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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 users manual provides guidance for using version V060188 (or P060188) of the WSPRO model. 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.

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Section 1

INTRODUCTION

This manual presents data preparation instructions for WSPRO, a water-surface profile computation model. Version numbers have been (will be) used to identify the various modifications and enhancements of the model. The version number consists of either a V or P followed by the six-digit date (month, day, year). This manual corresponds with version V060188 (P060188). 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 8,000 lines of Fortran source code. The code conforms to the American National Standards Institute (ANSI) Fortran 77 Standards. The program can be implemented on mainframe computers and microcomputers. Execution of the program requires about 200 to 250 kilobytes of memory on mainframe computers and fewer than 400 kilobytes of memory on microcomputers. Standard card reader logic is used for data input. Three printer-compatible output files are automatically created with successful model execution. The user may choose to have up to four additional printer-compatible output files created. Two direct-access files in machine-readable format are used, one for storing input data and the other for storing computed results. 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 fairly strong 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). 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). Roughness coefficients are discussed in most by Benson and Dalrymple (1967). Roughness coefficients are discussed in most standard hydraulics texts, such as those by Chow (1959) and Henderson (1966). Barnes (1967) presents color photos of sites for which roughness coefficients have been computed for measured discharges. Davidian (1984) discusses proper location and subdivision of cross sections as well as additional topics related to water-surface profile computations.

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 spur dikes; (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.

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.

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, etc.
J3 - special tabling parameters

PROFILE CONTROL DATA

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

CROSS-SECTION DEFINITION - Header Records
(required for each cross section)

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

Table 2-1.--Tabulation of data records by group (continued).

CROSS-SECTION DEFINITION - Cross-sectional Geometry Data

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

CROSS-SECTION DEFINITION - 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

CROSS-SECTION DEFINITION - Flow Length Data

FL - flow lengths and (or) friction slope averaging technique

CROSS-SECTION DEFINITION - Special Data

Bridge Section Data (**DESIGN MODE** - **no GR data**)
BL - bridge length and location
BD - bridge deck parameters
AB - abutment slopes
CD - opening type and configuration
PW - pier or pile data
KD - conveyance breakpoints

Bridge Section Data (**FIXED-GEOMETRY MODE** - **requires GR data**)
CD - opening type and configuration
AB - abutment toe elevations
PW - pier or pile data
KD - conveyance breakpoints

Approach Section Data
BP - horizontal datum correction between bridge and approach sections

Road-grade Section Data
BP - horizontal datum correction between bridge and road-grade sections

Culvert Section Data
CG - culvert geometry
CC - culvert coefficients

Template Geometry Propagation
GT - replaces GR data when propagating template section geometry

DATA DISPLAY COMMANDS

HP - produce tables of cross-sectional properties or velocity and conveyance distribution
PX - produce plot of cross section
* - insert comments and (or) blank lines in the input data sequence

2.1 Title Information

Title information is used only for output identification. No other data 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 J3) are available to define parameters that pertain to the entirety of the profile computations. A J1 record can be used to define error tolerances, parameter test values, computational increments, and so on. Reasonable default values are provided for each of the parameters, thus negating the need for J1 data for many relatively standard applications. The J3 record 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 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 in one or more WS records. 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 except approach sections;
2) BR -- bridge-opening section;
3) SD -- spur-dike section;
4) XR -- road-grade section;
5) AS -- approach section;
6) CV -- culvert section; and
7) 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, SD, XR, and CV records provide for additional parameters unique to bridge, spur dike, road-grade, 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 in 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, some spur-dike 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, one or more of these three record types may not be required at each 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 (referred to hereafter as "**design mode**") minimizes input data requirements for subsequent modifications of bridge geometry but requires additional record types to define specific components of the bridge. Design mode simply provides the user with the flexibility to analyze design alternatives; the model itself has no design capabilities. The record identifiers and the data contained in the additional records are:

1) BL -- parameters defining the bridge length and the horizontal location of the opening;
2) BD -- parameters defining the bridge deck; and
3) AB -- parameters defining the abutments.

In design mode a bridge-opening cross section is created by combining the data from the BL, BD, 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 design mode only for spill-through type abutments. The BL and BD records are always required in design 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.

Some bridge geometries, such as arched openings, defy adequate definition in the above manner. Also, for existing bridges it is highly preferable to not have to break down the geometry into design components if nothing is going to be modified. Therefore, a second option (hereafter referred to as "**fixed-geometry 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 and the first coordinate pair 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) KD -- parameters for user override of stationing related to conveyance breakpoints in the approach sections; and
3) PW -- parameters defining piers or piles.

The CD record is **mandatory**, the KD and PW records are optional.

2.4.6 Spur dikes

Two conventions also are available for defining spur-dike geometry. One of the parameters in the SD header record is the horizontal offset of the spur dikes relative to the bridge abutments (measured normal to the flow at the mouth of the spur dikes). In design mode, if the user codes a value for this parameter, the model will construct a cross section at the mouth of the spur dikes. 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 fixed-geometry mode requires defining spur-dike section geometry with GR data.

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 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 section and any other unconstricted valley section is the AS header record requirement. The AS header record indicates the first valley cross section upstream from the bridge opening(s) (thus the last section describing a bridge situation). This enables the the model to account for the absence or presence of the optional spur-dike and (or) road-grade sections in single-opening situations and the essentially unlimited combinations of bridge, spur-dike, culvert, and road-grade sections in multiple-opening situations. 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 and as stand-alone (single- or multi-barrel) installations. However, as illustrated in section 7.9, the analyses are limited in scope for the stand-alone installations. In any case, a culvert can be completely 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 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 design mode or fixed-geometry mode is being used. Horizontal stationing of the bridge opening may vary for different alternatives in design mode. Therefore, the location constraining stations (XCONLT and XCONRT in the BL record) are the logical reference points if using design mode. In fixed-geometry 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 analyses 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.

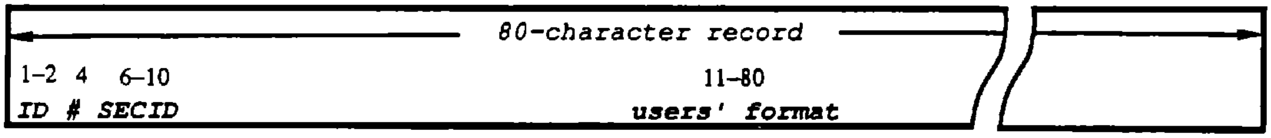
2.5 Data Display Commands

Plots of cross-section data and tables of cross-sectional properties, and (or) velocity and conveyance distribution are optional forms of model output. Cross-section plots can be obtained using PX records. 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.



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.

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3.1 Reaches With No Bridges

The first example is a curvilinear stream reach with variable land cover and a slightly meandering main channel (fig. 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 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.

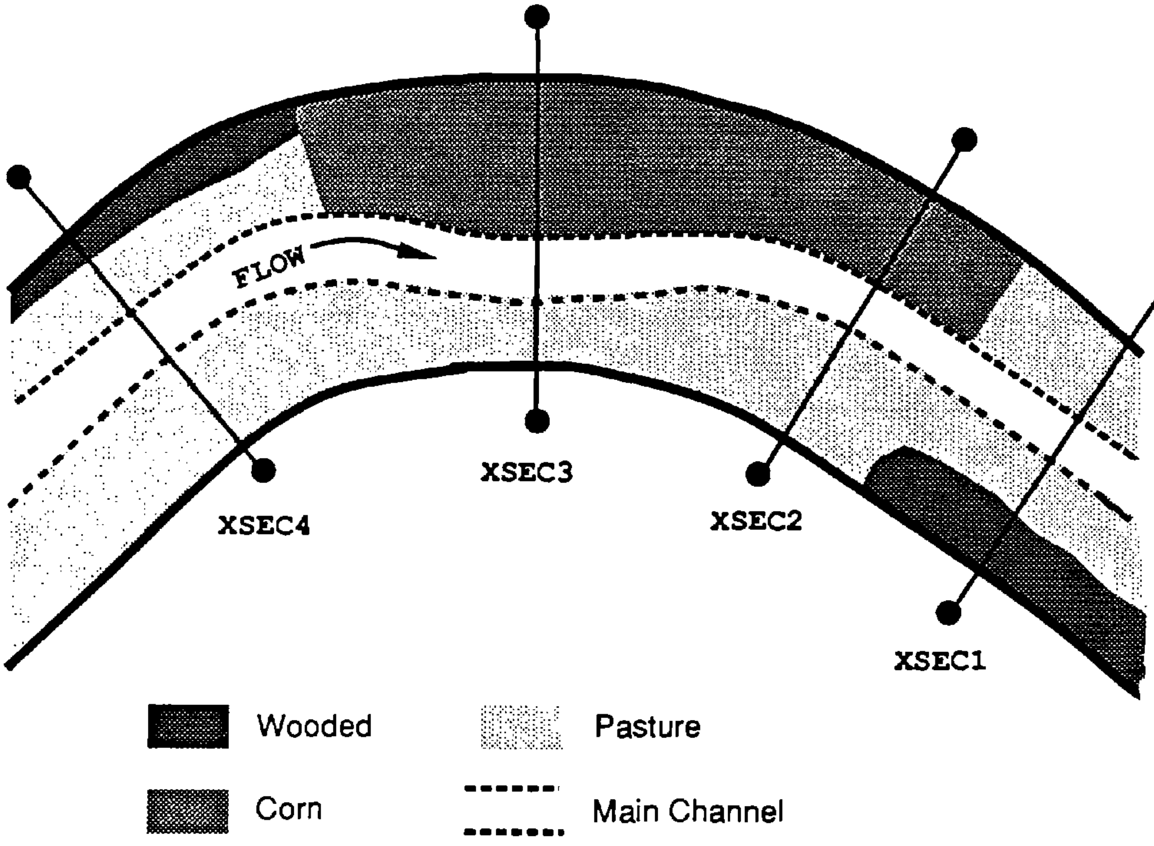
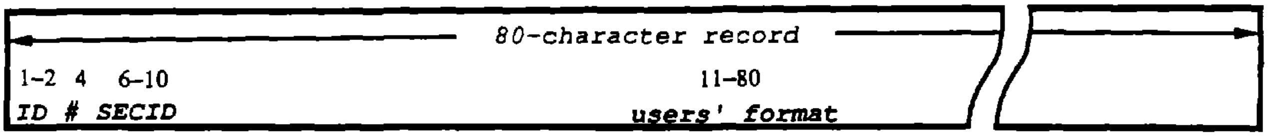


Figure 3-2.--Definition sketch: curvilinear reach with variable land cover.



```
T_           T1, T2, T3 records as desired
J_           J1 and J3 records 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 J3 records) must precede all other data. 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.

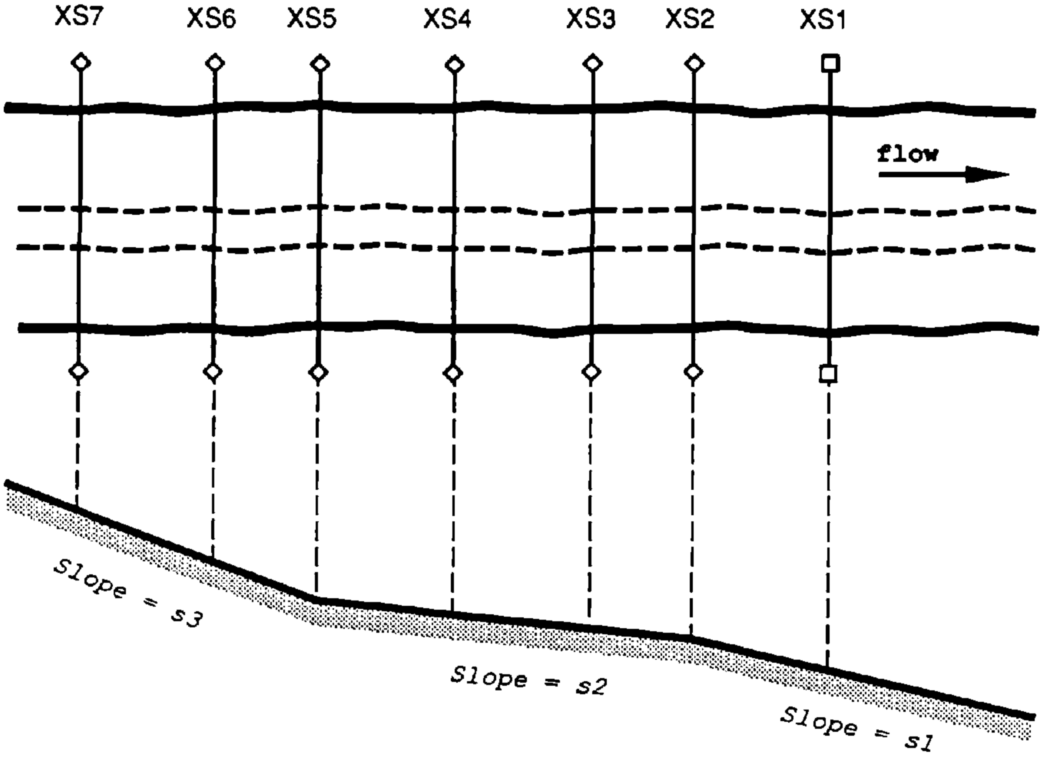


Figure 3-4.--Definition sketch: idealistic reach; data propagation.

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 downstream 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	users' format
T_			T1, T2, T3 records as desired
J_			J1 and J3 records 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.

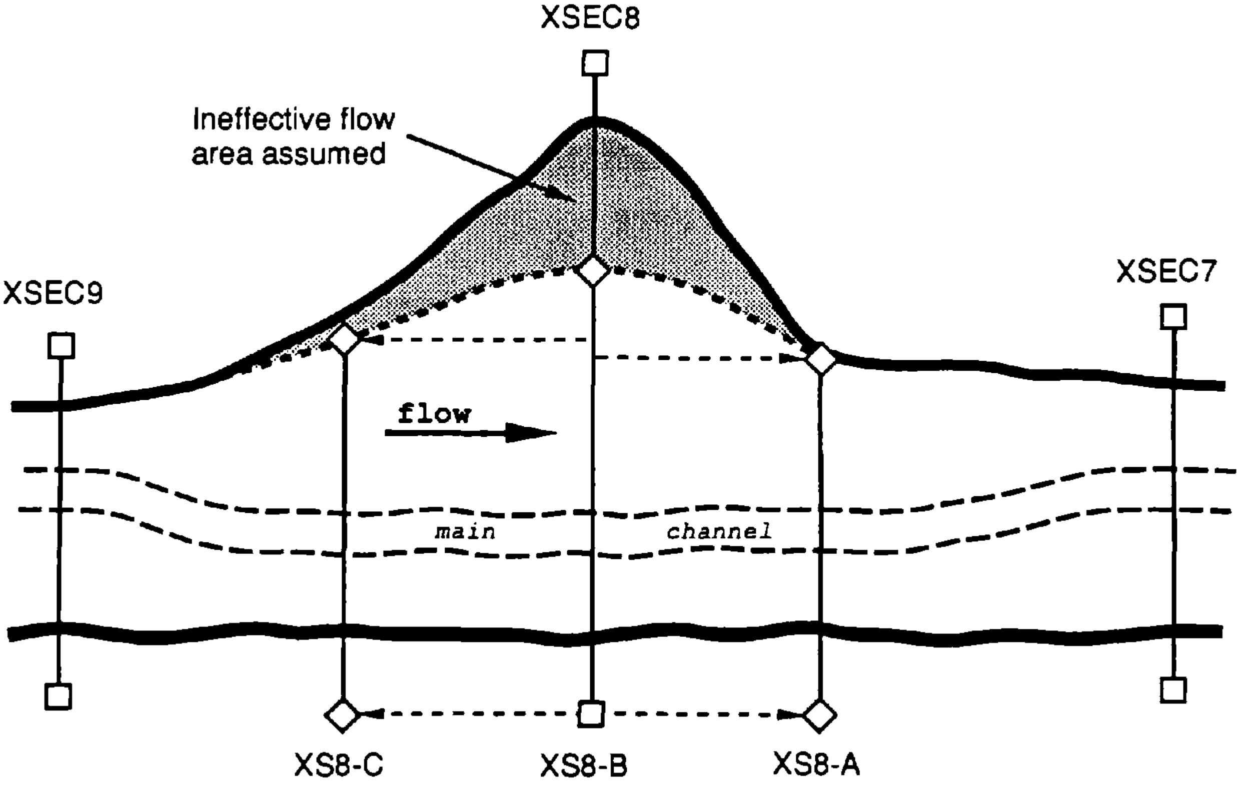


Figure 3-6.--Definition sketch: example application of a template cross section.

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 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***	***users' 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 spur dikes and (or) possible road overflow introduces the possibility for an additional one or two optional cross sections.

3.2.1 Basic bridge situation

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

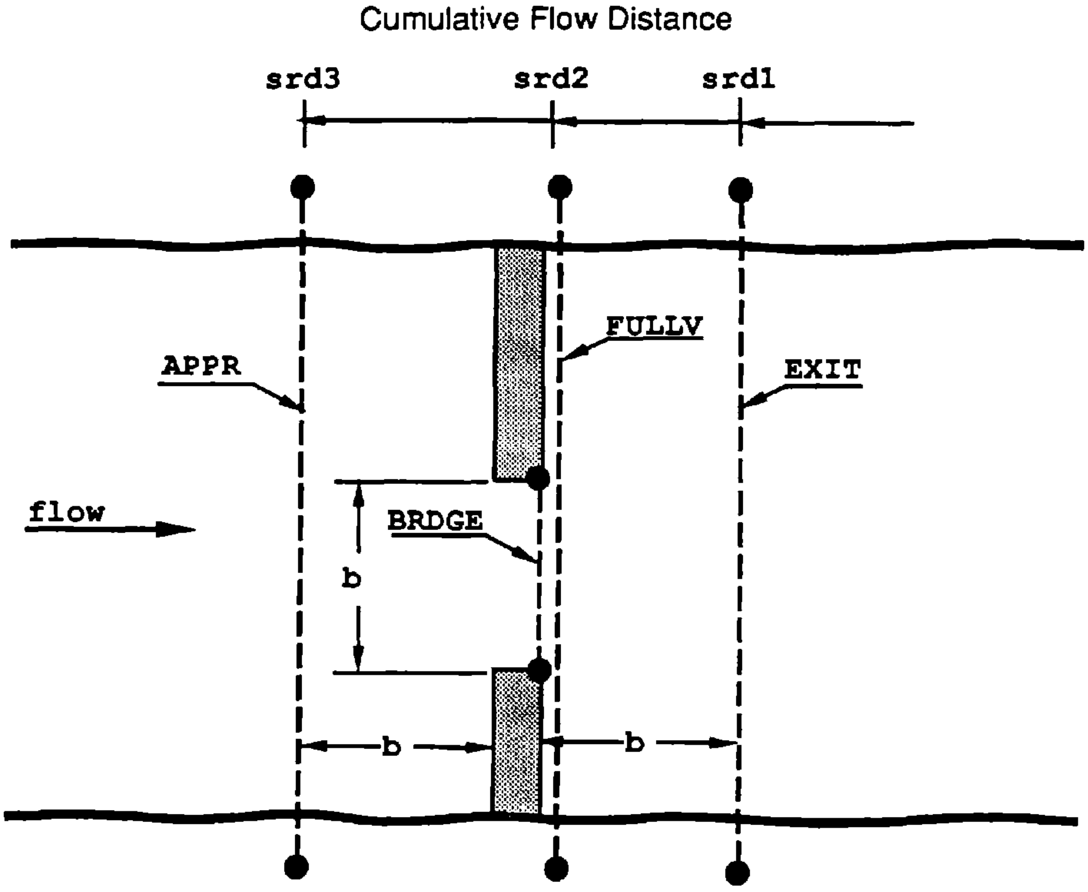


Figure 3-8.--Definition sketch: Cross-section locations, single-opening bridge.

Figure 3-9 illustrates a data sequence for a case where: (1) design 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 spur dikes; 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                                  users' 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
BD            girdep, bdelev [,as needed]
CD            brtype, brwdth [,as needed]
AB                                - - - - - - - - - -
PW                                 optional  records
KD                                - - - - - - - - - -
*
AS     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, design 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 BD records **are mandatory in design 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 BD 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 design mode follows.

1) In design 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 PW data.
3) The KD record is required only when it is necessary to override the default determination of K_q segment of the approach cross section which influences the computation of the flow-contraction ratio. These requirements are further defined in the KD record explanation in section 4.

Because there are no spur-dike nor road-grade sections involved, definition of the approach section immediately follows the definition of the bridge-opening section. A header record (AS record) and the appropriate GR, N, ND, and SA data are required to define the approach section.

Existing bridges, or bridges that do not conform to the design mode data requirements (e.g., arch bridges), can be defined using the fixed-geometry 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 fixed-geometry mode data sequence for the preceding example. The BL and BD data **are not used** because the GR data defines the bridge-opening geometry. As is the case for design mode, the CD record is mandatory and the PW and KD records are optional for the fixed-geometry mode. The AB record is again optional but is used to satisfy a different requirement. The AB record is required in fixed-geometry mode **only** to specify elevations at the toes of the abutments for a Type 2 opening. These elevations (determined by the model in the design 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                         users' 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                                 - - - - - - - - - - -
PW                                   optional  records
KD                                 - - - - - - - - - - -
*
AS     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, fixed-geometry mode.

3.2.2 Addition of spur-dike data

Figure 3-11 is a definition sketch of a bridge with spur dikes. As with bridge sections, there are two conventions applicable to definition of a spur-dike section. Design mode permits superimposing spur dikes on the full-valley section. This is only applicable when design mode is also being used for the bridge-opening section. The SDOFF parameter (horizontal offset) on the SD header record initiates design mode for spur dikes (see table 4-31). Side slopes of the spur dikes are equal to the slope(s) of the bridge abutments. These data, combined with the appropriate segment of the full-valley section, define spur-dike geometry. Fixed-geometry mode requires GR data to define spur-dike 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 spur-dike adjustment factor applied to the coefficient of discharge are coded in the SD header record.

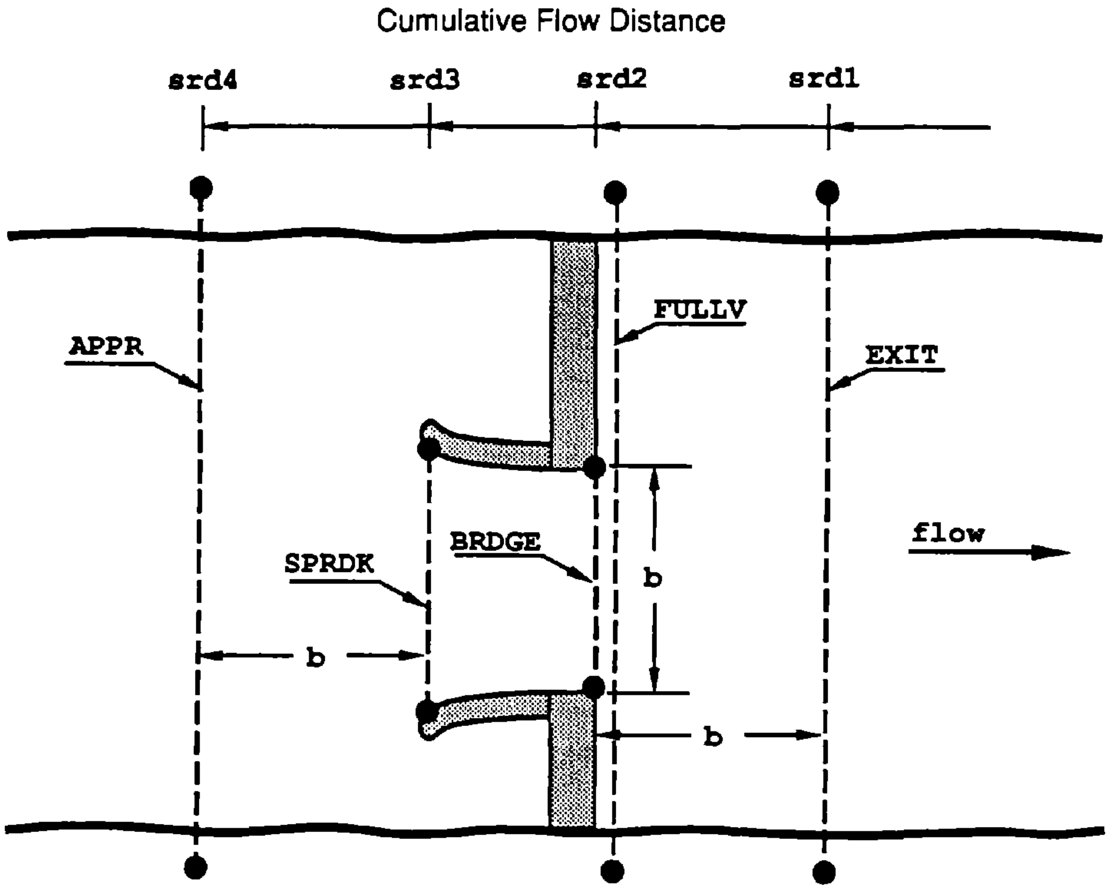


Figure 3-11.--Definition sketch: cross-section locations, single-opening bridge with spur dikes.

Figure 3-12 illustrates a data sequence for the sketch of figure 3-11, including GR data to define spur-dike geometry. Spur-dike section data are always input immediately following the input data for the bridge opening to which the spur dikes are attached.

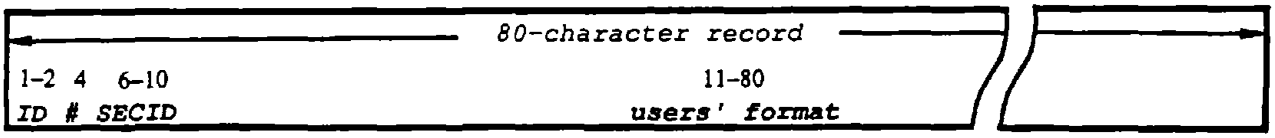
```
<------------------------ 80-character record ------------------------->
1-2 4  6-10                              11-80
ID  #  SECID                         users' format

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 BD data or GR data, and
___                  N, ND, and SA data, as appropriate ]
CD            brtype, brwdth  [,as needed]
___           [ AB, PW, and KD data as appropriate ]
SD     SPRDK  srd3, sdtype, bsubd  [,as needed]
___           [ GR, N, ND, and SA data, as appropriate ]
AS     APPR   srd4  [,as needed]
___           [ GR, N, ND, and SA data, as appropriate ]
```

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

3.2.3 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.



```
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 BD data or GR data, and
__                   N, ND, and SA data, as appropriate ]
CD           brtype, brwdth  [,as needed]
              [ AB, PW, and KD data as appropriate ]
__
*
XR    ROAD   srdrd  [,as needed]
              [ GR data ]
__
*
AS    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).

3.2.4 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                         users' format

T1          RISK ANLYSIS 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 ]
__
*
AS    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.

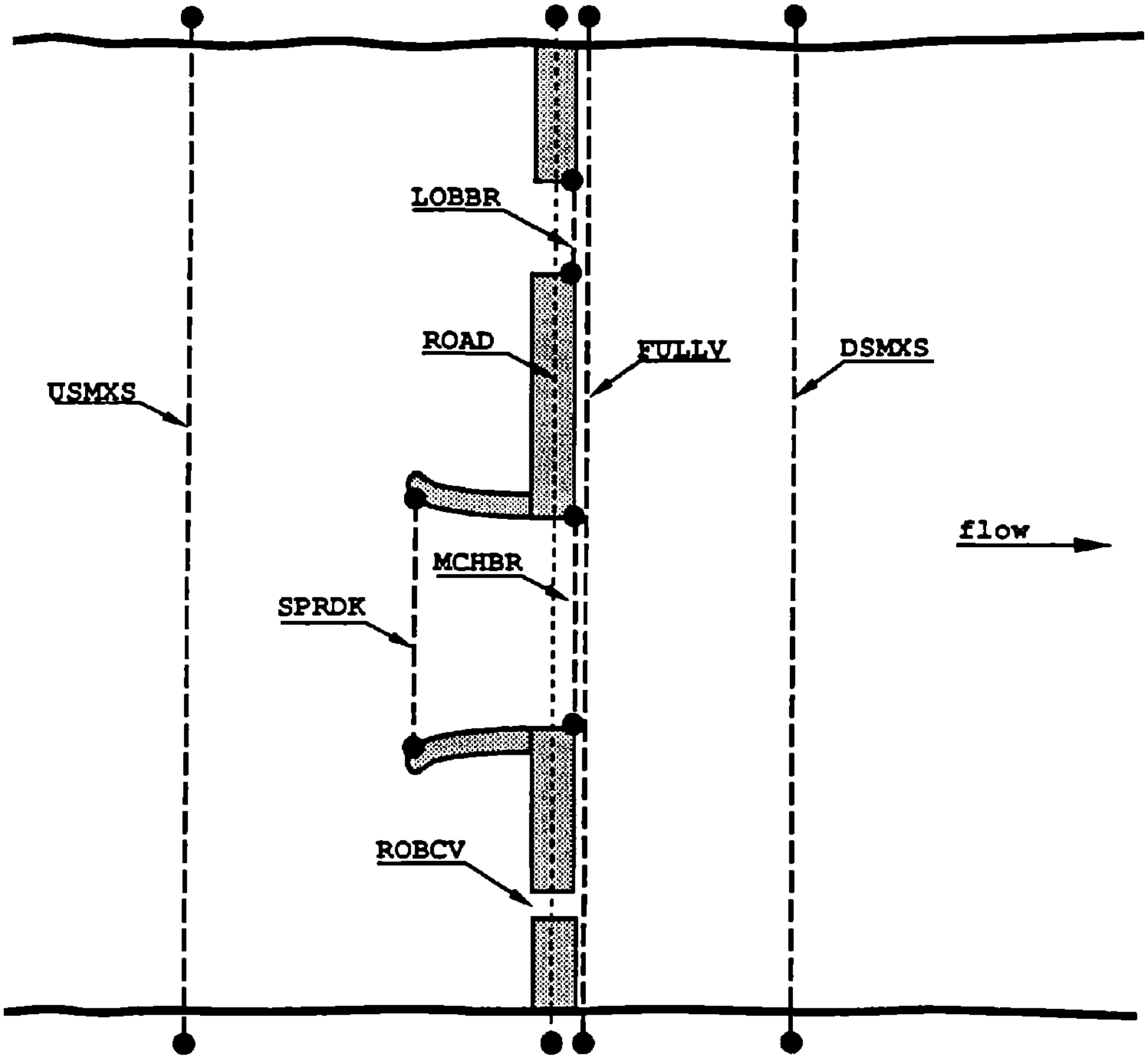
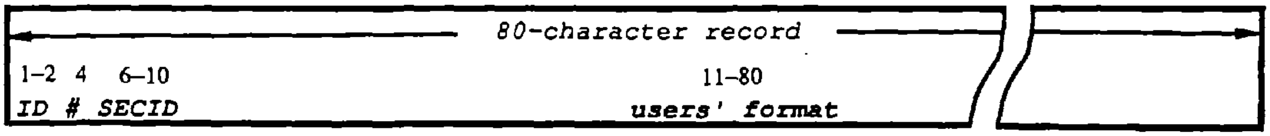


Figure 3-15.--Definition sketch: multiple-opening stream crossing.

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 spur dikes. 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) spur-dike 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 AS header record).



```
XS    DSMXS
                [ downstream match section data ]
__
*
XS    FULLV
                [ full-valley section data ]
__
*
BR    LOBBR
                [ bridge section data ]
__
*
BR    MCHBR
                [ bridge section data ]
__
*
SD    SPRDK
                [ spur-dike data ]
__
*
CV    ROBCV
                [ culvert data ]
__
*
XR     ROAD
                [ road-grade data ]
__
*
AS    USMXS
                [ upstream match section data ]
__
```

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

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	Record identifier
3	1x	Blank
4	I1	Option code
5	1x	Blank
6-10	A5	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.

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 design mode** or (2) abutment toe elevations for Type 2 openings **in fixed-geometry mode**.
AS	Header record for approach cross section.
BD	Specifying bridge deck parameters (**design mode only**).
BL	Specifying bridge length and abutment location constraints **design 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.
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.
GR	Specifying x,y-coordinates to define cross-section geometry.
GT	Replaces GR data for sections being fabricated from template section.
HP	Requesting tables of cross-sectional properties and (or) velocity and conveyance distribution.

(CONTINUED NEXT PAGE)

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

Record identifier	Purpose of data record
J1,J3	Specifying parameters for computational control and for user-defined tables.
KD	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.
PW	Specifying pier or pile data.
PX	Requesting cross-section plots.
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.
SD	Header record for spur-dike cross section.
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.
WS	Specifying starting water-surface elevation(s) for profile computations.
XR	Header record for road-grade cross section.
XS	Header record for unconstricted valley cross section.
XT	Header record for template cross section.
*	Inserting comments and (or) blank lines into the input data sequence.

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.

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 design mode (not used** for other opening types in design mode). **Mandatory** record to specify abutment toe elevations **for Type 2 openings in fixed-geometry mode (not used** for other opening types in fixed-geometry model).

Format:

Columns	Format	Contents	
1-2	A2	**AB**	
3-10	8X	blank	
11-80	free	**Either**	**ABSLPL** [,**ABSLPR**]
		or	***, *, YABLT,YABRT**

Definition of variables:

ABSLPL, ABSLPR -- Slope (horizontal distance per foot change in elevation) of the left and right abutments, respectively. **Required only for Type 3 openings when using DESIGN 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 FIXED-GEOMETRY mode** (in design 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.

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

AS AS Record AS

Purpose: Header record for approach cross section.

Format:

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

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

SRD -- Section reference distance. A cumulative distance, in feet, 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 spur dikes if they exist). See **section 4.3.4** and **figures 3-8 and 3-11** for additional information.

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 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 feet per foot. 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.

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

BD BD Record BD

Purpose: Specifying bridge deck parameters. **Mandatory for design mode, not used for fixed-geometry mode.**

Format:

Columns	Format	Contents
1-2	A2	**BD**
3-10	8X	blank
11-80	free	**GIRDEP,BDELEV [,BDSLP,BDSTA]**

Definition of variables:

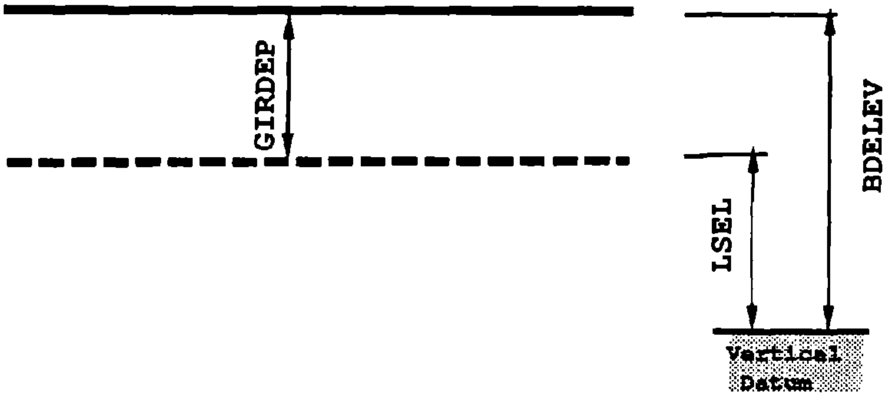
GIRDEP -- Depth of bridge deck (top of pavement to bottom of "girder"), in feet.

BDELEV -- Elevation of the top of the bridge deck. Low-chord elevation, **LSEL**, is computed by subtracting **GIRDEP** from **BDELEV**. If bridge deck is not horizontal, **BDSLP** and **BDSTA** also are required.

BDSLP -- Bridge deck slope, in feet per foot; left to right fall is negative.

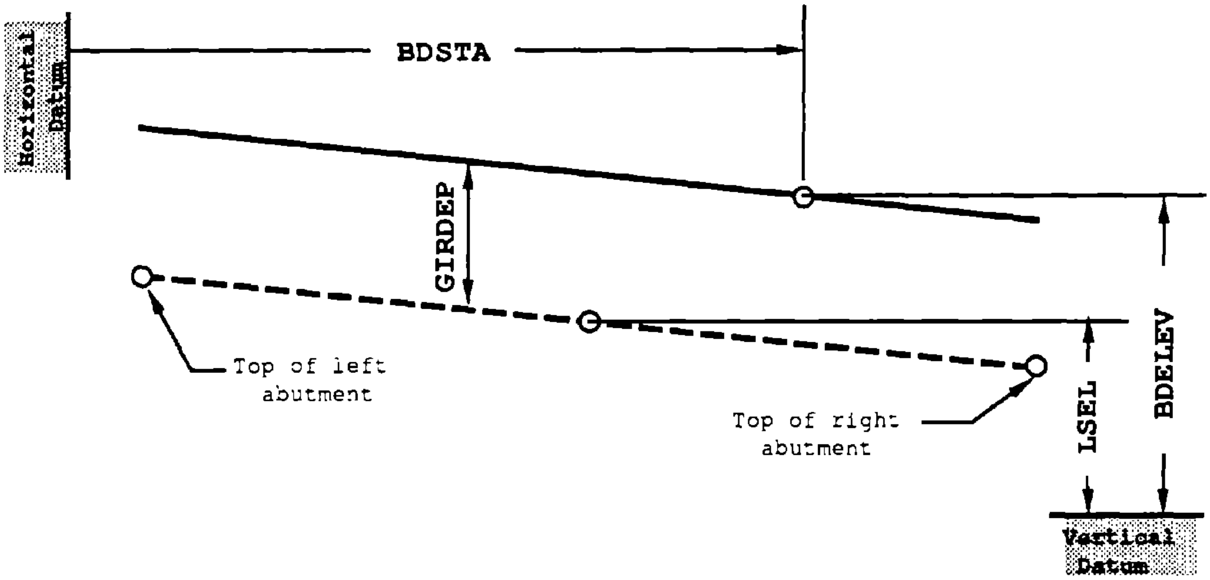
BDSTA -- The x-coordinate corresponding to the y-coordinate of **BDELEV**.

The above data provide the information necessary to to connect the tops of the abutments to the low chord. Figure 4-1 illustrates the **BD** record parameters and their relation to **LSEL**.

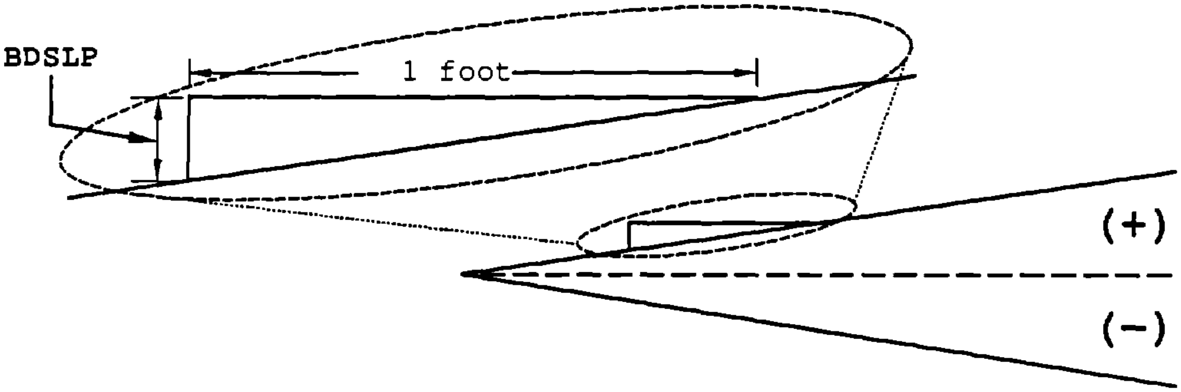


a) Relation of GIRDEP, BDELEV, and LSEL; horizontal bridge decks.

Figure 4-1.--Definition sketch: BD record parameters.



b) Relation of GIRDEP, BDELEV, BDSTA, and LSEL; sloping bridge decks.



c) Definition of and sign convention for BDSLP.

Figure 4-1.--Definition sketch: BD record parameters (continued).

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

BL BL Record BL

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

Format:

Columns	Format	Contents
1-2	A2	**BL**
3	1X	blank
4	I1	[**LOCOPT**]
5-10	6X	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 (or blank) -- **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.

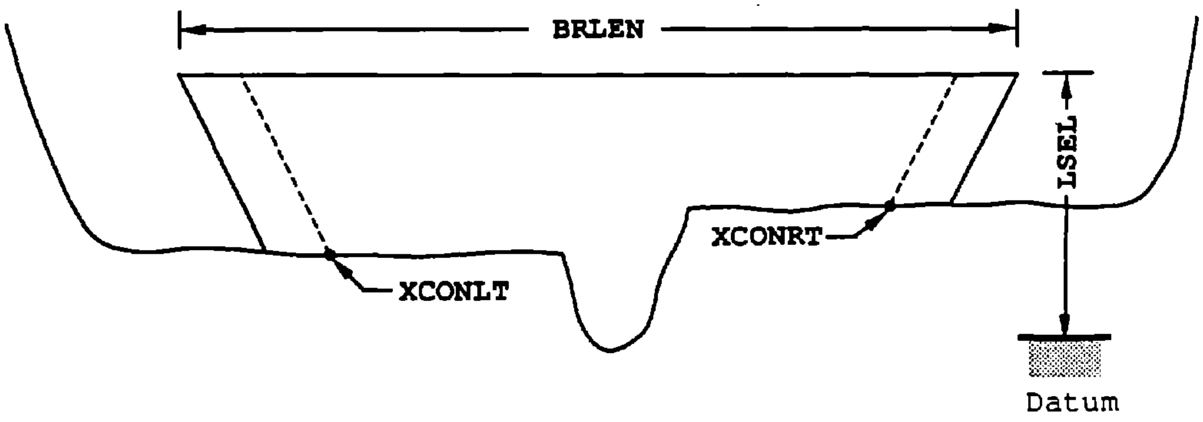
1 -- The toe of the right abutment is placed at the location specified by **XCONRT**.

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

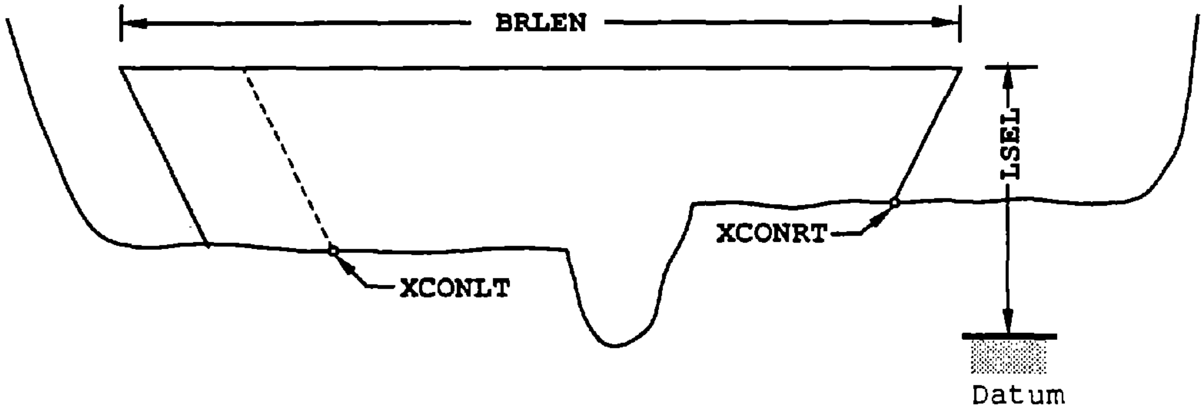
BRLEN -- The length of the bridge (between the tops of the abutments) in feet. Must be specified for the first alternative of a series, but is optional on subsequent alternative designs.

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.

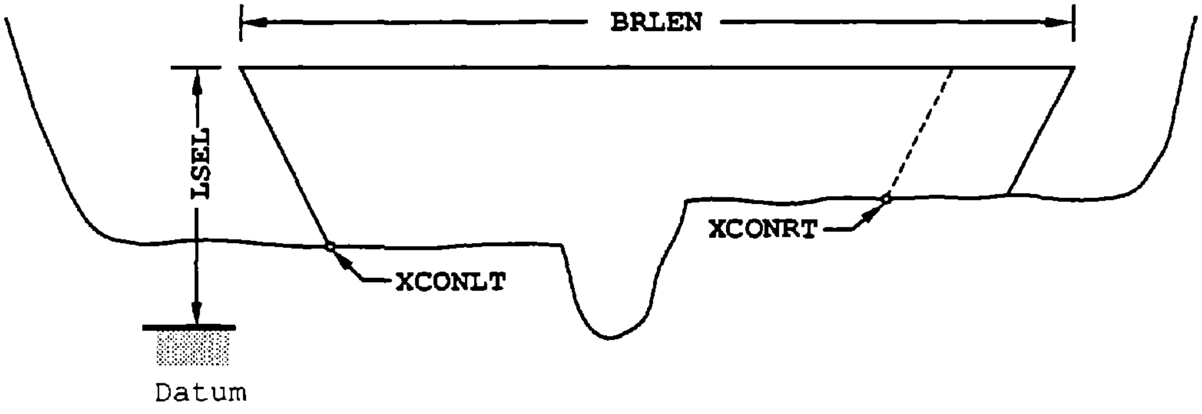
Figure 4-2 illustrates the effect of **LOCOPT** on the location of the bridge opening in DESIGN MODE. Figure 4-3 illustrates the determination of the minimum bridge length in DESIGN MODE's "bridge-building" process.



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.

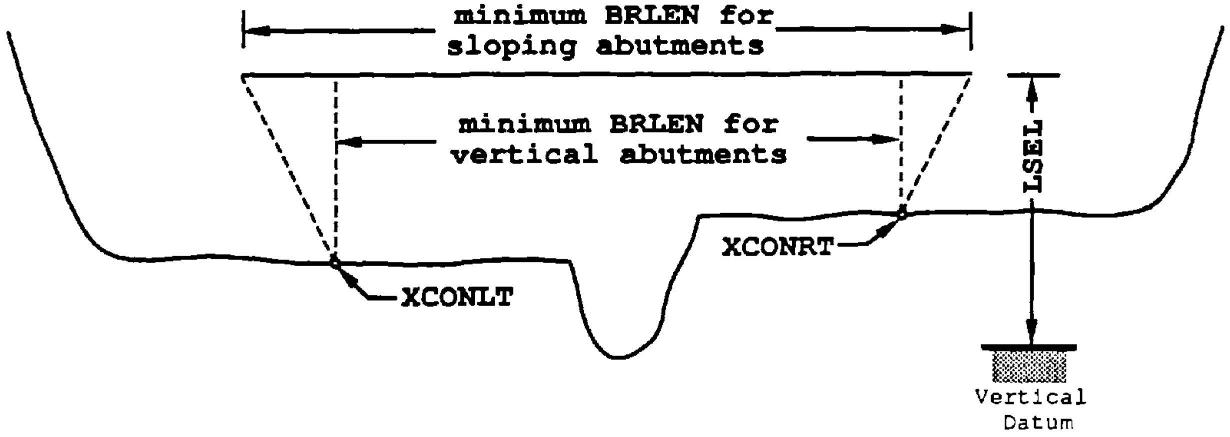


Figure 4-3.--Definition sketch: BL record parameters.

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**
3-10	8X	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 DESIGN MODE or (2) the minimum x-coordinate of the bridge section for FIXED-GEOMETRY 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 fig. 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 alined properly and (or) if either (or both) of those sections are skewed to the direction of flow (see fig. 4-5)

(CONTINUED ON NEXT PAGE)

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

BP BP Record BP

(CONTINUED)

Curvilinear flow requires three additional parameters. A typical situation is illustrated in figure 4-6. The bridge and approach sections must be alined 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 righthand reference point in the bridge section, which is either (1) **XCONRT** (in **BL** record) for DESIGN MODE or (2) maximum x-coordinate of the bridge section for FIXED-GEOMETRY 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**.

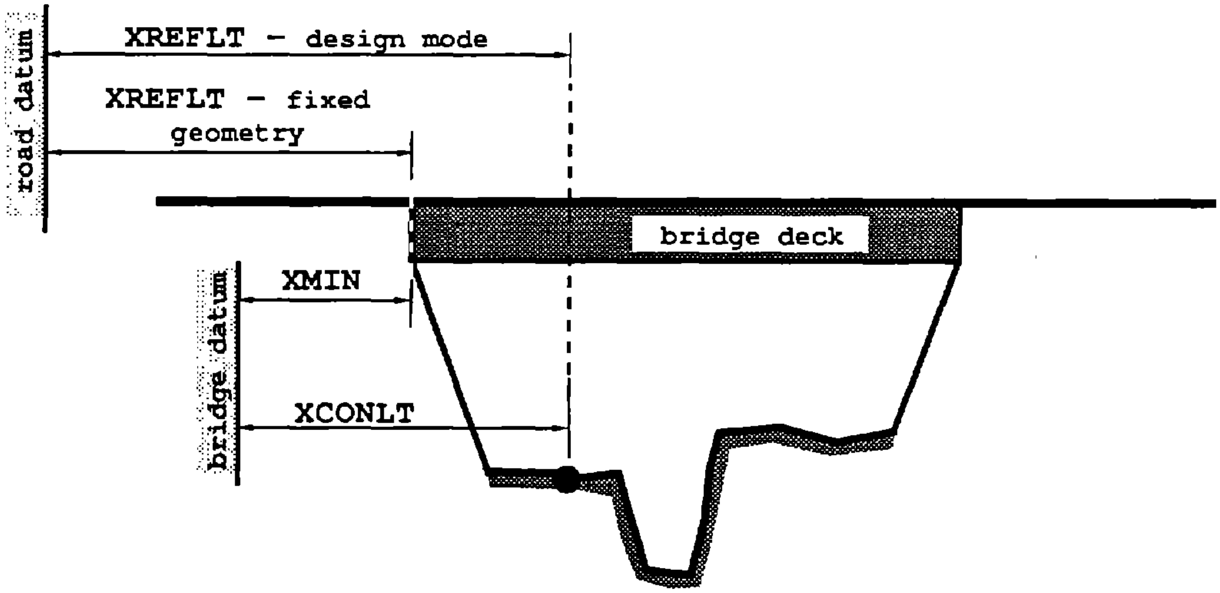


Figure 4-4.--Definition sketch: application of BP record for datum correction between bridge-opening and road-grade sections.

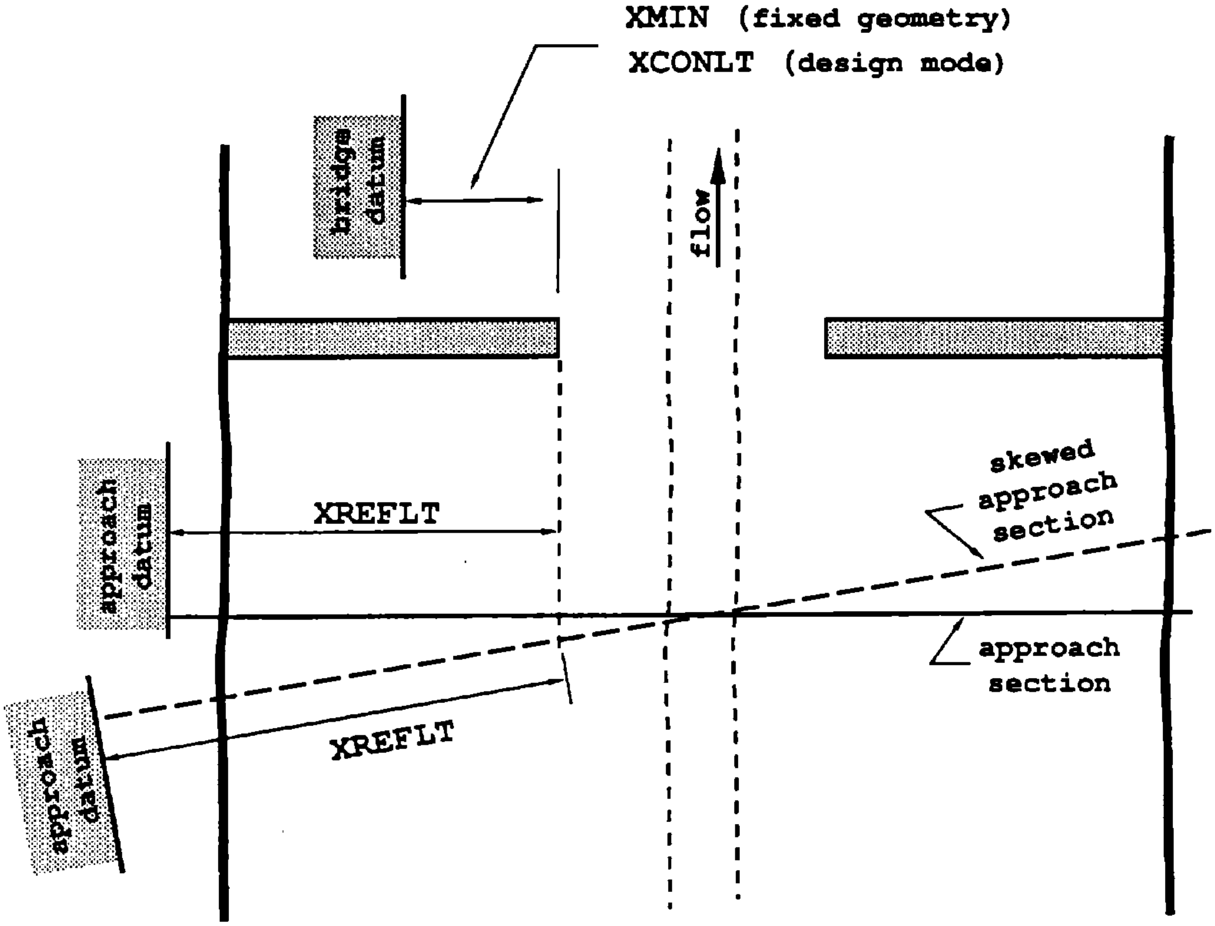


Figure 4-5.--Definition sketch: application of BP record for datum correction between bridge-opening and approach sections.

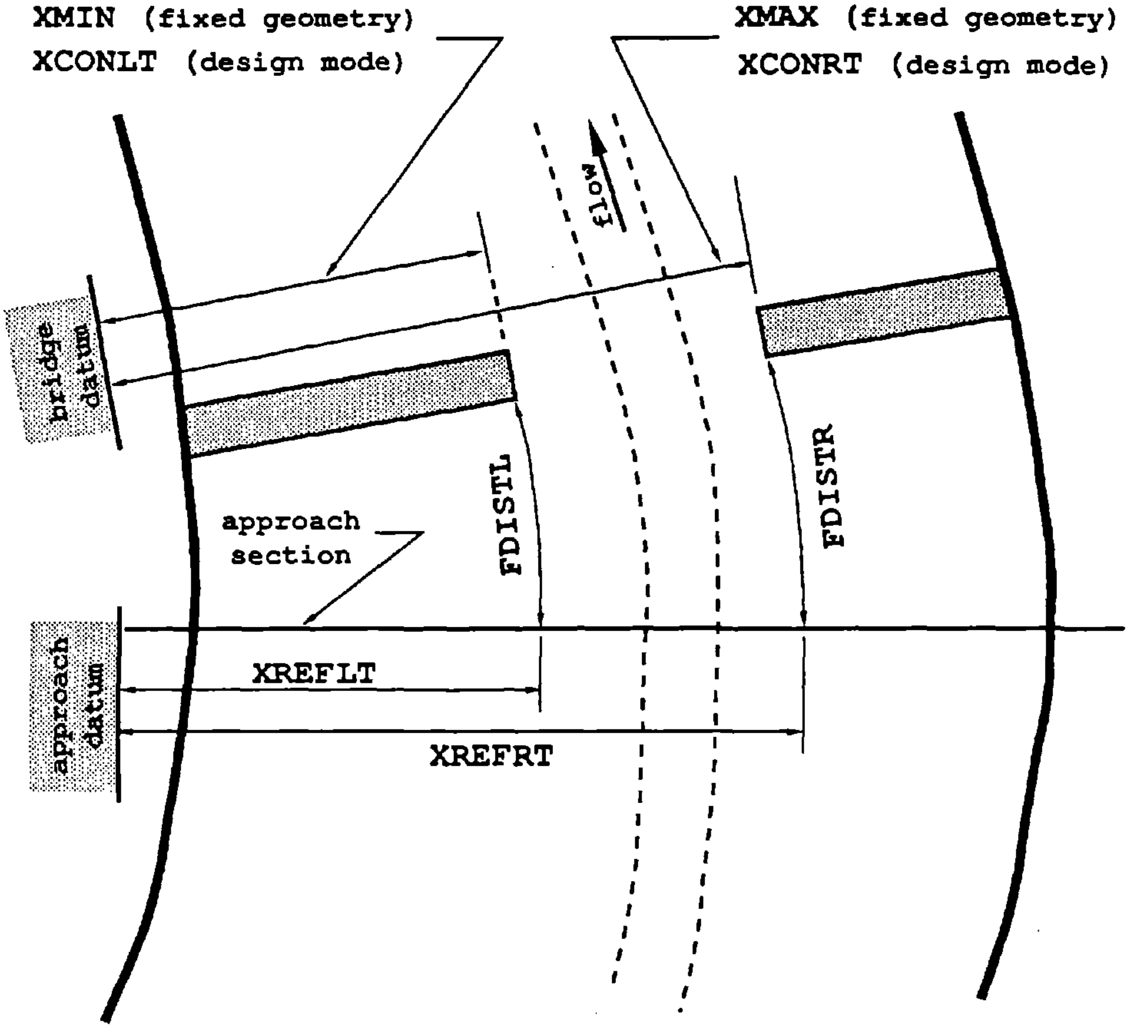


Figure 4-6.--Definition sketch: application of BP record for curvilinear flow between approach and bridge.

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**
3-5	3X	blank
6-10	A5	**SECID**
11-80	free	**SRD** [,**LSEL**,**SKEW**,**EK**,**CK**,**USERCD**]

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

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

LSEL -- Elevation of the low chord of the bridge opening. Should be coded for **FIXED-GEOMETRY** 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 **DESIGN MODE**. An average elevation is computed for sloping decks. Users may **override** the **DESIGN MODE** computed value by coding **LSEL** in the **BR** header record. See **section 4.3.7** and **figure 4-1** for additional information on **LSEL**.

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
3-10	8X	blank
11-80	free	[*,**CKE**,**CVALPH**,**CN**]

Definition of variables:

CKE -- The culvert entrance-loss coefficient, k_e.

CVALPH -- The velocity head coefficient, α, 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.

The default value indicator preceding **CKE** is required to account for the position of a parameter that has been discarded since the initial development of the model.

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

	n	α		
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 Record

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**
3-10	8X	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 (fig. 4-7).

2 -- Sloping embankments and vertical abutments without wingwalls (fig. 4-8).

3 -- Sloping embankments and sloping spillthrough abutments (fig. 4-9).

4 -- Sloping embankments and vertical abutments with wingwalls (fig. 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 wingwalls. 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 feet per foot change of elevation (e.g., 3 to 1 may be expressed as 3.0 or 3 and 2 1/2 to 1 would be expressed as 2.5). Default value is 0. **This parameter must be specified for BRTYPE 2, 3, and 4.**

EMBELV -- Embankment elevation **must be coded 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 the x-component(s) of the flow length through the bridge (see fig. 4-11).

WWANGL -- Wingwall angle, in degrees. Required **only** for **type 1** openings with wingwalls (fig. 4-7) and **type 4** openings (fig. 4-10). Default is zero degrees.

(CONTINUED ON NEXT PAGE)

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

CD CD Record CD
(CONTINUED)

WWWID -- Wingwall width, in feet. Required **only** for **type 1** openings with wingwalls (see fig. 4-7). Default is 0.

ENTRND -- Radius of entrance rounding, in feet. Required **only** for **type 1** openings with rounded entrance corners. Default is 0.

ADDITIONAL NOTES:

BRTYPE and **BRWDTH must be coded** for **all** opening types.

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.

For **BRTYPE 1, EMBSS** and **EMBELV** should be allowed to default.

EMBSS and **EMBELV must be coded** for **BRTYPE 2, 3, and 4**.

There are **NO** additional parameters for **BRTYPE 2 and 3**.

WWANGL should be coded for **BRTYPE 4**.

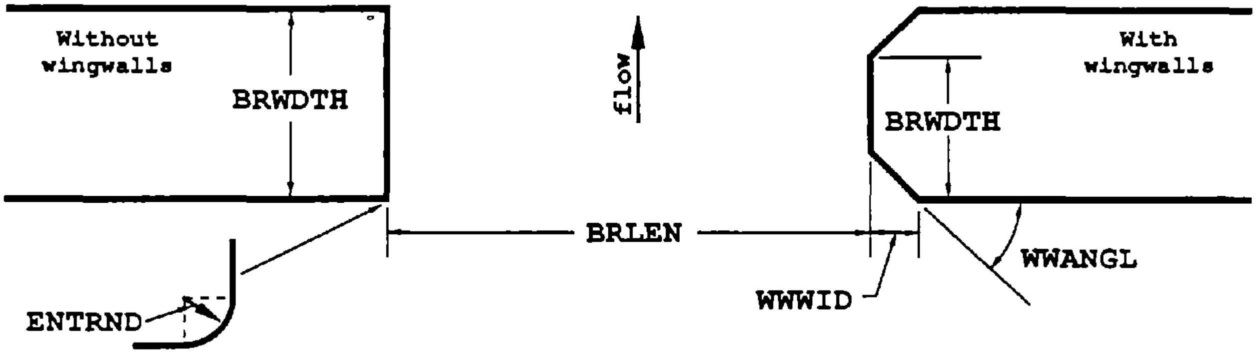
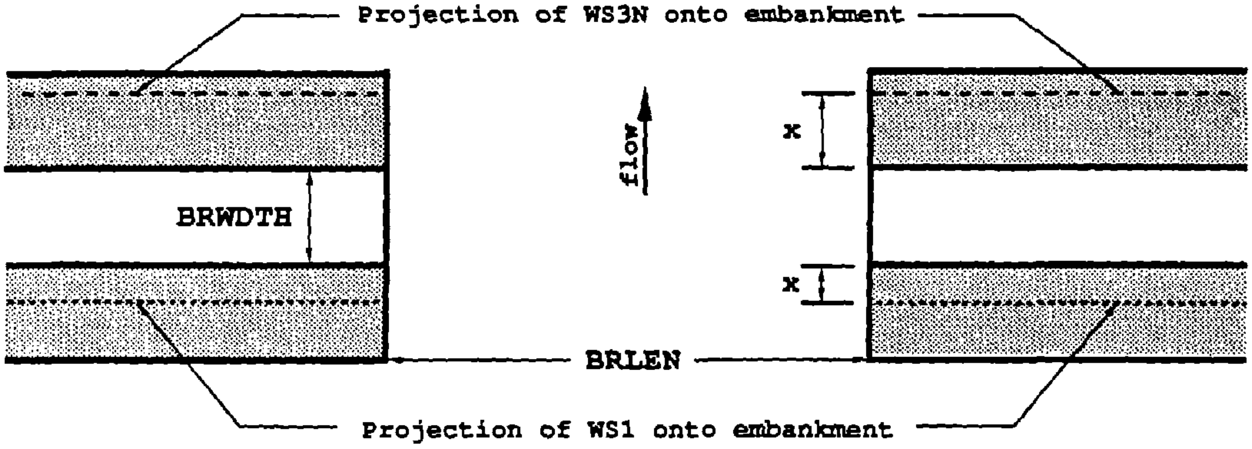
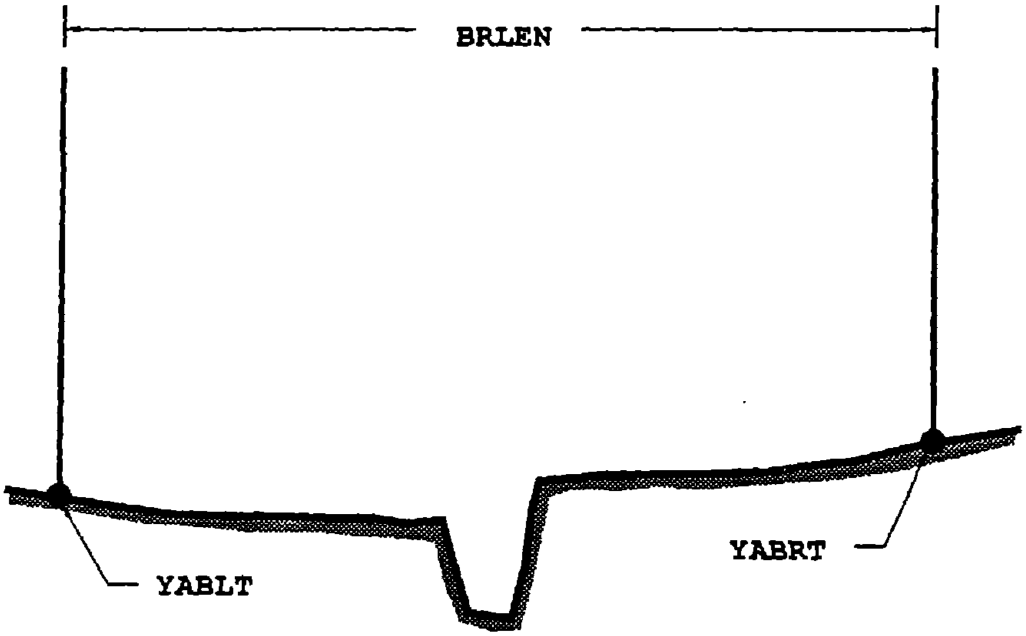


Figure 4-7.--Definition sketch: Type 1 bridge opening (BRTYPE = 1).

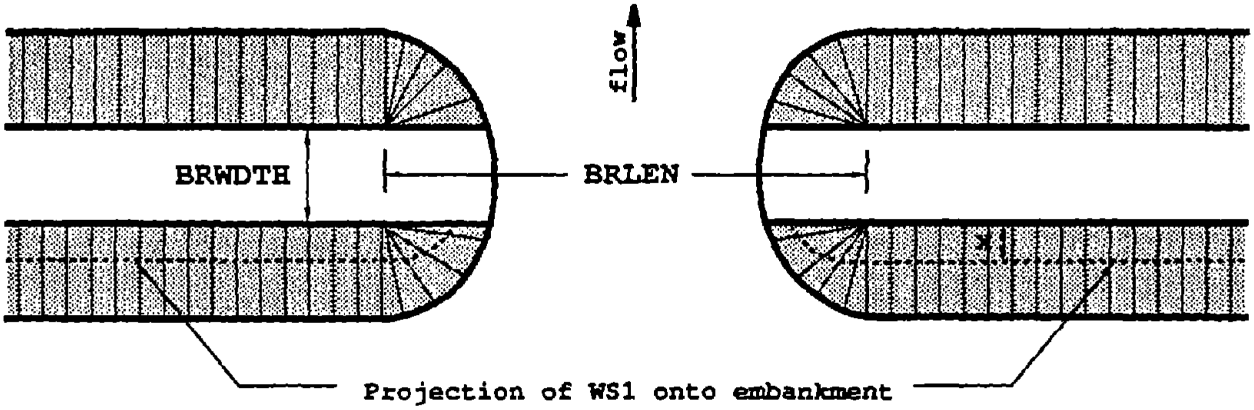


a) Plan view

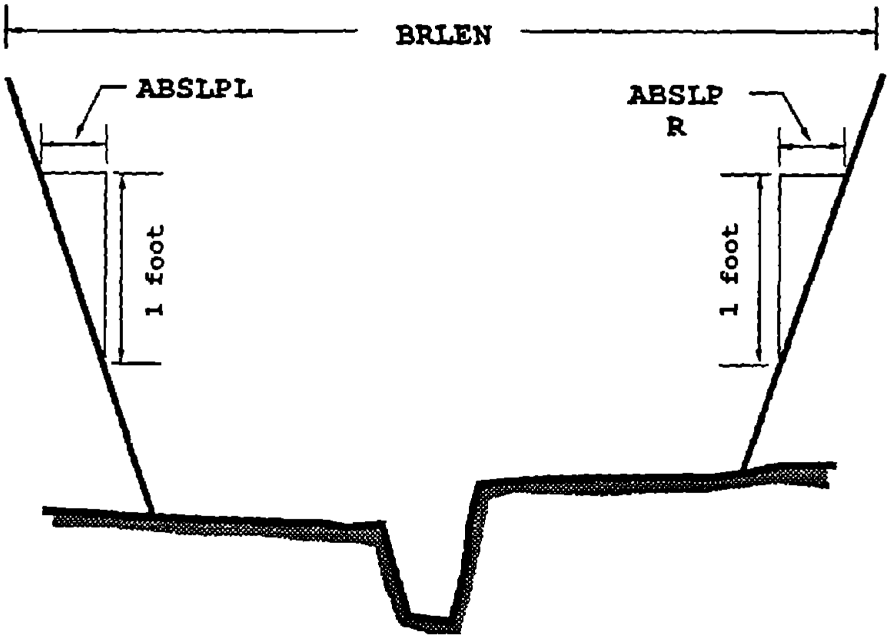


b) Elevation view, upstream side of bridge

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



a) Plan view



b) Elevation view, upstream side of bridge

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

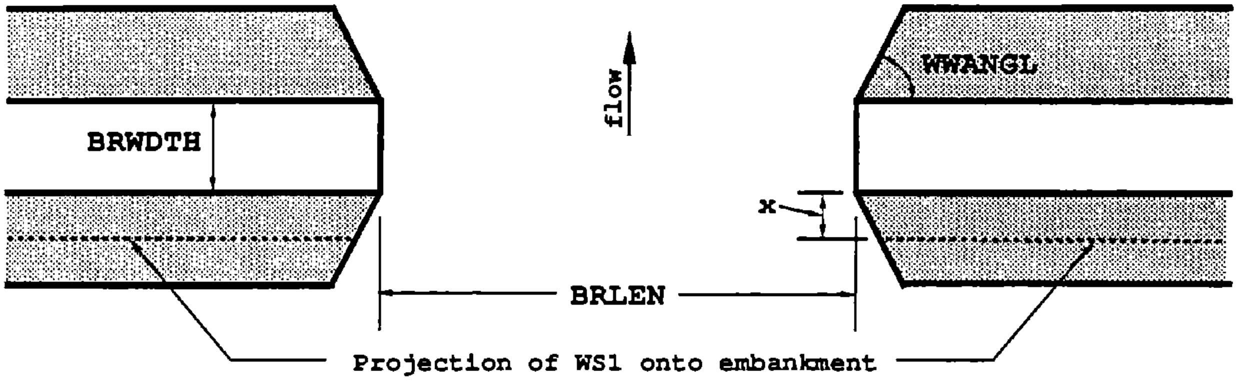


Figure 4-10.--Definition sketch: Type 4 bridge opening (BRTYPE = 4).

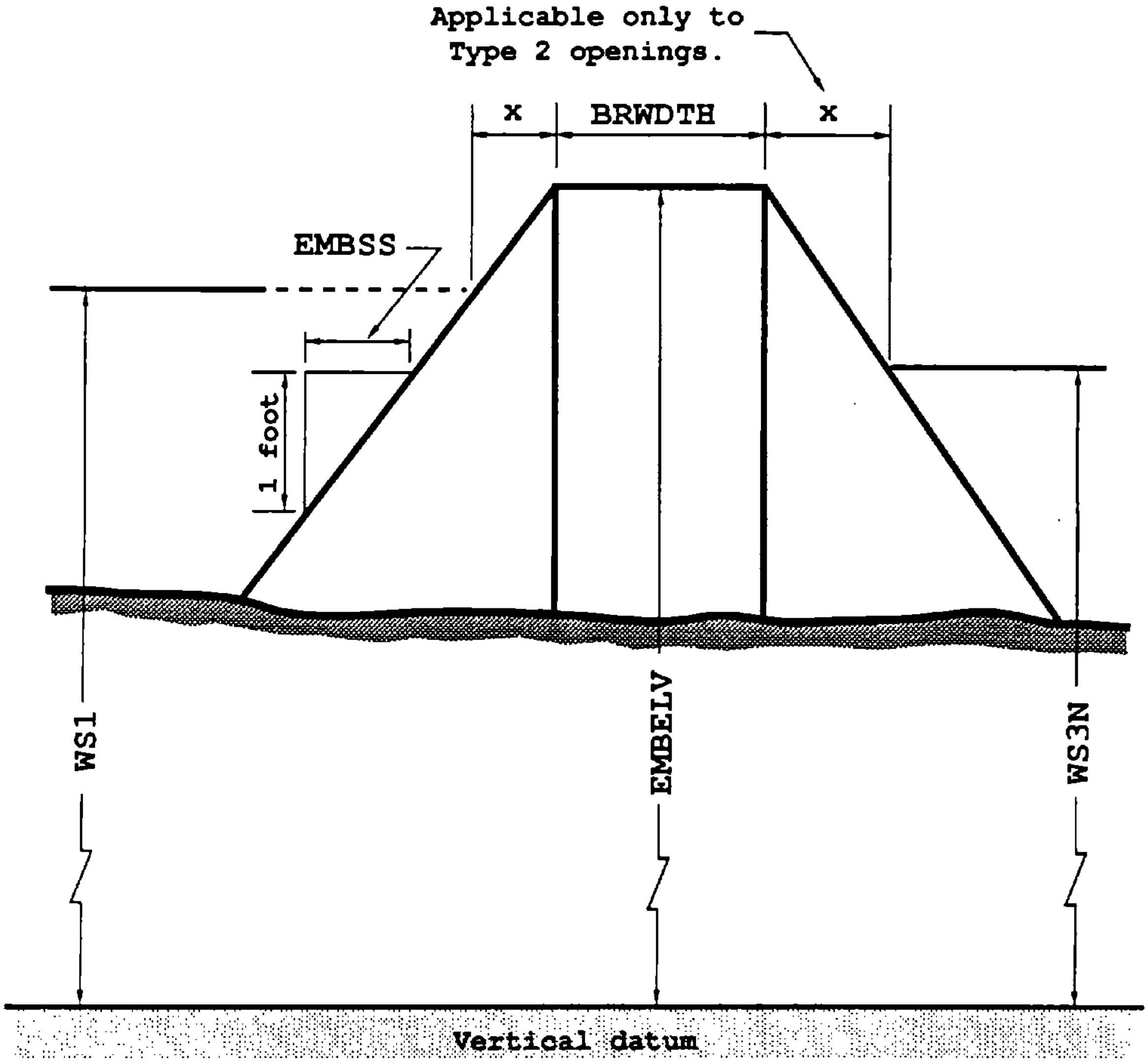


Figure 4-11.--Definition sketch: embankment parameters (BRTYPE 2, 3, AND 4)

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**
3-10	8X	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 inches**, of the culvert barrel. The rise equals the diameter for circular culverts.

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

BOTRAD, **TOPRAD**, **CORRAD** -- Bottom, top, and corner radii, respectively, of pipe-arch culvert barrel, **in inches**. Appropriate values are tabulated in CDS-4 (FHWA, 1982). If not specified, approximate values of these parameters will be computed on the basis of **ICODE**, **SPAN**, and **RISE** using the equations tabulated in table 4-14.

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

Codes[1]				
I	J	K	Type of inlet	K_e[2]
1	1	1	WINGWALLS: 30° - 75° flare; square top edge	0.4
1	1	2	HEADWALL: (a) normal or (b) 45∞ skew; square edge	0.5
1	1	3	WINGWALLS: 15° flare with square edges	0.5
1	1	4	WINGWALLS: extended with 0° flare; square top edge	0.7
1	1	5	HEADWALL: (a) normal or (b) 45° skew; 1:1 bevels	0.2
1	1	6	WINGWALLS: (a) 18° - 33.7° flare with 1 1/2:1 top bevel; or (b) 45° flare with 1:1 top bevel	0.2
1	1	7	HEADWALL: normal with 1 1/2:1 bevel on three sides	0.2
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:	0.5
2	2	5		
2	1	6	BEVEL: 1:1	0.2
2	2	6		
2	1	7	BEVEL: 1 1/2:1	0.2
2	2	7		
2	2	1	PROJECTING:	0.9
2	2	2	MITERED:	0.7
2	2	3	HEADWALL:	0.5
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: CR[3] ≤ 18"	0.9
3	2	2	PROJECTING: CR = 31"	0.9
3	2	3	PROJECTING: CR = 47"	0.9
3	2	4	MITERED: CR ≤ 18"	0.7
3	3	1	PROJECTING: CR = 31.8"	0.9
3	2	4	MITERED: CR ≤ 18"	0.7

(CONTINUED ON NEXT PAGE)

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

Codes[1]				
I	J	K	Type of inlet	K_e[2]
3	2	5	MITERED: CR = 31"	0.7
3	2	6	MITERED: CR = 47"	0.7
3	3	2	MITERED: CR = 31.8"	0.7
3	2	7	HEADWALL: CR ≤ 18"	0.5
3	2	8	HEADWALL: CR = 31"	0.5
3	2	9	HEADWALL: CR = 47"	0.5
3	3	3	HEADWALL: CR = 31.8"	0.5

---

[1] I, J, and K are codes representing shape, material, and inlet type, respectively. The shape code (I) indicates either box (1), circular (2), or arch (3). The material code (J) indicates either concrete (1), corrugated meter (steel) pipe (2), or aluminum (3). The inlet code (K) indicates the inlet conditions described under the Type of inlet column.

[2] K_e is the culvert entrance-loss coefficient.

[3] CR is the corner radius of pipe-arch culverts.

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

NOTE: all dimensions in inches.

$\mathbf{R}$ = rise
$\mathbf{B}$ = span
r_t = top radius
r_b = bottom radius
r_c = corner radius
CR is corner radius

Reinforced concrete pipe arch

$r_c = 0.598 + 0.243\mathbf{R}$
$r_t = 1.21 + 0.499\mathbf{B}$
$r_b = -60.13 + 2.106\mathbf{B} + 0.583(|\mathbf{B} - 95|)$

Corrugated metal pipe arch, CR < 18"

$r_c = 1.141 + 0.205\mathbf{R}$ if $\mathbf{R} < 55''$
$r_c = 18.0$ if $\mathbf{R} > 55''$
$r_t = 0.594 + 0.498\mathbf{B}$
$r_b = 7.0 - 2.036\mathbf{R} + 2.741\mathbf{B}$

(CONTINUED ON NEXT PAGE)

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

Corrugated metal pipe arch, CR = 31"

$$r_t = -0.346 + 0.505\mathbf{B}$$
$$r_b = -956.6 + 29.39\mathbf{R} - 13.49\mathbf{B}$$

Corrugated metal long-span pipe arch, CR = 47"

$$r_t = -3.27 + 0.521\mathbf{B}$$
$$r_b = -928.3 + 18.44\mathbf{R} - 7.805\mathbf{B}$$

Aluminum pipe arch, CR = 31.8"

$$r_t = -0.696 + 0.522\mathbf{B}$$
$$r_b = 363.0 - 9.639\mathbf{R} + 5.398\mathbf{B}$$

NOTE: all dimensions in inches.

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**
3-5	3X	lank
6-10	A5	SECID
11-80	free	**SRD,XCTR,CVLENG,DSINV,USINV**[,**NBBL**]

Definition of variables:

SECID -- Unique cross-section identification code (see discussion of **SECID** in section 4.1).

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 feet.

(CONTINUED ON NEXT PAGE)

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

CV CV Record CV
(CONTINUED)

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

USINV -- Elevation of upstream invert, in feet 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 ER record.

ER ER Record ER

Purpose: Specifying end of run (end of input data).

Format:

Columns	Format	Contents
1-2	A2	**ER**
3-80	--	blank

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

Table 4-17.--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	I1	**IEX**
5-10	6X	blank
11-80	free	[**IDIR**(1),**IDIR**(2), ... **IDIR**(**NPROF**)]

(CONTINUED ON NEXT PAGE)

Table 4-17.--Description of format and contents of EX record (continued).

EX EX Record EX
(CONTINUED)

Definition of variables:

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** ≤ 20.

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 the i^{th} profile, **IDIR** = 0 for upstream (subcritical and (or) critical) computations and **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 the **Q** record. See **sections 4.3.2 and 4.3.3** and **figure 4-13** for additional information.

Table 4-18.--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	I1	**IHFNO**
5-10	6X	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 (or blank) -- 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.

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Table 4-18.--Description of format and contents of FL record (continued).

FL **FL Record** **FL**

(CONTINUED)

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 4-12 illustrates the **FLEN** and **XFL** parameters.

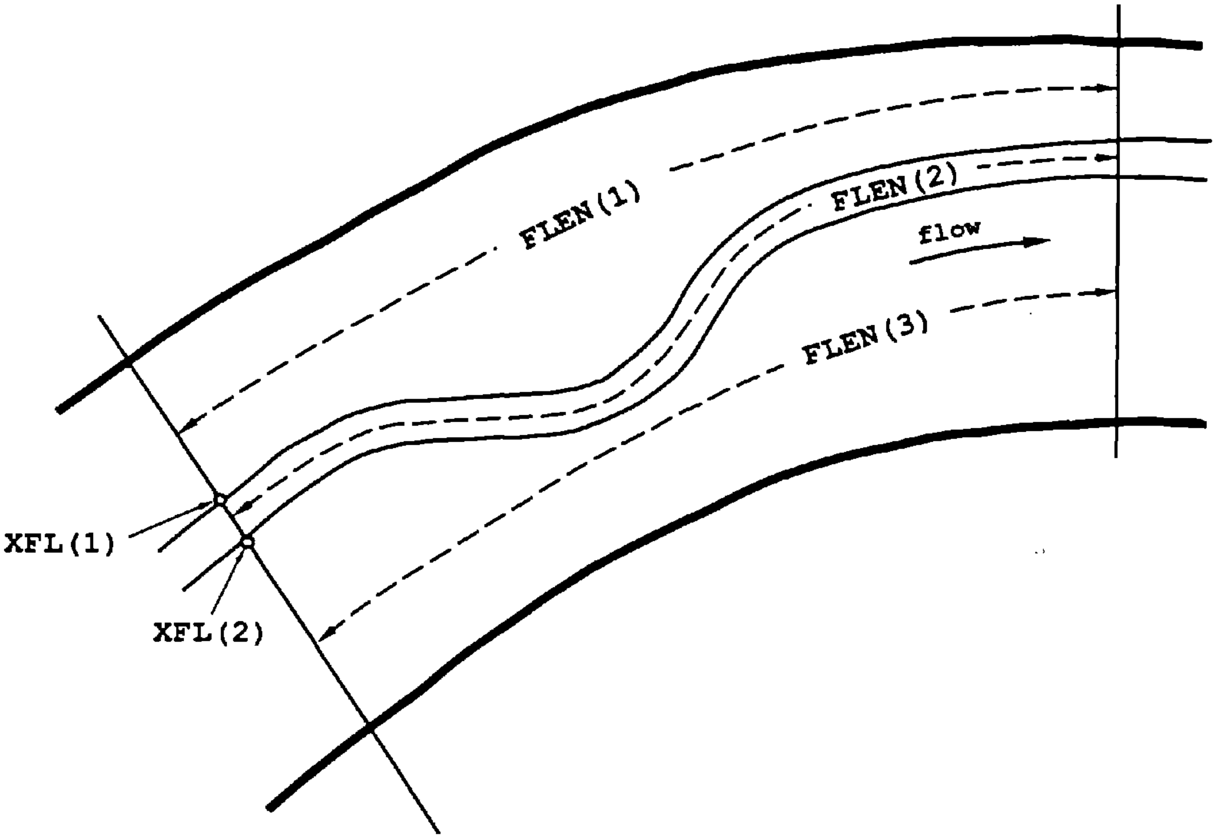


figure 4-12.--Definition sketch: FL record parameters.

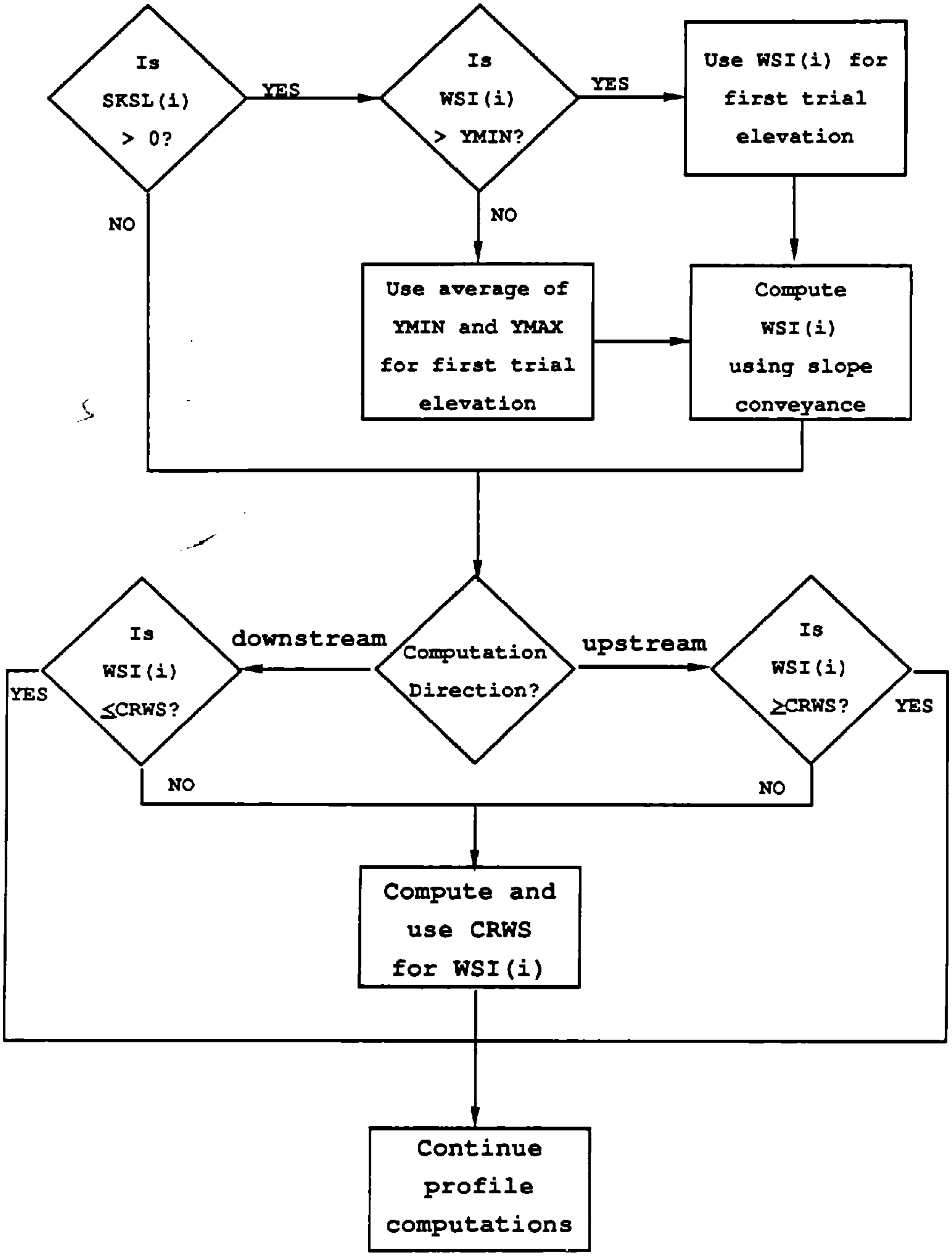


Figure 4-13.--Flow chart: computational path for various combinations of WS, SK, and EX data.

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

GR GR Record GR

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

Format:

Column	Format	Contents
1-2	A2	**GR**
3-10	8X	blank
11-80	free	**X**(1),**Y**(1),**X**(2),**Y**(2), ... **X(NGP)**,**Y(NGP)**

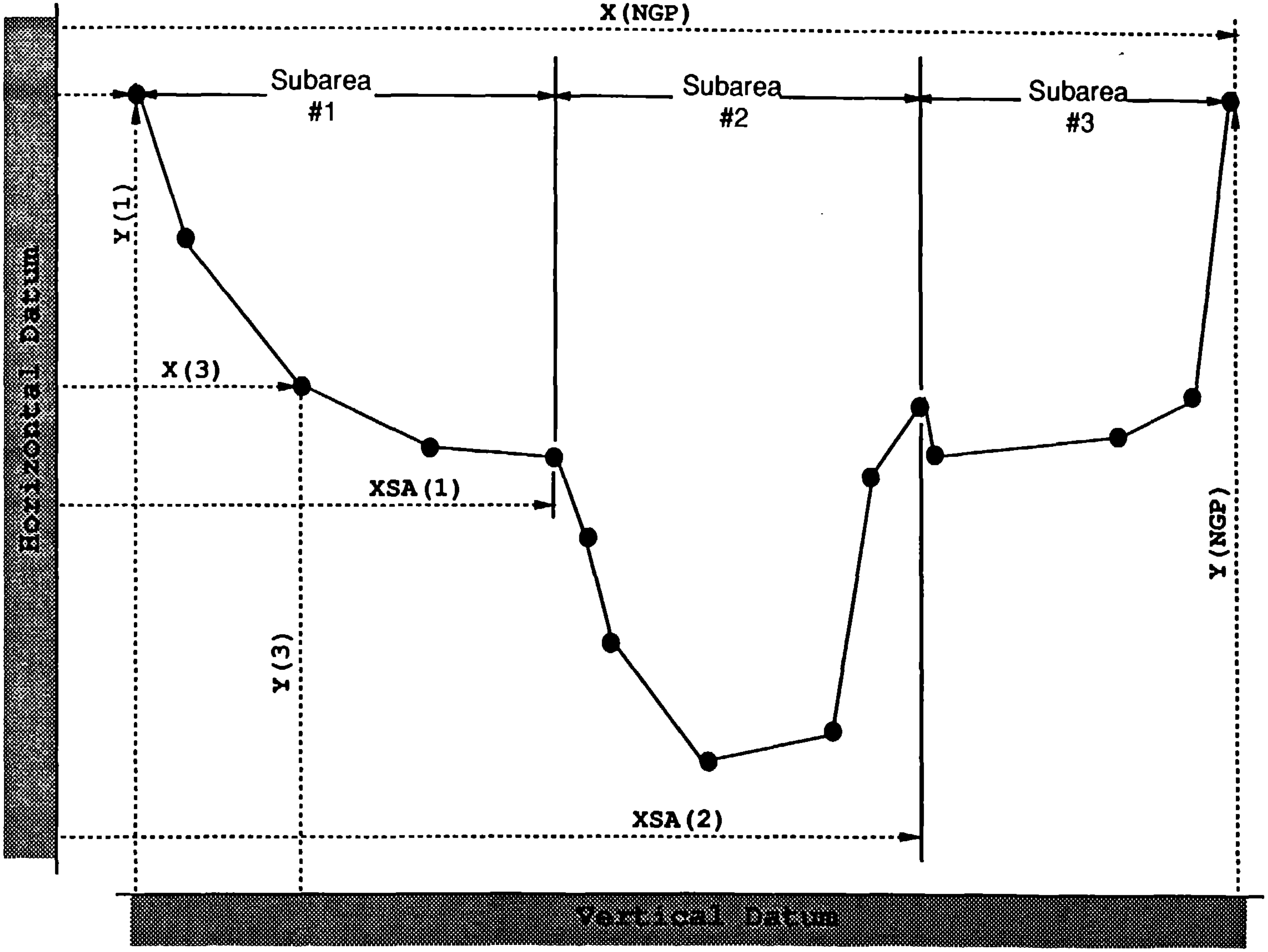
Definition of variables:

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.

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

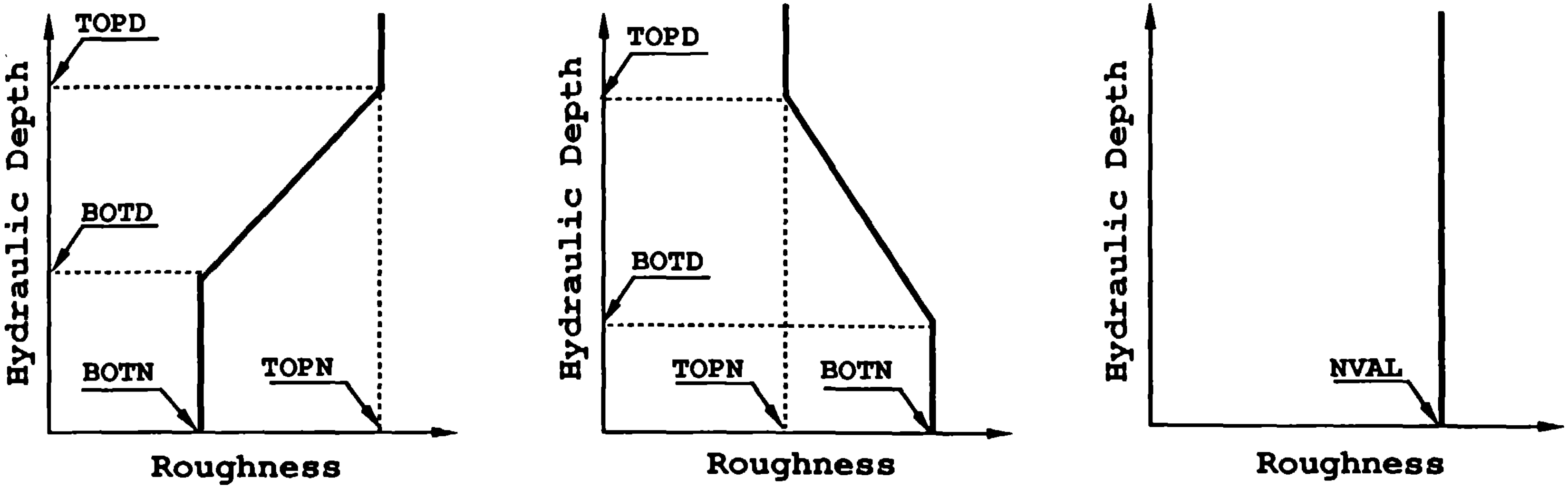
Y(i) -- y-coordinate of the i^{th} ground point, in feet above elevation datum.

Successive coordinates are coded from left to right (counter-clockwise) 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 4-14 illustrates the x,y-coordinate system and its interrelation with roughness data.



a) GR and SA record parameters

Figure 4-14.--Definition sketch: GR, N, ND, and SA parameters.



Roughness increasing with depth

Roughness decreasing with depth

Roughness constant with depth

b) N and ND record parameters

Figure 4-14.--Definition sketch: GR, N, ND, and SA parameters (continued).

Table 4-20.--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**
3-10	8X	blank
11-80	free	[**YSHIFT,XLIML,XLIMR,SCALE,XORIG**]

Definition of variables:

YSHIFT -- Vertical distance, in feet, 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 alinement if so desired; **SCALE** alters the x-coordinates on either side of **XORIG**.

Table 4-21.--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	I1	**IHP**
5	1X	blank
6-10	A5	[**SECID**]
11-80	free	[**ELMIN,YINC,ELMAX,Q**]

(CONTINUED ON NEXT PAGE)

Table 4-21.--Description of format and contents of HP record (continued).

HP HP Record HP
(CONTINUED)

Definition of variables:

IHP -- Option code indicating: (1) table of cross-sectional properties for the entire cross section (**IHP** = 0 or blank); (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 foot.

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 4.3.2 and 7.6** for additional information.

Table 4-22.--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
3-10	8X	blank
11-80	free	[**DELTAY, YTOL, QTOL, FNTEST, IHFNOJ**]

Definition of variables:

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

(CONTINUED ON NEXT PAGE)

Table 4-22.--Description of format and contents of J1 record (continued).

J1 J1 Record J1
(CONTINUED)

YTOL -- Allowable tolerance (error), in feet, between successive computed elevations for acceptable energy equation balance. Default value is 0.02 feet.

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 (coded 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 (or blank) 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 4-23.--Description of format and contents of J3 record.

J3 J3 Record J3

Purpose: Specifying parameters for user-defined output tables.

Format:

Columns	Format	Contents
1-2	A2	J3
3-10	8X	blank
11-80	free	1st list of **PARNOS** [* 2nd list of **PARNOS**] [* 3rd list of **PARNOS**]

Definition of variables:

PARNOS -- Parameter code numbers. As many as three user-defined tables can be obtained. Lists must be separated by a null value (*). Total number of parameters in the list(s) cannot exceed 50. Number of parameters in each list is constrained only by screen or printer line length; the model uses 14 columns. Parameter codes and required field widths are tabulated in **table 5-1**. See **section** 7.5 for an example of generating user-defined tables.

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

KD KD Record KD

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

Format:

Columns	Format	Content
1-2	A2	KD
3-10	8X	blank
11-80	free	*,*,*,**XLKQ**,**XRKQ**

Definition of variables:

XLKQ, **XRKQ** -- x-coordinates of left and right limits of the Kq section. The model, by default, centers the Kq section on the computed center of conveyance. Matthai (1967) suggests that the K_q section should generally include the low-water channel. The computed center of conveyance, especially in wide floodplain situations, may thus lead to undesirable default placement of the Kq section.

The three null values preceding **XLKQ** and **XRKQ** are required to account for the positions of three parameters that have been discarded since initial model development. Figure 4-15 illustrates application of the KD record.

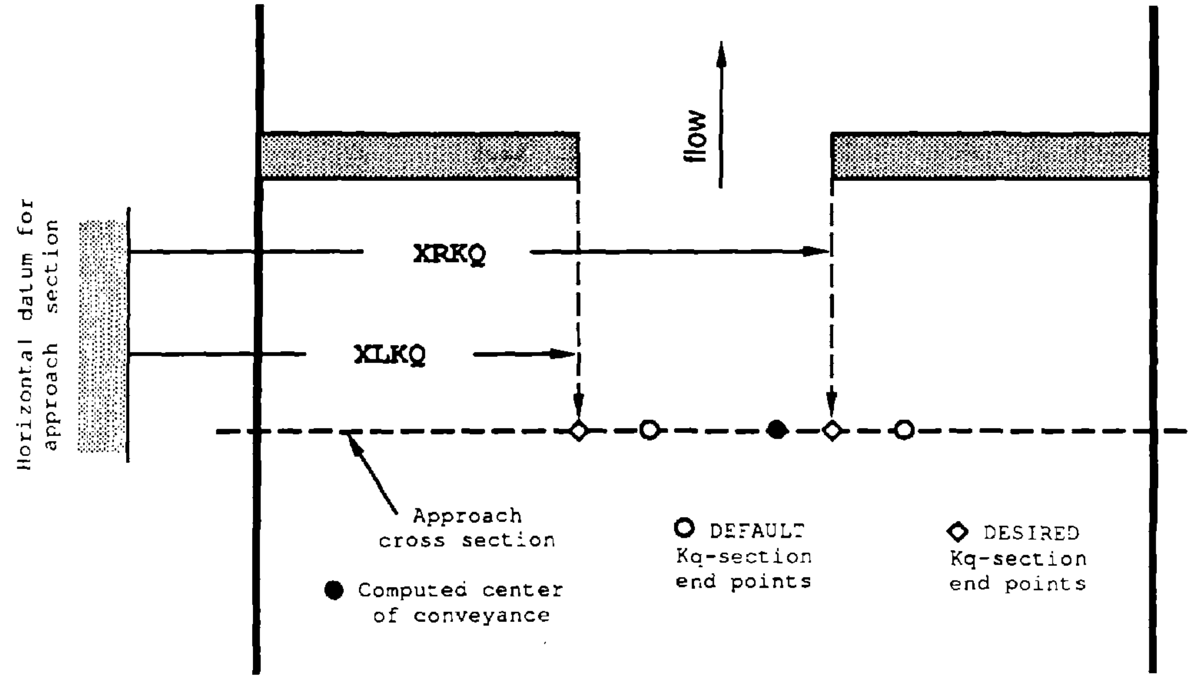


Figure 4-15.--Definition sketch: KD record parameters.

Table 4-25.--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	A1	**N**	
2-10	9X	blank	
11-80	free	**EITHER**	**NVAL**(1) [,**NVAL**(2) ... **NVAL**(**NSA**)]
		or	**BOTN**(1),**TOPN**(1) [,**BOTN**(2),**TOPN**(2) ... **BOTN**(**NSA**),**TOPN**(**NSA**)]

Definition of variables:

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.

The first coding alternative **must be used** when roughness **is not being varied with depth** (**ND data are not coded** for the cross section). **Only one n-value can be coded for each subarea.**

NVAL(i) -- n-value applicable to the full range of depths in the i^{th} subarea.

The second coding alternative must be used if roughness is being varied with depth (**ND data are coded** for the cross section). **A pair of n-values must be coded for each subarea.**

BOTN(i) -- n-value for the i^{th} subarea; applicable to depths equal to or less than the **BOTD** specified for the i^{th} subarea in the **ND** data.

TOPN(i) -- n-value for the i^{th} subarea; applicable to depths equal to or greater than the **TOPD** specified for the i^{th} subarea in the **ND** data.

It is possible, however, to have subareas with variable roughness and subareas with constant roughness in a cross section. For constant roughness in a subarea, code equal n-values for **BOTN** and **TOPN**.

See **figure 4-14** and **tables 4-26 and 4-30** for additional information.

Table 4-26.--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
3-10	8X	blank
11-80	free	**BOTD**(1),**TOPD**(1) [,**BOTD**(2),**TOPD**(2) ... **BOTD**(**NSA**),**TOPD**(**NSA**)

Definition of variables:

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.

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 4-14** and **tables 4-25 and 4-30** for additional information.

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

PW PW Record PW

Purpose: Specifying pier or pile data.

Format:

Columns	Format	Contents
1-2	A2	**PW**
3	1X	blank
4	I1	**PPCD**
5-10	6X	blank
11-80	free	**PELV**(1),**PWDTH**(1) [,**PELV**(2),**PWDTH**(2) ... **PELV**(**NPW**),**PWDTH**(**NPW**)

Definition of variables:

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

PPCD -- Code to identify piers (**PPCD** = 0 or blank) or piles (**PPCD** = 1); affects the pier adjustment to the coefficient of discharge.
for piers requires this distinction.

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

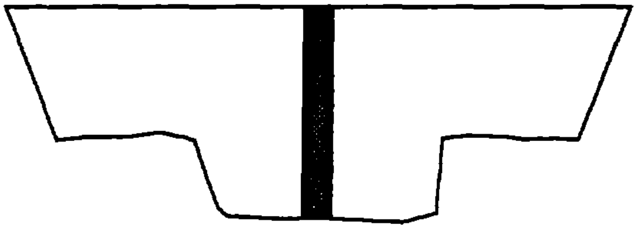
PWDTH(i) -- The **gross** width, in feet, of **all** piers (and (or) pile bents) for the i^{th} pair of elevation-width data.

Figure 4-15 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 fig. 4-16a).

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 fig. 4-16b).

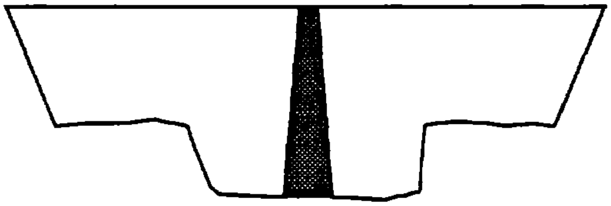
Non-uniform variation of gross width requires two elevation-width pairs at each elevation that gross width.changes abruptly. An abrupt change can be: (1) additional piers coming into effect with increasing elevation; (2) changes in pier dimensions; and (3) loss of piers with increasing elevation (sloping low chord). Figures 4-16c and 4-16d illustrate the latter cases,



Constant pier width (5 feet) from channel bottom (elevation 100) to horizontal low chord

```
PW             100,5
```

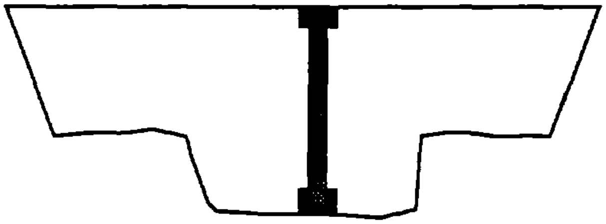
a)constant pier width



Uniformly varying pier width: 6 feet at channel bottom (elevation 100) to 4 feet at horizontal low chord (elevation 125).

```
PW             100,6   125,4
```

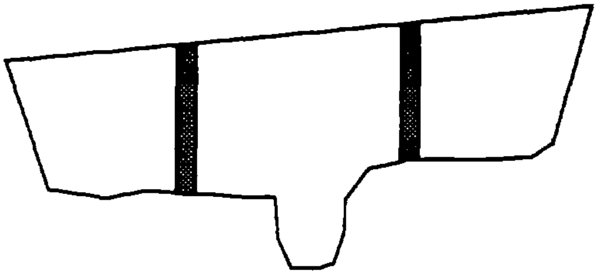
b) uniformly varying pier width



Abrupt variation in pier width due to shape: channel bottom elevation is 100; horizontal low chord elevation is 125; 3-foot wide footer extends 2 feet above channel bottom; 3-foot wide pier cap extends 2 feet below low chord; 1.5-foot pier.

```
PW             100,3  102,3  102,1.5  123,1.5  123,3
```

c) abruptly varying pier width with shape



Abrupt variation in pier width due to elevation: each pier is 2-foot wide. Elevations: left pier - at ground 101, at low chord 120; right pier - at ground 103.5, at low chord 121.

```
PW             101,2  103.5,2  103.5,4  120,4  120,2  121,2  121,0
```

d) abrupt changes in pier width with elevation

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

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

PX PX Record PX

Purpose: Requesting cross-section plots.

Format:

Columns	Format	Contents
1-2	A2	**PX**
3-5	3X	blank
6-10	A5	[**SECID**]
11-80	free	[**XRANGE,YRANGE**]

Definition of variables:

SECID -- Section identification code, not required if **PX** record included with the section data. See **sections 4.3.2 and 7.6** for additional informaton.

XRANGE -- A single value indicating the total horizontal distance to be encompassed by the plot.

YRANGE -- A single value indicating the total vertical distance to be encompassed by the plot.

XRANGE and **YRANGE** default values are computed from minimum and maximum cross section coordinates and may result in fractional and (or) unwieldy increments for axes divisions. The user may find it expedient to code values that best match the cross-section data to the six divisions of the X-axis and the four divisions of the Y-axis on the plot. When plotting two or more sections, it may be desirable to specify the same range values for each section to obtain consistent scaling for cross-section comparisons.

Table 4-29.--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	A1	**Q**
2-5	4X	blank
6-10	A5	[**SECID**]
11-80	free	**Q**(1),**Q** (2), ... **Q**(**NPROF**)

(CONTINUED ON NEXT PAGE)

Table 4-29.--Description of format and contents of Q record (continued).

Q Q Record Q

Definition of variables:

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** ≤ 20.

Q(i) -- Discharge, in cubic feet 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 and 7.6** for additional information.

Table 4-30.--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**
3-10	8X	blank
11-80	free	**XSA**(1),**XSA**(2) ... **XSA**(**NSA**-1)

Definition of variables:

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** ≤ 20.

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**. See **section 3.2.1** and **figure 4-14** for additional information.

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

SD SD Record SD

Purpose: Header record for spur-dike cross section.

Format:

Columns	Format	Contents
1-2	A2	**SD**
3-5	3X	blank
6-10	A5	**SECID**
11-80	free	**SRD,SDTYPE [,BSUBD,SDOFF,SKEW,EK,CK,VSLOPE]**

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

SRD -- Section reference distance.

SDTYPE -- Code to indicate the type of spur dikes. Valid entries are:

1 -- Elliptical spur dikes, no skew.
2 -- Elliptical spur dikes, skewed.
3 -- Straight spur dikes, no offset.
4 -- Straight spur dikes, with offset.

BSUBD -- Distance, in feet, that straight dikes are offset from the bridge abutments (not to be confused with **SDOFF** below). This parameter is only relevant to **SDTYPE** = 4.

SDOFF -- Measured normal to the flow at the mouth of the dikes, the horizontal offset, in feet, between the dikes and the bridge abutments. Use an average value if the left and right offsets are not equal. The model places the base of the dikes at this distance from the abutment stations (see fig. 4-17). Side slope of the dikes are equal to the bridge abutment slopes. Remaining ground points are obtained from the full-valley cross section.

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 for computing the expansion and contraction losses, respectively, for the energy equation balance. These coefficients would apply only to downstream computations from the spur dike to the 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 spur dike when geometric data are propagated. Default value is zero or the current value being propagated from downstream data.

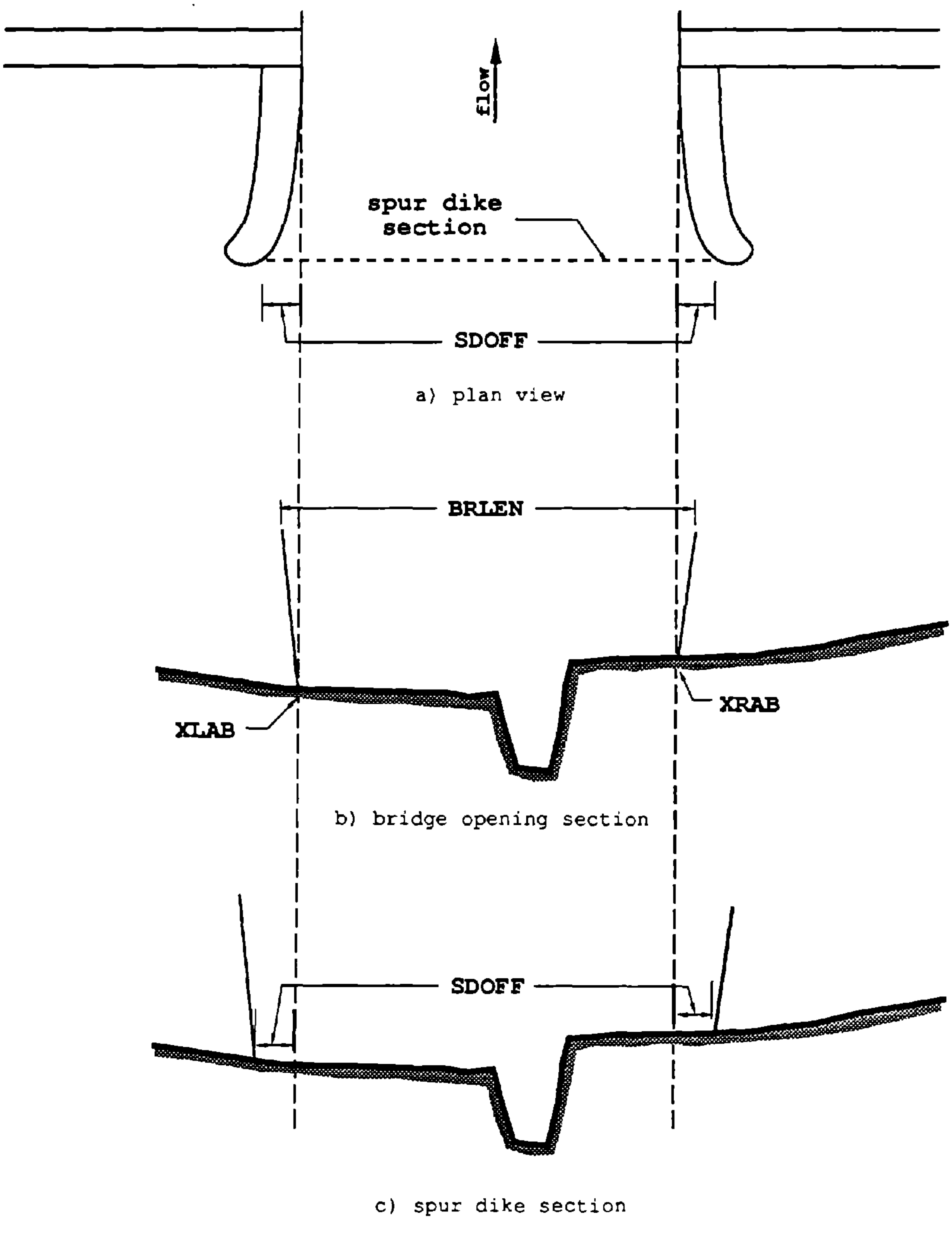


Figure 4-17.--Definition sketch: spur-dike section from design mode.

Table 4-32.--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**
3-10	8X	blank
11-80	free	**SKSL(1),SKSL(2) ... SKSL(NPROF)**

Definition of variables:

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.

SKSL(i) -- Friction slope (energy gradient), in feet per foot, 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 4-13** for additional information.

Table 4-33.--Description of format and contents of T1, T2, and T3 records.

T1, T2, T3 T1, T2, T3 Record T1, T2, T3

Purpose: Specifying title information for identification of model output.

Format:

Columns	Format	Contents
1-2	A2	**T1, T2,** or **T3**
3-10	8X	blank
11-80	70A1	Any alphanumeric character string.

Discussion:

Information in the free-format area of the **T1, T2,** and **T3** records is printed on essentially every page of printed output, along with date and time of job execution. When analyzing a series of alternative designs, it is possible to change some or all of these records for each alternative without recoding all three records. The user may choose to provide a new **T2** and **T3** record or just a new **T3** record for each alternative. If a new **T2** record is coded without a new **T3** record, a blank line is printed for **T3** record information.

Table 4-34.--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**
3-10	8X	blank
11-80	free	**WSI**(1),**WSI**(2), ... **WSI**(**NPROF**)

Definition of variables:

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.

WSI(i) -- Elevation, in feet 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 4-17** for additional information.

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

XR XR Record XR

Purpose: Header record for road-grade cross section.

Format:

Columns	Format	Contents
1-2	A2	**XR**
3-5	3X	blank
6-10	A5	**SECID**
11-80	free	**SRD**,**EMBWID** [,**IPAVE**,**USERCF**,**SKEW**]

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

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

(CONTINUED ON NEXT PAGE)

Table 4-35.--Description of format and contents of XR record (continued).

XR XR Record XR
(CONTINUED)

EMBWID -- Embankment top width, in feet. 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 length.

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.

See **section 4.3.9** for additional information.

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

XS XS Record XS

Purpose: Header record for unconstricted valley cross section (**except for approach cross section**).

Format:

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

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

(CONTINUED ON NEXT PAGE)

Table 4-36.--Description of format and contents of XS record (continued).

XS XS Record XS
(CONTINUED)

SRD -- Section reference distance, in feet. 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 feet/foot, 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 4-37.--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**
3-5	3X	blank
6-10	A5	**SECID**
11-80	free	**SRD** [,**VSLOPE**]

Definition of variables:

SECID -- Unique cross-section identification code (see **section 4.1** for additional discussion of **SECID**).

(CONTINUED ON NEXT PAGE)

Table 4-37.--Description of format and contents of XT record (continued).

XT XT Record XT
(CONTINUED)

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

VSLOPE -- Valley slope, in feet per foot. 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 4-38.--Description of format and contents of * record.

* * Record *

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

Format:

Columns	Format	Contents
1	A1	* (asterisk)
2-10	9X	blank
11-80	70A1	Any alphanumeric characters.

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 J3 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 of the initial cross section; and (2) in the correct flow regime (subcritical or critical for upstream computations; supercritical or critical for downstream computations). Figure 4-13 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 4-17.

4.3.3 Placement of Q, HP, and PX 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 (never a default value). Most of the cross-sections are input in downstream to upstream order (except if both spur-dike 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 most simple 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 emulate 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.

Bridge openings can also be easily corrected for skew. A cross section can be surveyed parallel to the face of the opening and the skew angle coded in the BR header record. When using design mode, it is a logical requirement that both the full-valley and bridge-opening sections have the same orientation (i.e., correct bridge component and full-valley ground point connections are not possible if they are not in the same plane). The model forces this condition by assuming that if a skew angle is coded for either the full-valley or the bridge-opening section, both sections are skewed. If this is not the case, the user must revise the input data to satisfy this requirement.

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 flow patterns requiring 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. It appears that the model may not always correctly make all of the various projections for the needed intermediate exit and approach sections in the multiple-opening analysis 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 3.1 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 (LSEL), which may be coded in the BR header record. In design mode the model computes a value of LSEL (average of the elevations of abutment tops) and the user is not required to assign a value in the BR record. However, in fixed-geometry mode the model does not have sufficient information to compute LSEL. Therefore, the user must code LSEL in the BR record for fixed-geometry mode if there is any possibility of pressure flow. Without a value for LSEL, either computed (in design mode) or specified (in fixed-geometry 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 LSEL 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 LSEL is not tied into the computation of the bridge-opening properties. Thus the user may "mislead" the model by coding a LSEL 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 design and fixed-geometry 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 LSEL (computed in design mode or specified by the user for fixed-geometry mode) is 100.00 and the computed tailwater elevation is 100.01 (or 100.001, which would appear in the output as 100.00), the model will compute submerged pressure flow (obviously a very borderline case). By specifying a value of LSEL that is higher than the tailwater elevation, the user can force a free-surface solution. Sometimes it is also possible to vary LSEL 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, 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.

The AS header record requirement provides the model the means by which it recognizes the end of input data describing a bridge situation, either single or multiple openings. Unfortunately, an error trap does not exist for a missing AS record. In the event that the user mistakenly uses an XS record for the approach section header record, the model generates a message instructing the user to check for error messages at a section that has a blank SECID (this section, of course, is nonexistent).

The approach 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 spur dikes 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; slackwater 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 AS 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.

A value of valley slope must be coded in the XS header record of the downstream match section (which is analogous to the exit section of single-opening bridges). Code a zero if valley slope is not needed for propagation of cross-section data; do not allow a default value. Failure to code a value will cause the model to fail because of problems involved with fabricating the intermediate section required in the analysis.

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 alined 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.

The parameter to indicate the number of culvert barrels, NBBL, is not correctly interfaced with the multiple-opening computations. Therefore, instead of coding NBBL, a multi-barrel culvert must be coded as a single-barrel culvert with a SPAN that is equivalent to the gross width of the multi-barrel culvert.

Section 5

MODEL OUTPUT OVERVIEW

WSPRO automatically generates rather detailed output (on logical unit number 6) 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 (1) cross-section plots, (2) cross-sectional properties, and (3) user-defined tables also are directed to this "print" file. WSPRO may generate as many as three additional files (logical unit numbers 7, 8, and 9). These files have become obsolete since initial development and should be defined to the system as "scratch" or "temporary" files. Additional discussion of this topic is presented in section 8. WSPRO uses a temporary direct-access file (logical unit number 13) for storage and retrieval of cross-section data. Another temporary direct-access file (logical unit number 14) is used to store computed results and key input parameters. WSPRO treats both of these files as "work" files, but they are machine-readable files that could be retained and accessed by other computer programs if and when such uses are developed. 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-Section Plots

Plots of cross-section data can be obtained with PX records. These plots can provide a means of visually editing these data. Plots are directed to the "print" file. Each plot is placed on a "page" that is 132 columns wide and 66 lines in length. The plots will be intermingled with the processing information if the PX record is included with the input data of the section(s) plotted. The plots can be output on successive pages if all PX records are input in a group following input of all section data. The latter practice also makes it easier to delete the PX records for subsequent input of the same sections (unless duplicate plots are desired). See section 4.3.3 for additional discussion of the location of PX records in the data sequence.

5.3 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.

5.4 Standard Table of Computed Profile Results

This output, also directed to the "print" file, contains a section-to-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

5.5 User-Defined Tables

Tables of selected parameters can be generated by coding a sequence of parameter code numbers (J3 record(s)). The parameters are retrieved from file 14 (see section 5.7). Table 5-1 lists the parameters that can be tabled along with the headings used, parameter code numbers, and the required field widths. Table 5-2 lists the headings in alphabetical order and cross references them to table 5-1 by parameter code number. WSPRO uses 14 columns for section identification and error flagging. Users are free to use (and responsible for restricting use of) the remaining columns up to their desired "page" width (hard copy or screen) in accordance with the required field widths. "Undefined" parameters, such as a 400-series code when a road-grade section has not been input, cannot be tabled. User-defined tables cannot be generated for multiple-opening analyses. Attempting either of these two actions cause an abortive system error relative to file 14.

Table 5-1.--Parameters available for user-defined tables.

	See footnote number(s)	Parameter code number	On output	
			Heading	Field width[1]
Water-surface elevation	2,4	3	WSEL	8.2
Velocity head	2,4	4	VHD	6.2
Discharge	2,4	5	Q	8.0
Section reference distance	2,4	6	SRD	7.0
Energy grade line	2,4	7	EGL	8.2
Error in energy/discharge balance	2,4	8	ERR	8.2
Flow distance	2,4	9	FLEN	7.0
Straight-line (SRD) distance	2	10	SLEN	7.0
Friction loss	2,4	11	HF	6.2
Other losses (expansion/contraction)	2	12	HO	6.2

(CONTINUED ON NEXT PAGE)

Table 5-1.--Parameters available for user-defined tables (continued).

	See footnote number(s)	Parameter code number	On output	
			Heading	Field width[1]
Velocity	2	13	VEL	8.2
Froude number	2	14	FR#	8.2
Critical water-surface elevation	2	15	CRWS	8.2
Cross-section conveyance	2	16	K	9.0
Cross-section area	2	17	AREA	9.0
Velocity head correction factor, α	2	18	ALPH	6.2
Momentum correction factor, β		19	BETA	6.2
Maximum station in cross section		20	XMAX	7.0
Maximum elevation in cross section		21	YMAX	8.2
Minimum station in cross section		22	XMIN	7.0
Minimum elevation in cross section		23	YMIN	8.2
Stagnation point, left	6	24	SPLT	7.0
Stagnation point, right	6	25	SPRT	7.0
Skew of cross section		26	SKEW	7.0
Cross-section wetted perimeter		27	XSWP	7.0
Cross-section top width		28	XSTW	7.0
Left edge of water	2	29	LEW	7.0
Right edge of water	2	30	REW	7.0
Expansion loss coefficient		150	EK	6.2
Contraction loss coefficient		151	CK	6.2
Bridge opening length	3	250	BLEN	7.0
Abutment station, left toe	3	251	XLAB	7.0
Abutment station, right toe	3	252	XRAB	7.0
Low steel (submergence) elevation	3	253	LSEL	8.2
Flow classification code	3	254	FLOW	5.0
Bridge opening type	3	255	TYPE	5.0
Coefficient of discharge	3	256	C	7.3
Pier or pile code	3	257	PPCD	5.0
Pier area ratio	3	258	P/A	7.3
Flow over road	4	430	Q	8.0
Weir length	4	432	WLEN	7.0
Left edge of weir	4	434	LEW	7.0
Right edge of weir	4	436	REW	7.0
Maximum depth of flow	4	438	DMAX	6.1
Average weir coefficient	4	440	CAVG	6.1
Average total head	4	442	HAVG	6.1
Average depth of flow	4	444	DAVG	6.1
Maximum velocity	4	446	VMAX	6.1
Average velocity	4	448	VAVG	6.1
Flow contraction ratio (conveyance)	5	550	M(K)	7.3

(CONTINUED ON NEXT PAGE)

Table 5-1.--Parameters available for user-defined tables (continued).

	See footnote number(s)	Parameter code number	On output Heading	On output Field width[1]
Conveyance of Kq-section	5	551	KQ	9.0
Left edge of Kq-section	5	552	XLKQ	7.0
Right edge of Kq-section	5	553	XRKQ	7.0
Geometric contraction ratio (width)	5	554	M(G)	7.3
Road overtopping elevation	5	555	OTEL	8.2

[1] First digit represents total column width (allows for spacing), second digit indicates digits to right of decimal.

[2] Printed in standard profile table for all sections except road grade.

[3] Additional parameters printed in standard table for bridge sections.

[4] Additional parameters printed in standard table for road-grade sections.

[5] Additional parameters printed in standard table for approach sections.

[6] Applicable only for multiple-opening situations.

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

Heading	Code number[1]	Heading	Code number[1]
ALPH	18	Q	430
AREA	17	REW	30
BETA	19	REW	436
BLEN	250	SKEW	26
C	256	SLEN	10
CAVG	440	SPLT	24
CK	151	SPRT	25
CRWS	15	SRD	6
DAVG	444	TYPE	255
DMAX	438	VAVG	448
EGL	7	VEL	13
EK	150	VHD	4
ERR	8	VMAX	446
FLEN	9	WLEN	432
FLOW	254	WSEL	3

(CONTINUED ON NEXT PAGE)

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

Heading	Code number[1]	Heading	Code number[1]
FR#	14	XLAB	251
HAVG	442	XLKQ	552
HF	11	XMAX	20
HO	12	XMIN	22
K	16	XRAB	252
KQ	551	XRKQ	553
LEW	29	XSTW	28
LEW	434	XSWP	27
LSEL	253	YMAX	21
M(G)	554	YMIN	23
M(K)	550		
OTEL	555		
P/A	258		
PPCD	257		
Q	5		

[1] Parameter code number in table 5-1.

5.6 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.

5.7 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 5.5).

Section 6

MESSAGES

Messages are presented in two tables; 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

Comments

+++001 DATA RECORD OUT OF ORDER IGNORED. **itype**

Record type **itype** is not in proper sequence. See note at end of table.

+++002 SECID MISMATCH - "**secid1**" AND "**secid2**"

SECID of previous data record, **secid1**, does not match **secid2**, SECID of the data being processed.

+++003 ORDER: NO PROFILE CONTROL DATA CHANGES AFTER EX RECORD.

Profile control data must be established prior to the first EX Record and must not be changed thereafter.

(CONTINUED ON NEXT PAGE)

Table 6-1.--Input data messages (continued).

+++**xxx** MESSAGE Comments
+++**004** UNEXPECTED CONTINUATION RECORD SKIPPED. Improper use of a continuation record, data record ignored.
+++**005** IGNORED UNRECOGNIZED RECORD IDENTIFIER - "**cc**" **cc** is an invalid record identifier, data record not used.
+++**006** INVALID CHARACTERS IN OPTION FIELD - "**aaa**" **aaa** appears in columns 3-5. Columns 3 and 5 must always be blank; column 4 must be blank except when a valid option code (integer value) is applicable.
+++**007** DATA COUNT EXCEEDS ALLOWABLE MAXIMUM: FOUND - **nnn** MAX - **max** COL# - **col** **nnn**, number of entries found, exceeds **max**, maximum number of entries permitted; processing stopped at column number **col**.
+++**008** INVALID DATA NEAR COLUMN **col** Invalid character(s) near column number **col** in the preceding data record.
+++**009** INVALID CONTINUATION, COLUMNS 3-10 MUST BE BLANK. Columns 3-10 of any continuation record must be blank.
+++**010** CONTINUATION RECORD FLUSHED. Unexpected or invalid continuation; data record not used.
+++**011** EXPECTED CONTINUATION NOT FOUND. Model expected continuation of data, check last two data records.
+++**013** CVTAD2 - ILLEGAL **word1** IN **word2** AT END OF **col**-CHAR FIELD "**string**" **word1** is either CHARAC or MAGNIT (for character or magnitude); **word2** is INTGR, FRACTN, or EXPONT (for integer, fraction, or exponent); **col** is the approximate column number of the problem; and **string** is a printout of the first **col** characters of the data record.

(**CONTINUED ON NEXT PAGE**)

Table 6-1.--Input data messages (continued).

+++xxx MESSAGE

Comments

+++014 WARNING: EXCESS DATA ITEMS IGNORED.

Check for miscoded data values or extraneous data entries.

+++015 WARNING: TOO MANY DATA ITEMS ON J3 RECORD; ONLY **nn** ITEMS USED.

Maximum number of parameters in user-defined tables is limited to **nn**.

+++016 NOTE: EXTRANEOUS OPTION/SECID IGNORED.

Data entered in columns 3-10 (which should be blank) were ignored.

+++017 DATA COUNT INCONSISTENT WITH PROFILE COUNT - **ndata** **nprof**

ndata, number of entries in current data record, is not equal to **nprof**, number of entries in previous profile control data record(s). Final number of profiles that will be computed is equal to the minimum number of corresponding, valid entries in the Q, WS, SK, and EX records.

+++018 UNKNOWN SECID; DATA IGNORED - **"secid"**

secid does not match the SECID of any cross section previously input.

+++019 INVALID OPTION CODE IGNORED - **n**

n, invalid (out-of-range) option code ignored, default value used.

+++020 COMPUTATION DIRECTION ESTABLISHED BY EX RECORD.

There is no problem unless message **+++021** follows.

+++021 DATA COUNT INCONSISTENT WITH PROFILE COUNT - **ndata** **nprof**

ndata, number of entries in EX record, is not equal to **nprof**, number of entries in one or more of the Q, WS, and SK record(s).

+++022 PROFILE COUNT REDUCED TO DATA COUNT - **ndata** **nprof**

If **nprof>ndata** (message **+++021**), **nprof**, number of profiles computed, is set equal to **ndata**, number of entries in the EX record.

+++023 DISCHARGE DATA INVALID OR MISSING - **nth**

Negative value or no discharge data found, check **nth** value in Q record(s).

(CONTINUED ON NEXT PAGE)

Table 6-1.--Input data messages (continued).

+++xxx MESSAGE

Comments

+++024 PROFILE COMPUTATIONS BYPASSED DUE TO INCONSISTENT CONTROL DATA.

Profile control data problems not resolved by internal checks. Job terminated prior to profile computations. Check data in the Q, WS, SK, and EX records.

+++025 CALCULATIONS MAY BE INCOMPLETE DUE TO INCONSISTENT DATA.

Model detected input data error(s); attempts to compute profiles for all valid data.

+++026 DATA COUNT EXCEEDS CAPACITY FOR TYPE - **nn** **jtype**

Number of values **nn** is greater than permitted for record type **jtype**. See note at end of table.

+++027 ORDER: INVALID CONTINUATION OR REDEFINITION - **jtypec** **jtypep**

Current and previous record types, **jtypec**, and **jtypep**, are inconsistent. Check for: 1) duplicate input record; 2) missing header record between sections; or 3) interruption in what should be a continuous sequence of one record type. See note at end of table.

+++028 ORDER: RECORD TYPE INVALID FOR X-SEC TYPE - **jtype**

Record type **jtype** not applicable to cross section indicated by header record. See note at end of table.

+++029 MISSING FLOW LENGTH OR BREAKPOINT STATION - **nn**

The even number of entries, **nn**, in the FL record indicates a missing value.

+++030 INVALID FRICTION LOSS OPTION CODE - **n**

The option code, **n**, in the FL record is greater than 4.

+++032 ERROR - XSEC STATION REVERSAL AT X = **xsta**

xsta must be equal to or greater than previous x-coordinate in GR data; reversals permitted only in bridge sections.

+++033 MISSING -- X OR Y VALUE IN GR DATA. **nn**

Number of GR data values, **nn**, is not even, which indicates missing data.

(CONTINUED ON NEXT PAGE)

Table 6-1.--Input data messages (continued).

+++**xxx** MESSAGE

Comments

+++034 MISSING - WIDTH OR ELEV IN PIER-ELEV-WIDTH TABLE. **nn**

Number of PW data values, **nn**, is not even, which indicates missing data.

+++035 ERROR - BRIDGE OPENING XSEC MUST BE CLOSED.

In the first and last GR data pairs for a bridge, the x-coordinate must be the minimum x-coordinate of the bridge, and if there is a vertical wall at that station, the y-coordinate must be the highest elevation on the wall.

+++036 CULVERT CODE INVALID - **ishape** **icode**

icode is invalid for the shape factor, **ishape** (CG record).

+++037 CULVERT LENGTH/INVERT INVALID - **cvleng** **usinv** **dsinv**

Culvert length, **cvleng**, is negative or zero and (or) one or both invert elevations, **usinv** and **dsinv**, are missing (CV record).

+++038 CULVERT PIPE-ARCH AUXILIARY DIMENSIONS INVALID - **botrad** **toprad** **corrad**

One or more of the user-specified radii are invalid.

+++039 CULVERT RISE/SPAN INVALID FOR SHAPE - **span** **rise** **icode**

Check validity of **rise** and (or) **span** for the **icode** value (CG record).

+++040 FULL VALLEY SECTION NOT ON FILE -- ABORTIVE ERROR.

Bridge-opening section cannot be constructed because a full-valley section has not been input.

+++041 ABUTMENT TOP STATION OUTSIDE VALLEY LIMITS - **xatop** **xmin** **xmax**

Computed x-coordinate for top of abutment, **xatop**, is not between the minimum and maximum x-coordinates of the full-valley section, **xmin** and **xmax**.

+++042 ABUTMENT TOP STATION BELOW GROUND SURFACE - **xatop** **yatop** **ygrnd**

Computed y-coordinate for top of abutment, **yatop**, is less than the ground elevation, **ygrnd**, at the computed x-coordinate, **xatop**.

(CONTINUED ON NEXT PAGE)

Table 6-1.--Input data messages (continued).

+++xxx MESSAGE

Comments

+++043 ABUTMENT TOP STATION ABOVE VALLEY END-POINT -
xatoe yatoe abslp xendpt yendpt yatop

Abutment top elevation, **yatop**, computed from abutment toe coordinates and slope, **xatoe**, **yatoe**, and **abslp**, is higher than the valley end-point coordinates, **xendpt** and **yendpt**.

+++044 BRIDGE TOO SHORT FOR SELECTED ABUTMENTS - **brlen xatopl xatopr**

brlen must be greater than the distance between **xatopl** and **xatopr**, the abutment top stations based on abutment toes at XCONLT and XCONRT (BL record).

+++045 TEMPLATE EXPANSION ERROR: NEGATIVE SCALE FACTOR - **scale**

A positive value for **scale** must be coded in the GT record.

+++046 ERROR: ALL POINTS DELETED BY MODIFICATION - **ngp xmax xliml**

xliml in the GT record is greater than **xmax**, the maximum x-coordinate in the template section, thereby causing deletion of all **ngp** ground points.

+++047 INCONSISTENT ROUGHNESS DEPTHS - **nn**

nn, number of depths in the ND record(s) inconsistent with the number of subareas determined from the N data and (or) the SA data.

+++048 INCONSISTENT ROUGHNESS COEFFICIENTS - **nn**

nn, number of n-values in the N record(s) inconsistent with the number of subareas determined from the ND data and (or) the SA data.

+++049 WARNING: SEC REF DIST CHANGED - **srdold srdnew**

Input data contains a different SRD, **srdnew**, for a section which was previously assigned a SRD of **srdold**; **srdnew** is used in computations.

+++050 ERROR: SECTION TYPE CODE CHANGED - **ixsold ixsnew**

Input data revises section type from **ixsold** to **ixsnew**; job is terminated.

+++051 Q RECORD OUT OF ORDER - IGNORED.

Discharge data must be input in the upstream order of the sections.

(CONTINUED ON NEXT PAGE)

Table 6-1.--Input data messages (continued).

+++xxx MESSAGE

Comments

+++052 Q RECORD IGNORED - NO ROOM TO STORE IT.

Memory allocated to storing discharge data has been filled. If input data are correct the job will have to be separated into shorter segments.

+++054 PIER ELEV-WIDTH POINT INVALID - **nth** **pelev** **pwid**

The **nth** pair of the pier width-elevation data, **pwid** and **pelev**, reflects one or more of the following problems: 1) elevation lower than the previous elevation; 2) negative width; or 3) elevation below minimum ground elevation.

> **NOTE**: 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	PX		3	N		2
T3		3				SA		3
			WS	5	1	ND		4
J1	2	1	SK		2	FL		5
J3		3	Q		3	GT		6
						BP		8
XS	3	1	EX	6	1	BL		11
BR		2	ER		0	PW		12
SD		3				AB		13
XR		4				BD		14
AS		5				CD		16
CV		6				KD		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 different 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, 0.25' above channel bottom, and WSMAX, 0.02' 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  A _ S _ S _ U _ M _ E _ D  !!!!!
                 ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  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  T _ E _ R _ M _ I _ N _ A _ T _ E _ D  !!!!!
             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 6-1). 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, spur-dike (if any), and bridge-opening sections. WS1 is higher than mininum 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, spur-dike (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, spur-dike 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 re-compute. 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.

(CONTINUED ON NEXT PAGE)

Table 6-3.--Profile computation messages (continued).

+++xxx MESSAGE
pertinent variables
Comments

===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.

===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 commputations. 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 A _ S _ S _ U _ M _ E _ D !!!!!
SECID "aaaaa" Q,CRWS = xxxxxxx. xxxxx.xx

At the section with SECID of aaaaa, for the dicharge, 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 computions may be advisable to determine if supercritical flow occurs at such sections.

===295 PROFILE COMPUTATIONS T _ E _ R _ M _ I _ N _ A _ T _ E _ D !!!!!
IPR = nn BRIDGE FLOW COMPUTATIONS F_A_I_L_E_D !!!!!

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

This report is intended to serve as a users manual as opposed to a full-blown applications manual. 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 line-numbered input data and output. WSPRO does not require (nor will it accept) line-numbered input and it does not produce line-numbered output. The line numbers were added to facilitate references to the illustrations in the discussions. Also, in order to reduce the bulk of this report, many figures have been shortened by deleting parts of the output. Generally a note has been inserted to indicate where a deletion has been made; the line numbers enable the user to determine the amount of deleted output. Output from the current version, V060188, would have a few minor differences.

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 (lines 8, 15, 21, 27, and 33). 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 line 12 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 (lines 13, 19, 25, 31, and 37). A single profile is computed for the discharge specified in the Q record (line 5). The initial water-surface elevation is computed by slope conveyance using the energy gradient coded in the SK record (line 6).

```
001:T1                   SOME CREEK NEAR ANYWHERE, USA
002:T2                SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
003:T3               CONSTANT DISCHARGE, SUBCRITICAL FLOW
004:*
005:Q             10000
006:SK            0.0023
007:*
008:XS   SEC-A  100
009:GR        107,622.8    132,611.1   170,601.8   190,594   248,590.5
010:GR        271,590.5    293,590.1   310,590.5   318,593.1 338,595.9
011:GR        350,600.5    368,603.8   380,605     400,605.2
012:N            0.065        0.027       0.065
013:SA                 170         368
014:*
015:XS   SEC-B   210
016:GR        144,622.1    182,605.5   205,595.5   219,593.6  222,593.7
017:GR        275,589.9    297,589.8   316,590     345,590.6  357,593.7
018:GR        384,604.1    385,605.2   400,605.6
019:SA                 182         384
020:*
021:XS   SEC-C   375
022:GR        197,619.4    224,608.4   247,596   274,591.5   276,589.5
023:GR        294,589.3    305,588.5   317,588.1   327,588.5   353,589.7
024:GR        355,592.8    374,596.2   393,603.4   397,604.6   400,604.7
025:SA                 224           397
026:*
027:XS   SEC-D  500
028:GR        220,619.1    240,603.7   253,593.5    273,593.2   276,590.8
029:GR        295,590.6    312,590.6   315,589.0    328,589.1   340,589.2
030:GR        341,590.8    372,594.8   389,603.4    400,603.7
031:SA                  240            384
032:*
033:XS   SEC-E  640
034:GR        204,619     240,593.1   258,593.2    276,592.3    293,592.1
035:GR        311,592.1  329,591.8   347,593    365,592.8  384,601
036:GR        400,602   401,608
037:SA                  249            365.3
038:*
039:EX
040:ER
```

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

Figure 7-2 illustrates the output for this example. WSPRO is a Fortran program, thus the output contains Fortran carriage-control characters (e.g., the "1" in lines 1 and 15 indicate a page eject). The first part of the output (lines 1-220) summarizes the input data. This summary includes an echo of each input data record (lines 7-11, 13, 25-31, etc.). 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 input data for the current section. Any missing data are obtained from the previous section. Data for the current section are then summarized in a neat, tabular format (lines 36-56 and 201-220). 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 or PX 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 a "data out of order" message. Part of the desired output may be obtained, the amount depending on where the problem occurs.

```
1
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V063087           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: mo-dy-yr  hr:mn

  T1                SOME CREEK NEAR ANYWHERE, USA
  T2             SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
  T3            CONSTANT DISCHARGE, SUBCRITICAL FLOW
  *
  Q             10000
*** Q-DATA FOR SEC-ID, ISEQ =            1
  SK            0.0023
  *
1
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V063087           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

                  SOME CREEK NEAR ANYWHERE, USA
               SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
              CONSTANT DISCHARGE, SUBCRITICAL FLOW
           *** RUN DATE & TIME: mo-dy-yr  hr:mn

*** START PROCESSING CROSS SECTION - "SEC-A"
  XS   SEC-A  100
  GR         107,622.8    132,611.1   170,601.8   190,594   248,590.5
  GR         271,590.5    293,590.1   310,590.5   318,593.1 338,595.9
  GR         350,600.5    368,603.8   380,605     400,605.2
  N             0.065       0.027      0.065
  SA                  170          368
  *

*** FINISH PROCESSING CROSS SECTION - "SEC-A"
*** CROSS SECTION "SEC-A" WRITTEN TO DISK, RECORD NO. =  1

--- DATA SUMMARY FOR SECID "SEC-A" AT SRD =    100.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
      0.0        0.    0.0000      0.50      0.00

```

- - - - - - - - continuation on next page - - - - - - - -

Figure 7-2.--Output for the simple, open-channel reach of example #1.

- - - - - - - continuation from previous page - - - - - - -

```
041: X-Y COORDINATE PAIRS  (NGP =  14):
042:         X      Y           X      Y           X      Y           X      Y
043:      107.0  622.80      132.0  611.10      170.0  601.80      190.0  594.00
044:      248.0  590.50      271.0  590.50      293.0  590.10      310.0  590.50
045:      318.0  593.10      338.0  595.90      350.0  600.50      368.0  603.80
046:      380.0  605.00      400.0  605.20
047:
048:  X-Y MAX-MIN POINTS:
049:       XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
050:      107.0  622.80      293.0  590.10      400.0  605.20      107.0  622.80
051:
052: SUBAREA BREAKPOINTS (NSA =  3):
053:          170.    368.
054:
055: ROUGHNESS COEFFICIENTS (NSA =  3):
056:          0.065   0.027   0.065
057:1
058: WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
059: V063087           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
060:
061:                       SOME CREEK NEAR ANYWHERE, USA
062:                    SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
063:                   CONSTANT DISCHARGE, SUBCRITICAL FLOW
064:               *** RUN DATE & TIME: mo-dy-yr  hr:mn
065:
066: *** START PROCESSING CROSS SECTION - "SEC-B"
067:   XS   SEC-B   210
068:   GR          144,622.1    182,605.5   205,595.5   219,593.6  222,593.7
069:   GR          275,589.9    297,589.8   316,590     345,590.6  357,593.7
070:   GR          384,604.1    385,605.2   400,605.6
071:   SA                    182          384
072:   *
073:
074: *** FINISH PROCESSING CROSS SECTION - "SEC-B"
075: *** CROSS SECTION "SEC-B" WRITTEN TO DISK, RECORD NO. =  2
```

- - - - - - - - - section of output deleted - - - - - - - -

```
189: *** START PROCESSING CROSS SECTION - "SEC-E"
190:   XS   SEC-E  640
191:   GR          204,619     240,593.1   258,593.2   276,592.3    293,592.1
192:   GR          311,592.1  329,591.8   347,593    365,592.8  384,601
193:   GR          400,602    401,608
194:   SA                   249            365.3
195:   *
196:   EX
197:
198: *** FINISH PROCESSING CROSS SECTION - "SEC-E"
199: *** CROSS SECTION "SEC-E" WRITTEN TO DISK, RECORD NO. =  5
200:
201: --- DATA SUMMARY FOR SECID "SEC-E" AT SRD =     640.  ERR-CODE =       0
202:
203:      SKEW     IHFNO    VSLOPE        EK         CK
204:       0.0        0.    0.0000      0.50       0.00
205
206: X-Y COORDINATE PAIRS  (NGP =  12):
207:         X      Y           X      Y           X      Y           X      Y
208:      204.0  619.00      240.0  593.10      258.0  593.20      276.0  592.30
209:      293.0  592.10      311.0  592.10      329.0  591.80      347.0  593.00
210:      365.0  592.80      384.0  601.00      400.0  602.00      401.0  608.00
```

- - - - - - - - - continuation on next page - - - - - - - -

Figure 7-2.--Output for the simple, open-channel reach of example #1 (continued).

```
      - - - - - - - continuation   from   previous   page - - - - - - -
211:
212:  X-Y MAX-MIN POINTS:
213:      XMIN       Y          X    YMIN       XMAX        Y          X    YMAX
214:     204.0  619.00      329.0  591.80      401.0  608.00      204.0  619.00
215:
216: SUBAREA BREAKPOINTS (NSA =  3):
217:         249.    365.
218:
219: ROUGHNESS COEFFICIENTS (NSA =  3):
220:        0.065   0.027   0.065
221:
222: +++ BEGINNING PROFILE CALCULATIONS --       1
223:1
224: WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
225: V063087           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
226:
227:                   SOME CREEK NEAR ANYWHERE, USA
228:                SIMPLE OPEN-CHANNEL PROFILE EXAMPLE
229:               CONSTANT DISCHARGE, SUBCRITICAL FLOW
230:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
231:
232:  XSID:CODE    SRDL     LEW     AREA    VHD    HF     EGL     CRWS       Q    WSEL
233:        SRD    FLEN     REW        K   ALPH    HO     ERR      FR#     VEL
234:
235: SEC-A:XS    ******    178.    1093.   1.30 *****  600.15  596.99  10000.  598.85
236:       100. ******    346.  208443.   1.00 ***** *******    0.63    9.15
237:
238: SEC-B:XS      110.    196.    1292.   0.93  0.20  600.35 *******  10000.  599.42
239:       210.    110.    372.  266870.   1.00  0.00    0.00    0.50    7.74
240:
241: SEC-C:XS      165.    240.    1129.   1.22  0.26  600.74 *******  10000.  599.52
242:       375.    165.    383.  242382.   1.00  0.14    0.00    0.55    8.86
243:
244: SEC-D:XS      125.    245.    1034.   1.45  0.24  601.09 *******  10000.  599.64
245:       500.    125.    382.  214300.   1.00  0.12   -0.01    0.62    9.67
246:
247: SEC-E:XS      140.    231.     996.   1.88  0.35  601.65 *******  10000.  599.77
248:       640.    140.    381.  185390.   1.20  0.21   -0.01    0.75   10.04
249:   ER
250:
251:1  NORMAL  END  OF  WSPRO  EXECUTION.
```

Figure 7-2.--Output for the simple, open-channel reach of example #1 (continued).

Although not illustrated in this example, the section of output in lines 1-220 is also where +++xxx messages might be found. The user should look for such messages 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). If the first +++ string found is the message in line 222, no input-related messages have been generated. This only ensures that the input data are free of any "detectable" error(s); problems that WSPRO cannot detect might still exist.

Output for profile computations is shown in lines 223-248. Two lines of data (corresponding to the two sets of headings in lines 232-233) are output for each section. Headings are defined in section 5 and (or) the Appendix. 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. Line 249 reflects the ER record which indicates the end of the run and line 251 indicates normal termination of WSPRO execution.

7.2 Example #2: single-opening bridge (fixed-geometry mode)

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

```
001:T1                DRY CREEK NEAR BARREN HILLS
002:T2         SIMPLE BRIDGE EXAMPLE, FIXED-GEOMETRY MODE
003:*
004:Q               5200
005:WS             1104.4
006:*             ----------------------------------------------
007:XS    EXIT     47750
008:*                   EXIT CROSS SECTION
009:*              GR DATA (X-Y COORDINATES)
010:GR           0,1107.6   70,1105.9   145,1104.5   161,1099.5   187,1096.4
011:GR           223,1098.1   233,1097.5  243,1097.1   258,1094.6    273,1093.6
012:GR           288,1093.6    308,1094.2   328,1094.4  344,1096.9    350,1097.8
013:GR            367,1097.3   390,1096.7  407,1095.6   433,1095.6  447,1094.3
014:GR          465,1093.8  486,1096.9  489,1099  515,1099.5  549,1102  567,1108
015:*
016:*            N DATA (MANNING N-VALUE)
017:N           0.040
018:*             ----------------------------------------------
019:XS    FULLV     47900
020:*             FULL-VALLEY SECTION (ALL DATA PROPAGATED FROM EXIT)
021:*             ----------------------------------------------
022:BR    BRIDG   47900  1108.3    30
023:*              SRD     LSEL     SKEW    (HEADINGS FOR BR RECORD)
024:*            BRIDGE SECTION (FIXED-GEOMETRY MODE)
025:GR          0,1108.3   0,1105.5  16,1099.2  50,1093.1  68,1093.3   95,1093.5
026:GR           117,1097.1  137,1104.3   137,1106.9  0,1108.3
027:*
028:*             PIER DATA  -  ELEV,WIDTH PAIRS
029:PW 1         1094,2.3     1105.3,2.3   1105.3,6  1108.3,6
```

- - - - - - - - continuation on next page - - - - - - - -

Figure 7-3.--Input data for the single-opening bridge (fixed-geometry mode) of example #2.

```
     - - - - - - - continuation   from   previous   page - - - - - - -
030:*
031:*            BRTYPE  BRWDTH  EMBSS  EMBELV
032:CD             2      60.4    1.0   1111.5
033:*
034:*           ABUTMENT TOE ELEVATIONS (TYPE 2 ONLY)
035:AB             *   *   1105.5   1104.3
036:*             ---------------------------------------------
037:AS   APPRO      48100
038:*            APPROACH SECTION
039:GR          0,1106.7   75,1105.7  140,1104.8   165,1100.1   185,1096.6
040:GR          225,1098.3   235,1097.5    245,1097.4   260,1094.7   275,1093.7
041:GR          290,1093.7   310,1094.4   330,1094.4   345,1097.1   350,1098
042:GR           370,1097.5   390,1096.9   405,1095.8  435,1095.8   450,1094.5
043:GR           465,1094   485,1097.1  490,1099.2   515,1100
044:GR           550,1102   575,1109
045:*
046:*             CORRECT HOR. DATUM OF BRIDGE TO "APPRO" DATUM
047:BP             225
048:*             ---------------------------------------------
049:EX
050:ER
```

Figure 7-3.--Input data for the single-opening bridge (fixed-geometry mode) of example #2 (continued).

A single profile is computed for the specified discharge (line 4) using the water-surface elevation in the WS record (line 5). Exit-section geometry and roughness (lines 10-14, 17) are propagated to the full-valley section. Because valley slope is not coded in either XS header record (lines 7 and 19), elevations are projected horizontally. Bridge-opening data, beginning with the required BR header record and including comment records, are shown in lines 21-35. WSPRO recognizes fixed-geometry mode because GR data (lines 25-26) are used instead of BL and BD 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, line 32), an AB record (line 34) is required to specify abutment toe elevations (see table 4-3). In the PW data (line 29) note that: (1) the PPCD value of 1 in column 4 indicates pile data; and (2) the last data pair (1108.3,6) is redundant (see table 4-27 and fig. 4-15). Approach-section data begins with the required AS header record (line 37) and geometry is defined by GR data (lines 39-44). 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 (line 47) 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 225 (see table 4-7 and fig. 4-5). Figure 7-4 shows input-data-processing output for the bridge opening. The input data are echoed in lines 106-119 and summarized in lines 125-149. Profile output is shown in figure 7-5.

```
101:                 DRY CREEK NEAR BARREN HILLS
102:          SIMPLE BRIDGE EXAMPLE, FIXED-GEOMETRY MODE
103:              *** RUN DATE & TIME: mo-dy-yr  hr:mn
104:
105: *** START PROCESSING CROSS SECTION - "BRIDG"
106:   BR    BRIDG   47900  1108.3     30
107:   *              SRD     LSEL    SKEW    (HEADINGS FOR BR RECORD)
108:   *            BRIDGE SECTION (FIXED-GEOMETRY MODE)
109:   GR          0,1108.3   0,1105.5  16,1099.2  50,1093.1  68,1093.3   95,1093.5
110:   GR           117,1097.1  137,1104.3   137,1106.9  0,1108.3
111:   *
112:   *             PIER DATA  -  ELEV,WIDTH PAIRS
113:   PW 1         1094,2.3    1105.3,2.3   1105.3,6  1108.3,6
114:   *
115:   *            BRTYPE  BRWDTH  EMBSS  EMBELV
116:   CD             2      60.4    1.0   1111.5
117:   *
118:   *           ABUTMENT TOE ELEVATIONS (TYPE 2 ONLY)
119:   AB             *   *   1105.5   1104.3
120:   *             -----------------------------------------------
121:
122: *** FINISH PROCESSING CROSS SECTION - "BRIDG"
123: *** CROSS SECTION "BRIDG" WRITTEN TO DISK, RECORD NO. =  3
124:
125: --- DATA SUMMARY FOR SECID "BRIDG" AT SRD =  47900.  ERR-CODE =       0
126:
127:      SKEW     IHFNO    VSLOPE        EK        CK
128:      30.0        0.    0.0000      0.50      0.00
129:
130: X-Y COORDINATE PAIRS  (NGP =  10):
131:        X       Y          X      Y           X       Y           X       Y
132:       0.0 1108.30      0.0 1105.50      16.0 1099.20      50.0 1093.10
133:      68.0 1093.30     95.0 1093.50     117.0 1097.10     137.0 1104.30
134:     137.0 1106.90      0.0 1108.30
135:
136:  X-Y MAX-MIN POINTS:
137:      XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
138:       0.0 1108.30     50.0 1093.10     137.0 1104.30       0.0 1108.30
139:
140: ROUGHNESS COEFFICIENTS (NSA =  1):
141:         0.040
142:
143: BRIDGE PARAMETERS:
144:  BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV    YABLT    YABRT
145:     2      60.4  1108.30 *******   1.00  1111.50  1105.50  1104.30
146:
147: PIER DATA:  NPW =  4   PCODE = 1.
148:      PELV  PWDTH      PELV  PWDTH       PELV  PWDTH      PELV  PWDTH
149:   1094.00   2.3   1105.30   2.3    1105.30   6.0   1108.30   6.0
```

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

```
206:                DRY CREEK NEAR BARREN HILLS
207:         SIMPLE BRIDGE EXAMPLE, FIXED-GEOMETRY MODE
208:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
209:
210:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
211:        SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
212:
213: EXIT :XS    ******    145.    3090.   0.04 ***** 1104.44 1097.78   5200. 1104.40
214:     47750. ******    556.  439663.   1.00 ***** *******    0.11    1.68
215:
216: FULLV:FV     150.     145.    3099.   0.04  0.02 1104.47 *******   5200. 1104.42
217:     47900.   150.     556.  441750.   1.00  0.00    0.00    0.11    1.68
218:         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
219:
220: APPRO:AS     200.     142.    3018.   0.05  0.03 1104.50 *******   5200. 1104.45
221:     48100.   200.     559.  418993.   1.00  0.00    0.00    0.11    1.72
222:         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
223:
224:            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
225:
226:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
227:        SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
228:
229: BRIDG:BR     150.      3.      914.   0.92  0.07 1105.07 1099.61   5200. 1104.16
230:     47900.   150.     137.  132596.   1.82  0.56    0.00    0.48    5.69
231:
232:      TYPE PPCD FLOW      C    P/A    LSEL    BLEN   XLAB   XRAB
233:        2.   1.   1.  0.741  0.026 1108.30 ****** ****** ******
234:
235:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
236:        SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
237:
238: APPRO:AS     140.     109.    3348.   0.04  0.07 1105.26 1097.98   5200. 1105.22
239:     48100.   168.     562.  472036.   1.00  0.11    0.00    0.10    1.55
240:
241:       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
242:      0.678  0.541  216841.   265.   398.  1105.21
243:
244:                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
245:  ER
246:
247:1  NORMAL  END  OF  WSPRO  EXECUTION.
```

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

Lines 213-222 reflect the unconstricted ("normal") profile computed from the exit section to the full-valley and the approach sections (i.e., disregarding the effects of the bridge). Bridge-backwater computations are then made and the results are shown in lines 229-242. Besides the information output for other sections, additional parameters are output for the bridge (lines 232-233) and approach (lines 241-242) sections. The last three parameters in line 233 (bridge length and abutment toe stations) are undefined in fixed-geometry mode causing these data fields to be filled with asterisks. The data in line 242, applicable only to free-surface flow, should be used to check the default location of the Kq-section. XLKQ and XRKQ, the left and right limits of the Kq-section, should be about equal to LEW and REW, the left and right edges of water of the bridge opening (lines 229 and 230). LEW and REW, adjusted for the datum correction, are 228 and 362 versus Kq-section limits of 265 and 398. Generally the Kq-section should be alined with the bridge opening and should include the entire low-water channel of the approach section. A plot of the approach section is not provided, but inspection of the GR data reveals that the left and right banks of the low-water channel are at stations 245 and 345. Thus, not only is the Kq-section offset about 40 feet to the right of the bridge opening, its left limit is in the low-water channel. Therefore, a KD record is used (included with the bridge data) to specify override values of 225 and 365 for XLKQ and XRKQ and the profile is re-computed. Slightly different XLKQ and XRKQ values, such as 228 and 365, 225 and 362, or 225 and 360,.are equally appropriate. The re-computed results are shown in figure 7-6 (fig. 7-6 line numbers differ by 5 from those in fig. 7-5). The re-computation made no significant difference in the final result (lines 238 and 243). Although the conveyance of the Kq-section, KQ, is about 5 percent greater (lines 242 and 247), which reduces the flow-contraction ratio, M(K), from 0.541 to 0.514 (lines 242 and 257), the discharge coefficient, C, (lines 233 and 238) is only improved by 0.007. Had the approach section had higher roughness on the overbanks, the difference might have been significant.

```
215:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
216:        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
217:
218: EXIT :XS   ******   145.    3090.  0.04 ***** 1104.44 1097.78   5200. 1104.40
219:     47750. ******   556.  439663.  1.00 ***** *******    0.11    1.68
220:
221: FULLV:FV     150.   145.    3099.  0.04  0.02 1104.47 *******   5200. 1104.42
222:     47900.   150.   556.  441750.  1.00  0.00    0.00    0.11    1.68
223:          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
224:
225: APPRO:AS     200.   142.    3018.  0.05  0.03 1104.50 *******   5200. 1104.45
226:     48100.   200.   559.  418993.  1.00  0.00    0.00    0.11    1.72
227:          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
228:
```

- - - - - - - - - **continuation on next page** - - - - - - - - -

Figure 7-6.--Computed profile output for the single-opening bridge (fixed-geometry mode) of example #2, second analysis.

- - - - - - - continuation from previous page - - - - - - -

```
229:            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
230:
231:  XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL     CRWS       Q    WSEL
232:        SRD   FLEN    REW        K   ALPH     HO     ERR      FR#     VEL
233:
234: BRIDG:BR     150.     3.      914.   0.90   0.07 1105.06 1099.61    5200. 1104.16
235:     47900.   150.   137.  132690.   1.79   0.55    0.00    0.48     5.69
236:
237:      TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
238:        2.    1.   1.  0.748  0.026 1108.30 ****** ****** ******
239:
240:  XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL     CRWS       Q    WSEL
241:        SRD   FLEN    REW        K   ALPH     HO     ERR      FR#     VEL
242:
243: APPRO:AS     140.   110.     3342.   0.04   0.07 1105.25 1097.98    5200. 1105.21
244:     48100.   168.   561.  471291.   1.00   0.11    0.00    0.10     1.56
245:
246:        M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
247:       0.678  0.514  228827.   225.   365.  1105.19
248:
249:                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

Figure 7-6.--Computed profile output for the single-opening bridge (fixed-geometry mode) of example #2, second analysis (continued).

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 compute the unconstricted water-surface profile. An affirmative answer raises additional questions. Another 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 man-induced influences on the water-surface profile downstream from the bridge site?" If response 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 would like 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 simlar 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 7-7 and the streambed profile plot is shown in figure 7-8.

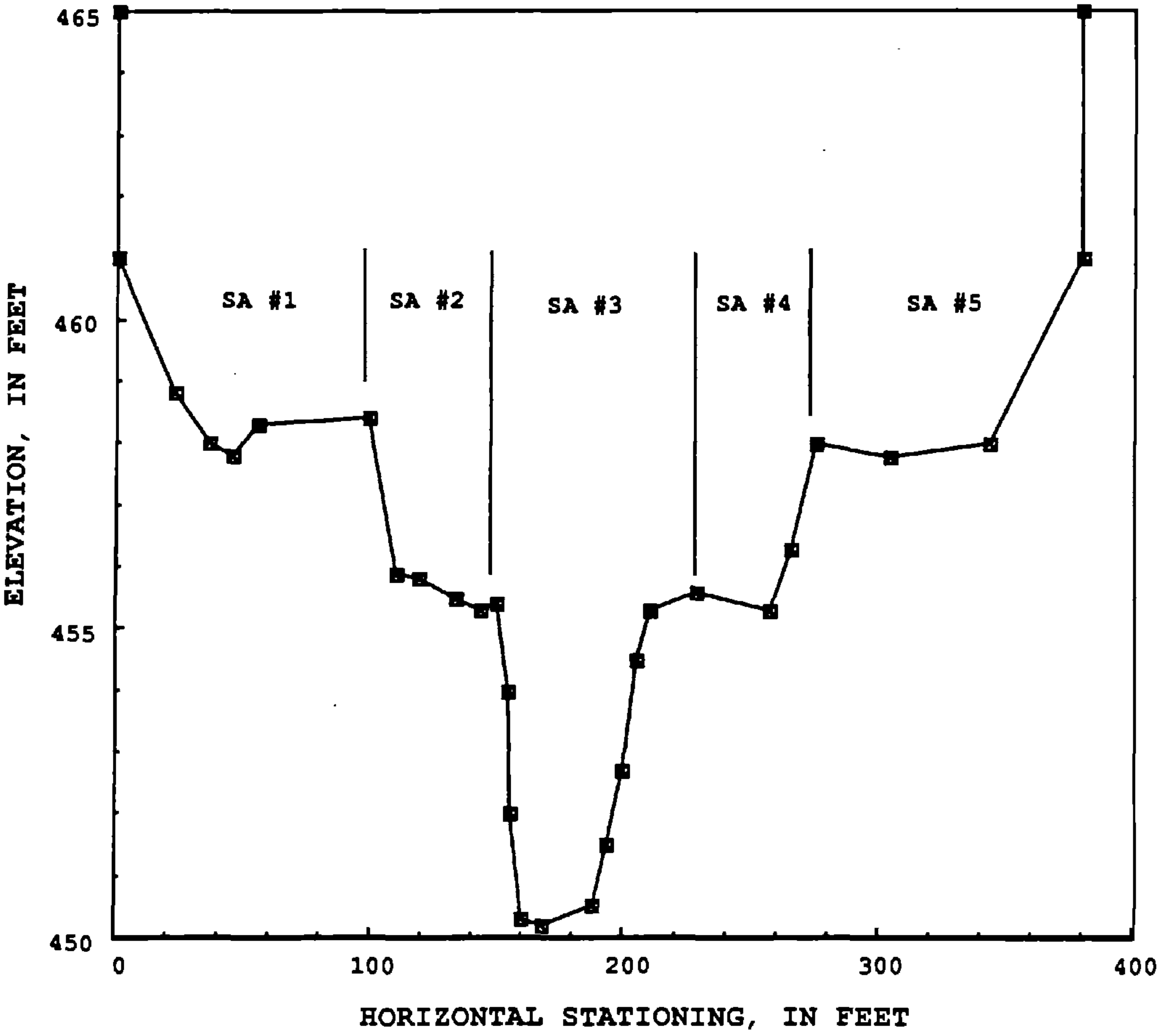


Figure 7-7.--Plot of surveyed cross section for example #3.

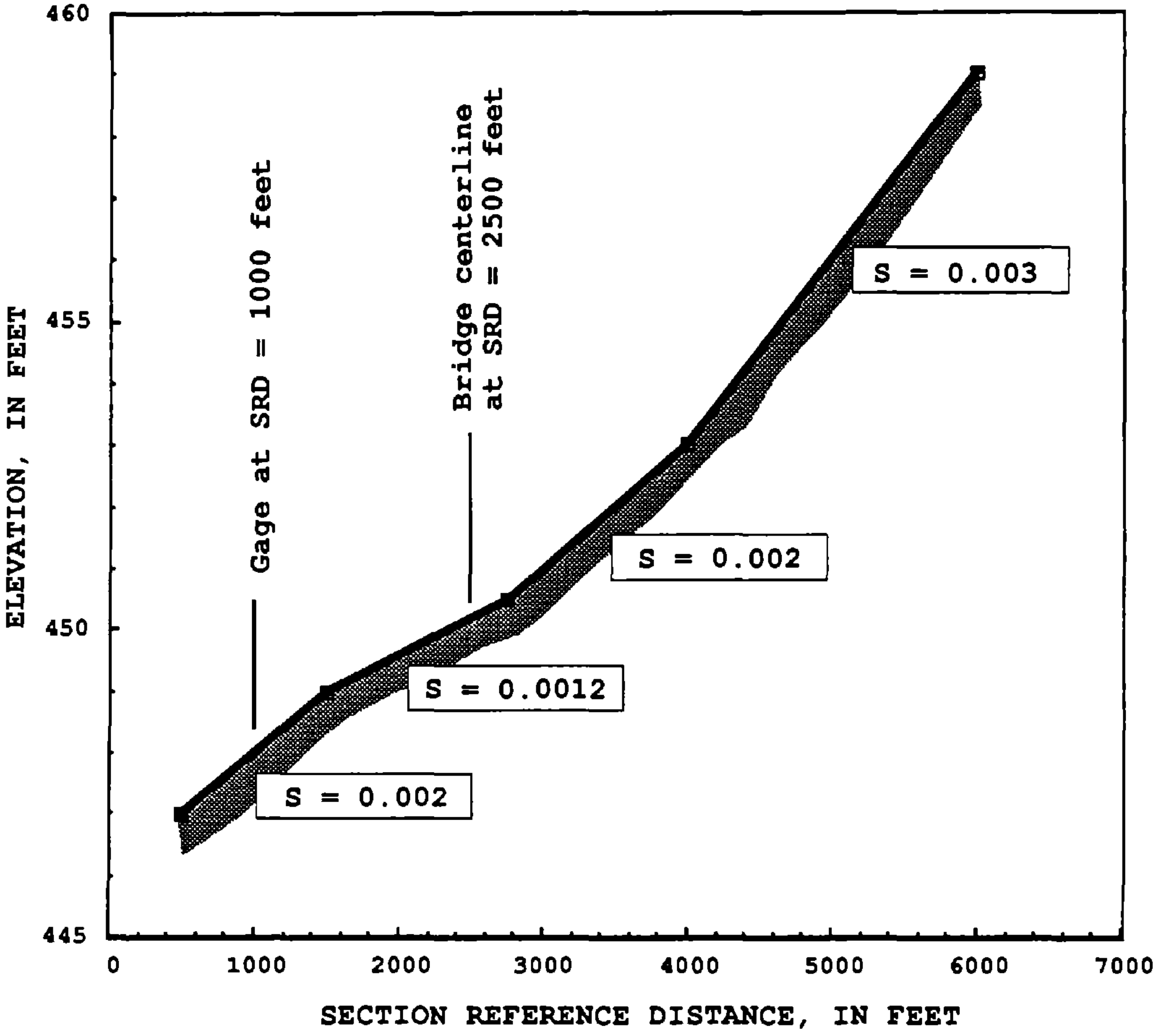


Figure 7-8.--Plot of streambed profile for example #3.

The section was surveyed along the centerline of the proposed stream crossing (SRD = 2500). The known stage-discharge relation is available from a streamflow-gaging station at SRD = 1000. The input data for transferring this known relation to the bridge site are illustrated in figure 7-9. Profiles are computed for five discharges (line 5) using water-surface elevations (line 6) 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 (line 8) and GR data (lines 9-14). Line 16 is the XS header record for the section needed at SRD = 1000. The GT record in line 17 instructs the model to get the geometry for that section from the template section. The -2.2 coded in the GT record is the elevation difference from SRD = 2500 to SRD = 1000. That value is used to lower the template-section elevations to fabricate the section at SRD = 1000. If a uniform valley slope exists between two points, the slope can be coded in either header record (line 8 or 17) to accomplish the necessary elevation adjustment. Lines 18-21 are the roughness data for the most downstream section. 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 (the slope in line 24 propagates to lines 25-27) and roughness data are also propagated. The SRD values of the last three sections reflect appropriate locations for the subsequent bridge-backwater analysis.

```
001:T1          EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
002:T2          FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
003:T3          <<<<< TRANSFER KNOWN RATING TO UPSTREAM SECTIONS >>>>>
004:*
005:Q             3000       3500       4500       5500       7500
006:WS          456.22     456.63     457.33     457.92     458.92
007:*
008:XT   SURVY    2500
009:GR          0,465      0,461      23,458.8   36,458    45,457.8
010:GR          55,458.3  99,458.4  110,455.9  119,455.8   133,455.5
011:GR          143,455.3   150,455.4    154,454    155,452   160,450.3
012:GR            168,450.2  188,450.5  193 451.5   200 452.7   205,454.5
013:GR         210,455.3    229 ,455.6   258,455.3   266,456.3   276,458
014:GR           305,457.8   344,458   380,461     380,465
015:*
016:XS    GAGE  1000
017:GT          -2.2
018:N            0.055,0.050      0.065,0.060   0.040,0.040
019:N               0.065,0.060       0.055,0.050
020:SA                  99       150         210         276
021:ND             1,3       2,5        0,1         1,4    1,3
022:*
023:XS     XS2  1500    *    *    *      0.002
024:XS     XS3  2000    *    *    *     0.0012
025:XS    EXIT  2365
026:XS   FULLV  2485
027:XS    APPR  2635
028:*
029:EX
030:ER
```

Figure 7-9.--Input data for transferring stage-discharge relation to the bridge site, example #3.

Figure 7-10 presents parts of the output for this example. Lines 2-313 show part of the input-data-processing output, and lines 329-344 and 441-460 show the output for the first and fifth computed profiles.

```
002: WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
003: V063087           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
004:
005:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
006:
007:  T1          EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
008:  T2          FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
009:  T3          <<<<< TRANSFER KNOWN RATING TO UPSTREAM SECTIONS >>>>>
010:  *
011:  Q              3000       3500       4500       5500       7500
012: *** Q-DATA FOR SEC-ID, ISEQ =           1
013:  WS           456.22     456.63     457.33     457.92     458.92
014:  *
      - - - - - - - - - -   page  heading  deleted   - - - - - - - - - -
024: *** START PROCESSING CROSS SECTION - "SURVY"
025:  XT   SURVY    2500
026:  GR            0,465      0,461      23,458.8   36,458   45,457.8
027:  GR            55,458.3  99,458.4  110,455.9  119,455.8   133,455.5
028:  GR            143,455.3   150,455.4    154,454   155,452   160,450.3
029:  GR              168,450.2  188,450.5  193 451.5   200 452.7   205,454.5
030:  GR           210,455.3    229 ,455.6   258,455.3   266,456.3   276,458
031:  GR             305,457.8   344,458   380,461     380,465
032:  *
033:
034: *** FINISH PROCESSING CROSS SECTION - "SURVY"
035: *** TEMPLATE CROSS SECTION "SURVY" SAVED INTERNALLY.
      - - - - - - - - - -   page  heading  deleted   - - - - - - - - - -
045: *** START PROCESSING CROSS SECTION - " GAGE"
046:  XS    GAGE  1000
047:  GT           -2.2
048:  N             0.055,0.050     0.065,0.060   0.040,0.040
049:  N                0.065,0.060      0.055,0.050
050:  SA                   99        150         210         276
051:  ND              1,3       2,5        0,1         1,4    1,3
052:  *
053:
054: *** FINISH PROCESSING CROSS SECTION - " GAGE"
055: *** CROSS SECTION " GAGE" WRITTEN TO DISK, RECORD NO. =  1
056:
057: --- DATA SUMMARY FOR SECID " GAGE" AT SRD =   1000.  ERR-CODE =      0
058:
059:     SKEW     IHFNO    VSLOPE        EK        CK
060:      0.0        0.    0.0000      0.50      0.00
061:
     - - - - - - - -   continuation   on   next   page   - - - - - - - -
```

Figure 7-10.--Output for transferring stage-discharge relation to the bridge site, example #3.

```
     - - - - - - - continuation   from   previous   page - - - - - - -
062: X-Y COORDINATE PAIRS   (NGP =  29):
063:          X        Y            X        Y            X        Y            X        Y
064:        0.0   462.80          0.0   458.80         23.0   456.60         36.0   455.80
065:       45.0   455.60         55.0   456.10         99.0   456.20        110.0   453.70
066:      119.0   453.60        133.0   453.30        143.0   453.10        150.0   453.20
067:      154.0   451.80        155.0   449.80        160.0   448.10        168.0   448.00
068:      188.0   448.30        193.0   449.30        200.0   450.50        205.0   452.30
069:      210.0   453.10        229.0   453.40        258.0   453.10        266.0   454.10
070:      276.0   455.80        305.0   455.60        344.0   455.80        380.0   458.80
071:      380.0   462.80
072:
073:  X-Y MAX-MIN POINTS:
074:       XMIN        Y            X     YMIN         XMAX        Y             X     YMAX
075:        0.0   462.80        168.0   448.00        380.0   458.80           0.0   462.80
076:
077: SUBAREA BREAKPOINTS (NSA =  5):
078:           99.     150.     210.     276.
079:
080: ROUGHNESS DEPTHS (NRD =  2):
081: BOT:      1.00     2.00     0.00     1.00     1.00
082: TOP:      3.00     5.00     1.00     4.00     3.00
083:
084: ROUGHNESS COEFFICIENTS (NSA =  5):
085: BOT:    0.055    0.065    0.040    0.065    0.055
086: TOP:    0.050    0.060    0.040    0.060    0.050
     - - - - - - - - - -      page   heading   deleted      - - - - - - - - -
096: *** START PROCESSING CROSS SECTION - "  XS2"
097:   XS      XS2  1500     *    *    *      0.002
098:
099: *** FINISH PROCESSING CROSS SECTION - "  XS2"
100: *** CROSS SECTION "  XS2" WRITTEN TO DISK, RECORD NO. =  2
101:
102: --- DATA SUMMARY FOR SECID "  XS2" AT SRD =   1500.  ERR-CODE =      0
103:
104:      SKEW      IHFNO     VSLOPE         EK         CK
105:       0.0         0.     0.0020       0.50       0.00
106:
107: X-Y COORDINATE PAIRS   (NGP =  29):
108:          X        Y            X        Y            X        Y            X        Y
109:        0.0   463.80          0.0   459.80         23.0   457.60         36.0   456.80
    - - - - - - - - -   section   of   output   deleted  - - - - - - - -
118:  X-Y MAX-MIN POINTS:
119:       XMIN        Y            X     YMIN         XMAX        Y             X     YMAX
120:        0.0   463.80        168.0   449.00        380.0   459.80           0.0   463.80
121:
122: SUBAREA BREAKPOINTS (NSA =  5):
123:           99.     150.     210.     276.
124:
125: ROUGHNESS DEPTHS (NRD =  2):
126: BOT:      1.00     2.00     0.00     1.00     1.00
127: TOP:      3.00     5.00     1.00     4.00     3.00
128
129: ROUGHNESS COEFFICIENTS (NSA =  5):
130: BOT:    0.055    0.065    0.040    0.065    0.055
131: TOP:    0.050    0.060    0.040    0.060    0.050
     - - - - - - - - -   continuation   on   next   page   - - - - - - - -
```

Figure 7-10.--Output for transferring stage-discharge relation to the bridge site, example #3.

```
      - - - - - - - continuation   from   previous   page - - - - - - -
      - - - - - - - - -  section   of   output   deleted  - - - - - - - -
276: *** START PROCESSING CROSS SECTION - " APPR"
277:   XS    APPR  2635
278:   *
279:   EX
280:
281: *** FINISH PROCESSING CROSS SECTION - " APPR"
282: *** CROSS SECTION " APPR" WRITTEN TO DISK, RECORD NO. =  6
283:
284: --- DATA SUMMARY FOR SECID " APPR" AT SRD =   2635.  ERR-CODE =      0
285:
286:      SKEW     IHFNO    VSLOPE        EK        CK
287:       0.0        0.    0.0012      0.50      0.00
288:
289: X-Y COORDINATE PAIRS  (NGP =  29):
290:         X      Y            X      Y            X      Y            X      Y
291:       0.0  465.16        0.0  461.16       23.0  458.96       36.0  458.16
      - - - - - - - - -  section   of   output   deleted  - - - - - - - -
300:  X-Y MAX-MIN POINTS:
301:      XMIN      Y          X    YMIN      XMAX       Y          X    YMAX
302:       0.0  465.16     168.0  450.36     380.0  461.16       0.0  465.16
303:
304: SUBAREA BREAKPOINTS (NSA =  5):
305:          99.    150.    210.    276.
306:
307: ROUGHNESS DEPTHS (NRD =  2):
308: BOT:     1.00    2.00    0.00    1.00    1.00
309: TOP:     3.00    5.00    1.00    4.00    3.00
310:
311: ROUGHNESS COEFFICIENTS (NSA =  5):
312: BOT:    0.055   0.065   0.040   0.065   0.055
313: TOP:    0.050   0.060   0.040   0.060   0.050
      - - - - - - - - -  section   of   output   deleted  - - - - - - - -
325:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
326:        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
327:
328:  GAGE:XS    ******    29.     760.  0.43 *****  456.65  454.16   3000.  456.22
329:      1000. ******   349.   67119.  1.76 ***** *******    0.60    3.95
330:
331:    XS2:XS     500.    29.     760.  0.43  1.00  457.65 *******   3000.  457.22
332:      1500.    500.   349.   67183.  1.76  0.00    0.00    0.60    3.95
333:
334:    XS3:XS     500.    23.     880.  0.33  0.87  458.52 *******   3000.  458.19
335:      2000.    500.   353.   77036.  1.84  0.00    0.01    0.50    3.41
336:
337:   EXIT:XS     365.    22.     918.  0.31  0.53  459.05 *******   3000.  458.74
338:      2365.    365.   355.   80408.  1.86  0.00    0.00    0.47    3.27
339:
340: FULLV:XS      120.    21.     932.  0.30  0.16  459.23 *******   3000.  458.93
341:      2485.    120.   355.   81666.  1.87  0.00    0.01    0.46    3.22
342:
343:  APPR:XS      150.    21.     946.  0.29  0.20  459.44 *******   3000.  459.15
344:      2635.    150.   356.   82878.  1.87  0.00    0.01    0.46    3.17
      - - - - - - - - -  section   of   output   deleted  - - - - - - - -
      - - - - - - - - -  continuation   on   next   page  - - - - - - - -
```

Figure 7-10.--Output for transferring stage-discharge relation to the bridge site, example #3.

```
          - - - - - - - continuation   from   previous   page - - - - - - -
441:  XSID:CODE   SRDL     LEW     AREA   VHD    HF      EGL     CRWS       Q     WSEL
442:        SRD   FLEN     REW        K  ALPH    HO      ERR      FR#     VEL
443:
444:  GAGE:XS   ******      0.     1710.  0.52 *****  459.44  457.05   7500.  458.92
445:      1000. ******    380.  167653.  1.73 ***** *******    0.48    4.38
446:
447:    XS2:XS     500.      0.     1712.  0.52  1.00  460.44 *******   7500.  459.92
448:      1500.    500.    380.  167860.  1.73  0.00    0.00    0.48    4.38
449:
450:    XS3:XS     500.      0.     1859.  0.42  0.89  461.33 *******   7500.  460.91
451:      2000.    500.    380.  188144.  1.67  0.00    0.00    0.42    4.03
452:
453:  EXIT:XS      365.      0.     1915.  0.39  0.56  461.89 *******   7500.  461.50
454:      2365.    365.    380.  195999.  1.65  0.00    0.00    0.40    3.92
455:
456: FULLV:XS      120.      0.     1933.  0.39  0.17  462.07 *******   7500.  461.69
457:      2485.    120.    380.  198626.  1.65  0.00    0.01    0.39    3.88
458:
459:  APPR:XS      150.      0.     1952.  0.38  0.21  462.29 *******   7500.  461.92
460:      2635.    150.    380.  201333.  1.64  0.00    0.01    0.38    3.84
```

Figure 7-10.--Output for transferring stage-discharge relation to the bridge site, example #3 (continued).

7.3.2 Bridge-backwater analysis (design mode) with road grade

Figure 7-11 illustrates input data for analysis of a bridge to be located at SRD = 2500. The results of the analysis in the preceding section provide known water-surface elevations (line 6) at the exit section. Again the surveyed section is introduced as a template section (lines 8-14). The exit section (XS header record in line 16) is fabricated from the template-section geometry (GT record in line 17). Elevation adjustmenta are made using the product of the valley slope in line 16 (which could alternatively been coded in line 8) and the difference in section reference distances (i.e., 2500-2365). Roughness data for the exit section are coded in lines 18-21. 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 design mode, is shown in lines 25-31. Had roughness data (lines 29-30) not been coded for the bridge opening, it would have been obtained from the full-valley section. The road-grade section is coded in lines 32-33. The roughness data shown for the road grade (lines 222-231) result from the data propagation process but are not actually used in any computations. Bridge data are never propagated, and even in design 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 (AS header record in line 35) are propagated from the full-valley section, with elevations adjusted for the specified valley slope.

```
001:T1        EXAMPLES OF INPUT AND OUTPUT FOR COMPUTER PROGRAM WSPRO
002:T2        FHWA/USGS MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS
003:T3        <<<<< ADDITIONAL BRIDGE BACKWATER COMPUTATIONS >>>>>
004:*
005:Q            3000       3500       4500       5500      7500
006:WS          458.74     459.16     459.87      460.48    461.5
007:*
008:XT   SURVY    2500
009:GR          0,465      0,461      23,458.8   36,458   45,457.8
010:GR          55,458.3  99,458.4  110,455.9  119,455.8   133,455.5
011:GR          143,455.3   150,455.4    154,454   155,452   160,450.3
012:GR            168,450.2  188,450.5  193 451.5   200 452.7   205,454.5
013:GR         210,455.3    229 ,455.6   258,455.3   266,456.3   276,458
014:GR           305,457.8   344,458   380,461     380,465
015:*
016:XS    EXIT  2365    *   *   *   0.0012
017:GT
018:N            0.055,0.050     0.065,0.060   0.040,0.040
019:N               0.065,0.060      0.055,0.050
020:SA                  99      150        210        276
021:ND            1,3      2,5       0,1        1,4    1,3
022:*
023:XS   FULLV  2485
024:*
025:BR   BRDGE  2485
026:BD          1.0    463.0
027:BL                120   135   225
028:CD               1    30
029:N               0.040,0.050
030:ND                 3,5
031:*
032:XR    ROAD      2500   30
033:GR                0,462   120,463   240,463    380,462
034:*
035:AS    APPR  2635
036:*
037:EX
038:ER
```

Figure 7-11.--Input data for single-opening bridge (design mode) and road grade, example #3.

Figure 7-12 presents parts of the output for the bridge-backwater computations. Lines 11-288 reflect parts of the input-data-processing output and lines 300-337 and 488-539 show the output for the first and fifth computed profiles. 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.

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 (lines 502-503) because the class 1 solution has a water-surface elevation at the approach section (WS1=463.02) higher than the minimum road-grade elevation (RGMIN=462.00). Message ===260 indicates that a class 4 solution (free-surface bridge flow with road overflow) is attempted. The class 4 solution generates message ===220 (lines 507-508) because the water-surface elevation immediately upstream from the bridge (WSIU=462.66) is higher than the low-chord elevation (LSEL=462.00). Message ===245 indicates that an unsubmerged pressure flow solution, with or without road overflow (class 5 or 2) is attempted. No more messages means that the last alternative was accepted (class 5 is indicated in line 521). 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.

Road overflow results for the fifth discharge are shown in lines 523-528. Lines 523-524 refer to the entire road-grade section, lines 526-528 separate the results into left and right segments (the breakpoint, in this case station 178, is based on the center of conveyance in the bridge opening).

```
      - - - - - - - - -   section   of   output   deleted   - - - - - - - -
011:   Q            3000       3500       4500       5500       7500
012: *** Q-DATA FOR SEC-ID, ISEQ =             1
013:   WS          458.74     459.16     459.87     460.48     461.5
      - - - - - - - - -   section   of   output   deleted   - - - - - - - -
143: *** START PROCESSING CROSS SECTION - "BRDGE"
144:   BR   BRDGE  2485
145:   BD          1.0    463.0
146:   BL                120   135   225
147:   CD               1    30
148:   N              0.040,0.050
149:   ND                  3,5
150:   *
151:
152: *** FINISH PROCESSING CROSS SECTION - "BRDGE"
153: *** CROSS SECTION "BRDGE" WRITTEN TO DISK, RECORD NO. =  3
154:
      - - - - - - - -   continuation   on   next   page   - - - - - - - -
```

Figure 7-12.--Output for single-opening bridge (design mode) and road grade, example #3.

```
     - - - - - - - continuation   from   previous   page - - - - - - -
155: --- DATA SUMMARY FOR SECID "BRDGE" AT SRD =   2485.  ERR-CODE =      0
156:
157:      SKEW     IHFNO    VSLOPE        EK        CK
158:       0.0        0.    0.0012      0.50      0.00
159:
160: X-Y COORDINATE PAIRS  (NGP =  18):
161:          X       Y            X       Y            X       Y            X       Y
162:      120.0  462.00        120.0  455.76        133.0  455.48        143.0  455.28
163:      150.0  455.38        154.0  453.98        155.0  451.98        160.0  450.28
164:      168.0  450.18        188.0  450.48        193.0  451.48        200.0  452.68
165:      205.0  454.48        210.0  455.28        229.0  455.58        240.0  455.47
166:      240.0  462.00        120.0  462.00
167:
168:  X-Y MAX-MIN POINTS:
169:       XMIN       Y            X    YMIN        XMAX       Y            X    YMAX
170:      120.0  462.00        168.0  450.18        240.0  455.47        120.0  462.00
171:
172: ROUGHNESS DEPTHS (NRD =  2):
173: BOT:      3.00
174: TOP:      5.00
175:
176: ROUGHNESS COEFFICIENTS (NSA =  1):
177: BOT:    0.040
178: TOP:    0.050
179:
180: BRIDGE PARAMETERS:
181:  BRTYPE  BRWDTH     LSEL  USERCD  WWANGL  WWWID ENTRND
182:     1      30.0   462.00 ******* ******* ****** ******
183:
184: DESIGN DATA:     BRLEN  LOCOPT  XCONLT  XCONRT
185:                  120.0      0.    135.    225.
186:
187:                GIRDEP  BDELEV  BDSLP   BDSTA
188:                  1.00  463.00 ******* *******
189:
190: PIER DATA:  NPW =  0    PPCD = **
     - - - - - - - - -   section   of   output   deleted   - - - - - - - -
200: *** START PROCESSING CROSS SECTION - " ROAD"
201:   XR    ROAD      2500   30
202:   GR                 0,462   120,463   240,463    380,462
203:   *
204:
205: *** FINISH PROCESSING CROSS SECTION - " ROAD"
206: *** NO ROUGHNESS DATA INPUT, WILL PROPAGATE FROM PREVIOUS CROSS SECTION.
207: *** CROSS SECTION " ROAD" WRITTEN TO DISK, RECORD NO. =  4
208:
209: --- DATA SUMMARY FOR SECID " ROAD" AT SRD =   2500.  ERR-CODE =      0
210:
211:      SKEW     IHFNO    VSLOPE        EK        CK
212:       0.0        0.    0.0012      0.50      0.00
213:
214: X-Y COORDINATE PAIRS  (NGP =   4):
215:          X       Y            X       Y            X       Y            X       Y
216:        0.0  462.00        120.0  463.00        240.0  463.00        380.0  462.00
217:
218:  X-Y MAX-MIN POINTS:
219:       XMIN       Y            X    YMIN        XMAX       Y            X    YMAX
220:        0.0  462.00          0.0  462.00        380.0  462.00        120.0  463.00
     - - - - - - - - -   continuation   on   next   page   - - - - - - - -
```

Figure 7-12.--Output for single-opening bridge (design mode) and road grade, example #3 (continued).

- - - - - - - continuation from previous page - - - - - - -

```

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

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00    2.00    0.00    1.00    1.00
TOP:      3.00    5.00    1.00    4.00    3.00

ROUGHNESS COEFFICIENTS (NSA =  5):
BOT:    0.055   0.065   0.040   0.065   0.055
TOP:    0.050   0.060   0.040   0.060   0.050

ROAD GRADE DATA:  IPAVE  RDWID  USERCF
                  *****   30.0 *******

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

- - - - - - - - - section of output deleted - - - - - - - - -

```
*** START PROCESSING CROSS SECTION - " APPR"
  AS    APPR  2635
  *
  EX
*** FINISH PROCESSING CROSS SECTION - " APPR"
*** NO ROUGHNESS DATA INPUT, WILL PROPAGATE FROM PREVIOUS CROSS SECTION.
*** CROSS SECTION " APPR" WRITTEN TO DISK, RECORD NO. =  5

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

     SKEW     IHFNO    VSLOPE        EK        CK
      0.0        0.    0.0012      0.50      0.00

X-Y COORDINATE PAIRS  (NGP =  29):
           X      Y            X      Y            X      Y            X      Y
         0.0  465.16         0.0  461.16        23.0  458.96        36.0  458.16
        45.0  457.96        55.0  458.46        99.0  458.56       110.0  456.06
       119.0  455.96       133.0  455.66       143.0  455.46       150.0  455.56
       154.0  454.16       155.0  452.16       160.0  450.46       168.0  450.36
       188.0  450.66       193.0  451.66       200.0  452.86       205.0  454.66
       210.0  455.46       229.0  455.76       258.0  455.46       266.0  456.46
       276.0  458.16       305.0  457.96       344.0  458.16       380.0  461.16
       380.0  465.16

 X-Y MAX-MIN POINTS:
      XMIN      Y            X    YMIN        XMAX       Y            X    YMAX
       0.0  465.16       168.0  450.36       380.0  461.16          0.0  465.16

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

ROUGHNESS DEPTHS (NRD =  2):
BOT:      1.00    2.00    0.00    1.00    1.00
TOP:      3.00    5.00    1.00    4.00    3.00

```

- - - - - - - - - continuation on next page - - - - - - - -

Figure 7-12.--Output for single-opening bridge (design mode) and road grade, example #3 (continued).

```
      - - - - - - - - continuation   from   previous   page - - - - - - - -
283: ROUGHNESS COEFFICIENTS (NSA =  5):
284: BOT:     0.055   0.065   0.040   0.065   0.055
285: TOP:     0.050   0.060   0.040   0.060   0.050
286:
287: BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
288:                          ******* ******* ******* *******
289:
290: +++ BEGINNING PROFILE CALCULATIONS --    5
      - - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
300:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
301:         SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
302:
303:  EXIT:XS    ******     22.     917.   0.31 *****  459.05  456.20    3000.   458.74
304:       2365. ******    355.   80313.   1.86 ***** *******    0.47     3.27
305:
306: FULLV:FV     120.     21.     931.   0.30  0.16  459.23 *******   3000.   458.93
307:       2485.   120.    355.   81584.   1.87  0.00    0.01    0.46     3.22
308:           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
309:
310:  APPR:AS     150.     21.     945.   0.29  0.20  459.44 *******   3000.   459.15
311:       2635.   150.    356.   82810.   1.87  0.00    0.01    0.46     3.18
312:           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
313:
314:              <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
315:
316:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
317:         SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
318:
319: BRDGE:BR     120.    120.     638.   0.45  0.24  459.31  456.24    3000.   458.87
320:       2485.   120.    240.   55252.   1.30  0.02    0.00    0.41     4.70
321:
322:       TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
323:         1. ****    1.  0.877 ******  462.00    120.    120.    240.
324:
325:      XSID:CODE     SRD    FLEN     HF    VHD      EGL      ERR        Q     WSEL
326:      ROAD:RG     2500.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>
327:
328:  XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS        Q     WSEL
329:         SRD   FLEN     REW        K   ALPH     HO      ERR      FR#      VEL
330:
331:  APPR:AS     120.     19.    1021.   0.25  0.22  459.62  456.53    3000.   459.37
332:       2635.   123.    359.   89862.   1.88  0.09    0.00    0.41     2.94
333:
334:        M(G)    M(K)        KQ    XLKQ    XRKQ     OTEL
335:       0.642   0.147    76494.    122.    242.   459.24
336:
337:                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>
      - - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
      - - - - - - - - - -  continuation   on   next   page   - - - - - - - - -
```

Figure 7-12.--Output for single-opening bridge (design mode) and road grade, example #3 (continued).

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

  EXIT:XS    ******      0.     1916.  0.39 *****  461.89  459.09    7500.  461.50
       2365. ******    380.   196258.  1.65 ***** *******    0.39     3.91

FULLV:FV      120.      0.     1935.  0.38  0.17  462.08 *******    7500.  461.69
       2485.  120.     380.   198857.  1.65  0.00    0.01    0.39     3.88
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  APPR:AS     150.      0.     1953.  0.38  0.21  462.30 *******    7500.  461.92
       2635.  150.     380.   201535.  1.64  0.00    0.01    0.38     3.84
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
            WS1,WSSD,WS3,RGMIN =   463.02       0.00     461.17     462.00

  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =    461.27     462.66     462.92     462.00

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

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

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

BRDGE:BR      120.    120.     1014.  0.74 *****  462.74  458.26    6992.  462.00
       2485. ******    240.    75838.  1.00 ***** *******    0.42     6.89

     TYPE PPCD FLOW      C     P/A     LSEL    BLEN    XLAB    XRAB
       1. ****   5.  0.373  0.000  462.00    120.    120.    240.

     XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
     ROAD:RG    2500.   120.  0.09  0.22  463.32    0.02    651.  463.10

                  Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
     LT:     302.   178.     0.   178.   1.1   0.4   3.9   3.9   0.7   3.2
     RT:     349.   202.   178.   380.   1.1   0.4   3.9   3.9   0.7   3.2

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

  APPR:AS     120.      0.     2434.  0.22  0.32  463.41  459.42    7500.  463.19
       2635.  129.     380.   275750.  1.51  0.15    0.02    0.26     3.08

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

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

Figure 7-12.--Output for single-opening bridge (design mode) and road grade, example #3, continued.

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 7-13 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. The purpose of and the output for the J3 record (line 4) are discussed in the next section. 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 (lines 6, 7, and 47). The entries for the first profile reflect a discharge of 12,800 ft^3/s, 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).

Figure 7-14 shows the output for both profile computations for the 12,800 ft^3/s (cubic feet per second) discharge. Lines 290-360 show the output for upstream computations. 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. Lines 384-426 show the output for downstream computations. 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.

```
001:T1        STEEP CREEK NEAR NOWHERE, USA
002:*
003:*           SRD  SLEN  Q  YMIN  FR#  CRWS  WSEL  EGL
004:J3            6    10  5    23   14    15     3    7
005:*
006:Q          12800     12800    14000    14000
007:SK        0.0037        -1   0.0037       -1
008:*
009:XS   XSEC1 100
010:GR        107,622.8  132,611.1  170,601.8  190,594  248,590.5  271,590.5
011:GR        293,590.1  310,590.5  318,593.1  338,595.9  350,600.5
012:N             0.065        0.027        0.065
013:SA                   170            368
014:*
015:XS   XSEC2 200
016:GR        144,622.1  182,605.5  205,595.5  219,593.6  222,593.7  275,589.9
017:GR        297,589.8  316,590  345,590.6  357,593.7  384,604.1
018:SA                   182            384
019:*
020:XS   XSEC3 300
021:GR        197,619.4  224,609.4  247,596.9  274,592.5  276,590.5  294,590.3
022:GR        305,589.5  317,589.1  327,589.5  353,590.7  355,593.8  374,597.2
023:GR        393,604.4
024:SA                   224              397
025:*
026:XS   XSEC4 400
027:GR        220,619.1  240,605.7  253,595.5  273,595.2  276,592.8  295,592.6
028:GR        312,592.6  315,591  328,591.1  340,591.2  341,592.8  372,596.8
029:GR        389,605.4
030:SA                    240              384
031:*
032:XS   XSEC5 544
033:GR        204,619  249,596.6  258,596.7  276,595.8  294,595.6  312,595.6
034:GR        329,595.3  347,596.5  365,596.3  385,606
035:SA                    249              365.3
036:*
037:XS   XSEC6 707
038:GR        217,621.9  233,613.5  247,607.4  267,598.8  277,597.4  286,596.6
039:GR        308,596.1  319,595.6  333,595.6  347,596.6  377,597.4  380,608.4
040:SA              247          377
041:*
042:XS   XSEC7 807
043:GR        228,622.9  258,606.5  279,599.1  279,597.6  290,597.3  298,596.2
044:GR        319,595.8  329,595.4  342,595.7  352,596.8  387,597.4  390,609.1
045:SA             258         387
046:*
047:EX           0    1    0    1
048:ER
```

Figure 7-13.--Input data for upstream/downstream profile computations.

```
  - - - - - - - - - -   section   of   output   deleted   - - - - - - - - - -
290:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
291:         SRD   FLEN     REW         K   ALPH     HO      ERR      FR#      VEL
292:
293: XSEC1:XS    ******    177.     1100.   2.11  *****  601.00  597.92   12800.   598.89
294:       100.  ******    346.   210225.   1.00  ***** *******    0.80    11.64
295:
296:  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
297:                               "XSEC2"      KRATIO =  1.40
298:
299: XSEC2:XS      100.    195.     1379.   1.34   0.26  601.25 *******   12800.   599.91
300:       200.    100.    373.   294519.   1.00   0.00   -0.01    0.59     9.29
301:
302:  ===125 FR# EXCEEDS FNTEST AT SECID "XSEC3":  TRIALS CONTINUED.
303:                FNTEST,FR#,WSEL,CRWS =  0.80     0.84     599.56      598.71
304:
305:  ===110 WSEL NOT FOUND AT SECID "XSEC3":  REDUCED DELTAY.
306:                     WSLIM1,WSLIM2,DELTAY =   599.41      619.40     0.50
307:
308:  ===115 WSEL NOT FOUND AT SECID "XSEC3":  USED WSMIN = CRWS.
309:                     WSLIM1,WSLIM2,CRWS =   599.41      619.40      598.71
310:
311:  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
312:                               "XSEC3"      KRATIO =  0.68
313:
314: XSEC3:XS      100.    242.      997.   2.56   0.28  602.13  598.71   12800.   599.57
315:       300.    100.    380.   201152.   1.00   0.61    0.00    0.84    12.84
316:
317:  ===110 WSEL NOT FOUND AT SECID "XSEC4":  REDUCED DELTAY.
318:                     WSLIM1,WSLIM2,DELTAY =   599.07      619.10     0.50
319:
320:  ===115 WSEL NOT FOUND AT SECID "XSEC4":  USED WSMIN = CRWS.
321:                     WSLIM1,WSLIM2,CRWS =   599.07      619.10      600.46
322:
323:  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
324:                ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC4"
325:                     WSBEG,WSEND,CRWS =   600.46      619.10       600.46
326:
327: XSEC4:XS      100.    247.      876.   3.32  *****  603.78  600.46   12800.   600.46
328:       400.    100.    379.   165977.   1.00  ***** *******    1.00    14.62
329:
330:  ===110 WSEL NOT FOUND AT SECID "XSEC5":  REDUCED DELTAY.
331:                     WSLIM1,WSLIM2,DELTAY =   599.96      619.00     0.50
332:
333:  ===115 WSEL NOT FOUND AT SECID "XSEC5":  USED WSMIN = CRWS.
334:                     WSLIM1,WSLIM2,CRWS =   599.96      619.00      603.11
335:
336:  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
337:                ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC5"
338:                     WSBEG,WSEND,CRWS =   603.11      619.00      603.11
339:
340: XSEC5:XS      144.    236.      921.   3.42  *****  606.53  603.11   12800.   603.11
341:       544.    144.    379.   174687.   1.14  ***** *******    1.03    13.90
342:
343:  ===125 FR# EXCEEDS FNTEST AT SECID "XSEC6":  TRIALS CONTINUED.
344:                FNTEST,FR#,WSEL,CRWS =  0.80     1.02     603.93      604.03
345:
346:  ===110 WSEL NOT FOUND AT SECID "XSEC6":  REDUCED DELTAY.
347:                     WSLIM1,WSLIM2,DELTAY =   602.61      621.90     0.50
348:
  - - - - - - - -   continuation   on   next   page   - - - - - - - -
```

Figure 7-14.--Output for upstream/downstream profile computations.

```
    - - - - - - - - continuation   from   previous   page - - - - - - -
349:  ===115 WSEL NOT FOUND AT SECID "XSEC6":  USED WSMIN = CRWS.
350:                    WSLIM1,WSLIM2,CRWS =    602.61      621.90      604.03
351:
352:  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
353:                ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC6"
354:                    WSBEG,WSEND,CRWS =   604.03      621.90      604.03
355:
356: XSEC6:XS      163.   255.      860.  3.49 *****  607.52  604.03  12800.  604.03
357:        707.   163.   379.  171118.  1.01 ***** *******    1.00   14.89
358:
359: XSEC7:XS      100.   261.     1052.  2.34  0.41  607.93 *******  12800.  605.59
360:        807.   100.   389.  231799.  1.01  0.00    0.00    0.76   12.17
   - - - - - - - - - - -   section   of   output   deleted   - - - - - - - - - -
384:  ===010 WSI BELOW YMIN AT SECID "XSEC7":  USED WSI = CRWS.
385:                          YMIN,WSI,CRWS =     595.4     ********      604.06
386:
387:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
388:         SRD   FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
389:
390: XSEC7:XS    ******   265.      858.  3.50 *****  607.56  604.06  12800.  604.06
391:        807. ******   389.  169652.  1.01 ***** *******    1.00   14.92
392:
393:  ===110 WSEL NOT FOUND AT SECID "XSEC6":  REDUCED DELTAY.
394:                    WSLIM1,WSLIM2,DELTAY =    604.03      595.80    -0.50
395:
396:  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
397:                ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC6"
398:                    WSBEG,WSEND,CRWS =   604.03      595.80      604.03
399:
400: XSEC6:XS     -100.   255.      860.  3.49 *****  607.52  604.03  12800.  604.03
401:        707.   100.   379.  171118.  1.01 ***** *******    1.00   14.89
402:
403: XSEC5:XS     -163.   237.      878.  3.75  0.96  606.55  603.11  12800.  602.80
404:        544.   163.   378.  162419.  1.13  0.00    0.01    1.10   14.58
405:
406:  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
407:                                "XSEC4"     KRATIO =  1.66
408:
409: XSEC4:XS     -144.   249.      624.  6.55  1.48  605.06  600.46  12800.  598.51
410:        400.   144.   375.   97867.  1.00  0.00    0.00    1.63   20.52
411:
412: XSEC3:XS     -100.   248.      619.  6.66  1.70  603.35  598.71  12800.  596.69
413:        300.   100.   371.   98564.  1.00  0.00    0.01    1.63   20.69
414:
415: XSEC2:XS     -100.   204.      717.  4.96  1.55  600.94  597.38  12800.  595.98
416:        200.   100.   363.  107397.  1.00  0.85    0.01    1.48   17.86
417:
418:  ===110 WSEL NOT FOUND AT SECID "XSEC1":  REDUCED DELTAY.
419:                    WSLIM1,WSLIM2,DELTAY =    597.92      590.30    -0.50
420:
421:  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
422:                ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "XSEC1"
423:                    WSBEG,WSEND,CRWS =   597.92      590.30      597.92
424:
425: XSEC1:XS     -100.   180.      940.  2.89 *****  600.81  597.92  12800.  597.92
426:        100.   100.   343.  165209.  1.00 ***** *******    1.00   13.62
```

Figure 7-14.--Output for upstream/downstream profile computations (continued).

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 7-15 shows the user-defined tables generated with the computed profiles of the previous section. The user-defined tables (as is indicated by the line numbers) are output immediately following their associated profile output. They were separated from that output and placed in figure 7-15 to facilitate discussion. User-defined tables are created by using one (or more) J3 record(s) as explained in table 4-23 and section 5. The J3 record (and some comment records) from figure 7-13 are reproduced at the top of figure 7-15 for easy reference. The series of numbers in the free-format area of the J3 record (line 4) 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). The comment record in line 3 indicates the "names" of the parameters selected for the user-defined tables for these profiles.

```
002:*
003:*          SRD  SLEN  Q  YMIN  FR#  CRWS  WSEL  EGL
004:J3           6    10  5    23   14    15     3    7
005:*
    - - - - - - - - - -   section   of   output   deleted   - - - - - - - - - -
365:         STEEP CREEK NEAR NOWHERE, USA
366:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
367:   FIRST USER DEFINED TABLE.
368:
369:     XSID:CODE     SRD   SLEN         Q     YMIN      FR#    CRWS    WSEL     EGL
370:    XSEC1:XS      100.*******  12800.  590.10     0.80  597.92  598.89  601.00
371:    XSEC2:XS      200.   100.  12800.  589.80     0.59********  599.91  601.25
372:    XSEC3:XS      300.   100.  12800.  589.10     0.84  598.71  599.57  602.13
373:    XSEC4:XS      400.   100.  12800.  591.00     1.00  600.46  600.46  603.78
374:    XSEC5:XS      544.   144.  12800.  595.30     1.03  603.11  603.11  606.53
375:    XSEC6:XS      707.   163.  12800.  595.60     1.00  604.03  604.03  607.52
376:    XSEC7:XS      807.   100.  12800.  595.40     0.76********  605.59  607.93
    - - - - - - - - - -   section   of   output   deleted   - - - - - - - - - -
431:         STEEP CREEK NEAR NOWHERE, USA
432:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
433:   FIRST USER DEFINED TABLE.
434:
435:     XSID:CODE     SRD   SLEN         Q     YMIN      FR#    CRWS    WSEL     EGL
436:    XSEC1:XS      100.  -100.  12800.  590.10     1.00  597.92  597.92  600.81
437:    XSEC2:XS      200.  -100.  12800.  589.80     1.48  597.38  595.98  600.94
438:    XSEC3:XS      300.  -100.  12800.  589.10     1.63  598.71  596.69  603.35
439:    XSEC4:XS      400.  -144.  12800.  591.00     1.63  600.46  598.51  605.06
440:    XSEC5:XS      544.  -163.  12800.  595.30     1.10  603.11  602.80  606.55
441:    XSEC6:XS      707.  -100.  12800.  595.60     1.00  604.03  604.03  607.52
442:    XSEC7:XS      807.*******  12800.  595.40     1.00  604.06  604.06  607.56
```

Figure 7-15.--User-defined tables.

Lines 365-376 and 431-442 are the user-defined tables requested for upstream and downstream profile computations for the 12,800 ft^3/s discharge. User-defined tables summarize results in downstream to upstream progression regardless of computational direction. The comment card in line 3 indicates the parameter "names" selected for tabling (see section 5). The second parameter selected, SLEN (identical to SRDL in the profile output), 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 and (or) PX records to obtain properties and (or) plots of sections is subject to specific rules of "order dependence" (unlike most of the record types for WSPRO). 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 between XSECB and XSECC. Hydrologic analyses indicate that for discharges of 5,000 and 3,500 ft^3/s at XSECA, the tributary stream contributes 1,000 and 700 ft^3/s, thus dictating the need to specify discharges of 4,000 and 2,800 ft^3/s at XSECC.

Figure 7-16a illustrates one alternative for coding the necessary discharge data. Q data that precede all section data (e.g., line 1), are assigned to the most downstream section. New discharge data may be coded with the 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 (e.g., line 8 of figure 7-16a). However, this Q data must follow all section data (GR, N, ND, SA, and FL records) for the section at which the new discharge data are introduced.

Figure 7-16b presents a second alternative for coding the appropriate Q data. Q data for the initial section is coded as in the preceding discussion. Q record(s) for the new discharge data required at XSECC may be introduced any time after XSECC has been input (but not interspersed with any section data). These Q record(s) must include the appropriate SECID. The most logical placement would be immediately prior to the EX record as shown (line 12).

Figure 7-16c indicates that all Q data, appropriately identified with the applicable SECID, can be introduced after all section data have been input. Again, the most logical placement would be immediately prior to the EX record as shown in lines 11-12. 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.

```
 1: Q           5000   3500
 2: XS   XSECA   srd_A, [,as needed]
 3: __                [ GR, N, ND, and SA data as appropriate ]
 4: XS   XSECB   srd_B, [,as needed]
 5: __              [ GR, N, ND, SA, and FL data as appropriate ]
 6: XS   XSECC   srd_C, [,as needed]
 7: __              [ GR, N, ND, SA, and FL data as appropriate ]
 8: Q           4000   2800
 9: XS   XSECD   srd_D, [,as needed]
10: __              [ GR, N, ND, SA, and FL data as appropriate ]
11: XS   XSECE   srd_E, [,as needed]
12: __              [ GR, N, ND, SA, and FL data as appropriate ]
13: EX
```

a) new discharge data coded with cross section data

```
 1: Q           5000   3500
 2: XS   XSECA   srd_A, [,as needed]
 3: __              [ GR, N, ND, and SA data as appropriate ]
 4: XS   XSECB   srd_B, [,as needed]
 5: __              [ GR, N, ND, SA, and FL data as appropriate ]
 6: XS   XSECC   srd_C, [,as needed]
 7: __              [ GR, N, ND, SA, and FL data as appropriate ]
 8: XS   XSECD   srd_D, [,as needed]
 9: __              [ GR, N, ND, SA, and FL data as appropriate ]
10: XS   XSECE   srd_E, [,as needed]
11: __              [ GR, N, ND, SA, and FL data as appropriate ]
12: Q    XSECC   4000    2800
13: EX
```

b) new discharge data coded after all cross section data

```
 1: XS   XSECA   srd_A, [,as needed]
 2: __              [ GR, N, ND, and SA data as appropriate ]
 3: XS   XSECB   srd_B, [,as needed]
 4: __              [ GR, N, ND, SA, and FL data as appropriate ]
 5: XS   XSECC   srd_C, [,as needed]
 6: __              [ GR, N, ND, SA, and FL data as appropriate ]
 7: XS   XSECD   srd_D, [,as needed]
 8: __              [ GR, N, ND, SA, and FL data as appropriate ]
 9: XS   XSECE   srd_E, [,as needed]
10: __              [ GR, N, ND, SA, and FL data as appropriate ]
11: Q    XSECA  5000   3500
12: Q    XSECC   4000    2800
13: EX
```

c) all discharge data coded after all cross section data

Figure 7-16.--Alternatives for coding discharge data.

HP and PX record placement follows the same rules as Q record placement, except there is no analogy for an "unidentified" HP and (or) PX record preceding all section data as there is with Q data. HP and (or) PX 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 7-16c). 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 and culvert 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 4-21 should be consulted for HP record details. Figure 7-17 shows hydraulic- properties output for the total section for a range of elevations from 454 to 462 in increments of 0.5 foot as reflected by the HP record in line 32. IHP (column 4) is blank but could have been assigned a value of zero. The repeat of elevation 462 results (lines 93-94) is due to a roundoff error which causes the incremented value to be slightly different than the input value.

```
019:   XS   SURVY    2500
020:   GR          0,465      0,461      23,458.8   36,458   45,457.8
021:   GR          55,458.3  99,458.4  110,455.9  119,455.8   133,455.5
022:   GR          143,455.3   150,455.4    154,454    155,452   160,450.3
023:   GR            168,450.2  188,450.5  193 451.5   200 452.7   205,454.5
024:   GR         210,455.3    229 ,455.6   258,455.3   266,456.3   276,458
025:   GR           305,457.8   344,458   380,461     380,465
026:   *
027:   N            0.055,0.050     0.065,0.060   0.040,0.040
028:   N               0.065,0.060      0.055,0.050
029:   SA                   99       150         210          276
030:   ND             1,3       2,5         0,1         1,4    1,3
031:   *
032:   HP              454   0.5   462
- - - - - - - -   section   of   output   deleted   - - - - - - - -
071:          DATA FOR CROSS-SECTIONAL PROPERTIES EXAMPLES
072:            HYDRAULIC PROPERTIES - TOTAL SECTION
073:              *** RUN DATE & TIME: mo-dy-yr  hr:mn
074:     CROSS-SECTION PROPERTIES:  ISEQ =  1;  SECID = SURVY;  SRD =     2500.
075:
076:      WSEL      AREA         K   TOPW    WETP  ALPH    LEW     REW     QCR
077:     454.00     149.    11248.    50.     52.  1.00   154.    204.   1464.
078:     454.50     174.    14100.    52.     55.  1.00   153.    205.   1805.
079:     455.00     202.    17015.    57.     59.  1.00   151.    208.   2154.
080:     455.50     237.    20669.   111.    113.  1.04   133.    260.   1924.
081:     456.00     306.    25934.   154.    156.  1.28   110.    264.   2170.
082:     456.50     385.    32378.   160.    162.  1.44   107.    267.   2826.
083:     457.00     466.    39839.   165.    168.  1.53   105.    270.   3598.
084:     457.50     550.    48250.   170.    173.  1.57   103.    273.   4473.
085:     458.00     644.    57646.   256.    259.  1.63    36.    344.   4540.
086:     458.50     785.    69141.   322.    325.  1.78    28.    350.   5212.
087:     459.00     950.    83237.   335.    338.  1.87    21.    356.   6632.
088:     459.50    1120.    99637.   346.    349.  1.88    16.    362.   8334.
089:     460.00    1296.   118188.   358.    361.  1.85    10.    368.  10289.
090:     460.50    1477.   138811.   369.    372.  1.81     5.    374.  12486.
091:     461.00    1664.   161603.   380.    383.  1.75     0.    380.  14929.
092:     461.50    1854.   187490.   380.    384.  1.67     0.    380.  17965.
093:     462.00    2044.   214748.   380.    385.  1.61     0.    380.  21182.
094:     462.00    2045.   214803.   380.    385.  1.61     0.    380.  21189.
```

Figure 7-17.--Table of hydraulic properties; total cross section.

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 7-18 shows parts of this expanded table.

```
071:         DATA FOR CROSS-SECTIONAL PROPERTIES EXAMPLES
072:           HYDRAULIC PROPERTIES - SUBAREA BREAKDOWN
073:             *** RUN DATE & TIME: mo-dy-yr  hr:mn
074:      CROSS-SECTION PROPERTIES:  ISEQ =  1;  SECID = SURVY;  SRD =    2500.
075:
076:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
077:              3     149.   11248.    50.    52.                        1464.
078:    454.00          149.   11248.    50.    52.  1.00   154.   204.   1464.
079:
080:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
081:              3     174.   14100.    52.    55.                        1805.
082:    454.50          174.   14100.    52.    55.  1.00   153.   205.   1805.
083:
084:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
085:              3     202.   17015.    57.    59.                        2154.
086:    455.00          202.   17015.    57.    59.  1.00   151.   208.   2154.
087:
088:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
089:              2       2.      11.    17.    17.                           4.
090:              3     231.   20641.    60.    62.                        2576.
091:              4       3.      17.    34.    34.                           6.
092:    455.50          237.   20669.   111.   113.  1.04   133.   260.   1924.
093:
094:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
095:              2      17.     215.    40.    40.                          62.
096:              3     261.   25294.    60.    62.                        3093.
097:              4      28.     425.    54.    54.                         117.
098:    456.00          306.   25934.   154.   156.  1.28   110.   264.   2170.
- - - - - - - -   section   of   output   deleted   - - - - - - - -
112:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
113:              2      82.    2738.    47.    47.                         619.
114:              3     351.   41426.    60.    62.                        4822.
115:              4     116.    4085.    63.    63.                         895.
116:    457.50          550.   48250.   170.   173.  1.57   103.   273.   4473.
117:
118:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
119:              1       1.       8.    13.    13.                           2.
120:              2     106.    4085.    49.    49.                         889.
121:              3     381.   47489.    60.    62.                        5453.
122:              4     148.    6024.    66.    66.                        1264.
123:              5       7.      39.    68.    68.                          12.
124:    458.00          644.   57646.   256.   259.  1.63    36.   344.   4540.
- - - - - - - -   section   of   output   deleted   - - - - - - - -
206:      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
207:              1     332.   22008.    99.   100.                        3452.
208:              2     310.   25565.    51.    51.                        4340.
209:              3     621.  107171.    60.    62.                       11344.
210:              4     413.   34684.    66.    66.                        5852.
211:              5     369.   25374.   104.   105.                        3941.
212:    462.00         2045.  214803.   380.   385.  1.61     0.   380.  21189.
```

Figure 7-18.--Table of hydraulic properties; subarea breakdown.

7.7.3 Velocity and conveyance distribution

Velocity and conveyance distribution(s) for the same data can be obtained by coding IHP = 2. The results illustrated in figure 7-19 were obtained by coding an elevation of 459 for ELMIN and a discharge of 5,000 ft^3/s. Parameters reflecting the total section (lines 79-80) are provided as well as stationing, area, and velocity for 20 equal-conveyance "tubes." Five percent of the discharge is assigned to each "tube" in accordance with the assumption of one-dimensional flow. Additional distributions for a single elevation can be obtained by using multiple HP records with different discharges. Also, for a given discharge, a range of elevations and an elevation increment can be specified. The velocities should prove useful for potential scour concerns and the stationing of the conveyance "tubes" could assure proper placement of the bridge opening(s) relative to flow distribution in the valley.

```
071:         DATA FOR CROSS-SECTIONAL PROPERTIES EXAMPLES
072:           VELOCITY/CONVEYANCE DISTRIBUTION
073:            *** RUN DATE & TIME: mo-dy-yr  hr:mn
074:
075:
076:
077:     VELOCITY DISTRIBUTION:  ISEQ =  1;  SECID = SURVY;  SRD =    2500.
078:
079:          WSEL     LEW     REW    AREA        K        Q    VEL
080:        459.00    20.9   356.0   949.7   83256.    5000.   5.26
081:
082: X STA.         20.9       125.4       146.4       157.4       160.7       163.8
083:   A(I)             125.6        74.5        54.2        27.7        27.1
084:   V(I)              1.99        3.35        4.62        9.02        9.24
085:
086: X STA.        163.8       166.8       169.9       173.0       176.1       179.2
087:   A(I)              26.3        27.1        26.6        27.1        26.9
088:   V(I)              9.51        9.21        9.40        9.23        9.28
089:
090: X STA.        179.2       182.3       185.4       188.6       192.1       196.3
091:   A(I)              26.9        26.7        26.8        28.4        30.2
092:   V(I)              9.31        9.36        9.31        8.81        8.29
093:
094: X STA.        196.3       201.5       215.1       236.6       256.5       356.0
095:   A(I)              33.7        57.2        75.0        71.4       130.3
096:   V(I)              7.41        4.37        3.33        3.50        1.92
```

Figure 7-19.--Table of velocity and conveyance distribution.

7.8 Example #8: multiple-opening bridge

Figure 7-20 shows the input data for a simple, multiple-opening bridge problem. A definition sketch for the problem is shown in figure 7-21. The valley is 500 feet wide with two 50-foot low-flow channels. The left-channel bridge is 110 feet long (lines 15-18) and the right-channel bridge is 90 feet long (lines 20-23). Design mode is used for both bridges (lines 16-17 and 21-22). The geometry (lines 9-10) and roughness (line 11) of the downstream match section, DNSTM, (XS header record in line 8) is assumed representative of the entire reach. Those data are thus propagated to the full-valley, FULLV, (XS header record in line 13) and upstream match, UPSTM, (AS header record in line 25) sections with elevation adjustments for a valley slope of 0.002 (line 8). DNSTM and UPSTEM are located at SRD's that satisfy exit and approach section locations for the longest opening (see figures 3-15 and 3-16). One profile is computed for a discharge of 8,000 ft^3/s (line 5) using an energy gradient (line 6) equal to the valley slope (assuming uniform flow downstream from DNSTM).

```
001:T1             MULTIPLE OPENING BRIDGE EXAMPLE
002:T2             SYMMETRICAL VALLEY
003:T3             110 FT AND 90 FT BRIDGES
004:*
005:Q              8000
006:SK             0.002
007:*
008:XS   DNSTM      0  *  *  *  0.002
009:GR           0,20  0,5  100,5  100,0  150,0  150,5
010:GR             350,5  350,0  400,0  400,5  500,5  500,20
011:N               0.040
012:*
013:XS   FULLV  110
014:*
015:BR    LTBO  110
016:BL                   110  100  150
017:BD           3      15
018:CD               1    50
019:*
020:BR    RTBO  110
021:BL                   90  350  400
022:BD           3    15
023:CD               1    50
024:*
025:AS   UPSTM     270
026:*
027:EX
028:ER
```

Figure 7-20.--Input data for multiple-opening bridge of example #8.

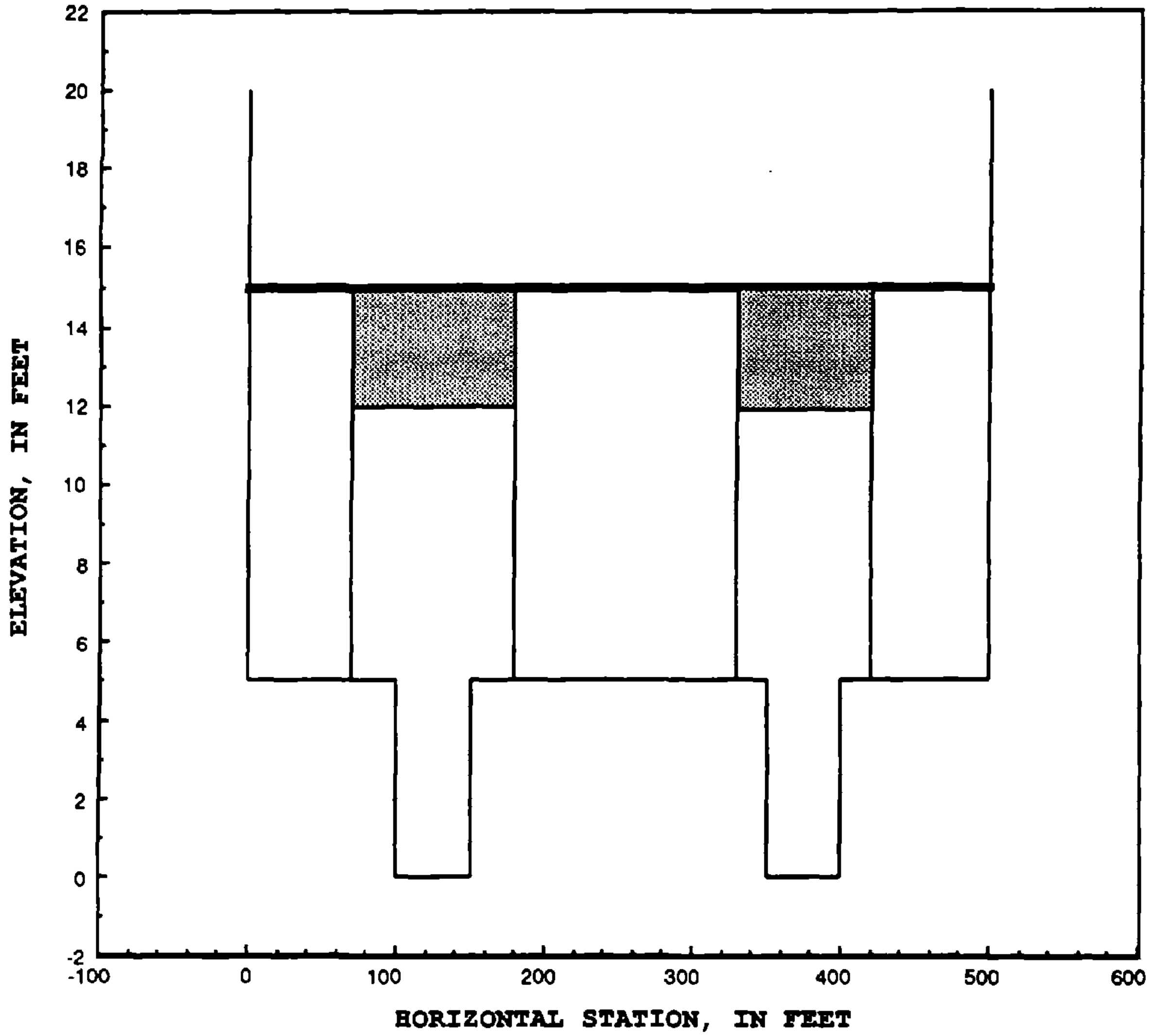


Figure 7-21.--Definition sketch: multiple-opening bridge of example #8.

Figure 7-22 is part of the profile output. Lines 232-244 show the unconstricted profile results. These results are used to make the initial estimates of the valley strips and their properties shown in lines 246-272 (annotated with brief definitions of the variables; see Appendix for better definitions). Lines 284-302 and 306-324 are the first-iteration backwater computations for the left and right openings. Approach-section results for the right opening (lines 318-322) are at SRD 250, which is 20 feet downstream from UPSTM. Therefore, a step-backwater computation is made to determine the elevation at UPSTM for that strip (lines 329-330). The valley-strip elevation and conveyance at UPSTM for each opening (lines 318-319 and 329-330) are then used to compute the conveyance-weighted elevation at UPSTEM (line 343).

Lines 346-425 are the output for the second iteration. The final elevation (line 424) is the conveyance-weighted average of the results at UPSTM for the left opening (lines 380-381) and the right opening (lines 421-422). The elevation in line 424 is within tolerance (0.02) of the elevation for the previous iteration (line 343). Also, each of the valley strip discharges for the second iteration (line 362) are with tolerance (2 percent) of the first iteration discharges (line 270). Therefore, the results of the second iteration are considered acceptable by the model. The user must examine the results further to check for unreasonable differences in water-surface elevations of the valley strips. Significant differences could very well indicate that application of this one-dimensional flow model is not adequate (i.e., perhaps a two-dimensional flow model is required).

```
232:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q     WSEL
233:         SRD   FLEN    REW        K  ALPH    HO     ERR     FR#    VEL
234:
235: DNSTM:XS    ******    0.     1982.  0.25 *****    8.22    6.00   8000.    7.96
236:          0. ******   500.  178815.  1.00 ***** *******    0.36    4.04
237:
238: FULLV:FV     110.     0.     1989.  0.25  0.22    8.45 *******   8000.    8.20
239:        110.   110.   500.  179795.  1.00  0.00    0.01    0.36    4.02
240:           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
241:
242: UPSTM:AS     160.     0.     1993.  0.25  0.32    8.78 *******   8000.    8.53
243:        270.   160.   500.  180435.  1.00  0.00    0.01    0.35    4.01
244:           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
245:
246: A3 ---      578.    518.     [flow area in each bride opening]
247:
248: QS ---     4217.   3783.     [1st estimate of discharge in each valley strip]
249:
250: BOLEW ---       70.     330.     [left edge of water in each bridge]
251:
252: BOREW ---      180.     420.     [right edge of water in each bridge]
253:
254: STAGLT --- ********     259.     [left stagnation point, each strip]
255:
256: STAGRT ---      259.********     [right stagnation point, each strip]
257:
258: AS ---     1024.     969.   1993.     [area, each strip and total]
259:
260: KS ---    92234.  88207. 180440.     [conveyance, each strip and total]
261:
262: CA3 ---      505.     452.    956.     ['live' flow area, each bridge, total]
263:
264: CJ ---     0.874   0.872     [discharge coefficient, each opening]
265:
266: CDF ---     1.031   0.967     [conveyance distribution factor, each strip]
267:
```

- - - - - - - - - continuation on next page - - - - - - - -

Figure 7-22.--Computed profile output for multiple-opening bridge of Example #8.

- - - - - - - continuation from previous page - - - - - - -

```
268: CRF ---    2.300   2.305     [channel resistance ratio, each strip]
269:
270: QS ---    4218.   3782.     [discharge in each valley strip]
271:
272: CDF ---    1.031   0.967     [conveyance distribution factor, each strip]
```

- - - - - - - - - - - - - section of output deleted - - - - - - - - - - - - -

```
282:             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
283:
284:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
285:        SRD    FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
286:
287:  LTBO:BR      110.     70.      527.   1.29   0.42     9.04     6.52   4218.    7.74
288:       110.    110.    180.    51254.   1.30   0.39     0.00     0.73    8.00
289:
290:      TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
291:        1. ****    1.  0.877 ******    12.00    110.     70.    180.
292:
293:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
294:        SRD    FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
295:
296: SLICE:AS      110.      0.     1278.   0.17   0.30     9.68     4.34   4218.    9.51
297:       270.    120.    259.   137401.   1.00   0.34     0.00     0.26    3.30
298:
299:        M(G)    M(K)        KQ    XLKQ    XRKQ     OTEL
300:       0.575   0.386    84263.     71.    181.     9.40
301:
302:                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
303:
304:             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
305:
306:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
307:        SRD    FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
308:
309:  RTBO:BR       90.    330.      488.   1.22   0.27     9.09     6.24   3782.    7.87
310:       110.     90.    420.    50615.   1.31   0.41     0.00     0.67    7.74
311:
312:      TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
313:        1. ****    1.  0.873 ******    12.00     90.    330.    420.
314:
315:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
316:        SRD    FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
317:
318: SLICE:AS       90.    259.     1183.   0.16   0.24     9.61     6.24   3782.    9.45
319:       250.    100.    500.   118532.   1.00   0.28     0.02     0.25    3.20
320:
321:        M(G)    M(K)        KQ    XLKQ    XRKQ     OTEL
322:       0.626   0.400    70757.    331.    421.     9.36
323:
324:                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
325:
326:  XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS       Q     WSEL
327:        SRD    FLEN     REW         K   ALPH     HO      ERR      FR#     VEL
328:
329: UPSTM:XS       20.    259.     1199.   0.15   0.02     9.63 *******   3782.    9.48
330:       270.     20.    500.   125350.   1.00   0.00     0.00     0.25    3.16
```

- - - - - - - - - - section of output deleted - - - - - - - - -

- - - - - - - - - continuation on next page - - - - - - - -

Figure 7-22.--Computed profile output for multiple-opening bridge of Example #8 (continued).

- - - - - - - - continuation from previous page - - - - - - -

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

UPSTM:XS    ******    0.    2477.  0.16 *****    9.66 *******   8000.    9.49
      270. ******   500.  258578.  1.00 *****    0.97    0.26    3.23

STAGLT --- ********    258.

STAGRT ---      258.********

AS ---    1270.   1207.   2477.

KS ---  132130. 126451. 258581.

CA3 ---     462.    426.    889.

CJ ---    0.877   0.873

CDF ---    1.031   0.967

CRF ---    2.301   2.304

QS ---    4159.   3841.

CDF ---    1.017   0.982

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

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

 LTBO:BR     110.     70.     528.  1.26  0.41     9.01    6.50   4159.    7.75
      110.   110.    180.   51364.  1.31  0.37    -0.01    0.72    7.88

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       1. ****   1.   0.875 ******    12.00    110.     70.    180.

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

SLICE:AS     110.      0.    1262.  0.17  0.31     9.63    4.32   4159.    9.47
      270.   120.    258.  133142.  1.00  0.33     0.02    0.26    3.30

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
      0.573  0.381   81830.    71.   181.     9.36

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

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

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

 RTBO:BR      90.    330.     488.  1.26  0.28     9.12    6.29   3841.    7.86
      110.    90.    420.   50475.  1.31  0.42    -0.01    0.68    7.88

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       1. ****   1.   0.874 ******    12.00     90.    330.    420.
```

- - - - - - - - - continuation on next page - - - - - - - - -

Figure 7-22.--Computed profile output for multiple-opening bridge of Example #8 (continued).

```
      - - - - - - - continuation   from   previous   page - - - - - - -
398:
399:  XSID:CODE     SRDL     LEW      AREA   VHD     HF      EGL     CRWS       Q      WSEL
400:        SRD     FLEN     REW         K  ALPH     HO      ERR      FR#     VEL
401:
402: SLICE:AS       90.     258.     1196.  0.16  0.24     9.65     6.29   3841.      9.49
403:        250.    101.    500.  122284.  1.00  0.29     0.02     0.25    3.21
404:
405:        M(G)    M(K)        KQ    XLKQ   XRKQ     OTEL
406:       0.628   0.404    72483.    331.   421.      9.40
407:
408:                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>
      - - - - - - - - - -  section   of   output   deleted  - - - - - - - -
418:  XSID:CODE     SRDL     LEW      AREA   VHD     HF      EGL     CRWS       Q      WSEL
419:        SRD     FLEN     REW         K  ALPH     HO      ERR      FR#     VEL
420:
421: UPSTM:XS       20.     258.     1213.  0.16  0.02     9.67 *******   3841.      9.52
422:        270.     20.    500.  127359.  1.00  0.00     0.00     0.25    3.17
423:
424: UPSTM:XS    ******       0.     2475.  0.16 *****     9.65 *******   8000.      9.49
425:        270. ******     500.  258227.  1.00 *****     0.00     0.26    3.23
```

Figure 7-22.--Computed profile output for multiple-opening bridge of Example #8 (continued).

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). However, such analyses are subject to the following limitations: tailwater elevation(s) must be known; no valley cross-section data can be included; and upstream ponding (no approach velocity) is assumed. Input data are thus limited to [T1], [T2], [T3], Q, WS, CV, CG, [CC], EX, and [ER] records; no additional data are permitted but some or all of the bracketed (optional) records can be omitted. An example of WSPRO culvert analyses follows.

A culvert installation is required for a design discharge of 4,800 ft^3/s. Site characteristics and other factors suggest a battery of six 9-foot, circular, concrete pipes might suffice. The sag-curve roadway has a minimum elevation of 600 feet, thus road overflow is possible. First, because of WSPRO's limitations, a separate step is needed to determine tailwater elevation. Figure 7-23 shows the input and output for the "normal" profile computations. SEC-C is at the downstream end of the proposed culvert; thus the culvert tailwater elevation is 596.99 (line 172).

```
001:T1                     CULVER CREEK AT FARAWAY, USA
002:*
003:Q             4800
004:SK            0.002
005:*
006:XS    SEC-A  200
007:GR          170,601.8  190,594  248,590.5  271,590.5  293,590.1  310,590.5
008:GR          318,593.1  338,595.9  350,600.5  368,603.8  380,605
009:N             0.028
010:XS    SEC-B   315
011:GR          182,605.5  205,595.5  219,593.6  222,593.7  275,589.9  297,589.8
012:GR          316,590  345,590.6  357,593.7  385,605.2
013:XS    SEC-C   375
014:GR          220,604.8  247,596  274,591.5  276,589.5  294,589.3  305,588.5
015:GR          317,588.1  327,588.5  353,589.7  355,592.8  374,596.2  393,603.4
016:GR          400,604.3
017:XS    SEC-D  500
018:GR          220,604.8  240,603.7  253,593.5  273,593.2  276,590.8  295,590.6
019:GR          312,590.6  315,589  328,589.1  340,589.2  341,590.8  372,594.8
020:GR          389,603.4  400,604.3  400,607
021:EX
022:ER
```

a) input data for open-channel computations

- - - - - - - - **continuation on next page** - - - - - - - -

Figure 7-23.--Computation of open-channel profile for Example #9.

```
       - - - - - - - continuation  from  previous  page - - - - - - -
163:  XSID:CODE   SRDL    LEW      AREA   VHD     HF      EGL     CRWS        Q     WSEL
164:        SRD   FLEN    REW         K  ALPH     HO      ERR      FR#      VEL
165:
166: SEC-A:XS   ******   183.      728.   .68 *****  597.28  594.87    4800.  596.60
167:       200. ******   340.  107318.  1.00 ***** *******     .54     6.59
168:
169: SEC-B:XS     115.   202.      877.   .47    .17  597.44 *******    4800.  596.98
170:       315.   115.   365.  142144.  1.00    .00     .00     .42     5.47
171:
172: SEC-C:XS      60.   244.      783.   .58    .07  597.57 *******    4800.  596.99
173:       375.    60.   376.  134105.  1.00    .06     .00     .44     6.13
174:
175: SEC-D:XS     125.   248.      698.   .74    .19  597.83 *******    4800.  597.10
176:       500.   125.   377.  112507.  1.00    .08    -.01     .52     6.88
```

b) open-channel profile for "normal" flow

Figure 7-23.--Computation of open-channel profile for Example #9 (continued).

The input data for culvert computations is shown in figure 7-24. Because road overflow is possible, a range of discharges from 3,600 to 4,800 ft^3/s are input for analysis. Parts of the culvert analysis output are shown in figure 7-25. Inspection of the headwater elevations (lines 70, 93, 116) indicate that road overflow will begin at a discharge of about 3,960 ft^3/s (estimated by straight-line interpolation).

```
001:T1            CULVER CREEK NEAR FARAWAY, USA
002:T2          EXAMPLE #8 - CULVERT COMPUTATIONS
003:*
004:Q           4800     4200     3600
005:WS          596.99   596.99   596.99
006:*
007:*    SECID      SRD  XCTR  CVLENG  DSINV  USINV  NBBL
008:CV   PIPES      375   315    60    588.9   589     6
009:*
010:*           ICODE   RISE
011:CG           214     108
012:*
013:EX
014:ER
```

Figure 7-24.--Input data for culvert analysis.

```
     - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
038: CULVERT PARAMETERS:  ISHAPE   IEQNO     CKE  CVALPH      CN
039:                          2.      4.     .50    1.04    .012
040:
041:                        NBBL  CVLENG   USINV   DSINV    XCTR
042:                          6.    60.0  589.00  588.90   315.0
043:
044:                        RISE    SPAN  BOTRAD  TOPRAD  CORRAD
045:                      108.00     .00     .00     .00     .00
046:
047: +++ BEGINNING PROFILE CALCULATIONS --    3
     - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
055:     CULVERT SUMMARY:
056:
057:         ISHAPE       RISE       SPAN      BOTRAD      TOPRAD      CORNER
058:              2     108.00        .00         .00         .00         .00
059:
060:          IEQNO        CKE         CN      CVALPH      CVLENG      CVSLPE
061:              4        .50       .012        1.04       60.00       .0017
062:
063:          TWDEP       QBBL       HWIC        HWOC      OTFULL
064:           8.09     800.00      12.40       12.45        -.80
065:
066:          DSUBC      ASUBC      DSUBN       ASUBN
067:           7.05      53.50       9.00       63.62
068:
069:          VELOT       AOUT      VELIN         AIN         HWE
070:          13.28      60.25      13.10       61.08      601.35
     - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
086:          TWDEP       QBBL       HWIC        HWOC      OTFULL
087:           8.09     700.00      10.98       11.45        -.85
088:
089:          DSUBC      ASUBC      DSUBN       ASUBN
090:           6.61      50.09       9.00       63.62
091:
092:          VELOT       AOUT      VELIN         AIN         HWE
093:          11.62      60.25      11.55       60.59      600.35
     - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
109:          TWDEP       QBBL       HWIC        HWOC      OTFULL
110:           8.09     600.00       9.71       10.56        -.89
111:
112:          DSUBC      ASUBC      DSUBN       ASUBN
113:           6.12      46.03       9.00       63.62
114:
115:          VELOT       AOUT      VELIN         AIN         HWE
116:           9.96      60.25       9.95       60.28      599.46
     - - - - - - - - -  section   of   output   deleted   - - - - - - - - -
```

Figure 7-25.--Culvert analysis output.

A convenient way to estimate the road overflow in such a case 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 the battery of culverts (each barrel is about 64 square feet, thus a 40 by 9.6 foot bridge opening). Input data for this analysis is shown in figure 7-26.

```
001:T1                   CULVER CREEK AT FARAWAY, USA
002:*
003:Q           4800
004:SK          0.002
005:*
006:XS   SEC-A  200
007:GR        170,601.8  190,594  248,590.5  271,590.5  293,590.1  310,590.5
008:GR        318,593.1  338,595.9  350,600.5  368,603.8  380,605
009:N           0.028
010:*
011:XS   SEC-B   315
012:GR        182,605.5  205,595.5  219,593.6  222,593.7  275,589.9  297,589.8
013:GR        316,590  345,590.6  357,593.7  385,605.2
014:*
015:XS   SEC-C   375
016:GR        220,604.8  247,596  274,591.5  276,589.5  294,589.3  305,588.5
017:GR        317,588.1  327,588.5  353,589.7  355,592.8  374,596.2  393,603.4
018:GR        400,604.3
019:*
020:BR   BRDG1    375  598
021:GR            295,598  295,588.4   335,588.4   335,598  295,598
022:N               0.012
023:CD            2    60    2     600
024:AB            *    *   588.4
025:*
026:XR   ROAD      405
027:GR         220,604.8    315,600    400,604.3
028:*
029:AS   SEC-D  500
030:GR        220,604.8  240,603.7  253,593.5  273,593.2  276,590.8  295,590.6
031:GR        312,590.6  315,589  328,589.1  340,589.2  341,590.8  372,594.8
032:GR        389,603.4  400,604.3  400,607
033:*
034:EX
035:ER
```

Figure 7-26.--Input data for "equivalent-bridge" analysis.

Part of the profile output is shown in figure 7-27. It should be noted that the headwater elevation from culvert computations is for a point immediately upstream from the culvert, 65 feet downstream from the approach section. The water-surface elevation difference between these points is less than 0.1 foot for "normal" flow. If adjustment is made for total loss of velocity head for ponded conditions the difference may be about 0.2 foot. Another important point to be made is the confirmation of the above statement about differences between culvert and bridge hydraulics. The bridge computations show 4,500 ft^3/s (line 275) flowing through the opening with a headwater elevation of 601.94 (line 291) whereas the culvert results indicate (by interpolation) a headwater elevation of about 600.85 for a similar discharge. The elevation immediately upstream from the embankment used for road-overflow computations in WSPRO is the approach elevation minus an "estimated" friction loss (about 0.02 foot for this case). Thus we have a road overflow of 291 ft^3/s (line 282) at a 601.92 HWE. This is a valid point on the weir (road overflow) rating curve. One could estimate weir flow at any HWE between elevations 600 and 601.92 by interpolation. For example, the weir flow at 601.35 (HWE for culvert flow of 4,800 ft^3/s) is about 205 ft^3/s, for a total flow of about 5,000 ft^3/s. Simultaneous interpolation of the culvert flow rating between elevations 600.35 (4,200 ft^3/s) and 601.35 (4,800 ft^3/s) would result in an estimated HWE of 601.08 for the 4,800 ft^3/s flow. Of course the above analysis is also easily accomplished graphically.

A more refined estimate may be obtained by additional bridge analyses. Because the initial bridge analysis resulted in weir flow and HWE that were too high, simply enlarge the bridge opening. A second analysis (not shown) was made for a bridge opening that was 5 feet longer than the previous analysis. This analysis resulted in a weir flow of 88 ft^3/s for a 601.07 HWE. Culvert flow at 601.07 is about 4,650 ft^3/s for a total discharge of about 4,740 ft^3/s. Further interpolation results in an estimated HWE of 601.15 for the 4,800 ft^3/s flow. The 0.07 foot difference from the first estimate is due to straight-line interpolation, which can be quite imprecise, especially at the lower end of the weir rating curve. A graphical solution with enough points to adequately account for the curvature of rating curves is probably preferable. The number of bridge alternatives attempted depends on the desired accuracy of the final solution.

```
243:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
244:        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
      - - - - - - - - -  section  of  output  deleted  - - - - - - - - -
252: SEC-C:FV      60.   244.     783.   .58   .07  597.57 *******  4800.  596.99
253:       375.    60.   376.  134105.  1.00   .06     .00     .44    6.13
254:          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
255:
256: SEC-D:AS     125.   248.     698.   .74   .19  597.83 *******  4800.  597.10
257:       500.   125.   377.  112507.  1.00   .08    -.01     .52    6.88
258:          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
259:
260:  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
261:           WS1,WSSD,WS3,RGMIN =   601.59        .00     596.05     600.00
262:
263:  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
264:
265:  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
266:           WS3,WSIU,WS1,LSEL =   595.92     601.28     601.33     598.00
267:
268:  ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
269:
270:              <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
271:
272:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
273:        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
274:
275: BRDG1:BR      60.   295.     384.  2.14 *****  600.14  595.74   4502.  598.00
276:       375. ******   335.  117548.  1.00 ***** *******     .67   11.73
277:
278:      TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
279:        2. ****    5.   .490   .000  598.00 ****** ****** ******
280:
281:     XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
282:    ROAD :RG     405.    65.   .02    .19  602.12     .00    291.  601.76
283:
284:               Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
285:    LT:     145.     35.   280.   315.   1.8    .9   5.1   4.7   1.2   3.0
286:    RT:     145.     35.   315.   350.   1.8    .9   5.1   4.7   1.2   3.0
287:
288:  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
289:        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
290:
291: SEC-D:AS      65.   242.    1356.   .19   .04  602.13  595.05   4800.  601.94
292:       500.    69.   386.  311982.  1.00   .11     .00     .20    3.54
293:
294:        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
295:      ****** ****** ******** ****** ****** ********
296:
297:                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

Figure 7-27.--Output for "equivalent-bridge" analysis.

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 PC's. WSPRO requires less than 400 kilobytes 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 2 minutes on a math-coprocessor-equipped IBM PC/AT (or compatible model) may be 5-7 minutes on a similarly equipped IBM PC/XT (or compatible model) and one-half hour 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 4 file names. All file names, of course, must conform to MS/DOS conventions. The first response must be the file name of an existing file that contains the input data. The second prompt can be responded to with either a valid file name to store the "print" file output or the device name that would direct the output to the screen or a printer. Specifying a file name provides an opportunity to "preview" the results prior to generating a hard copy. A response of NUL to the remaining prompts is convenient because that causes two "obsolete" files to be treated as "temporary" files which are

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[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 U.S. Geological Survey nor recommendation for use.

automatically deleted when program execution is complete. An extremely remote possibility exists for the user to be prompted for a file name for unit 9. Response to that prompt should also be a file name of NUL to conveniently eliminate this "obsolete" file.

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 users manual.

Appendix

GLOSSARY

This section, 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 the: (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.

Preceding page blank

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.

AS - multiple-opening output, flow area in each valley strip at the upstream match section.

ASUBC - culvert output, flow area in culvert at critical depth.

ASUBN - culvert output, flow area in culvert at normal depth.

BDELEV - input parameter, bridge-deck elevation [see table 4-5; figure 4-1].

BDSLP - input parameter, bridge-deck slope [see table 4-5; figure 4-1].

BDSTA - input parameter, bridge-deck station [see table 4-5; figure 4-1].

BETA - user-defined table parameter, momentum correction factor for nonuniform velocity distribution, used in computing expansion loss downstream from bridge.

BLEN - output for bridge section, bridge length output for design 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 4-25 4-26; figure 4-14].

BOTN - input parameter, roughness coefficient for BOTD breakpoint [see tables 4-25, 4-26; figure 4-14].

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, 4-11].

BRWDTH - input parameter, width of bridge longitudinal to the flow [see table 4-11; figures 4-7, 4-8, 4-9, 4-10, 4-11].

BSUBD - input parameter, offset for straight spur dikes; perpendicular distance between abutment toes and dikes [see table 4-31].

C - output for bridge section, coefficient of discharge for bridge opening [see tables 4-8, 4-35].

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, 4-15, 4-31, 4-36].

CKE - input parameter, entrance-loss coefficient for culvert [see tables 4-9, 4-13].

CN - input parameter, culvert roughness coefficient [see tables 4-9, 4-10].

CODE - label used in output headings for record identifiers.

CORRAD - input parameter, corner radii for pipe-arch culvert [see tables 4-12, 4-13, 4-14].

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 4-13; section 4.3.5].

CVALPH - input parameter, velocity head correction factor for culvert [see tables 4-9, 4-10].

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 4-22].

DMAX - road overflow output, maximum 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, 4-15, 4-31, 4-36].

ELMAX - input parameter, maximum elevation for cross-sectional properties computations [see table 4-21; section 7.7].

ELMIN - input parameter, minimum elevation for cross-sectional properties computations [see table 4-21; section 7.7].

EMBELV - input parameter, embankment elevation [see table 4-11; figure 4-11].

EMBSS - input parameter, embankment side slope [see table 4-11; figure 4-11].

EMBWID - input parameter, embankment width [see table 4-35].

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 4-18; figure 4-12]. 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 4-22].

FR# - profile output, computed value of Froude number for approximate check for possibility of critical flow.

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 feet 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 tables 4-12, 4-13].

IDIR - input parameter, indicates computational direction [see table 4-17].

IEX - input parameter, indicates computational direction [see table 4-17].

IHFNO - input parameter, indicates averaging method(s) for friction-loss computations [see table 4-18].

IHFNOJ - input parameter, indicates averaging method for friction-loss computations [see table 4-22].

IHP - input parameter, option code for selecting cross-sectional properties output [see table 4-21; section 7.7].

IPAVE - input parameter, indicates road-surface condition [see table 4-35].

K - cross-sectional properties and profile output, cross-sectionalconveyance.

KQ - profile output, conveyance of the Kq segment of the approach section.

KS - multiple-opening output, valley-strip conveyance at the upstream match section.

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 4-3].

LSEL - 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].

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) [see table 4-24; figure 4-14; 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 4-19; figure 4-14].

NPROF - output parameter, number of profiles to be computed [see tables 4-29, 4-32, 4-34].

NPW - output parameter, number of data pairs in PW record(s) [see table 4-27].

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 4-25, 4-26, 4-30; figure 4-14].

NVAL - input parameter, constant roughness coefficient for a subarea [see table 4-25; figure 4-14].

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.

PARNOS - list of parameter codes for user-defined tables [see table 4-23; sections 5, 7.5].

PELV - input parameter, elevation at which gross pier (pile) width, PWDTH, is input [see table 4-27; figure 4-16].

PPCD - input parameter, option code to distinguish between piers and piles [see table 4-27; figure 4-15].

PWDTH - input parameter, gross pier (pile) width for an associated PELV [see table 4-27; figure 4-16].

Q - input parameter, discharge specified for each profile [see table 4-29] and velocity and conveyance distribution [see table 4-21].

QBBL - culvert output, discharge per barrel (discharge in Q record divided by NBBL in CV record).

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 4-22].

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, 4-13].

SCALE - input parameter, scaling factor for fabricating cross sections [see table 4-20].

SDOFF - input parameter, offset distance for elliptical spur dikes [see table 4-31; figure 4-17].

SDTYPE - input parameter, indicates type of spur dike [see table 4-31].

SECID - input parameter, unique identifier for each cross section [see tables 4-4, 4-8, 4-15, 4-21, 4-28, 4-29, 4-31, 4-35, 4-36, 4-37; section 4.1].

SKEW - input parameter, angle at which the cross section is skewed to the flow [see tables 4-4, 4-8, 4-31, 4-35, 4-36; section 4.3.6].

SKSL - input parameter, energy gradient [see table 4-32; 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 12, 4-13, 4-14].

SRD - input parameter, section reference distance [see tables 4-4, 4-8, 4-15, 4-31, 4-35, 4-36, 4-37; sections 4.1, 4.3.4].

SRDL - profile output, difference between adjacent SRD's (same as SLEN).

TOPD - input parameter, hydraulic-depth breakpoint for TOPN [see tables 4-25, 4-26; figure 4-14].

TOPN - input parameter, roughness coefficient for TOPD breakpoint [see tables 4-25, 4-26; figure 4-14].

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 4-35].

USINV - input parameter, upstream culvert invert elevation [see table 4-15].

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, 4-31, 4-36, 4-37].

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, 4-10, 4-11].

WS3N - profile output, computed water-surface elevation at the full-valley section for unconstricted flow [see figures 4-8, 4-11].

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 4-34; figure 4-13; 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 4-19; figure 4-14].

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 4-18; figure 4-12].

XLAB - bridge section output, x-coordinate at toe of left abutment (design mode only).

XLIML, XLIMR - input parameter, left and right limits for fabricated cross section [see table 4-20; figures 3-6, 3-7; section 3-1].

XLKQ - input parameter, left limit of Kq-section [see table 4-24; figure 4-15; section 7.2].

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 4-20].

XRAB - bridge-section output, x-coordinate at toe of right abutment (design mode only).

XRANGE - input parameter, total range of horizontal distance encompassed by plot [see table 4-28].

XREFLT - input parameter, for horizontal datum correction(s) between approach section and bridge and (or) road-grade section(s) [see table 4-7; figures 4-4, 4-5; section 7.2].

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 4-24; figure 4-15; section 7.2].

XSA - input parameter, x-coordinate(s) at subarea breakpoints [see table 4-30; figure 4-14].

XSID - output parameter, column heading for SECID's.

XSTW - output parameter, cross-sectional top width.

XSWP - output parameter, cross-sectional wetted perimeter.

Y - input parameter, elevation(s) of GR data [see table 4-19; figure 4-14].

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 4-21; section 7.7].

YMAX - output parameter, maximum cross-section elevation [see figure 4-13; section 4.3.5].

YMIN - output parameter, minimum cross-section elevation [see figure 4-13]. ??

YRANGE - input parameter, total range of vertical distance encompassed by plot [see table 4-28].

YSHIFT - input parameter, for vertical shift of GR data [see table 4-20; section 7.3.1].

YTOL - input parameter, allowable tolerance for balancing energy equation [see table 4-22].

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