      .930  ( associated X-Station:    396.240 )
  Maximum Y-Elevation:     5.790  ( associated X-Station:       .000 )

                    Roughness Data (  3 SubAreas )
                             Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1         .042         ---
                               ---        335.280
                     2         .032         ---
                               ---        457.200
                     3         .042         ---
                  -------  -----------  ------------

         *----------------------------------------------------*
```

```
*      Finished Processing Header Record  XS#1      *
*---------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *----------------------------------------------------------------*
            WORKSHOP PROBLEM - FLOOD CREEK - METRIC
      FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                      HYPOTHETICAL CHANNEL

       *----------------------------------------------------*
       *      Starting To Process Header Record  XS#2       *
       *----------------------------------------------------*

XS    XS#2 457.20
FW         0.3048

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

 ***              Data Summary For Header Record  XS#2              ***
 SRD Location:      457.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00200    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

         ** Floodway Computations Selected for this Section **
            Details: Encroachment from left and right banks
                     Maximum Surcharge:   .305


                     X,Y-coordinates (17 pairs)
     X          Y            X          Y            X          Y
 ---------- ----------   ---------- ----------   ---------- ----------
       .000      6.704       30.480      5.484       60.960      4.264
    152.400      4.194      274.320      3.964      335.280      3.654
    370.330      2.594      381.000      2.404      396.240      1.844
    411.480      2.394      422.150      2.464      457.200      3.654
    518.160      3.964      640.080      4.194      731.520      4.264
    762.000      5.484      792.480      6.704
 ---------- ----------   ---------- ----------   ---------- ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:    6.704 )
  Maximum X-Station:     792.480  ( associated Y-Elevation:    6.704 )
  Minimum Y-Elevation:     1.844  ( associated X-Station:    396.240 )
  Maximum Y-Elevation:     6.704  ( associated X-Station:       .000 )

                    Roughness Data (  3 SubAreas )
                            Roughness    Horizontal
                  SubArea  Coefficient   Breakpoint
                  -------  -----------  ------------
                     1        .042          ---
                              ---         335.280
                     2        .032          ---
                              ---         457.200
                     3        .042          ---
                  -------  -----------  ------------

       *----------------------------------------------------*
       *      Finished Processing Header Record  XS#2       *
       *----------------------------------------------------*
```

```
************************* W S P R O ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
*----------------------------------------------------------------*
           WORKSHOP PROBLEM - FLOOD CREEK - METRIC
      FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                    HYPOTHETICAL CHANNEL

      *---------------------------------------------------*
      *      Starting To Process Header Record  XS#3      *
      *---------------------------------------------------*

XS    XS#3 685.80
FW         0.3048

 ***   Completed Reading Data Associated With Header Record  XS#3   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  3  ***

 ***              Data Summary For Header Record  XS#3              ***
 SRD Location:      686.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00200    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

        ** Floodway Computations Selected for this Section **
           Details: Encroachment from left and right banks
                    Maximum Surcharge:   .305


                    X,Y-coordinates (17 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000       7.162       30.480       5.942       60.960       4.722
   152.400       4.652      274.320       4.422      335.280       4.112
   370.330       3.052      381.000       2.862      396.240       2.302
   411.480       2.852      422.150       2.922      457.200       4.112
   518.160       4.422      640.080       4.652      731.520       4.722
   762.000       5.942      792.480       7.162
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:    7.162 )
  Maximum X-Station:     792.480  ( associated Y-Elevation:    7.162 )
  Minimum Y-Elevation:     2.302  ( associated X-Station:    396.240 )
  Maximum Y-Elevation:     7.162  ( associated X-Station:       .000 )

                    Roughness Data (  3 SubAreas )
                         Roughness    Horizontal
                 SubArea  Coefficient   Breakpoint
                 -------  -----------  ------------
                    1         .042         ---
                              ---        335.280
                    2         .032         ---
                              ---        457.200
                    3         .042         ---
                 -------  -----------  ------------

      *---------------------------------------------------*
      *      Finished Processing Header Record  XS#3      *
      *---------------------------------------------------*
```

```
    ************************  W S P R O  **************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
              Input Units: Metric  /  Output Units: Metric
    *---------------------------------------------------------------*
               WORKSHOP PROBLEM - FLOOD CREEK - METRIC
         FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                        HYPOTHETICAL CHANNEL

          *-----------------------------------------------------*
          *      Starting To Process Header Record  XS#4      *
          *-----------------------------------------------------*

XS    XS#4 914.40
FW         0.3048

 ***   Completed Reading Data Associated With Header Record  XS#4   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***              Data Summary For Header Record  XS#4              ***
 SRD Location:      914.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00200    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

         ** Floodway Computations Selected for this Section **
            Details: Encroachment from left and right banks
                     Maximum Surcharge:   .305


                     X,Y-coordinates (17 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
      .000       7.619       30.480       6.399       60.960       5.179
   152.400       5.109      274.320       4.879      335.280       4.569
   370.330       3.509      381.000       3.319      396.240       2.759
   411.480       3.309      422.150       3.379      457.200       4.569
   518.160       4.879      640.080       5.109      731.520       5.179
   762.000       6.399      792.480       7.619
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:        .000  ( associated Y-Elevation:    7.619 )
  Maximum X-Station:     792.480  ( associated Y-Elevation:    7.619 )
  Minimum Y-Elevation:     2.759  ( associated X-Station:    396.240 )
  Maximum Y-Elevation:     7.619  ( associated X-Station:       .000 )

                   Roughness Data (  3 SubAreas )
                         Roughness    Horizontal
                 SubArea  Coefficient   Breakpoint
                 -------  -----------  ------------
                    1         .042          ---
                              ---         335.280
                    2         .032          ---
                              ---         457.200
                    3         .042          ---
                 -------  -----------  ------------

          *-----------------------------------------------------*
          *      Finished Processing Header Record  XS#4      *
          *-----------------------------------------------------*
```

```
 *************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
           WORKSHOP PROBLEM - FLOOD CREEK - METRIC
      FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                      HYPOTHETICAL CHANNEL
EX

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

         Reach      Water Surface   Friction
  #    Discharge      Elevation      Slope        Flow Regime
 --    ---------    -------------   --------   --------------------
  1       849.51      ********        .0020        Sub-Critical
 --    ---------    -------------   --------   --------------------

      *====================================================*
      *        Beginning  1 Profile Calculation(s)         *
      *====================================================*
```

```
 ************************* W S P R O ***************************
    Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
           Input Units: Metric  /  Output Units: Metric
 *-------------------------------------------------------------*
            WORKSHOP PROBLEM - FLOOD CREEK - METRIC
      FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                      HYPOTHETICAL CHANNEL

                 << Beginning Computations for Profile  1 >>

                    WSEL    VHD       Q          AREA      SRDL      LEW
                    EGEL     HF       V            K       FLEN      REW
                    CRWS     HO     FR #          SF       ALPHA     ERR
                 --------- ------ ---------- ---------- --------- ---------
Section:  XS#1       3.833   .173    849.510    622.719 *********    48.886
Header Type: XS      4.006 ******      1.364   18992.98 *********   743.592
SRD:        .000     3.611 ******       .622     ******     1.829    ******

Section:  XS#2       4.747   .173    849.510    623.075   457.200    48.874
Header Type: XS      4.921   .913      1.363   19006.80   457.200   743.605
SRD:     457.200     4.525   .000       .622      .0020     1.829      .002

Section:  XS#3       5.205   .173    849.510    623.175   228.600    48.870
Header Type: XS      5.378   .456      1.363   19010.66   228.600   743.609
SRD:     685.800     4.983   .000       .622      .0020     1.829      .002

Section:  XS#4       5.662   .173    849.510    623.170   228.600    48.870
Header Type: XS      5.835   .456      1.363   19010.47   228.600   743.609
SRD:     914.400     5.440   .000       .622      .0020     1.829      .002

                 << Completed Computations of Profile  1 >>
```

```
 *************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
          Input Units: Metric  /  Output Units: Metric
 *-----------------------------------------------------------------*
           WORKSHOP PROBLEM - FLOOD CREEK - METRIC
     FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                    HYPOTHETICAL CHANNEL

      *=====================================================*
      *           Floodway Analysis Computations            *
      *=====================================================*


                    WSEL    VHD        Q          AREA      SRDL      LEW
                    EGEL     HF        V           K        FLEN      REW
                    CRWS     HO       FR #         SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section:  XS#1      4.137   .264    849.510    409.578 *********   284.920
Header Type: XS     4.402 ******      2.074   18917.72 *********   507.302
SRD:         .000   3.527 ******       .536     ******     1.206     -.004

Section:  XS#2      5.057   .263    849.510    409.998   457.200   285.882
Header Type: XS     5.321   .918      2.071   18983.40   457.200   507.559
SRD:      457.200   4.441   .000       .534      .0020     1.204      .001

Section:  XS#3      5.515   .263    849.510    410.197   228.600   285.881
Header Type: XS     5.779   .457      2.070   18997.30   228.600   507.560
SRD:      685.800   4.898   .000       .534      .0020     1.204      .001

Section:  XS#4      5.973   .263    849.510    410.256   228.600   285.881
Header Type: XS     6.236   .457      2.070   19001.47   228.600   507.560
SRD:      914.400   5.355   .000       .533      .0020     1.204      .001
```

```
     *************************  W S P R O  ***************************
        Federal Highway Administration  -  U. S. Geological Survey
               Model for Water-Surface Profile Computations.
               Input Units: Metric  /  Output Units: Metric
     *-----------------------------------------------------------------*
                WORKSHOP PROBLEM - FLOOD CREEK - METRIC
          FLOODWAY ENCROACHMENT ANALYSIS - COMPUTER SIMULATION
                           HYPOTHETICAL CHANNEL

 # SECID   SRD       d    FW-WSEL  UN-WSEL  WIDTH     LEW      REW      AREA     VEL
-- ----- -------- ------ -------- -------- -------- -------- -------- --------- ------
 1  XS#1     .000  .304    4.137    3.833  222.382  284.920  507.302   409.578  2.074
 2  XS#2  457.200  .310    5.057    4.747  221.676  285.882  507.559   409.998  2.071
 3  XS#3  685.800  .310    5.515    5.205  221.679  285.881  507.560   410.197  2.070
 4  XS#4  914.400  .311    5.973    5.662  221.678  285.881  507.560   410.256  2.070
-- ----- -------- ------ -------- -------- -------- -------- -------- --------- ------
   ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  1 Seconds  **************
```

Figure 7-36. WSPRO Output Data File For Floodway Computation Example.

SECTION 8 - COMPUTER CONSIDERATIONS

Implementation of WSPRO can range from a quite simple procedure on a microcomputer to a relatively major task on some minicomputers and (or) large mainframe computers. Discussions in this section are intentionally general because details of implementation may vary greatly depending on where, from whom, and in what form the user obtains the model.

The microcomputer version in its executable form (i.e., .EXE file) is quite easily implemented. Some modification of the CONFIG.SYS file relative to BUFFERS and FILES may be required. The first personal computer (PC) implementation of WSPRO used an IBM PC/AT[1] but the model has since been implemented on several different brands and models of personal computers. WSPRO requires less than 400 kb of memory. Execution time, which is greatly reduced by a math coprocessor, varies considerably depending on the model of PC used. Typical run times of from one-half to two min on a math-coprocessor-equipped IBM PC/AT (or compatible model) may be five to seven min on a similarly equipped IBM PC/XT (or compatible model) and one-half h or more on less powerful IBM PC's (or compatible models) without a math coprocessor.

Implementation also depends somewhat on how the user operates (i.e., with an internal hard disk, one or two external disks, or some combination thereof). Regardless of the system, WSPRO execution results in the user being "prompted" for the input and output file names or other information depending on the user's intentions. To execute the WSPRO program, the user needs to enter the name of the WSPRO executable from a DOS prompt. The first response must be to enter the file name of an existing file that contains the input data. If the user is willing to accept the default output file name extension (*.lst), the second prompt can be responded to with a simple "yes" command. If the user desires a different name for the output file, one can be selected at this time. On second, and subsequent, executions of the WSPRO executable, the file names are read from a "master" data file. Accepting the file names recorded in the master data file assumes the user wants the same input and output file names to be used for the current program execution. All file names must conform to standard MS/DOS conventions.

The output can also be redirected to the computer screen or a printer. Specifying a file name provides an opportunity to "preview" the results prior to generating a hard copy.

---

[1] Reference to trade names, commercial products, manufacturers, or distributors in this manual is for identification purposes only and does not constitute endorsement by the Federal Highway Administration or the U.S. Geological Survey and are not necessarily recommended for use.

Many minicomputers and mainframe computers require additional detail regarding all files to be used by a program. Some systems require only that the user specify how each file is to be used (i.e., input, output, or both input and output). Other systems need information (for at least some files) regarding record length, record format, etc., and perhaps the amount of space to be allocated for each file. Such information is included in the following descriptions of each "unit" used by WSPRO.

Unit 5: Input file ("card reader") requires 80 characters per record; may be blocked; space required depends on the total number of individual data records.

Unit 6: Output file ("printer") requires 133 characters per record (includes carriage-control character); may be blocked; space required depends on the number of cross-sections and the number of profiles computed.

Unit 7: "obsolete" output file (can be "dummied") requires 80 characters per record; may be blocked; space required depends on the total number of individual data records.

Unit 8: "obsolete" output file (can be "dummied") requires 80 characters per record; may be blocked; space required depends on the volume of bridge computations.

Unit 9: "obsolete" output file (can be "dummied") requires 133 characters per record (includes carriage-control character); may be blocked; space required depends on the number of cross-sections and the number of profiles computed.

Unit 13: Input and output file (direct-access) requires 1680 characters per record; unformatted, variable block size; requires one record per cross-section.

Unit 14: Input and output file (direct-access) requires 400 characters per record; unformatted, variable block size; requires one record per cross-section per profile plus overhead of about 10 records per profile.

Executable code generally cannot be transferred between different brands (and frequently not between different installations of like brand) of minicomputers and large mainframe computers. Users of such systems will need to acquire WSPRO source code, which will more than likely require some minor revisions. This can easily be accomplished, but the pertinent instructions are beyond the scope of this user's manual.

SECTION 9 - APPENDIX A / GLOSSARY

This section, although referred to as a glossary, actually has characteristics of both a glossary and an index while not totally conforming to the normal content or structure of either. The tables in Section 4, which describe the individual data records, provide complete definitions of the input parameters associated with each data record. Those definitions are not repeated in this section. Instead a very brief definition is provided along with cross references to: (1) table(s) in which they are defined; (2) figure(s) in which they are illustrated; and (3) section(s) of the report where additional discussion or examples of them may be found.

Many output parameters appear in several places in the output and those are simply labeled as "output parameters" in this section. Single- (and some dual-) purpose output parameters are defined in terms of "culvert output," "profile output," etc. Most input parameters double as output parameters but are not doubly defined as such in this section.

Individual data records are not re-defined in this section. The user can refer to: (1) Table 2-1 which lists all of the data records in groups by function; (2) Table 4-2 which lists all of the data records with a brief statement of the purpose of each record (in alphabetical order of record identifiers); and (3) to the individual tables in Section 4 which define each record and all of its associated parameters in detail (the individual tables are alphabetically ordered). Also, the detail in the table of contents and the lists of figures and tables should be very useful in locating specific items of interest.

The remainder of this section is devoted to the alphabetical list of parameters and abbreviations with associated definitions and cross-reference information.

A3	-	Multiple-opening output, flow area in each opening.
ABSLPL, ABSLPR	-	Input parameters, left and right abutment slopes [see Table 4-3; Figure 4-9].
AIN	-	Culvert output, flow area at culvert inlet.
ALPH	-	Cross-sectional properties and profile output, velocity head correction factor for nonuniform velocity distribution.
AOUT	-	Culvert output, flow area at culvert outlet.
AREA	-	Cross-sectional properties and profile output, flow area of a cross-section.
ASUBC	-	Culvert output, flow area in culvert at critical depth.

ASUBN	-	Culvert output, flow area in culvert at normal depth.
BCELEV	-	Input parameter, bridge-deck elevation [see Table 4-5; Figure 4-1].
BCSLP	-	Input parameter, bridge-deck slope [see Table 4-5; Figure 4-1].
BCSTA	-	Input parameter, bridge-deck station [see Table 4-5; Figure 4-1].
BETA	-	User-defined table parameter, momentum correction factor for non-uniform velocity distribution, used in computing expansion loss downstream from bridge.
BLEN	-	Output for bridge section, bridge length output for component mode (also see BRLEN).
BOLEW, BOREW	-	Multiple-opening output, left and right edge of water in each opening.
BOTD	-	Input parameter, hydraulic-depth breakpoint for BOTN [see Tables 4-31, 4-32; Figure 4-15].
BOTN	-	Input parameter, roughness coefficient for BOTD breakpoint [see Tables 4-31, 4-32; Figure 4-15].
BOTRAD	-	Input parameter, bottom radius of pipe-arch culvert [see Table 4-12].
BRLEN	-	Input parameter, bridge length measured between tops of abutments, [see Table 4-6; Figures 4-3, 4-7, 4-8, 4-9, 4-10].
BRTYPE	-	Input parameter, indicates type of bridge opening [see Table 4-11; Figures 4-7, 4-8, 4-9, 4-10].
BRWDTH	-	Input parameter, width of bridge longitudinal to the flow [see Table 4-11; Figures 4-7, 4-8, 4-9, 4-10].
BSUBD	-	Input parameter, offset for straight grade banks; perpendicular distance between abutment toes and dikes [see Table 4-25].
C	-	Output for bridge or roadway weir section, coefficient of discharge for bridge opening or roadway weir [see Tables 4-8, 4-41].
CA3	-	Multiple-opening output, "live" flow area (product of CJ and A3) for each opening.
CAVG	-	Road overflow output, average of the weir coefficient(s) used for computing the flow over the road.
CDF	-	Multiple-opening output, conveyance distribution factor for each valley strip (see Shearman and others, 1986).
CJ	-	Multiple-opening output, coefficient of discharge for each opening.

CK - Input parameter, contraction coefficient for open-channel computations [see Tables 4-4, 4-8, 4-25, 4-41, 4-42].

CKE - Input parameter, entrance-loss coefficient for culvert [see Table 4-9].

CN - Input parameter, culvert roughness coefficient [see Table 4-9].

CODE - Label used in output headings for record identifiers.

CORRAD - Input parameter, corner radii for pipe-arch culvert [see Table 4-12].

CRF - Multiple-opening output, channel resistance ratio for each valley strip (see Shearman and others, 1986).

CRWS - Profile output, water-surface elevation for critical flow [see Figure 4-11; Section 4.3.5].

CVALPH - Input parameter, velocity head correction factor for culvert [see Table 4-9].

CVLENG - Input parameter, culvert length [see Table 4-15].

DAF - Output parameter, abbreviation for direct-access file.

DAVG - Road overflow output, average weir-flow depth.

DELTAY - Input parameter, elevation increment used in search for energy balance [see Table 4-29].

DMAX - Road overflow output, maximum weir-flow depth.

DMIN - Road overflow output, minimum weir-flow depth.

DSINV - Input parameter, downstream culvert invert elevation [see Table 4-15].

DSUBC - Culvert output, critical flow depth in the culvert.

DSUBN - Culvert output, normal flow depth in the culvert.

EGL - Profile output, elevation of the energy-grade line.

EK - Input parameter, expansion coefficient for open-channel computations [see Tables 4-4, 4-8, 4-25, 4-41, 4-42].

ELMAX - Input parameter, maximum elevation for cross-sectional properties computations [see Table 4-28, Section 7.7].

ELMIN - Input parameter, minimum elevation for cross-sectional properties computations [see Table 4-28; Section 7.7].

EMBELV - Input parameter, embankment elevation [see Table 4-11].

EMBSS - Input parameter, embankment side slope [see Table 4-11].

EMBWID - Input parameter, embankment width [see Table 4-41].

ENTRND - Input parameter, radius of entrance rounding [see Table 4-11; Figure 4-7].

ERR - Profile output, discrepancy in balancing energy and (or) discharge.

ERR-CODE - Input data summary output, indicates +++xxx message for that section (magnitude of ERR-CODE not important), consult Table 6-1.

FDSTLT, FDSTRT - Input parameters, permit adjustment of effective flow length upstream from a bridge [see Table 4-7; Figure 4-6].

FLEN - As input parameter(s), permits specification of variable flow lengths across the valley [see Table 4-22; Figure 4-13]. In the profile output it indicates the effective flow length computed for: (1) the FLEN input for open-channel computations; and (or) (2) the approach reach in the bridge-backwater computations.

FLOW - Output for bridge section (see Shearman and others, 1986), indicates FLOW class as follows:

FLOW = 1 - free-surface flow through bridge, no road overflow.
FLOW = 2 - unsubmerged pressure flow through bridge, no road overflow.
FLOW = 3 - submerged pressure flow through bridge, no road overflow.
FLOW = 4 - free-surface flow through bridge, with road overflow.
FLOW = 5 - unsubmerged pressure flow through bridge, with road overflow.
FLOW = 6 - submerged pressure flow through bridge, with road overflow.

FNTEST - Input parameter, test value of Froude number for approximate check for possibility of critical flow [see Table 4-29].

FR# - Profile output, computed value of Froude number for approximate check for possibility of critical flow.

GBOFF - Input parameter, offset distance for elliptical guidebanks [see Table 4-25; Figure 4-14].

GBTYPE - Input parameter, indicates type of guidebanks [see Table 4-25].

GIRDEP - Input parameter, vertical distance between top of bridge deck and low-chord elevation of the opening [see Table 4-5; Figure 4-1].

HAVG - Road overflow output, average total head for weir-flow computations.

HF	-	Profile output, friction loss.
HO	-	Profile output, losses other than friction loss.
HWE	-	Culvert output, headwater elevation.
HWIC, HWOC	-	Culvert output, these two variables represent the number of meters to be added to the DSINV to obtain the HWE for inlet and outlet control, respectively. WSPRO assumes the maximum of the two is applicable. If, in the user's judgement, this assumption is invalid for a given flow situation, simply add the other quantity to DSINV to obtain the HWE for the alternate controlling condition.
ICODE	-	Input parameter, indicates culvert characteristics [see Table 4-12].
IDIR	-	Input parameter, indicates computational direction [see Table 4-21].
IEX	-	Input parameter, indicates computational direction [see Table 4-21].
IHFNO	-	Input parameter, indicates averaging method(s) for friction-loss computations [see Table 4-22].
IHFNOJ	-	Input parameter, indicates averaging method for friction-loss computations [see Table 4-29].
IHP	-	Input parameter, option code for selecting cross-sectional properties output [see Table 4-28; Section 7.7].
IPAVE	-	Input parameter, indicates road-surface condition [see Table 4-41].
K	-	Cross-sectional properties and profile output, cross-sectional conveyance.
KQ	-	Profile output, conveyance of the KQ segment of the approach section.
KS	-	Multiple-opening output, valley-strip conveyance at the upstream match section.
K1,K2,K3,K4	-	Input parameters, adjustment/correction factors applied to local pier scour estimation equation.
LEW	-	Cross-sectional properties and profile output, left edge of water.
LOCOPT	-	Input parameter, option code controlling bridge-opening location [see Table 4-6; Figure 4-2].
M[G]	-	Bridge-backwater output, geometric contraction ratio (see Shearman and others, 1986).
M[K]	-	Bridge backwater output, flow contraction ratio (see Shearman and others, 1986) [Table 4-30; Figure 4-15; Section 7.2].

NBBL	-	Input parameter, number of barrels for multi-barrel culverts [see Table 4-15].
NGP	-	Output parameter, number of x,y-coordinates in GR data for a cross-section [see Table 4-26; Figure 4-15].
NPD	-	Output parameter, number of data pairs in PD record(s) [see Table 4-33].
NPROF	-	Output parameter, number of profiles to be computed [see Tables 4-34, 4-37, 4-40].
NRD	-	Output parameter, number of x,y-coordinates in GR data for a road-grade section.
NSA	-	Output parameter, number of subareas in the cross-section [see Tables 4-31, 4-32, 4-35; Figure 4-15].
OTEL	-	Profile output, minimum elevation at which road grade could be built without being subjected to overtopping.
OTFULL	-	Culvert output, a "flag" to indicate the existence of full-pipe flow; positive value indicates full-pipe flow.
P/A	-	Output for bridge section, ratio of pier (pile) area to gross area in the bridge opening.
PD	-	Input parameter, pier width used in pier scour calculations.
PDTH	-	Input parameter, gross pier (pile) width for an associated PELV [see Table 4-33; Figure 4-17].
PELV	-	Input parameter, elevation at which gross pier (pile) width, PDDTH, is input [see Table 4-33; Figure 4-17].
PFELEV	-	Input parameter, test value for low-chord elevation in a bridge used to test for possible pressure flow [see Table 4-8; Figures 4-1, 4-2, 4-3; Section 4.3.7].
PPCD	-	Input parameter, option code to distinguish between piers and piles [see Table 4-33; Figure 4-17].
Q	-	Input parameter, discharge specified for each profile [see Table 4-34] and velocity and conveyance distribution [see Table 4-28].
QBBL	-	Culvert output, discharge per barrel (discharge in Q record divided by NBBL in CV record).
QB	-	Input parameter, discharge through the bridge opening (used in pier scour analysis).

QS	-	Multiple-opening output, discharge apportioned to each valley strip and its associated opening (see Shearman and others, 1986).
QTOL	-	Input parameter, allowable tolerance for balancing discharge in a combined bridge flow and road overflow situation [see Table 4-29].
RECORD NO	-	Input data processing output, indicates the "sequence" number of each cross-section as it is stored on the direct-access file.
REW	-	Cross-sectional properties and profile output, right edge of water.
RISE	-	Input parameter, vertical dimension of culvert [see Tables 4-12, 4-14].
SCALE	-	Input parameter, scaling factor for fabricating cross-sections [see Table 4-27].
SECID	-	Input parameter, unique identifier for each cross-section [see Tables 4-4, 4-8, 4-15, 4-16, 4-17, 4-18, 4-25, 4-28, 4-41, 4-42, 4-43; Section 4.1].
SKEW	-	Input parameter, angle at which the cross-section is skewed to the flow [see Tables 4-4, 4-8, 4-25, 4-41, 4-42; Section 4.3.6].
SKSL	-	Input parameter, energy gradient [see Table 4-36; Figure 4-17].
SLEN	-	User-defined table parameter, difference between adjacent SRD's (same as SRDL).
SPAN	-	Input parameter, horizontal dimension of culvert [see Tables 4-12, 4-14].
SRD	-	Input parameter, section reference distance [see Tables 4-4, 4-8, 4-15, 4-25, 4-41, 4-42, 4-43; Section 4.3.4].
SRDL	-	Profile output, difference between adjacent SRD's (same as SLEN).
TOPD	-	Input parameter, hydraulic-depth breakpoint for TOPN [see Tables 4-31, 4-32; Figure 4-15].
TOPN	-	Input parameter, roughness coefficient for TOPD breakpoint [see Tables 4-31, 4-32; Figure 4-15].
TOPRAD	-	Input parameter, top radius for pipe-arch culvert [see Table 4-12].
TWDEP	-	Culvert output, tailwater depth (elevation on WS record minus DSINV).
TYPE	-	Output for bridge section, type of bridge opening (same as BRTYPE).
USERCD	-	Input parameter, to override C-value for bridge [see Table 4-8].

USERCF	-	Input parameter, to override weir coefficient [see Table 4-41].
USINV	-	Input parameter, upstream culvert invert elevation [see Table 4-15].
V1	-	Input parameter, used as safety factors in pier scour depth calculations.
VARNOS	-	List of parameter codes for user-defined Tables [see Table 4-39; Sections 5, 7.5].
VAVG	-	Road overflow output, estimated average velocity of road overflow.
VEL	-	Output parameter, flow velocity.
VELIN	-	Culvert output, flow velocity at the culvert inlet.
VELOT	-	Culvert output, flow velocity at the culvert outlet.
VHD	-	Profile output, velocity head.
VMAX	-	Road overflow output, estimated maximum velocity of road overflow.
VSLOPE	-	Input parameter, valley slope for data propagation [see Tables 4-4, 4-25, 4-41, 4-42].
WLEN	-	Road overflow output, length of weir section for road overflow.
WS1	-	Profile output, computed water-surface elevation at approach section [see Figures 4-8, 4-9, 4-11].
WS3N	-	Profile output, computed water-surface elevation at the full-valley section for unconstricted flow [see Figures 4-8, 4-10].
WSEL	-	Profile output, computed or assumed water-surface elevation.
WSI	-	Profile output, assigned or computed water-surface elevation at the initial cross-section [see Table 4-40; Figure 4-11; Section 4.3.2].
WWANGL	-	Input parameter, wingwall angle [see Table 4-11; Figures 4-7, 4-10].
WWWID	-	Input parameter, wingwall width [see Table 4-11; Figure 4-7].
x	-	Incremental distance(s) added to BRWDTH to compute total flow length through bridges with sloping embankments [see Table 4-11; Figures 4-8, 4-9, 4-10, 4-11].
X	-	Input parameter, x-coordinate(s) of GR data [see Table 4-26; Figure 4-15].
XCONLT, XCONRT	-	Input parameter, left and right horizontal constraints on bridge location [see Table 4-6; Figures 4-2, 4-3].

XCTR	-	Input parameter, x-coordinate at centerline of culvert(s) [see Table 4-15].
XFL	-	Input parameter, x-coordinate(s) of breakpoint(s) for FLEN input data [see Table 4-22; Figure 4-13].
XLAB	-	Bridge section output, x-coordinate at toe of left abutment (component mode only).
XLIML, XLIMR	-	Input parameter, left and right limits for fabricated cross-section [see Table 4-27; Figures 3-6, 3-7; Section 3-1].
XLKQ	-	Input parameter, left limit of Kq-section [see Table 4-30; Figure 4-16; Section 7.2].
XLT	-	Input parameter, left limit of channel segment to be analyzed for pier scour depth estimations.
XMAX, XMIN	-	Output parameter, maximum and minimum cross-section stations.
XORIG	-	Input parameter, to fix a point in a scaled, fabricated cross-section [see Table 4-26].
XRAB	-	Bridge-section output, x-coordinate at toe of right abutment (component mode only).
XREFLT	-	Input parameter, for horizontal datum correction(s) between approach section and bridge and (or) road-grade section(s) [see Table 4-7; Figures 5-4, 5-5; Section7.2].
XREFLT, XREFRT	-	Input parameters, permit adjustment of effective flow length for curvilinear flow upstream from a bridge [see Table 4-7; Figure 4-6].
XRKQ	-	Input parameter, right limit of Kq-section [see Table 4-30; Figure 4-16; Section 7.2].
XS	-	Multiple-opening output, flow area in each valley strip at the upstream match section.
XSA	-	Input parameter, x-coordinate(s) at subarea breakpoints [see Table 4-35; Figure 4-15].
XSID	-	Output parameter, column heading for SECIDs.
XSTW	-	Output parameter, cross-sectional top width.
XSWP	-	Output parameter, cross-sectional wetted perimeter.
Y1M	-	Input parameter, depth multiplier used in pier scour analysis.
Y	-	Input parameter, elevation(s) of GR data [see Table 4-26; Figure 4-15].

YABLT, YABRT	-	Elevations at toes of left and right abutments [see Table 4-3; Figure 4-8].
YINC	-	Input parameter, elevation increment for cross-sectional properties computations [see Table 4-28; Section 7.7].
YMAX	-	Output parameter, maximum cross-section elevation [see Figure 4-12; Section 4.3.5].
YMIN	-	Output parameter, minimum cross-section elevation [see Figure 4-12].
YSHIFT	-	Input parameter, for vertical shift of GR data [see Table 4-27; Section 7.3.1].
YTOL	-	Input parameter, allowable tolerance for balancing energy equation [see Table 4-29].

SECTION 10 - APPENDIX B / THE HYDRAIN WSPRO INPUT / OUTPUT PROGRAM

The WSPRO Input/Output Program is a Graphical User Interface (GUI) program and set of supporting files which allow a user to interface with the WSPRO model in a Windows-like environment. This facilitates viewing and editing input data, output data, cross-sections and other aspects of interaction with WSPRO. The Input/Output Program is not intended to replace familiarity with the WSPRO model. Its objective is to facilitate interaction with the model. Use of the WSPRO Input/Output Program requires a VGA monitor or better. See Section 8 for further information on computer configuration considerations. The purpose of this section is to familiarize WSPRO users with the GUI and help associate the imagery of the GUI with the WSPRO functionality it facilitates.

The WSPRO Input/Output Program can be run by itself or through the HYDRAIN program. To run the program standalone, the name of the executable (WSHLL.EXE) needs to be entered from a DOS prompt. To run the WSPRO Input/Output Program through HYDRAIN, access the Analyze pull down menu and choose WSPRO. HYDRAIN also has an editor that provides long and short help which can be used to enter data interactively into an ASCII data file. A more comprehensive overview of the HYDRAIN editor can be found in the HYDRAIN User's Manual (1998).[15]

Much of the user's interaction with the program is done with the mouse. Actions which can be taken with the mouse are pointing, clicking, left-clicking, right-clicking, double-clicking, dragging and "dragging and dropping." The user gets visual feedback of actions taken by movements of the arrow-shaped cursor on the screen.

- Pointing is done by moving the mouse so the cursor points at a desired location on the screen. As the mouse is moved, the cursor tracks its movements.

- Left- and right-clicking are done by pointing to a desired location on the screen and then operating the mouse's left or right button, respectively, by pressing and then releasing the appropriate mouse button. Right-clicking on an icon button displays a short help message about that object at the bottom of the screen.

- Double-clicking is done by pointing at the desired screen object and then pressing and releasing the left mouse button twice in quick succession. Pointing and left-clicking is the standard action to take to select and object for use. Double-clicking both selects the object for use and causes a logical action to be taken on it.

C Dragging is done by pointing to a desired location on the screen, pressing (and holding) the left mouse button, moving the mouse to another desired location on the screen, and the releasing the mouse button.

C Dragging and dropping is a special capability offered by some screen objects. Physically, it is done exactly like dragging; however, there are additional visual and functional effects. When the mouse button is pressed on an object offering drag-and-drop functionality, the cursor will change to indicate it has be "loaded" and is prepared for the drop. When the mouse is moved to the target area of the screen and the mouse button released, the cursor returns to its normal appearance and the action represented by the dragged icon takes effect.

10.1 SCREEN

The WSPRO Input/Output Program divides the screen into four areas: the Command Bar, the Tool Bar, the Schematic Layout Window, and the Browser Window. These areas are used in conjunction with each other to carry out WSPRO-related tasks. Only one of these areas is "active" at a time. The active area is indicated by an orange box which highlights the perimeter of the active area. In addition to the orange box which indicates the active window, the title bars of the Schematic Layout and Browser windows are green when active and white when not.

Some screen control features are common to more than one area. They are discussed below.

Up, down, left, and right, respectively. These icon buttons are the up, down, left, and right button icons, respectively. There are left and right buttons at the left end of the Command Bar and one of each on appropriate ends of the scroll bars in the Schematic Layout and Browser windows. Clicking on one of these buttons causes the affected bar or window to scroll in the indicated direction revealing additional information or icon buttons.

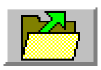
Maximize and *minimize window*, respectively. One of these buttons can always be found in the upper right-hand corner of the Schematic Layout and Browser windows. When the button is present and left clicked, the affected window will expand to full-screen size. When the is present and left-clicked, the window contracts to its normal size and place on the screen.

Clear. This button is found in the upper left-hand corner of the Schematic Layout and Browser Windows and in dialog boxes. In the Schematic Layout and Browser windows, left-clicking it causes whatever information is displayed there to be cleared. In dialog boxes, it has the same effect as the Cancel button.

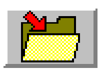
Scroll Bar. A vertical or horizontal scroll bar appear at the bottom or right edge, respectively, of the Schematic Layout and Browser windows. Only a horizontal scroll bar is shown here. Clicking on the arrow button at either end of the scroll bar causes the affected display to scroll in increments of one line or character. Dragging the "thumb" (the button icon on the scroll bar between the arrow buttons) causes the display to scroll an amount proportional to the distance the thumb is dragged. Clicking in the gray area between the thumb and the arrow causes the display to scroll an amount equal the one window's width.

10.2 COMMAND BAR

The command bar contains 17 button icons which, when left-clicked with the mouse, carry out specific actions. Not all 17 buttons are visible simultaneously. At the left end of the command bar are left and right scroll buttons. Clicking these buttons causes the command bar to "scroll" making the "hidden" buttons "scroll" into view for access. The actions associated with each button is described below.



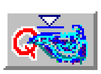
Open/Create. This icon summons a dialog from which the user selects and loads a particular existing input data set or creates a new one.



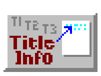
Save. This icon saves the currently open data set to disk.

Run. This icon executes (analyzes) the currently open data set and displays the output in the Browser window.

Quit. This icon quits and exits the WSPRO Input/Output Program.



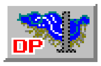
Flow Characteristics. This icon summons a scrollable dialog box where the user enters information from which a starting water-surface elevation can be obtained. This record is also used to insert a Q record in the data set. See Tables 4-33, 4-36, and 4-39 for details about use of this record.



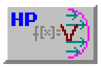
Title Information. This icon summons a dialog for entry of up to three lines of textual information inserted into the ASCII data set as T1, T2, and T3 commands. See Table 4-37 for details about this use of this record.

DA Command. This icon summons a scrollable dialog box which allows entry of abutment scour information and inserts an appropriate DA command into the ASCII data set. See Table 4-15 for details about use of this record.

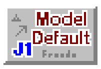
DC Command. This icon summons a scrollable dialog box for entry of live-bed and clear-water scour information and inserts an appropriate DC command into the ASCII data set. See Table 4-16 for details about use of this record.



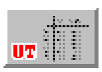
DP Command. This icon summons a scrollable dialog box for entry of local pier scour computation parameters and inserts an appropriate DP command into the ASCII data set. See Table 4-18 for details about use of this record.



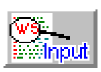
HP command. This icon summons a scrollable dialog box where the user provides hydraulic property information and inserts an HP record into the ASCII data set. See Table 4-28 for details about use of this record.



J1 Command. This icon summons a dialog for entry of computational control parameters and inserts a J1 record into the ASCII data set. See Table 4-29 for details about use of this record.



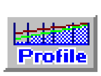
UT command. This icon summons a scrollable dialog box for entry of parameters specifying user-defined output tables by inserting a UT record into the ASCII data set. See Table 4-39 for details about use of this record.



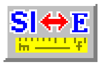
Input. This icon summons the currently established input data set to the Browser window. Whatever was previously displayed in the Browser window is cleared before the input file is displayed. No input data are lost when the Browser window is cleared.

Output. This icon summons the current output data file to the Browser window. Whatever was previously displayed in the Browser window is cleared before the output file is shown. No output data are lost when the Browser window is cleared.

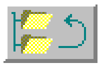
Section. This icon summons a scrollable dialog in which the names of cross-sections available for plotting are displayed. Left-clicking on a cross-section name and the OK button (or double-clicking on the cross-section name) displays the cross-section with water-surface elevation in the Browser window. Note: Since no output cross-sections are available until after the input data set has been analyzed, the dialog will be empty until the input data are analyzed.



Profile. This icon summons a scrollable dialog in which the names of available output profiles are displayed. Left-clicking on a profile name and the OK button (or double-clicking on the profile name) displays the cross-section and water-surface elevation in the Browser window. Note: Since no output profile are available until after the input data set has been analyzed, the dialog will be empty until the input data are analyzed.

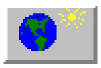


Units. This icon summons a dialog where the user sets the unit system for the input data set and inserts and appropriate SI command in the data set. Note: Four additional buttons are displayed with this dialog. They are for options not implemented in the current version of the program. See Table 4-36 for details about use of this record.

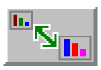


Paths. This icon allows the user to change the default path and file name information. This option is not implemented in the current version of the program.

Device. This icon allows the user to set the default output device. This options is not implemented in the current version of the program.



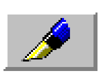
Global Defaults. This icon summons a dialog in which the user specifies global defaults. This option is not implemented in the current version of the program.



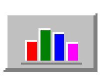
Graphic Defaults. This icon summons a dialog in which the user specifies defaults for the graphic devices. This capability is not implemented in the current version of the program.

10.3 TOOL BAR

The Tool Bar becomes active when clicked. This is indicated by the orange box surrounding its three icon buttons. The tools in the Tool Bar are used to select and view elements of the WSPRO data set and its output. Icon buttons are used by dragging and dropping them onto the icons attached to the River in the Schematic Layout window. The reverse, dragging and dropping the attached icons from the Schematic Layout window onto these buttons, has the same effect. The three buttons are:



Edit. This icon summons the dialog associated with the edit function. This allows the user to edit an existing header. Using this icon button has the same effect as double-clicking an attached icon. Whatever was previously displayed in the Browser window is first cleared. No data are lost by clearing the Browser window.



Graph. This icon summons a graph of that cross-section to the Browser window. Whatever was previously displayed in the Browser window is first cleared. No data are lost by clearing the Browser window.

Print. This icon sends the current data to the output device.

10.4 SCHEMATIC LAYOUT WINDOW

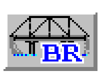
The Schematic Layout window normally occupies the left side of the screen. It becomes "active" when left-clicked. This is indicated when its title bar turns green and the orange box surrounds it. When no header information is available in the data set, most of the window is blank containing only a representation of a channel labeled "RIVER".

To the far left of the Schematic Layout is an area labeled "Header" containing eight icon buttons. The top six of these buttons represent header records. To use one of these icons, drag and drop it on the "RIVER" in the Schematic Layout window. This will summon a dialog box in which the user can specify parameters associated with that header and attach an icon to the River to indicate the header is present in the data set. Initially, the icon will attach to the River at the top, but its location along the River will change when its location is edited in the corresponding dialog box.

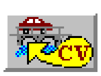
Once attached to the River, information associated with these icons can be viewed and modified. Dragging and dropping an attached icon on the Edit, Graph, or Print icons causes and edit, graph, or print action, respectively, to be carried out on the information associated with the dragged icon. The reverse action, dragging and dropping the Edit, Graph, or Print icons on an attached header icon, has the identical effect. Left-clicking on an attached icon selects it as indicated by highlighting around its perimeter. Double-clicking on an attached icon summons its dialog box so data associated with that element can be edited.

The six header icons are:

XS Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines cross-section information. See Table 4-42 for details about use of this record.



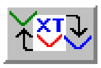
BR Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines bridge section information. See Table 4-8 for details about use of this record.



CV Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines culvert section information. See Table 4-15 for details about use of this record.

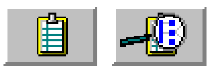
GB Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines guidebank section information. See Table 4-25 for details about use of this record.

XR Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines road-grade section information. See Table 4-41 for details about use of this record.

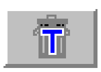


XT Header. This icon when dragged to the River in the Schematic Layout window summons a dialog box where the user defines template section information. See Table 4-43 for details about use of this record.

Two of the icons under the Header title allow the user to edit header records. These icons are also "drag and drop" icons.



Clipboard. Dragging and dropping an icon attached to the River onto the Clipboard icon (or vice versa) creates a copy of the dragged header information and summons its dialog box for the user to edit. The two icon button images shown represent an empty and loaded clipboard, respectively.



Trash can. Dragging an attached header record icon from the River to the trash can icon (or vice versa) deletes information associated with that header from the data set.

10.5 BROWSER WINDOW

The Browser window allows the user to view both textual and graphical input and output information. It is a "read only" viewer and does not allow the displayed files or graphics to be edited. When occupying only half the screen, the Browser window can be enlarged to full screen by left-clicking on the button at its upper-right corner. Left-licking the button in the same corner again causes the Browser window to reduce to its normal size. When the information being browsed contains more data than can be displayed in the window, the scroll bars can be used to access the additional data. Graphical data are always displayed in a format which fits within the boundaries of the Browser window, regardless of its size.

10.6 DIALOG BOXES

Not all interaction is done through the mouse and screen. Text input to the program is entered by the user with the keyboard and accepted by the Input/Output Program through dialog boxes. Dialog boxes may contain circular “radio” buttons, text fields, and scroll bars. When a dialog box is displayed, the user can left-click in a text field to begin data entry in that field. Clicking on a radio button sets the associated property or option. In some cases clicking on a radio button leads to other options which can be set through additional radio buttons. When too many fields are needed to display all the available fields within the space of the dialog box, a vertical scroll bar is available on the right side of the dialog box allowing the user to scroll up and down to reach all the available data fields. Once all the data is entered and the choices made, the user accepts the information in the dialog box by left-clicking on the OK button. If the user left-clicks on the Cancel button, conditions are reset to the state which existed before the dialog was summoned.

10.7 COMPUTER CONSIDERATIONS

The HYDRAIN WSPRO Input/Output Program is designed to run only on a PC/AT (or higher) IBM-compatible using MS/DOS or an equivalent operating system. Computers running the HYDRAIN WSPRO Input/Output Program must have at least 560 Kb free memory. It is also necessary to load the HYMOUSE mouse driver by typing “HYMOUSE” from a DOS prompt. The program can be evoked from the WSPRO directory by typing "WSHLL" on the command line.

SECTION 11 - APPENDIX C / THE SURFACE WATER MODELING SYSTEM (SMS) WSPRO GRAPHICAL USERS INTERFACE

The information in this appendix is modified from the corresponding chapter in the Surface Water Modeling Systems Reference Manual, Brigham Young University, Engineering Computer Graphics Laboratory (1997)[16].

WSPRO is a water-surface profile computation model that can be used to analyze one-dimensional, gradually-varied, steady flow in open channels. WSPRO also can be used to analyze flow through bridges and culverts, embankment overflow, and multiple-opening stream crossings. WSPRO is supported and maintained by the U.S. Federal Highways Administration (FHWA).

WSPRO categorizes its input data into five general groups:

- Title information. Used for output identification.
- Job parameters. Used to define parameters that pertain to the entirety of the profile computations.
- Profile control data. Information regarding discharge, starting elevation and computation direction.
- Cross-section definition. Information describing physical system (geometry, roughness, etc.).
- Data display commands. Used to control output of tables of cross-sectional properties, velocity, conveyance, etc..

SMS provides graphical tools for defining and editing the data in each of these groups, graphically editing cross-sectional information, and visualization of profiles and cross-sectional properties computed by WSPRO.

This chapter describes the commands used to create and edit the WSPRO specific parameters included in the WSPRO menu. The commands for selecting sections and operating on the river model are described in Chapter 7. SMS also interfaces to WSPRO to invoke analysis of a river model. After the analysis is complete, SMS can import the solution file via the WSPRO Display Options Dialog to allow the user to view cross section and profile plots of all the data generated by WSPRO (See Lesson 13 of the SMS Tutorial and the WSPRO Users Manual for more about running WSPRO).

11.1 NEW SIMULATION

The *New Simulation* command in the WSPRO menu deletes the current river model including all of the WSPRO specific data. This data includes the run control data, the job parameters, and the solution data. Run control data contains the computation directions, profile discharges etc. Job parameters include output tables and tolerances. Solution data includes all variables computed for profile or cross section visualization that is not geometric. The *New Simulation* command also deletes the general river model data (geometric cross sections). To delete all the data currently in SMS, the user should select *New* from the *File* menu which causes all existing data (geometry and model specific data) to be deleted from memory.

11.2 OPEN SIMULATION

The *Open Simulation* command in the *WSPRO Menu* reads in a data file that has been previously created and saved. These files typically have the file extension ".dat". The name of the current simulation is displayed at the top of the River Window. The data file contains both the geometric and model control data for a WSPRO analysis. Geometric data consists of both the definition of the shape of the section and the section reference distance locating sections in relation to each other. See Section 4.2 of the WSPRO Users Manual for more information on data record formats. Opening a new simulation file causes all existing river data (geometry and model specific data) to be deleted from memory, however, data in other formats (such as two dimensional mesh data is not affected).

11.3 SAVE SIMULATION

The *Save Simulation* command in the *WSPRO Menu* saves a data file so that it can be opened at a later time or used in an analysis.

11.4 EDIT SECTION

The *Edit Section* command in the *WSPRO Menu* invokes the *Section Editor* (see Figure 11.1). This editor can also be invoked by double clicking on a section in the *River Window*.

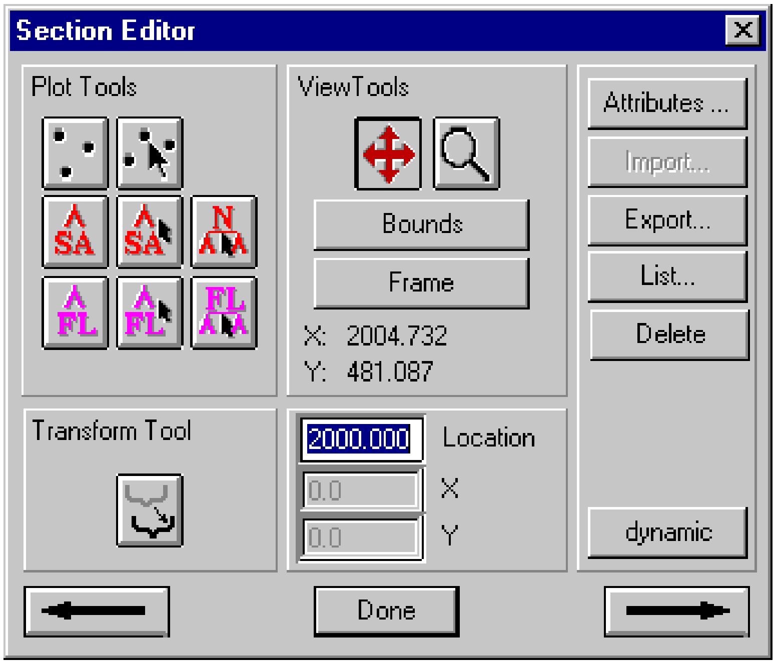


Figure 11-1. WSPRO River Section Editor.

The *Section Editor* is divided into five areas. These include the plot tools in the upper left portion of the dialog, the view tools in the upper center, the section translation tool in the lower left, section edit fields in the lower center, and various graphical buttons on the right side. Each of these areas are described in some detail in the sections to follow. In the bottom corners of the *Section Editor* are arrows that allow the user to step through the selected sections and edit each in turn. If only one section is selected, the arrows cause the current section to be unselected and the next section in the river model to be selected.

11.4.1 Plot Tools

The plot tools area in the upper left portion of the *Section Editor* presents a set of tools that apply to the river section that is currently being edited. For example, if the user is editing a cross- section, up to three rows of tools are available (see Figure 11.1). The first row consists of tools to edit the geometry points (GR records). The second row consists of tools to create and edit the materials data including break points (SA records) and roughness data (N or ND records). The third row includes tools to specify flow lengths (FL records) for different portions of the section. The visible tools change based on the section type, and the section position. For example, the flow length tools are not visible if the section being edited is the outlet of the river model, due to the fact that no flow lengths are applicable to the outlet. They also vanish if the section has a bridge section defined because this is an unsupported combination of records in *WSPRO*.

The tools for bridges, guide banks, culverts and roads are all specific to the section type. The available tools also change based on the attributes of the section. An instance of this is a component mode bridge as opposed to a coordinate mode bridge. Coordinate mode includes tools for geometry point manipulation, while component mode does not.

11.4.2 View Tools

The view tools area in the upper center portion of the *Section Editor* presents tools which allow the user to pan, zoom, frame, and specify specific window boundaries for the plots of the cross sections and profiles. These tools function exactly as their counterparts in the display menu for the graphics window (see Sections 2.3.2 & 2.9.4 of the SMS Version 5.0 Reference Manual).

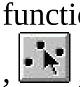
SMS tracks the location of the cursor in the plot window, both in cross sections and profile plots. This information is reported below the view tools.

11.4.3 Section Translation Tools

The section translation tool is located in the lower left portion of the *Section Editor.* When this tool is selected, the user can translate the entire section either graphically by clicking on the cross section and dragging the geometric data. This is useful for general placement of one section with respect to another. For example, a bridge can be dragged to an approximate location with respect to the full valley cross section.

If a specific translation is desired, such as would be the case if the datum for one section was different than the other sections in the model, the user can specify the translation in the *X* direction and/or the *Y* direction and click on the bottom graphics button on the right side of the editor to invoke a translation. This bottom button reads “translate” while the section translation tool is selected.

11.4.4 Section Edit Fields

The lower middle region of the *Section Editor* includes three edit fields that are used to enter specific numbers for editing the section. The top edit field allows the user to specify a new section reference distance (SRD) for the current section. The lower two edit fields change function based on the current tool. For example, if the current tool is the edit geometry point tool , , the edit fields represent the X and Y location of the currently selected geometry point (GR record). This allows the user to edit the point graphically in the plot window, or explicitly using the edit fields. These fields are also used for specific section translations as described in Section 12.4.3 of the SMS Version 5.0 Reference Manual, as well as specific values for SA or FL breakpoints for the section. The label to the right of the edit field updates to reflect the current purpose of the edit field.

11.4.5 Section Editor

The right side of the *Section Editor* includes six buttons to operate on the section. The *Attribute* button allows the user to access additional dialogs to edit the current section. Each section type has its own set of attributes. For each section type, the attribute dialog is described below.

11.4.5.1 Cross-Section Attributes

Cross- sections require only a name and section reference distance (SRD). The SRD is specified in the *Section Editor*, the name can be specified at the top of the *Cross Section* dialog. The user can access other optional attributes including skew, loss coefficients, valley slope and friction slope averaging method. Default values are filled into these attributes when they are turned on. Any unspecified attribute is entered as a blank in the *WSPRO* data file, causing *WSPRO* to assume a default value.

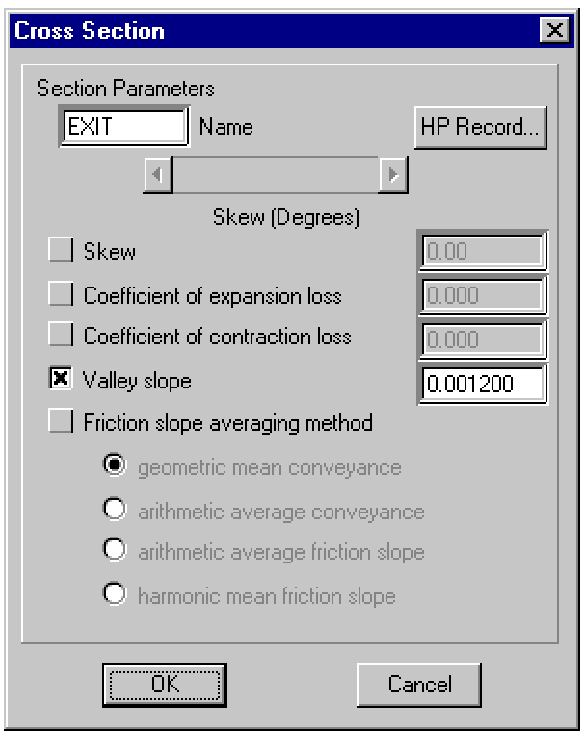


Figure 11-2. Cross-Section Attributes Dialog.

WSPRO also includes an option to create tables of cross sectional properties (HP record). The user defines the desired tables using the HP Record button in the upper right corner of the attribute dialog. This invokes the *WSPRO HP Tables* dialog (see Figure 11.3). Tables can be generated for the entire cross section or for sub areas. The user may also define one velocity conveyance table for each section. If the user desires additional velocity conveyance tables the extra records must be managed by hand.

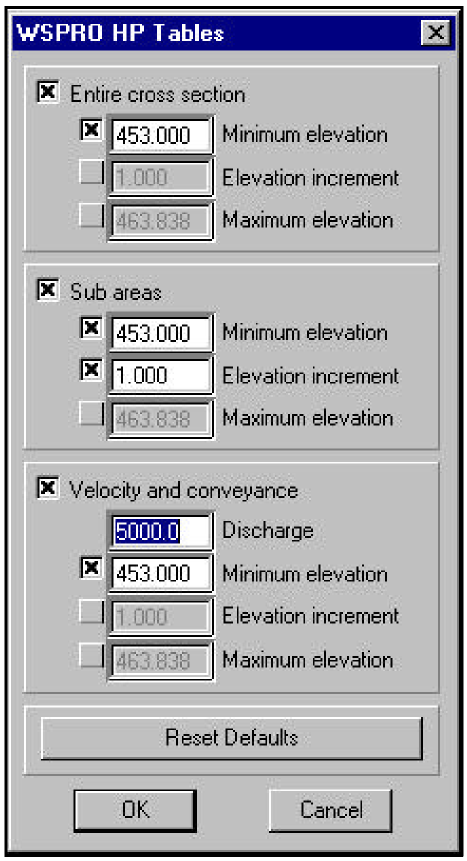


Figure 11-3. HP Record Dialog.

11.4.5.2 Bridge Section Attributes

Bridge sections have many attributes. The *Bridge Section* dialog is divided into four parts (see Figure 11-4).

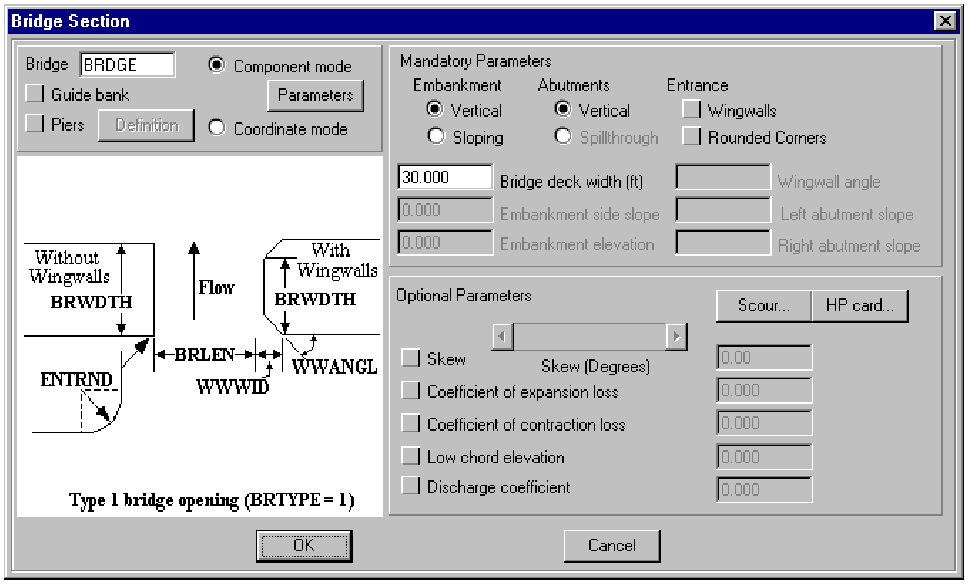


Figure 11-4. Bridge Section Attributes Dialog.

The upper left portion allows the user to change the section name, add piers and/or guidebanks, and specify the geometry mode for the bridge. *WSPRO* allows bridges to be defined explicitly (coordinate mode) using points (GR record), or explicitly using parameters (component mode). If component mode is used, the parameters defining the bridge are defined using the *Bridge Component Mode Parameters* dialog (see Figure 11-5), which is invoked using the *Parameters* button. If the *Pier* toggle is selected, *SMS* will create a pier record for the bridge (PD record). The *Definition* button allows the user to define the widths of the piers and the number of piers at different elevation.

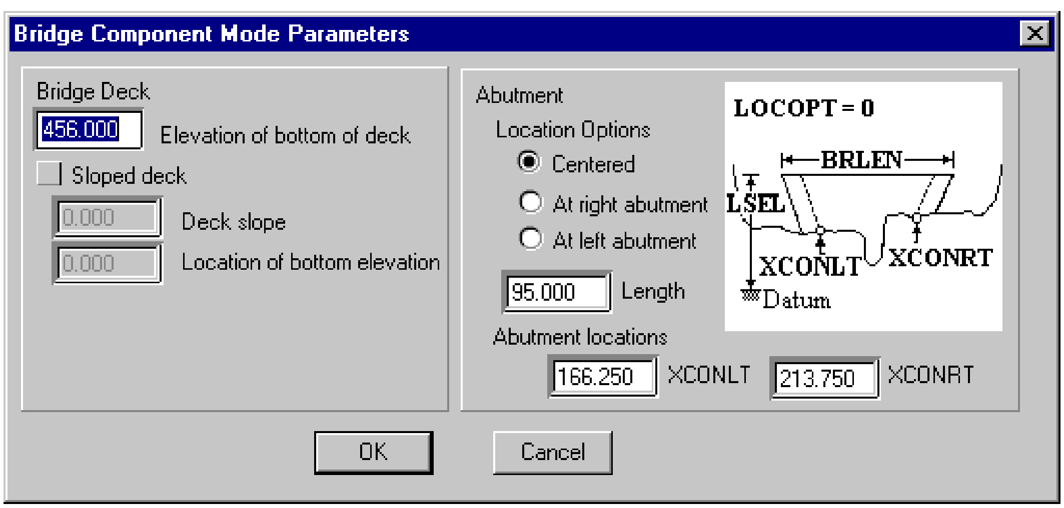


Figure 11-5. Bridge Component Mode Parameters Dialog.

The upper right portion of the dialog includes the mandatory parameters for the bridge. These include the embankment type, the abutment type, the deck width and several slopes and angles that may or may not be required depending on the bridge type and mode. The elements which don't apply to the currently selected type are dimmed. The lower left portion displays the parameters for the currently selected bridge type.

The lower right portion includes optional parameters including skew, discharge and loss coefficients., cross sectional, and scour parameters. The scour is defined using the *Bridge Scour Options* dialog (see Figure 11.6). Three types of scour records are defined. These include abutment scour (DA records) , live-bed/clear-water scour (DC records), and pier scour (DP records).

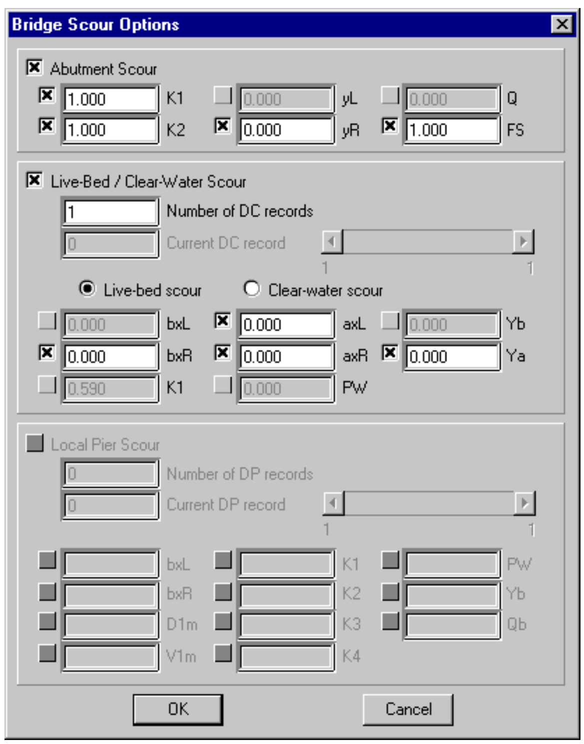


Figure 11-6. Bridge Scour Options Dialog.

11.1.5.3 Road Section Attributes

Road grade sections require a name, SRD, road type and embankment top width. Optional parameters include a skew and weir flow coefficient. These are all specified in the *Road Grade Section* dialog shown in Figure 11-7.

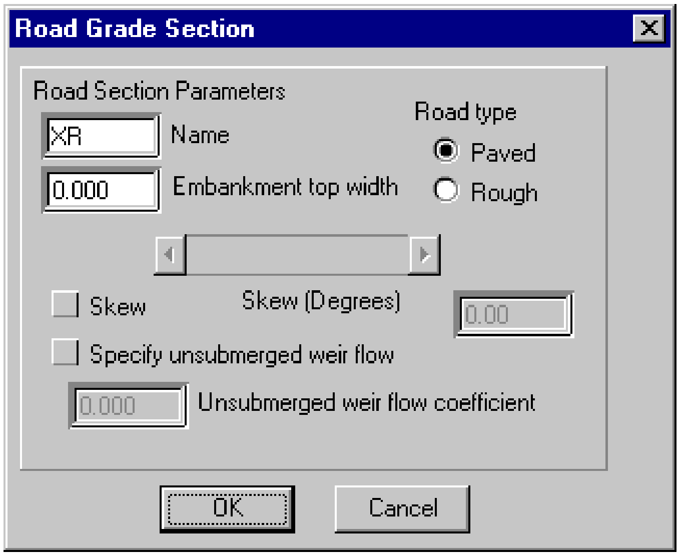


Figure 11-7. Road Section Attributes Dialog.

11.1.5.4 Culvert Section Attributes

Culvert sections can be used to model simple culverts, or culverts in combinations with one or more bridge openings. Culvert section attributes are specified using the *Culvert Section* dialog shown in Figure 11-8. The left side of the dialog allows for definition of culvert parameters, while the right side allows the users to define the type and size of culvert.

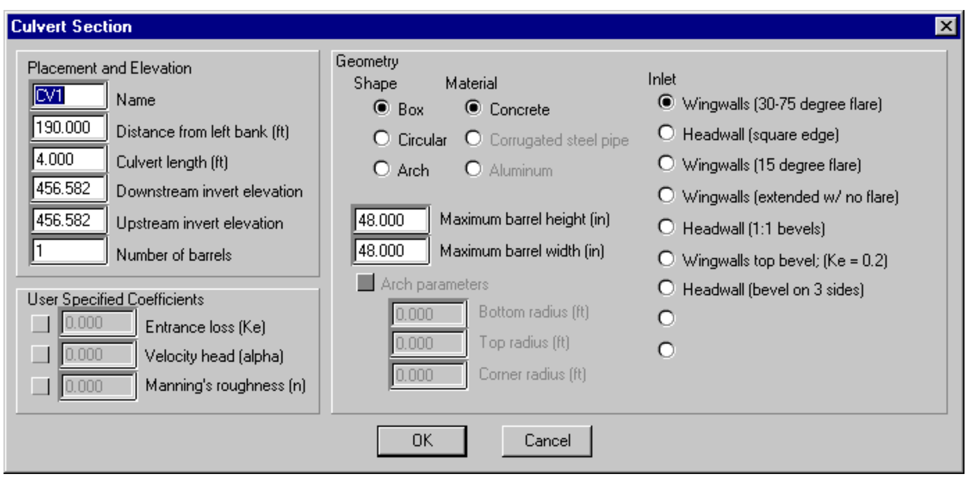


Figure 11-8. Culvert Section Attributes Dialog.

11.1.5.5 Guide Bank Section Attributes

Guide bank sections are bound to a specific bridge section. They are created by selecting the *Guide Bank* toggle in *the Bridge Section* dialog (see Figure 11-4). Once a guide bank exists, its parameters can be modified using the *Guide Bank Section* dialog (see Figure 11-9) accessed through the *Section Editor*. This dialog allows the user to define the name of the section, loss coefficients, skew, cross sectional tables, and the type of guide bank.

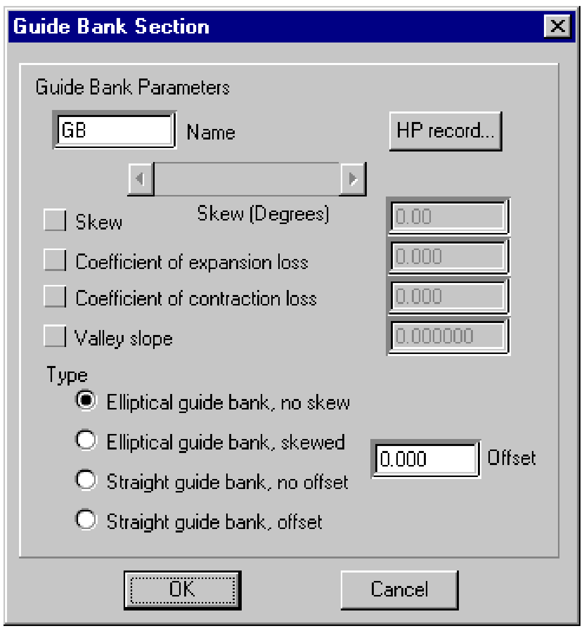


Figure 11-9. Guidebank Section Attributes Dialog.

11.5 VIEW DATA FILE

The *View Data File* command in the *WSPRO* menu asks the user to select a text editor and then a file. The default editor is Notepad on PC systems and VI on UNIX systems. *SMS* then launches the specified text editor with the specified file. This allows the user to look at the input files used to run *WSPRO*, and the output files generated by *WSPRO*.

11.6 ROUGHNESS PARAMETERS

WSPRO uses roughness parameters or Manning's n values to simulate the different types of bed conditions in the river. In the *Section Editor* (Section 11.4), the user assigns materials to the different regions in a cross section. The *WSPRO Material Editor* (see Figure 11-10) allows the user to associate Manning's n values to the materials used by each section. Materials can use a single roughness value, or have a roughness that varies based on the depth of the flow. This simulates situations such as tall grass that resists flow (high roughness) until the flow reaches a depth at which the grass is pushed over and lays down.

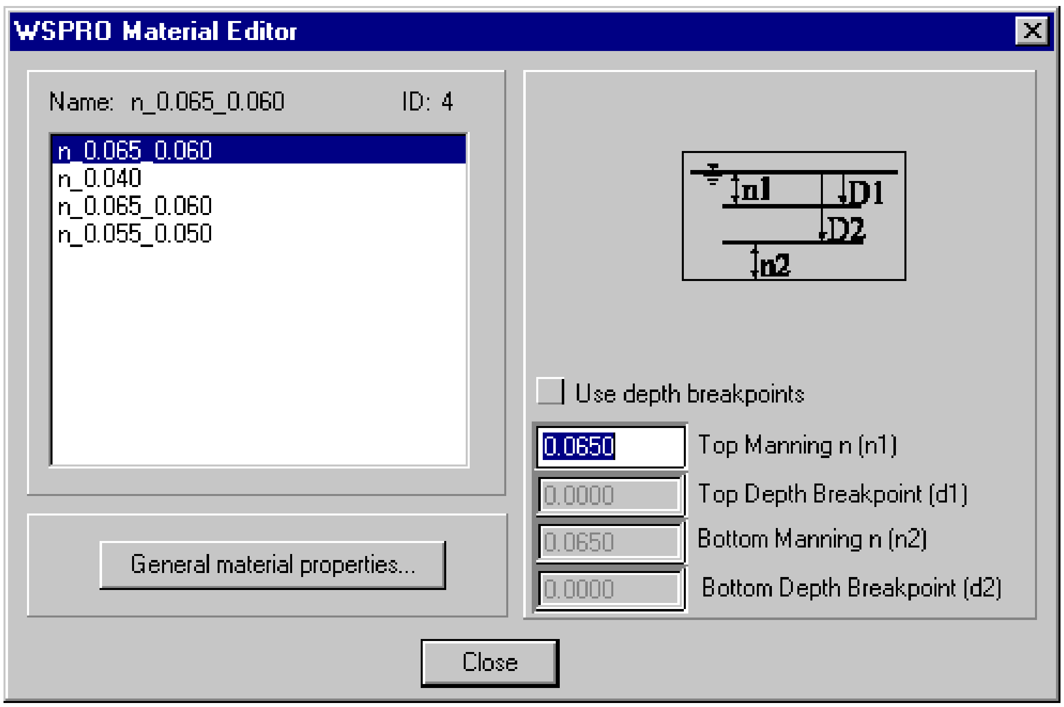


Figure 11-10. WSPRO Material Editor Dialog To Specify Roughness Parameters.

11.7 WSPRO RUN CONTROL

WSPRO requires the user to specify the flow rates for which profiles are to be computed. The *WSPRO Run Control* dialog (see Figure 11-11), which can be accessed from the *WSPRO* pull down menu, allows the user to specify the flow rates, and boundary conditions as well as assign a title to the simulation. Multiple profiles can be computed at once, and branches in the river may be simulated by changing the flow rate at various sections. The user also controls the direction of computation. Upstream is usually used for subcritical situations while downstream is applied for critical and supercritical flow.

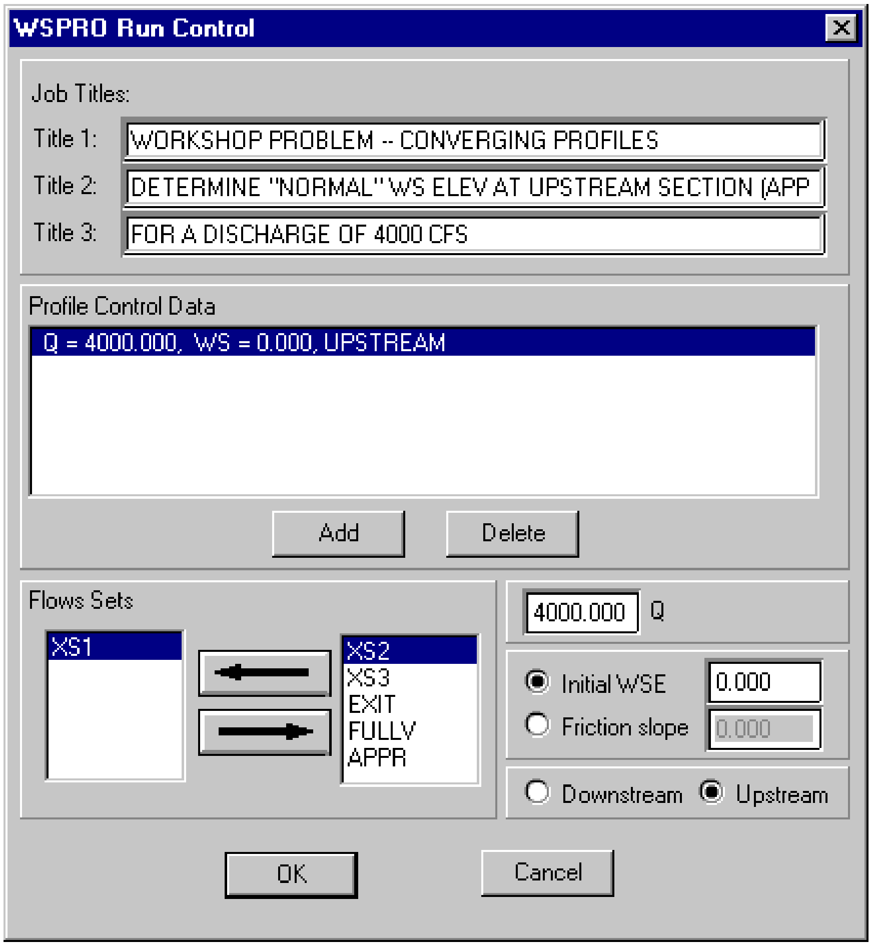


Figure 11-11. WSPRO Run Control Dialog.

11.8 JOB PARAMETERS

The *Job Parameters* command allows the user to specify the optional parameters associated with a numerical analysis. These include computational step size and tolerances to be used during computation. The *WSPRO Job Parameters* dialog (see Figure 11-12) also allows the user to specify the units to be used in *WSPRO*, and to specify any output tables desired from the analysis.

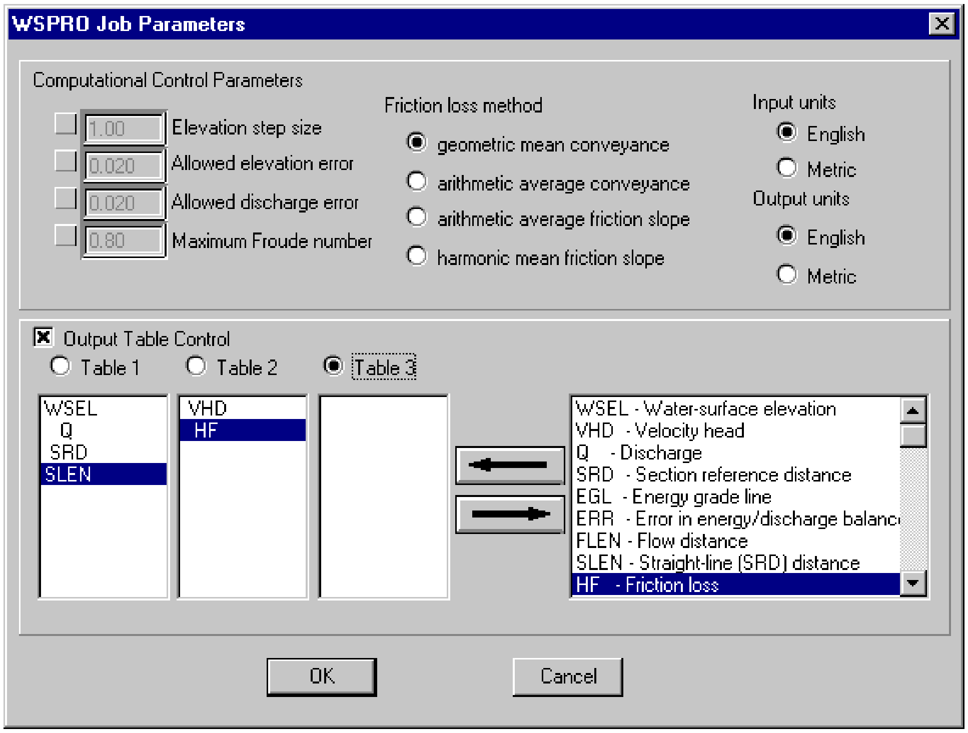


Figure 11-12. WSPRO Job Parameters Dialog.

11.9 DISPLAY OPTIONS

SMS provides tools for both *WSPRO* model constructions and visualization of the results of a *WSPRO* analysis. The *Display Options* menu item allows you to specify what can be displayed, and how it will look. The top portion of the *Display Options* dialog (see Figure 11-13) allow the user to specify what colors will be used to display each type of section. The lower portion of the dialog includes tools to import the solution file created by *WSPRO* and specify which variables will be plotted in the *Plot* window.

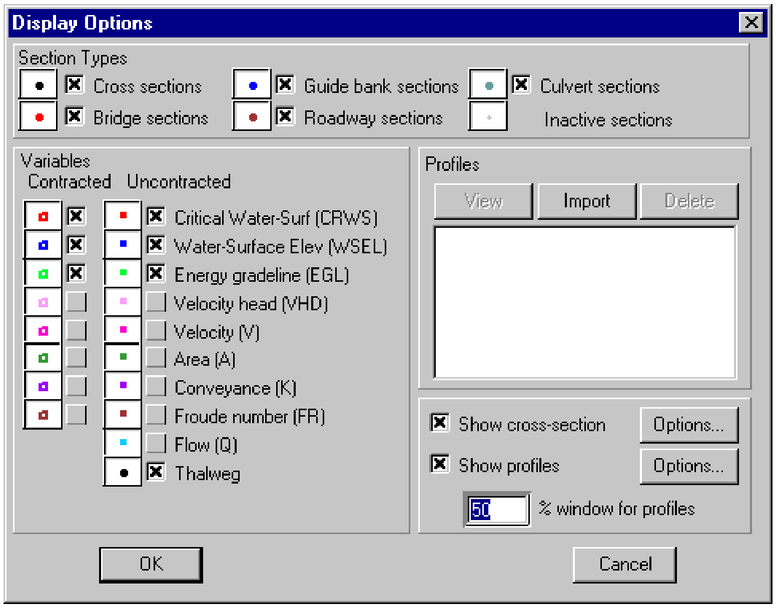


Figure 11-13. WSPRO Display Options Dialog.

Each variable may be plotted for both the constricted and unconstricted flow cases. If no bridge or culvert sections exist, only the unconstricted case is available. The user also controls whether the plot window will include profiles, cross sections or both. If the user invokes the section editor, cross section display is turned on.

11.10 MODEL CHECK

A *Model Check* should be performed on all *WSPRO* models before attempting an analysis. The model check will perform a basic check to insure that all of the needed information to run the analysis is present. The *Model Check* command in the *WSPRO* menu causes the *Model Check* dialog to appear.

Selecting the *Checker Options* button will cause the *WSPRO Model Checking Options* dialog to appear. This dialog lists the checks that may be performed during the model checking procedure. By default all supported checks are enabled. The checks include:

- Check Profiles. This check assures that at least one profile has been specified and that the appropriate number of discharges and boundary conditions are specified for each profile.

- Check SRD Values. This option checks the SRD of each section in the model. SRD values should increase monotonically from the exit to the most upstream section. There are some exceptions for multiple opening situations. This option also checks the placement of bridge approach and exit sections to assure correct placement.

- Check GR Points. Cross sections geometry should proceed from left to right. Coordinate mode bridge openings should proceed across the bottom of the opening, then change direction one time and define the bottom of the bridge deck.

- After running the model check, messages are generated to aid in the correction of the problems. To save this information to a text log file, click the *Save Messages* button and choose a file to save the information in. To close the *Model Checker*, click the *Done* button.

11.11 RUN WSPRO

Once the data for an analysis has been defined, *WSPRO* may be invoked by selecting the *Run WSPRO* menu item. This command checks the status of the model in *SMS*. If edits have been made, the user is prompted to save his files before running. It then launches *WSPRO* using the data files loaded into *SMS*. If multiple runs are desired, the user should go to the *Display Options* and delete previous solutions before reading in new one. numerical model requires several user specified parameters to control the analysis.

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