ANALYSIS OF FLOW PROFILES

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A Project Report
Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree
Master of Engineering

McMaster University
November 1981

MASTER OF ENGINEERING (1981)
(Civil Engineering)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Computer Analysis of Flow Profiles in Hydraulic Networks

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NO. OF PAGES: ix, 1-107, Appendix A - ii, A1-A38
Appendix B - i, B1-B70
Appendix C - i, C1-C47
Appendix D - D1-D41

ABSTRACT

The report describes an interactive computer program that can be used to determine the steady state piezometric surface profile for given flow conditions in various hydraulic networks. The program is designed for use in a time-sharing mode to facilitate the setup, calibration and modification of cross-sectional data defining a hydraulic network. The network may include open channels (either natural or manmade) or closed conduits, or both, in configurations of single reach, multiple tributaries or bifurcated branches with its resultant "island" flows. In addition, bridges, weirs, culverts and manholes can be modelled as transitional structures. There is a choice of six resistance laws which are selected during run time. The network geometry file is stored on secondary devices such that relatively large systems can be handled on computers of moderate size. A large part of the report comprises a set of Appendices which can serve as independent manuals for the use and modification of the programs.

ACKNOWLEDGEMENTS

The author wishes to express his thanks and appreciation to Dr. A.A. Smith for his help and guidance in writing this paper; to K.B. Lee for suggestions with programming techniques; to C.C. Parker Consultants for the use of their computer facilities; to Joyce Daly for typing the original draft of this manuscript; to Nancy M. Sine at the McMaster University Engineering Word Processing Centre for typing the final manuscript; and to my wife and children for bearing with me.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (cont'd)

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (cont'd)

ANALYSIS OF FLOW PROFILES

CHAPTER 1

1.1 Introduction

With the increased use of storm water management techniques, whether it be flood plain studies or the analysis of overland flow in subdivision design, flow profiles are usually required in order to determine the maximum extent of flooding. At present, many computer programs are available to the designer for modelling the system being studied [9, 11, 12, 13]. These programs are usually large, comprehensive programs designed for a specific use and commonly used in batch mode. When some element in design is involved where configurations or geometry may change, requiring a number of trial runs, the use of these comprehensive programs can be both time consuming and expensive. This project involves the development and testing of a relatively simple program intended specifically for the purpose of trial and error analysis of various design alternatives for a number of differing hydraulic networks.

The Appendices include a user's manual, worked examples, and a programmer's manual. The appendices have been written so as to provide the potential user with a complete guide to program use without having to refer to the technical information in this paper. As such, the appendices repeat much of that which appears in the text of this paper.

The worked examples in Appendix B cover a wide variety of hydraulic configurations in order to aid the user in understanding the methods used and the scope of applications available in the program.

1.2 Background

The initial concept for the present program originated in the need to compute steady state backwater profiles quickly, easily and with limited data preparation. The result was a library of subroutines, each of which performed specific computations. The library has since been extended to cover a wide variety of hydrologic and hydraulic computations. The library is called the Civil Engineering Program Library (C.E.P.L.) or "Civlib" for short [1].

The first backwater program developed for the library was known as RIVER1/2. This program is a self contained subroutine in the C.E.P.L. which calls upon other routines in the library for specific computations. In this version, the geometry file was stored in the computer core in order to facilitate the modification of the channel geometry if required. It became apparent, though, that for extensive networks, the amount of core memory used to retain the geometry limited the extent to which RIVER1/2 could be expanded to include various hydraulic phenomena. A new subroutine was thus developed in which the geometry file resided on secondary devices such as tapes or discs. The routine resulted in greatly reduced core requirements such that programming could be provided for additional hydraulic analysis. The one drawback to the new subroutine is the increase in computation time by about 50%-60%. The new subroutine is known as RIVER4.

The original project was intended to be the preparation of a set of manuals for the use of RIVER4. In addition, the program was to be tested for use on a closed conduit network such as a sewer system. This would enhance the program's generality by being able to analyse both natural and man-made systems.

In preparing the manuals, it was noted that for practical usage, certain aspects of the program could be greatly enhanced with minor modifications. These included additional summary output with each command, a reorganization of some of the commands available and the addition of a command to summarize the input data. It was observed that in the branched flow computation, closure was very slow with the existing algorithm if the system included invert discontinuities. It was therefore decided to improve the computations of branched networks to speed convergence.

In addition, modelling of branches and their numbering was quite restrictive. All branches had to start on the main channel and end on the main channel. This usually resulted in inconsistent and discontinuous number sequences being used to define a tributary. The numeric modelling was therefore revised so that contiguous streams could be numbered independently of the branching scheme.

The analysis of pipe flow presented problems in the original program. Circular conduits were defined by a set of coordinate pairs. When critical depth was being calculated, the depth was often too high. The solution was to use routines specifically intended for circular sections and to define the pipe as such (i.e. diameter and invert). This modification was achieved by the device of using one set of coordinates in which the horizontal value defines the diameter and the vertical coordinate represents the invert. This procedure not only increased the accuracy of the analysis, but also decreased the amount of preparatory work required in creating and/or altering a data file for sewer systems.

In modelling sewer systems, it became apparent that the number of nodes required was usually more than desired. This usually resulted from modelling all tributaries with at least one node in order to account for the flow contribution. Often the profiles were not required on all the tributaries. In order to eliminate excess modelling and still account for the flow contribution, a method of entering point lateral inflows was developed and added to the program.

In addition to the above modifications and improvements, the project was intended to test the applicability of the model to different problem types and, where appropriate or possible, to compare the results with other solutions either published, observed or computed by means of other programs.

Though much more work could be done on the program, it is felt that that which is presented is a very useful and utilitarian program for most backwater calculations.

CHAPTER 2

SYSTEM GEOMETRY

2.1 General

The hydraulic system for a RIVER4 analysis is described by a series of cross-sections spaced along the network so as to adequately represent the system. Each section is described by a set of coordinate pairs which approximates the cross-section shape. The number of points may vary for each cross-section depending on its complexity. In addition, the section is defined by a characteristic resistance coefficient and chainage. Only one resistance coefficient is used per cross-section. Chainage can be either negative or positive but it must increase algebraicly in the direction of flow.

It is recommended that if tributaries are being modelled, negative chainage be used starting with 0.0 at the downstream end and increasing in negative distance in the upstream direction. This will result in confluences having the same chainage for tributary and main channel.

Transitions can be modelled by using two consecutive cross-sections with the same chainage. By doing so, contractions and expansions can be modelled in order to represent bridges, culverts, drop manholes or weirs. Complex transitions can be modelled by three or more sections at the same chainage.

Each cross-section is described by two record types. The first field of both record types (I5), contains the cross-section number. The first record type also includes the number of points in the cross-section, its chainage and roughness coefficient. The second record contains the horizontal and vertical coordinate pairs defining the cross-section shape. The horizontal stations can be negative or positive.

Three pairs of coordinates can be accommodated on each type two record. Table 2.1 details the information required for the geometry file. If the user wishes to add additional comments to the data file, the comments should start after column 10. In this way, the comments are "transparent" to the program and processing will occur normally.

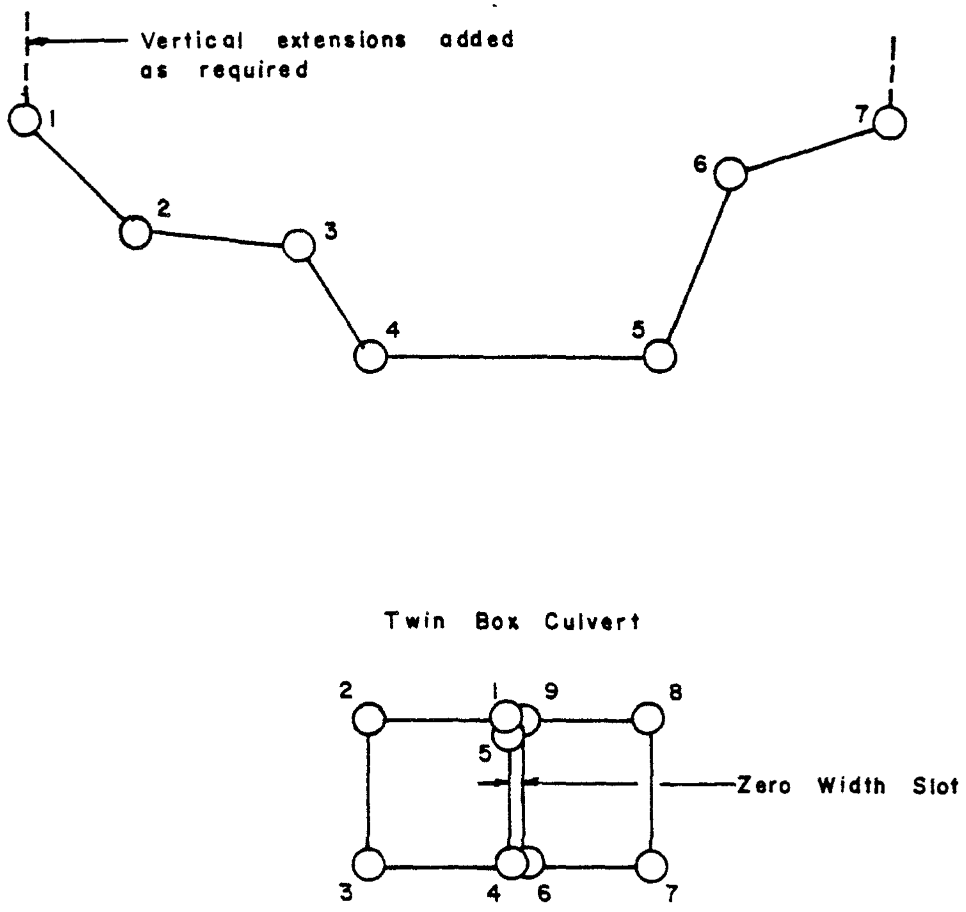
Circular pipes are described by one pair of coordinates (NPTS=1) in which HORZ(1) is the diameter and VERT(1) is the invert elevation. Figure 2.1 shows the modelling of a transition and the typical data for these cross-sections. The geometry file of the system resides on secondary devices such as tapes or discs. Though computation time is increased using secondary systems, the reduction in core size enables computers of modest size to analyse relatively large networks.

When computing a backwater profile, the geometry file is assigned to unit 1 as input, (i.e. TAPE1 under CDC operating systems).

TABLE 2.1

GEOMETRY FILE FORMAT

Record	Field	Format	Variable	Description
1	1-5	I5	ISEC	Cross-section number
1	6-10	I5	NPTS	No. of points describing the section
1	11-20	F10.1	CHAIN	Cross-section chainage
1	21-30	F10.3	RC	Roughness coefficient
2	1-5	I5	ISEC	Cross-section number
2	6-15	F10.3	HORZ(1)	Horiz. coord. of pt. 1
2	16-25	F10.3	VERT(1)	Vert. coord. of pt. 1
2	26-35	F10.3	HORZ(2)	
2	36-45	F10.3	VERT(2)	
2	46-55	F10.3	HORZ(3)	Coordinate pairs for
2	56-65	F10.3	VERT(3)	points 2 & 3
3 etc.	As record 2 for subsequent coordinate pairs.			



(a) TYPICAL CROSS-SECTIONS

1	7	-1250.0	0.20			
1	0.0	110.0	10.0	102.0	20.0	100.0
1	25.0	93.0	45.0	93.0	60.0	103.0
1	70.0	110.0				
2	9	-1250.0	0.10			
2	35.0	98.0	25.0	98.0	25.0	93.0
2	35.0	93.0	35.0	98.0	35.0	93.0
2	45.0	93.0	45.0	98.0	35.0	98.0

(b) TYPICAL DATA FOR ABOVE CROSS-SECTIONS

FIGURE 2·1

TYPICAL CROSS-SECTIONS

2.2 Network Configuration and Numbering

There are few limitations on the configuration of nodes and their numbering. The basic rule is that there can be no more than one tributary or bifurcated branch off of any one node.

If there are two tributaries at the "same" confluence, the main channel must be modelled by two cross-sections with the same chainage. Each tributary can be modelled by one cross-section if so desired, representing a minor tributary. The program as later modified allows point lateral inflows to be defined without the necessity of defining tributaries in this way.

Each tributary is numbered consecutively from the upstream limit to the downstream limit. The downstream limit of the principle channel must have the highest node number.

Bifurcated branches are numbered as if they were a tributary. The connectivity procedure defines the tributary as a branch using an array KDS(node). In order to arrive at a numbering scheme, the user should have a schematic of the configuration present. Then, starting at the upstream end of the shortest or least important tributary, number the nodes from one to the downstream end of the tributary (say 5). The next tributary would start at the upstream limit with 6 and continue to its downstream limit. This would be continued until the main channel is consecutively numbered with the highest set of numbers.

These rules can be summarized as follows:

(1) All tributaries (branches) must be numbered consecutively in the direction of flow.

(2) The furthest downstream section must have the highest number representing the maximum number of sections in the current geometry file.

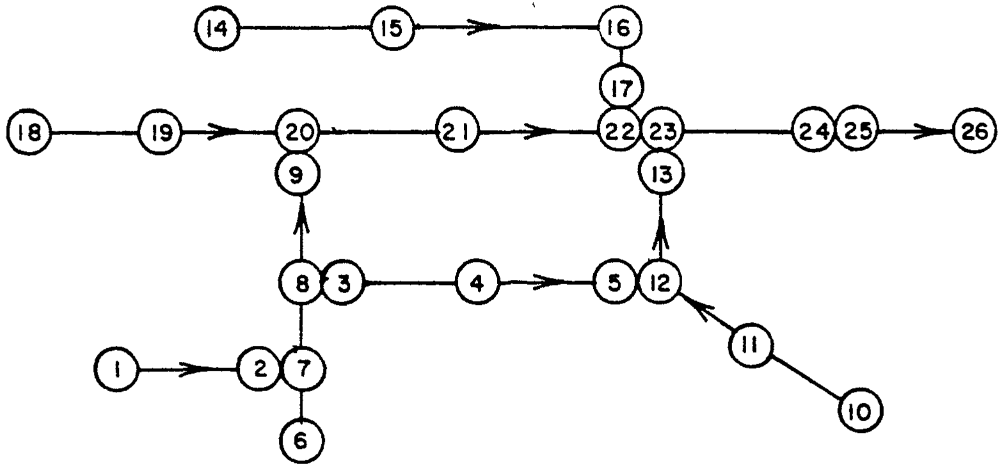
(3) Only one tributary or branch can exist at any one node.

Figure 2.2 shows a correct numbering scheme and one with typical violations. For further illustrations of the numbering scheme see Appendix B - Worked Examples.

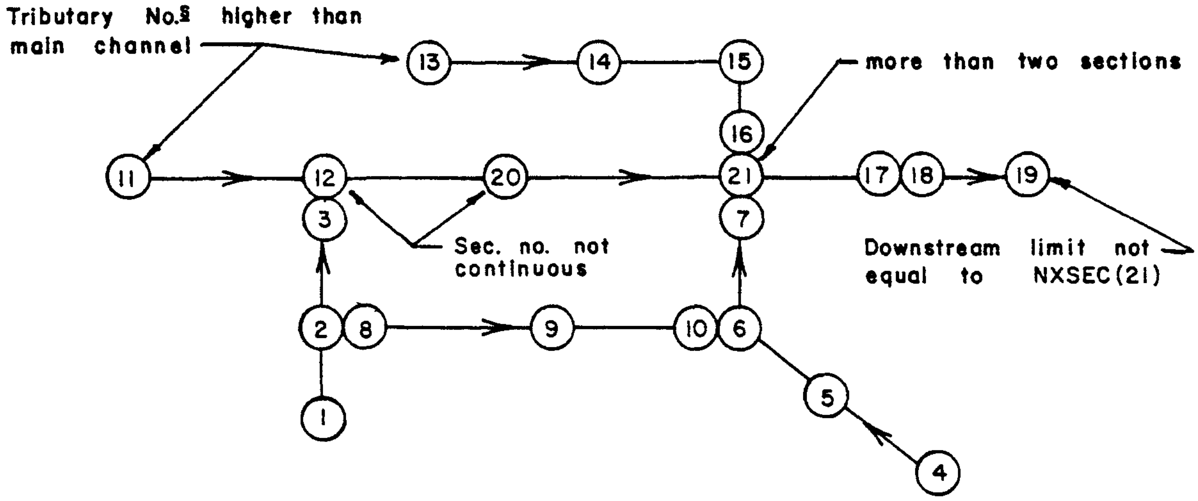
2.3 Use of EDITXS

The geometry file can be created by one of two methods. It can be created using a text editing language or it can be created using the subroutine EDITXS. This subroutine is command oriented and is a part of the backwater library. The commands available are:

ADD - to add a new section
CHANGE - to alter any section property
DELETE - to delete an existing section
END - to end this edit session



(a) Typical Network System (1 branch, 5 confluences)



(b) Typical Violations of Numbering and Connectivity Constraints

NODE(J)	1	2	3	4	5	6	7	8	9	10	11	12	13
KDS(J)	0	7	−8	0	12	0	0	0	20	0	0	0	23

NODE(J)	14	15	16	17	18	19	20	21	22	23	24	25	26
KDS(J)	0	0	0	22	0	0	0	0	0	0	0	0	999

(c) Connectivity Array for Network of (a)

FIGURE 2·2

TYPICAL NETWORK

HELP - to print list of available commands

PRINT - to print out properties of section(s)

RETURN - to return to the calling routine

In order to use the subroutine to create a data file, a simple driving program is required as follows:

Assume 25 cross-sections (NXSEC) with maximum number of points being 5(MAXPTS).

```
   PROGRAM TST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2)
C  Program card for CDC6400
   DIMENSION ITST(25),KSREC(100)
   NTAPE1=1
   NTAPE2=2
   NXSEC=25
   MAXPTS=5
   NR=5
   NW=6
   CALL FILEXS(NTAPE1,KSREC,NXSEC,MAXPTS)
C  This routine initializes KSREC()
   CALL EDITXS(NTAPE1,NTAPE2,KSREC,ITST,NXSEC,MAXPTS,NR,NW,NOCOPY)
   END
```

After the file has been created by entering commands and responding to prompts within subroutine EDITXS, the file TAPE1 contains the data and is usually saved as a permanent file for future use.

It should be noted that the subroutine is awkward to use in creating data files. In addition, when changes are made through the command CHANGE, the whole of the cross-section data for both record types must be reentered. Therefore it is, in general, recommended that the computer text editing system be used for modifying data or creating a file, especially if a screen editor is available.

The useful part of the subroutine is in the commands ADD and DELETE. After a data file has been created by some means and a backwater calculation has been performed, it may be desired to add a cross-section in the middle of the data set. Within the subroutine RIVER4 (of which more will be said later), EDITXS can be accessed. By using the command ADD, a new cross-section can be inserted. In doing so, the routine adds one to all cross-sections with the same and higher cross-section number resulting in NXSEC being increased by one. This would be difficult to do with a text editor. Likewise, a section can be deleted resulting in higher section numbers being reduced by one. After alterations, the new TAPE1 would have to be saved in order to preserve the altered geometry.

For more information on the use of EDITXS, see Appendix A.3.7-EDIT.

CHAPTER 3

THE PROGRAM

3.1 Organization

The backwater program consists of 19 subroutines in total. The heart of the program is subroutine RIVER4 which is command structured. There are 14 commands available to the user (see Table 3.1). After having typed one of the commands, the program is directed to the appropriate section in the subroutine whence specific information is requested from the user. The appropriate computation is performed and the results returned to the user. The calculations are usually performed by specialized subroutines that reside in a library of subroutines. Throughout the subroutine, a check is made that certain prerequisite information is available before continuing, such as flows have been defined before computing critical depth. If the information does not exist, the program is redirected to the appropriate section and the necessary data is requested. After each set of computations, the user is invited to submit another command until the command STOP is used which terminates the session. Results are printed out in a simple tabular form, each tributary being printed separately with its own heading.

TABLE 3.1

COMMANDS AVAILABLE IN ROUTINE RIVER4

BRANCH	To define one or more branching junctions
COMPUTE	To compute surface profiles between a specified downstream control and any upstream section.
CONNECT	To define one or more confluence junctions.
CRITIC	To compute critical depth and energy level at any section for current discharges.
DISCHARGE	To specify discharges in the channel system explicitly.
D/S WL	To define the downstream control level.
EDIT	To edit the current geometry file.
HELP	To list the available command options.
INFLOWS	To specify inflow discharges at the upstream end of tributary channels.
LOSS COEFF	To define the energy loss coefficients at transitions.
RESISTANCE	To define the desired flow resistance equation.
RESTART	To begin again with the currently defined geometry file.
STOP	To terminate the session.
SUMMARY	To summarize input data.

RIVER4 has complete dynamic allocation of array dimensions. The parameter list is quite extensive and the dimensioning has been simplified through the use of an enclosing subroutine, RIVER3. The advantage of the enclosing routine RIVER3, is the simplicity of the driving program to be provided by the user, consisting of three lines.

(a) a program description defining files

(b) a simple one-dimension work array

(c) a calling statement for RIVER3.

The files defined are TAPE5, TAPE6 for input and output respectively, TAPE1 for the geometry file and TAPE2 for a "scratch" file.

The size of the work array is calculated by the user as follows:

NWK = 5*NXSEC + 4*MAXPTS

Using the previous example of NXSEC=25 and MAXPTS=5, the work array would be

NWK = 5*25 + 4*5
= 145
say, 200 in anticipation of adding cross-section.

Therefore, the driving program takes the following form:

```
   PROGRAM TST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2)
C  Program card for CDC 6400
   DIMENSION WK(200)
   CALL RIVER3(1,2,5,6,32.2,WK)
   END
```

where 32.2 is the value of gravity in Imperial units. Though intended for interactive use, the computations can be performed by batch mode. Care must be taken in anticipating the order in which data is entered (see Appendix A.6 - Batch Mode Usage).

3.2 Defining Connectivity

Each cross-section is identified by its own number and a connectivity number called KDS(node). All KDS values are preset to zero except for KDS(NXSEC) which is set to 999.

By the use of commands CONNECT and BRANCH, individual KDS values are changed. The KDS value defines the node on the "main" channel that a tributary connects to. The value is always positive for confluences. For bifurcated branches, the KDS value is entered positive but made negative within the program. It could be considered a negative confluence. Unless a node connects to another node as a confluence or a branch, its KDS value remains zero.

It is through the positive KDS value that the program identifies the limits of the main channel and its tributaries. By reference to Figures 3.1(a) and 3.1(b), it can be seen that each tributary is bounded by positive KDS values. The downstream limit has a positive KDS value and for the upstream node (J), the KDS(J-1) is positive.

In addition, when accumulating flows in a downstream direction, the positive KDS value indicates when a confluence has been met requiring a change in the numbering system. Thus, in the aforesaid figures, flows at node 6 are accumulated to node 9, whence KDS(9)=23. Flows are now accumulated from 23 through to NXSEC=26.

Within command SUMMARY, the connectivity table is printed out indicating node number and its KDS value. The connectivity can be checked before proceeding, thus eliminating potential errors before the backwater computations are performed.

3.3 Defining Discharge

The discharge in the system can be defined using one of either INFLOWS or DISCHARGE. Using either commands, the program presets all flow values at each node to QMIN=0.0001 units per second. When INFLOWS is used, the program checks the connectivity array for the upstream limit of tributaries. The upstream limit is presented to the user and the discharge value is requested. The values of all tributaries are accumulated in the downstream

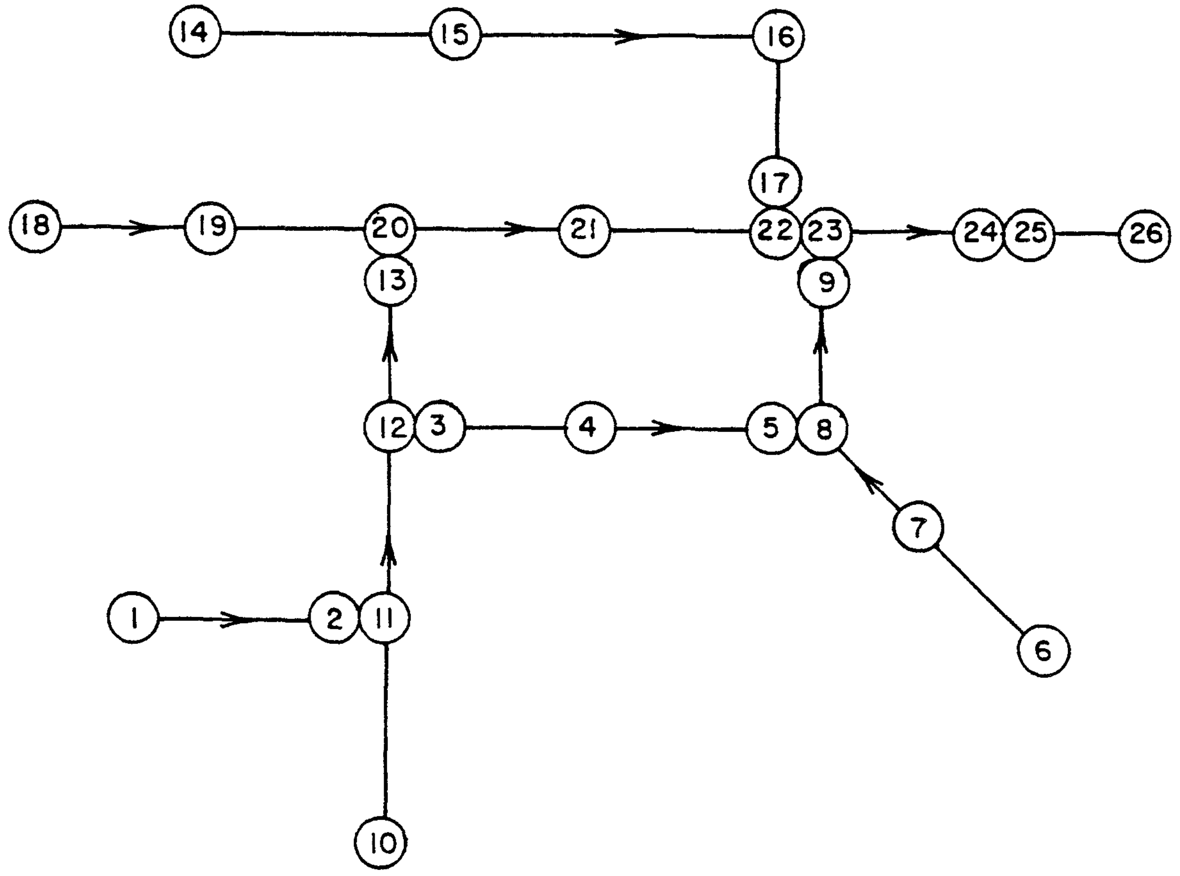


FIGURE 3·1 (a) Typical Network

NODE(J)	1	2	3	4	5	6	7	8	9	10
KDS(J)	0	11	-12	0	8	0	0	0	23	0

NODE(J)	11	12	13	14	15	16	17	18	19	20
KDS(J)	0	0	20	0	0	0	22	0	0	0

NODE(J)	21	22	23	24	25	26
KDS(J)	0	0	0	0	0	999

FIGURE 3·1 (b) Connectivity Array

FIGURE 3·1

CONNECTIVITY
ARRAY

direction to the last node NXSEC, taking into consideration any confluence that may occur. In addition, point lateral inflows may be defined without having to model a tributary with one or more nodes. These lateral inflows can be negative to represent a withdrawal of water from the system if so desired.

If branched flows are being modelled, command INFLOWS calculates the initial approximate division of flow between the main and branching channels. Figure 3.2(a) represents a typical branched network with the bifurcation from node 5 to node 1. With reference to Figure 3.2(b), the algorithm takes the following form:

(i) Determine the total flow Q_{total} entering from node 4, $Q_{4,5}$.

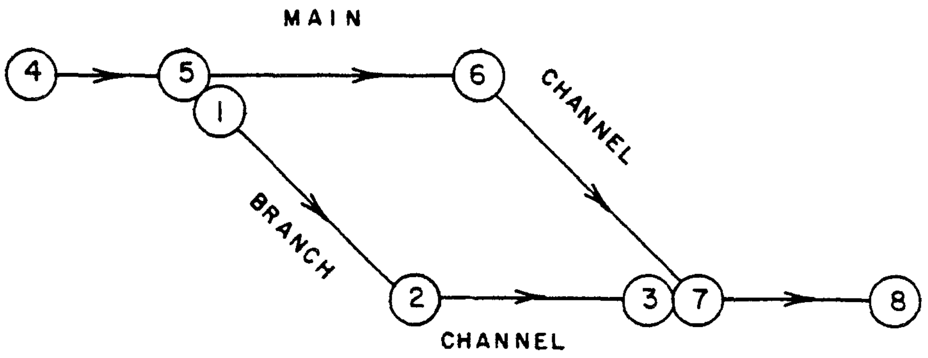
(ii) Compute the critical energy level E_{cr} at section 5 for flow Q_{total}.

(iii) For the calculated energy level E_{cr} at section 1, compute the critical discharge in section 1.

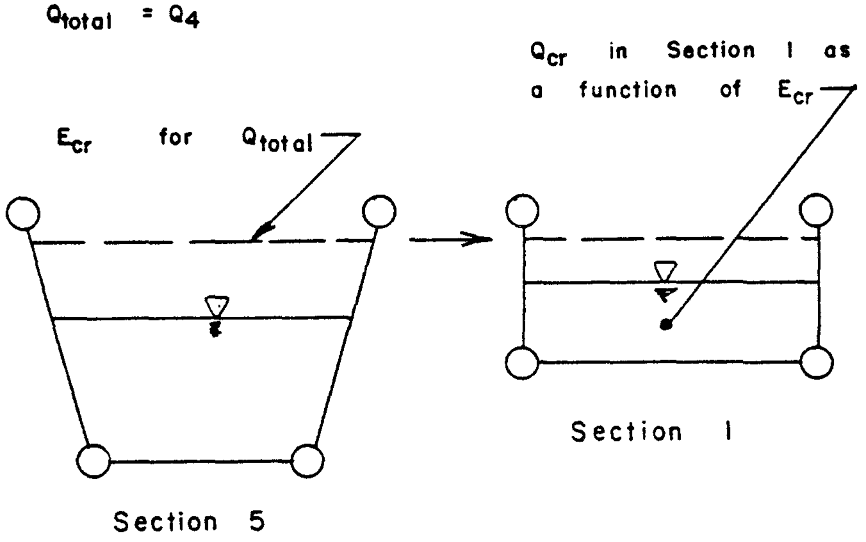
(iv) Calculate $Q_{5,6}$ and $Q_{1,2}$ in the same proportion as Q_{total} and Q_{cr}:

$$Q_{5,6} = Q^2_{total}/(Q_{total} + Q_{cr})$$
$$Q_{1,2} = Q_{total} - Q_{5,6}$$

The alternative method using DISCHARGE, requires the user to specify the number of different discharge values to be defined, followed by a detailed itemization of flow values and the section



(a) TYPICAL LOOP



(b) INITIAL ESTIMATE OF BRANCHED FLOW

FIGURE 3.2

TYPICAL LOOP

downstream of which each value is to be used. This value is used in all downstream reaches until overwritten by another input value. As such, considerable care must be taken by the user in accumulating tributary inflows and observing continuity at confluences. Although more tedious, the use of DISCHARGE is more general and allows each elementary reach to be assigned a different flow if required (e.g. for quasi-steady flows in which $\partial Q/\partial x \neq 0$ and $\partial Q/\partial t \approx 0$).

3.4 Flow Resistance Equations

A choice of six resistance equations are available in the program [2]. Therefore, it is important that the correct roughness coefficient, including units, be used when setting up the data file. The equations available are:

Chezy, Manning, Strickler, Colebrook-White, and
Nikuradse's smooth and rough turbulent equations.

A summary of the particular equations is presented in Table 3.2. Except for Manning's equation, all are presented in the Chezy form of $Q = CA(RS)^{1/2}$. The value of kinematic viscosity has a default value in the program equal to that of water at 60°F being:

$$VISC = 0.000012\ G^2/32.2^2$$

TABLE 3·2 FLOW RESISTANCE EQUATIONS

Chezy Equation

$$Q = CA\sqrt{RS}$$

Manning Equation

$$Q = \frac{(0{\cdot}4671\,G^{\frac{1}{3}})}{n}\,AR^{\frac{2}{3}}S^{\frac{1}{2}}$$

Strickler Equation

$$Q = \left[8{\cdot}41\sqrt{G}\left(\frac{R}{k}\right)^{\frac{1}{6}}\right]A\sqrt{RS}$$

Colebrook-White Equation

$$Q = -\left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{k}{14{\cdot}8R}+\frac{1{\cdot}255\ \nu}{R\sqrt{32\ RSG}}\right)\right]A\sqrt{RS}$$

Nikuradse 'Rough' Turbulent Equation

$$Q = \left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{14{\cdot}8\ R}{k}\right)\right]A\sqrt{RS}$$

Nikuradse 'Smooth' Turbulent Equation

$$Q = \left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{R\sqrt{32\ RSG}}{1{\cdot}255\ \nu}\right)\right]A\sqrt{RS}$$

where:

Q - discharge (ft^3/sec, m^3/s)

A - cross section area (ft^2, m^2)

R - hydraulic radius (ft, m)

S - slope of energy gradient (ft/ft, m/m)

G - gravitational acceleration (ft/sec^2, m/s^2)

ν - kinematic viscosity (ft^2/sec, m^2/s)

C, n, k - roughness coefficient (ft, m - where appropriate)

The use of the gravitational constant, G, here and elsewhere in the routine allows either Imperial or Metric units to be used, as long as the units employed are otherwise consistent.

3.5 Head Loss Coefficient

Head losses at transitions are accounted for in the program at contractions and expansions. The loss is defined as a constant times the difference in velocity heads and is applied to the energy levels at the transition [2,5,8]. In order to account for the loss, the point in question must be modelled with two consecutive cross-sections with the same chainage. When the program detects a transition, a specialized subroutine is called upon to analyze the sections. Complex transitions can be modelled with three or more consecutive sections with the same chainage.

The coefficients have been defaulted in the program to: contractions (CLC) = 0.0, expansions (CLE) = 1.0. These values can be altered during run time through the command LOSS COEFF. Typical values would be as follows

	Coefficients	
	Contraction	Expansion
No transition loss	0.0	0.0
Gradual transitions	0.1	0.3
Bridge Sections (with wing walls)	0.3	0.5
Bridge Sections (no wing walls)	0.6	0.8
Very abrupt transitions	0.7	0.9

3.6 Method of Profile Computations

The profile computations are performed using the standard step procedure as developed by A.A. Ezra and known as the "Ezra" method [2,3,6]. Though originally designed as a graphical procedure, it is ideally suited for computer use. Since only two cross-sections are analysed at one time, the amount of core memory required is significantly reduced.

The profiles are steady state profiles assuming one dimensional flow. Two dimensional flow is assumed in subroutines QCR2D and CRITIC which computes the critical discharge and the critical depth, respectively. Referring to Figure 3.3(a), the total energy for steady-state flow may be written as[4,7]:

$$z_1 + y_1 + \alpha_1 \frac{V_1^2}{2g} = z_2 + y_2 + \alpha_2 \frac{V_2^2}{2g} + h_f \qquad (3.1)$$

where z_1, z_2 - elevations above datum

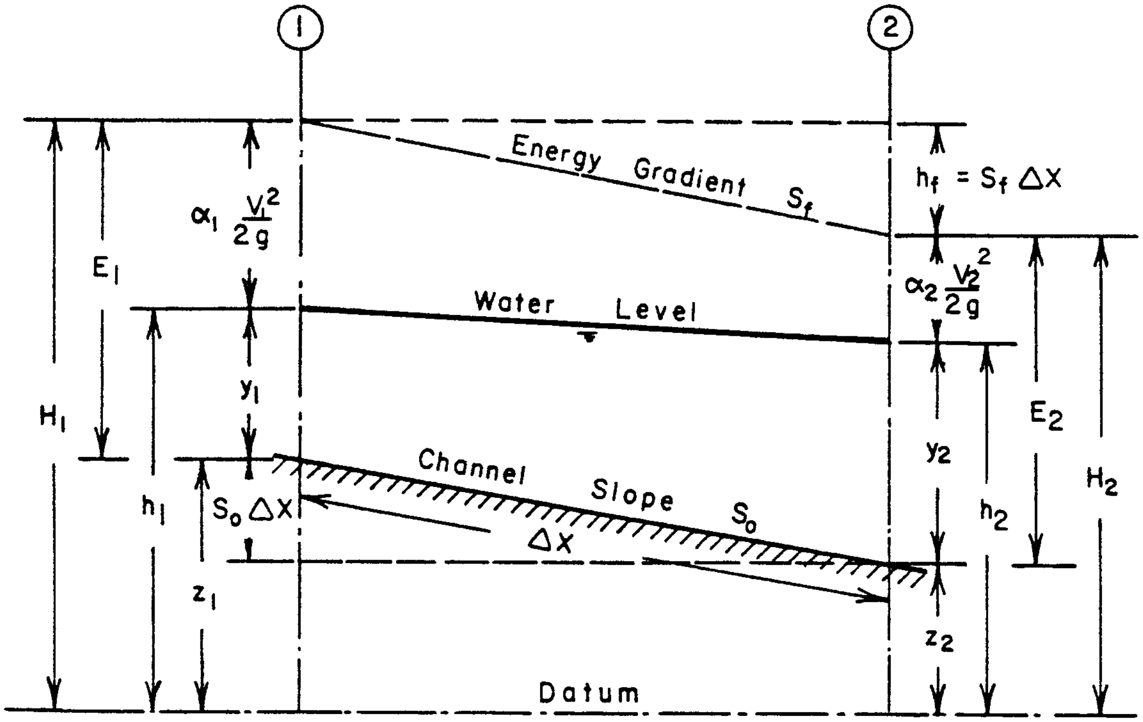
y_1, y_2 - depth of water

V_1, V_2 - velocity

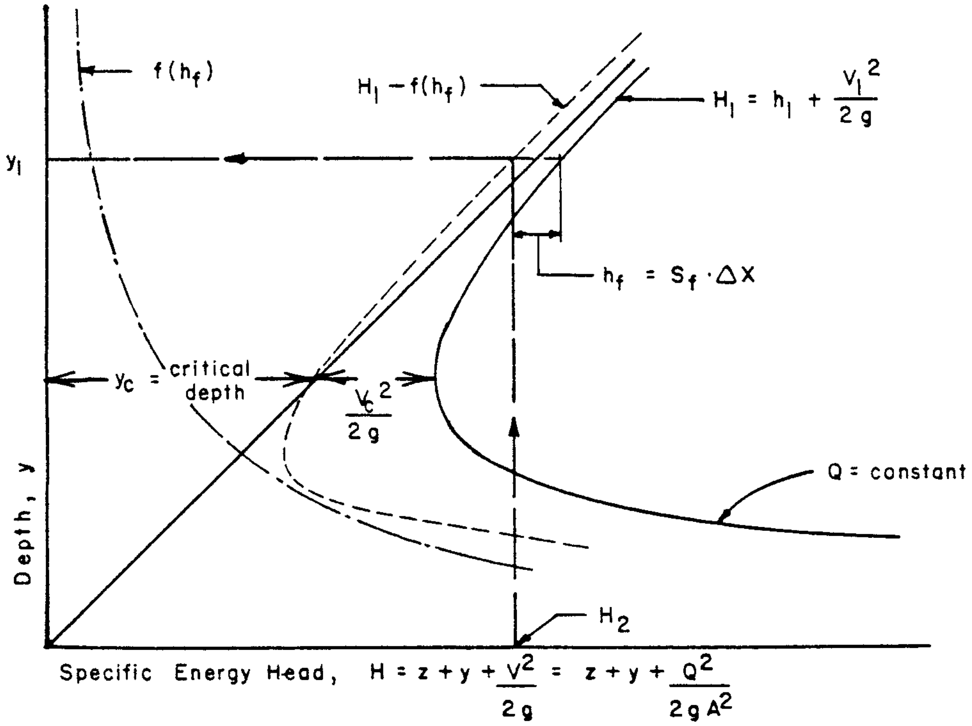
α_1, α_2 - velocity coefficient = 1.0

h_f - head loss between section 1 and 2

g - gravitational accleration



(a) Energy Terms for Gradually Varied Flow



(b) Specific Energy Curve

FIGURE 3·3
ENERGY TERMS
for
GRADUALLY VARIED
FLOW

The head loss is further defined as

$$h_f = \frac{(S_1 + S_2)}{2} \cdot \Delta x \qquad (3.2)$$

where S_1 - energy slope at section 1

S_2 - energy slope at section 2

Δx - distance between 1 and 2

In the Ezra method, the depth of flow and the elevation datum are combined to produce the following equations:

$$h_1 = x_1 + y_1 \qquad (3.3)$$

$$h_2 = z_2 + y_2 \qquad (3.4)$$

Therefore, the steady state equation can be rewritten as:

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g} + h_f \qquad (3.5)$$

or

$$h_1 + F(h_1) = h_2 + F(h_2) \qquad (3.6)$$

where

$$F(h_1) = \frac{V_1^2}{2g} - \frac{S_1}{2} \cdot \Delta x \qquad (3.7)$$

and
$$F(h_2) = \frac{V_2^2}{2g} + \frac{S_2}{2} \cdot \Delta x \tag{3.8}$$

The original method [6] as indicated above used the arithmetic mean of the two friction slopes. It is felt, though, that the geometric mean of the friction slopes gives a better representation of the friction slope between the two sections. Thus for

$$h_f = \Delta x \cdot (S_1 \cdot S_2)^{1/2} \tag{3.9}$$

$$F(h_1) = h_1 + \frac{V_1^2}{2g} - \Delta x \cdot (S_1 \cdot S_2)^{1/2} - h_2 - \frac{V_2^2}{2g} = 0 \tag{3.10}$$

The friction slope is calculated using the discharge and conveyance at the end sections, i.e.

$$S_1 = (\frac{Q}{K_1})^2 \tag{3.11}$$

$$S_2 = (\frac{Q}{K_2})^2 \tag{3.12}$$

Since the water level at section 2 is known as an initial condition, the total energy (H_2) and friction slope (S_2) are easily calculated. In order to determine the energy terms of the upstream section (1), the program calls on subroutine EZRA to solve the basic equation (3.10) by interval halving techniques applied to an assumed water depth. If the initial estimate is in error, the routine improves its estimate as follows, assuming y_r is the initial estimate and y_{r+1} is the improved estimate.

The routine first determines a range of uncertainty, $y_r < y_1 < y_{r+1}$ such that $F_1(y_r) < 0$ and $F_1(y_{r+1}) > 0$. The average depth $(y_r + y_{r+1})/2$ is tested and the following strategy used to shrink the interval of uncertainty, i.e.

$$y_r = (y_r + y_{r+1})/2 \quad \text{if} \quad F((y_r + y_{r+1})/2) > 0 \qquad (3.13)$$

$$y_{r+1} = (y_r + y_{r+1})/2 \quad \text{if} \quad F((y_r + y_{r+1})/2) < 0 \qquad (3.14)$$

A solution is reached when

$$\text{abs}\ [(y_r - y_{r+1})/y_{r+1}] \leq 10^{-5} \qquad (3.15)$$

The routine EZRA is used in a loop analysing successive pairs of cross-sections in an upstream direction using the previously calculated water level as the starting water level for the next set of computations.

Through the command D/S WL, the downstream limit of the profiles is defined while the command COMPUTE is used to define the upstream limit of profile calculations. Only a part of the geometry file need be analysed if desired. Profile computations start by first searching for the upstream limit of the first reach. This is done through the KDS(NODE-1) being greater than zero. In addition, a check is made that NODE is equal to or greater than the upstream limit of profile computations. A profile is then calculated for this particular reach. For each node, critical depth is calculated and compared to the computed water level. If the section is supercritical, the critical water level is used and the section is flagged with the term *CRIT*.

After this tributary is calculated, a search is made for the next tributary by searching for a section with a non-zero water level. It is known that somewhere amongst the higher node numbers, water levels have been computed. Therefore, the search is made starting with node 1, for the node number with the highest positive KDS value. A check is made that this node is between the upstream and downstream limits of the overall computations. This node becomes the new downstream limit of the tributary and the local upstream limit is then defined. Again profiles are calculated for this reach as previously stated and when finished, a new tributary is sought. This time an additional check is made to test the new KDS value such that it is less than the previous highest KDS value used. This process of search and compute is repeated until all profiles contained between the requisite limits have been calculated.

As a sample, and referring to Figures 3.1(a) and 3.1(b), the following would be the order of tributary computations assuming the whole system is to be analysed.

reach	maximum KDS
26-18	999
9-6	23
17-14	22
13-10	20
2-1	11
5-3	8

For each new tributary, the starting water level is derived from the energy level previously calculated for the confluence. This level is compared to the critical energy level for the new downstream node of the tributary. The higher of the two energy levels is used. Again, if the section is critical, it is flagged with the term *CRIT*.

After all tributaries have been analysed between the prescribed limits, the user is invited to submit another command. Now a new downstream water level can be selected and/or a new set of discharge values can be entered to test alternate flow conditions. This process can continue until the command STOP is used to terminate the session. It may be desirable to change cross-section properties through the command EDIT and rerun the profile computations for the same flow conditions.

3.7 Branched Flow Computations

Once the profiles have been calculated, usually the energy levels are incompatible at bifurcations when branches are being modelled. The routine attempts to make the energy levels compatible at the bifurcation by using a modified form of Kirchoff's Laws, i.e.

(i) the sum of the inflows equals the sum of the outflows at the bifurcation;

(ii) the sum of the head loss around the loop is zero.

With reference to Figure 3.2(a), these can be rewritten as:

(i) $$Q_{5,6} + Q_{1,2} = Q_{4,5} \tag{3.16}$$

(ii) $$H_{5,6} + H_{6,7} + H_{7,3} + H_{3,2} + H_{2,1} + H_{1,5} = 0 \tag{3.17}$$

and $$H_{ij} = K_{ij}\ Q^n_{ij} \tag{3.18}$$

that is, for an unbalanced flow condition at the bifurcation

$$\Sigma\ K_{ij} Q^n_{ij} \neq 0 \tag{3.19}$$

In order to improve the flow conditions, an increment of flow is added to the branch.

$$\Sigma\ K_{ij}(Q_{ij} + \Delta Q)^{n} = 0 \tag{3.20}$$

Using a Taylor's expansion and ignoring higher order terms, then,

$$\Sigma\ K_{ij}Q_{ij}^{n} + n\ \Sigma\ \left(K_{ij}Q_{ij}^{n-1}\right) \cdot \Delta Q = 0 \tag{3.21}$$

$$\text{i.e. } \Delta Q = -\frac{\Sigma\ K_{ij}Q_{ij}^{n-1}}{n\Sigma\ K_{ij}Q_{ij}^{n-1}} \tag{3.22}$$

From (3.18), it can be seen that

$$K_{ij} = \frac{H_{ij}}{Q_{ij}^{n}}$$

which can be defined as the head loss per unit flow. This becomes important when there are lateral inflows along the loop. Therefore, by substitution and transposing of terms, the estimated correction to flow is

$$\Delta Q = -\frac{\Sigma\ \Delta E_{ij}}{n\ \Sigma\ \frac{\Delta E_{ij}}{Q_{ij}}} \tag{3.23}$$

where the numerator is the energy difference at the bifurcation and the summation in the denominator is the sum of the individual reach head loss divided by the flow in that reach.

Two problems must be considered when using (3.23). The incremental head loss may be due to an invert discontinuity. If so, this loss should not be included as it is the friction head that is to be balanced. Therefore, a local check is made for critical depth. If the section is critical, then the head loss function between this section and the next downstream section is not included. The other problem is the definition of the head loss to be corrected (the numerator). The head loss to be balanced is the difference between the energy levels and the velocity head at the bifurcation. Strictly speaking, the velocity head correction should be a function of the angle of diversion but this would required additional input data to the program.

Therefore, using m and b to denote the main channel and branch channel, respectively, at the bifurcation, and WL for water level,

$$\Delta E = E_m - E_b - [(E_m - WL_m) - (E_b - WL_b)]$$

$$= E_m - E_b - E_m + WL_m + E_b - WL_b$$

$$\Delta E = WL_m - WL_b \tag{3.24}$$

The index n in (3.18) and subsequently, is defaulted to a value of 2.0 in the program. By applying (3.23) to each loop, the local flow correction is determined and the flow values in the loop are adjusted accordingly. Equation (3.23) is completely correct when using the complete head loss around the loop but when invert discontinuities exist, it is possible that the sign of ΔQ is incorrect. Therefore, in order to derive the correct sign, a comparison is made of the relative energy elevations at the bifurcation,

i.e. if $(E_m \geq E_b)$, $\Delta Q = |\Delta Q|$ (3.25a)

if $(E_m < E_b)$, $\Delta Q = -|\Delta Q|$ (3.25b)

Due to the algorithm used, the downstream and upstream limits of profile computations must encompass all branches modelled.

The method of balancing used is a relaxation process similar to the Hardy-Cross method used in water pipe network analysis. As such, the solution oscillates about the final answer. With not only the flow varying but also the cross-sectional properties varying, the corrections calculated are usually extreme such that an excessive number of iterations are required to obtain a final acceptable solution, especially when two or more loops are being modelled. Therefore, a relaxation factor is applied to all calculated ΔQ corrections resulting in a much faster closure on the solution. The factor is based on the average percentage error difference with respect to total depth of both the water level and energy level expressed as a decimal value. If the average error is greater than 10 percent, then FACTOR = 0.5. If the average error is less than 10 percent, then, FACTOR = (percent error/100)*5.0. It has been found that, assuming six loops are modelled, five loops will close very fast while closure on the sixth loop is somewhat tardy. For single loops, closure occurs well within six iterations depending on its complexity.

When branches are modelled and the command COMPUTE is used, an information statement is printed informing the user that two options are available for branched computations; either profiles and/or error limits can be printed out for every iteration, or printout starts after a predefined error in depth has been reached. If the former option is selected (every iteration printed out), the program asks for the upstream limit of the profiles as previously described. If the user chooses the latter option, the user is asked to define the percent error limit in depth of water relative to the shallower of the two depths at a branch.

It is difficult to say what the percentage should be, although a value suggested in 10.0 percent. Engineering judgement must be used as best fits the problem at hand. The program then asks for the upstream limit of the profiles to be computed.

If the user has chosen to have every iteration printed out, the routine asks if this particular iteration is to be printed out. If the answer is yes, then the title and the profiles are printed out. At the end of the profiles, the error in energy level and water level is printed out together with the correction to flow required to try to balance the energy levels. If printout for the particular iteration is not desired then only the error limits are printed out. In either case, after the error limits are presented, the user is asked if profiles are to be recomputed. If the answer is yes, then the program reverts to the beginning of the command and starts over again. If the answer is no, control passes to COMMAND.

If the user had selected to have printout start after a predetermined error limit is reached, then all previous printout does not appear. One of two statements will appear. If due to the geometric or flow configuration, the balancing process takes more than 10 iterations, the word COMPUTING is printed out to inform the user that computations are proceeding normally. This information is printed every 10 iterations. When the maximum error in all branches is less than the percent error set by the user, the program responds with the request if the next iteration is to be printed out. The error in the next iteration will be less than the error limit defined, since the correction to flow has been added from the previous iteration.

It should be noted that after 50 iterations, the program prints a message accordingly with the comment that one more iteration will be tried.

In actuality, the program reverts to user control, iteration by iteration. If this limit is reached, either the configuration is extremely complex or there is an error in information or data (i.e. flows, connectivity or cross-section data, resistance law) and these should be checked carefully.

In the solution of bifurcated branches, two options presented themselves; explicit solution by trial and error, or, implicit solution by matrix analysis. The method used is the former by applying EZRA around the loop and calculating a flow correction. The implicit method would compute a solution directly but would require a large matrix if the geometry file is extensive. In addition, the speed of computation would probably not be any faster. For channel systems without branches, the explicit method is fast and efficient whereas the implicit method would be no faster than if branches were being modelled. The method used in this program has been selected in consideration that the majority use of the program is the analysis of nonbranched systems.

CHAPTER 4

BRIDGE MODELLING

4.0 GENERAL

One of the main uses of a backwater program is the analysis of the potential inundation of bridges. Therefore, it is incumbent that all sorts of bridge configurations are able to be modelled with reasonable accuracy, taking into consideration size and shape of the opening and the elevation of the road relative to the top of the opening. It is possible for three flow conditions to exist at a bridge, (1) low flow, (2) pressure flow through the opening, (3) weir flow over the roadway, or, any combination of the three types of flow [8,9,10,13].

As such, there are basically three types of bridges to be modelled. Figures 4.1, 4.2 and 4.3 show typical flow conditions at a bridge together with the schematic representation. (The figures appearing in those sections describing the particular bridge type.) In addition, the cross-sections modelled are shown. Most bridges will be modelled as one of these three types or as a combination of them.

It should be noted that pressure flow and weir flow are analyzed using the flow resistance equation selected by the user at the beginning of the program. Pressure flow is not analyzed using an orifice equation and road flow is not treated as a weir using the weir equation. For flooded roads, a Type 2 or Type 3 bridge should be used as explained further in this chapter.

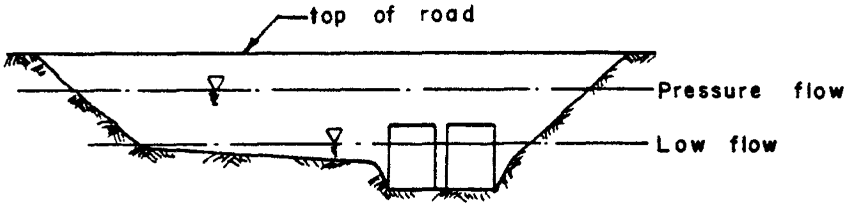
Since the flow resistance equation alone is used, it is difficult to model culverts and bridges with piers in them. Yarnell's work on piers and pier shape is not accounted for in this program [8,9,10].

4.1 Type 1 Bridge

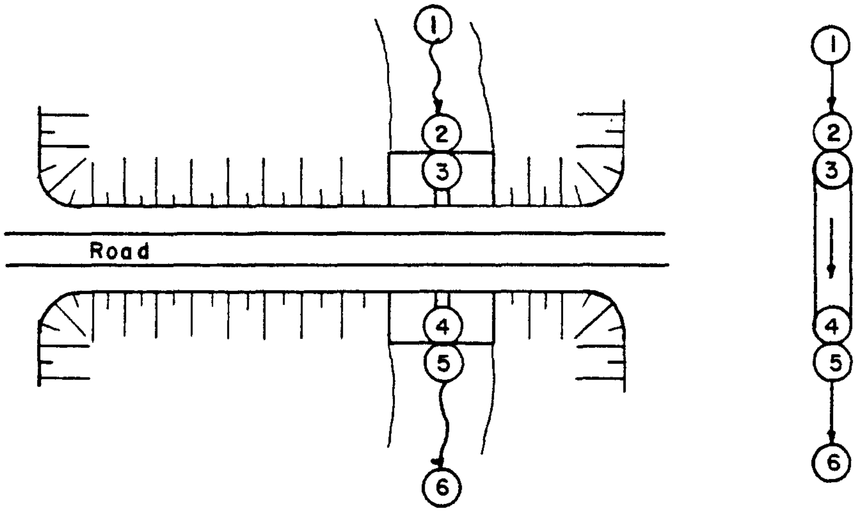
This type of bridge is one in which the roadway or top of the embankment does not flood (Figure 4.1). In addition, the conduit consists of a single structure such as a pipe or box culvert, or as twin box culverts with the same invert and obvert. This bridge represents the simplest form of embankment condition with a closed conduit. The following example illustrates the definition of a twin box culvert as a single cross-section. In Table 4.1.1, the complete geometry file is presented which corresponds to the system shown in Figure 4.1.

It will be noted in cross-sections 3 and 4, that the thickness of the common wall is not represented in the coordinate pairs. Instead, the boundary wall is defined as having zero width, starting at the fourth pair of coordinates and ending with the sixth pair (see Figure 2.1 for typical section).

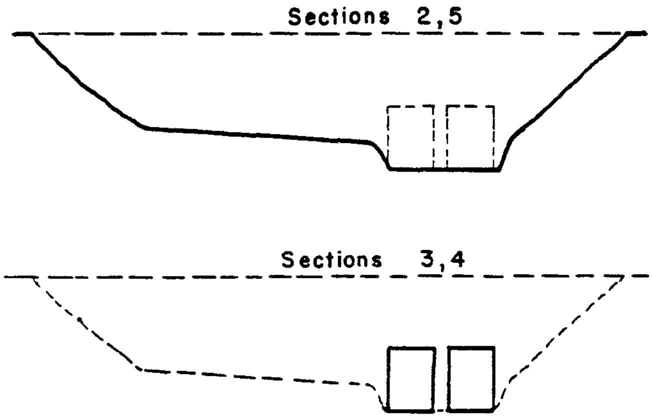
Using Manning's equation, the system was analyzed for four flow conditions, these being 250 cfs, 500 cfs, 750 cfs and 1000



a) PROFILE



b) PLAN and SCHEMATIC



c) CROSS SECTIONS

NOTE: For use with low flow, pressure flow, NO road flow
For use with
- single pipe culvert
- single box culvert
- multi box culvert with same invert and obvert (width may vary)

FIGURE 4·1

TYPE I BRIDGE

TABLE 4.1.1

TYPE 1 BRIDGE DATA

```
              TYPE 1 BRIDGE
                 MAIN CHANNEL   1 - 6
                 TWIN BOX       3 - 4
 1     6    -800.0      0.035
 1       0.0       100.0       20.0        95.0       98.0        94.0
 1     100.0        92.5      122.0        92.5      150.0       100.0
 2     6    -500.0      0.035
 2       0.0       100.0       20.0        95.0       98.0        94.0
 2     100.0        92.0      122.0        92.0      150.0       100.0
 3     9    -500.0      0.013
 3     110.0        97.0      100.0        97.0      100.0        92.0
 3     110.0        92.0      110.0        97.0      110.0        92.0
 3     120.0        92.0      120.0        97.0      110.0        97.0
 4     9    -300.0      0.013
 4     110.0        96.8      100.0        96.8      100.0        91.8
 4     110.0        91.8      110.0        96.8      110.0        91.8
 4     120.0        91.8      120.0        96.8      110.0        96.8
 5     6    -300.0      0.035
 5       0.0       100.0       20.0        95.0       98.0        94.0
 5     100.0        91.8      122.0        91.8      150.0       100.0
 6     6       0.0      0.035
 6       0.0       100.0       20.0        94.0       98.0        93.0
 6     100.0        91.0      122.0        91.0      150.0       100.0
```

TABLE 4.1.2 TYPE 1 BRIDGE (250 c.f.s.)

```
SUMMARY OF INPUT DATA FOR

    TYPE 1 BRIDGE



 UNITS USED ARE  -IMPERIAL-



 CONNECTIVITY TABLE


NODE NO.       1     2     3     4     5     6
KDS(NODE)      0     0     0     0     0   999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO    6  INCLUSIVE, IN ORDER:-

  250.000   250.000   250.000   250.000   250.000
  250.000

INITIAL WATER LEVEL AT NODE    6  IS    93.968

RESISTANCE LAW BEING USED IS - MANNING  -

HEAD LOSS COEFF. AT CONTRACTIONS CLC =      .600
                 AT EXPANSIONS   CLE =      .800


COMMAND?

? COMPUTE
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (   )
?     1


    TYPE 1 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.      EN.LEV.     INV.       VEL.

  6              0.0   250.000    93.968    94.036    91.000    2.092
  5           -300.0   250.000    94.694    94.790    91.800    2.492
  4           -300.0   250.000    94.654    94.952    91.800    4.380
  3           -500.0   250.000    94.773    95.088    92.000    4.508
  2           -500.0   250.000    95.207    95.251    92.000    1.687
  1           -800.0   250.000    95.497    95.532    92.500    1.511

COMMAND?

?
```

TABLE 4.1.2 (CONT'D) (500 c.f.s.)

```
SUMMARY OF INPUT DATA FOR

    TYPE 1 BRIDGE


 UNITS USED ARE  -IMPERIAL-


 CONNECTIVITY TABLE


NODE NO.      1     2     3     4     5     6
KDS(NODE)     0     0     0     0     0   999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO    6  INCLUSIVE, IN ORDER:-

  500.000   500.000   500.000   500.000   500.000
  500.000

INITIAL WATER LEVEL AT NODE    6  IS    95.321

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .600
                 AT EXPANSIONS   CLE =       .200


COMMAND?

? COMPUTE
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (   )
?     1


    TYPE 1 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.    W.L.      EN.LEV.    INV.      VEL.

  6              0.0   500.000   95.321    95.372    91.000   1.814
  5           -200.0   500.000   95.504    95.683    91.000   3.521
  4           -300.0   500.000   95.459    96.124    91.000   6.533
  3           -500.0   500.000   95.745    96.437    92.000   6.676
  2           -500.0   500.000   96.798    96.832    92.000   1.474
  1           -800.0   500.000   96.897    96.932    92.500   1.496

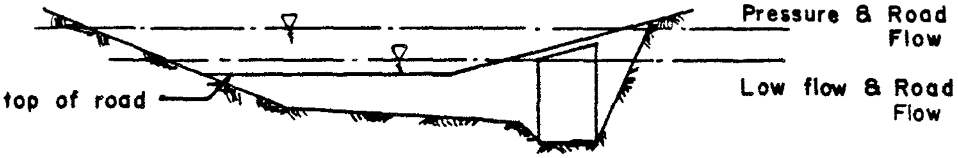
COMMAND?
```

cfs. The summary listing and profile results for 250 cfs and 1000 cfs are presented in Table 4.1.2. The initial water level at section 6 was assumed to be twice critical depth. As is to be expected, the higher the discharge, the higher is the water level upstream of the bridge. At a flow of 1000 cfs, the accleration created by the head upstream of the bridge has forced the flow to be supercritical at the downstream end of the bridge. This is shown by the term *CRIT* listed for section 4 indicating the possibility of a hydraulic jump occuring.

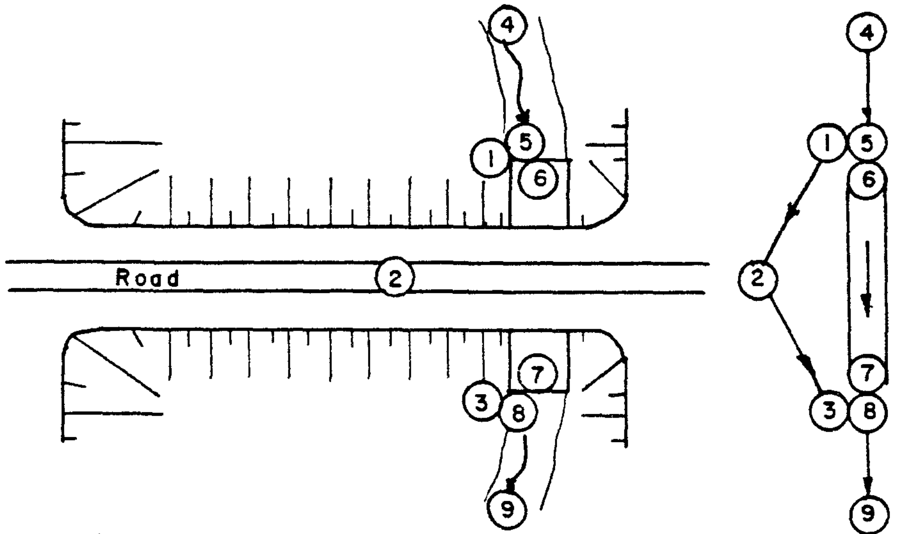
In section 3, the water level is listed as 97.521 which is above the crown of the culvert. What has been printed is not the "water level", but the piezometric surface. For very long culverts, it may be desirable to model one or more sections between the inlet and outlet in order to determine the piezometric profile throughout its length. The computed results have been compared to those obtained by other more traditional methods and the results are quite similar.

4.2 Type 2 Bridge

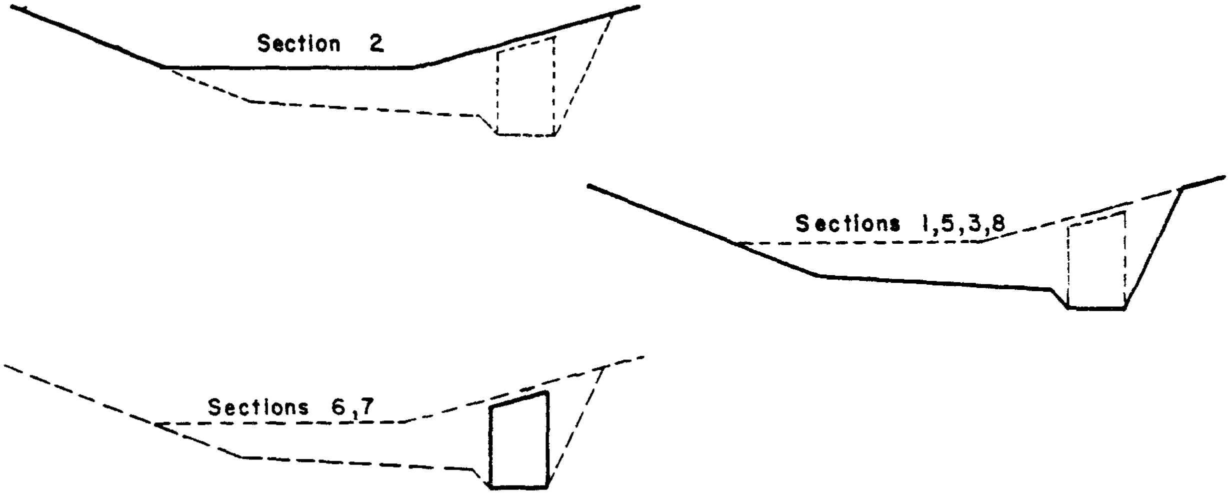
The bridge shown in Figure 4.2 represents the typical bridge that may be subject to flooding of the roadway. The flow path for the flooded roadway is represented as a bifurcated branch using nodes 1 to 3 inclusive. The example also defines a perched bridge where the road may be subject to flooding while low flow



a) PROFILE



b) PLAN and SCHEMATIC



c) CROSS SECTIONS

FIGURE 4·2

TYPE 2 BRIDGE

TABLE 4.2.1

TYPE 2 BRIDGE DATA

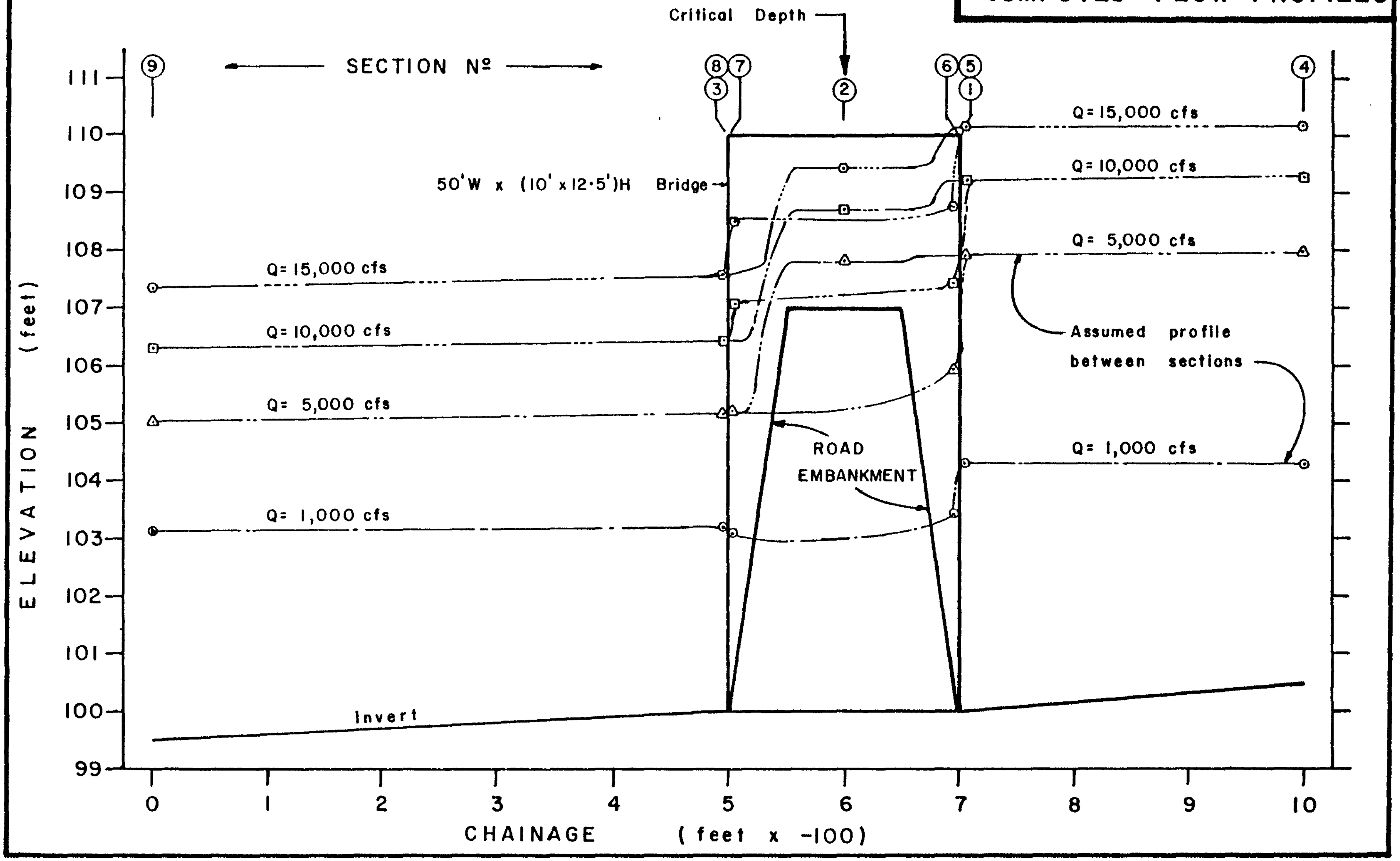
```
      TYPE 2 BRIDGE
         MAIN CHANNEL   4 - 9  WITH BRIDGE AT  6,7
         TOP OF ROAD    1 - 3 , CONNECT @ 8, BRANCH @ 5

1     6   -700.0      0.035
1       0.0     120.0      50.0     102.0     850.0     102.0
1     860.0     100.0     910.0     100.0     960.0     120.0
2     4   -600.0      0.02
2       0.0     120.0     200.0     107.0     700.0     107.0
2     960.0     120.0
3     6   -500.0      0.035
3       0.0     120.0      50.0     102.0     850.0     102.0
3     860.0     100.0     910.0     100.0     960.0     120.0
4     6  -1000.0      0.035
4       0.0     120.5      50.0     102.5     850.0     102.5
4     860.0     100.5     910.0     100.5     960.0     120.5
5     6   -700.0      0.035
5       0.0     120.0      50.0     102.0     850.0     102.0
5     860.0     100.0     910.0     100.0     960.0     120.0
6     5   -700.0      0.018
6     860.0     110.0     860.0     100.0     910.0     100.0
6     910.0     112.5     860.0     110.0
7     5   -500.0      0.018
7     860.0     110.0     860.0     100.0     910.0     100.0
7     910.0     112.5     860.0     110.0
8     6   -500.0      0.035
8       0.0     120.0      50.0     102.0     850.0     102.0
8     860.0     100.0     910.0     100.0     960.0     120.0
9     6      0.0      0.035
9       0.0     119.5      50.0     101.5     850.0     101.5
9     860.0      99.5     910.0      99.5     960.0     119.5
```

still exists through the bridge. As a design alternative, it may be advisable to have the road flood in order to save the bridge. If the bridge were to be washed out, the cost in money and time to replace it are usually quite high whereas if the road is washed out, the cost in time and money is considerably less in hauling and compacting earth fill.

A typical data set for the system shown in Figure 4.2 is presented in Table 4.2.1. The system was analysed using Mannings equation for several discharge values. Initially, the system was represented as having only a tributary (nodes 1 to 3, inclusive) and no branches. A flow of 1,000 cfs entering at node 4 was modelled in which the computed profile indicated the existence of low flow through the bridge. The tributary 1-3 was said to have a discharge of QMIN. Profiles were not calculated for this tributary as no flow existed (i.e. upstream and downstream limits of computations were defined as 4 and 9, respectively). The starting downstream water level was arbitrarily defined as twice critical depth for the previous and all subsequent discharges. When the discharge was increased to 2,500 cfs, the calculated water elevation at node 5 was higher than the low elevation of the road indicating that the road was flooding. Command BRANCH was then used to define a bifurcation from node 5 to node 1, and the profile was recalculated for a flow of 2,500 cfs. Figure 4.2.1 shows a plot of the calculated profiles for flows ranging from

FIGURE 4·2·1
TYPE 2 BRIDGE
COMPUTED FLOW PROFILES



1,000 cfs to 15,000 cfs. The percent error limit for termination of computations was set at 10 percent.

Though the road flow is not calculated using a weir formula, it is of interest to compare the computed depth of flow to the weir formula. The road cross-section in the direction of flow is similar to that of a broad crested weir [3,4,8,10]. The broad crested weir formula is

$$Q = 3.087L(h+h_v)^{3/2} \tag{4.1}$$

where Q - flow, cfs

L - average length of the weir (road) (ft)

h - depth of water upstream of weir above the weir (road) elevation (ft)

h_v - corresponding velocity head of approach (ft)

The term in brackets is the same as the difference between the energy elevation upstream and the elevation of the road. Using the average of the energy levels at nodes 1 and 5, the theoretical depth $(h+h_v)$ for the computed road flow has been calculated and the percent error determined. These results are presented in Table 4.2.2. The results are in good agreement especially at the higher flow levels. At the low flows, the percent error is quite high but considering the actual depth,

TABLE 4.2.2 COMPARISON OF ROAD FLOW AND WEIR FLOW

$$h(\text{weir}) = \left[\frac{Q(\text{weir})}{3.087\,L}\right]^{2/3}$$

Road Elevation = 107.0

Elevation in feet
Flow in c.f.s.

Q(Total)	Q(bridge)	EL(bridge)	Q(road)	EL(road)	EL% error	No.of Comp.	h_e(avg.)	L(avg.)	h(weir)	% error in h
2,500	2371.122	107.335	128.878	107.193	1.98	3	0.264	504.06	0.190	+38.00
3,500	2511.292	107.606	988.708	107.746	1.85	3	0.676	510.40	0.733	- 7.77
4,000	2548.399	107.681	1451.601	107.962	3.67	2	0.822	512.65	0.944	-12.93
5,000	2684.892	107.971	2315.108	108.306	4.21	2	1.139	517.52	1.281	-11.05
7,000	3320.667	109.149	3679.333	108.766	4.36	2	1.958	530.12	1.714	+14.09
8,000	3460.721	109.428	4539.279	109.024	4.47	2	2.226	534.25	1.964	+13.34
10,000	3190.896	109.259	6809.105	109.627	3.97	2	2.443	537.58	2.563	- 4.68
12,000	3295.690	109.676	8704.310	110.073	4.10	3	2.875	544.23	2.994	- 3.98
15,000	3273.979	110.148	11726.021	110.711	5.55	6	3.430	552.77	3.604	- 5.10

Q - discharge (cfs); EL - energy level; h_e(avg.) - effective head over road ($h + h_v$)

EL% error - error in computed energy level expressed as a percentage of depth

No. of comp - number of iterations computed to reduce error to below 10%

L(avg.) - average length of flooded road

h(weir) - computed equivalent weir depth for given Q(road)

% error in h - percentage difference between h of weir formula and computed depth over road the results are acceptable. The item "No. of Comp" indicates the number of iterations required to reduce the error to less than 10 percent.

The stage-discharge relationship at the bifurcation has been plotted in Figure 4.2.2 together with the maximum velocity at the downstream end of the bridge. It will be noted in the stage curves that the road system begins to take more and more of the flow for small increased in elevation. The curves also indicate that the road would start to flood at a discharge of about 2,400 cfs.

The velocity curve indicates a design condition for the bridge occurs at about 2,400 cfs just as the road begins to flood. At this discharge, the maximum velocity occurs at the downstream end of the bridge. This would be the critical velocity as an upper limit to be designed for when considering erosion of footings and channel materials. At about 7,000 cfs, a secondary peak velocity occurs though it is lower than that which occurs at 2,400 cfs. At higher discharges upstream, the velocity through the bridge tends to decrease. It will be noted in the curve that the flow through the bridge begins to decrease as the total flow increases. The profile results for an initial flow of 5,000 cfs is presented in Table 4.2.3.

The use of the program as a design tool is indicated by the time spent analyzing all the flow ranges, from 1,000 cfs to 15,000 cfs. In three-quarters of an hour, the road flooding discharge,

FIGURE 4·2·2
TYPE 2 BRIDGE
VELOCITY PROFILE and DISCHARGE DISTRIBUTION

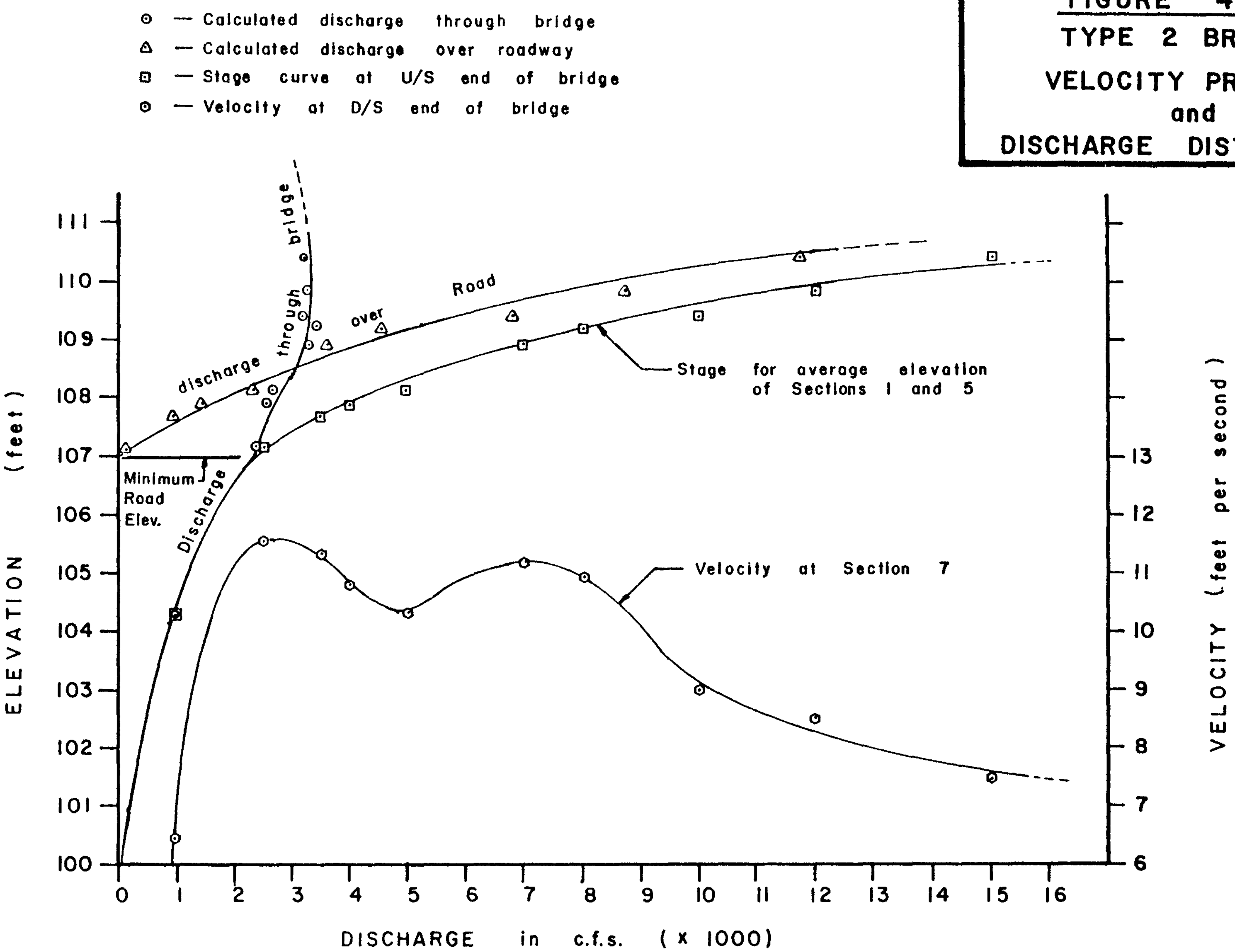


TABLE 4.2.3 TYPE 2 BRIDGE
PROFILE FOR 5000 CFS

```
TYPE 2 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.       EN.LEV.     INV.       VEL.

  9              0.0  5000.000   105.028   105.066    99.500   1.563
  8           -500.0  5000.000   105.163   105.210   100.000   1.737
  7           -500.0  2684.892   105.193   106.853   100.000  10.340
  6           -700.0  2684.892   105.949   107.214   100.000   9.026
  5           -700.0  2684.892   107.967   107.971   100.000    .500
  4          -1000.0  5000.000   107.980   107.996   100.500   1.013


SEC.  STATN.  CHAINAGE  DISCH.     W.L.       EN.LEV.     INV.       VEL.

  3           -500.0  2315.108   105.200   105.210   100.000    .795
  2           -600.0  2315.108   107.860   108.281   107.000   5.210*CRIT*
  1           -700.0  2315.108   108.304   108.306   100.000    .408

BRANCH     5  TO      1
E.L.   107.971   108.306 DIFF AS PCNT OF SMALLER DEPTH=  4.21
W.L.   107.967   108.304 DIFF AS PCNT OF SMALLER DEPTH=  4.22
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=   -82.709

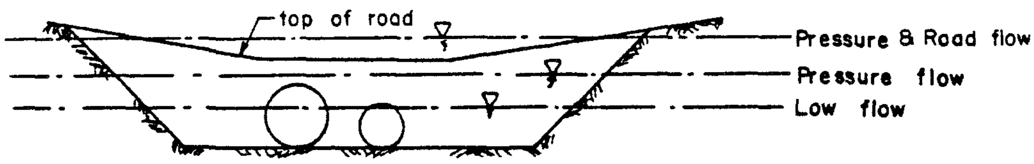
DO YOU WANT PROFILES RECOMPUTED...YES/NO?
? NO
```

the maximum erosion velocity for both the bridge and the roadway, and maximum stage upstream were all determined. The turnaround speed is sufficiently fast enough that an additional one-half hour could be spent testing the effects of changing the value of the head loss coefficients. If desired a wider or narrower bridge may also be considered for analysis.

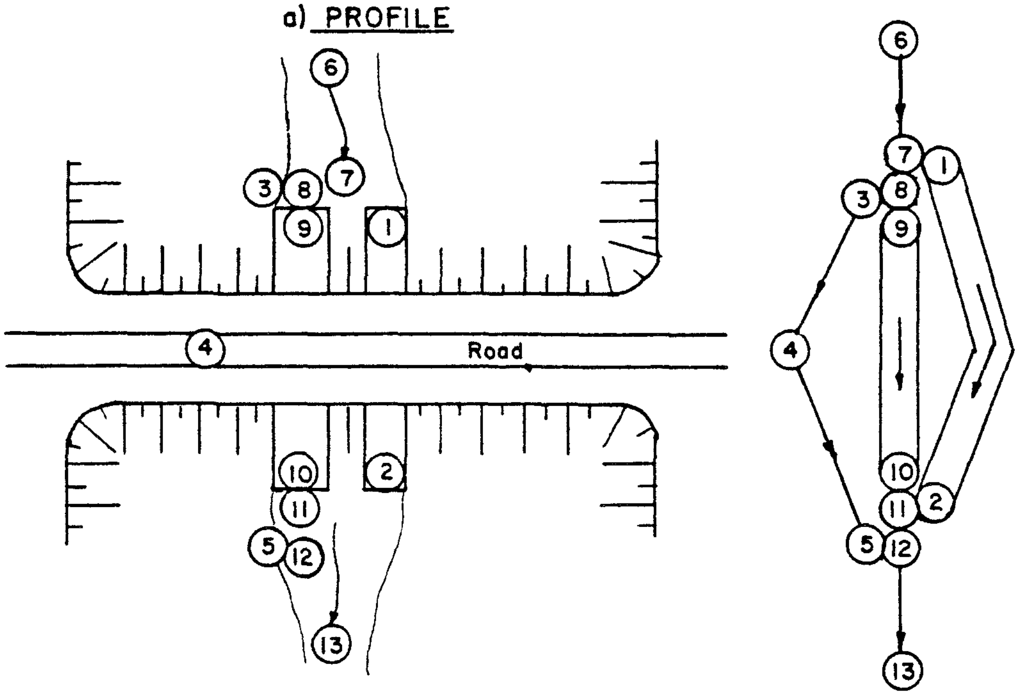
Of importance in this example is the use of defining branched flows. At the initial stages, branch flow was assumed not to exist until information was presented indicating that flooding of the road was likely to occur. Then the BRANCH option was used to define the road system. By not defining the road system at low flows, the computation time has been reduced significantly.

4.3 Type 3 Bridge

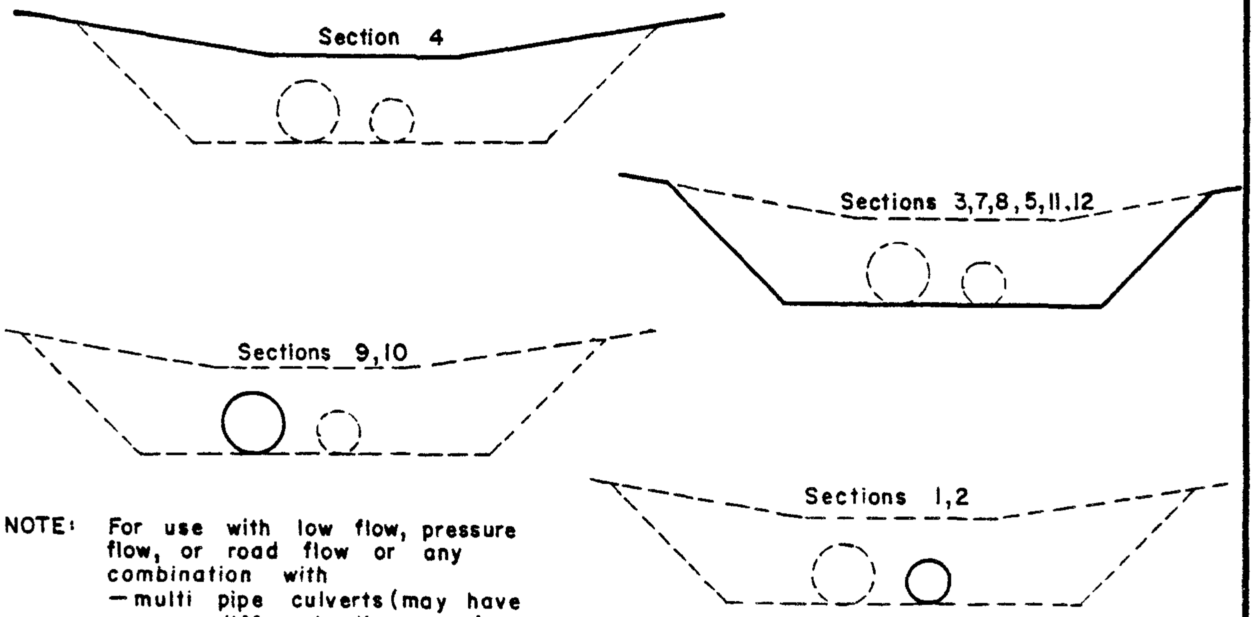
In this example, the bridge structure is represented by two pipe culverts of different diameters. Due to the difference in diameters, each culvert is modelled separately and joined together by command BRANCH at the beginning of the computations. In addition, there is a possibility of the road being flooded and it, too, is modelled separately. The example as shown illustrates the consideration that should be given to the numbering of the nodes. As presented, the small culvert is modelled by nodes 1 and 2 and the road by nodes 3 to 5, inclusive. This means that the limits



a) PROFILE



b) PLAN and SCHEMATIC



NOTE: For use with low flow, pressure flow, or road flow or any combination with
- multi pipe culverts (may have different diameters)
- multi box culverts with different inverts/obverts

c) CROSS SECTIONS

FIGURE 4·3

TYPE 3 BRIDGE

TABLE 4.3.1 TYPE 3 BRIDGE DATA

```
          TYPE 3 BRIDGE
             MAIN CHANNEL   6 - 13
             3.0 DIAM.      9 - 10
             2.0 DIAM.      1 -  2 , CONNECT @ 11, BRANCH @ 7
             TOP OF ROAD    3 -  5 , CONNECT @ 12, BRANCH @ 8
   1    1   -500.0     0.024
   1      2.0      100.0
   2    1   -300.0     0.024
   2      2.0       99.5
   3    4   -500.0     0.035
   3      0.0      110.0      110.0      100.0      130.0      100.0
   3    230.0      110.0
   4    4   -400.0     0.020
   4      0.0      110.0      100.0      105.0      130.0      105.0
   4    230.0      110.0
   5    4   -300.0     0.035
   5      0.0      110.0      110.0       99.5      120.0       99.5
   5    230.0      110.0
   6    4   -800.0     0.035
   6      0.0      110.0      110.0      100.5      120.0      100.5
   6    230.0      110.0
   7    4   -500.0     0.035
   7      0.0      110.0      110.0      100.0      120.0      100.0
   7    230.0      110.0
   8    4   -500.0     0.035
   8      0.0      110.0      110.0      100.0      120.0      100.0
   8    230.0      110.0
   9    1   -500.0     0.024
   9      3.0      100.0
  10    1   -300.0     0.024
  10      3.0       99.5
  11    4   -300.0     0.035
  11      0.0      110.0      110.0       99.5      120. 0       99.5
  11    230.0      110.0
  12    4   -300.0     0.035
  12      0.0      110.0      110.0       99.5      120.0       99.5
  12    230.0      110.0
  13    4      0.0     0.035
  13      0.0      110.0      110.0       99.0      120.0       99.0
  13    230.0      110.0
-EOR-
 -END OF INFORMATION-
```

of computations must include the road tributary even at low flows, as only by including the road can the bifurcated flow through the culverts be assessed. When the results are printed out, it will be noted that the road flow is listed with Q = .000 (i.e. QMIN) and an appropriate velocity. Although the example has been modelled as shown to illustrate this point, it would have been better to model the road by node numbers 1 to 3 inclusive and the smaller culvert by nodes 4 and 5. The example shows that some thought should be given to the overall numbering of networks. It should also be noted that the bifurcation for the culvert occurs further upstream followed by the road bifurcation. By modelling this way, the culvert receives its share of the divided flow before the road does. In addition, the culvert joins the main stream before the road.

Table 4.3.1 shows a typical data list for a Type 3 bridge and corresponds to the network shown in Figure 4.3. The system was subjected to flows ranging from 25 cfs to 150 cfs using Mannings equation. The downstream water level was set at twice critical depth.

At flows above 50 cfs, the roadway begins to flood. The profile results for 25 cfs, 75 cfs, and 150 cfs are plotted in Figure 4.3.1. Again the error limits for termination of computation was set at 10 percent. The division of flow between the two culverts and the roadway has been plotted in Figure 4.3.2.

FIGURE 4·3·1

TYPE 3 BRIDGE

COMPUTED FLOW PROFILES

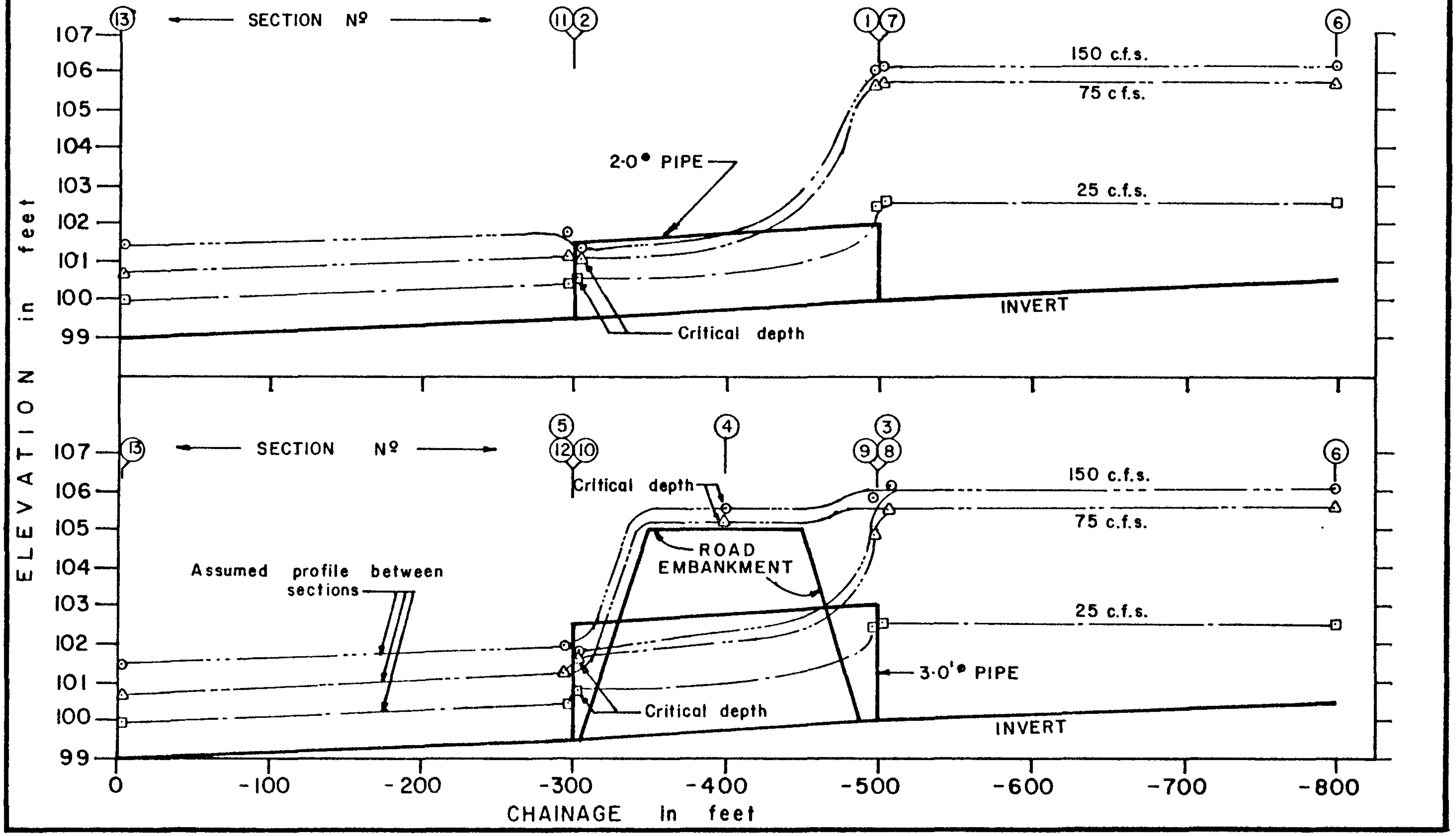


FIGURE 4·3·2

TYPE 3 BRIDGE

DISCHARGE DISTRIBUTION

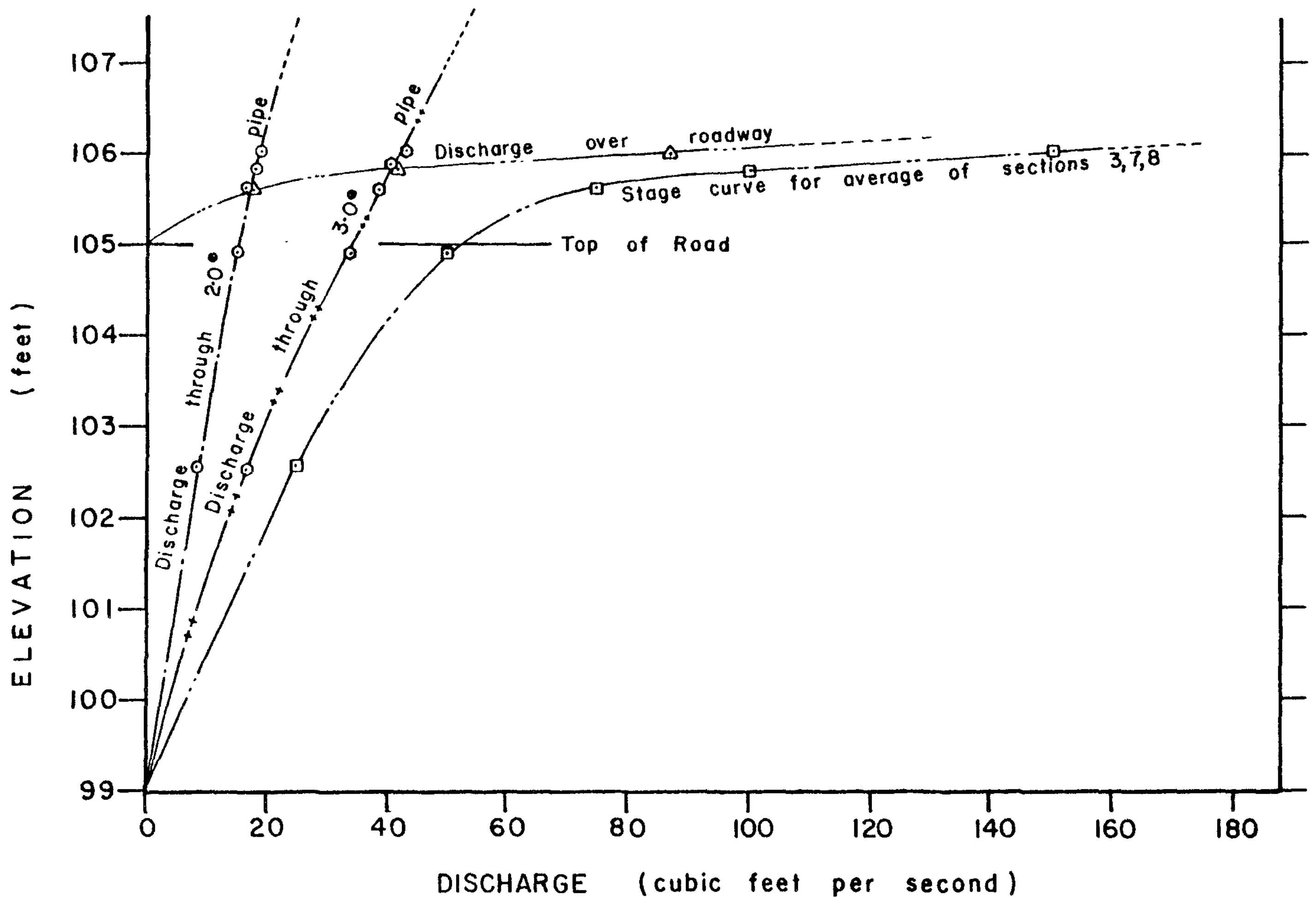


TABLE 4.3.2(a) TYPE 3 BRIDGE
PROFILE FOR 50 CFS

```
   TYPE 3 BRIDGE



SEC.  STATN.  CHAINAGE  DISCH.     W.L.      EN.LEV.     INV.       VEL.

 13              0.0    50.000   100.390   100.425     99.000   1.505
 12           -300.0    50.000   100.852   100.888     99.500   1.531
 11           -300.0    50.000   100.852   100.888     99.500   1.531
 10           -300.0    34.325   101.403   102.221     99.500   7.259*CRIT*
  9           -500.0    34.325   104.307   104.673    100.000   4.856
  8           -500.0    34.325   104.893   104.893    100.000    .110
  7           -500.0    34.325   104.893   104.893    100.000    .110
  6           -800.0    50.000   104.894   104.895    100.500    .187


SEC.  STATN.  CHAINAGE  DISCH.     W.L.      EN.LEV.     INV.       VEL.

  5           -300.0      .000   100.888   100.888     99.500    .000
  4           -400.0      .000   105.000   105.000    105.000    .060*CRIT*
  3           -500.0      .000   105.000   105.000    100.000   0.000


SEC.  STATN.  CHAINAGE  DISCH.     W.L.      EN.LEV.     INV.       VEL.

  2           -300.0    15.675   100.927   101.590     99.500   6.535*CRIT*
  1           -500.0    15.675   104.986   105.373    100.000   4.990

BRANCH     7  TO      1
E.L.   104.893   105.373 DIFF AS PCNT OF SMALLER DEPTH=  9.80
W.L.   104.893   104.986 DIFF AS PCNT OF SMALLER DEPTH=  1.90
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=     -.142
```

TABLE 4.3.2(b) TYPE 3 BRIDGE
PROFILE FOR 150 CFS

```
  TYPE 3 BRIDGE



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.       VEL.

 13               0.0   150.000   101.478   101.525     99.000    1.740
 12            -300.0   150.000   101.318   101.873     99.500    1.088
 11            -300.0    62.962   101.931   101.939     99.500     .730
 10            -300.0    43.640   101.824   102.680     99.500    7.429
  9            -500.0    43.640   105.150   105.742    100.000    6.174
  8            -500.0    43.640   106.097   106.097    100.000     .093
  7            -500.0   130.673   106.097   106.098    100.000     .278
  6            -800.0   150.000   106.101   106.103    100.500     .358



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.       VEL.

  5            -300.0    87.039   101.855   101.873     99.500    1.066
  4            -400.0    87.039   105.544   105.773    105.000    3.840*CRIT*
  3            -500.0    87.039   105.800   105.800    100.000     .186


SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.       VEL.

  2            -300.0    19.322   101.268   101.939     99.500    6.576
  1            -500.0    19.322   106.019   106.607    100.000    6.150

BRANCH      7  TO      1
E.L.    106.098   106.607 DIFF AS PCNT OF SMALLER DEPTH=  8.34
W.L.    106.097   106.019 DIFF AS PCNT OF SMALLER DEPTH=  1.29
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=      -.133


BRANCH      8  TO      3
E.L.    106.097   105.800 DIFF AS PCNT OF SMALLER DEPTH=  5.12
W.L.    106.097   105.800 DIFF AS PCNT OF SMALLER DEPTH=  5.13
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=       .777
```

As is to be expected, the roadway takes the majority flow at high initial flow levels. The figure indicates that flooding of the road occurs at about 53 cfs.

Tables 4.3.2(a) and (b) show the computed profiles for 50 cfs and 150 cfs respectively. In part (a) the flow over the roadway has been defined as Q = .000 (i.e. QMIN).

4.4 Modelling Overland Flow

The previous "bridge" types serve as an introduction to modelling sewer systems with or without overland flow. The basic sewer system is modelled as a plain network without considering manholes. If the discharge is sufficiently large, causing the sewer(s) to surcharge, the system is acting similar to a Type 1 bridge. That is, the water level printed out is the pieozometric surface. From this information, the potential of reverse slope driveways being flooded can be assessed [5].

If the flow is very large, it is possible that manholes may be flooded causing overland flow through gutters and ditches to occur. When such a situation occurs, the manhole is usually modelled in order to represent the road elevation. Figure 4.4 shows such a system. In addition, the system has been designed to flood by using a sub-diameter pipe from nodes 22 to 23. The technique can be used to force overland flow around some particularly sensitive location. Alternatively, an elevated sewer

FIGURE 4·4

SEWER SYSTEM WITH OVERLAND FLOW

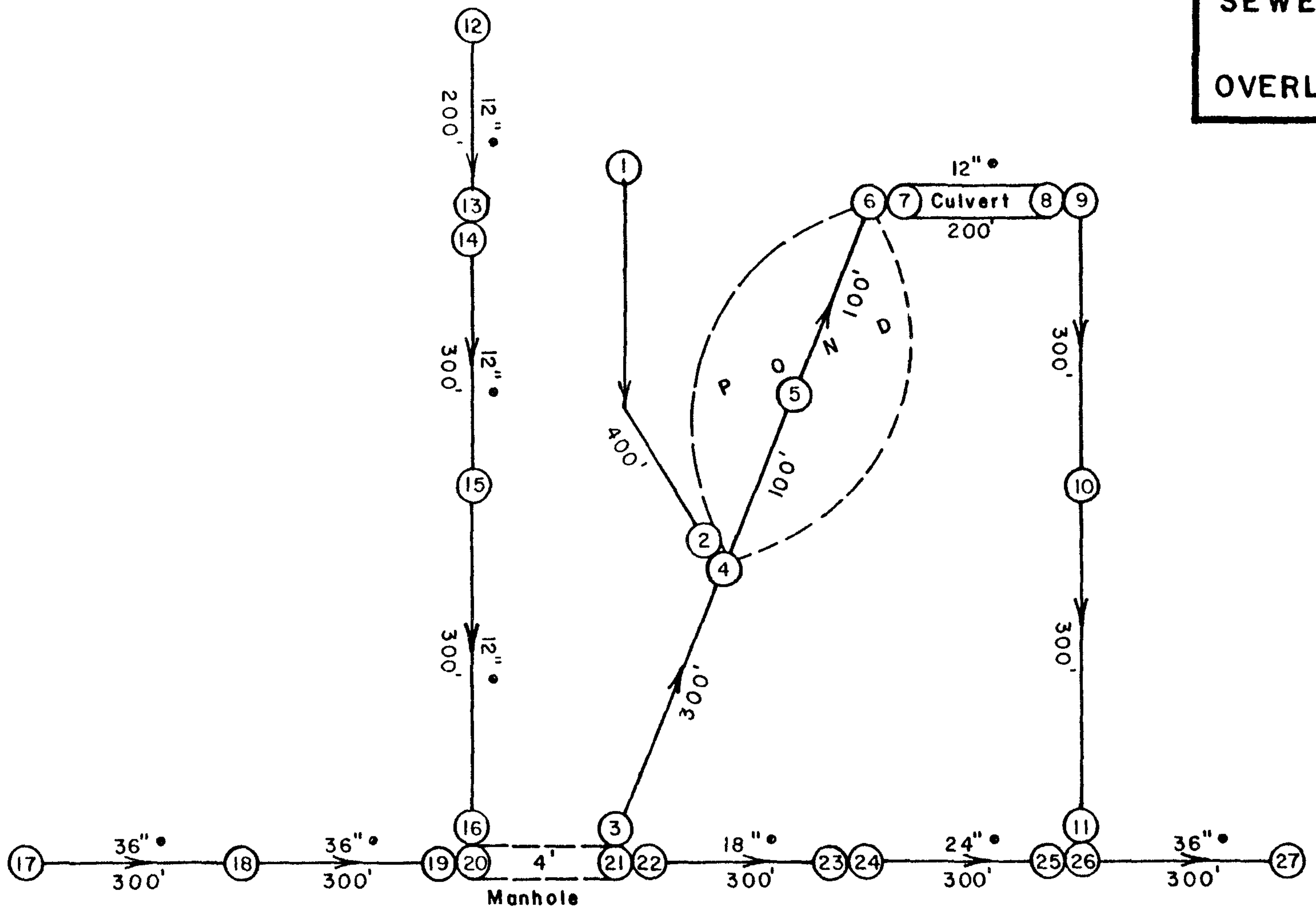


TABLE 4.4.1 SEWER SYSTEM DATA

```
            SEWER SYSTEM WITH OVERLAND FLOW
                   MAIN     17 -- 27
                   TRIBS    12 -- 16 CONNECT @ 20
                              3 -- 11 CONNECT @ 26, BRANCH @ 21
                              1 --  2 CONNECT @  4

            BACK YARD DRAINAGE DITCH
 1     3   -1200.     0.030
 1      0.0      116.00      6.0       114.00      12.0      116.00
 2     3   -1400.     0.030
 2      0.0      114.00      6.0       112.00      12.0      114.00
            MAIN OVERFLOW DITCH ( 3-11) FROM 21
 3     3   -1700.     0.030
 3      0.0      114.00      6.0       112.00      12.0      114.00
 4     3   -1400.     0.030
 4      0.0      114.00     10.0       110.50      20.0      114.00
            POND
 5     4   -1300.     0.020
 5      0.0      114.00     30.0       105.00      40.0      105.00
 5     70.0      114.00
 6     4   -1200.     0.020
 6      0.0      114.00     10.0       110.00      11.0      110.00
 6     21.0      114.00
            OVERFLOW CONTROL PIPE FOR POND
 7     1   -1200.     0.024
 7      1.0      110.00
 8     1   -1000.     0.024
 8      1.0      109.50
 9     4   -1000.     0.030
 9      0.0      113.00     10.0       109.00      12.0      109.00
 9     22.0      113.00
10     3    -600.     0.030
10      0.0      110.00      6.0       108.00      12.0      110.00
11     3    -300.     0.030
11      0.0      109.00      6.0       106.50      12.0      109.00
            TRIBUTARY SEWER (12 - 16)
12     1   -1704.     0.013
12      1.0      110.00
13     1   -1504.     0.013
13      1.0      109.00
14     1   -1504.     0.015
14      1.0      109.00
15     1   -1204.     0.015
15      1.0      107.50
16     1    -904.     0.015
16      1.0      106.00
```

TABLE 4.4.1 (CONT'D)

```
             MAIN SEWER FROM HERE TO END OF FILE
    17     1   -1504.    0.013
    17      3.0       108.00
    18     1   -1204.    0.013
    18      3.0       106.50
    19     1     -904.    0.013
    19      3.0       105.00
    20     4     -904.    0.013
    20      0.0       112.00      0.0      105.00       4.0      105.00
    20      4.0       112.00
             (20 & 21) MANHOLE
    21     4     -900.    0.013
    21      0.0       112.00      0.0      105.00       4.0      105.00
    21      4.0       112.00
             NEXT 2 SEC. - RESTRICTION IN SEWER SIZE
    22     1     -900.    0.015
    22      1.5       105.00
    23     1     -600.    0.015
    23      1.5       103.50
    24     1     -600.    0.013
    24      2.0       102.5
    25     1     -300.    0.013
    25      2.0       101.75
    26     1     -300.    0.013
    26      3.0       100.75
    27     1         0.    0.013
    27      3.0       100.00

*EOR*
 *END OF INFORMATION*
?
```

outlet could be used to divert flow to another sewer system. Table 4.4.1 comprises the typical data for this system.

In the system, the overland flow is defined as going to a detention pond for which the outlet is a one foot diameter pipe. Flows then go to a ditch inlet and drop into the sewer system. Nodes 1 and 2 represent a ditch or a backyard swale.

The system was assumed to have an inflow condition of:

NODE	INFLOW
1	1 cfs
12	1 cfs
17	15 cfs

The computed profile results are presented in Table 4.4.2. In order to derive the profile, 14 iterations were required due to the invert difference between nodes 21 and 3. The initial computation has computed a critical depth considerably lower than the invert at node 3. Therefore, the branch flow starts with a flow of QMIN requiring the increased number of iterations to reduce the error in water level.

It should be noted that the 5 percent error in water levels is referenced to the depth of the ditch at node 3 (being 1.59 feet) and not the depth of the manhole, it being 8.66 feet deep.

TABLE 4.4.2 PROFILE FOR SEWER SYSTEM

```
SEWER SYSTEM WITH OVERLAND FLOW.


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 27                0.0   17.000  102.636   102.740   100.000   2.583
 26             -300.0   17.000  102.796   102.967   100.750   3.310
 25             -300.0   14.965  103.144   103.780   101.750   6.400*CRIT*
 24             -600.0   14.965  104.992   105.344   102.500   4.764
 23             -600.0   14.965  104.905   106.080   103.500   8.700*CRIT*
 22             -900.0   14.965  112.442   113.555   105.000   2.469
 21             -900.0   14.965  113.663   113.666   105.000    .432
 20             -904.0   16.000  113.663   113.667   105.000    .462
 19             -904.0   15.000  113.615   113.685   105.000   2.122
 18            -1204.0   15.000  113.766   113.836   106.500   2.122
 17            -1504.0   15.000  113.916   113.986   108.000   2.122


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 11             -300.0    2.025  107.037   107.171   106.500   2.940*CRIT*
 10             -600.0    2.025  108.827   108.843   108.000    .991
  9            -1000.0    2.025  109.521   109.543   109.000   1.182
  8            -1000.0    2.025  110.109   110.365   109.500   4.064*CRIT*
  7            -1200.0    2.025  113.472   113.576   110.000   2.591
  6            -1200.0    2.025  113.587   113.587   110.000    .057
  5            -1300.0    2.025  113.587   113.587   105.000   0.000
  4            -1400.0    2.025  113.587   113.587   110.500    .075
  3            -1700.0    1.025  113.587   113.588   112.000    .137


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 16             -904.0    1.000  113.641   113.667   106.000   1.273
 15            -1204.0    1.000  113.954   113.979   107.500   1.273
 14            -1504.0    1.000  114.266   114.291   109.000   1.273
 13            -1504.0    1.000  114.266   114.291   109.000   1.273
 12            -1704.0    1.000  114.422   114.447   110.000   1.273


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  2            -1400.0    1.000  113.587   113.587   112.000    .132
  1            -1300.0    1.000  114.370   114.462   114.000   2.440*CRIT*

BRANCH    21   TO      3
E.L.    113.666    113.588 DIFF AS PCNT OF SMALLER DEPTH=  4.95
W.L.    113.663    113.587 DIFF AS PCNT OF SMALLER DEPTH=  4.79
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=       .004
```

CHAPTER 5

TESTING THE PROGRAM

5.1 Theoretical Configurations

In Chapter 4, four theoretical configurations were considered from the point of view of flooded roads due to inadequate capacity of bridges and overland flow resulting from a surcharged sewer system. This section concerns itself with two samples of open channel flow in order to test the versatility of the program. The first example considers a typical river system with tributaries and drop structures together with water being withdrawn from the system and replaced further downstream. The second example considers a multiple island network which indicates the complexity of networks that the program can analyse. The next two examples compare the accuracy of the new program to profiles determined by the Corp. of Army Engineers' program - HEC2.

5.1.1 River System

Figure 5.1 shows the schematic of a typical river system. The channels have been defined as trapezoidal having a side slope of 2:1. Table 5.1.1. contains the data for the river system shown in Figure 5.1. Drop structures exist at nodes 21, 11 and 7. A 5'

FIGURE 5·1

RIVER SYSTEM

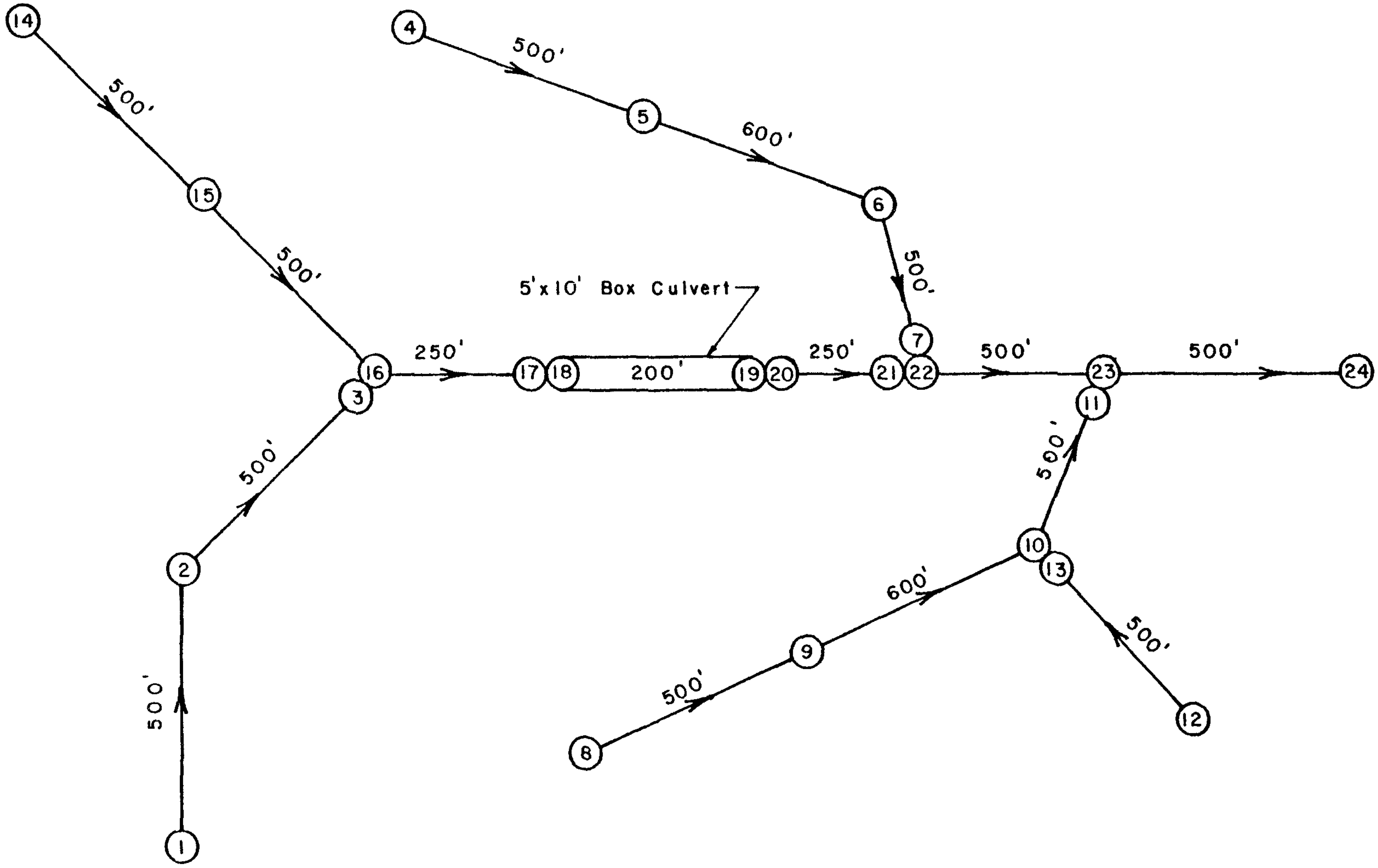


TABLE 5.1.1 DATA FOR RIVER SYSTEM

```
          CROSS SECTION DATA FOR -RIVER- SYSTEM
                        MAIN     14 - 24
                        TRIBS     1 -  3 CONNECT @ 16
                                  4 -  7 CONNECT @ 22
                                  8 - 11 CONNECT @ 23
                                 12 - 13 CONNECT @ 10

 1     4    -2700.          0.02
 1       -25.0       114.0        -5.0        104.0          5.0        104.0
 1        25.0       114.0
 2     4      -2200.        0.02
 2       -25.0       113.5        -5.0        103.5          5.0        103.5
 2        25.0       113.5
 3     4      -1700.        0.02
 3       -25.0       113.0        -5.0        103.0          5.0        103.0
 3        25.0       113.0
 4     4      -2300.        0.03
 4       -20.0       116.0         0.0        106.0          5.0        106.0
 4        25.0       116.0
 5     4      -2100.        0.03
 5       -20.0       115.0         0.0        105.0          5.0        105.0
 5        25.0       115.0
 6     4      -1500.        0.03
 6       -20.0       114.0         0.0        104.0          5.0        104.0
 6        25.0       114.0
 7     4      -1000.        0.03
 7       -20.0       113.0         0.0        103.0          5.0        103.0
 7        25.0       113.0
 8     4      -2100.        0.03
 8       -20.0       115.5         0.0        105.5          5.0        105.5
 8        25.0       115.5
 9     4      -1600.        0.03
 9       -20.0       114.5         0.0        104.5          5.0        104.5
 9        25.0       114.5
10     4      -1000.        0.03
10       -20.0       113.5         0.0        103.5          5.0        103.5
10        25.0       113.5
11     4        -500.       0.03
11       -20.0       112.5         0.0        102.5          5.0        102.5
11        25.0       112.5
12     4      -1500.        0.03
12       -20.0       114.0         0.0        104.5          5.0        104.5
12        25.0       114.0
13     4      -1000.        0.03
13       -20.0       113.5         0.0        103.5          5.0        103.5
13        25.0       113.5
14     4      -2700.        0.02
14       -25.0       114.5        -5.0        104.5          5.0        104.5
14        25.0       114.5
15     4      -2200.        0.02
15       -25.0       114.0        -5.0        104.0          5.0        104.0
15        25.0       114.0
```

TABLE 5.1.1 (CONT'D)

```
:
   16      4     -1700.       0.02
   16       -25.0       112.8          -5.0        102.8          5.0        102.2
   16        25.0       112.8
   17      4     -1450.       0.02
   17       -25.0       112.6          -5.0        102.6          5.0        102.6
   17        25.0       112.6
   18      5     -1450.       0.013
   18        -5.0       107.5          -5.0        102.5          5.0        102.5
   18         5.0       107.5          -5.0        107.5
   19      5     -1250.       0.013
   19        -5.0       106.7          -5.0        101.7          5.0        101.7
   19         5.0       106.7          -5.0        106.7
   20      4     -1250.       0.02
   20       -25.0       111.5          -5.0        101.5          5.0        101.5
   20        25.0       111.5
   21      4     -1000.       0.02
   21       -25.0       111.0          -5.0        101.0          5.0        101.0
   21        25.0       111.0
   22      4     -1000.       0.02
   22       -35.0       112.0          -5.0         97.0          5.0         97.0
   22        35.0       112.0
   23      4      -500.       0.02
   23       -35.0       111.0          -5.0         96.0          5.0         96.0
   23        35.0       111.0
   24      4        0.0       0.02
   24       -35.0       110.0          -5.0         95.0          5.0         95.0
   24        35.0       110.0

*EOR*
 *END OF INFORMATION*
?
```

x 10' box culvert under an embankment is modelled at nodes 18 and 19. Water is withdrawn by an industry at node 6 and put back into the system at node 21.

Using command INFLOWS, the initial flow condition was set as follows:

NODE	FLOW
1	50 cfs
4	100 cfs
8	100 cfs
12	10 cfs
14	100 cfs

Point lateral inflows	NODE	FLOW
	6	-20 cfs
	21	+20 cfs

Table 5.1.2 presents the summary table and the computed profile for the typical river system. Each tributary is printed out under its own heading such that tributaries of interest can be easily identified. The two tributaries that contain a drop at the confluence have their profiles at critical depth as indicated by the term *CRIT* at the end of the line.

5.1.2 Multiple Islands

As previously stated, this example has been designed to indicate the complexity of networks that can be analysed with the routine RIVER4. It comprises six islands in total as shown in

TABLE 5.1.2 SUMMARY OF INPUT DATA AND PROFILE RESULTS FOR A RIVER SYSTEM

```
SUMMARY OF INPUT DATA FOR

    --RIVER-- SYSTEM



 UNITS USED ARE  --IMPERIAL--



 CONNECTIVITY TABLE


NODE NO.      1     2     3     4     5     6     7     8     9    10
KDS(NODE)     0     0    16     0     0     0    22     0     0     0

NODE NO.     11    12    13    14    15    16    17    18    19    20
KDS(NODE)    23     0    10     0     0     0     0     0     0     0

NODE NO.     21    22    23    24
KDS(NODE)     0     0     0   999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO   24  INCLUSIVE, IN ORDER:-

    50.000     50.000     50.000    100.000    100.000
    80.000     80.000    100.000    100.000    110.000
   110.000     10.000     10.000    100.000    100.000
   150.000    150.000    150.000    150.000    150.000
   170.000    250.000    360.000    360.000

INITIAL WATER LEVEL AT NODE   24   IS    100.448

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =      .300
                 AT EXPANSIONS   CLE =      .500
```

TABLE 5.1.2 (CONT'D)

```
-RIVER- SYSTEM


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

 24               0.0   360.000  100.442   100.603    95.000   3.162
 23            -500.0   360.000  100.602   100.860    96.000   4.073
 22           -1000.0   250.000  100.764   100.987    97.000   2.789
 21           -1000.0   170.000  102.772   103.521   101.000   6.944*CRIT*
 20           -1250.0   150.000  103.205   104.113   101.500   4.454
 19           -1250.0   150.000  103.612   104.568   101.700   7.046*CRIT*
 18           -1450.0   150.000  104.412   105.368   102.500   7.046*CRIT*
 17           -1450.0   150.000  105.421   105.601   102.600   3.399
 16           -1700.0   150.000  105.624   105.812   102.800   3.377
 15           -2200.0   100.000  105.879   106.112   104.000   3.067
 14           -2700.0   100.000  106.625   106.794   104.500   3.203


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

 11            -500.0   110.000  104.341   105.076   102.500   6.880*CRIT*
 10           -1000.0   110.000  106.986   107.094   103.500   2.636
  9           -1600.0   100.000  107.632   107.756   104.500   2.835
  8           -2100.0   100.000  108.424   108.579   105.500   3.152


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  7           -1000.0    80.000  104.547   105.121   103.000   6.389*CRIT*
  6           -1500.0    80.000  107.062   107.148   104.000   2.348
  5           -2100.0   100.000  108.022   108.161   105.000   2.996
  4           -2600.0   100.000  108.903   109.061   106.000   3.108


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  3           -1700.0    50.000  105.791   105.812   103.000   1.150
  2           -2200.0    50.000  105.847   105.880   103.500   1.450
  1           -2700.0    50.000  105.959   106.011   104.000   1.824


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

 13           -1000.0    10.000  107.092   107.094   103.500    .220
 12           -1500.0    10.000  107.100   107.102   104.500    .367

COMMAND?

? STOP
```

Figure 5.2. An attempt has been made to model division of flow for all possible combinations. The channels have been represented as being rectangular, thus only two stations need be defined per section as the program will add the vertical extensions as required. The system geometry is shown in Table 5.2.1. Transitions and bridges have not been modelled in this network. The network may be said to be similar to a river delta or a bayou.

The initial flow condition was set at 10,000.0 cfs entering at node 26. The program then computed the divison of flow and the profiles, terminating at a ten percent error limit. Two iterations were required to arrive at all branches having less than the requisite error with the third iteration being printed out. Table 5.2.2 presents the summary of the input data while Table 5.2.3 contains the computed profile together with the calculated error at each branch. Figure 5.2.1 summarizes the division of flow as calculated together with the computed error in energy level and water level. In the calculated error it will be noted that all the errors are quite small except for one (node 27 to 6) but it is well within acceptable limits.

From the proposed correction to branch flow, the branch from 16 to 12 presents an interesting result. The flow correction is considerably larger than the flow in the channel at 12. Together with the energy levels and water levels, this may indicate that the flow is in the other direction even though the

FIGURE 5·2

ISLAND NETWORK

REACH	WIDTH
26 – 34	100'
19 – 25	50'
14 – 18	30'
12 – 13	20'
6 – 11	50'
3 – 5	30'
1 – 2	20'

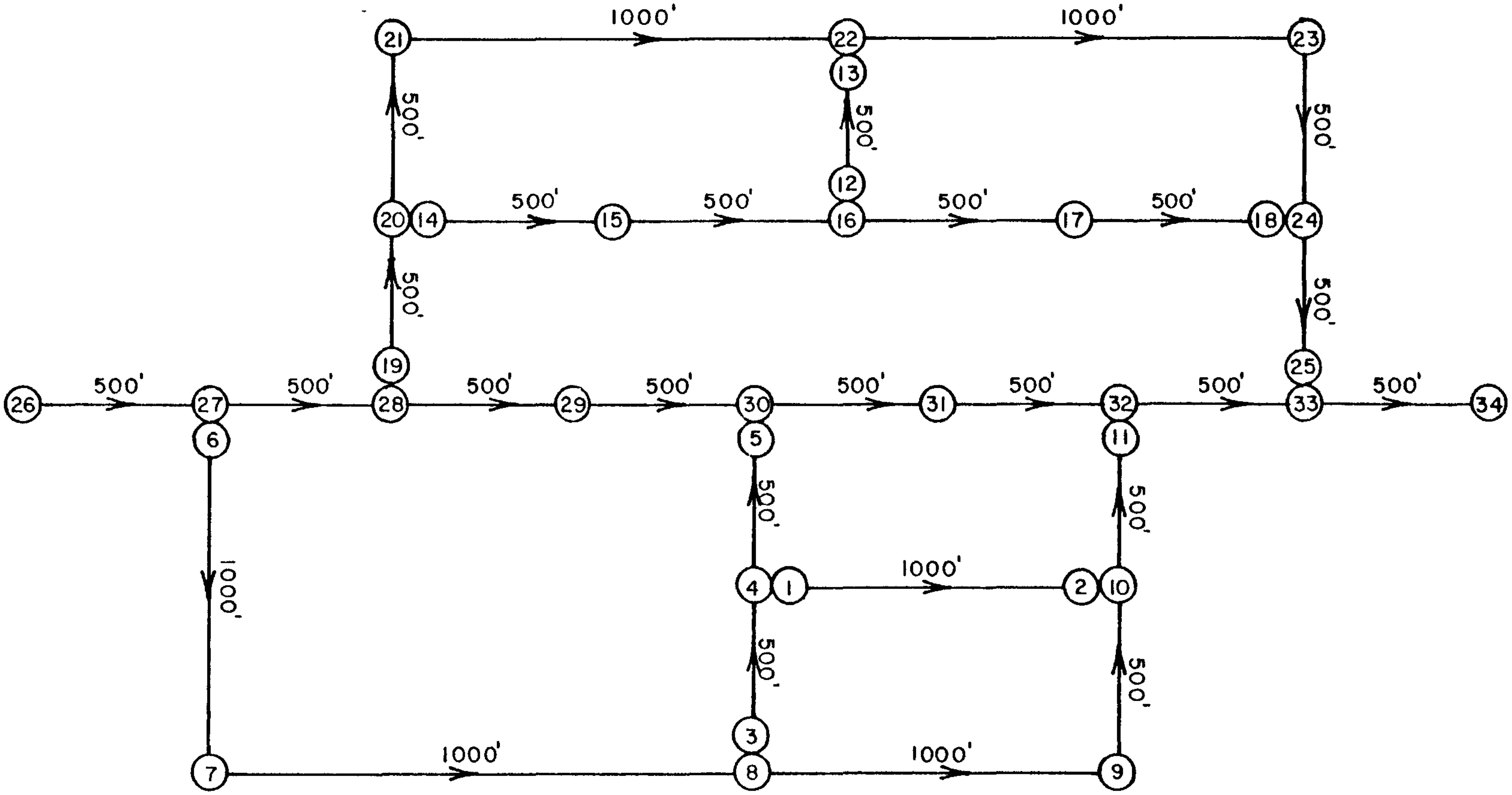


TABLE 5.2.1 DATA FOR ISLAND NETWORK

```
                 DATA SET FOR -ISLAND- FLOW
                 MAIN CHANNEL       26-34
                 TRIBS:-    1  -  2 CONNECT @ 10, BRANCH @  4
                            3  -  5 CONNECT @ 30, BRANCH @  3
                            6  - 11 CONNECT @ 32, BRANCH @ 27
                           12  - 13 CONNECT @ 32, BRANCH @ 13
                           14  - 18 CONNECT @ 34, BRANCH @ 20
                           19  - 25 CONNECT @ 33, BRANCH @ 29
  1     2   -2100.       .025
  1     0.0      105.0      30.0       105.0
  2     2   -1100.       .025
  2     0.0      104.0      30.0       104.0
  3     2   -2600.       .025
  3     0.0      105.5      30.0       105.5
  4     2   -2100.       .025
  4     0.0      105.0      30.0       105.0
  5     2   -1600.       .025
  5     0.0      104.5      30.0       104.5
  6     2   -4600.       .025
  6     0.0      107.5      50.0       107.5
  7     2   -3600.       .025
  7     0.0      106.5      50.0       106.5
  8     2   -2600.       .025
  8     0.0      105.0      50.0       105.0
  9     2   -1600.       .025
  9     0.0      103.5      50.0       103.5
 10     2   -1100.       .025
 10     0.0      103.0      50.0       103.0
 11     2    -600.       .025
 11     0.0      102.5      50.0       102.5
 12     2   -2000.       .025
 12     0.0      104.5      30.0       104.5
 13     2   -2500.       .025
 13     0.0      103.5      30.0       103.5
 14     2   -3000.       .025
 14     0.0      105.5      30.0       105.5
 15     2   -2500.       .025
 15     0.0      105.0      30.0       105.0
 16     2   -2000.       .025
 16     0.0      104.0      30.0       104.0
 17     2   -1500.       .025
 17     0.0      102.5      30.0       102.5
 18     2   -1000.       .025
 18     0.0      103.0      30.0       103.0
 19     2   -4500.       .025
 19     0.0      106.5      50.0       106.5
 20     2   -4000.       .025
 20     0.0      105.0      50.0       105.0
```

TABLE 5.2.1 (CONT'D)

```
   21     2    -3500.       .025
   21     0.0      104.5      50.0       104.5
   22     2    -2500.       .025
   22     0.0      103.5      50.0       103.5
   23     2    -1500.       .025
   23     0.0      102.5      50.0       102.5
   24     2    -1000.       .025
   24     0.0      102.0      50.0       102.0
   25     2     -500.       .025
   25     0.0      101.5      50.0       101.5
   26     2    -3600.       .025
   26     0.0      108.0      100.0      108.0
   27     2    -3100.       .025
   27     0.0      107.0      100.0      107.0
   28     2    -2600.       .025
   28     0.0      106.0      100.0      106.0
   29     2    -2100.       .025
   29     0.0      105.0      100.0      105.0
   30     2    -1600.       .025
   30     0.0      104.0      100.0      104.0
   31     2    -1100.       .025
   31     0.0      103.0      100.0      103.0
   32     2     -600.       .025
   32     0.0      102.0      100.0      102.0
   33     2     -500.       .025
   33     0.0      101.0      100.0      101.0
   34     2      0.0        .025
   34     0.0      100.0      100.0      100.0
*EOR*
 *END OF INFORMATION*
?
```

EL – difference in energy level expressed as a percentage of depth.

WL – difference in water level expressed as a percentage of depth.

FIGURE 5·2·1
ISLAND NETWORK COMPUTED DIVISION OF FLOW

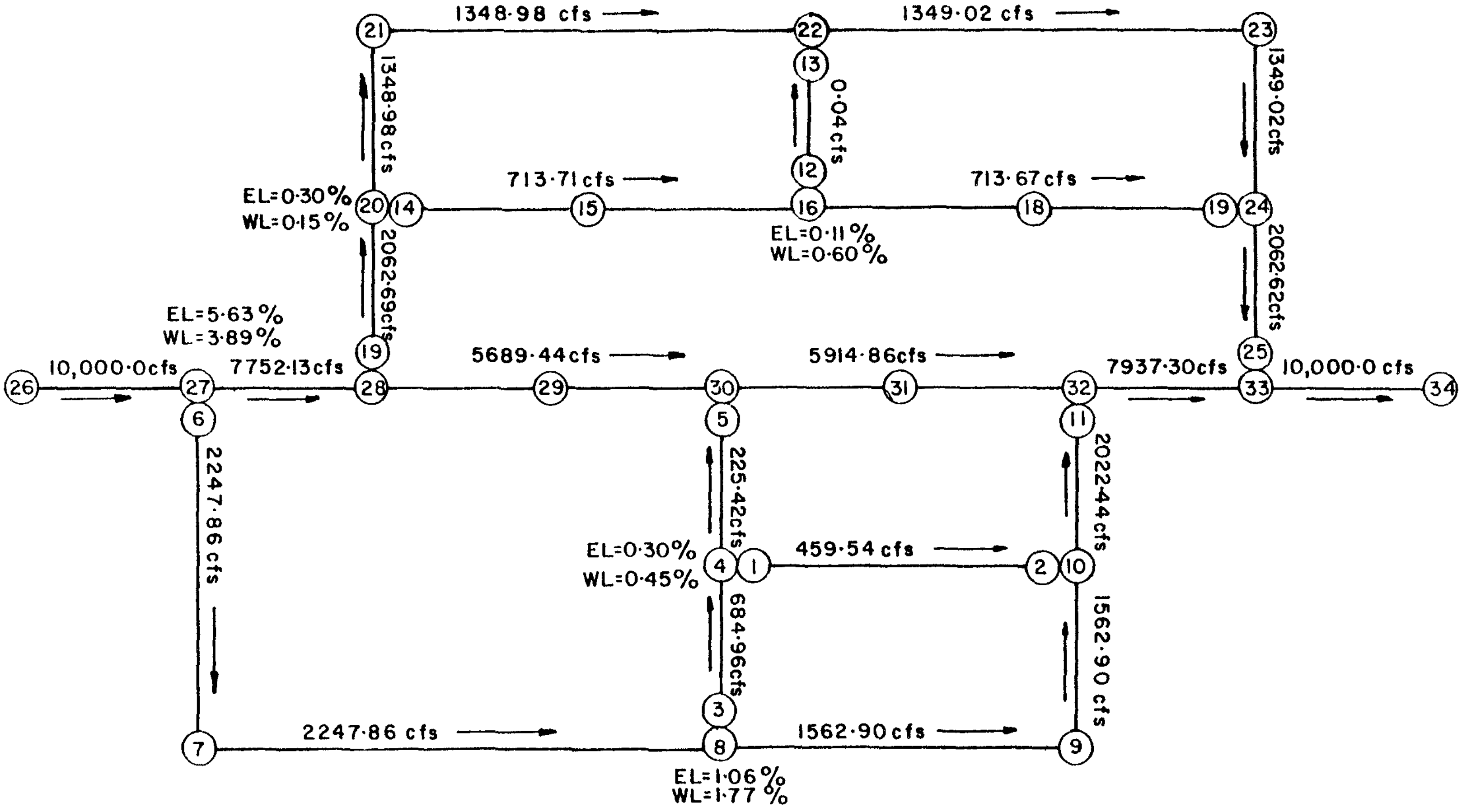


TABLE 5.2.2 SUMMARY OF INPUT DATA FOR ISLAND NETWORK

```
SUMMARY OF INPUT DATA FOR

    --ISLAND-- NETWORK



 UNITS USED ARE  --IMPERIAL-



 CONNECTIVITY TABLE


NODE NO.       1     2     3     4     5     6     7     8     9    10
KDS(NODE)     -4    10    -8     0    30   -27     0     0     0     0

NODE NO.      11    12    13    14    15    16    17    18    19    20
KDS(NODE)     32   -16    22   -20     0     0     0    24   -28     0

NODE NO.      21    22    23    24    25    26    27    28    29    30
KDS(NODE)      0     0     0     0    33     0     0     0     0     0

NODE NO.      31    32    33    34
KDS(NODE)      0     0     0   999

SINCE BRANCHED FLOWS ARE BEING MODELLED,
INITIAL FLOWS ARE NOT PRINTED OUT IN
ORDER TO PREVENT POSSIBLE CONFUSION.


INITIAL WATER LEVEL AT NODE   34  IS   113.544

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =      0.000
                 AT EXPANSIONS   CLE =      1.000
```

TABLE 5.2.3 PROFILE FOR ISLAND NETWORK

```
   --ISLAND-- NETWORK



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.      VEL.

 34               0.0 10000.000   113.544    114.390    100.000    7.383
 33            -500.0 10000.000   113.798    114.746    101.000    7.814
 32            -600.0  7937.308   114.076    114.747    102.000    6.573
 31           -1100.0  5914.863   114.323    114.747    103.000    5.224
 30           -1600.0  5914.863   114.475    114.970    104.000    5.647
 29           -2100.0  5689.443   114.658    115.197    105.000    5.891
 28           -2600.0  5689.443   114.903    115.537    106.000    6.390
 27           -3100.0  7752.135   115.572    116.842    107.000    9.044
 26           -3600.0 10000.000   117.018    118.927    108.000   11.089



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.      VEL.

 25            -500.0  2062.693   114.592    114.746    101.500    3.151
 24           -1000.0  2062.693   114.665    114.829    102.000    3.257
 23           -1500.0  1349.026   114.754    114.830    102.500    2.202
 22           -2500.0  1349.026   114.834    114.922    103.500    2.381
 21           -3500.0  1348.986   114.934    115.038    104.500    2.586
 20           -4000.0  1348.986   114.994    115.108    105.000    2.699
 19           -4500.0  2062.693   115.120    115.476    106.500    4.786



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.      VEL.

 11            -600.0  2022.445   114.572    114.747    102.500    3.351
 10           -1100.0  2022.445   114.661    114.848    103.000    3.469
  9           -1600.0  1562.900   114.728    114.848    103.500    2.784
  8           -2600.0  1562.900   114.864    115.020    105.000    3.169
  7           -3600.0  2247.865   115.290    115.696    106.500    5.115
  6           -4600.0  2247.865   115.899    116.344    107.500    5.353



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.      INV.      VEL.

  5           -1600.0   225.420   114.962    114.970    104.500     .718
  4           -2100.0   225.420   114.968    114.977    105.000     .754
  3           -2600.0   684.965   115.033    115.122    105.500    2.395
```

TABLE 5.2.3 (CONT'D)

SEC.	STATN.	CHAINAGE	DISCH.	W.L.	EN.LEV.	INV.	VEL.
18		-1000.0	713.666	114.766	114.829	103.000	2.022
17		-1500.0	713.666	114.810	114.872	103.500	2.103
16		-2000.0	713.666	114.859	114.923	104.000	2.191
15		-2500.0	713.706	114.909	114.999	105.000	2.401
14		-3000.0	713.706	114.981	115.078	105.500	2.509

SEC.	STATN.	CHAINAGE	DISCH.	W.L.	EN.LEV.	INV.	VEL.
13		-2500.0	.040	114.922	114.922	103.500	.000
12		-3000.0	.040	114.922	114.922	104.500	.000

SEC.	STATN.	CHAINAGE	DISCH.	W.L.	EN.LEV.	INV.	VEL.
2		-1100.0	459.545	114.777	114.848	104.000	2.132
1		-2100.0	459.545	114.923	115.006	105.000	2.316

TABLE 5.2.3 (CONT'D)

```
BRANCH     4   TO       1
E.L.    114.977    115.006 DIFF AS PCNT OF SMALLER DEPTH=    .30
W.L.    114.968    114.923 DIFF AS PCNT OF SMALLER DEPTH=    .45
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    -34.304

BRANCH     8   TO       3
E.L.    115.020    115.122 DIFF AS PCNT OF SMALLER DEPTH=  1.06
W.L.    114.864    115.033 DIFF AS PCNT OF SMALLER DEPTH=  1.77
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=  -368.560

BRANCH    27   TO       6
E.L.    116.842    116.344 DIFF AS PCNT OF SMALLER DEPTH=  5.63
W.L.    115.572    115.899 DIFF AS PCNT OF SMALLER DEPTH=  3.89
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    197.855

BRANCH    16   TO      12
E.L.    114.933    114.922 DIFF AS PCNT OF SMALLER DEPTH=    .11
W.L.    114.859    114.922 DIFF AS PCNT OF SMALLER DEPTH=    .60
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=     20.074

BRANCH    20   TO      14
E.L.    115.108    115.078 DIFF AS PCNT OF SMALLER DEPTH=    .30
W.L.    114.994    114.981 DIFF AS PCNT OF SMALLER DEPTH=    .15
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=     23.302

BRANCH    28   TO      19
E.L.    115.537    115.476 DIFF AS PCNT OF SMALLER DEPTH=    .69
W.L.    114.903    115.120 DIFF AS PCNT OF SMALLER DEPTH=  2.51
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    191.604

DO YOU WANT PROFILES RECOMPUTED...YES/NO?
? NO
```

inverts indicate the flow is in the direction shown. It may be of interest to reverse the node numbers at 12 and 13, redefine the confluence as being at node 16 and the branch occurring at 22. The new system could then be tested for the same initial flow condition to check the potential of flow in the opposite direction.

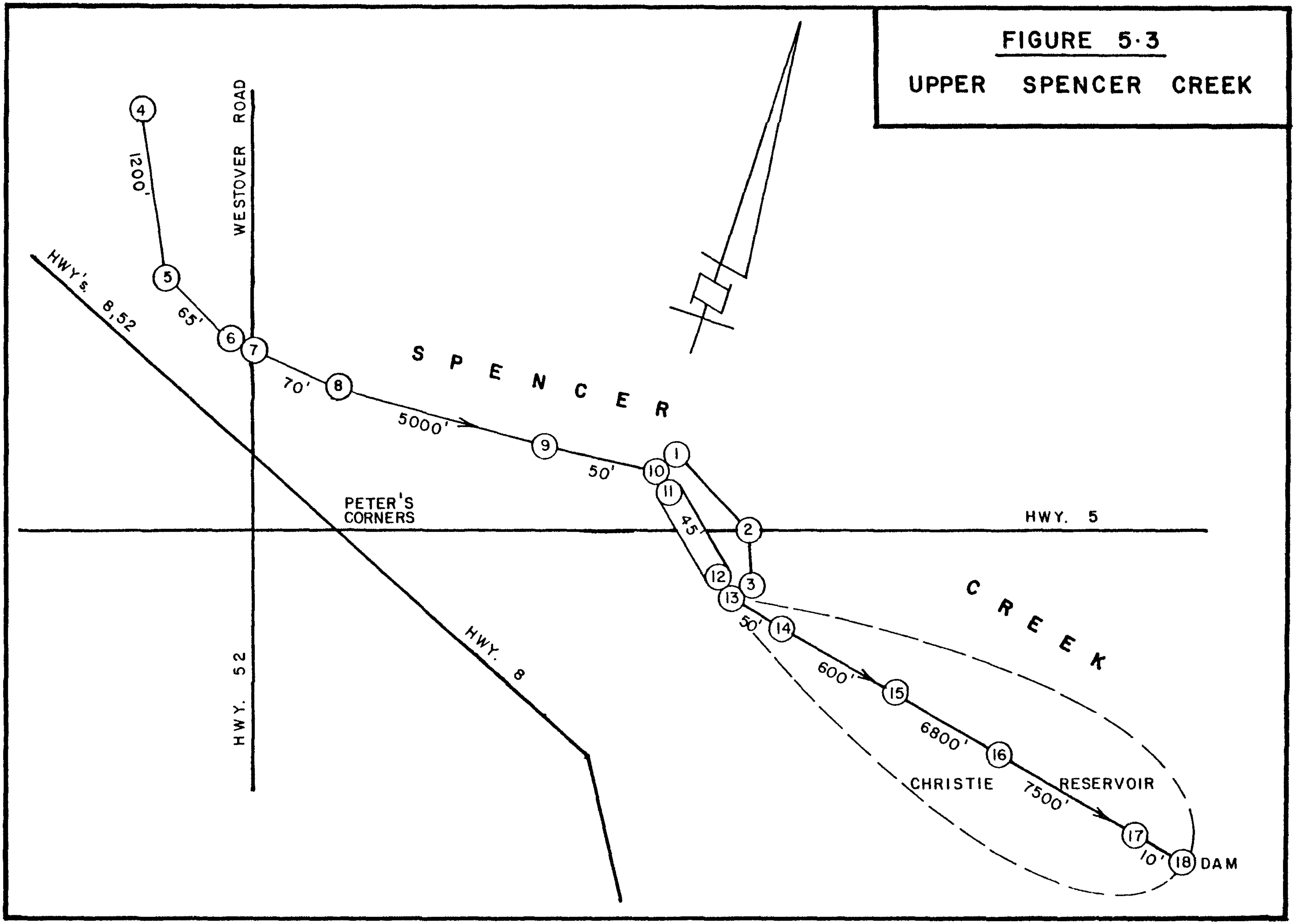
In general, solving this type of network would be quite tedious and difficult with other programming available in common usage.

5.2 Upper Spencer Creek

In order to validate the program RIVER3/4, a comparison was made with an uncalibrated HEC-2 analysis of the Spencer Creek in Wentworth County. A program was written which converted the HEC-2 data format into RIVER4 data format. After conversion with the new program, the bridges were defined using a modified form of subroutine EDITXS.

For the Upper Spencer Creek, the limits of analysis were set from Christie Dam at the downstream end to Westover Road at the upstream end. The reach included the Christie reservoir. A schematic of the reach is shown in Figure 5.3. The flow condition analyzed was that of the regional storm as represented by Hurricane Hazel. The initial water level at the downstream limit was set at critical depth over the dam.

FIGURE 5·3
UPPER SPENCER CREEK



The reach originally included two bridges, one at Highway 5 and the other at Westover Road. The latter bridge was not modelled in the RIVER4 analysis. The bridge dimensions are quite small in comparison to the flow passing the section. In addition, the minimum top of road elevation is lower than the elevation of the crown of the bridge. Thus the section was modelled as a combination weir using the elevation of the road with a rectangular notch equivalent to the width and invert of the original bridge. The computed profile by RIVER4 is presented in Table 5.3.1. In the analysis of the bifurcation over Highway 5, the computed differences in energy and water levels are very low, being considerably less than normally expected. The computed profile took five iterations to arrive at the final results as presented. The initial termination error was set at ten percent.

A comparison of the computed energy and water levels was made between the results of HEC-2 and RIVER4. The difference in the energy and water levels have been expressed as a percentage of the depth as calculated by HEC-2 and are shown in Table 5.3.2. The table shows good agreement between the two programs.

The one exception is at the outlet of the Highway 5 bridge (node 13). Though the water level is in good agreement, the energy level is considerably out. Part of the explanation is in the difference between the two programs in the modelling of bridge sections. Within HEC-2, the end of the bridge is treated as a

TABLE 5.3.1 UPPER SPENCER CREEK
COMPUTED PROFILE

```
UPPER SPENCER CR., ONTARIO, FROM CHRISTIE DAM TO WESTOVER RD


SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.     INV.       VEL.

 18              0.0   9942.000   776.877    778.316    774.000    9.626*CRIT*
 17            -10.0   9942.000   778.292    778.316    749.000    1.229
 16          -7510.0  10213.000   778.679    778.743    760.000    2.031
 15         -14310.0  10422.000   780.715    780.794    770.500    2.265
 14         -14910.0  10422.000   781.092    781.205    770.500    2.699
 13         -14960.0  10422.000   781.120    781.246    770.500    2.849
 12         -14960.0   7767.678   779.809    785.719    770.500   19.510*CRIT*
 11         -15005.0   7767.678   782.384    785.719    770.500   14.656
 10         -15005.0   7767.678   787.712    787.717    770.500     .564
  9         -15055.0  10422.000   787.715    787.722    770.500     .682
  8         -20055.0  10255.000   787.852    787.911    772.000    1.954
  7         -20125.0  10255.000   787.782    787.919    772.500    2.967
  6         -20125.0  10255.000   787.876    787.954    772.500    2.247
  5         -20190.0  10255.000   787.925    787.960    772.000    1.500
  4         -21390.0  10255.000   787.997    788.006    772.000     .770


SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.     INV.       VEL.

  3         -14960.0   2654.322   781.238    781.246    770.500     .699
  2         -14985.0   2654.322   787.090    787.699    784.000    6.267*CRIT*
  1         -15005.0   2654.322   787.723    787.724    770.500     .192


BRANCH    10   TO      1
E.L.    787.717    787.724 DIFF AS PCNT OF SMALLER DEPTH=    .04
W.L.    787.712    787.723 DIFF AS PCNT OF SMALLER DEPTH=    .06
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=      -.056


DO YOU WANT PROFILES RECOMPUTED...YES/NO?
? NO
```

TABLE 5.3.2

UPPER SPENCER CREEK

Comparison of RIVER4 and HEC-2 results

Sec.	RIVER4			HEC-2		% DIFFERENCE	
No.	EL	WL	INVERT	EL	WL	EL	WL
18	778.32	776.87*	774.00	778.32	776.87*	0	0
17	778.32	778.29	749.00	778.74	778.72	- 1.4	- 1.5
16	778.74	778.68	760.00	778.99	778.93	- 1.3	- 1.3
15	780.79	780.72	770.50	780.73	780.46	+ 0.6	+ 2.6
14	781.21	781.09	770.50	781.27	780.95	- 0.6	+ 1.3
13	781.25	781.12	770.50	786.44	781.13*	-33.5	- 0.1
12	785.71	779.81*	770.50	- - - - - HWY. 5 BRIDGE - - - -			
11	785.72	782.38	770.50				
10	787.72	787.71	770.50	787.62	787.61	+ 0.6	+ 0.6
9	787.72	787.72	770.50	787.62	787.61	+ 0.6	+ 0.6
8	787.91	787.85	773.00	787.86	787.78	+ 0.3	+ 0.7
7	787.92	787.78	773.50	- - - WESTOVER RD. BRIDGE - - -			
6	787.95	787.88	773.50	788.15	788.06	- 1.4	- 1.2
5	787.96	787.93	773.00	788.17	788.13	- 1.4	- 1.3
4	788.01	788.00	773.00	788.24	788.23	- 1.5	- 1.5

EL - energy level (computed)
WL - water level (computed)

* - critical depth

Flow over road HEC-2 - 2018 cfs
RIVER4 - 2654 cfs

confined, open ended section equivalent to the invert and width of the bridge [8,10]. Therefore, as the flow comes through the bridge, the water can only expand upward and not out to the sides. In RIVER4, the total width of the cross-section is used resulting in a lower energy level. This concept of the differences in modelling shows up more prominantly in the example to follow.

In general, though, RIVER4 produces a water surface profile similar to HEC-2 for rivers and reservoirs. It must be remembered, though, that this has been an uncalibrated analysis [14].

5.3 Lower Spencer Creek

This section of the Spencer Creek is that part which flows through the Town of Dundas, Ontario. A reach was selected that is representative of a number of river conditions, from subcritical to supercritical flow, tributary inflows, and with numerous bridges. Figure 5.4 shows a schematic of the reach under consideration. The flow condition selected was the 100 year flood. Again, a comparison was made with an uncalibrated HEC-2 analysis of the same reach. The downstream water level at node 30 was taken from the original HEC-2 analysis. Table 5.4.1 contains the results of the RIVER4 analysis. The comparison results are shown in Table 5.4.2. The profile for both the energy and water levels derived from the two programs have been plotted together in Figure 5.4.1(a) and (b).

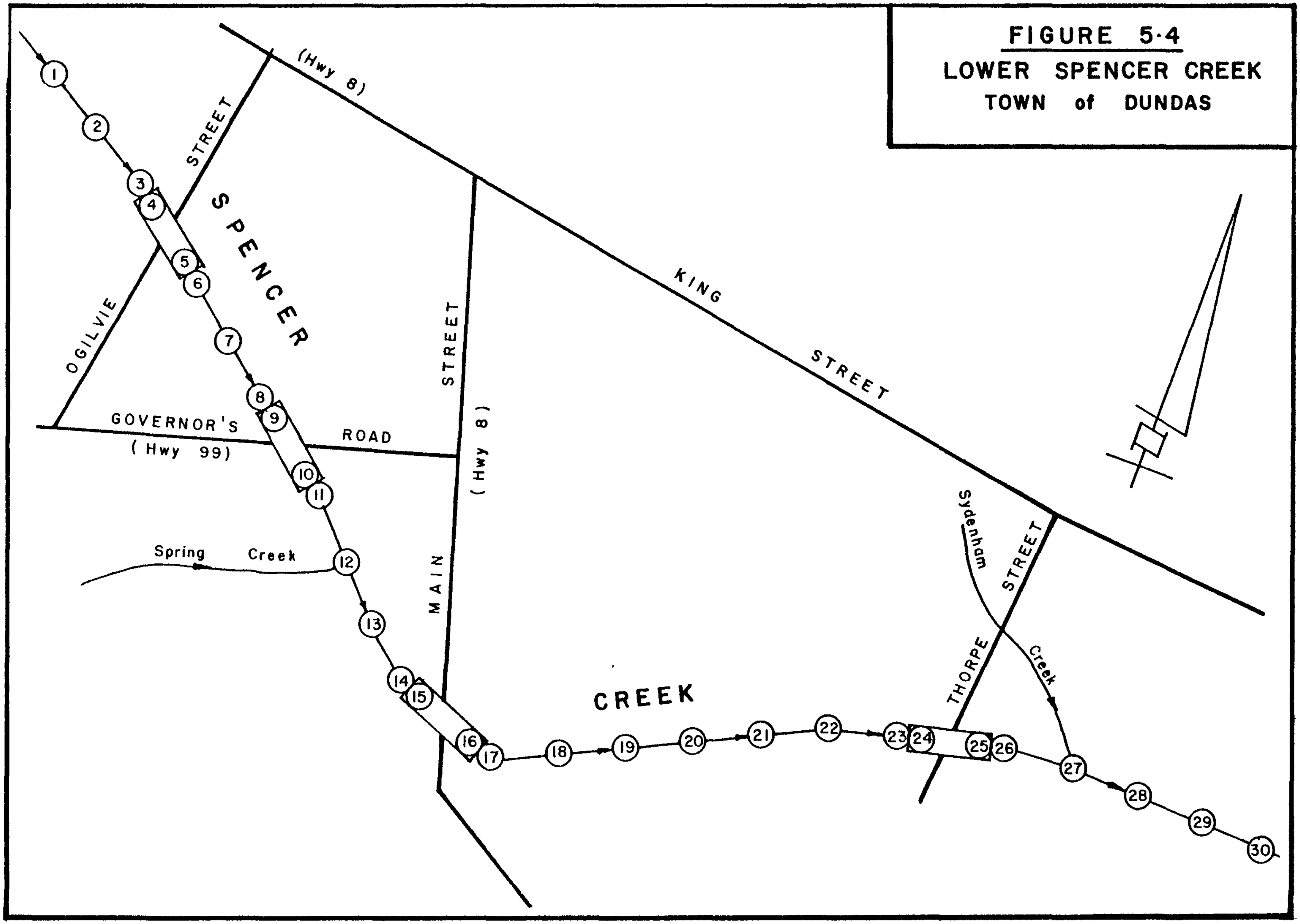


FIGURE 5·4

LOWER SPENCER CREEK
TOWN of DUNDAS

TABLE 5.4.1 LOWER SPENCER CREEK
COMPUTED PROFILE

```
LOWER SPENCER CREEK, DUNDAS, ONTARIO, 100 YR. STORM



SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.     INV.       VEL.

 30               0.0  3138.000   253.340    253.520    247.600    3.402
 29            -300.0  3138.000   253.975    254.911    247.700    7.766
 28            -600.0  3138.000   255.515    257.422    251.000   11.084+CRIT+
 27            -900.0  3138.000   258.393    259.224    251.500    7.314
 26           -1100.0  2988.000   257.614    260.192    251.900   12.889+CRIT+
 25           -1100.0  2988.000   258.571    262.885    251.900   16.667+CRIT+
 24           -1121.0  2988.000   260.438    262.885    251.900   12.555
 23           -1121.0  2988.000   263.602    263.615    251.900     .912
 22           -1221.0  2988.000   263.589    263.633    252.500    1.677
 21           -1521.0  2988.000   263.729    263.870    254.500    3.010
 20           -1821.0  2988.000   264.078    264.265    256.100    3.464
 19           -2171.0  2988.000   263.300    265.340    258.900   11.460+CRIT+
 18           -2521.0  2988.000   266.611    269.075    260.900   12.599+CRIT+
 17           -2721.0  2988.000   271.156    273.209    266.100   11.497+CRIT+
 16           -2721.0  2988.000   272.369    275.254    267.300   13.630+CRIT+
 15           -2786.0  2988.000   273.360    276.086    266.000   13.240
 14           -2786.0  2988.000   275.328    276.679    266.500    9.327
 13           -2986.0  2988.000   276.525    277.128    269.300    6.232
 12           -3286.0  2846.000   277.506    277.999    270.900    5.634
 11           -3486.0  1777.000   277.938    279.338    274.600    9.495+CRIT+
 10           -3486.0  1777.000   278.643    280.615    274.700   11.268+CRIT+
  9           -3529.0  1777.000   278.768    280.936    273.800   11.818+CRIT+
  8           -3529.0  1777.000   281.280    281.572    274.600    4.335
  7           -3579.0  1777.000   281.335    281.733    275.100    5.061
  6           -3629.0  1777.000   280.786    282.587    277.000   10.771+CRIT+
  5           -3629.0  1777.000   280.943    282.914    277.000   11.268+CRIT+
  4           -3674.0  1777.000   283.543    285.514    279.600   11.268+CRIT+
  3           -3674.0  1777.000   285.193    285.895    279.600    6.722
  2           -3824.0  1777.000   287.657    289.308    283.700   10.310+CRIT+
  1           -4074.0  1777.000   293.296    295.043    288.800   10.605+CRIT+

COMMAND?

? STOP
```

FIGURE 5·4·1(a)

LOWER SPENCER CREEK

Comparison of
HEC-2 and RIVER4 profiles

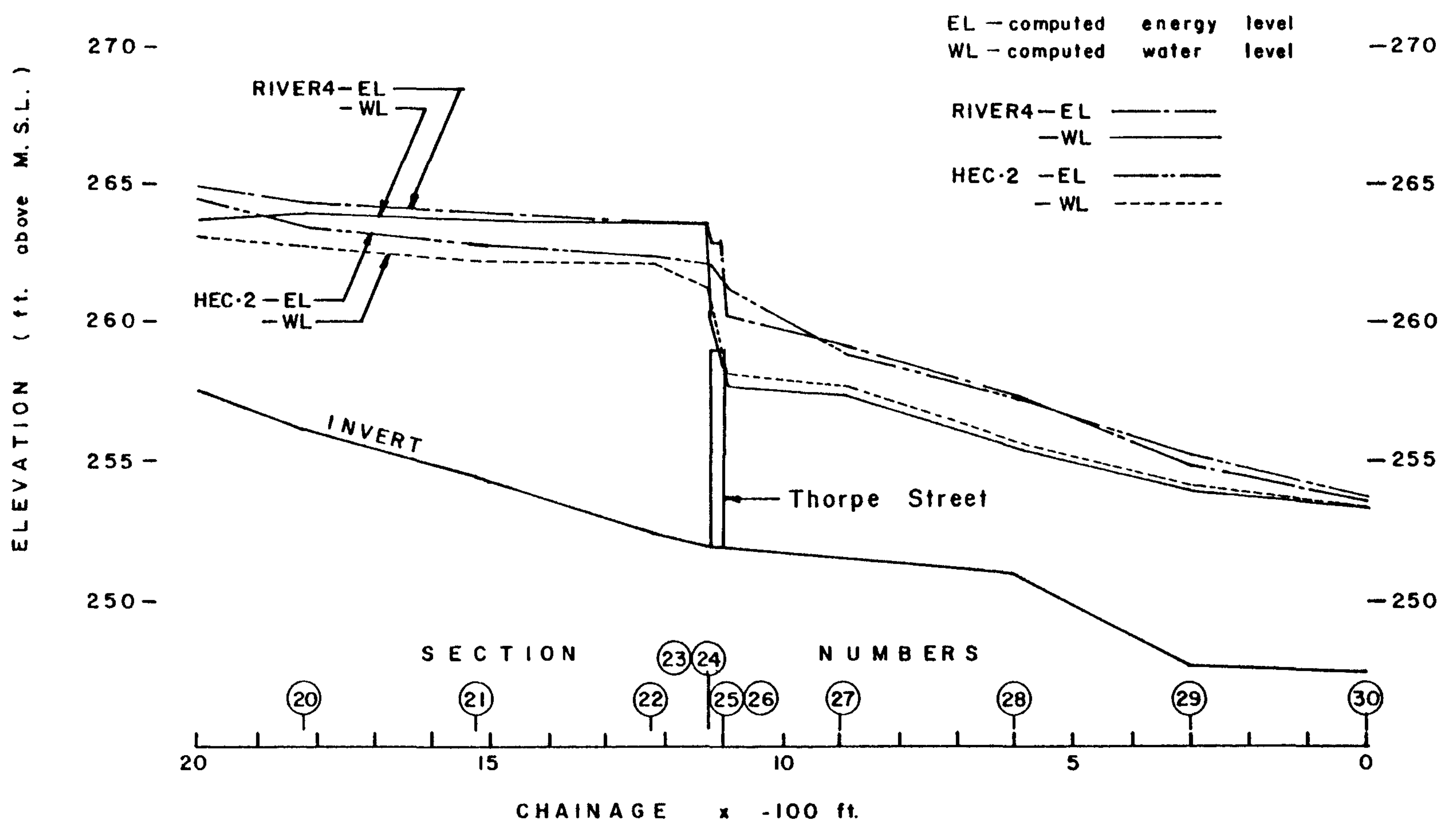


FIGURE 5·4·1(b)

LOWER SPENCER CREEK

Comparison of HEC-2 and RIVER4 profiles

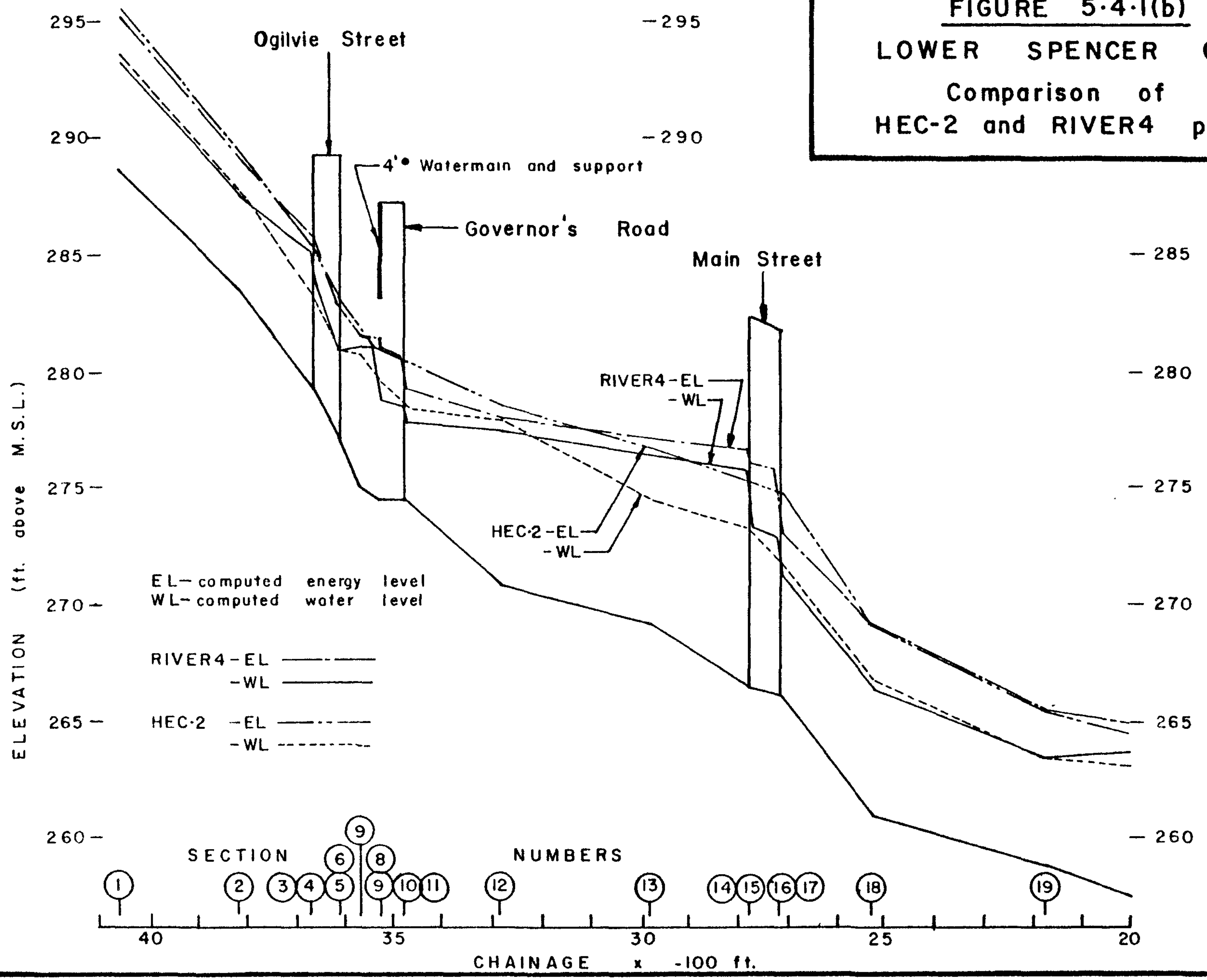


TABLE 5.4.2
LOWER SPENCER CREEK
TOWN OF DUNDAS

Comparison of RIVER4 and HEC-2 results

Sec.	RIVER4			HEC-2		% DIFFERENCE	
No.	EL	WL	INVERT	EL	WL	EL	WL
30	253.52	253.34	247.6	253.74	253.34	- 3.6	0
29	254.91	253.97	247.7	255.15	254.11	- 3.2	- 2.2
28	257.42	255.52*	251.0	257.30	255.68	+ 1.9	- 3.4
27	259.22	258.39	251.5	258.77	257.72	+ 6.2	+10.8
26	260.20	257.61*	251.9	261.22	258.09*	-10.9	- 7.7
25	262.88	258.57*	251.9	- - -	THORPE ST.	BRIDGE	- - -
24	262.88	260.44	251.9				
23	263.61	263.60	251.9	262.11	261.29	+14.7	+24.6
22	263.63	263.58	252.5	262.42	262.14	+12.2	+14.9
21	263.87	263.73	254.5	262.86	262.21	+12.1	+19.7
20	264.27	264.08	256.1	263.39	262.69	+12.0	+21.1
19	265.34	263.30*	258.9	265.38	263.37*	+ 0.6	+ 1.6
18	269.08	266.61*	260.9	269.16	266.75*	- 1.0	- 2.4
17	273.21	271.16*	266.1	274.75	271.83*	-17.8	-11.7
16	275.85	272.97*	267.2	- - - -	MAIN ST.	BRIDGE	- - - -
15	276.09	273.36	266.0				
14	276.68	275.93	266.5	275.41	273.37	+14.2	+37.2
13	277.13	276.53	269.3	276.77	274.62*	+ 4.8	+35.9
12	278.00	277.51	270.9	278.67	278.02	- 8.9	- 7.6
11	279.34	277.94*	274.6	280.51	278.53*	-19.8	-15.0
10	280.62	278.64*	274.7	- -	GOVERNOR'S RD.	BRIDGE	- -
9	280.94	278.77*	273.8				
8	281.57	281.28	274.6	280.99	279.90	+ 9.1	+26.0
7	281.63	281.24	275.1	281.29	280.81	+ 5.5	+ 7.5
6	282.59	280.79*	277.0	287.91	280.93*	- 5.4	- 3.8
5	282.91	280.94*	277.0	- - -	OGILVIE ST.	BRIDGE	- - -
4	285.51	283.54*	279.6				
3	285.89	285.19	279.6	285.52	283.63*	+ 6.3	+38.7
2	289.31	287.66*	283.7	289.58	287.91*	- 4.6	- 5.9
1	295.04	293.30*	288.8	295.68	293.70*	- 3.3	- 8.2

EL - energy level (computed)
WL - water level (computed)
* - critical depth

The profile around the bridges generally show the greatest differences between the two programs. As previously mentioned, this difference arises from the method of modelling bridges. Although the two programs present different profiles at bridges, the true water surface could be said to be a combination of the two results. That is, the HEC-2 profile represents the surface at the bridge opening and the RIVER4 profile represents the water surface at the bank of the river, resulting in a warped surface caused by the drawdown through the bridge [8]. In general, the RIVER4 results are on the conservative side.

The main bridge of interest is the Thorpe Street bridge. Both programs calculate a water level above the minimum top of road elevation. The HEC-2 analysis did not determine a weir flow over the road but assessed the flow to be low flow by the normal bridge routine. The computed water level by HEC-2 is about one foot above the road. Obviously from the comparison table, RIVER4 produces a flooded road but the extent of flooding was not analysed by means of a bifurcated branch.

In order to test the effect of modelling bridges using artificial levees [9,10], the RIVER4 cross-sections just upstream and downstream of the bridges were revised to constrict the flow to a section equal to the channel invert and the width of the bridge. The revised geometry was then analysed for the same flow condition. The results are a considerably improved comparison between the two profiles produced by HEC-2 and RIVER4. This comparison is shown in Table 5.4.3. The table only shows the percentage difference for the two runs. Again the depth as calculated by HEC-2 was taken as the base depth. The term "Original % Difference" refers to the computation using the full width of the river section upstream and downstream of the bridge while the term "Modified % Difference" refers to the analysis where the corresponding sections are modelled using only the channel invert and width of the bridge.

The largest difference now occurs at node 13, it being a 35.9 percent difference in water level between the HEC-2 and RIVER4 profiles. This difference also occured in the original RIVER4 analysis. At present, no explanation can be offered for the discrepancy nor for the large differences at nodes 20 and 21.

Considering these results (modified analysis), it would seem to be advisable to model bridges with constricted sections both upstream and downstream of the structure. In general, provided the correct modelling technique is used, RIVER4 provides reasonable results.

TABLE 5.4.3
LOWER SPENCER CREEK

Comparison of Modelling Techniques

SEC. NO.	ORIGINAL % DIFFERENCE		COMPUTED HEC-2 DEPTH		MODIFIED % DIFFERENCE	
	EL	WL	EL	WL	EL	WL
30	- 3.6	0	6.14	5.74	- 3.6	0
29	- 3.2	- 2.2	7.45	6.41	- 3.2	- 2.2
28	+ 1.9	- 3.4	6.3	4.68	+ 1.9	- 3.4
27	+ 6.2	+10.8	7.27	6.22	+ 6.2	+10.8
26	-10.9	- 7.7	9.32	6.19	0.0	+ 0.3
25 24	THORPE ST. BRIDGE					
23	+14.7	+24.6	10.21	9.39	+11.0	+ 9.0
22	+12.2	+14.9	9.92	9.64	+ 9.8	+12.3
21	+12.1	+19.7	8.36	7.71	+10.0	+17.0
20	+12.0	+21.1	7.29	6.58	+10.7	+19.6
19	+ 0.6	+ 1.6	6.48	4.47	+ 0.6	+ 1.6
18	- 1.0	- 2.4	8.26	5.85	- 1.0	- 2.4
17	-17.8	-11.7	8.65	5.73	0.0	+ 0.3
16 15	MAIN ST. BRIDGE					
14	+14.2	+37.2	8.91	6.87	+ 9.5	+10.8
13	+ 4.8	+35.9	7.47	5.32	+ 4.8	+35.9
12	- 8.9	- 7.6	7.77	7.12	- 8.9	- 7.6
11	-19.8	-15.0	5.91	3.93	+ 1.7	+ 2.8
10 9	GOVERNOR'S RD. BRIDGE					
8	+ 9.1	+26.0	6.39	5.30	+ 5.5	-10.9
7	+ 5.5	+ 7.5	6.19	5.71	+ 5.5	+ 7.5
6	- 5.4	- 3.8	5.91	3.93	0.0	0.0
5 4	OGILVIE ST. BRIDGE					
3	+ 6.3	+38.7	5.92	4.03	+ 2.9	+16.9
2	- 4.6	- 5.9	5.88	4.21	- 4.6	- 5.9
1	- 3.3	- 8.2	6.88	4.90	- 3.3	- 8.2

EL - energy level
WL - water level

ORIGINAL % DIFFERENCE - difference based on full river section upstream and downstream of bridges

MODIFIED % DIFFERENCE - difference based on using artificial levees upstream and downstream of bridges

CHAPTER 6

FUTURE WORK

While developing and modifying subroutine RIVER4, it became apparent that the routine was becoming much too large and unwieldy. Further modifications of the routine should aim at reducing its size. This could be accomplished by removing the statements referring to branched flow computations and rewriting them as subroutines. This would result in a reduction of about 30 per cent in the number of lines in the routine. If one wished to reduce the subroutine size further, each command could be written as its own subroutine.

During the review of the program, concern has been expressed that only one roughness coefficient is used per cross-section. Some users may find this a serious drawback, especially when modelling rivers with extensive flood plains. Future work should look into the development of methods for using two coefficients, one for the main channel and one for the flood plain. In sewer systems, where NPTS=1, or in any closed top section, a default value could be used to indicate that an overbank does not exist.

One of the major requirements that needs to be completed is the extensive testing of the program on a "well behaved" river and sewer system. This means a system for which flows are known at discrete locations together with the corresponding water levels. In addition, the water level should be known at other locations throughout the system. A series of flow ranges for the same system should be tested in order to check the effect of using a single roughness coefficient. If possible, the system should include at least one bifurcated branch with the branch flow known so that the branch flow algorithm can be verified.

Supercritical flow is not modelled as of now. Subroutine EZRA should be expanded to include the analyis of supercritical flow. The other option is to develop a new subroutine that would only analyse supercritical flow.

In the multiple island configuration as described in Section 5.1.2, the system was correctly analysed for continuity at confluences. A problem could arise if a reach were determined to have flow going in the opposite direction. This flow would be set to a positive value of QMIN. It is possible with multiple islands, that flow direction would depend entirely on the amount of discharge available, thereby resulting in a reversal of flow. It would be desirable to have the flow listed negative, indicating modelling at this discharge is in the wrong direction. It would be useful to look at the viability of modifying the appropriate routines to handle negative flows.

A reasonable number of lines in the program have been devoted to defining the connectivity of the system being studied. Much thought has been given to having the connectivity defined in the geometry file. A problem arises when sections are added or deleted, thus changing the connectivity. Further work should be done checking the feasibility of being able to modify a predefined connectivity table. In addition, a user may not wish to analyse a bifurcated branch in the initial analysis. Therefore, it may be desirable to look at only confluences being predefined with the user defining branches during the analysis.

At present, when bifurcated branches are being modelled, the upstream and downstream limits of the profile computation must encompass all the branches. Occasions may arise where only one branch (a particular bridge, for instance) is the subject of study. It would be desirable to modify the branched flow computations so that only those branches of interest are analysed without having to include all the bifurcations. With the present algorithm, command BRANCH would have to be recalled, all branches eliminated and only the branch(es) of interest defined.

CHAPTER 7

CONCLUSIONS

There are several advantages to using the new program RIVER4. The geometry file is easy to prepare in time and effort. It is not encumbered with information about flow conditions, therefore, the file need not be altered. The data file is easy to change during a session resulting in faster turnaround time when testing design alternatives. Also, the complete geometry file need not be analysed. Therefore, time is saved in not having to re-create, alter or append the data file.

The command structure allows the designer to have complete control of the computation process. Some of the more comprehensive programs perform complete computations from the initial data entry to finished printout without the designer being able to monitor the process or review intermediate steps. With the summary command, initial conditions can be checked before proceeding with the profile computation and corrected if needs be without having a complete printout before discovering an error in input.

The printed profile itself is a straight forward simple table giving the pertinent results required by the designer. Some of the more comprehensive programs are well noted for the excessive amount of information printed out for each cross-section.

Although Manning's equation will be used most of the time, the program is not restricted to analysis by Manning's equation alone - the user has the option of selecting the flow resistance equation best suited to the analysis.

The user time to complete an analysis obviously varies with the system being studied. Typically, for plain river reaches or sewer systems, either without bifurcations, the complete analysis takes less than 10 minutes from start to finish for systems of about 50 nodes. For each additional analyses (new flow, different starting water levels, etc.) less than five minutes is required. With a single bifurcation per set of cross-sections, the time increase is about one half minute each. With multi-bifurcations at a set of cross-sections, the time increase is about one minute per additional bifurcation. The above listed times are only approximate but it may offer the user an indication of the time required to do an analysis. An exception to the above was the analysis of the "Island" network. Total time from start to finish was eight minutes using a CDC 6400 computer.

The original intent of the project was to produce a viable backwater program and documentation for its use. It is felt that this has been accomplished through the following steps:

(1) The command organization of input and output data has been improved.

(2) The addition of a command to summarize the initial conditions has been included.

(3) The loss coefficient command, including the appropriate subroutines, have been modified to include both contraction and expansion losses.

(4) The bifurcated branch flow algorithm has been improved resulting in a faster convergence to the solution.

(5) Preparation of a set of manuals (Appendix A to C, inclusive) for the use and modification of routine RIVER4 has been completed.

The program has been tested to validate its use for analysing various hydraulic systems. These include:

(1) Use on open channel systems.

(2) Closed conduit flow in a sewer system.

(3) The complex analysis of a multiple island network.

(4) The analysis of overland flow.

(5) The testing of various bridge modelling techniques.

In addition, the program results have been compared to the results of an accepted program (HEC-2) and the comparison has been quite favourable.

In general, it is felt that that which has been presented is a versatile and utilitarian program for the analysis of backwater profiles for design purposes.

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APPENDIX A

USER'S MANUAL

DISCLAIMER

This program is furnished by the authors and is accepted and used by the recipient upon the express understanding that the authors and McMaster University make no warranties, express or implied, concerning the accuracy, reliability, useability, suitability or completeness for any particular purpose of the information and data contained in this program or furnished in connection therewith and the authors and McMaster University shall be under no liability whatsoever to any person or organization by reason of any use made thereof.

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INDEX

USER'S MANUAL

A.1.0 Introduction

With the increase in storm water management, whether it be flood plain analysis or overland flow conditions in subdivision design, flow profiles are usually required. When the system is being designed, involving a number of trial and error runs, the use of large, complex programs becomes time consuming and expensive. In addition, depending on the particular configuration, the designer often has to select one of several complex programs available that has been designed for the particular problem. The program described herein has been specifically created to facilitate such trial and error analysis in order to test and compare various design options through the use of interactive computing.

The program is able to handle a broad selection of channel geometry and configurations ranging from natural river systems through to closed conduits such as sewer systems. In addition, the program can analyse bifurcated branches with the resulting "island" flow. Thus, an economic analysis can be performed for alternate design concepts, such as, diversion channels versus increase in bridge size or construction of an overflow relief sewer versus complete reconstruction of the sewer system.

The profile calculations are performed using the standard step procedure as developed by A.A. Ezra and now known as the "Ezra" method. Though originally a graphical procedure, it is ideally suited for computer use.

The profiles are steady state profiles assuming one dimensional flow. Two dimensional flow is assumed in subroutines QCR2D and CRITIC which computes the critical discharge and the critical depth, respectively. By reference to Figure A.1, the total energy for steady-state flow may be written as:

$$z_1 + y_1 + \alpha_1 \frac{V_1^2}{2g} = z_2 + y_2 + \alpha_2 \frac{V_2^2}{2g} + h_f \qquad (A.1)$$

where z_1, z_2 - elevations above datum

y_1, y_2 - depth of water

V_1, V_2 - velocity

α_1, α_2 - velocity coefficient = 1.0

h_f - head loss between section 1 and 2

g - gravitational acceleration

The head loss is further defined as

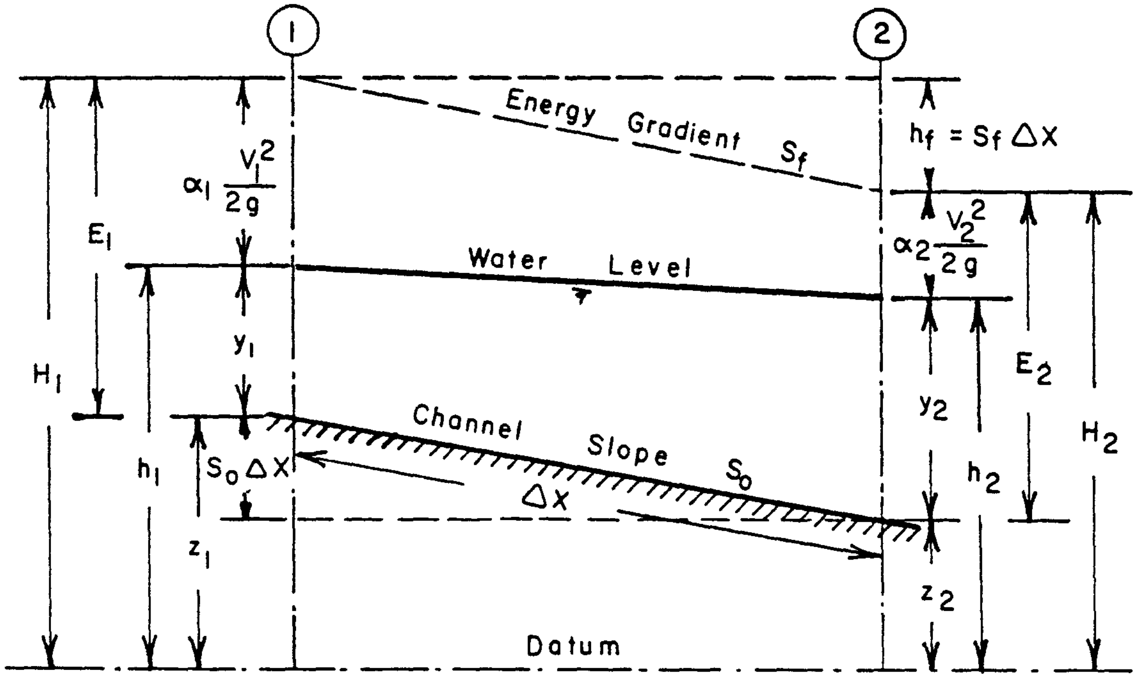
$$h_f = \frac{(S_1 + S_2)}{2} \Delta x \qquad (A.2)$$

and S_1 - energy slope at section 1

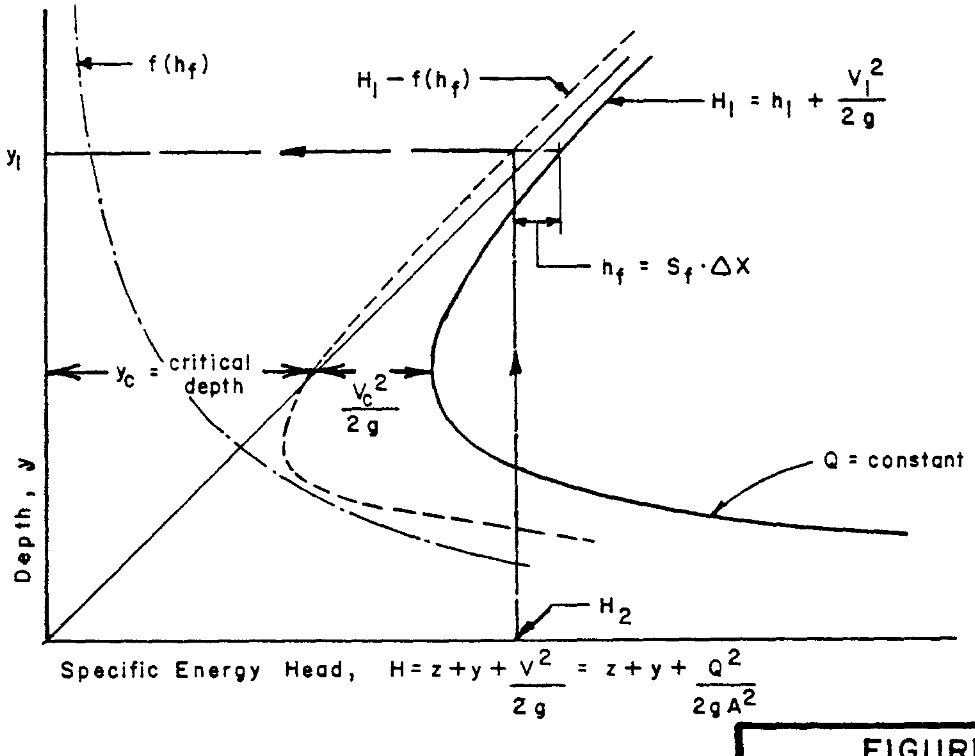
S_2 - energy slope at section 2

Δx - distance between 1 and 2

In the Ezra method, the depth of flow and the elevation above datum are combined to produce the following equations:



(a) Energy Terms for Gradually Varied Flow



(b) Specific Energy Curve

FIGURE A·1

ENERGY TERMS
for
GRADUALLY VARIED
FLOW

$$h_1 = z_1 + y_1 \tag{A.3}$$

$$h_2 = z_2 + y_2 \tag{A.4}$$

Therefore, the steady state equation can be rewritten as:

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g} + h_f \tag{A.5}$$

or
$$h_1 + F(h_1) = h_2 + F(h_2) \tag{A.6}$$

where
$$F(h_1) = \frac{V_1^2}{2g} - \frac{S_1}{2} \cdot \Delta x \tag{A.7}$$

where
$$F(h_2) = \frac{V_2^2}{2g} - \frac{S_2}{2} \cdot \Delta x \tag{A.8}$$

The original method as indicated above used the arithmetic mean of the two friction slopes. It is felt, though, that the geometric mean of the friction slopes gives a better representation of the friction slope between the two sections. Thus for

$$h_f = \Delta x \cdot (S_1 \cdot S_2)^{1/2} \tag{A.9}$$

$$F(h_1) = h_1 + \frac{V_1^2}{2g} - \Delta x (S_1 \cdot S_2)^{1/2} - h_2 - \frac{V_2^2}{2g} = 0 \tag{A.10}$$

The friction slope is calculated using the discharge and conveyance at the end sections, i.e.

$$S_1 = (\frac{Q}{K_1})^2 \qquad (A.11)$$

$$S_2 = (\frac{Q}{K_2})^2 \qquad (A.12)$$

Since the water level at section 2 is known as an initial condition, the total energy (H_2) and friction slope (S_2) are easily calculated. In order to determine the energy terms of the upstream section (1), the program calls on subroutine EZRA to solve the basic equation (A.10) by interval halving techniques applied to an assumed water depth. If the initial estimate is in error, the routine improves its estimate as follows, assuming y_r is the initial estimate and y_{r+1} is the improved estimated.

The routine first determines a range of uncertainty, $y_r < y_1 < y_{r+1}$ such that $F_1(y_r) < 0$ and $F_1(y_{r+1}) > 0$. The average depth $(y_r + y_{r+1})/2$ is tested and the following strategy used to shrink the interval of uncertainty, i.e.

$$y_r = (y_r + y_{r+1})/2 \quad \text{if } F((y_r + y_{r+1})/2) > 0 \qquad (A.13)$$

$$y_{r+1} = (y_r + y_{r+1})/2 \quad \text{if } F((y_r + y_{r+1})/2) < 0 \qquad (A.14)$$

A solution is reached when

$$\text{abs}\,[(y_r - y_{r+1})/y_{r+1}] \;\leq 10^{-5} \qquad (A.15)$$

The routine EZRA is used in a loop analysing successive pairs of cross-sections in an upstream direction using the previously calculated water level as the starting water level for the next set of computations.

A.1.1 The Program

The initial concept for the present program originated in the need to compute steady state backwater profiles quickly, easily and with limited data preparation. The result was a library of subroutines, each of which performed specific computations. The library, developed by A.A. Smith [1] is quite extensive, covering a wide variety of hydrologic and hydraulic phenomena. The library is called the Civil Engineering Program Library (C.E.P.L.) or "Civlib" for short. The heart of the backwater program is routine RIVER4, which is a part of the library. Since its initial development, RIVER4 has been extensively revised and improved by P.B. Ashenhurst [2]. This manual is one of three manuals derived from the appendices of the report written by Ashenhurst.

Subroutine RIVER4 is command structured of which there are 14 commands available to the user (see Table A1). After having typed one of the commands, the program is directed to the appropriate section in the subroutine whence specific information is requested from the user. The appropriate computation is performed and the results returned to the user. The calculations are usually performed by specialized subroutines that reside in the library (C.E.P.L.). Throughout the subroutine, a check is made that certain prerequisite information is available before continuing, such as flows have been defined before computing critical depth. If the information does not exist, the program is redirected to the appropriate section and the necessary data is requested. After each set of computations, the user is invited to submit another command until the command STOP is used which terminates the

TABLE A.1

Commands available in routine RIVER4

BRANCH	To define one or more branching junctions
COMPUTE	To compute surface profiles between a specified downstream control and any upstream section.
CONNECT	To define one or more confluence junctions.
CRITIC	To compute critical depth and energy level at any section for current discharges.
DISCHARGE	To specify discharges in the channel system explicitly.
D/S WL	To define the downstream control level.
EDIT	To edit the current geometry file.
HELP	To list the available command options.
INFLOWS	To specify inflow discharges at the upstream end of tributary channels.
LOSS COEFF	To define the energy loss coefficients at transitions
RESISTANCE	To define the desired flow resistance equation
RESTART	To begin again with the currently define geometry file
STOP	To terminate the session
SUMMARY	To summarize input data

session. Results are printed out in a simple tabular form, each tributary being printed separately with its own heading.

RIVER4 has complete dynamic allocation of array dimensions. The parameter list is quite extensive and the dimensioning has been simplified through the use of an enclosing subroutine, RIVER3. This subroutine is called by the user using one work array in a simple calling program.

The geometry file of the system resides on secondary devices such as disc or tapes. Though computation time is increased using secondary systems, the reduction in core size results in relatively large networks being handled in computers of modest size.

A.1.2 Geometry File

The hydraulic system is described by a series of cross-sections spaced along the network so as to adequately represent the system. Each section is described by a set of coordinate pairs which approximates the cross-section shape. The number of points may vary for each cross-section depending on its complexity. In addition, the section is defined by a characteristic resistance coefficient and chainage. Only one resistance coefficient is used per cross-section. Chainage can be either negative or positive but it must increase in the direction of flow.

It is recommended that if tributaries are being modelling, negative chainage be used starting with 0.0 at the downstream end and increasing in negative distance in the upstream direction. This will result in confluences having the same chainage for tributary and main channel.

Transitions can be modelled by using two consecutive cross-sections with the same chainage. By doing so, contractions and expansions can be modelled in order to represent bridges, culverts, drop manholes or weirs. Complex transitions can be modelled by three or more sections at the same chainage. Each cross-section is described by two record types. The first field of both record types contains the cross-section number. The first record type also includes the number of points in the cross-section, its chainage and roughness coefficient. The second record contains the horizontal and vertical coordinate pairs defining the cross-section shape. The horizontal station can be negative or positive.

Three pairs of coordinates can be accommodated on each type two record. Table A2 details the information required for the geometry file. If the user wishes to add additional comments to the data file, the comments should start after field 10. In this way, the comments are "transparent" to the program and processing will occur normally.

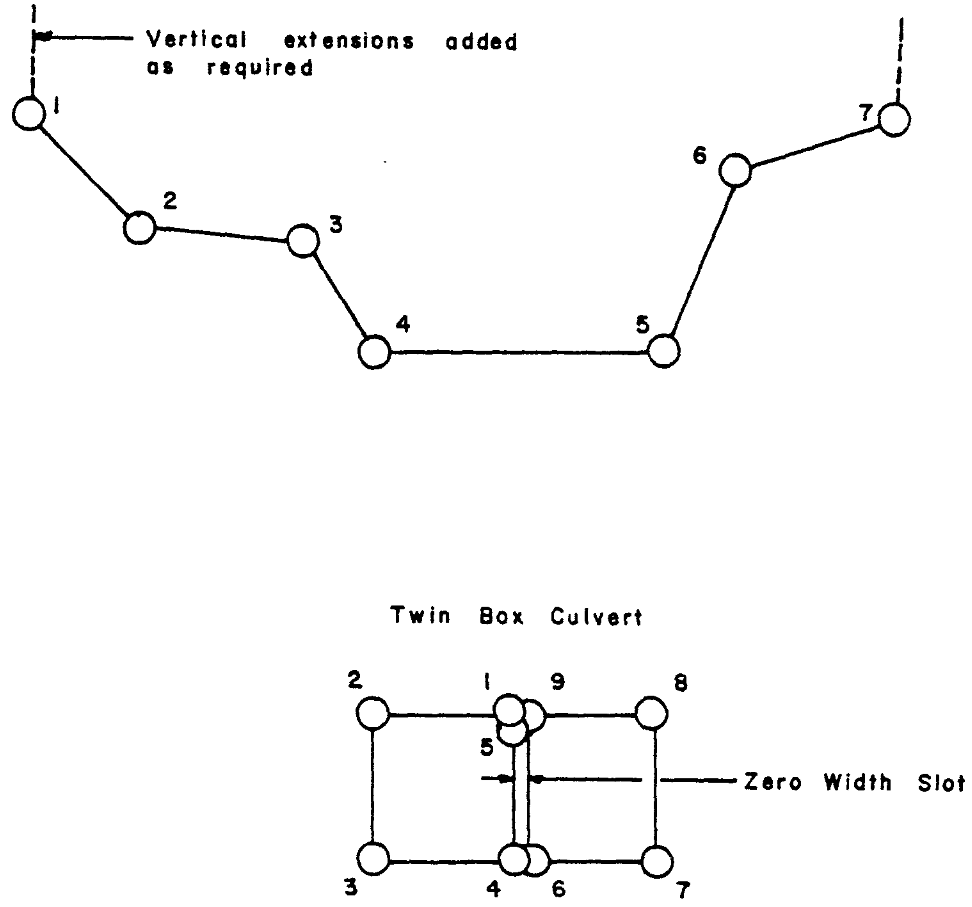
Circular pipes are described by one pair of coordinates (NPTS=1) in which HORZ(1) is the diameter and VERT(1) is the invert elevation. Figure A2 shows the modelling of a transition and the typical data for these cross-sections. Note the method of defining a twin box culvert.

The geometry file is always assigned to peripheral unit 1 and for CDC operating systems, it is attached as TAPE1.

TABLE A.2

Geometry File Format

Record	Field	Format	Variable	Description
1	1-5	I5	ISEC	cross-section number
1	6-10	I5	NPTS	No. of points describing the section
1	11-20	F10.1	CHAIN	cross-section chainage
1	21-30	F10.3	RC	Roughness coefficient
2	1-5	I5	ISEC	cross-section number
2	6-15	F10-3	HORZ(1)	Horiz. coord. of pt. 1
2	16-25	F10.3	VERT(1)	Vert. coord. of pt. 1
2	26-35	F10.3	HORZ(2)	
2	36-45	F10.3	VERT(2)	
2	46-55	F10.3	HORZ(3)	Coordinate pairs for
2	56-65	F10.3	VERT(3)	points 2 & 3
3 etc.	As record 2 for subsequent coordinate pairs.			



(a) Typical Cross-sections

1	7	-1250.0	0.20			
1	0.0	110.0	10.0	102.0	20.0	100.0
1	25.0	93.0	45.0	93.0	60.0	103.0
1	70.0	110.0				
2	9	-1250.0	0.10			
2	35.0	98.0	25.0	98.0	25.0	93.0
2	35.0	93.0	35.0	98.0	35.0	93.0
2	45.0	93.0	45.0	98.0	35.0	98.0

(b) Typical Data for above Cross sections

FIGURE A·2

TYPICAL
CROSS-SECTIONS

A.1.3 Network Configuration and Numbering

There are few limitations on the configuration of nodes and their numbering. The basic rule is that there can be no more than one tributary or bifurcated branch off of any one node. If there are two tributaries at the "same" confluence, the main channel would have to be modelled by two cross-sections with the same chainage. Each tributary can be modelled by one cross-section if so desired. This in general would represent a minor tributary and is included in order to account for flow contribution. This need not be done if command INFLOWS is used as point lateral inflows can be defined without the lateral cross-section being defined (see A.3.9 - INFLOWS).

Each tributary is numbered consecutively from the upstream limit to the downstream limit. The downstream limit of the principle channel must have the highest node number.

Bifurcated branches are numbered as if they were a tributary. The connectivity procedure defines the tributary as a branch. In order to arrive at a numbering scheme, the user should have a schematic of the configuration present. Then, starting at the upstream end of the shortest or least important tributary, number the nodes from one to the downstream end of the tributary (say 5). The next tributary would start at the upstream limit with 6 and continue to its downstream limit. This would be continued until the main channel is consecutively numbered with the highest set of numbers.

These rules can be summarized as follows:

(1) All tributaries (branches) must be numbered consecutively in the direction of flow.

(2) The furthest downstream section must have the highest number representing the maximum number of sections in the current geometry file.

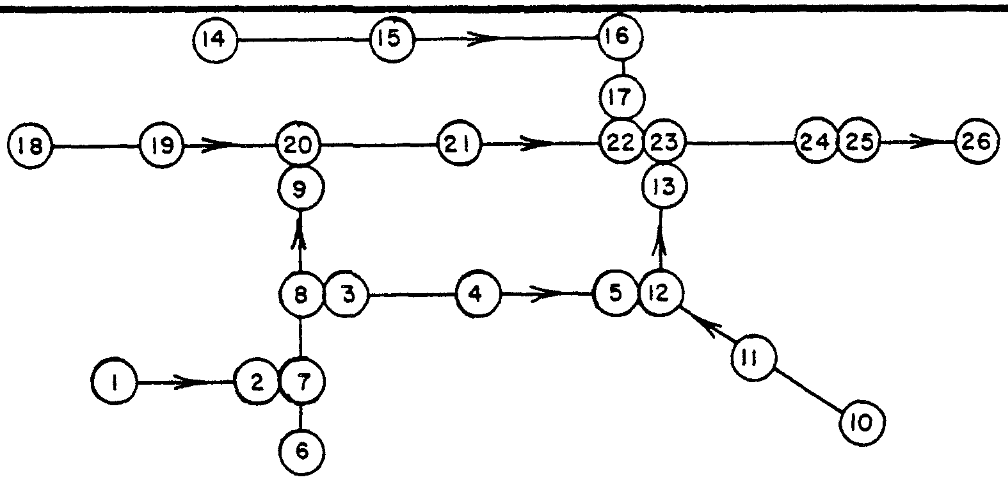
(3) Only one tributary or branch can exist at any one node.

Figure A3 shows a correct numbering scheme and one with typical violations. For further numbering schemes see Appendix B - Worked Examples.

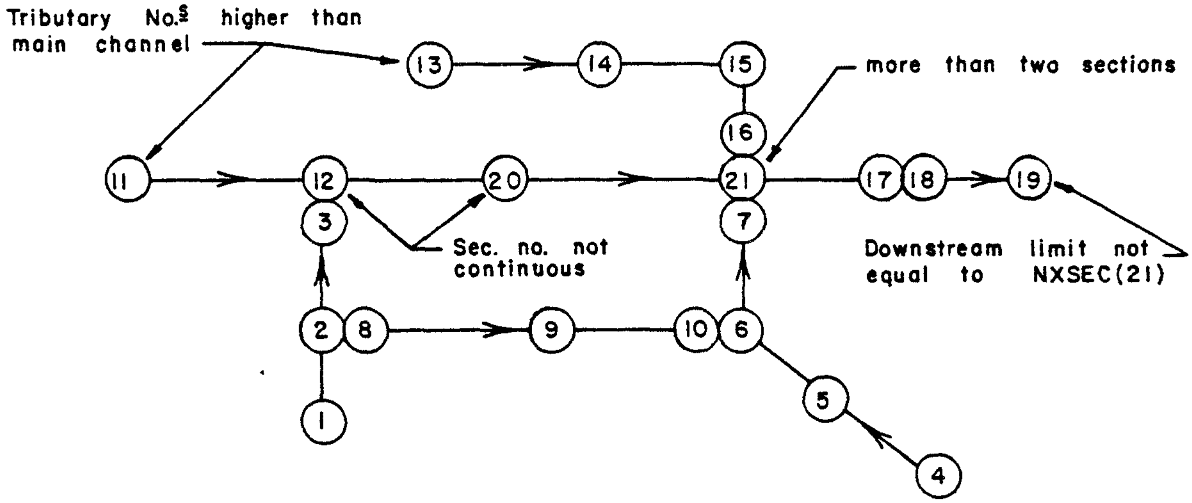
A.2.0 Driving Programs

Two driving programs provided by the user are required if data is to be created by the subroutine EDITXS and backwater calculations are to be performed.

In order to create a data file, the following program is used. The example assumes 55 cross-sections and maximum number of points for any one section is 20.



(a) Typical Network System (1 branch, 5 confluences)



(b) Typical Violations of Numbering and Connectivity Constraints

NODE(J)	1	2	3	4	5	6	7	8	9	10	11	12	13
KDS(J)	0	7	-8	0	12	0	0	0	20	0	0	0	23
NODE(J)	14	15	16	17	18	19	20	21	22	23	24	25	26
KDS(J)	0	0	0	22	0	0	0	0	0	0	0	0	999

(c) Connectivity Array for Network of (a)

FIGURE A·3

TYPICAL NETWORK

```
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
+                  TAPE1,TAPE2)
C     Program card for CDC 6400
      DIMENSION ITST(55), KSREC(100)
      NTAPE1=1
      NTAPE2=2
      NXSEC=55
      MAXPTS=20
      NR=5
      NW=6
      NOCOPY=0
      CALL FILEXS(NTAPE1,KSREC,NXSEC,MAXPTS)
C     This routine initializes KSREC()
      CALL EDITXS(NTAPE1,NTAPE2,KSREC,ITST,NXSEC,
+                 MAXPTS,NR,NW,NOCOPY)
      END
```

After the file has been created by responding to the prompts of routine EDITXS, the file TAPE1 contains the data and is saved for future use.

In order to use this file or any other file, a simple driving program is created to call subroutine RIVER3. First, the size of working array is calculated as

```
      NWK = 5*NXSEC + 4*MAXPTS

          = 5X55    + 4X20     = 355, say 400
```

Therefore, the program is as follows:

```
      PROGRAM TST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
+                 TAPE1,TAPE2)
C     Program card for CDC 6400
      DIMENSION WK(400)
      CALL RIVER3(1,2,5,6,32.2,WK)
      END
```

where 32.2 is the value of gravity in imperial units.

The use of the gravitational constant here and elsewhere in the routines allows either Imperial or Metric units to be used, as long as the units employed are otherwise consistent.

Though intended for interactive use, the backwater computations can be performed by batch mode. Care must be taken in anticipating the order in which data is entered. (See Appendix A.6 - Batch Mode Usage.)

A.3.0 Description of Commands

The following is a description of each command available in the program. The commands listed are in alphabetical order and in no way are related to the order of use. Section A.4 gives typical command sequences and should be referred to before proceeding with a computer run.

Most of the commands prompt the user with questions requesting specific information. The data is then entered according to the format given with the request. Therefore, a knowledge of the I format and F format of data entry is required. Parenthesis are printed out as an aid to data entry (see Appendix B - Worked Examples).

A.3.1 BRANCH

This command is used when a bifurcated branch resulting in "island" flow is modelled. The first piece of information requested is the number of bifurcated branches to be modelled. Then, for each branch, the upstream section number of the branching channel and the intermediate section number of the main channel is requested. This information is entered for each branch, each branch being entered on a separate line. After having entered the data required for all the branches, the BRANCH flag is set. It should be noted that after a branched computation, BRANCH can be reused and the number of branches entered as zero so as to remove all branch connectivity. Control then reverts to COMMAND.

A.3.2 COMPUTE

The backwater profiles are computed with this command. The description is in three parts: (a) general, (b) no bifurcated branches and (c) with bifurcated branches.

(a) General With or without branches, the command makes a general check for certain information. The first set of data checked is if the flow flag has been set. If not, a statement is printed out indicating that flows are missing and INFLOWS or DISCHARGE should be used. Since an option exists, control is passed to COMMAND for the user to select the command desired.

If this flag is set, the next flag checked is the downstream water level. If not set, the program jumps to the D/S WL command and requests this information. Again control reverts to COMMAND. The resistance flag is then checked. If the resistance flag is not set, control jumps to the RESISTANCE command requesting this information.

If all three flags are set, a check is made for bifurcated branches. If there are no branches, the program requests the upstream limit of the profiles to be computed. In other words, the whole geometry file need not be used.

Together with the D/S WL command and the upstream limit, those reaches of specific interest can be checked without altering the previous input data. Computation of the profiles then commence.

If branches do exist, then an information statement is printed informing the user that two options are available for branched computations - either profiles and/or error limits can be printed out for every iteration or printout starts after a predefined error in depth has been reached. If the former option is selected (every iteration printed out), the program asks for the upstream limit of the profiles as previously described. If the user chooses the latter option, the user is asked to define the percent error limit in depth of water relative to the shallower of the two depths at a branch.

It is difficult to say what the percentage should be though a value suggested is 10.0 percent. Engineering judgement must be used as best fits the problem at hand. The program then asks for the upstream limit of the profiles to be computed.

Due to the algorithm used, the downstream and upstream limits must encompass all branches modelled.

(b) No Bifurcated Branches The computations are straight forward. The first item printed is the title. Then, the water level, energy level, invert, and velocity are printed out for each node in a tributary, each tributary being prefaced with column titles. The limits are those as stated by the D/S WL and upstream limit. At the end of the computations, control reverts to COMMAND.

Now a new run can be made if required by using INFLOWS or DISCHARGE together with D/S WL. In addition, the limits of computation can be changed. If need be, the cross-section data can be changed using EDIT, then followed by the appropriate commands.

(c) With Bifurcated Branches The computation proceeds in two fashions. If the user has chosen to have every iteration printed out, the program asks if this particular iteration is to be printed out. If the answer is yes, then the title and the profiles are printed out. At the end of the profiles, the error in energy level and water level is printed out together with the correction to flow required to try to balance the energy levels. If printout for the particular iteration is not desired then only the error limits are printed out. In either case, after the error limits are presented, the user is asked if profiles are to be recomputed. If the answer is yes, then the program reverts to the beginning of the command and starts over again. If the answer is no, control passes to COMMAND.

If the user had selected to have printout start after a predetermined error limit is reached, then all previous printout does not appear. One of two statements will appear. If due to the geometric or flow configuration, the balancing process takes more than 10 iterations, the word COMPUTING is printed out to inform the user that computations are proceeding normally. This information is printed every 10 iterations. When the maximum error in all branches is less than the percent error set by the user, the program responds with the request if the next iteration is to be printed out. The error in the next iteration will be less than the error limit defined, since the correction to flow has been added from the previous iteration. The rest of the run is the same as with no bifurcated branches.

It should be noted that after 50 iterations, the program prints a message accordingly with the comment that one more iteration will be tried.

In actuality, the program reverts to user control, iteration by iteration. If this limit is reached, either the configuration is extremely complex or there is an error in information or data (i.e. flows, connectivity or cross-section data, resistance law). These should be checked carefully.

A.3.3 CONNECT

As the data file is in consecutive order from 1 to NXSEC, this command instructs the program as to the connectivity of the data in defining tributaries. The first request for information is the number of confluences in the system. If there are none (single reach) zero is entered. If one or more exists, then this number is entered. In response, the program asks for the downstream section number of the tributary and the intermediate section number of the receiving stream, respectively. This is repeated for each confluence. When all confluences have been thus defined, the connectivity flag is set and control reverts to COMMAND.

A.3.4 CRITIC

On some occasions, it may be useful to know the critical depth and critical energy level at a particular cross-section. This command is used to calculate this information. The command first checks if the DISCHARGE/ INFLOWS flag has been set (i.e. has the flow been defined). If the flag is not set, control is transferred to DISCHARGE where the flow is defined. If the flag has been set, the program asks for the section number for which critical depth is to be determined. The critical water level and critical energy level are then calculated and printed out together with the section number and the flow value. Control then reverts to COMMAND.

A.3.5 DISCHARGE

This command is used to define flows at nodes independently of the connectivity or branching scheme. Thus, it must be used very carefully. Once a secton number and flow are given by the user, the program makes that flow value exist for every section from the given node to the last node (NXSEC). Therefore, if several different flow values are to be entered, it is advisable to start with the lowest section number (i.e. 1) and continue through to the highest section number.

The first request for information is the number of subreaches with different flow values. Then, for each reach, the upstream section number and discharge is requested. When all reaches have been defined, the initial flow values at each section is printed out going from 1 to NXSEC, inclusive, and in order. This allows the user to check the flow at each node before proceeding. If the values are correct, the user can request another command. If the values are incorrect, DISCHARGE can be reused.

It should be noted that if a flow is defined as 0.0, the program defaults the flow to QMIN = 0.0001 units per second. This is printed out as .000. In addition, the first function of the command is to preset all flows to QMIN before proceeding.

A.3.6 D/S WL

The initial or starting water level at the downstream section number where profile computations are to start, is defined using this command. The downstream section number is first requested followed by the initial water level to be used. Control then reverts to COMMAND.

A.3.7 EDIT

This command is unique in that it in itself is command oriented. The command is used to alter cross-section properties or channel geometry. The commands available for use are:

ADD - to add a new section
CHANGE - to alter any section property
DELETE - to delete an existng section
END - to end this edit session
HELP - to print list of available commands
PRINT - to print out properties of section(s)
RETURN - to return the calling routine

When adding or deleting sections, it is advisable to have present a schematic of the existing network in order to note the changes as these will affect the connectivity. If ADD is used to define a new section between two existing nodes, then all sections from the new one to NXSEC are increased by one. Correspondingly, the use of DELETE reduces higher numbered sections by one.

In addition, care must be taken in the original driving program if new sections are added. The size of variable WK must be large enough in anticipation of the added sections. WK should be no less than

$$WK = 5*NXSEC + 4*MAXPTS$$

with respect to the latest network configuration. WK is not affected when sections are deleted.

A further note on the use of command EDIT is in order. All alterations must start from section one and follow through to NXSEC in numerical order no matter what command is being used. The process involves the copying of the original data tape (TAPE1) onto the scratch tape (TAPE2) starting at the first section. When an alteration is requested, the additions and changes are copied onto TAPE2. For deletions, the particular section data is bypassed and not written onto TAPE2. Therefore, if ADD or DELETE is used a second or subsequent time, the section number referred to will be that which corresponds to the original data on TAPE1, not the assumed altered data file on TAPE2.

When all alterations have been completed and command END is used, TAPE2 is copied back onto TAPE1. It is at this time that the section numbers are altered as required to reflect the additions and deletions requested by the user. If the user attempts to alter a section number lower than the previous altered section, a message is printed informing the user that section numbers must increase and if the section number entered by the user is to be changed, then command END should be used. If END is used the data file to be altered will be the new file showing all previous alterations. (See Appendix B.8 - Use of EDIT).

A.3.8 HELP

This command is used to printout the command options available. It defines the format to be used and gives a description as to the command's use. The command listing is the same as is printed (if requested) at the beginning of the program. After printing the commands, control reverts to COMMAND.

A.3.9 INFLOWS

Upstream tributary inflows are defined using this command. The first function of this command is to set all flow values equal to QMIN. This allows the command to be reused after a profile computation in order to test another flow condition without having spurious flows appear. The program then informs the user that for NCONF confluences and NBRNCH branches, the number of inflows is NCONF-NBRNCH + 1 occurring at specific section numbers. Each upstream section number is printed out, after which the user enters the flow for that tributary. The upstream flows are added together at confluences and the result carried downstream to the next confluence or the end of the system.

After all the upstream tributary inflows have been defined, the program asks if the user wishes to define point lateral inflows. The advantage of this request is that minor tributaries need not be modelled with one or more cross-sections yet the flow contribution to the system can be accounted for. On request, the number of point lateral inflows is given. Then, for each lateral inflow, the section number and flow value is given. Each of these flow values are then added to every node in the downstream direction to the last section number. Point lateral inflows can be negative if modelling involves a large industry that is withdrawing water from the system. A check is made to make sure that the minimum flow is no less than QMIN at any section. If there are no point lateral inflows or after all point lateral inflows have been defined, the program prints out the initial flow values at each node. The user is then able to verify the starting flows before continuing. The flow flag is then set and control reverts to COMMAND.

It should be noted that after the flow flag is set a check is made for branched flows. If branched flows do exist, this command makes the initial estimate of the division of flow between branches based on the critical energy at the bifurcation.

A.3.10 LOSS COEFF

Head losses at transitions are accounted for in the program at contractions and expansions. The loss is defined as a constant times the difference in velocity heads and is applied to the energy levels at the transition. In order to account for the loss, the point in question must be modelled with two consecutive cross-sections with the same chainage. Complex transitions can be modelled with three or more consecutive sections with the same chainage.

The coefficients have been defaulted to a value of: contractions (CLC) = 0.0, expansions (CLE) = 1.0. These values can be altered during the computation. Typical values would be:

	Coefficient	
	Contraction	Expansion
No transition loss	0.0	0.0
Graduation transition	0.1	0.3
Bridge section (wtih wingwalls)	0.3	0.5
Bridge section (no wingwalls)	0.6	0.8
Very abrupt transitions	0.7	0.9

In using the command, the program prints out the presently listed values of the coefficients and asks the user if the values are to be changed. If the answer is NO, control reverts to COMMAND. If the answer is YES, the program requests the new values of CLC and CLE in order. These are the values that will be listed at the next use of this command. After having entered the new values, control reverts to COMMAND.

A.3.11 RESISTANCE

The resistance law to be used in the analysis is set using this command. The program asks the user to type one of:

CHEZY, MANNING, STRICKLER, COLEBROOK, ROUGH or SMOOTH

together with a cautionary question as to whether the resistance name and the roughness measure used in the data file are compatible. If the command is typed again the program asks the user to respecify the law. Control then reverts to COMMAND. The user is referred to Table A.3 for the complete formulation of the flow resistance equations available. Except for Manning's equation, all are presented in the form of Chezy's equation, i.e.:

$Q = CA(RS)^{1/2}$.

TABLE A·3 FLOW RESISTANCE EQUATIONS

Chezy Equation

$$Q = CA\sqrt{RS}$$

Manning Equation

$$Q = \left(\frac{0{\cdot}4671\, G^{\frac{1}{3}}}{n}\right) A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Strickler Equation

$$Q = \left[8{\cdot}41\sqrt{G}\cdot\left(\frac{R}{k}\right)^{\frac{1}{6}}\right] A\sqrt{RS}$$

Colebrook-White Equation

$$Q = -\left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{k}{14{\cdot}8R} + \frac{1{\cdot}255\ \nu}{R\sqrt{32\,RSG}}\right)\right] A\sqrt{RS}$$

Nikuradse 'Rough' Turbulent Equation

$$Q = \left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{14{\cdot}8\,R}{k}\right)\right] A\sqrt{RS}$$

Nikuradse 'Smooth' Turbulent Equation

$$Q = \left[\sqrt{32\ G}\cdot\log_{10}\left(\frac{R\sqrt{32\,RSG}}{1{\cdot}255\ \nu}\right)\right] A\sqrt{RS}$$

where:

Q - discharge (ft^3/sec , m^3/s)
A - cross section area (ft^2, m^2)
R - hydraulic radius (ft, m)
S - slope of energy gradient (ft/ft, m/m)
G - gravitational acceleration (ft/sec^2, m/s^2)
ν - kinematic viscosity (ft^2/sec , m^2/s)
C, n, k - roughness coefficient (ft, m – where appropriate)

A.3.12 RESTART

This option allows the user to start over again with the current geometry file. The main use would be to redefine the title for this profile if the run conditions are different.

A.3.13 STOP

This command terminates the session after all computations are complete. If EDIT has been used within the session to change the geometry file, then TAPE1 will have to be saved in order to preserve the new geometry for future use.

A.3.14 SUMMARY

This command prints out a summary of all input data that has been entered to date. It can be used at any time. The summary table lists the following, in order: the title, units used, the connectivity table defined by the node number and KDS (NODE), the initial flow at each node, initial water level, resistance law and the head loss coefficients. Control then reverts to COMMAND.

It should be noted that if branches are being modelled, the initial flows are not printed out. Instead, a message is typed indicating that the flows are not printed in order to prevent possible confusion with the final flow as calculated by the program.

A.4.0 Command Sequence

The previous section gave a brief description of the commands available. The following list indicates the general sequence of commands if all commands are to be used in a single run.

CONNECT
BRANCH
INFLOWS or DISCHARGE
RESISTANCE
D/S WL
LOSS COEFF
SUMMARY
COMPUTE
STOP

The command CRITIC could be used after INFLOWS/DISCHARGE in order to establish critical depth at points of interest before continuing. If a new flow condition is to be analysed for the same configuration, then INFLOWS/DISCHARGE can be reused after COMPUTE followed by D/S WL if the initial water level is different. COMPUTE is then called to calculate the new profile, or SUMMARY, COMPUTE if so desired.

If a redesign or alteration of cross-sections is desired after the profiles are computed, EDIT can be called. This will necessitate redefining the connectivity by CONNECT and all subsequent commands. It is effectively a complete restarting of the profile computation.

Command HELP can be used at any time after the command prompt.

A.5.0 Bifurcated Branches

One of the more useful aspects of this program is its ability to handle bifurcated branches and the resultant "island" flow. In most applications, a single branch will be modelled usually as a single diversion channel. There is no limit to the number of branches that can be modelled except for the size of KSREC which is set to a maximum size of 100 nodes or cross-sections.

There are certain criteria that must be followed. For every branch channel, the numbering of the nodes must be consecutive and in increasing order from the upstream end to the downstream end of the branch. In addition there must be one cross-section upstream of the bifurcation and one cross-section downstream of the junction, whether the junction is on the main stream or on another tributary.

It must be remembered that the more complex the configuration, the longer it will take to have the computations converge to the predefined error limit. This is particularly true if drop structures exist, such as, weirs, drop manholes or invert discontinuities defined by double nodes.

Profiles should be carefully checked afterwards if more than one branch is being modelled to check if the flow values are reasonable. Occasions have arisen where a branch will have no flow in it. This result usually demonstrates that the branch has been modelled to flow in the wrong direction.

Though the inverts of the channel may indicate flow in one direction, it is possible for certain flow conditions to cause a branch to flow in the opposite direction.

A.6.0 Batch Mode Usage

As previously stated, the program is intended for interactive use. The program can be used in batch mode but care must be used in the preparation of the data. The following is a sample of the records required for batch mode usage. There are two parts to the description, one with no branches and one for bifurcated branches. In dealing with branches, it has been assumed that a percentage error limit terminates the computation.

The order used is similar to that as indicated in A.4 - "Command Sequence". It should be noted that, except for the title card, all "A" format data is left justified. Between commands COMPUTE and STOP, the other commands can be interjected as required. The four most common commands used again are: INFLOWS, D/S WL, SUMMARY, COMPUTE. These are used to model another flow condition and can be repeated as often as required before command STOP is used.

If several branches are being modelling individually or in various combinations, the record set for BRANCH would be inserted before subsequent use of INFLOWS. Care must then be taken in correctly defining the tributary inflows for each configuration.

The commands EDIT and HELP are not amenable to batch mode use and are not represented in the following pages.

RIVER4
BATCH MODE
DATA PREPARATION

REC. NO.	VARIABLE NAME	VALUE	FORMAT	COMMENTS
1	TITLE		10A6	- title of project (up to 60 characters)
2	SKIP	NO	A3	- command options not printed out
3	COMND	CONNECT	A6	- command
4	NCONF		I5	- number of confluences
5A	K, KDSK		2I5	- K - D.S. limit of tributary KDSK - corresponding intermediate sec. no. of receiving stream - one record for each confluence (rec. no. 5B, 5C, etc.)
6	COMND	BRANCH	A6	- command (use only if branches are being modelled)
7	NBRNCH		I5	- number of bifurcated branches
8A	K, KDSK		2I5	- K - U/S Limit of branching channel KDSK - corresponding intermediate sec. no. of main channel - one record for each branch (rec. no. 8B, 8C, etc.)

RIVER4
BATCH MODE
DATA PREPARATION

REC. NO.	VARIABLE NAME	VALUE	FORMAT	COMMENTS
				- use only one of the following INFLOWS or DISCHARGE. Use INFLOWS if BRANCH has been used.
9	COMND	INFLOWS	A6	- command
10A	$(Q1)_1$		F10.3	- flow value for tributary with lowest U/S node number
10B	$(Q1)_2$		F10.3	- flow value for tributary with second lowest U/S node number - one record for each tributary going from lowest U/S node number to the highest U/S node number (rec. no. 10C, 10D, etc.)
11	ANS	YES	A3	- are there point lateral inflows - if answer is NO, go to the next command required
12	NLAT		I5	- number of lateral inflows
13A	NODE,QLAT		I5, F10.3	- node number, corresponding lateral inflow - one record for each lateral inflow (rec. no. 13B, 13C, etc.)

RIVER4
BATCH MODE
DATA PREPARATION

REC. NO.	VARIABLE NAME	VALUE	FORMAT	COMMENTS
14	COMND	DISCHARGE	A6	- command
15	NQS		I5	- number of subreaches with different flow
16A	I1, Q1		I5, F10.3	- U/S section no. of reach, flow value (start with lowest section number and work up to the highest) - one record for each subreach (rec. no. 16B, 16C, etc.)
17	COMND	D/S WL	A6	- command
18	NDS1		I5	- sec. no. where D/S water level to be defined
19	DSWL1		F10.3	- initial water level
20	COMND	RESISTANCE	A6	- command
21	QN		A6	- name of Resistance Law to be used
22	COMND	LOSS COEFF	A6	- command (use only if CLC and/or CLE are to be changed from CLC = 0.0, CLE = 1.0)
23	ANS	YES	A3	- a change in loss coefficient is desired
24	CLC, CLE		2 F10.3	- new value of loss coefficients in following order, CLC, CLE

RIVER4
BATCH MODE
DATA PREPARATION

REC. NO.	VARIABLE NAME	VALUE	FORMAT	COMMENTS
25	COMND	CRITIC	A6	- command (use only if critical condition desired)
26	ICRIT		I5	- section no. where critical flow conditions to be calculated
				- repeat above two records for every section where critical conditions are desired
27	COMND	SUMMARY	A6	- command (summarize input data)
				- There are two sets of command COMPUTE. The first one is used when there are no bifurcated branches, the second is used when bifurcated branches exist
28	COMND	COMPUTE	A6	- command (no branches)
29	NUS1		I5	- upstream limit of profiles by section number
30	COMND	STOP	A6	- command (terminate run) this is always the last record
28	COMND	COMPUTE	A6	- command (bifurcated branches being modelled)
29	ANS	NO	A3	- end result only to be printed out

RIVER4
BATCH MODE
DATA PREPARATION

REC. NO.	VARIABLE NAME	VALUE	FORMAT	COMMENTS
30	PERCNT		F 10.3	- percent error limit in depth of water at branch
31	NUS1		I5	- upstream limit of profiles by sec. no.
32	ANSW	YES	A3	- profiles to be printed for this iteration
33	ANS	NO	A3	- profiles are not to be recomputed
34	COMND	STOP	A6	- command (terminate run) this is always the last record

A.7.0 Limitations

The main limitation of this program is that supercritical flow is not modelled. Any section that is supercritical is flagged in the printout with the term *CRIT*. The energy and water level printed out is the critical level. If supercritical flow is of importance and a continuous set of cross-sections are flagged, alternate programming will have to be used. In general, profiles listed at critical depth provide an upper bound of the profile limit and could be of value in design.

Another limitation of the program is the use of a single roughness coefficient for each cross-section. If multiple profiles are computed with widely varying flow values, consideration should be given to altering the roughness value. In most cases, a single value provides a reasonable approximation to the roughness factor.

REFERENCES

1. A.A. Smith, "C.E.P.L., A Civil Engineering Program Library", McMaster University, Hamilton, Ontario, 1974.

2. P.B. Ashenhurst, "Computer Analysis of Flow Profiles in Hydraulic Networks", a project report submitted in partial fulfilment of the requirements for the Degree of Master of Engineering, McMaster University, Hamilton, Ontario, 1981.

APPENDIX B

WORKED EXAMPLES

INDEX

WORKED EXAMPLES

B.1 Introduction

These examples are presented to provide the user with information on modelling various networks and structures. Each example contains a description of use, a diagram of the network, and the appropriate printout for the example. The examples include modelling bridges, sewers with overland flow, river system and modelling of multiple islands in a river system.

Most hydraulic systems will be modelled as one of the examples or a combination of the different systems presented. Other modelling techniques may have to be used for the more unusual cases.

One of the main uses of a backwater program is the analysis of the potential inundation of bridges. Therefore, it is incumbent that all sorts of bridge configurations are able to be modelled with reasonable accuracy, taking into consideration size and shape of the opening and the elevation of the road relative to the top of the opening. It is possible for three flow conditions to exist at a bridge: (1) low flow, (2) pressure flow through the opening, (3) weir flow over the roadway, or any combination of the three types of flow.

As such, there are basically three types of bridges to be modelled. Figures B.1 to B.3, inclusive, show typical flow conditions at a bridge together with the schematic representation. The figures appear in those sections describing the particular bridge type. In addition, the cross-sections modelled are shown. Most bridges will be modelled as one of these three types or as a combination of them. There are several ways of modelling cross sections upstream and downstream of bridges. In the discussion to follow for a Type 1 bridge, two of the more common methods used are represented. One method uses the full valley section just upstream and downstream of the bridge as shown in Figure B.1(a) at nodes 2 and 5. The other method uses an open topped section equivalent to only the width of the bridge opening together with the invert of the bridge as shown in Figure B.1(b). The profile results are different and, for the Type 1 bridge, both have been included. The user should exercise judgement in choosing the method used to model these particular sections.

The remainder of the examples use only the full valley section (where appropriate). The primary purpose of the examples is to illustrate various procedures in using the program and to demonstrate the type of hydraulic system that can be analysed.

It should be noted that pressure flow and weir flow are analyzed using the flow resistance equation selected by the user at the beginning of the program. Pressure flow is not analyzed using an orifice equation and road flow is not treated as a weir using the weir equation. For flooded roads, a Type 2 or Type 3 bridge should be used as explained further in this appendix.

Since the flow resistance equation alone is used, it is difficult to model culverts and bridges with piers in them.

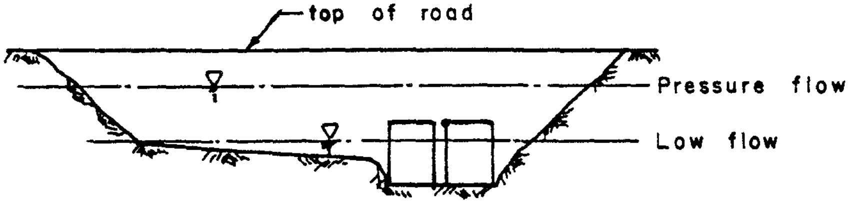
Yarnell's work on piers and pier shape is not accounted for in this program.

B.2 Type 1 Bridge

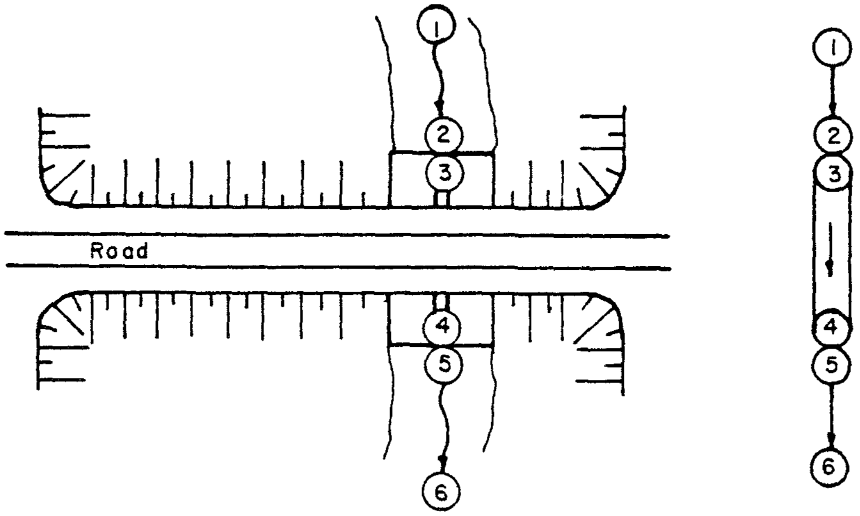
This type of bridge is one in which the roadway or top of the embankment does not flood (Figure B.1a and b). In addition, the conduit consists of a single structure such as a pipe or box culvert, or as twin box culverts with the same invert and obvert. This bridge represents the simplest form of embankment condition with a closed conduit. The following example illustrates the definition of a twin box culvert as a single cross-section. In Table B.1.1, the complete geometry files are presented which corresponds to the systems shown in Figure B.1(a) and Figure B.1(b).

It will be noted in cross-sections 3 and 4, that the thickness of the common wall is not represented in the coordinate pairs. Instead, the boundary wall is defined as having zero width, starting at the fourth pair of coordinates and ending with the sixth pair (see Figure A.2 for typical section).

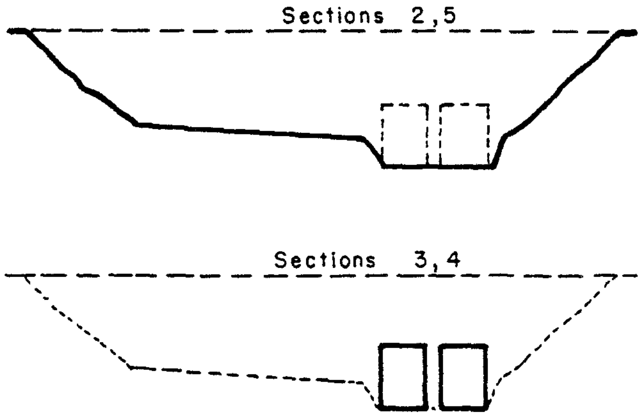
Using Mannings equation, the system was analyzed for four flow conditions, these being 250 cfs, 500 cfs, 750 cfs and 1000 cfs. The initial water level at section 6 was assumed to be twice critical depth. As is to be expected, the higher the discharge, the higher is the water level upstream of the bridge. At a flow of 1000 cfs, the acceleration created by the head upstream of the bridge has forced the flow to be supercritical at the downstream end of the bridge. This is shown by the term *CRIT* listed for



a) PROFILE



b) PLAN and SCHEMATIC

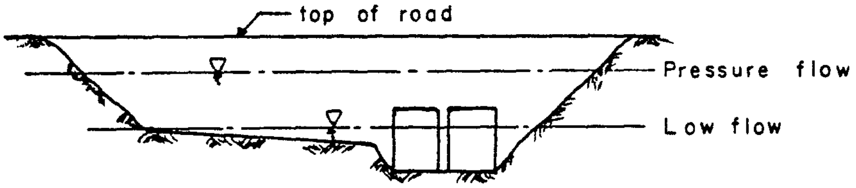


c) CROSS SECTIONS

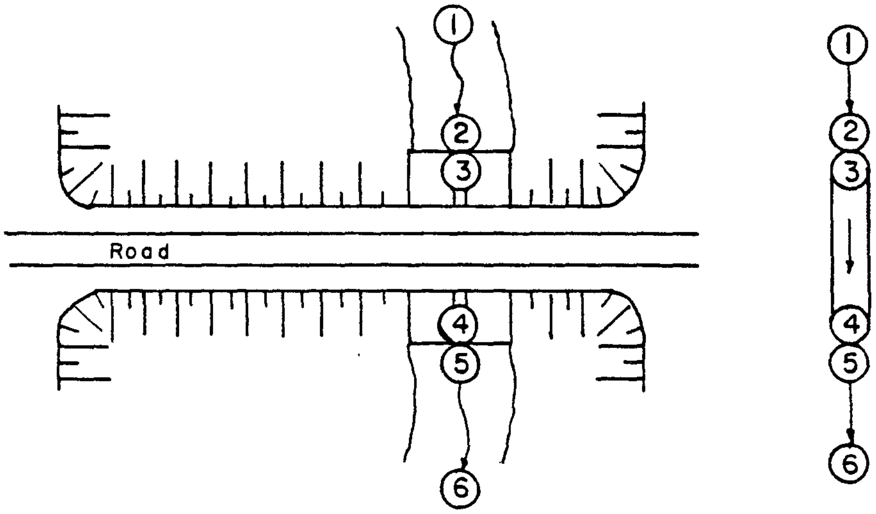
NOTE: For use with low flow, pressure flow, NO road flow
For use with
- single pipe culvert
- single box culvert
- multi box culvert with same invert and obvert (width may vary)

FIGURE B-1(a)

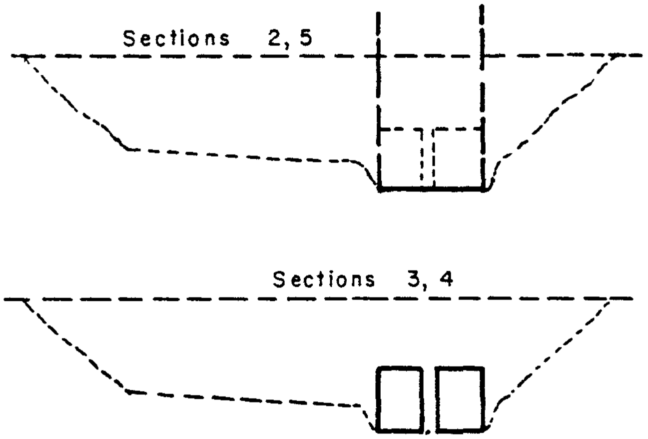
TYPE I BRIDGE



a) PROFILE



b) PLAN and SCHEMATIC



c) CROSS SECTIONS

NOTE : For use with low flow, pressure flow, NO road flow
For use with
- single pipe culvert
- single box culvert
- multi box culvert with same invert and obvert (width may vary)

FIGURE B·1(b)

TYPE I BRIDGE

TABLE B.1.1

TYPE 1 BRIDGE DATA

a) Based on Figure B.1 (a)

```
     TYPE 1 BRIDGE
        MAIN CHANNEL  1 - 6
        TWIN BOX      3 - 4
1    6   -800.0      0.035
1      0.0       100.0       20.0        95.0       98.0         94.0
1    100.0        92.5      122.0        92.5      150.0        100.0
2    6   -500.0      0.035
2      0.0       100.0       20.0        95.0       98.0         94.0
2    100.0        92.0      122.0        92.0      150.0        100.0
3    9   -500.0      0.013
3    110.0        97.0      100.0        97.0      100.0         92.0
3    110.0        92.0      110.0        97.0      110.0         92.0
3    120.0        92.0      120.0        97.0      110.0         97.0
4    9   -300.0      0.013
4    110.0        96.8      100.0        96.8      100.0         91.8
4    110.0        91.8      110.0        96.8      110.0         91.8
4    120.0        91.8      120.0        96.8      110.0         96.8
5    6   -300.0      0.035
5      0.0       100.0       20.0        95.0       98.0         94.0
5    100.0        91.8      122.0        91.8      150.0        100.0
6    6      0.0      0.035
6      0.0       100.0       20.0        94.0       98.0         93.0
6    100.0        91.0      122.0        91.0      150.0        100.0
```

b) Based on Figure B.1 (b)

```
0        TYPE 1 BRIDGE
0           MAIN CHANNEL  1 - 6
0           TWIN BOX      3 - 4
1    6   -800.0      0.035
1      0.0       100.0       20.0        95.0       98.0         94.0
1    100.0        92.5      122.0        92.5      150.0        100.0
2    2    -500.0       .035
2   100.000     92.000    120.000     92.000
3    9   -500.0      0.013
3    110.0        97.0      100.0        97.0      100.0         92.0
3    110.0        92.0      110.0        97.0      110.0         92.0
3    120.0        92.0      120.0        97.0      110.0         97.0
4    9   -300.0      0.013
4    110.0        96.8      100.0        96.8      100.0         91.8
4    110.0        91.8      110.0        96.8      110.0         91.8
4    120.0        91.8      120.0        96.8      110.0         96.8
5    2    -300.0       .035
5   100.000     91.800    120.000     91.800
6    6      0.0      0.035
6      0.0       100.0       20.0        94.0       98.0         93.0
6    100.0        91.0      122.0        91.0      150.0        100.0
```

section 4 indicating the possibility of a hydraulic jump occurring.

At section 3, the water level is listed as 97.521 which is above the crown of the culvert. What has been printed is not the "water level", but the piezometric surface. For very long culverts, it may be desirable to model one or more sections between the inlet and outlet in order to determine the piezometric profile throughout its length.

In this simple example, the complete listing of the printout is presented for a flow of 250 cfs in Table B.1.2. In addition, the profile results for a flow of 1000 cfs is shown in Table B.1.3. The two profiles presented for each flow condition should be carefully reviewed at the upstream and downstream limit of the bridge (nodes 2 and 5). In both cases, when the full valley section is used, the water level is higher and more conservative than when the sections are modelled as in Figure B.1(b). Note the command order used to input the data. Before COMPUTE is used, SUMMARY has been called upon to summarize the pertinent input data. It will be seen that the summary is quite short compared to the initial input.

TABLE B.1.2 TYPE 1 BRIDGE
PROFILE COMPUTATION FOR 250 CFS

```
                              **********
                              * RIVERS *
                              **********

             AN INTERACTIVE SIMULATION MODEL FOR STEADY
               STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                            ALAN A SMITH
                        MCMASTER UNIVERSITY

                       (REVISED APRIL 1981)



    CHANNEL GEOMETRY ON TAPE   1 HAS   6 CROSS-SECTIONS
    MAX. NO. OF PTS. PER SECTION IS   9
    DIMENTION OF ARRAY WK() IN CALLING PGM. .GE.   66


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
?      TYPE 1 BRIDGE
DO YOU WANT A LIST OF COMMANDS?...YES/NO
? YES
AFTER INVITATION GIVE ONE OF THE FOLLOWING COMMANDS
BRANCH........TO DEFINE BRANCHING NODES
COMPUTE.......TO COMPUTE SURFACE PROFILE(S)
CONNECT.......TO DEFINE CONNECTIVITY OF NETWORK BRANCHES
CRITIC........TO COMPUTE CRITICAL DEPTH AT A SECTION
DISCHARGE.....TO SPECIFY FLOW DISTRIBUTION ALONG CHANNELS
D/S WL........TO DEFINE DOWNSTREAM CONTROL LEVEL
EDIT..........TO EDIT GEOMETRY FILE
HELP..........TO LIST COMMAND OPTIONS
INFLOWS.......TO SPECIFY TRIBUTARY INFLOWS TO BRANCHES
LOSS COEFF....TO DEFINE TRANSITION LOSS COEFFICIENT
RESISTANCE....TO DEFINE FLOW RESISTANCE LAW
RESTART.......TO BEGIN AGAIN
STOP..........TO TERMINATE RUN
SUMMARY.......TO PRINT SUMMARY OF INPUT DATA.


COMMAND?

? CONNECT
SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE
SECTION), IN THE NETWORK...(I5)
  (   )
?     0

COMMAND?

? INFLOWS
FOR   0 JUNCTIONS AND   0 BRANCHES THERE SHOULD
BE   1 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
```

TABLE B.1.2 (CONT'D)

```
SECTION NO.   1
  (         )
?  250.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES/NO?
? NO

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO    6  INCLUSIVE, IN ORDER:--

  250.000   250.000   250.000   250.000   250.000
  250.000

COMMAND?

? CRITIC
SPECIFY SECTION NO.   I5
  (   )
?     6
AT SEC  6 WITH Q=   250.000
     CRITICAL WATER LEVEL   =  92.404  AND
     CRITICAL ENERGY LEVEL =  93.165

COMMAND?

? D/S WL
DEFINE SEC. NO. WHERE D/S WATER LEVEL TO BE SPECIFIED...(I5)
  (   )
?     6
DEFINE D/S WATER LEVEL, F10.3
  (         )
?   93.960

COMMAND?

? RESISTANCE
SPECIFY RESISTANCE LAW BY TYPING ONE OF...
CHEZY, MANNING, STRICKLER, COLEBROOK, SMOOTH, ROUGH,
..P.S.  IS YOUR ROUGHNESS MEASURE COMPATIBLE?
? MANNING

COMMAND?

? LOSS COEFF
HEAD LOSS COEFFICIENTS AT TRANSITIONS
HAVE BEEN DEFAULTED TO :--
CONTRACTIONS-- CLC=0.0, EXPANSIONS-- CLE=1.0
DO YOU WISH TO CHANGE THESE VALUES...YES/NO?
? YES
SPECIFY --CLC-- AND --CLE-- IN ORDER
(0.0 TO 1.0),    2F10.2...
  (         )(         )
?    0.0        0.2

COMMAND?
```

(3/4)

TABLE B.1.2 (CONT'D)

```
? SUMMARY


SUMMARY OF INPUT DATA FOR

    TYPE 1 BRIDGE


 UNITS USED ARE  --IMPERIAL--


 CONNECTIVITY TABLE


NODE NO.      1     2     3     4     5     6
KDS(NODE)     0     0     0     0     0   999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO     6  INCLUSIVE, IN ORDER:--

  250.000   250.000   250.000   250.000   250.000
  250.000

INITIAL WATER LEVEL AT NODE.    6  IS     93.960

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .600
                 AT EXPANSIONS   CLE =       .300
```

TABLE B.1.2   (CONT'D)

```
COMMAND?

? COMPUTE
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (    )
?      1


    TYPE 1 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  6              0.0   250.000    93.968    94.036    91.000    2.092
  5           -300.0   250.000    94.694    94.720    91.000    2.492
  4           -300.0   250.000    94.654    94.952    91.000    4.200
  3           -500.0   250.000    94.773    95.000    92.000    4.500
  2           -500.0   250.000    95.207    95.251    92.000    1.607
  1           -800.0   250.000    95.497    95.502    92.500    1.511

COMMAND?

? STOP
```

NOTE: The above profile is based on Figure B.1 (a).
The profile below is based on Figure B.1 (b).

```
    TYPE 1 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  6              0.0   250.000    93.968    94.036    91.000    2.092
  5           -300.0   250.000    94.594    94.905    91.000    4.474
  4           -300.0   250.000    94.594    94.905    91.000    4.473
  3           -500.0   250.000    94.722    95.050    92.000    4.591
  2           -500.0   250.000    94.723    95.050    92.000    4.591
  1           -800.0   250.000    95.527    95.571    92.500    1.470
```

TABLE B.1.3 TYPE 1 BRIDGE
FLOW PROFILE FOR 1000 CFS

a) Profile based on Figure B.1 (a)

```
TYPE 1 BRIDGE

SEC.  STATN.  CHAINAGE  DISCH.     W.L.      EN.LEV.     INV.      VEL.

  6                0.0  1000.000   96.812    96.885     91.000    2.167
  5           --300.0  1000.000   96.980    97.094     91.800    2.709
  4           --300.0  1000.000   96.296    99.073     91.800   13.374◆CRIT◆
  3           --500.0  1000.000   97.521    99.074     92.000   10.000
  2           --500.0  1000.000   99.264    99.290     92.000    1.299
  1           --800.0  1000.000   99.995   100.022     92.500    1.312
```

b) Profile based on Figure B.1 (b)

```
TYPE 1 BRIDGE

SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  6                0.0  1000.000   96.812   96.885     91.000    2.167
  5           --300.0  1000.000   96.066   98.199     91.800   11.720◆CRIT◆
  4           --300.0  1000.000   96.296   99.073     91.800   13.374◆CRIT◆
  3           --500.0  1000.000   97.521   99.074     92.000   10.000
  2           --500.0  1000.000   98.562   99.465     92.000    7.618
  1           --800.0  1000.000   99.682   99.712     92.500    1.398

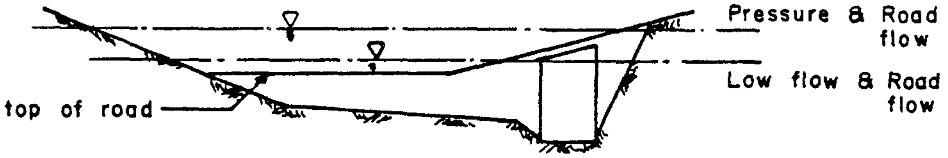
COMMAND?

? STOP
```

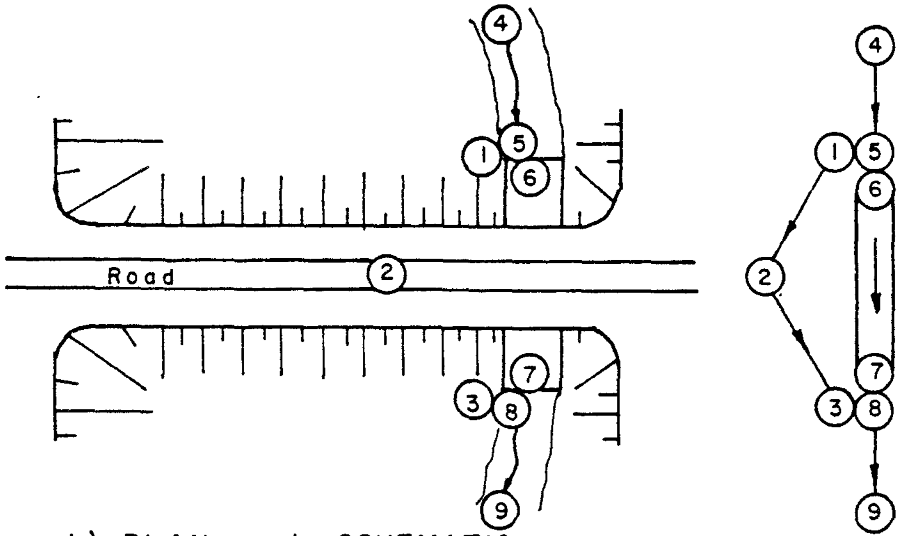
B.3 Type 2 Bridge

The bridge shown in Figure B.2 represents the typical bridge that may be subject to flooding of the roadway. The flow path for the flooded roadway is represented as a bifurcated branch using nodes 1 to 3 inclusive. The example also defines a perched bridge where the road may be subject to flooding while low flow still exists through the bridge. As a design alternative, it may be advisable to have the road flood in order to save the bridge. If the bridge were to be washed out, the cost in money and time to replace it are usually quite high whereas if the road is washed out, the cost in time and money is considerably less in hauling and compacting earth fill.

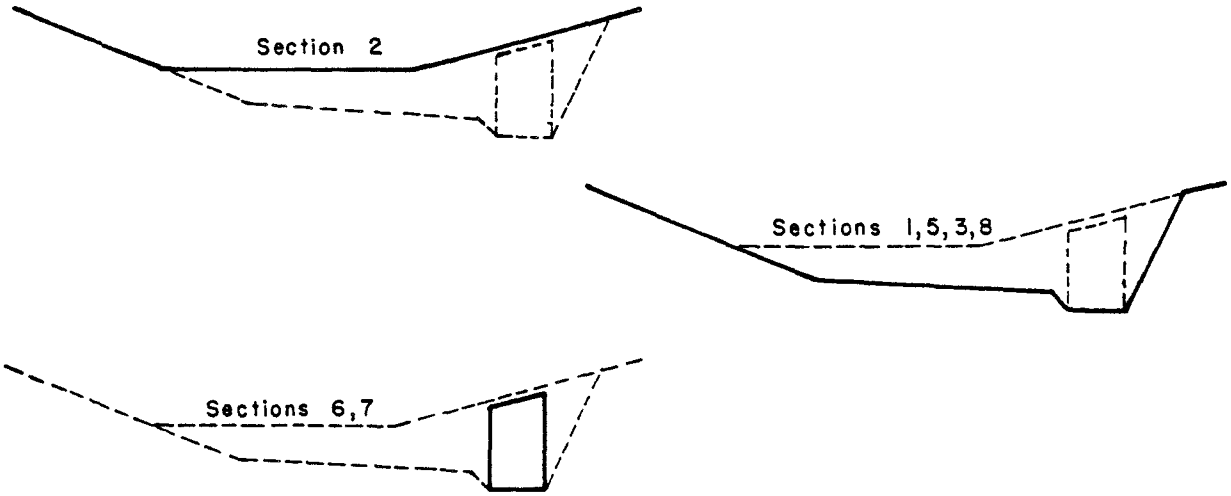
A typical data set for the system shown in Figure B.2 is presented in Table B.2.1. The system was analyzed using Mannings equation for several discharge values. Initially, the system was represented as having only a tributary (nodes 1 to 3, inclusive) and no branches. A flow of 1,000 cfs entering at node 4 was modelled in which the computed profile indicated low flow existed. The tributary 1-3 was said to have a discharge of QMIN. Profiles were not calculated for this tributary as no flow existed (i.e. upstream and downstream limits of computations were defined as 4 and 9, respectively). The starting downstream water level was arbitrarily defined as twice critical depth for the previous and all subsequent discharges. When the discharge was increased to 2,500 cfs, the calculated water elevation at node 5 was higher than the low elevation of the road indicating that the road was flooding. Command BRANCH was then used to define a bifurcation from node 5 to



a) PROFILE



b) PLAN and SCHEMATIC



c) CROSS SECTIONS

FIGURE B-2

TYPE 2 BRIDGE

TABLE B.2.1

TYPE 2 BRIDGE DATA

```
        TYPE 2 BRIDGE
           MAIN CHANNEL   4 - 9  WITH BRIDGE AT  6,7
           TOP OF ROAD    1 - 3 , CONNECT @ 8, BRANCH @ 5

1     6   -700.0      0.035
1       0.0      120.0       50.0      102.0      850.0      102.0
1     860.0      100.0      910.0      100.0      960.0      120.0
2     4   -600.0      0.02
2       0.0      120.0      200.0      107.0      700.0      107.0
2     960.0      120.0
3     6   -500.0      0.035
3       0.0      120.0       50.0      102.0      850.0      102.0
3     860.0      100.0      910.0      100.0      960.0      120.0
4     6  -1000.0      0.035
4       0.0      120.5       50.0      102.5      850.0      102.5
4     860.0      100.5      910.0      100.5      960.0      120.5
5     6   -700.0      0.035
5       0.0      120.0       50.0      102.0      850.0      102.0
5     860.0      100.0      910.0      100.0      960.0      120.0
6     5   -700.0      0.018
6     860.0      110.0      860.0      100.0      910.0      100.0
6     910.0      112.5      860.0      110.0
7     5   -500.0      0.018
7     860.0      110.0      860.0      100.0      910.0      100.0
7     910.0      112.5      860.0      110.0
8     6   -500.0      0.035
8       0.0      120.0       50.0      102.0      850.0      102.0
8     860.0      100.0      910.0      100.0      960.0      120.0
9     6      0.0      0.035
9       0.0      119.5       50.0      101.5      850.0      101.5
9     860.0       99.5      910.0       99.5      960.0      119.5
```

node 1, and the profile was recalculated for a flow of 2,500 cfs. The system has been analyzed for flows ranging from 1,000 cfs to 15,000 cfs.

Though the road flow is not calculated using a weir formula, it is of interest to compare the computed depth of flow over the road to the weir formula. The road cross-section in the direction of flow is similar to that of a broad crested weir. The broad crested weir formula is

$$Q = 3.087L(h + h_v)^{3/2} \tag{B.1}$$

where Q - flow, cfs
L - average length of the weir (road) (ft)
h - depth of water upstream of weir above the weir (road) elevation (ft)
h_v - corresponding velocity head of approach (ft)

The term in brackets is the same as the difference between the energy elevation upstream and the elevation of the road. Using the average of the energy levels at nodes 1 and 5, the theoretical depth $(h+h_v)$ for the computed road flow has been calculated and the percent error determined. These results are presented in Table B.2.2. The results are in good agreement especially at the higher flow levels.

The stage-discharge relationship at the bifurcation has been plotted in Figure B.2.1 together with the maximum velocity at the downstream end of the bridge. It will be noted in the stage curves that the road system begins to take more and more of the flow for small increases in elevation. The curves also indicate that the road would tend to flood at a discharge of about 2,400 cfs.

TABLE B.2.2 COMPARISON OF ROAD FLOW AND WEIR FLOW

$$h(weir) = \left[\frac{Q(weir)}{3.087\,L}\right]^{2/3}$$

Road Elevation = 107.0

Elevation in feet
Flow in c.f.s.

Q(Total)	Q(bridge)	EL(bridge)	Q(road)	EL(road)	EL% error	No. of Comp.	h_e(avg.)	L(avg.)	h(weir)	% error in h
2,500	2371.122	107.335	128.878	107.193	1.98	3	0.264	504.06	0.190	+38.00
3,500	2511.292	107.606	988.708	107.746	1.85	3	0.676	510.40	0.733	- 7.77
4,000	2548.399	107.681	1451.601	107.962	3.67	2	0.822	512.65	0.944	-12.93
5,000	2684.892	107.971	2315.108	108.306	4.21	2	1.139	517.52	1.281	-11.05
7,000	3320.667	109.149	3679.333	108.766	4.36	2	1.958	530.12	1.714	+14.09
8,000	3460.721	109.428	4539.279	109.024	4.47	2	2.226	534.25	1.964	+13.34
10,000	3190.896	109.259	6809.105	109.627	3.97	2	2.443	537.58	2.563	- 4.68
12,000	3295.690	109.676	8704.310	110.073	4.10	3	2.875	544.23	2.994	- 3.98
15,000	3273.979	110.148	11726.021	110.711	5.55	6	3.430	552.77	3.604	- 5.10

Q - discharge (cfs); EL - energy level; h_e(avg.) - effective head over road ($h + h_v$)

EL% error - error in computed energy level expressed as a percentage of depth

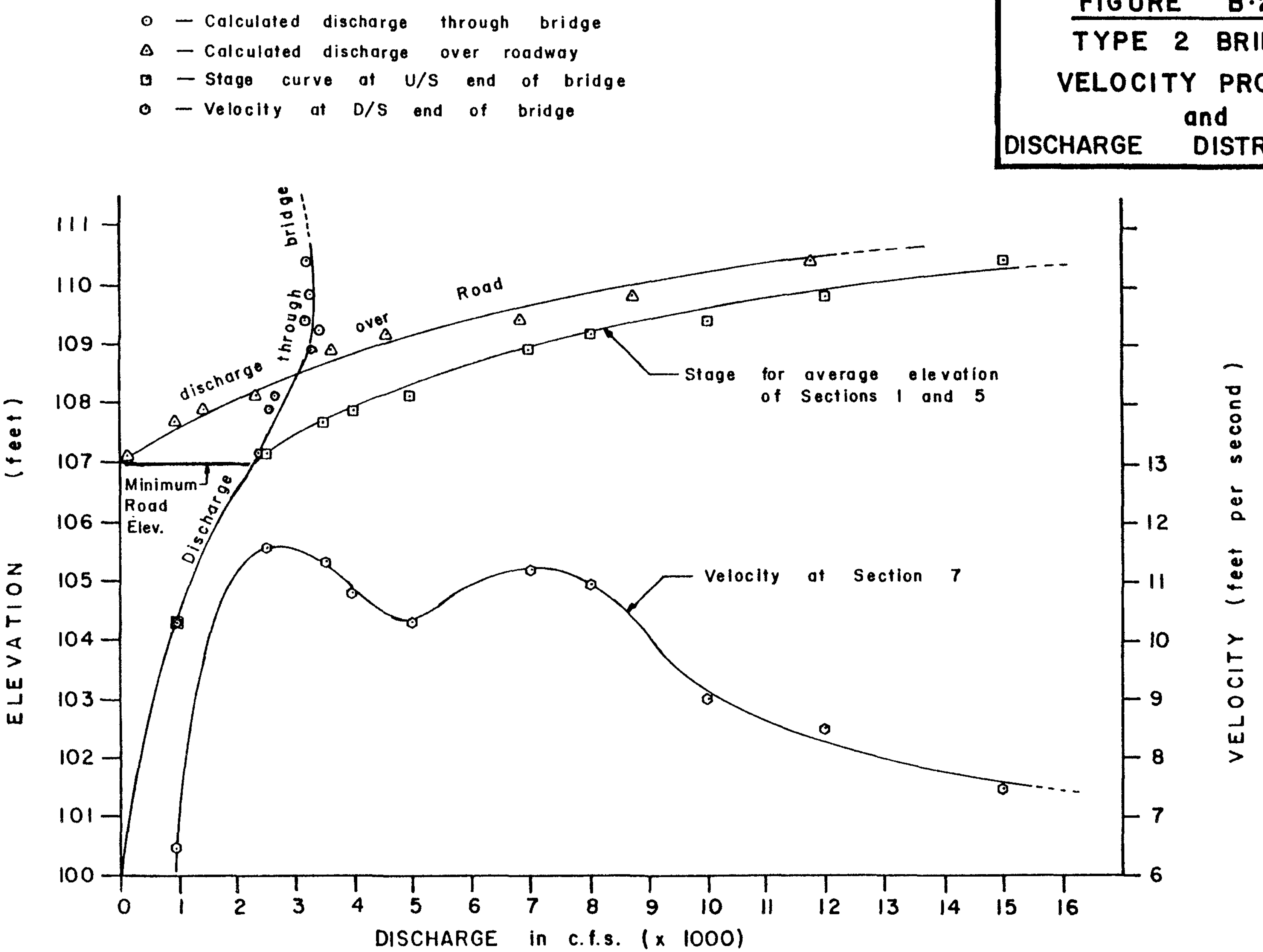
No. of comp - number of iterations computed to reduce error to below 10%

L(avg.) - average length of flooded road

h(weir) - computed equivalent weir depth for given Q(road)

% error in h - percentage difference between h of weir formula and computed depth over road

FIGURE B·2·1
TYPE 2 BRIDGE
VELOCITY PROFILE and DISCHARGE DISTRIBUTION



The velocity curve indicates a design condition for the bridge occurs at about 2,400 cfs first as the road begins to flood. At this discharge, the maximum velocity occurs at the downstream end of the bridge. This would be the critical velocity as an upper limit to be designed for when considering erosion of footings and channel materials. At higher discharges upstream, the velocity through the bridge tends to decrease.

Of importance in this example is the use of defining branched flows. At the initial stages, branch flow was assumed not to exist until information was presented indicating that flooding of the road was likely to occur. Then the BRANCH option was used to define the road system. By not defining the road system at low flows, the computation time has been reduced significantly.

Table B.2.3 shows a complete listing for a flow of 2,500 cfs as a non-branched system and 2,500 cfs as a branched flow. The example indicates the procedure of changing from a nonbranched to a branched network.

TABLE B.2.3 TYPE 2 BRIDGE
PROFILE COMPUTATIONS FOR 2500 CFS

```
                              **********
                              * RIVER2 *
                              **********

              AN INTERACTIVE SIMULATION MODEL FOR STEADY
               STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                            ALAN A SMITH
                         MCMASTER UNIVERSITY

                        (REVISED APRIL 1981)



    CHANNEL GEOMETRY ON TAPE   1 HAS   9 CROSS-SECTIONS
    MAX. NO. OF PTS. PER SECTION IS   6
    DIMENTION OF ARRAY WK() IN CALLING PGM. .GE.   69


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
?     TYPE 2 BRIDGE
DO YOU WANT A LIST OF COMMANDS?...YES,NO
? NO

COMMAND?

? CONNECT
SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE
SECTION), IN THE NETWORK...(I5)
  (    )
?     1
FOR   1 CONFLUENCES SUPPLY THE SECTION NO. AT THE
DOWNSTREAM LIMIT OF THE TRIBUTARY AND THE INTERMEDIATE
SEC. NO. AT THE RECEIVING STREAM...(2I5)
CONFLUENCE    1
  (    )(    )
?     3    8

COMMAND?

? INFLOWS
FOR   1 JUNCTIONS AND   0 BRANCHES THERE SHOULD
BE   2 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
SECTION NO.   1
  (         )
?   0.0
SECTION NO.   4
  (         )
?  2500.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES,NO?
? NO
```

TABLE B.2.3 (CONT'D)

```
 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO     9  INCLUSIVE, IN ORDER:-

     .000        .000        .000  2500.000  2500.000
 2500.000  2500.000  2500.000  2500.000

COMMAND?

? CRITIC
SPECIFY SECTION NO.    I5
  (    )
?     9
AT SEC  9 WITH Q=  2500.000
     CRITICAL WATER LEVEL  = 101.811  AND
     CRITICAL ENERGY LEVEL = 102.272

COMMAND?

? D/S WL
DEFINE SEC. NO. WHERE D/S WATER LEVEL TO BE SPECIFIED...(I5)
  (    )
?     9
DEFINE D/S WATER LEVEL, F10.3
  (          )
?   104.122

COMMAND?

? RESISTANCE
SPECIFY RESISTANCE LAW BY TYPING ONE OF...
CHEZY, MANNING, STRICKLER, COLEBROOK, SMOOTH, ROUGH,
..P.S.  IS YOUR ROUGHNESS MEASURE COMPATIBLE?
? MANNING

COMMAND?

? LOSS COEFF
HEAD LOSS COEFFICIENTS AT TRANSITIONS
HAVE BEEN DEFAULTED TO :-
CONTRACTIONS- CLC=0.0, EXPANSIONS- CLE=1.0
DO YOU WISH TO CHANGE THESE VALUES...YES/NO?
? YES
SPECIFY -CLC- AND -CLE- IN ORDER
(0.0 TO 1.0),     2F10.3...
  (          )(          )
?    0.6        0.2


COMMAND?

? SUMMARY
```

TABLE B.2.3 (CONT'D)

```
SUMMARY OF INPUT DATA FOR

   TYPE 2 BRIDGE



 UNITS USED ARE  -IMPERIAL-



 CONNECTIVITY TABLE


NODE NO.      1     2     3     4     5     6     7     8    9
KDS(NODE)     0     0     8     0     0     0     0     0  999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO     9  INCLUSIVE, IN ORDER:-

     .000       .000       .000  2500.000  2500.000
 2500.000  2500.000  2500.000  2500.000

INITIAL WATER LEVEL AT NODE     9  IS   104.122

RESISTANCE LAW BEING USED IS - MANNING  -

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .600
                 AT EXPANSIONS   CLE =       .800


COMMAND?

? COMPUTE
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (    )
?     4



   TYPE 2 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  9               0.0  2500.000  104.122   104.139    99.500   1.041
  8            -500.0  2500.000  104.218   104.241   100.000   1.222
  7            -500.0  2500.000  104.266   106.399   100.000  11.720*CRIT*
  6            -700.0  2500.000  105.640   106.861   100.000   8.864
  5            -700.0  2500.000  107.586   107.590   100.000    .497
  4           -1000.0  2500.000  107.590   107.595   100.500    .545
```

TABLE B.2.3 (CONT'D)

```
COMMAND?

? BRANCH
SUPPLY NO. OF BIFURCATION BRANCHES...(I5)
  (    )
?       1
FOR    1 BRANCHES, SUPPLY SEC. NO. AT THE UPSTREAM
LIMIT OF THE BRANCHING CHANNEL AND THE INTERMEDIATE
SEC. NO. OF THE MAIN CHANNEL....(2I5)
BRANCH NO.    1
  (    )(    )
?       1    5

COMMAND?

? INFLOWS
FOR    1 JUNCTIONS AND    1 BRANCHES THERE SHOULD
BE    1 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
SECTION NO.    4
  (          )
?    2500.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES/NO?
? NO

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO    9  INCLUSIVE, IN ORDER:-

       .000       .000       .000   2500.000   2500.000
  2500.000   2500.000   2500.000   2500.000

COMMAND?

? SUMMARY



 SUMMARY OF INPUT DATA FOR

    TYPE 2 BRIDGE



  UNITS USED ARE  -IMPERIAL-



  CONNECTIVITY TABLE


 NODE NO.      1     2     3     4     5     6     7     8     9
 KDS(NODE)    -5     0     0     0     0     0     0     0   999
```

TABLE B.2.3 (CONT'D)

```
SINCE BRANCHED FLOWS ARE BEING MODELLED,
INITIAL FLOWS ARE NOT PRINTED OUT IN
ORDER TO PREVENT POSSIBLE CONFUSION.


INITIAL WATER LEVEL AT NODE    9  IS   104.122

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .600
                 AT EXPANSIONS   CLE =       .300


COMMAND?

? COMPUTE

TWO OPTIONS ARE AVAILABLE FOR BRANCH FLOW
COMPUTATION.  EITHER EVERY ITERATION CAN BE PRINTED OUT
IN WHOLE OR PART --OR-- PRINTOUT STARTS AFTER A PREDEFINED
ERROR IN DEPTH HAS BEEN REACHED.


DO YOU WANT PROFILES AND/OR ERRORS PRINTED OUT
FOR EVERY ITERATION.....YES/NO?
? NO
SUPPLY PERCENT ERROR LIMIT FOR TERMINATION OF INITIAL
COMPUTATION OF WATER LEVELS AT BRANCHES(USUALLY 10.0)
......F10.3
  (         )
?   10.0
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (    )
?      1
DO YOU WANT PROFILES PRINTED FOR THIS ITERATION.(    4)
....YES/NO
? YES
```

TABLE B.2.3 (CONT'D)

```
    TYPE 2 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  9               0.0  2500.000   104.122   104.139    99.500   1.041
  8            -500.0  2500.000   104.218   104.241   100.000   1.222
  7            -500.0  2271.122   104.118   106.177   100.000  11.516*CRIT*
  6            -700.0  2271.122   105.470   106.637   100.000   2.669
  5            -700.0  2271.122   107.332   107.335   100.000    .494
  4           -1000.0  2500.000   107.336   107.341   100.500    .573


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.      VEL.

  3            -500.0   128.878   104.241   104.241   100.000    .062
  2            -600.0   128.878   107.127   107.190   107.000   2.019*CRIT*
  1            -700.0   128.878   107.193   107.193   100.000    .028

BRANCH     5  TO      1
E.L.   107.335   107.193 DIFF AS PCNT OF SMALLER DEPTH=  1.98
W.L.   107.332   107.193 DIFF AS PCNT OF SMALLER DEPTH=  1.93
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    73.060

DO YOU WANT PROFILES RECOMPUTED...YES/NO?
? NO

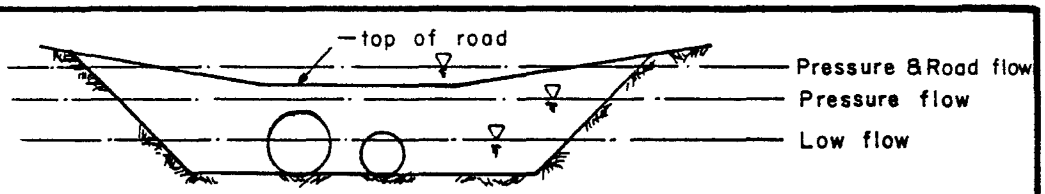
COMMAND?

? STOP
```

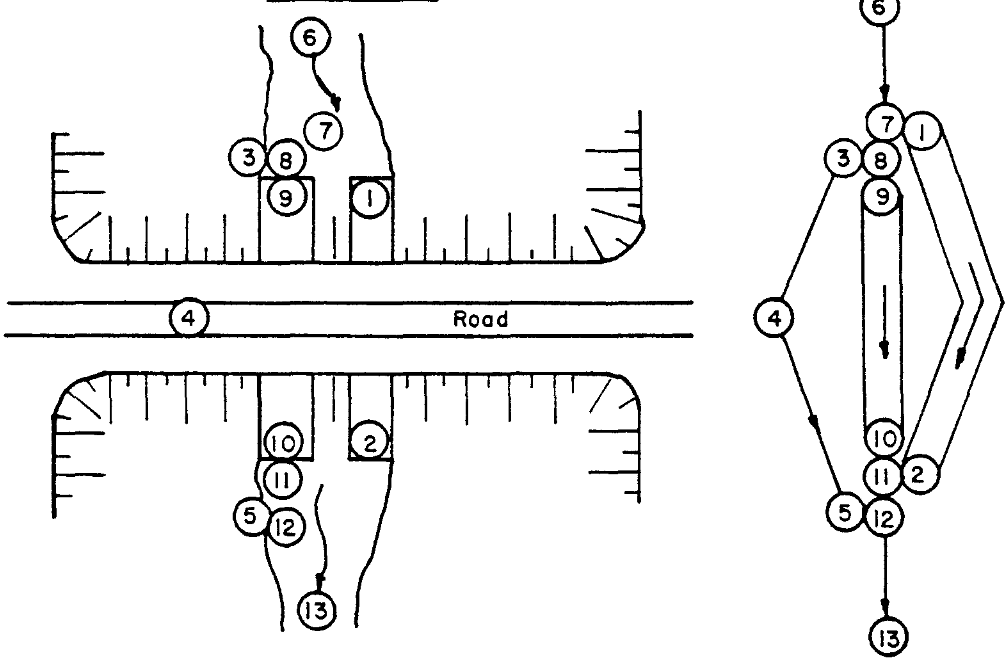
B.4 Type 3 Bridge

In this example, the bridge structure is represented by two pipe culverts of different diameters. Due to the difference in diameters, each culvert is modelled separately and joined together by command BRANCH. In addition, there is the possibility of the roadway being flooded and it, too, is modelled separately. Box culverts of differing inverts and/or obverts would be modelled this way also.

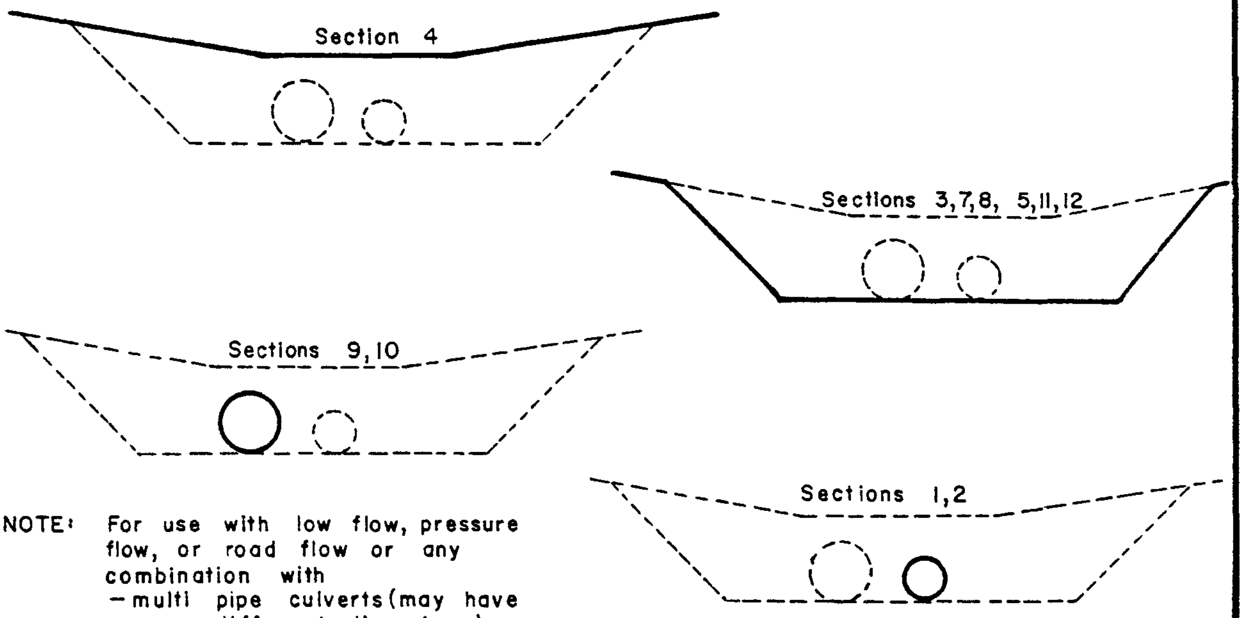
Table B.3.1 shows a typical data list for a Type 3 bridge and corresponds to the network shown in Figure B.3. It should be noted that the bifurcation for the culvert occurs furthest upstream followed by the road bifurcation. In addition, the culvert joins the main stream before the road. The example as shown illustrates the consideration that should be given to the numbering of the nodes. As presented, the small culvert is modelled by nodes 1 and 2 and the road by nodes 3 to 5 inclusive. This means that the limits of computations must include the road tributary even at low flows, as only by including the road can the bifurcated flow through the culverts be assessed. When the results are printed out, it will be noted that the road flow is listed with Q = .000 (i.e. QMIN) and an appropriate velocity. Although the example has been modelled as shown to illustrate this point, it would have been better to model the road by nodes 1 to 3 inclusive and the smaller culvert by nodes 4 and 5. The example shows that some thought should be given to the overall numbering of networks.



a) PROFILE



b) PLAN and SCHEMATIC



NOTE: For use with low flow, pressure flow, or road flow or any combination with
- —multi pipe culverts (may have different diameters)
- —multi box culverts with different Inverts/obverts

c) CROSS SECTIONS

FIGURE B·3

TYPE 3 BRIDGE

TABLE B.3.1 TYPE 3 BRIDGE DATA

```
            TYPE 3 BRIDGE
               MAIN CHANNEL   6 - 13
               3.0 DIAM.      9 - 10
               2.0 DIAM.      1 -  2 , CONNECT @ 11, BRANCH @ 7
               TOP OF ROAD    3 -  5 , CONNECT @ 12, BRANCH @ 8
    1    1   -500.0     0.024
    1      2.0     100.0
    2    1   -300.0     0.024
    2      2.0      99.5
    3    4   -500.0     0.035
    3      0.0     110.0     110.0     100.0     130.0     100.0
    3    230.0     110.0
    4    4   -400.0     0.020
    4      0.0     110.0     100.0     105.0     130.0     105.0
    4    230.0     110.0
    5    4   -300.0     0.035
    5      0.0     110.0     110.0      99.5     120.0      99.5
    5    230.0     110.0
    6    4   -800.0     0.035
    6      0.0     110.0     110.0     100.5     120.0     100.5
    6    230.0     110.0
    7    4   -500.0     0.035
    7      0.0     110.0     110.0     100.0     120.0     100.0
    7    230.0     110.0
    8    4   -500.0     0.035
    8      0.0     110.0     110.0     100.0     120.0     100.0
    8    230.0     110.0
    9    1   -500.0     0.024
    9      3.0     100.0
   10    1   -300.0     0.024
   10      3.0      99.5
   11    4   -300.0     0.035
   11      0.0     110.0     110.0      99.5     120. 0      99.5
   11    230.0     110.0
   12    4   -300.0     0.035
   12      0.0     110.0     110.0      99.5     120.0      99.5
   12    230.0     110.0
   13    4      0.0     0.035
   13      0.0     110.0     110.0      99.0     120.0      99.0
   13    230.0     110.0
*EOR*
 *END OF INFORMATION*
?
```

The system as shown was analysed for flows ranging from 25 cfs to 150 cfs using Manning's equation. At flows above 50 cfs, the road begins to flood. Command BRANCH was used to connect the road as a bifurcation for flows greater than 50 cfs. Error limits for termination of computation was set at 10 percent. The division of flow between the two culverts and the road has been plotted in Figure B.3.1. As is to be expected, the roadway takes the majority flow at high flow levels.

Since the use of the commands have been illustrated in the previous bridge types, a complete listing of a typical session is not presented for this example. Tables B.3.2(a) and (b) show the computed profile for 50 cfs and 150 cfs respectively. In part (a), the flow over the road has been defined as Q = .000 (QMIN).

FIGURE B·3·1

TYPE 3 BRIDGE

DISCHARGE DISTRIBUTION

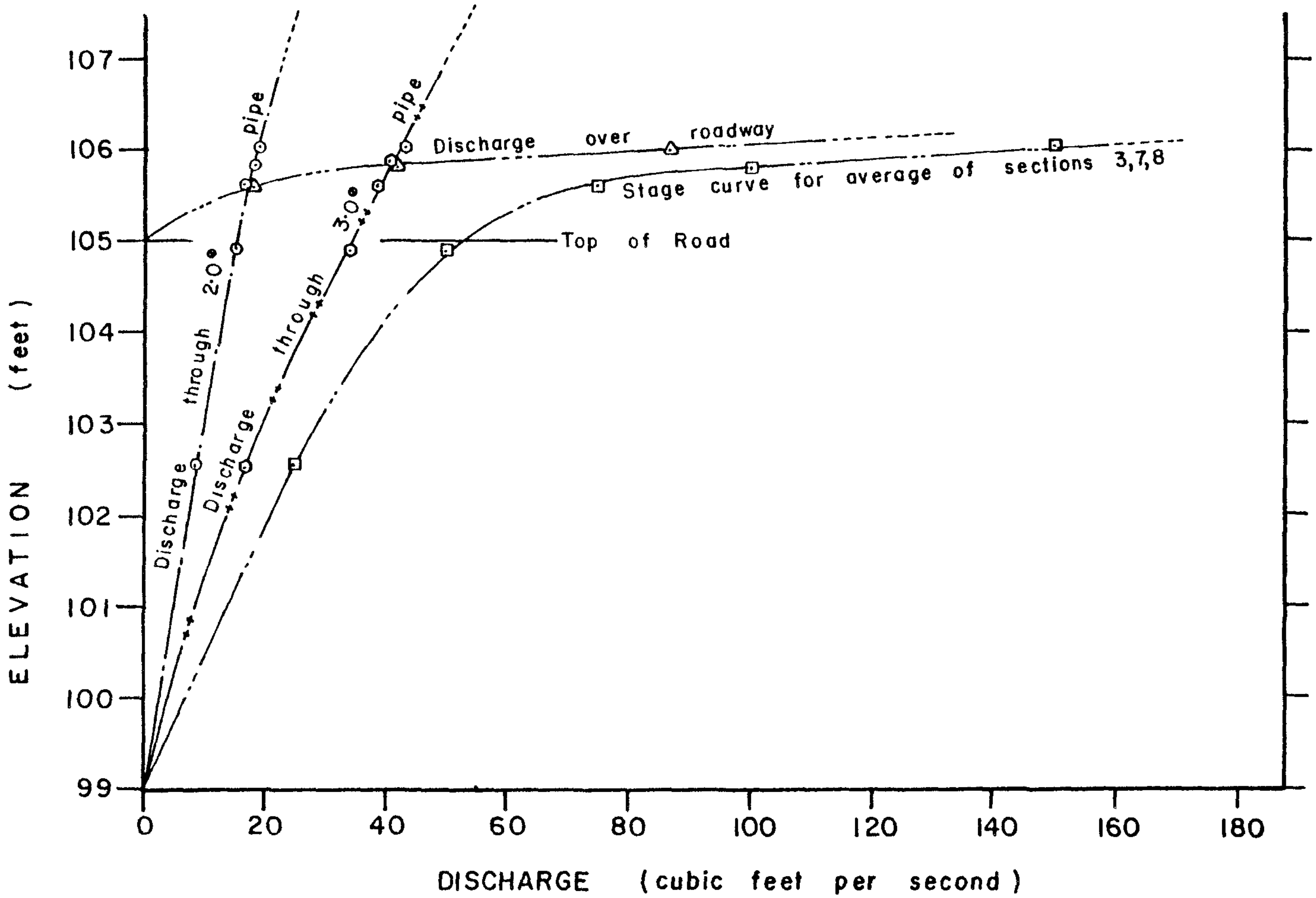


TABLE B.3.2(a) TYPE 3 BRIDGE
PROFILE FOR 50 CFS

```
TYPE 3 BRIDGE


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 13              0.0    50.000   100.390   100.425    99.000    1.505
 12           -300.0    50.000   100.852   100.888    99.500    1.531
 11           -300.0    50.000   100.852   100.888    99.500    1.531
 10           -300.0    34.325   101.403   102.221    99.500    7.259*CRIT*
  9           -500.0    34.325   104.307   104.673   100.000    4.856
  8           -500.0    34.325   104.893   104.893   100.000     .110
  7           -500.0    34.325   104.893   104.893   100.000     .110
  6           -800.0    50.000   104.894   104.895   100.500     .187


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  5           -300.0      .000   100.888   100.888    99.500     .000
  4           -400.0      .000   105.000   105.000   105.000     .060*CRIT*
  3           -500.0      .000   105.000   105.000   100.000    0.000


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  2           -300.0    15.675   100.927   101.590    99.500    6.535*CRIT*
  1           -500.0    15.675   104.986   105.373   100.000    4.990

BRANCH     7  TO     1
E.L.   104.893   105.373 DIFF AS PCNT OF SMALLER DEPTH=  9.80
W.L.   104.893   104.986 DIFF AS PCNT OF SMALLER DEPTH=  1.90
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=     -.142
```

TABLE B.3.2(b) TYPE 3 BRIDGE PROFILE FOR 150 CFS

```
    TYPE 3 BRIDGE



SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 13               0.0  150.000   101.478   101.525    99.000    1.740
 12            -300.0  150.000   101.818   101.873    99.500    1.888
 11            -300.0   62.962   101.931   101.939    99.500     .730
 10            -300.0   43.640   101.824   102.680    99.500    7.429
  9            -500.0   43.640   105.150   105.742   100.000    6.174
  8            -500.0   43.640   106.097   106.097   100.000     .093
  7            -500.0  130.678   106.097   106.098   100.000     .278
  6            -800.0  150.000   106.101   106.103   100.500     .358


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  5            -300.0   87.039   101.855   101.873    99.500    1.066
  4            -400.0   87.039   105.544   105.773   105.000    3.840*CRIT*
  3            -500.0   87.039   105.800   105.800   100.000     .186


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  2            -300.0   19.322   101.268   101.939    99.500    6.576
  1            -500.0   19.322   106.019   106.607   100.000    6.150

BRANCH     7  TO      1
E.L.   106.098   106.607 DIFF AS PCNT OF SMALLER DEPTH=  8.34
W.L.   106.097   106.019 DIFF AS PCNT OF SMALLER DEPTH=  1.29
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=     -.133


BRANCH     8  TO      3
E.L.   106.097   105.800 DIFF AS PCNT OF SMALLER DEPTH=  5.12
W.L.   106.097   105.800 DIFF AS PCNT OF SMALLER DEPTH=  5.13
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=      .777
```

B.5 Modelling Overland Flow

The previous "bridge" types serve as an introduction to modelling sewer systems with or without overland flow. The basic sewer system is modelled as a plain network without considering manholes. If the discharge is sufficiently large, causing the sewer(s) to surcharge, the system is acting similar to a Type 1 bridge. That is, the water level printed out is the pieozometric surface. From this information, the potential of reverse slope driveways being flooded can be assessed.

If the flow is very large, it is possible that manholes may be flooded causing overland flow through gutters and ditches to occur. When such a situation occurs, the manhole is usually modelled in order to represent the road elevation. Figure B.4 represents such a system. In addition, the system has been designed to flood by using a subdiameter pipe from nodes 22 to 23. The technique can be used to force overland flow around some particularly sensitive location. Alternatively, an elevated sewer outlet could be used to divert flow to another sewer system. Table B.4.1 comprises the typical data for this system. In the system, the overland flow is defined as going to a detention pond. The discharge from the pond then travels to a ditch inlet and drops into the sewer system. Nodes 1 and 2 represent a ditch or a backyard swale.

Table B.4.2 presents a complete listing of a typical flow condition causing the manhole to flood resulting in overland flow. In order to derive the profile, 14 iterations were required to reduce the error to the requisite limit.

Before the request to print the fifteenth iteration the word COMPUTING ... appears indicating that 10 iterations have been computed. It should be noted, though, that the five percent error in water levels is referenced to the depth of the ditch at node 3 (being 1.59 feet) and not the depth of the manhole, it being 8.66 feet deep. In this example, acceptable results would probably occur if a 20 percent error limit had been chosen.

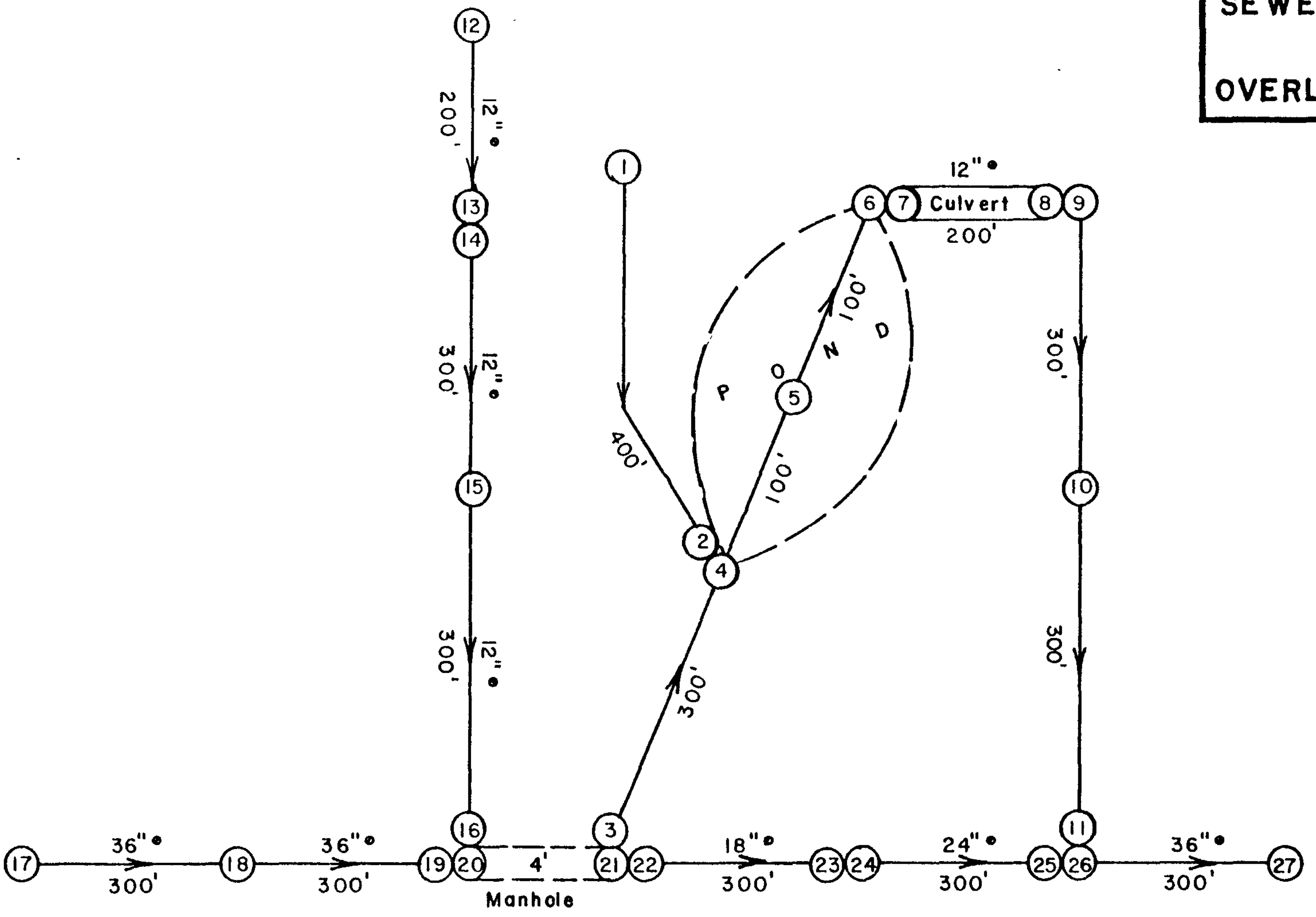


FIGURE B·4
SEWER SYSTEM WITH OVERLAND FLOW

TABLE B.4.1 SEWER SYSTEM DATA

```
          SEWER SYSTEM WITH OVERLAND FLOW
               MAIN    17 - 27
               TRIBS   12 - 16 CONNECT @ 20
                        3 - 11 CONNECT @ 26, BRANCH @ 21
                        1 -  2 CONNECT @  4

          BACK YARD DRAINAGE DITCH
 1     3   -1800.     0.030
 1      0.0       116.00      6.0       114.00      12.0      116.00
 2     3   -1400.     0.030
 2      0.0       114.00      6.0       112.00      12.0      114.00
          MAIN OVERFLOW DITCH ( 3-11) FROM 21
 3     3   -1700.     0.030
 3      0.0       114.00      6.0       112.00      12.0      114.00
 4     3   -1400.     0.030
 4      0.0       114.00     10.0       110.50      20.0      114.00
          POND
 5     4   -1200.     0.020
 5      0.0       114.00     30.0       105.00      40.0      105.00
 5     70.0       114.00
 6     4   -1200.     0.020
 6      0.0       114.00     10.0       110.00      11.0      110.00
 6     21.0       114.00
          OVERFLOW CONTROL PIPE FOR POND
 7     1   -1200.     0.024
 7      1.0       110.00
 8     1   -1000.     0.024
 8      1.0       109.50
 9     4   -1000.     0.030
 9      0.0       113.00     10.0       109.00      12.0      109.00
 9     22.0       113.00
10     3    -600.     0.030
10      0.0       110.00      6.0       108.00      12.0      110.00
11     3    -300.     0.030
11      0.0       109.00      6.0       106.50      12.0      109.00
          TRIBUTARY SEWER (12 - 16)
12     1   -1704.     0.013
12      1.0       110.00
13     1   -1504.     0.013
13      1.0       109.00
14     1   -1504.     0.015
14      1.0       109.00
15     1   -1204.     0.015
15      1.0       107.50
16     1    -904.     0.015
16      1.0       106.00
```

TABLE B.4.1 (CONT'D)

```
           MAIN SEWER FROM HERE TO END OF FILE
  17     1   -1504.    0.013
  17      3.0      108.00
  18     1   -1204.    0.013
  18      3.0      106.50
  19     1    -904.    0.013
  19      3.0      105.00
  20     4    -904.    0.013
  20      0.0      112.00      0.0      105.00       4.0      105.00
  20      4.0      112.00
           (20 & 21) MANHOLE
  21     4    -900.    0.013
  21      0.0      112.00      0.0      105.00       4.0      105.00
  21      4.0      112.00
           NEXT 2 SEC. - RESTRICTION IN SEWER SIZE
  22     1    -900.    0.015
  22      1.5      105.00
  23     1    -600.    0.015
  23      1.5      103.50
  24     1    -600.    0.013
  24      2.0      102.5
  25     1    -300.    0.013
  25      2.0      101.75
  26     1    -300.    0.013
  26      3.0      100.75
  27     1       0.    0.013
  27      3.0      100.00

*EOR*
 *END OF INFORMATION*
?
```

TABLE B.4.2 SEWER SYSTEM PROFILE COMPUTATION

```
                         ***********
                         * RIVER2 *
                         ***********

        AN INTERACTIVE SIMULATION MODEL FOR STEADY
          STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                       ALAN A SMITH
                    MCMASTER UNIVERSITY

                    (REVISED APRIL 1981)



   CHANNEL GEOMETRY ON TAPE   1 HAS  27 CROSS-SECTIONS
   MAX. NO. OF PTS. PER SECTION IS    4
   DIMENSION OF ARRAY WK() IN CALLING PGM. .GE.  151


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
? SEWER SYSTEM WITH OVERLAND FLOW.
DO YOU WANT A LIST OF COMMANDS?...YES,NO
? NO

COMMAND?

? CONNECT
SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE
SECTION), IN THE NETWORK...(I5)
-       3
FOR    3 CONFLUENCES SUPPLY THE SECTION NO. AT THE
DOWNSTREAM LIMIT OF THE TRIBUTARY AND THE INTERMEDIATE
SEC. NO. AT THE RECEIVING STREAM...(2I5)
CONFLUENCE    1
-      12    20
CONFLUENCE    2
?      11    26
CONFLUENCE    3
-       2     4

COMMAND?

? BRANCH
SUPPLY NO. OF BIFURCATION BRANCHES...(I5)
-       1
FOR    1 BRANCHES, SUPPLY SEC. NO. AT THE UPSTREAM
LIMIT OF THE BRANCHING CHANNEL AND THE INTERMEDIATE
SEC. NO. OF THE MAIN CHANNEL....(2I5)
```

TABLE B.4.2 (CONT'D)

```
BRANCH NO.    1
  (    ,(    )
?      3   21

COMMAND?

? RESISTANCE
SPECIFY RESISTANCE LAW BY TYPING ONE OF...
CHEZY, MANNING, STRICKLER, COLEBROOK, SMOOTH, ROUGH.
..P.S.  IS YOUR ROUGHNESS MEASURE COMPATIBLE?
? MANNING

COMMAND?

? LOSS COEFF
HEAD LOSS COEFFICIENTS AT TRANSITIONS
ARE PRESENTLY SET AT :-
CONTRACTIONS- CLC=      0.000       EXPANSIONS- CLE=      1.000
DO YOU WISH TO CHANGE THESE VALUES...YES/NO?
? YES
SPECIFY -CLC- AND -CLE- IN ORDER
(0.0 TO 1.0),    2F10.3...
  (          )(          )
?  0.1          0.25

COMMAND?

? INFLOWS
FOR   3 JUNCTIONS AND   1 BRANCHES THERE SHOULD
BE   3 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
SECTION NO.   1
  (         )
?   1.0
SECTION NO.  12
  (         )
?   1.0
SECTION NO.  17
  (         )
?   15.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES/NO?
? NO

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO   27  INCLUSIVE, IN ORDER:-

     1.000      1.000       .000      1.000      1.000
     1.000      1.000      1.000      1.000      1.000
     1.000      1.000      1.000      1.000      1.000
     1.000     15.000     15.000     15.000     16.000
    16.000     16.000     16.000     16.000     16.000
    17.000     17.000
```

TABLE B.4.2 (CONT'D)

```
COMMAND?

? CRITIC
SPECIFY SECTION NO.    I5

?     27
AT SEC 27 WITH Q=      17.000
      CRITICAL WATER LEVEL   = 101.318  AND
      CRITICAL ENERGY LEVEL = 101.820

COMMAND?

? D S WL
DEFINE SEC. NO. WHERE D.S WATER LEVEL TO BE SPECIFIED...(I5)

?     27
DEFINE D/S WATER LEVEL, F10.3

?  102.636

COMMAND?

? SUMMARY



SUMMARY OF INPUT DATA FOR

SEWER SYSTEM WITH OVERLAND FLOW.



 UNITS USED ARE  -IMPERIAL-



 CONNECTIVITY TABLE

NODE NO.       1     2     3     4     5     6     7     8     9    10
K D S(NODE)    0     4   -21     0     0     0     0     0     0     0

NODE NO.      11    12    13    14    15    16    17    18    19    20
K D S(NODE)   26     0     0     0     0    20     0     0     0     0

NODE NO.      21    22    23    24    25    26    27
K D S(NODE)    0     0     0     0     0     0   999

 SINCE BRANCHED FLOWS ARE BEING MODELLED.
 INITIAL FLOWS ARE NOT PRINTED OUT IN
 ORDER TO PREVENT POSSIBLE CONFUSION.
```

TABLE B.4.2 (CONT'D)

```
INITIAL WATER LEVEL AT NODE   27   IS    102.636

RESISTANCE LAW BEING USED IS - MANNING   -

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .100
                 AT EXPANSIONS   CLE =       .250


COMMANDS

? COMPUTE

TWO OPTIONS ARE AVAILABLE FOR BRANCH FLOW
COMPUTATION.  EITHER EVERY ITERATION CAN BE PRINTED OUT
IN WHOLE OR PART -OR- PRINTOUT STARTS AFTER A PREDEFINED
ERROR IN DEPTH HAS BEEN REACHED.


DO YOU WANT PROFILES AND/OR ERRORS PRINTED OUT
FOR EVERY ITERATION.....YES/NO?
? NO
SUPPLY PERCENT ERROR LIMIT FOR TERMINATION OF INITIAL
COMPUTATION OF WATER LEVELS AT BRANCHES(USUALLY 10.0)
......F10.3

?   10.
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)

?        1


 COMPUTING....
DO YOU WANT PROFILES PRINTED FOR THIS ITERATION.(    15)
....YES NO
? YES
```

TABLE B.4.2 (CONT'D)

```
SEWER SYSTEM WITH OVERLAND FLOW.


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 27              0.0    17.000   102.636   102.740   100.000   2.583
 26           -300.0    17.000   102.796   102.967   100.750   3.310
 25           -300.0    14.965   103.144   103.780   101.750   6.400*CRIT*
 24           -600.0    14.965   104.992   105.344   102.500   4.764
 23           -600.0    14.965   104.905   106.020   103.500   8.700*CRIT*
 22           -900.0    14.965   112.442   113.555   105.000   8.469
 21           -900.0    14.965   113.663   113.666   105.000    .432
 20           -904.0    16.000   113.663   113.667   105.000    .462
 19           -904.0    15.000   113.615   113.685   105.000   2.122
 18          -1204.0    15.000   113.766   113.836   106.500   2.122
 17          -1504.0    15.000   113.916   113.986   108.000   2.122



SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 11           -300.0     2.035   107.037   107.171   106.500   2.940*CRIT*
 10           -600.0     2.035   108.827   108.843   108.000    .991
  9          -1000.0     2.035   109.521   109.543   109.000   1.182
  8          -1000.0     2.035   110.109   110.365   109.500   4.064*CRIT*
  7          -1200.0     2.035   113.472   113.576   110.000   2.591
  6          -1200.0     2.035   113.587   113.587   110.000    .057
  5          -1300.0     2.035   113.587   113.587   105.000   0.000
  4          -1400.0     2.035   113.587   113.587   110.500    .075
  3          -1700.0     1.035   113.587   113.588   112.000    .137



SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 16           -904.0     1.000   113.641   113.667   106.000   1.273
 15          -1204.0     1.000   113.954   113.979   107.500   1.273
 14          -1504.0     1.000   114.266   114.291   109.000   1.273
 13          -1504.0     1.000   114.266   114.291   109.000   1.273
 12          -1704.0     1.000   114.422   114.447   110.000   1.273



SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  2          -1400.0     1.000   113.587   113.587   113.000    .132
  1          -1800.0     1.000   114.370   114.462   114.000   2.440*CRIT*


BRANCH    21  TO       3
E.L.    113.666    113.588 DIFF AS PCNT OF SMALLER DEPTH=  4.95
W.L.    113.663    113.587 DIFF AS PCNT OF SMALLER DEPTH=  4.79
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=       .004
```

B.6 River System

This example is provided to show a typical procedure for a natural river system. The system has several tributaries, drop structures and a Type 1 Bridge. In addition, water is assumed to be withdrawn from one tributary by an industry and returned to a different tributary. The schematic for the system is presented in Figure B.5 with Table B.5.1 containing the cross-section data. The initial flow condition was set as follows.

NODE	FLOW
1	50 cfs
4	100 cfs
8	100 cfs
12	10 cfs
14	100 cfs

	NODE	FLOW
point lateral inflows	6	-20 cfs
	21	+20 cfs

Table B.5.2 contains a complete listing of the data entry and results of the profile computations. As will be noted, each tributary is presented separately in the profile listing with its own column headings. The tributaries that start with a drop structure are readily identifiable by the term *CRIT* at the beginning of the tributary listing.

FIGURE B·5

RIVER SYSTEM

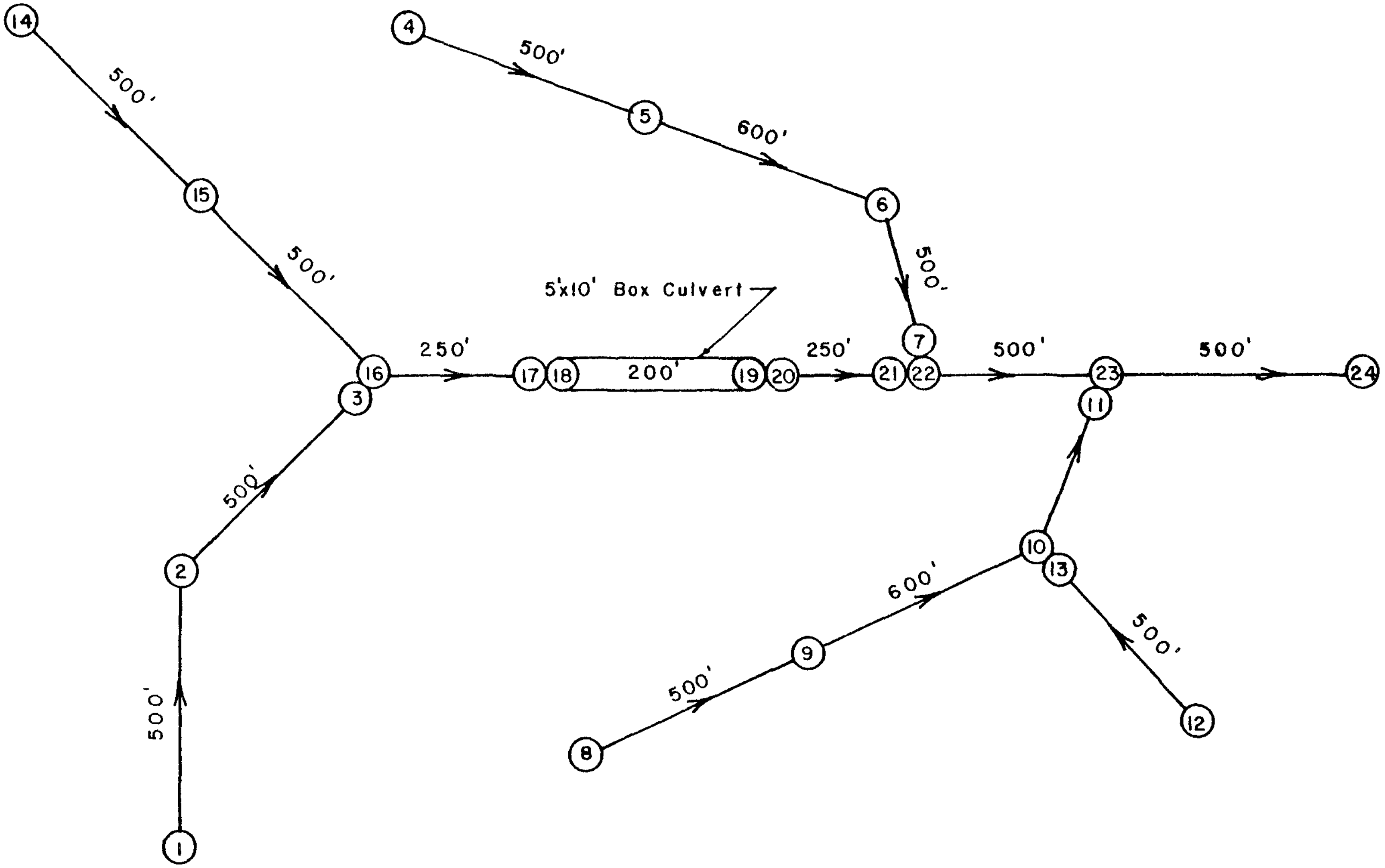


TABLE B.5.1 DATA FOR RIVER SYSTEM

```
   CROSS SECTION DATA FOR -RIVER- SYSTEM
           MAIN     14 - 24
           TRIBS     1 -  3 CONNECT @ 16
                     4 -  7 CONNECT @ 22
                     8 - 11 CONNECT @ 23
                    12 - 13 CONNECT @ 10

 1    4    -2700.        0.02
 1     -25.0      114.0       -5.0       104.0          5.0       104.0
 1      25.0      114.0
 2    4     -2200.      0.02
 2     -25.0      113.5       -5.0       103.5          5.0       103.5
 2      25.0      113.5
 3    4      -1700.     0.02
 3     -25.0      113.0       -5.0       103.0          5.0       103.0
 3      25.0      113.0
 4    4     -2600.      0.03
 4     -20.0      116.0        0.0       106.0          5.0       106.0
 4      25.0      116.0
 5    4      -2100.     0.03
 5     -20.0      115.0        0.0       105.0          5.0       105.0
 5      25.0      115.0
 6    4      -1500.     0.03
 6     -20.0      114.0        0.0       104.0          5.0       104.0
 6      25.0      114.0
 7    4     -1000.      0.03
 7     -20.0      113.0        0.0       103.0          5.0       103.0
 7      25.0      113.0
 8    4     -2100.      0.03
 8     -20.0      115.5        0.0       105.5          5.0       105.5
 8      25.0      115.5
 9    4      -1600.     0.03
 9     -20.0      114.5        0.0       104.5          5.0       104.5
 9      25.0      114.5
10    4     -1000.      0.03
10     -20.0      113.5        0.0       103.5          5.0       103.5
10      25.0      113.5
11    4       -500.     0.03
11     -20.0      112.5        0.0       102.5          5.0       102.5
11      25.0      112.5
12    4     -1500.      0.03
12     -20.0      114.0        0.0       104.5          5.0       104.5
12      25.0      114.0
13    4     -1000.      0.03
13     -20.0      113.5        0.0       103.5          5.0       103.5
13      25.0      113.5
14    4     -2700.      0.02
14     -25.0      114.5       -5.0       104.5          5.0       104.5
14      25.0      114.5
15    4     -2200.      0.02
15     -25.0      114.0       -5.0       104.0          5.0       104.0
```

TABLE B.5.1 (CONT'D)

```
 16     4    -1700.      0.02
 16      -25.0       112.8       -5.0       102.8          5.0       102.8
 16       25.0       112.8
 17     4    -1450.      0.02
 17      -25.0       112.6       -5.0       102.6          5.0       102.6
 17       25.0       112.6
 18     5    -1450.      0.013
 18       -5.0       107.5       -5.0       102.5          5.0       102.5
 18        5.0       107.5       -5.0       107.5
 19     5    -1250.      0.013
 19       -5.0       106.7       -5.0       101.7          5.0       101.7
 19        5.0       106.7       -5.0       106.7
 20     4    -1250.      0.02
 20      -25.0       111.5       -5.0       101.5          5.0       101.5
 20       25.0       111.5
 21     4    -1000.      0.02
 21      -25.0       111.0       -5.0       101.0          5.0       101.0
 21       25.0       111.0
 22     4    -1000.      0.02
 22      -35.0       112.0       -5.0        97.0          5.0        97.0
 22       35.0       112.0
 23     4     -500.      0.02
 23      -35.0       111.0       -5.0        96.0          5.0        96.0
 23       35.0       111.0
 24     4        0.0     0.02
 24      -35.0       110.0       -5.0        95.0          5.0        95.0
 24       35.0       110.0

*EOR*
 *END OF INFORMATION*
```

TABLE B.5.2 RIVER SYSTEM PROFILE COMPUTATION

```
                        ++++++++++
                        + RIVER3 +
                        ++++++++++

        AN INTERACTIVE SIMULATION MODEL FOR STEADY
         STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                      ALAN A SMITH
                   MCMASTER UNIVERSITY

                  (REVISED APRIL 1981)


  CHANNEL GEOMETRY ON TAPE   1 HAS  24 CROSS-SECTIONS
  MAX. NO. OF PTS. PER SECTION IS    5
  DIMENTION OF ARRAY WK() IN CALLING PGM. .GE.  140


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
?      -RIVER- SYSTEM
DO YOU WANT A LIST OF COMMANDS?...YES/NO
? NO

COMMAND?

? CONNECT
SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE
SECTION), IN THE NETWORK...(I5)
  (    )
?     4
FOR   4 CONFLUENCES SUPPLY THE SECTION NO. AT THE
DOWNSTREAM LIMIT OF THE TRIBUTARY AND THE INTERMEDIATE
SEC. NO. AT THE RECEIVING STREAM...(2I5)
CONFLUENCE    1
  (    )(    )
?    11   23
CONFLUENCE    2
  (    )(    )
?     7   22
CONFLUENCE    3
  (    )(    )
?     3   16
CONFLUENCE    4
  (    )(    )
?    13   10

COMMAND?

? INFLOWS
FOR   4 JUNCTIONS AND   0 BRANCHES THERE SHOULD
BE   5 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
```

TABLE B.5.2 (CONT'D)

```
SECTION NO.   1
  (        )
?   50.0
SECTION NO.   4
  (        )
?   100.0
SECTION NO.   8
  (        )
?   100.0
SECTION NO.  12
  (        )
?   10.0
SECTION NO.  14
  (        )
?   100.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES,NO?
? YES
 SUPPLY NO. OF LATERAL INFLOW POINTS.....I5
  (   )
?     2
FOR    2 LATERAL INFLOW POINTS, SUPPLY SECTION
NO. AND LATERAL INFLOW....I5,F10.3
LATERAL INFLOW NO.    1
  (   )(        )
?     6  -20.0
LATERAL INFLOW NO.    2
  (   )(        )
?    21   20.0

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO   24  INCLUSIVE, IN ORDER:-

   50.000     50.000     50.000    100.000    100.000
   80.000     80.000    100.000    100.000    110.000
  110.000     10.000     10.000    100.000    100.000
  150.000    150.000    150.000    150.000    150.000
  170.000    250.000    360.000    360.000

COMMAND?

? RESISTANCE
SPECIFY RESISTANCE LAW BY TYPING ONE OF...
CHEZY, MANNING, STRICKLER, COLEBROOK, SMOOTH, ROUGH,
..P.S.  IS YOUR ROUGHNESS MEASURE COMPATIBLE?
? MANNING

COMMAND?

? D/S WL
DEFINE SEC. NO. WHERE D/S WATER LEVEL TO BE SPECIFIED...(I5)
  (   )
?    24
```

TABLE B.5.2 (CONT'D)

```
DEFINE D/S WATER LEVEL, F10.3
  (          )
?  100.448

COMMAND?

? LOSS COEFF
HEAD LOSS COEFFICIENTS AT TRANSITIONS
HAVE BEEN DEFAULTED TO :-
CONTRACTIONS- CLC=0.0, EXPANSIONS- CLE=1.0
DO YOU WISH TO CHANGE THESE VALUES...YES/NO?
? YES
SPECIFY -CLC- AND -CLE- IN ORDER
(0.0 TO 1.0),     2F10.3...
  (          )(          )
?    0.3        0.5

COMMAND?

? SUMMARY



SUMMARY OF INPUT DATA FOR

    -RIVER- SYSTEM



 UNITS USED ARE  -IMPERIAL-



 CONNECTIVITY TABLE


NODE NO.      1     2     3     4     5     6     7     8     9    10
KDS(NODE)     0     0    16     0     0     0    22     0     0     0

NODE NO.     11    12    13    14    15    16    17    18    19    20
KDS(NODE)    23     0    10     0     0     0     0     0     0     0

NODE NO.     21    22    23    24
KDS(NODE)     0     0     0   999

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO   24  INCLUSIVE, IN ORDER:-

   50.000     50.000     50.000    100.000    100.000
   80.000     80.000    100.000    100.000    110.000
  110.000     10.000     10.000    100.000    100.000
  150.000    150.000    150.000    150.000    150.000
  170.000    250.000    360.000    360.000
```

TABLE B.5.2 (CONT'D)

```
INITIAL WATER LEVEL AT NODE   24  IS   100.448

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =       .300
                 AT EXPANSIONS   CLE =       .500


COMMAND?

? COMPUTE
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  <   >
?      1


    -RIVER- SYSTEM


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 24                0.0  360.000  100.448  100.603    95.000   3.162
 23             -500.0  360.000  100.602  100.860    96.000   4.073
 22            -1000.0  250.000  100.764  100.987    97.000   3.789
 21            -1000.0  170.000  102.772  103.521   101.000   6.944+CRIT+
 20            -1250.0  150.000  103.805  104.113   101.500   4.454
 19            -1250.0  150.000  103.612  104.568   101.700   7.846+CRIT+
 18            -1450.0  150.000  104.412  105.368   102.500   7.846+CRIT+
 17            -1450.0  150.000  105.421  105.601   102.600   3.399
 16            -1700.0  150.000  105.634  105.812   102.800   3.377
 15            -2200.0  100.000  105.879  106.112   104.000   3.867
 14            -2700.0  100.000  106.625  106.794   104.500   3.303


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 11             -500.0  110.000  104.341  105.076   102.500   6.880+CRIT+
 10            -1000.0  110.000  106.986  107.094   103.500   2.636
  9            -1600.0  100.000  107.632  107.756   104.500   2.835
  8            -2100.0  100.000  108.424  108.579   105.500   3.152


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  7            -1000.0   80.000  104.547  105.181   103.000   6.389+CRIT+
  6            -1500.0   80.000  107.062  107.148   104.000   2.348
  5            -2100.0  100.000  108.022  108.161   105.000   2.996
  4            -2600.0  100.000  108.903  109.061   106.000   3.188
```

TABLE B.5.2 (CONT'D)

```
SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.    INV.      VEL.

  3           -1700.0   50.000   105.791   105.812   103.000   1.150
  2           -2200.0   50.000   105.247   105.280   103.500   1.450
  1           -2700.0   50.000   105.959   106.011   104.000   1.834


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.    INV.      VEL.

 13           -1000.0   10.000   107.093   107.094   103.500    .228
 12           -1500.0   10.000   107.100   107.102   104.500    .367

COMMAND?

? STOP
```

B.7 Island Network

This example has been designed to indicate the complexity of networks that can be analysed with the program. It comprises six islands in total as shown in Figure B.6. An attempt has been made to model division of flow for all possible combinations of channels. The channels have been represented as being rectangular, thus only two stations need be defined per section as the program will add the vertical extensions as required. The system geometry is shown in Table B.6.1. Transitions and bridges have not been modelled in this network. The network may be said to be similar to a river delta or a bayou.

The initial flow condition was set at 10,000.0 cfs entering at node 26. The program then computed the division of flow and the profiles, terminating at a ten percent error limit.

Two iterations were required to reduce the error in all branches to less than ten percent with the third iteration printed out. Table B.6.2 presents the complete listing of the computation. In the calculated error it will be noted that all of the errors are quite small except for one (node 27 to 6) but it is well within acceptable limits.

FIGURE B·6

ISLAND NETWORK

REACH	WIDTH
26 - 34	100'
19 - 25	50'
14 - 18	30'
12 - 13	20'
6 - 11	50'
3 - 5	30'
1 - 2	20'

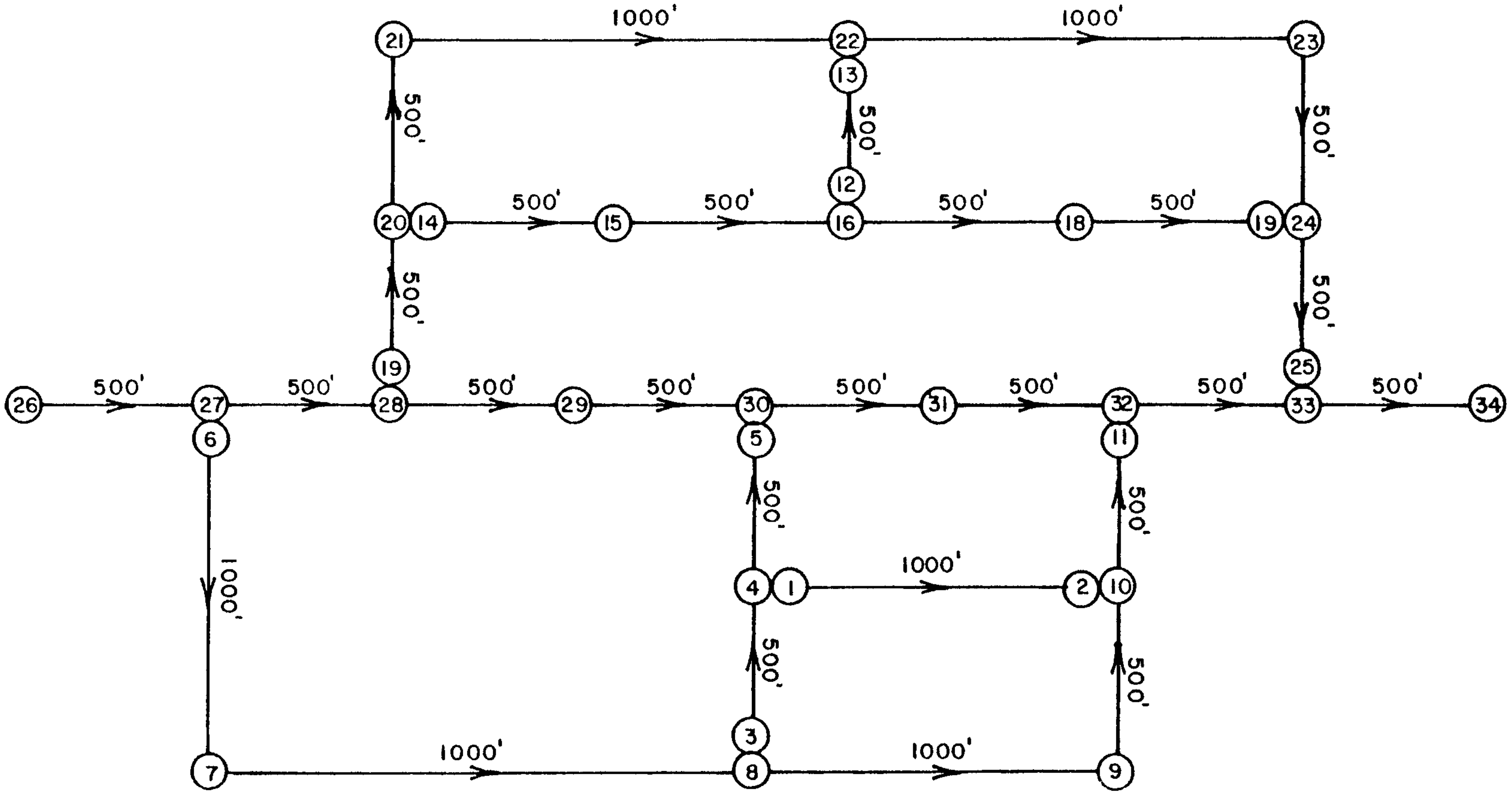


TABLE B.6.1 DATA FOR ISLAND NETWORK

```
                DATA SET FOR -ISLAND- FLOW
                MAIN CHANNEL      20-24
                TRIBS:-    1  -  2 CONNECT ? 10, BRANCH ?  4
                           3  -  5 CONNECT ? 20, BRANCH ?  8
                           6  - 11 CONNECT ? 22, BRANCH ? 27
                          12  - 13 CONNECT ? 22, BRANCH ? 16
                          14  - 18 CONNECT ? 24, BRANCH ? 20
                          19  - 25 CONNECT ? 20, BRANCH ? 28
  1     2   -2100.       .025
  1     0.0      105.0      20.0       105.0
  2     2   -1100.       .025
  2     0.0      104.0      20.0       104.0
  3     2   -2600.       .025
  3     0.0      105.5      30.0       105.5
  4     2   -2100.       .025
  4     0.0      105.0      30.0       105.0
  5     2   -1600.       .025
  5     0.0      104.5      30.0       104.5
  6     2   -4600.       .025
  6     0.0      107.5      50.0       107.5
  7     2   -3600.       .025
  7     0.0      106.5      50.0       106.5
  8     2   -2600.       .025
  8     0.0      105.0      50.0       105.0
  9     2   -1600.       .025
  9     0.0      103.5      50.0       103.5
 10     2   -1100.       .025
 10     0.0      103.0      50.0       103.0
 11     2    -600.       .025
 11     0.0      102.5      50.0       102.5
 12     2   -3000.       .025
 12     0.0      104.5      20.0       104.5
 13     2   -2500.       .025
 13     0.0      103.5      20.0       103.5
 14     2   -3000.       .025
 14     0.0      105.5      30.0       105.5
 15     2   -2500.       .025
 15     0.0      105.0      30.0       105.0
 16     2   -2000.       .025
 16     0.0      104.0      20.0       104.0
 17     2   -1500.       .025
 17     0.0      103.5      30.0       103.5
 18     2   -1000.       .025
 18     0.0      103.0      20.0       103.0
 19     2   -4500.       .025
 19     0.0      106.5      50.0       106.5
 20     2   -4000.       .025
 20     0.0      105.0      50.0       105.0
```

TABLE B.6.1 (CONT'D)

```
  21     2    -3500.       .025
  21     0.0       104.5      50.0       104.5
  22     2    -2500.       .025
  22     0.0       103.5      50.0       103.5
  23     2    -1500.       .025
  23     0.0       102.5      50.0       102.5
  24     2    -1000.       .025
  24     0.0       102.0      50.0       102.0
  25     2     -500.       .025
  25     0.0       101.5      50.0       101.5
  26     2    -3600.       .025
  26     0.0       108.0      100.0      108.0
  27     2    -3100.       .025
  27     0.0       107.0      100.0      107.0
  28     2    -2600.       .025
  28     0.0       106.0      100.0      106.0
  29     2    -2100.       .025
  29     0.0       105.0      100.0      105.0
  30     2    -1600.       .025
  30     0.0       104.0      100.0      104.0
  31     2    -1100.       .025
  31     0.0       103.0      100.0      103.0
  32     2     -600.       .025
  32     0.0       102.0      100.0      102.0
  33     2     -500.       .025
  33     0.0       101.0      100.0      101.0
  34     2      0.0        .025
  34     0.0       100.0      100.0      100.0
*EOR*
 *END OF INFORMATION*
?
```

TABLE B.6.2 ISLAND NETWORK PROFILE COMPUTATION

```
                         ***********
                         * RIVER3 *
                         ***********

         AN INTERACTIVE SIMULATION MODEL FOR STEADY
          STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                       ALAN A SMITH
                    MCMASTER UNIVERSITY

                   (REVISED APRIL 1981),



   CHANNEL GEOMETRY ON TAPE   1 HAS  34 CROSS-SECTIONS
   MAX. NO. OF PTS. PER SECTION IS   2
   DIMENTION OF ARRAY WK() IN CALLING PGM. .GE.  178


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
?      --ISLAND-- NETWORK
DO YOU WANT A LIST OF COMMANDS?...YES/NO
? NO

COMMAND?

? CONNECT
SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE
SECTION), IN THE NETWORK...(I5)
  (   )
?     6
FOR   6 CONFLUENCES SUPPLY THE SECTION NO. AT THE
DOWNSTREAM LIMIT OF THE TRIBUTARY AND THE INTERMEDIATE
SEC. NO. AT THE RECEIVING STREAM...(2I5)
CONFLUENCE   1
  (   )(   )
?    25   33
CONFLUENCE   2
  (   )(   )
?    11   32
CONFLUENCE   3
  (   )(   )
?     5   30
CONFLUENCE   4
  (   )(   )
?    13   24
CONFLUENCE   5
  (   )(   )
?    13   22
CONFLUENCE   6
  (   )(   )
?     2   10
```

TABLE B.6.2 (CONT'D)

```
CONMAND?

? BRANCH
SUPPLY NO. OF BIFURCATION BRANCHES...(I5)
  (    )
?     6
FOR   6 BRANCHES, SUPPLY SEC. NO. AT THE UPSTREAM
LIMIT OF THE BRANCHING CHANNEL AND THE INTERMEDIATE
SEC. NO. OF THE MAIN CHANNEL....(2I5)
BRANCH NO.    1
  (    )(    )
?     1    4
BRANCH NO.    2
  (    )(    )
?     3    8
BRANCH NO.    3
  (    )(    )
?     6   27
BRANCH NO.    4
  (    )(    )
?    12   16
BRANCH NO.    5
  (    )(    )
?    14   20
BRANCH NO.    6
  (    )(    )
?    19   28

CONMAND?

? INFLOWS
FOR   6 JUNCTIONS AND   6 BRANCHES THERE SHOULD
BE   1 TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.
SUPPLY INFLOW DISCHARGE (F10.3 ) AT:
SECTION NO.  26
  (         )
?  10000.0
DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES/NO?
? NO

 INITIAL FLOW VALUES AT EACH NODE GOING FROM
 1 TO   34  INCLUSIVE, IN ORDER:-

     .000       .000       .000       .000       .000
     .000       .000       .000       .000       .000
     .000       .000       .000       .000       .000
     .000       .000       .000       .000       .000
     .000       .000       .000       .000       .000
10000.000  10000.000  10000.000  10000.000  10000.000
10000.000  10000.000  10000.000  10000.000

CONMAND?
```

TABLE B.6.2 (CONT'D)

```
SUMMARY OF INPUT DATA FOR

    --ISLAND-- NETWORK


 UNITS USED ARE  --IMPERIAL-


 CONNECTIVITY TABLE

NODE NO.      1    2    3    4    5    6    7    8    9   10
KDS(NODE)    --4   10  --8    0   30  --27   0    0    0    0

NODE NO.     11   12   13   14   15   16   17   18   19   20
KDS(NODE)    32  --16  22  --20   0    0    0   24  --28   0

NODE NO.     21   22   23   24   25   26   27   28   29   30
KDS(NODE)     0    0    0    0   33    0    0    0    0    0

NODE NO.     31   32   33   34
KDS(NODE)     0    0    0  999

SINCE BRANCHED FLOWS ARE BEING MODELLED,
INITIAL FLOWS ARE NOT PRINTED OUT IN
ORDER TO PREVENT POSSIBLE CONFUSION.


INITIAL WATER LEVEL AT NODE   34   IS    113.544

RESISTANCE LAW BEING USED IS -- MANNING  --

HEAD LOSS COEFF. AT CONTRACTIONS CLC =      0.000
                 AT EXPANSIONS   CLE =      1.000


COMMAND?

? COMPUTE
```

TABLE B.6.2 (CONT'D)

```
TWO OPTIONS ARE AVAILABLE FOR BRANCH FLOW
COMPUTATION.  EITHER EVERY ITERATION CAN BE PRINTED OUT
IN WHOLE OR PART --OR-- PRINTOUT STARTS AFTER A PREDEFINED
ERROR IN DEPTH HAS BEEN REACHED.


DO YOU WANT PROFILES AND/OR ERRORS PRINTED OUT
FOR EVERY ITERATION.....YES/NO?
? NO
SUPPLY PERCENT ERROR LIMIT FOR TERMINATION OF INITIAL
COMPUTATION OF WATER LEVELS AT BRANCHES(USUALLY 10.0)
......F10.3
  (         )
?   10.0
SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
  (     )
?      1
DO YOU WANT PROFILES PRINTED FOR THIS ITERATION.(     3)
....YES/NO
? YES



     --ISLAND-- NETWORK


SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.     INV.       VEL.

 34               0.0 10000.000   113.544   114.390   100.000     7.383
 33            -500.0 10000.000   113.798   114.746   101.000     7.814
 32            -600.0  7937.308   114.076   114.747   102.000     6.573
 31           -1100.0  5914.863   114.323   114.747   103.000     5.224
 30           -1600.0  5914.863   114.475   114.970   104.000     5.647
 29           -2100.0  5689.443   114.658   115.197   105.000     5.891
 28           -2600.0  5689.443   114.903   115.537   106.000     6.390
 27           -3100.0  7752.135   115.572   116.842   107.000     9.044
 26           -3600.0 10000.000   117.018   118.927   108.000    11.089


SEC.  STATN.  CHAINAGE  DISCH.      W.L.      EN.LEV.     INV.       VEL.

 25            -500.0  2062.693   114.592   114.746   101.500     3.151
 24           -1000.0  2062.693   114.665   114.829   102.000     3.257
 23           -1500.0  1349.026   114.754   114.830   102.500     2.202
 22           -2500.0  1349.026   114.834   114.922   103.500     2.381
 21           -3500.0  1348.906   114.934   115.032   104.500     2.506
 20           -4000.0  1348.906   114.994   115.108   105.000     2.699
 19           -4500.0  2062.693   115.120   115.476   106.500     4.786
```

TABLE B.6.2 (CONT'D)

```
SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 11             --600.0  2022.445  114.572   114.747   102.500    3.351
 10            --1100.0  2022.445  114.661   114.848   103.000    3.469
  9            --1600.0  1562.900  114.728   114.848   103.500    2.704
  8            --2600.0  1562.900  114.864   115.020   105.000    3.169
  7            --3600.0  2247.865  115.290   115.696   106.500    5.115
  6            --4600.0  2247.865  115.399   116.344   107.500    5.353


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  5            --1600.0   225.420  114.962   114.970   104.500     .718
  4            --2100.0   225.420  114.968   114.977   105.000     .754
  3            --2600.0   684.965  115.033   115.122   105.500    2.395


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 18            --1000.0   713.666  114.766   114.829   103.000    2.022
 17            --1500.0   713.666  114.810   114.878   103.500    2.103
 16            --2000.0   713.666  114.859   114.933   104.000    2.191
 15            --2500.0   713.706  114.909   114.999   105.000    2.401
 14            --3000.0   713.706  114.981   115.078   105.500    2.509


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

 13            --2500.0      .040  114.922   114.922   103.500     .000
 12            --3000.0      .040  114.922   114.922   104.500     .000


SEC.  STATN.  CHAINAGE  DISCH.     W.L.     EN.LEV.     INV.       VEL.

  2            --1100.0   459.545  114.777   114.848   104.000    2.132
  1            --2100.0   459.545  114.923   115.006   105.000    2.316

BRANCH     4  TO      1
E.L.   114.977   115.006 DIFF AS PCNT OF SMALLER DEPTH=   .30
W.L.   114.968   114.923 DIFF AS PCNT OF SMALLER DEPTH=   .45
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=   --34.304


BRANCH     8  TO      3
E.L.   115.020   115.122 DIFF AS PCNT OF SMALLER DEPTH=  1.06
W.L.   114.864   115.033 DIFF AS PCNT OF SMALLER DEPTH=  1.77
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=  --368.560
```

TABLE B.6.2 (CONT'D)

```
BRANCH   27  TO     6
E.L.    116.242   116.344 DIFF AS PCNT OF SMALLER DEPTH=  5.63
W.L.    115.572   115.399 DIFF AS PCNT OF SMALLER DEPTH=  3.09
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=   137.855


BRANCH   16  TO    12
E.L.    114.933   114.922 DIFF AS PCNT OF SMALLER DEPTH=   .11
W.L.    114.859   114.922 DIFF AS PCNT OF SMALLER DEPTH=   .60
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    20.074


BRANCH   20  TO    14
E.L.    115.108   115.078 DIFF AS PCNT OF SMALLER DEPTH=   .30
W.L.    114.994   114.981 DIFF AS PCNT OF SMALLER DEPTH=   .15
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=    23.302


BRANCH   28  TO    19
E.L.    115.537   115.476 DIFF AS PCNT OF SMALLER DEPTH=   .69
W.L.    114.903   115.120 DIFF AS PCNT OF SMALLER DEPTH=  2.51
CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=   191.604

DO YOU WANT PROFILES RECOMPUTED...YES/NO?
? NO

COMMAND?
```

B.8 Use of EDIT

Since the command EDIT is somewhat tedious to use, this example demonstrates its use. Figure B.7 shows a schematic of the old file, the proposed alterations, and the arrangement of the new file when completed. A complete listing of the process is included in Table B.7.1. To start, the program provides a list of the commands available. The first use is the command PRINT in order to display the complete old file on TAPE1. Then the alterations are performed according to the middle schematic. At the end of the session, the user has the option of having the new file on TAPE2 copied onto TAPE1 (overwriting the old file) or leaving TAPE1 alone. Before terminating the session, command PRINT is used again to print out the new file (now an old file) on TAPE1.

The PRINT command only prints the data on TAPE1, not TAPE2. The advantage of the command END is the ability to check the file and, if need be, correct errors or omissions that have been made. The command RETURN returns the session to the enclosing routine RIVER3 which then calls RIVER4 again.

The differences in the schematics of TAPE1 and TAPE2 should be noted. The new file shows an increase in the number of cross sections resulting in a difference in the connectivity of the tributary. The new connectivity must be used if the new file on TAPE1 is to be analysed.

FIGURE B·7

Use of EDIT

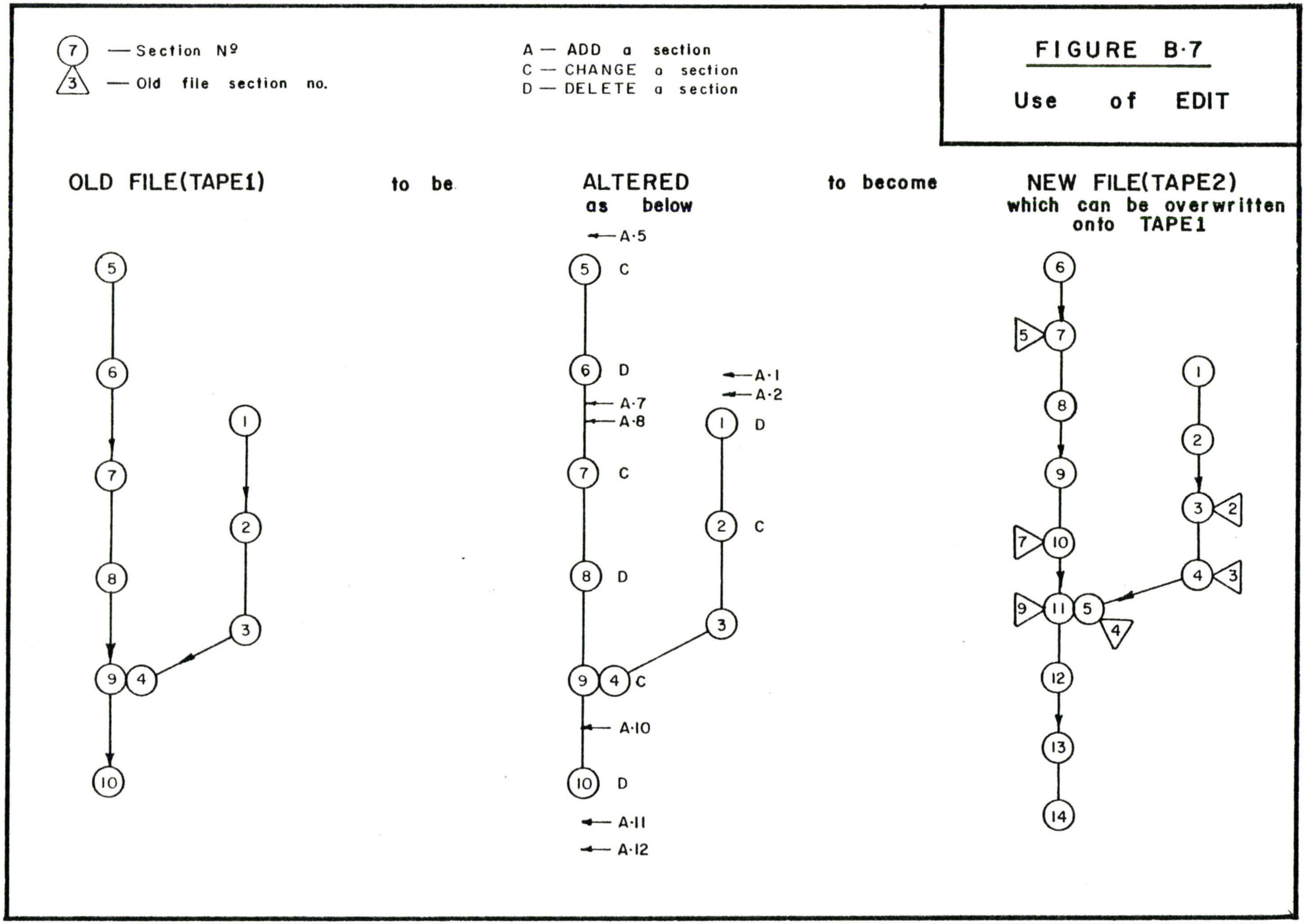


TABLE B.7.1 USE OF EDIT

```
                          ***********
                          * RIVERS *
                          ***********

          AN INTERACTIVE SIMULATION MODEL FOR STEADY
            STATE FLOWS IN NATURAL CHANNEL SYSTEMS

                        ALAN A SMITH
                     MCMASTER UNIVERSITY

                    (REVISED APRIL 1981)


   CHANNEL GEOMETRY ON TAPE    1 HAS  10 CROSS-SECTIONS
   MAX. NO. OF PTS. PER SECTION IS    1
   DIMENSION OF ARRAY WK() IN CALLING PGM. .GE.   54


SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
? TEST OF EDTI ROUTINE
DO YOU WANT A LIST OF COMMANDS?...YES/NO
? NO

COMMAND?

? EDIT
OLD FILE CONTAINS   10 SECTIONS WITH MAX. NO. PTS =     1


IN ROUTINE EDITMS AVAILABLE COMMANDS ARE:--
ADD......TO ADD A NEW SECTION
CHANGE...TO ALTER ANY SECTION PROPERTY
DELETE...TO DELETE AN EXISTING SECTION
END......TO END THIS EDIT SESSION
HELP.....TO PRINT LIST OF COMMANDS
PRINT....TO PRINT OUT PROPERTIES OF SECTION(S)
RETURN...TO RETURN TO DRIVING ROUTINE
EDIT SEC?
? PRINT
 SPECIFY FIRST & LAST SEC. NO. OF OLD FILE...(2I5)
  (    )(    )
?     1   10
   1     1   100.       .01
   1   1.0        101.
   2     1   200.       .02
   2   2.0        202.
   3     1   300.       .03
   3   3.0        303.
   4     1   400.       .04
   4   4.0        404.
   5     1   500.       .05
   5   5.0        505.
```

TABLE B.7.1 (cont'd)

```
    6    1   600.      .06
    6   6.0       606.
    7    1   700.      .07
    7   7.0       707.
    8    1   800.      .08
    8   8.0       808.
    9    1   900.      .09
    9   9.0       909.
   10    1  1010.      .10
   10  10.0      1010.
EDIT SEC?
? ADD
AFTER WHAT SECTION IS THE NEW SECTION(S) TO BE ADDED?...(I5)
IF BEFORE THE FIRST SECTION, ENTER...0
  (    )
?     0
HOW MANY SECTIONS TO BE ADDED IMMEDIATELY AFTER SECTION    0,...(I5)
  (    )
?     2
FOR ADDED SECTION    1 OF    2
SPECIFY SECTION NO....(I5)
  (    )
?     1
AT SEC. NO.    1 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (    )(         )(         )
?     1   101.1     .011
FOR SEC.NO.  1 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?    1.1        101.1
FOR ADDED SECTION    2 OF    2
SPECIFY SECTION NO....(I5)
  (    )
?     2
AT SEC. NO.    2 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (    )(         )(         )
?     1   202.2     .022
FOR SEC.NO.  2 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?    2.2        202.2
EDIT SEC?
? DELETE
SPECIFY SECTION NO....(I5)
  (    )
?     1
EDIT SEC?
? CHANGE
SPECIFY SECTION NO....(I5)
  (    )
?     2
AT SEC. NO.    2 SUPPLY
```

TABLE B.7.1 (cont'd)

```
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1   200.2     .022
FOR SEC.NO.   2 SUPPLY   1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?   2.02      200.02
EDIT SEC?
? CHANGE
SPECIFY SECTION NO....(I5)
  (   )
?     4
AT SEC. NO.     4 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1   400.4     .045
FOR SEC.NO.   4 SUPPLY   1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?   4.04      400.04
EDIT SEC?
? ADD
AFTER WHAT SECTION IS THE NEW SECTION(S) TO BE ADDED?...(I5)
  (   )
?     4
HOW MANY SECTIONS TO BE ADDED IMMEDIATELY AFTER SECTION     4,...(I5)
  (   )
?     1
FOR ADDED SECTION     1 OF     1
SPECIFY SECTION NO....(I5)
  (   )
?     5
AT SEC. NO.     5 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1   505.5     .055
FOR SEC.NO.   5 SUPPLY   1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?    5.5      505.5
EDIT SEC?
? CHANGE
SPECIFY SECTION NO....(I5)
  (   )
?     5
AT SEC. NO.     5 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1   500.5     .056
FOR SEC.NO.   5 SUPPLY   1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (         )(         )(         )(         )(         )(         )
?    5.05     500.05
EDIT SEC?
```

TABLE B.7.1 (cont'd)

```
? DELETE
SPECIFY SECTION NO....(I5)
  (   )
?     6
EDIT SECT
? ADD
AFTER WHAT SECTION IS THE NEW SECTION(S) TO BE ADDED?...(I5)
  (   )
?     6
HOW MANY SECTIONS TO BE ADDED IMMEDIATELY AFTER SECTION    6,...(I5)
  (   )
?     2
FOR ADDED SECTION    1 OF    2
SPECIFY SECTION NO....(I5)
  (   )
?     7
AT SEC. NO.    7 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1  707.7     .077
FOR SEC.NO.  7 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (        )(        )(        )(        )(        )(        )
?    7.7      707.7
FOR ADDED SECTION    2 OF    2
SPECIFY SECTION NO....(I5)
  (   )
?     8
AT SEC. NO.    8 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1  808.8     .088
FOR SEC.NO.  8 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (        )(        )(        )(        )(        )(        )
?    8.8      808.8
EDIT SECT
? CHANGE
SPECIFY SECTION NO....(I5)
  (   )
?     7
AT SEC. NO.    7 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  (   )(        )(        )
?     1  700.7      .078
FOR SEC.NO.  7 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  (        )(        )(        )(        )(        )(        )
?    7.07      700.07
EDIT SECT
```

```
? DELETE
SPECIFY SECTION NO....(I5)
  <    >
?     8
EDIT SEC?
? ADD
AFTER WHAT SECTION IS THE NEW SECTION(S) TO BE ADDED?...(I5)
  <    >
?     9
HOW MANY SECTIONS TO BE ADDED IMMEDIATELY AFTER SECTION    9,...(I5)
  <    >
?     1
FOR ADDED SECTION    1 OF    1
SPECIFY SECTION NO....(I5)
  <    >
?    10
AT SEC. NO.    10 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  <    ><        ><        >
?     1  1010.10     .101
FOR SEC.NO. 10 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  <         ><        ><        ><        ><        ><        >
?   10.10     1010.10
EDIT SEC?
? DELETE
SPECIFY SECTION NO....(I5)
  <    >
?    10
EDIT SEC?
? ADD
AFTER WHAT SECTION IS THE NEW SECTION(S) TO BE ADDED?...(I5)
  <    >
?    10
HOW MANY SECTIONS TO BE ADDED IMMEDIATELY AFTER SECTION   10,...(I5)
  <    >
?     2
FOR ADDED SECTION    1 OF    2
SPECIFY SECTION NO....(I5)
  <    >
?    11
AT SEC. NO.    11 SUPPLY
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  <    ><        ><
?     1  1111.10     1.111
FOR SEC.NO. 11 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  <         ><        ><        ><        ><        ><        >
?   11.11     1111.11
FOR ADDED SECTION    2 OF    2
SPECIFY SECTION NO....(I5)
  <    >
?    12
AT SEC. NO.    12 SUPPLY
```

TABLE B.7.1 (cont'd)

```
NO. PTS., CHAINAGE, ROUGH. COEFF.
...(I5,F10.1,F10.3)
  <    ><          ><          >
?     1  1212.12    1.212
FOR SEC.NO. 12 SUPPLY  1 PRS. COORDS. IN ROWS OF 3...(6F10.3)
  <          ><        ><        ><        ><        ><        >
?   12.12      1222122
EDIT SEC?
? END
 DO YOU WANT THE OLD FILE OVERWRITTEN
 WITH THE NEW FILE.....YES/NO?
? YES

MAX. NO. OF SEC. =    14       MAX. NO. OF PTS. =     1
EDIT SEC?
? PRINT
 SPECIFY FIRST & LAST SEC. NO. OF OLD FILE...(2I5)
  <    ><    >
?     1   14
    1     1      101.1       .011
    1      1.100   101.100
    2     1      202.2       .022
    2      2.200   202.200
    3     1      200.2       .023
    3      2.020   200.020
    4     1   300.       .03
    4    3.0       303.
    5     1      400.4       .045
    5      4.040   400.040
    6     1      505.5       .055
    6      5.500   505.500
    7     1      500.5       .056
    7      5.050   500.050
    8     1      707.7       .077
    8      7.700   707.700
   10     1      800.8       .088
   10      8.800   808.800
   10     1      700.7       .078
   10      7.070   700.070

   11     1   900.       .09
   11    9.0       909.
   12     1     1010.1       .101
   12     10.100  1010.100
   13     1     1111.1      1.111
   13     11.110  1111.110
   14     1     1212.1      1.212
   14     12.120  1212.120
 EDIT SEC?
 ? RETURN
```

TABLE B.7.1 (cont'd)

```
    CHANNEL GEOMETRY ON TAPE    1 HAS  14 CROSS-SECTIONS
    MAX. NO. OF PTS. PER SECTION IS    1
    DIMENSION OF ARRAY WK() IN CALLING PGM. .GE.    74

SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS)
? END OF EDIT TEST
DO YOU WANT A LIST OF COMMANDS?...YES,NO
? NO

COMMAND?

? STOP
```

APPENDIX C

PROGRAMMER'S MANUAL

INDEX

PROGRAMMER'S MANUAL

C.1 Introduction

This manual is written with the intent of providing the programmer with a further understanding of the details of the principle subroutine RIVER4. The routine resides in a library of subroutines known as the Civil Engineering Program Library (C.E.P.L.) developed by A.A. Smith [1]. The library is an extensive collection of routines which analyse a wide variety of hydrologic and hydraulic phenomena. For programming information about routines not detailed in this manual, reference should be made to the C.E.P.L. The following discussion on RIVER4 is based on the revisions and modifications made by P.B. Ashenhurst [2]. This information should be of value to the user who wishes to change, add or delete various component parts. In addition, a summary of the subroutines used is provided. At present, the program has been used only on a CDC 6400 computer and requires 42,670 octal words. Information with respect to mounting the program on other computer systems would be gratefully appreciated.

Reference to program lines is made by the statement number plus the number of lines after the statement number. Thus, line 4001.07 refers to the seventh line after statement number 4001 excluding comment cards.

C.2 Organization of Subroutine RIVER4

The subroutine is command oriented and divided into its appropriate parts. The first part of the subroutine includes a description of the purpose of the subroutine and definitions of the variables in the parameter list.

Each command has statement numbers limited to a certain range of values. Therefore it is relatively easy to add new commands and identify the command with its own number range. Certain format numbers are used throughout all commands. This is particularly true of format numbers 9001 to 9005 inclusive. These formats print out the field for data entry using brackets. The following is a list of the range of statement numbers for each command or part of the subroutine. They are listed in the order that they appear in the subroutine listing.

Statement Number Range	Purpose or Command
9001 - 9005 incl.	prints brackets defining data input field
0 - 199 incl.	program initialization and organization
200	command HELP
500 - 599 incl.	command CONNECT
1500-1599 incl.	command BRANCH
1000 - 1399 incl.	command INFLOWS
2000 - 2099 incl.	command DISCHARGE
2500 - 2599 incl.	command D/S WL
3000 - 3099 incl.	command RESISTANCE
4000 - 4499 incl.	command COMPUTE
5000 - 5099 incl.	command CRITIC
5500 - 5599 incl.	command LOSS COEFF
6000	command EDIT
6100 - 6299 incl.	command SUMMARY
9000	command STOP

The program is directed to the appropriate location through the use of the dummy variable IC which changes value depending on the recognition of the command. If the command is not recognized, the user is directed to reenter the command.

C.3 Subroutine Package

A total of 19 subroutines are used in the backwater program including RIVER4. Each of these may in turn call upon some other subroutines. Table C-1 contains a list of all the subroutines used. For each subroutine, the calling subroutine is listed of which there may be several, together with the subroutines used in the called subroutine, if any.

At the beginning of each subroutine, a description is given stating the purpose of the subroutine. In addition, the parameters in the arguments list are defined together with cautionary notes as required.

C.4 Flow Range

At present, with the F10.3 format, the maximum discharge the program can interpret is 99,999 cubic feet (metres) per second. If larger flow ranges are required, then the format could be changed to any size between F10.3 and F10.0. It is recommended that a field of ten be used so as not to require too extensive a change. Two subroutines provide the printout of the flow values in some form and these are RIVER4 and PROFL2. The following is a list of statements that would require change should larger flow values be desired.

TABLE C-1
SUBROUTINES USED IN BACKWATER CALCULATION

NAME	CALLED FROM	SUB'Rs USED
BOTTOM	CONTR2 CRITIC EZRA PROFL2 RIVER4 WLFRE	None
CONTR2	PROFL2	BOTTOM CRITIC PROPS
CRITIC	CONTR2 EZRA RIVER4 WLFRE	BOTTOM PICRIT PROPS QCR2D
EDITXS	RIVER4	FILEXS PRNTXS
EZRA	PROFL2	BOTTOM CRITIC PROPS SFROMQ
FILEXS	EDITXS RIVER3	None
FINDXS	PROFL2 RIVER4	None
NORMLQ	SFROMQ	None
PICRIT	CRITIC	PIPROP
PIPROP	PROPS	None
PIYFRE	WLFRE	PICRIT PIPROP
PRINTXS	EDITXS	None

TABLE C-1 (cont'd)

NAME	CALLED FROM	SUB'Rs USED
PROFL2	RIVER4	BOTTOM CONTR2 EZRA FINDXS PROPS
PROPS	CONTR2 CRITIC EZRA PROFL2 WLFRE	PIPROP
QCR2D	CRITIC RIVER4	None
RIVER3	Driving Program	FILEXS RIVER4
RIVER4	RIVER3	BOTTOM CRITIC EDITXS FINDXS PROFL2 QCR2D WLFRE
SFROMQ	EZRA	NORMLQ
WLFRE	RIVER4	BOTTOM CRITIC PIYFRE PROPS

Subroutine PROFL2

Statement No.	
30.00	change 4F10.3 to F10.n,3F10.3

Subroutine RIVER4

Statement No.	
80.09	change QMIN=0.0001 to appropriate value
1020.02	change (F10.3) to (F10.n)
1040.00	change FORMAT(F10.3) to FORMAT(F10.n)
1130.01	change I5,F10.3 to I5,F10.n
1150.00	change FORMAT(I5,F10.3) to FORMAT(I5,F10.n)
1220.00	change FORMAT(5F10.3) to FORMAT(5F10.n)
2040.01	change (I5,F10.3) to (I5,F10.n)
2060.00	change FORMAT(I5,F10.3) to FORMAT(I5,F10.n)
4410.03	change F10.3 to F10.n
5050.00	change F10.3 to F10.n

C.5 Increasing Number of Cross-sections

The variable KSREC controls the maximum number of cross-sections that can be handled in one run. If the user wishes to model more than the 100 sections (present dimension) in one run, KSREC will have to be redimensioned. This variable occurs in the following subroutines:

EDITXS,FILEXS,PROFL2,RIVER3,RIVER4

In addition, if the subroutine EDITXS is used to create a data file, KSREC would be appropriately dimensioned in the user provided driving program.

C.6 Adding Command Options

The user may wish to add a command option to the existing version of RIVER4. By using appropriate statement numbers not listed in item C.2, the command statements can be inserted easily. The command name should be listed in the description at statement 70.00+ in its appropriate alphabetic order. A six letter Hollerith string would have to be added in the IF(COMND.) structure after line 110.15 identifying IC=15 and upwards for each command added. In addition, the appropriate GOTO()IC statement number would have to be added at the end of statement 130.02 after 6100, i.e. (..., 6000, 6100, new nember)IC.

C.7 Removing Branched Computation

The most frequent use of this program will be to compute backwater profiles where there are no bifurcated branches being modelled. Therefore, the user may wish to create a copy with the BRANCH command and associated computations removed. This may also be of value in mounting the program on small computers. The following is recommended if branched computations are to be removed. Though other procedures are possible, the one listed appears to be the easiest to do. The changes are listed in the order that they appear in RIVER4. This is the only subroutine that needs to be changed.

(1) Redefine BRANCH at 70.01 to
"not available in this version"

(2) Command BRANCH
Leave statement 1500.00
Remove statements 1500.01 through to 1560.02 inclusive, and
Replace with:

```
     WRITE (NW,1510)
1510 FORMAT(/,42H THIS OPTION NOT AVAILABLE IN THIS
+               VERSION,/)
```

(3) Command INFLOWS
Remove statements 1220.02 through to 1330.00 incl.

(4) Command COMPUTE
Remove statements 4000.01 through to 4000.07 incl.
Remove statements 4020.03 through to 4080.01 incl.
Remove statements 4100.05 through to 4110.00 incl.
Remove statements 4130.01 through to 4180.01 incl.
Remove statements 4240.07 through to 4470.01 incl.

These changes complete the removal of the branch computations.

C.8 Hollerith Constants

Certain computer systems are limited in the size of Hollerith names that can be read. Most computers can read six characters in standard Fortran. Computers such as the Radio Shack TRS-80II can read only four characters. This affects the reading of the names of both the commands and the resistance law to be used. Therefore, the following changes are required in subroutines RIVER4,NORMLQ and SFROMQ assuming a four character Hollerith constant.

Subroutine RIVER4:

(1) Dimension Statements
    Statement 00.5 change TITLE (10) to TITLE (15)

(2) Statement 40.00 change 10A6 to 15A4

(3) IF(COMND.) statements
    Statements 110.02 to 110.14 inclusive
        change .6HXXXXXX) to .4HXXXX)
    where XXXXXX represents existing programming
    and XXXX represents the first 4 characters in the command.

(4) Command RESISTANCE
    Statement 3050.00 change A6 to A4
    IF(QN. statements
        Statements 3050.01 to 3050.06
        change EQ.6HXXXXXX to EQ.4HXXXX

(5) Command SUMMARY
    IF(QN. statements
        Statements 6260.01 to 6260.06 incl.
        change .6HXXXXXX) to .4HXXXX)

Subroutine NORMLQ:

(1) Change REAL MANNIN to REAL MANN

(2) Change data statement to

```
DATA CHEZ,MANN,STRI,ROUG,SMOO,COLE
   /4HCHEZ,4HMANN,4HSTRI,4HROUG,4HSMOO,4HCOLE/
```

(3) Statements 2.01 to 2.04 incl., and 2.07 to 2.08 incl.

IF(QNAME. statements

change .EQ.6HXXXXXX) to .EQ.4HXXXX)

(4) Statement 6.00

Change ,A6, to ,A4,

Subroutine SFROMQ:

(1) Change REAL MANNIN to REAL MANN

(2) Change data statement to

```
DATA CHEZ,MANN,STRI,ROUG
  /4HCHEZ,4HMANN,4HSTRI,4HROUG/
```

(3) Statements 2.01 to 2.04 incl.

IF (QNAME. statements

Change .EQ.6HXXXXXX) to .EQ.4HXXXX)

These changes complete the alteration of a 6 character READ statement to a 4 character Hollerith constant. The WRITE statements are not affected.

C.9 Computer BACKSPACE

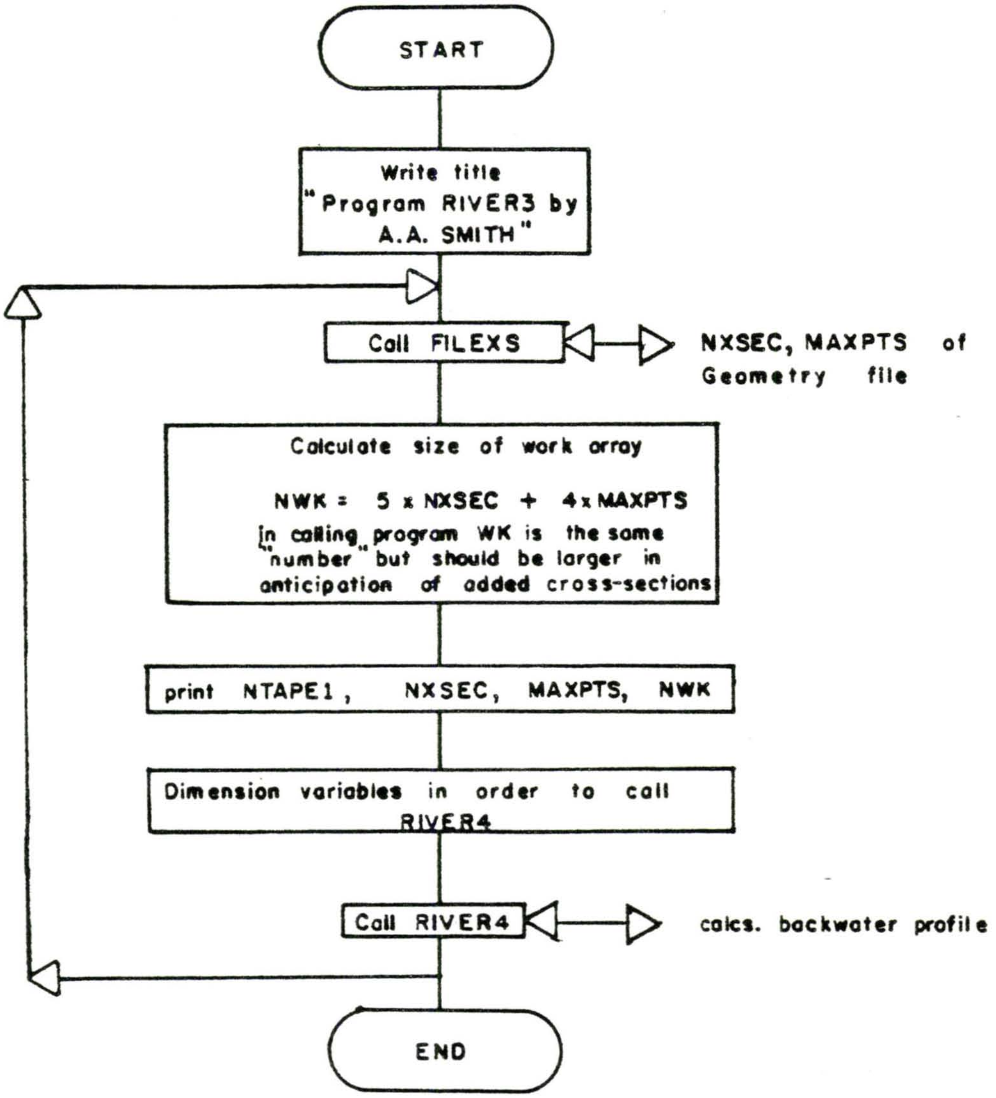
The present program requires a computer with a system that can backspace data files. Certain small computers do not have this facility, therefore, the program will have to be rewritten to accommodate the backward reading of data files. The only routine that uses - backspace - is subroutine FINDXS.

C.10 Flow Chart for RIVER4

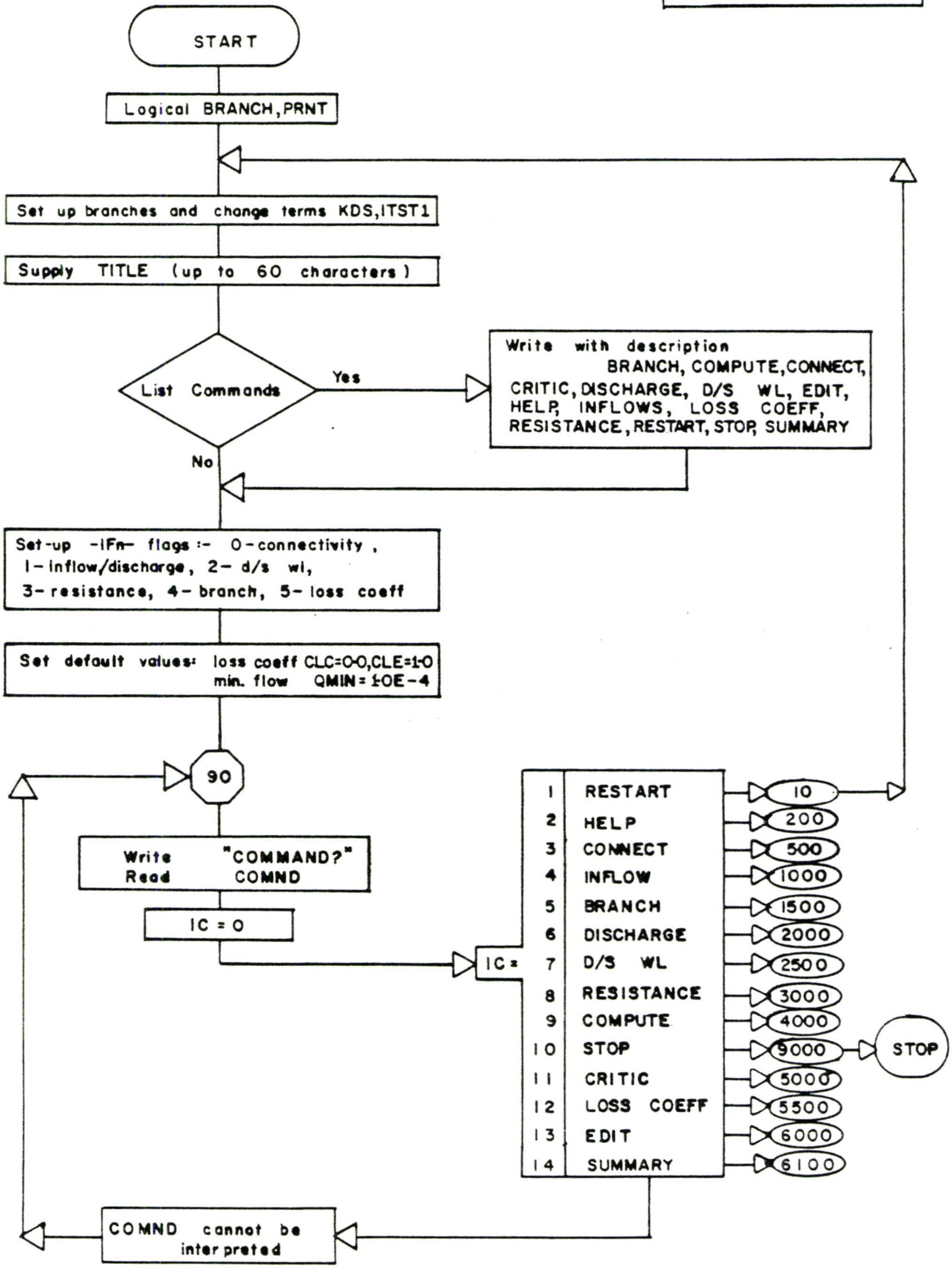
The following pages contain a detailed flow chart for subroutine RIVER4 together with the enclosing subroutine RIVER3. The flow chart indicates the logic for each command separately. The following is the order in which they are listed.

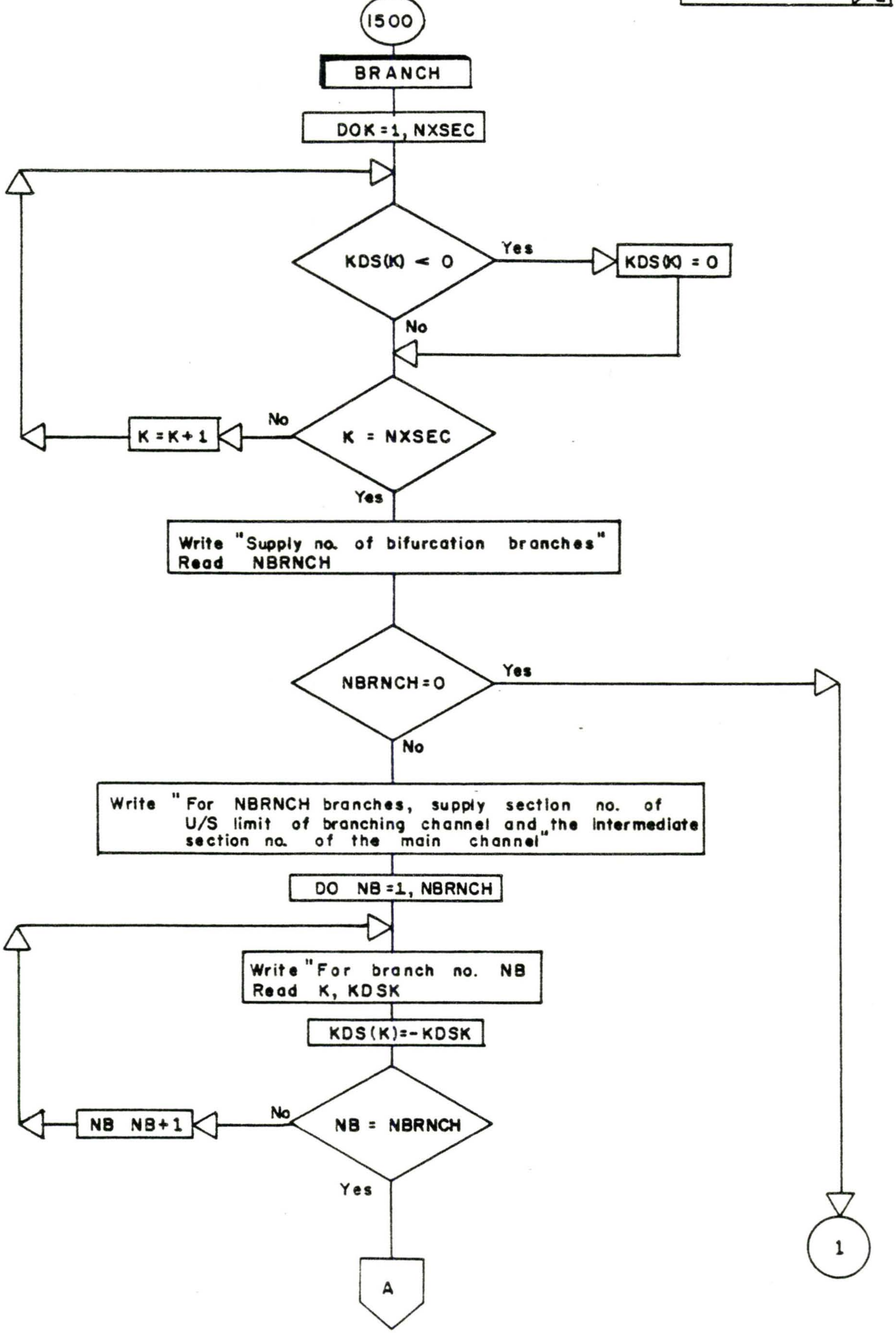
Item		No. of Pages
Subroutine	RIVER3	1
Subroutine	RIVER4	1
1500	BRANCH	2
4000	COMPUTE	13
500	CONNECT	1
5000	CRITIC	1
2000	DISCHARGE	1
2500	D/S WL	1
6000	EDIT	1
200	HELP	1
1000	INFLOWS	7
5500	LOSS COEFF	1
3000	RESISTANCE	1
6100	SUMMARY	3
TOTAL PAGES		35

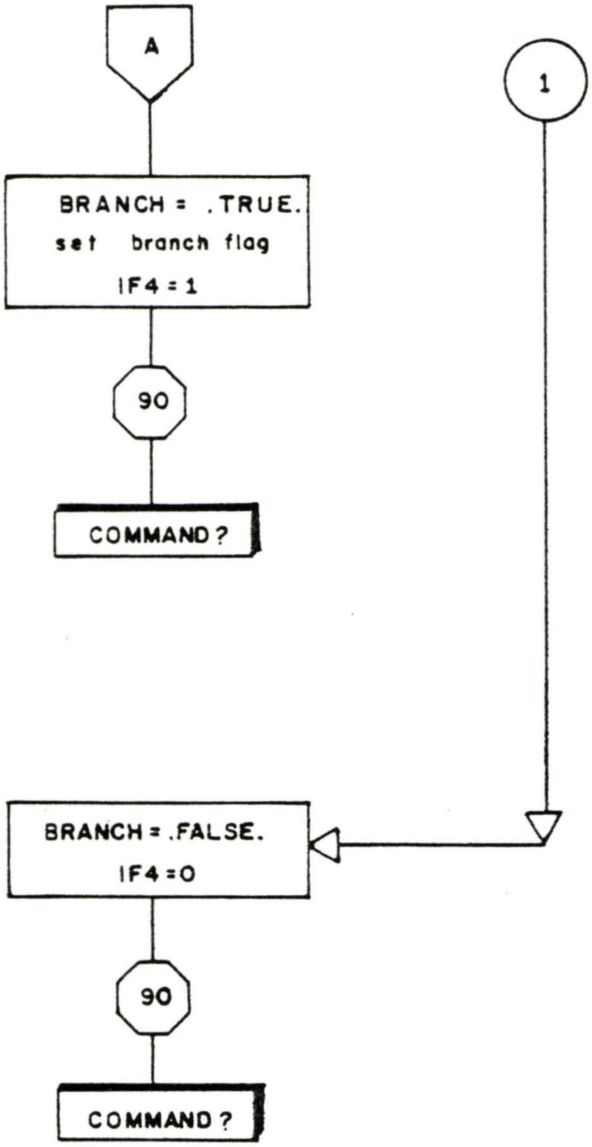
Subroutine RIVER3

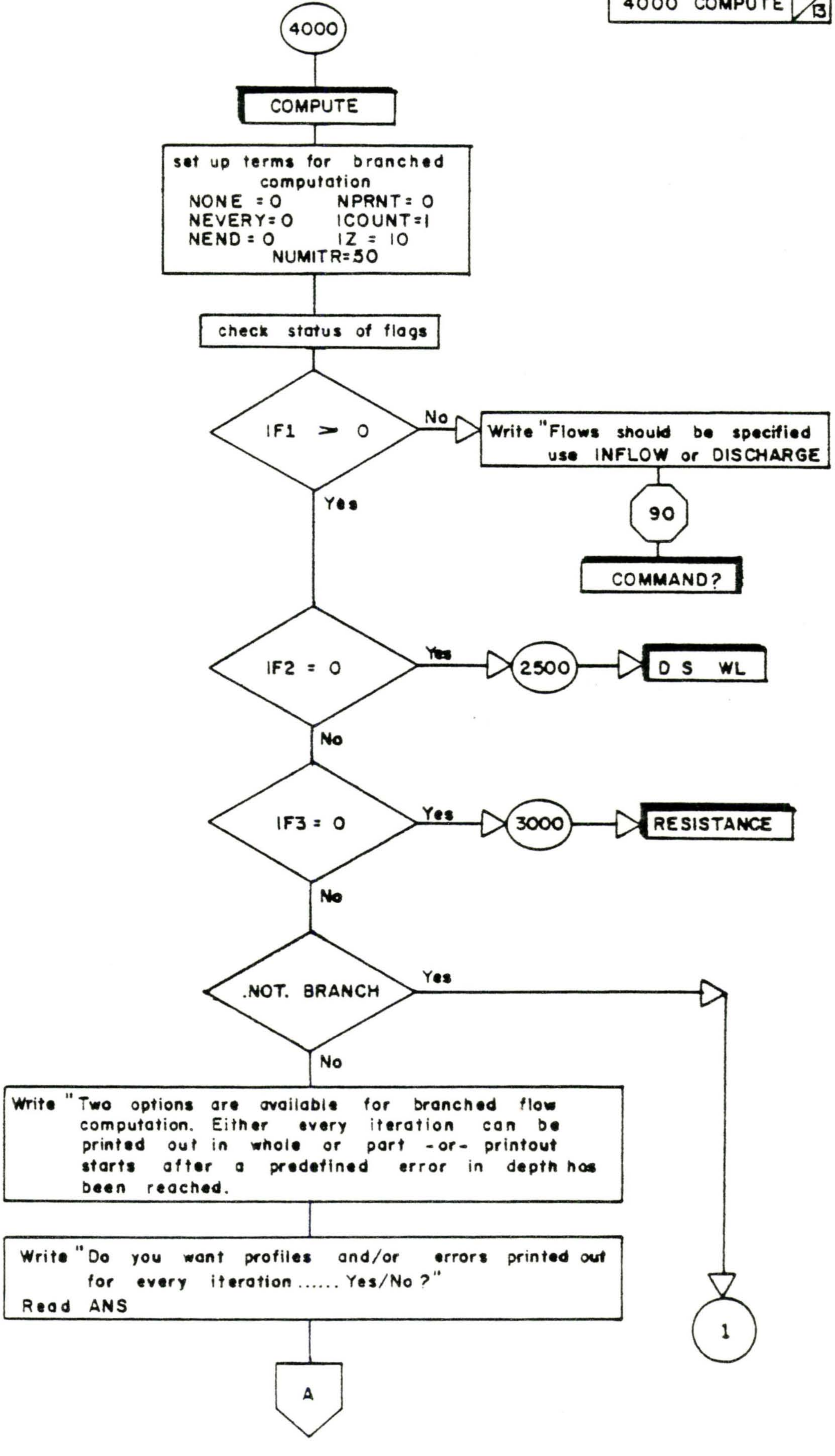


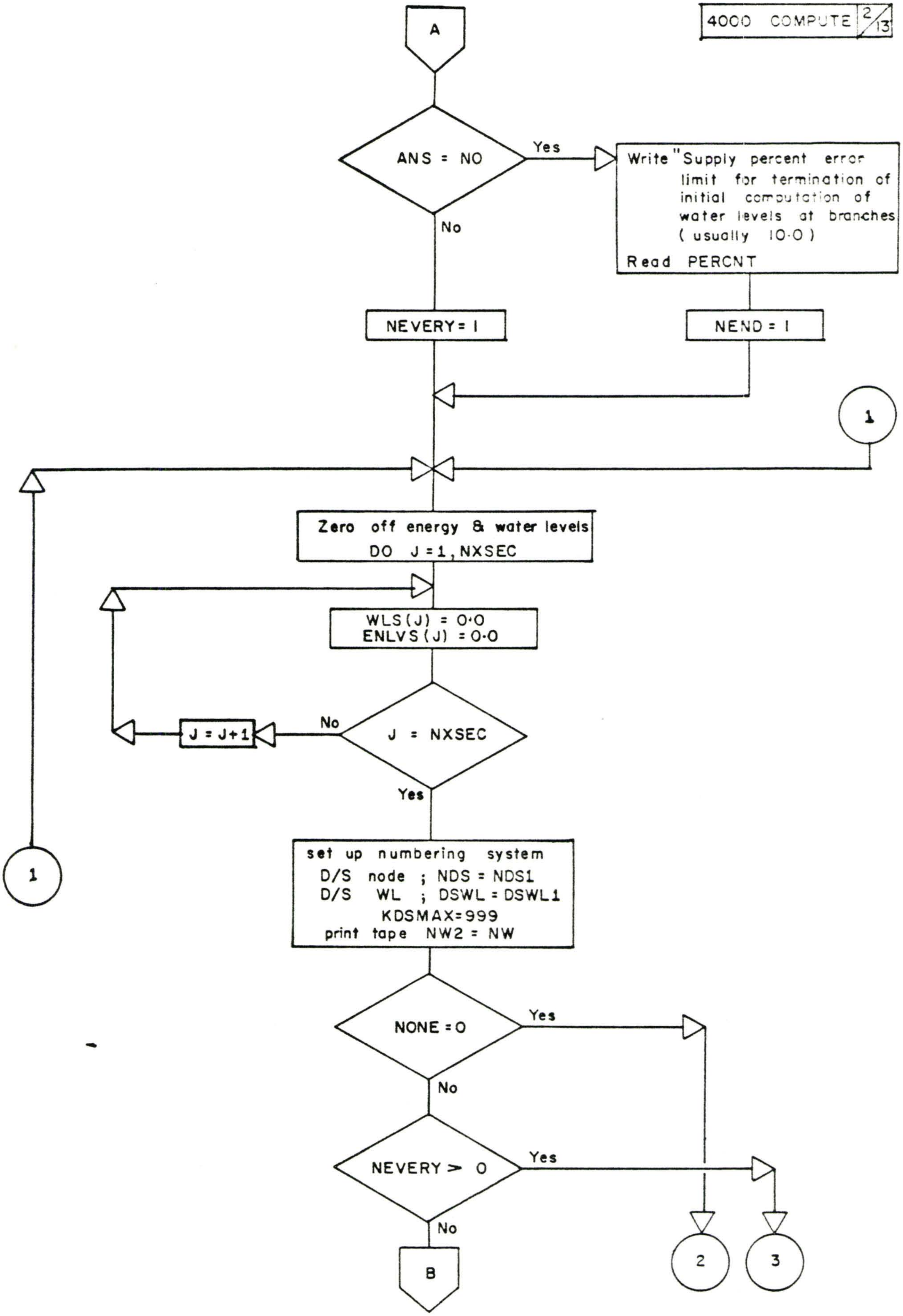
Subroutine RIVER4

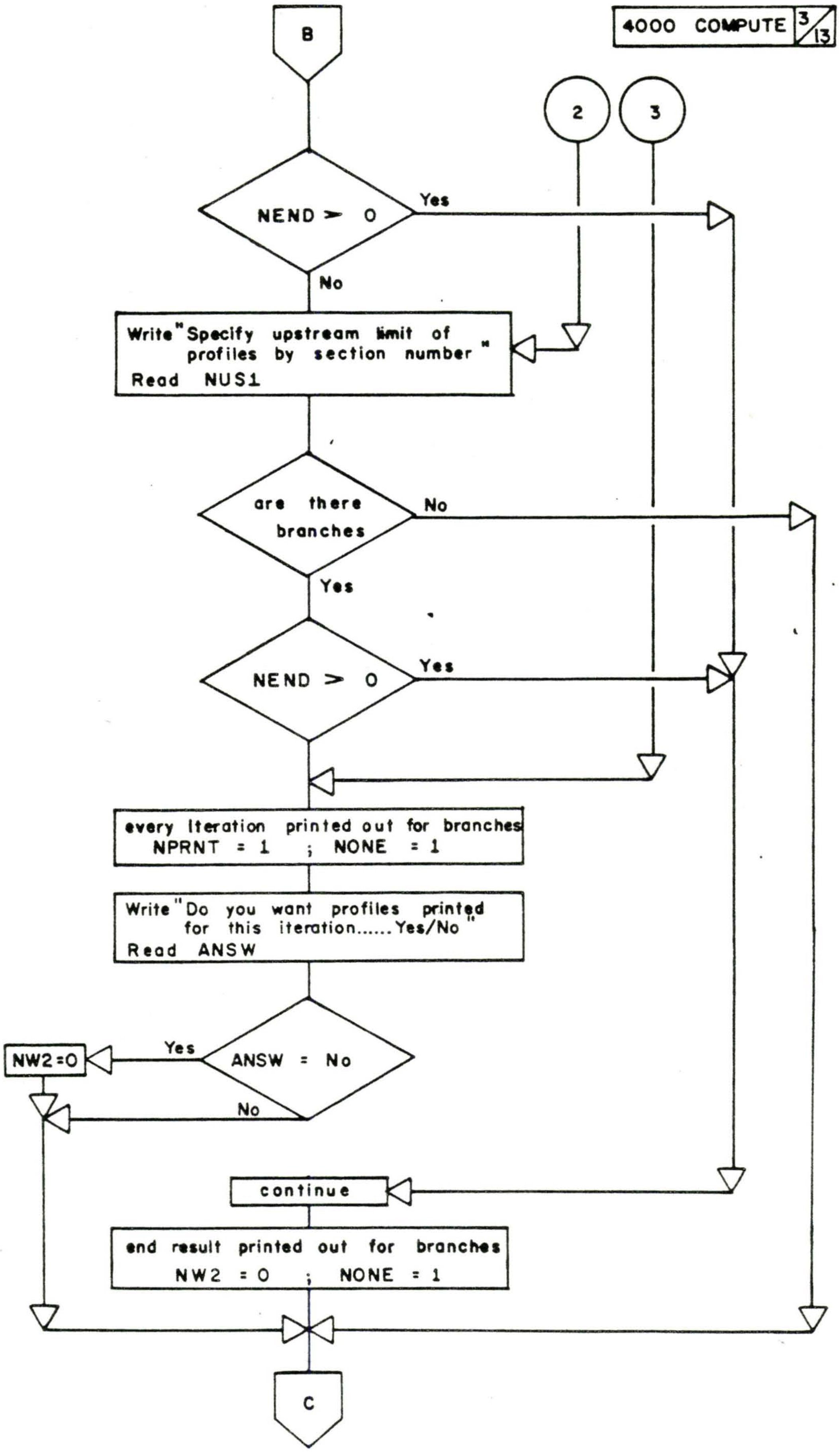


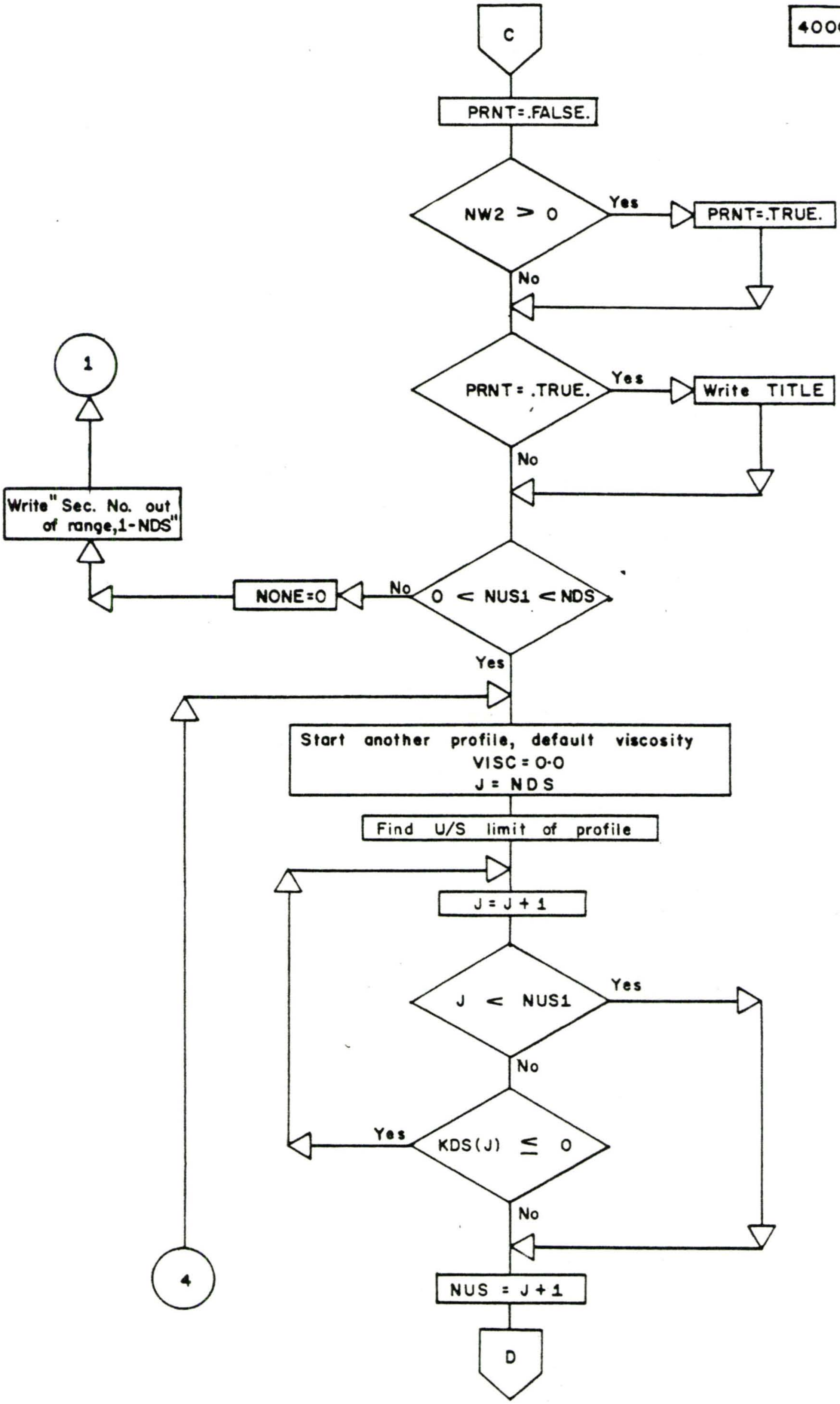

1500
BRANCH
DOK = 1, NXSEC
KDS(K) < 0
Yes
KDS(K) = 0
No
K = NXSEC
No
K = K + 1
Yes
Write "Supply no. of bifurcation branches"
Read NBRNCH
NBRNCH = 0
Yes
No
Write "For NBRNCH branches, supply section no. of U/S limit of branching channel and the intermediate section no. of the main channel"
DO NB = 1, NBRNCH
Write "For branch no. NB
Read K, KDSK
KDS(K) = - KDSK
NB = NBRNCH
No
NB NB + 1
Yes
A
1

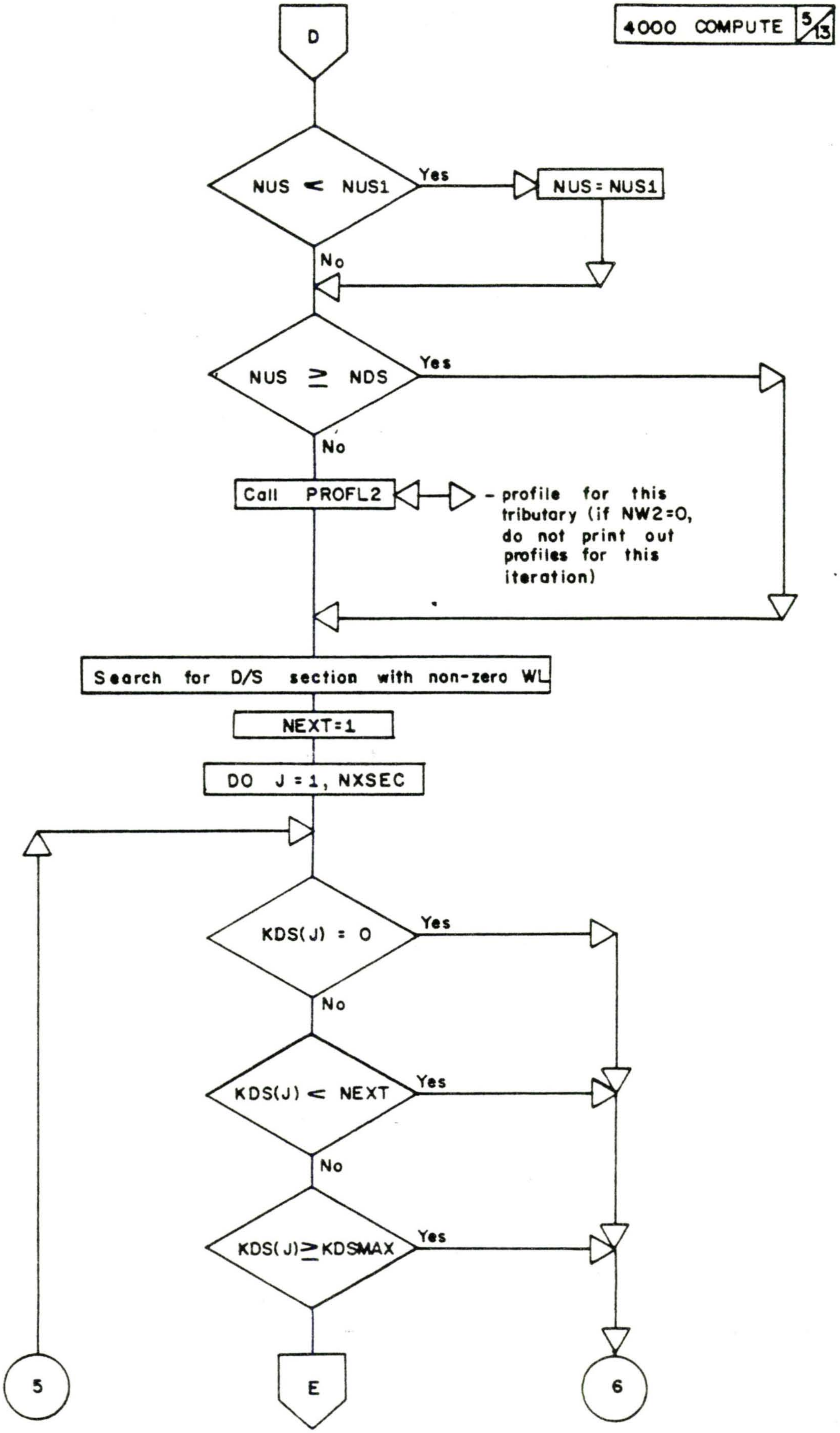

A
BRANCH = .TRUE.
set branch flag
IF4 = 1
90
COMMAND?
1
BRANCH = .FALSE.
IF4 = 0
90
COMMAND?

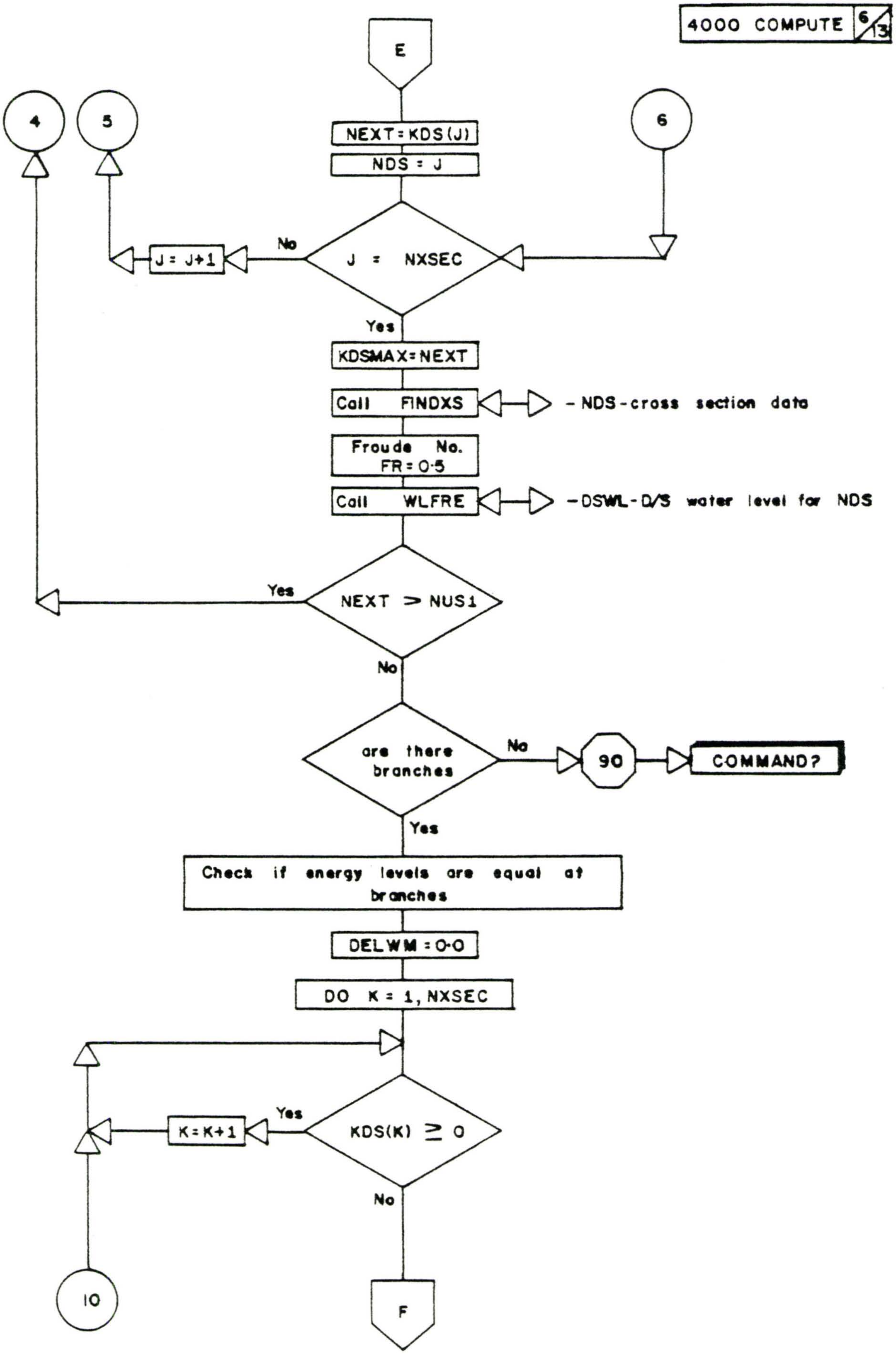

4000
COMPUTE
set up terms for branched computation
NONE = 0
NPRNT = 0
NEVERY = 0
ICOUNT = 1
NEND = 0
IZ = 10
NUMITR = 50
check status of flags
IF1 > 0
No
Write "Flows should be specified use INFLOW or DISCHARGE
90
COMMAND?
Yes
IF2 = 0
Yes
2500
D S WL
No
IF3 = 0
Yes
3000
RESISTANCE
No
.NOT. BRANCH
Yes
No
Write "Two options are available for branched flow computation. Either every iteration can be printed out in whole or part -or- printout starts after a predefined error in depth has been reached.
Write "Do you want profiles and/or errors printed out for every iteration ...... Yes/No ?"
Read ANS
1
A

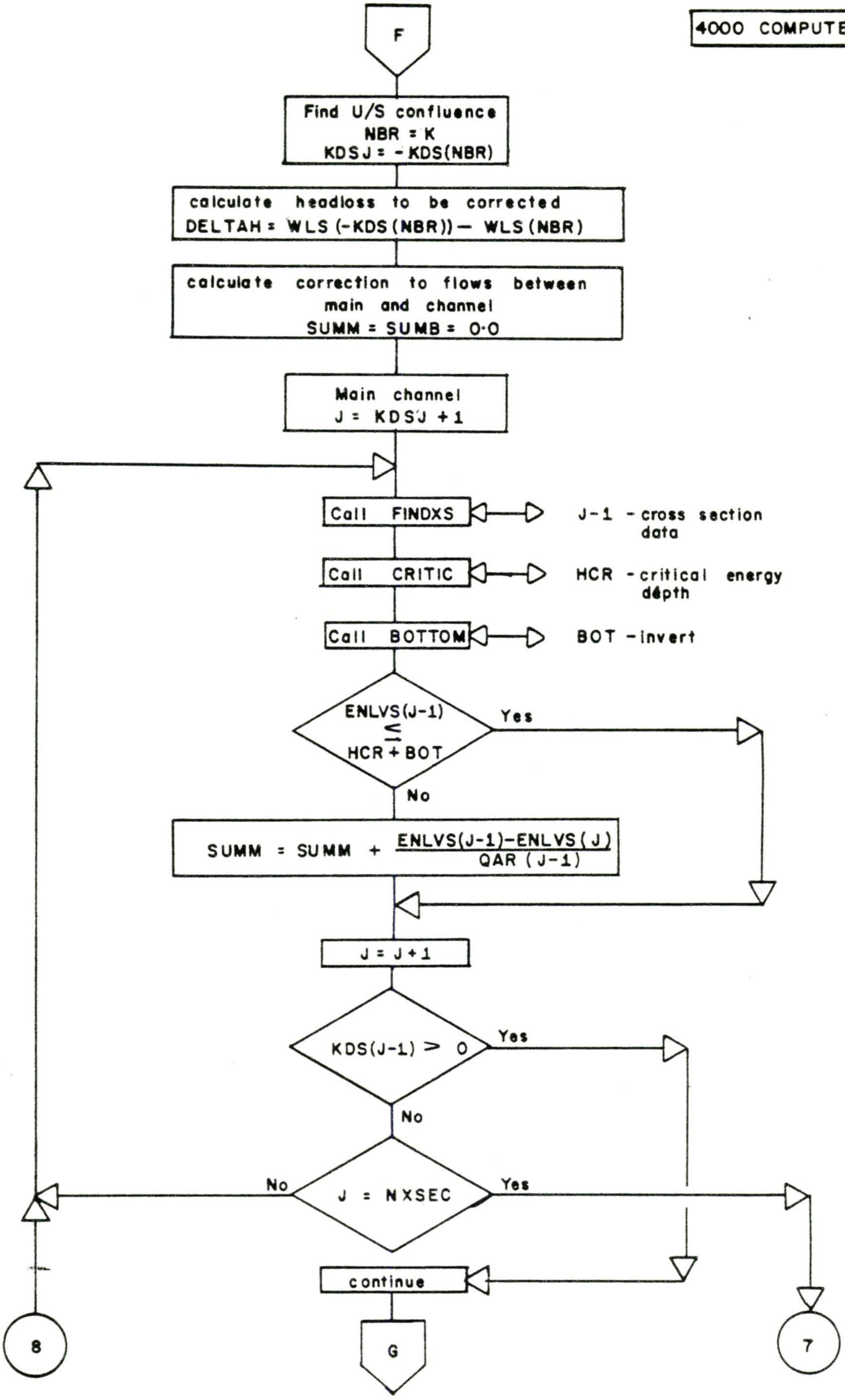

A
ANS = NO
Yes
Write "Supply percent error limit for termination of initial computation of water levels at branches (usually 10·0)
Read PERCNT
No
NEVERY = 1
NEND = 1
1
Zero off energy & water levels
DO J = 1, NXSEC
WLS(J) = 0·0
ENLVS(J) = 0·0
J = NXSEC
No
J = J+1
Yes
1
set up numbering system
D/S node ; NDS = NDS1
D/S WL ; DSWL = DSWL1
KDSMAX=999
print tape NW2 = NW
NONE = 0
Yes
No
NEVERY > 0
Yes
No
B
2
3

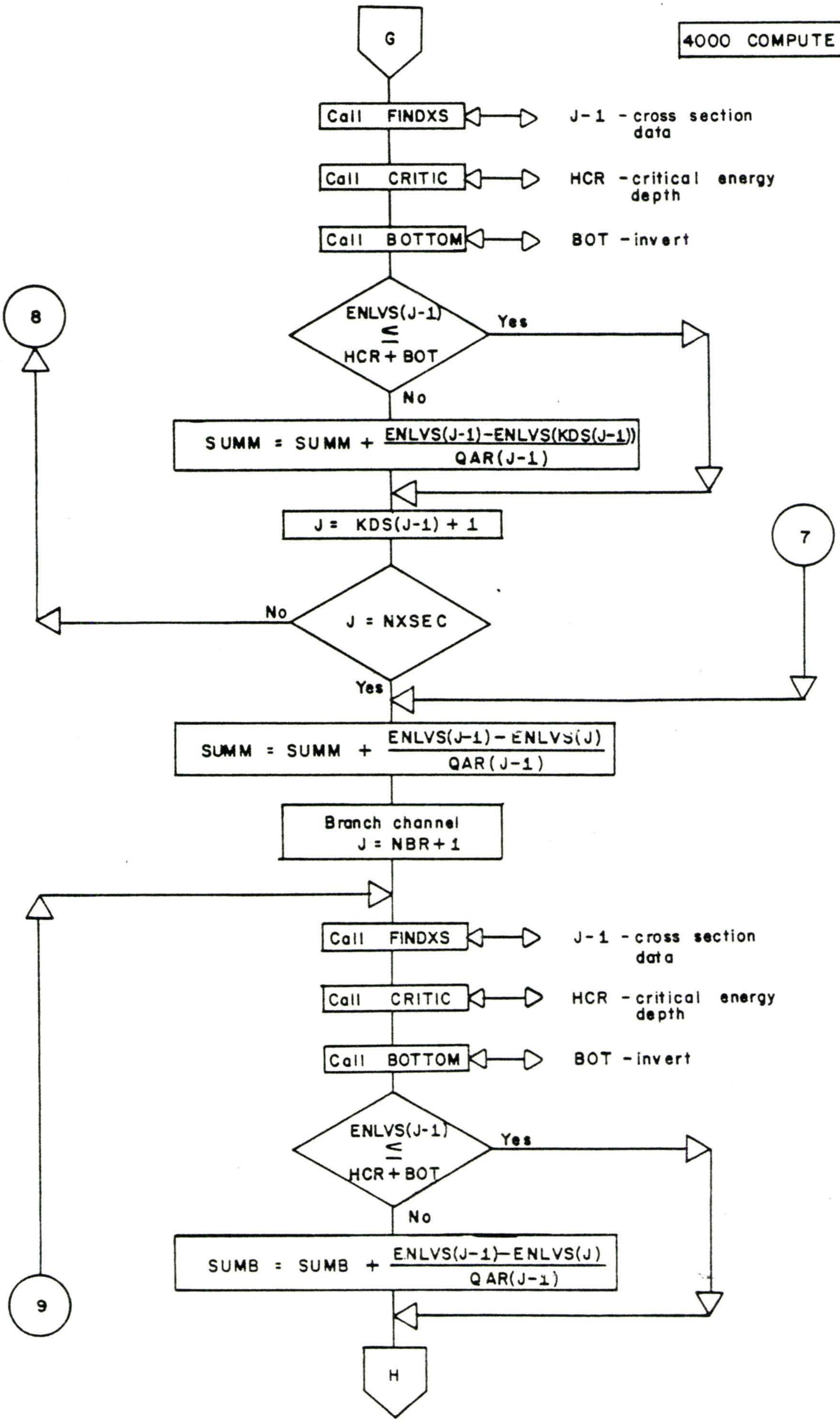

4000 COMPUTE 3/13
B
2
3
NEND > 0
Yes
No
Write "Specify upstream limit of profiles by section number"
Read NUS1
are there branches
No
Yes
NEND > 0
Yes
every Iteration printed out for branches
NPRNT = 1 ; NONE = 1
Write "Do you want profiles printed for this iteration...... Yes/No"
Read ANSW
ANSW = No
Yes
NW2=0
No
continue
end result printed out for branches
NW2 = 0 ; NONE = 1
C


C
PRNT=.FALSE.
NW2 > 0
Yes
PRNT=.TRUE.
No
PRNT=.TRUE.
Yes
Write TITLE
No
1
Write "Sec. No. out of range,1-NDS"
NONE=0
No
0 < NUS1 < NDS
Yes
Start another profile, default viscosity
VISC = 0.0
J = NDS
Find U/S limit of profile
J = J + 1
J < NUS1
Yes
No
Yes
KDS(J) ≤ 0
No
4
NUS = J + 1
D

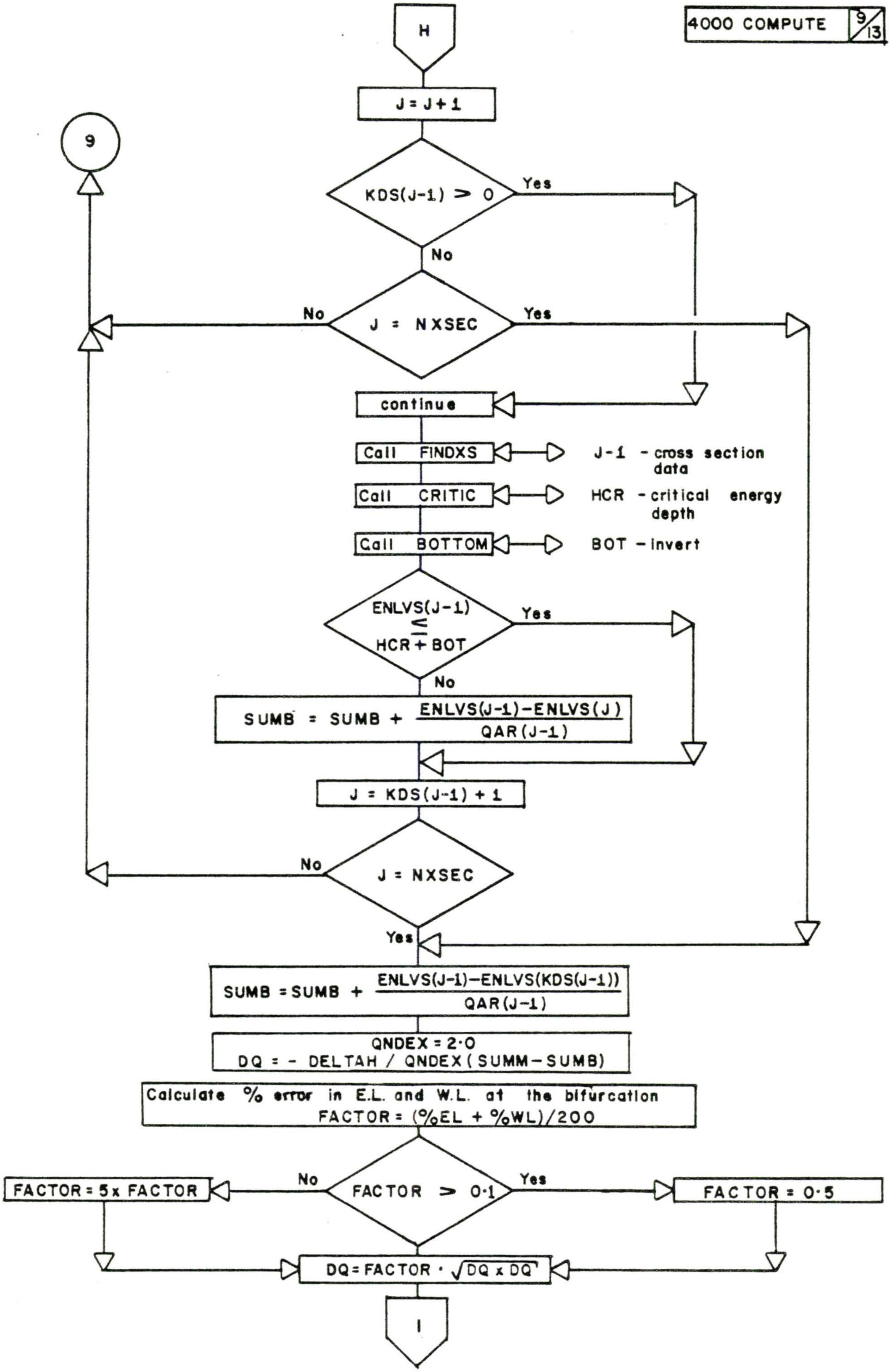

4000 COMPUTE 5/13
D
NUS < NUS1
Yes
NUS = NUS1
No
NUS ≥ NDS
Yes
No
Call PROFL2
- profile for this tributary (if NW2=0, do not print out profiles for this iteration)
Search for D/S section with non-zero WL
NEXT=1
DO J = 1, NXSEC
KDS(J) = 0
Yes
No
KDS(J) < NEXT
Yes
No
KDS(J) ≥ KDSMAX
Yes
5
E
6

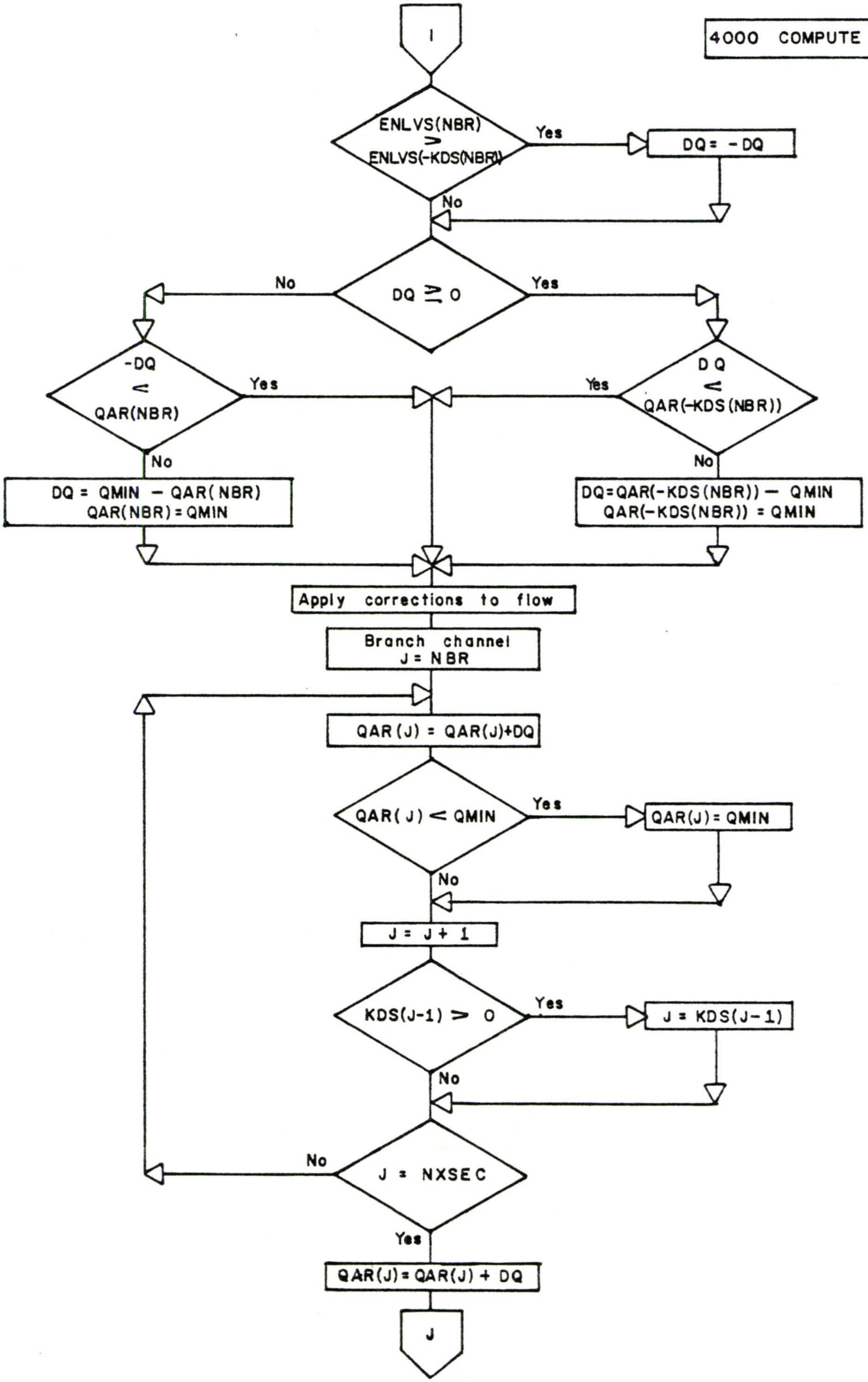

E
4
5
6
NEXT = KDS(J)
NDS = J
No
J = J+1
J = NXSEC
Yes
KDSMAX = NEXT
Call FINDXS
- NDS - cross section data
Froude No.
FR = 0·5
Call WLFRE
- DSWL - D/S water level for NDS
Yes
NEXT > NUS1
No
are there branches
No
90
COMMAND?
Yes
Check if energy levels are equal at branches
DELWM = 0·0
DO K = 1, NXSEC
Yes
K = K+1
KDS(K) ≥ 0
No
10
F

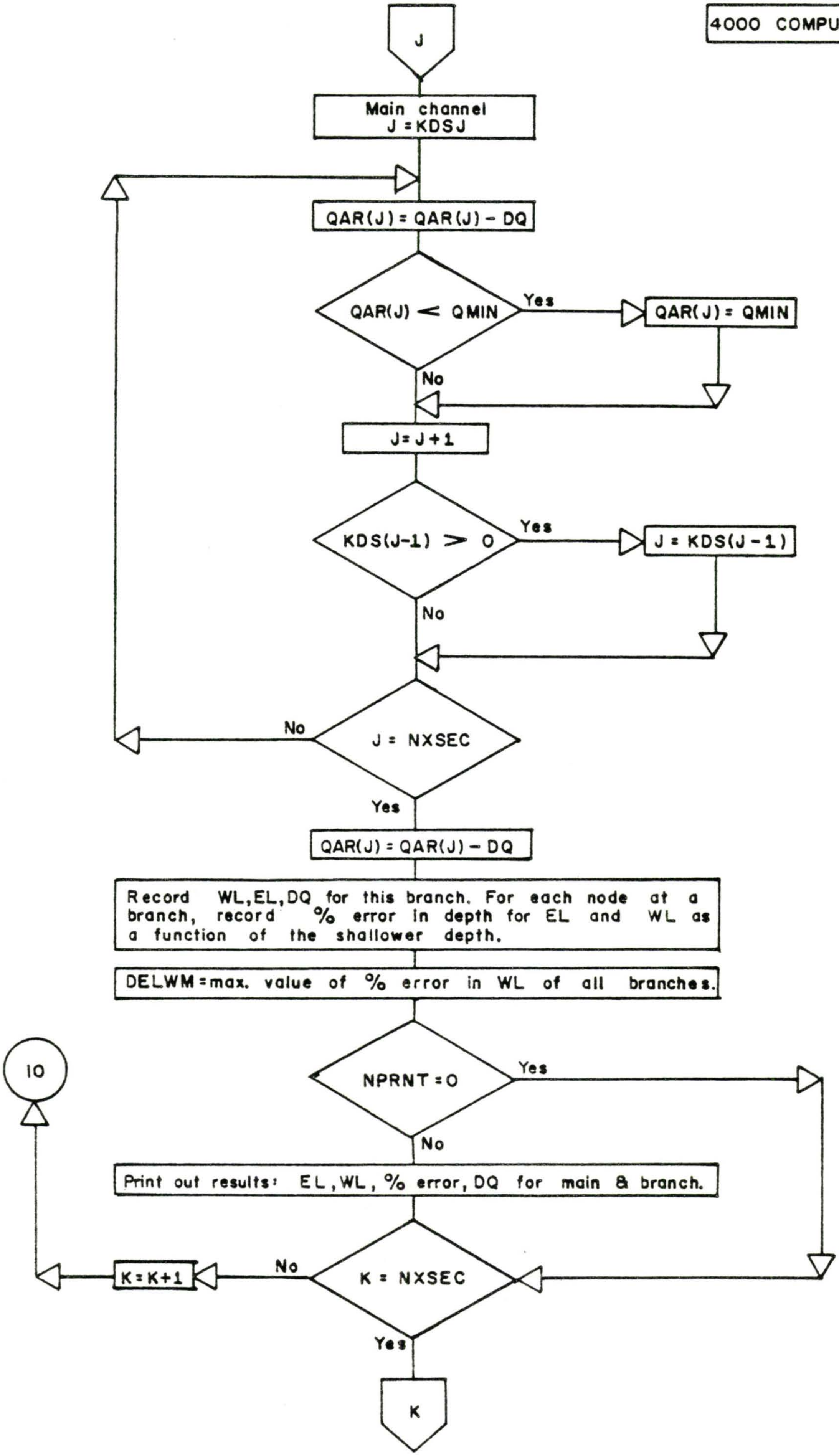

F
Find U/S confluence
NBR = K
KDSJ = - KDS(NBR)
calculate headloss to be corrected
DELTAH = WLS (-KDS (NBR)) — WLS (NBR)
calculate correction to flows between main and channel
SUMM = SUMB = 0·0
Main channel
J = KDSJ + 1
Call FINDXS
J-1 - cross section data
Call CRITIC
HCR - critical energy dépth
Call BOTTOM
BOT - invert
ENLVS(J-1) ≤ HCR + BOT
Yes
No
SUMM = SUMM + (ENLVS(J-1)-ENLVS(J)) / QAR (J-1)
J = J + 1
KDS(J-1) > 0
Yes
No
J = NXSEC
No
Yes
continue
8
G
7

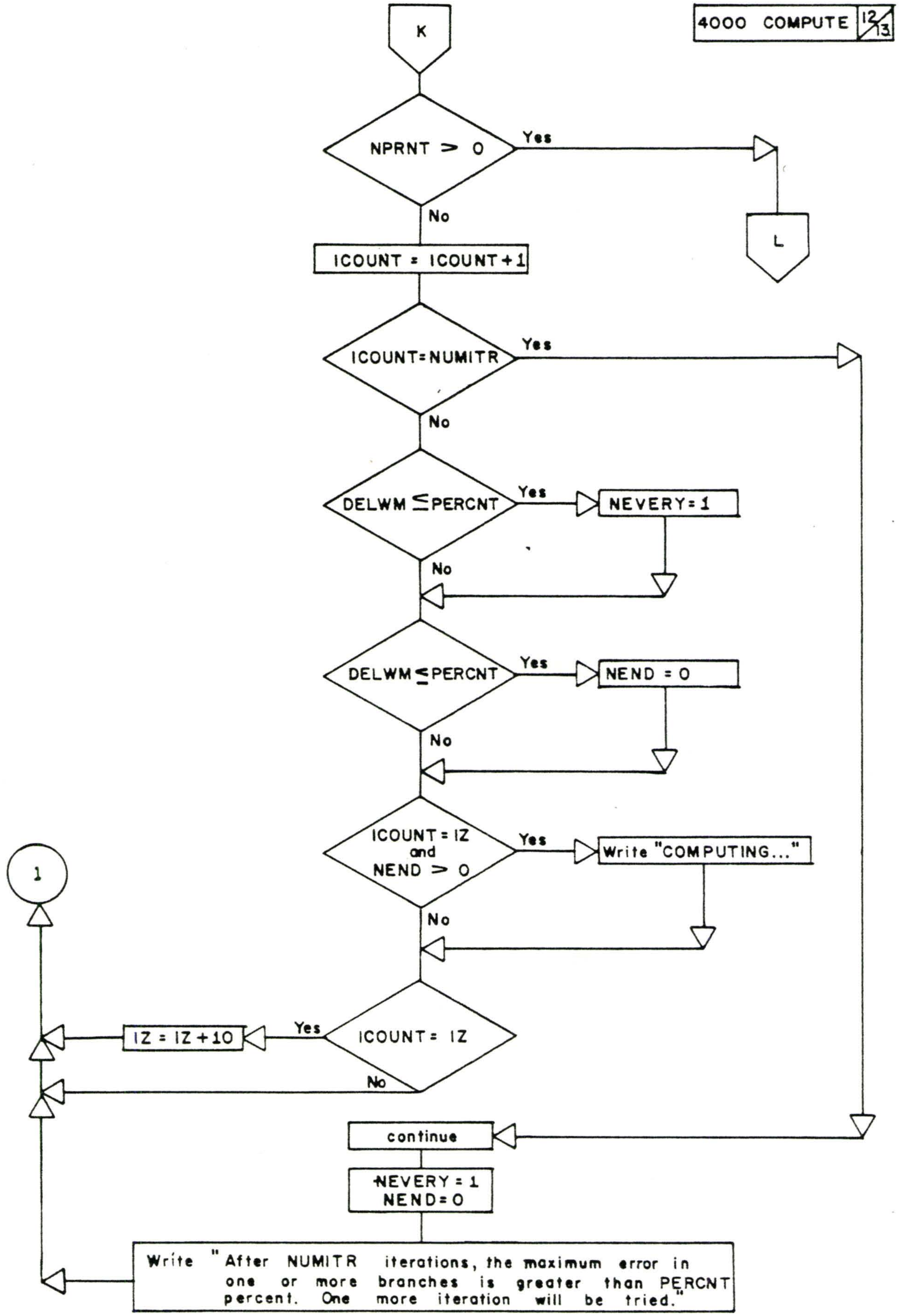


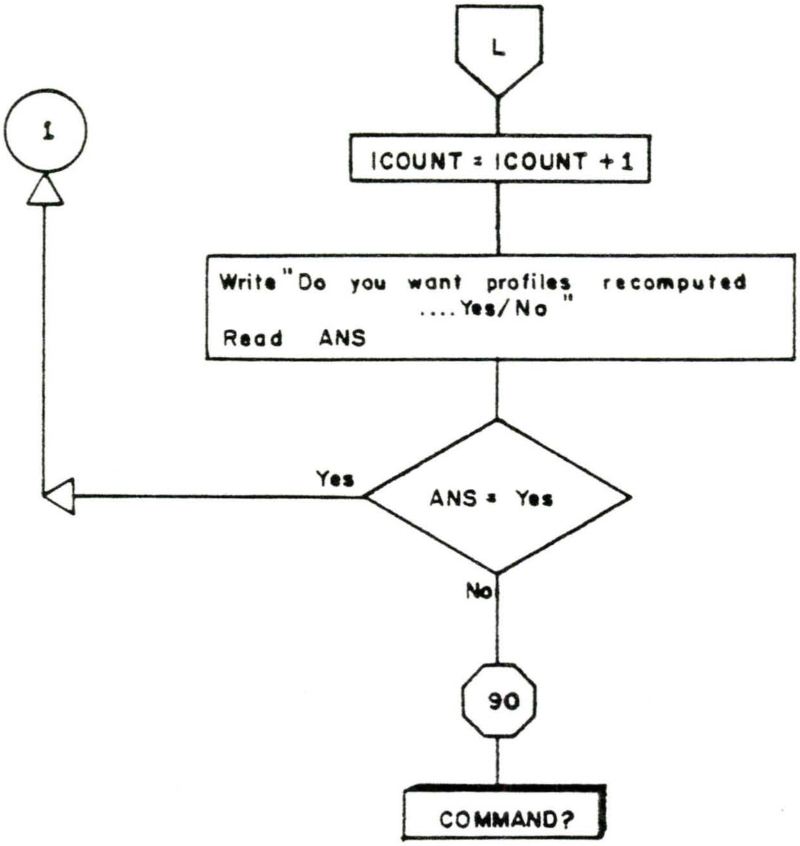
G
Call FINDXS
J-1 - cross section data
Call CRITIC
HCR - critical energy depth
Call BOTTOM
BOT - invert
ENLVS(J-1) ≤ HCR + BOT
Yes
No
SUMM = SUMM + (ENLVS(J-1)-ENLVS(KDS(J-1)))/QAR(J-1)
J = KDS(J-1) + 1
8
No
J = NXSEC
Yes
7
SUMM = SUMM + (ENLVS(J-1) - ENLVS(J))/QAR(J-1)
Branch channel J = NBR+1
Call FINDXS
J-1 - cross section data
Call CRITIC
HCR - critical energy depth
Call BOTTOM
BOT - invert
ENLVS(J-1) ≤ HCR + BOT
Yes
No
SUMB = SUMB + (ENLVS(J-1)-ENLVS(J))/QAR(J-1)
9
H

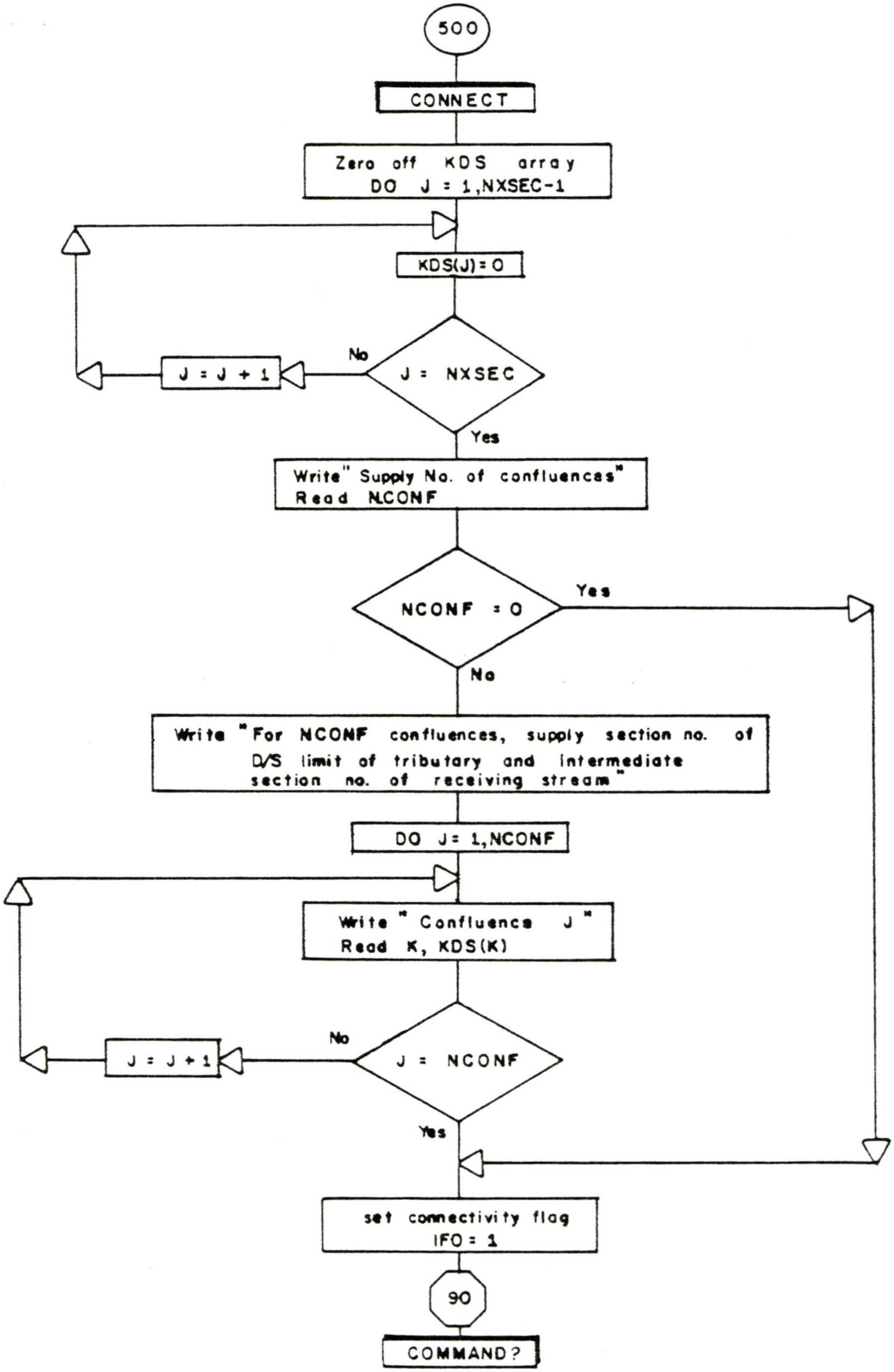

4000 COMPUTE 9/13
H
J = J + 1
9
KDS(J-1) > 0
Yes
No
J = NXSEC
No
Yes
continue
Call FINDXS
J-1 - cross section data
Call CRITIC
HCR - critical energy depth
Call BOTTOM
BOT - invert
ENLVS(J-1) ≤ HCR + BOT
Yes
No
SUMB = SUMB + (ENLVS(J-1)-ENLVS(J)) / QAR(J-1)
J = KDS(J-1) + 1
J = NXSEC
No
Yes
SUMB = SUMB + (ENLVS(J-1)-ENLVS(KDS(J-1))) / QAR(J-1)
QNDEX = 2·0
DQ = - DELTAH / QNDEX (SUMM-SUMB)
Calculate % error in E.L. and W.L. at the bifurcation
FACTOR = (%EL + %WL)/200
FACTOR > 0·1
No
Yes
FACTOR = 5 x FACTOR
FACTOR = 0·5
DQ = FACTOR · √(DQ x DQ)
I

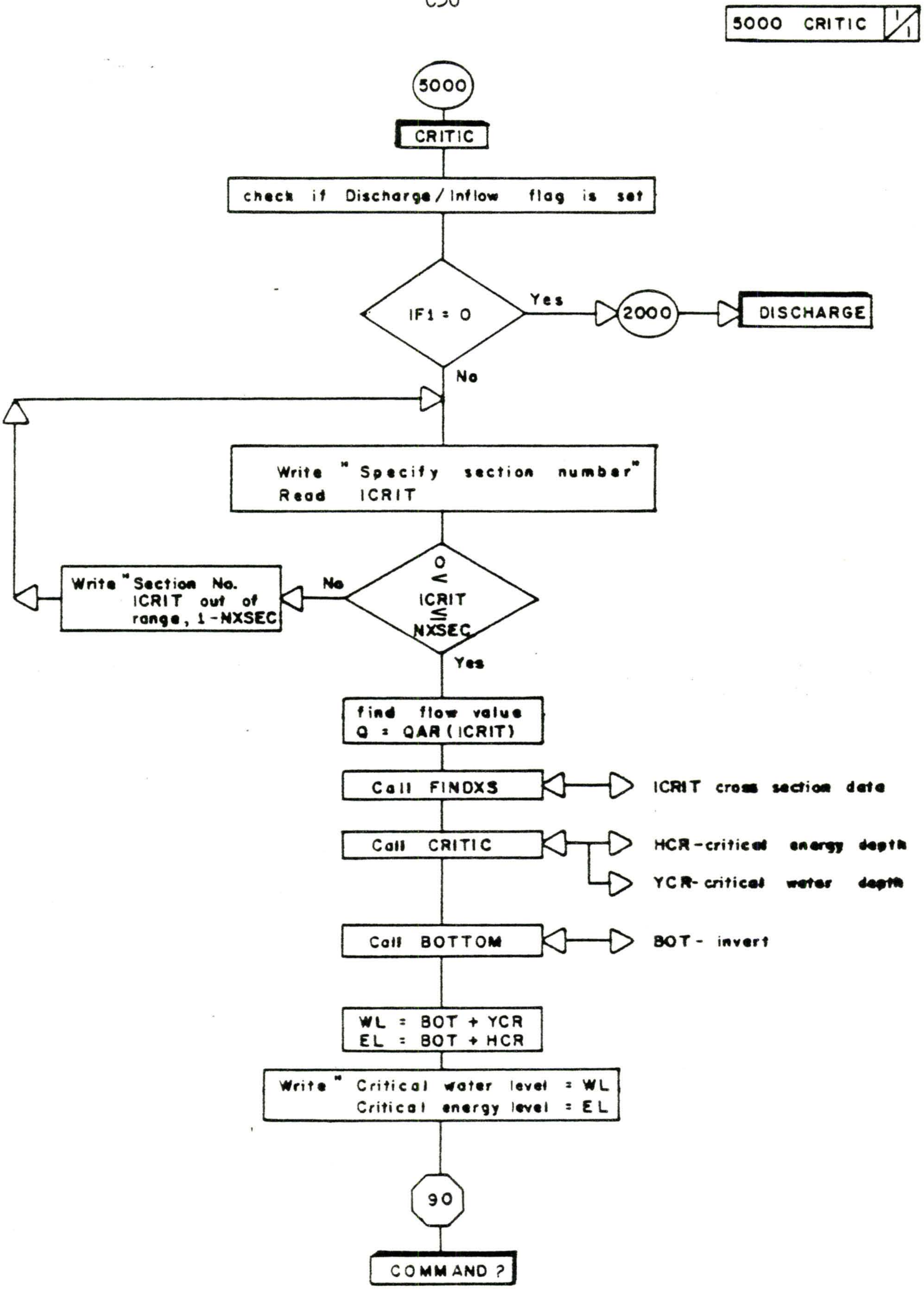

I
ENLVS(NBR) > ENLVS(-KDS(NBR))
Yes
DQ = -DQ
No
DQ ≥ 0
No
Yes
-DQ < QAR(NBR)
Yes
No
DQ = QMIN − QAR(NBR)
QAR(NBR) = QMIN
DQ < QAR(-KDS(NBR))
Yes
No
DQ=QAR(-KDS(NBR)) − QMIN
QAR(-KDS(NBR)) = QMIN
Apply corrections to flow
Branch channel
J = NBR
QAR(J) = QAR(J)+DQ
QAR(J) < QMIN
Yes
QAR(J) = QMIN
No
J = J + 1
KDS(J-1) > 0
Yes
J = KDS(J-1)
No
J = NXSEC
No
Yes
QAR(J) = QAR(J) + DQ
J

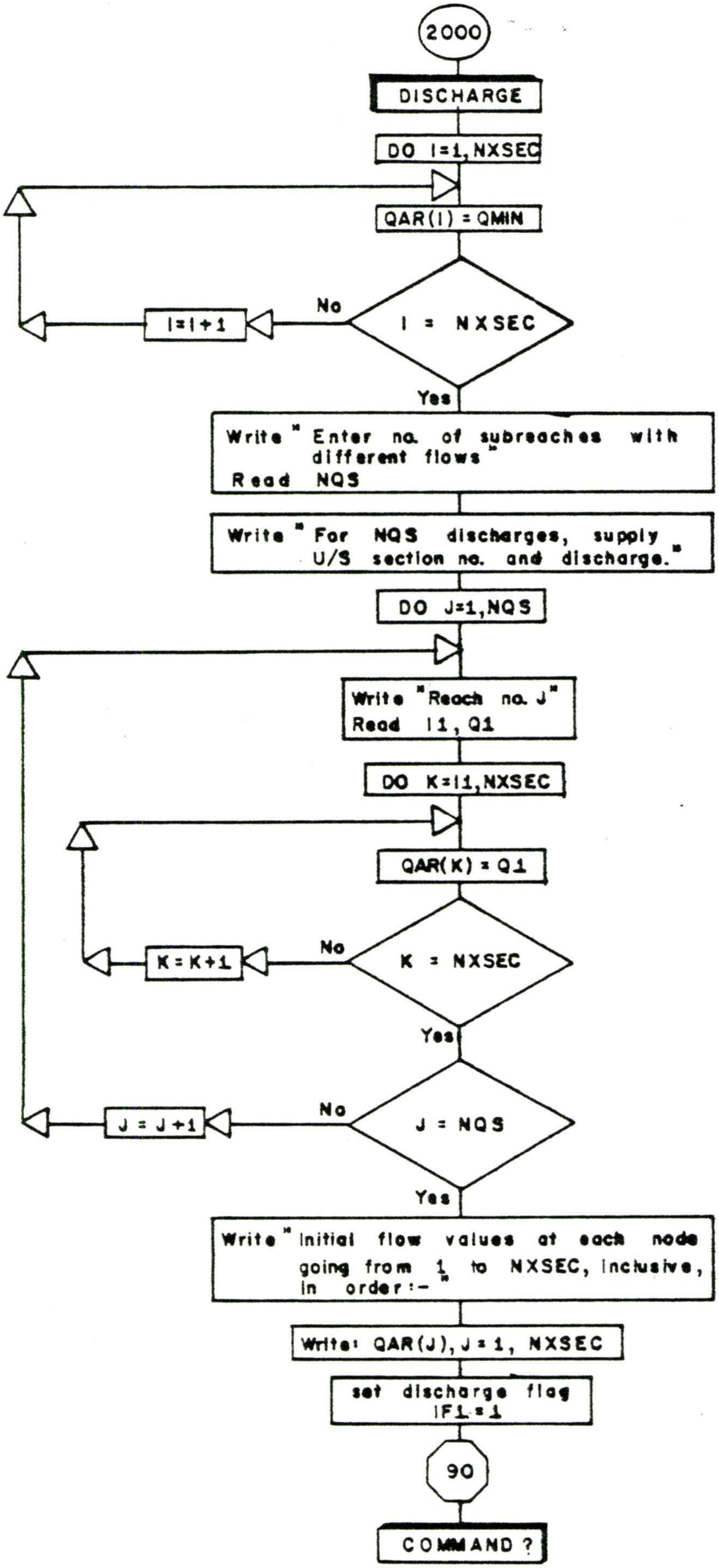

J
Main channel
J = KDSJ
QAR(J) = QAR(J) − DQ
QAR(J) < QMIN
Yes
QAR(J) = QMIN
No
J = J + 1
KDS(J-1) > 0
Yes
J = KDS(J − 1)
No
J = NXSEC
No
Yes
QAR(J) = QAR(J) − DQ
Record WL, EL, DQ for this branch. For each node at a branch, record % error in depth for EL and WL as a function of the shallower depth.
DELWM = max. value of % error in WL of all branches.
NPRNT = 0
Yes
No
Print out results: EL, WL, % error, DQ for main & branch.
10
K = NXSEC
No
K = K+1
Yes
K


K
NPRNT > 0
Yes
No
L
ICOUNT = ICOUNT + 1
ICOUNT = NUMITR
Yes
No
DELWM ≤ PERCNT
Yes
NEVERY = 1
No
DELWM ≤ PERCNT
Yes
NEND = 0
No
ICOUNT = IZ and NEND > 0
Yes
Write "COMPUTING..."
No
1
ICOUNT = IZ
Yes
IZ = IZ + 10
No
continue
NEVERY = 1
NEND = 0
Write "After NUMITR iterations, the maximum error in one or more branches is greater than PERCNT percent. One more iteration will be tried."

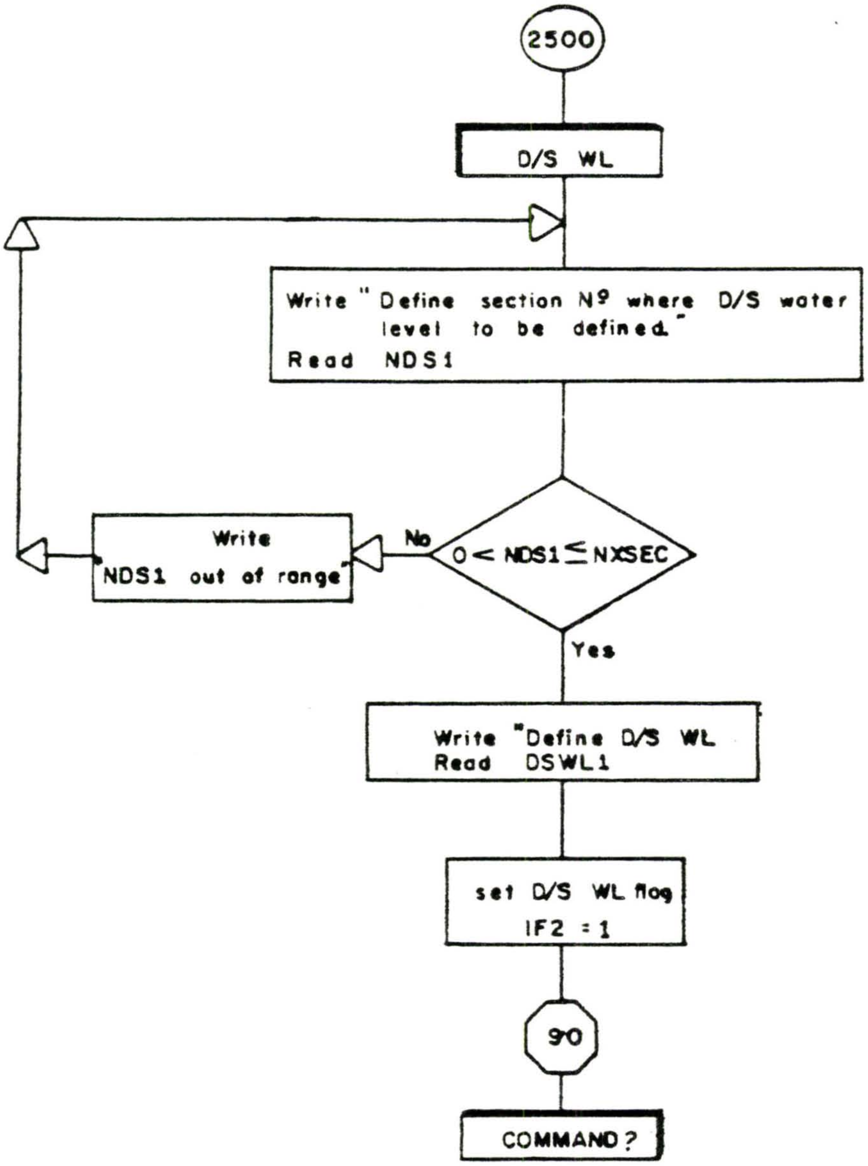

L
ICOUNT = ICOUNT + 1
Write "Do you want profiles recomputed ....Yes/No "
Read ANS
ANS = Yes
Yes
No
1
90
COMMAND?

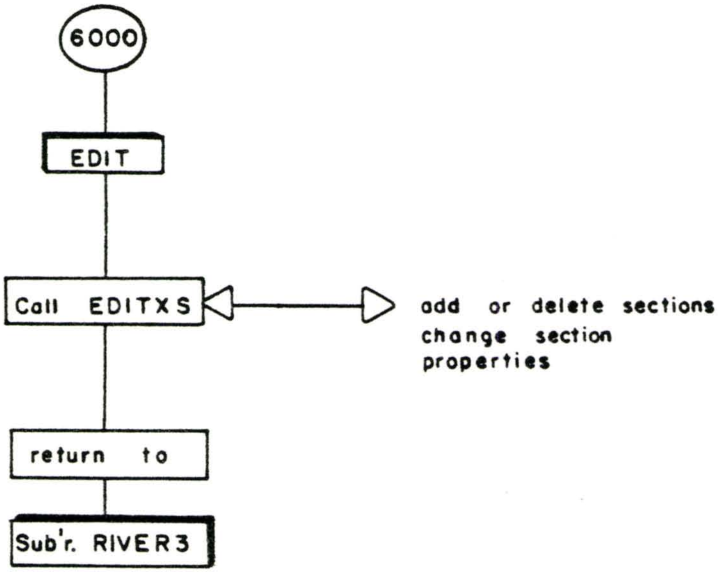

500
CONNECT
Zero off KDS array
DO J = 1,NXSEC-1
KDS(J) = 0
J = NXSEC
No
J = J + 1
Yes
Write" Supply No. of confluences"
Read NCONF
NCONF = 0
Yes
No
Write "For NCONF confluences, supply section no. of D/S limit of tributary and intermediate section no. of receiving stream"
DO J= 1,NCONF
Write " Confluence J "
Read K, KDS(K)
J = NCONF
No
J = J + 1
Yes
set connectivity flag
IFO = 1
90
COMMAND?

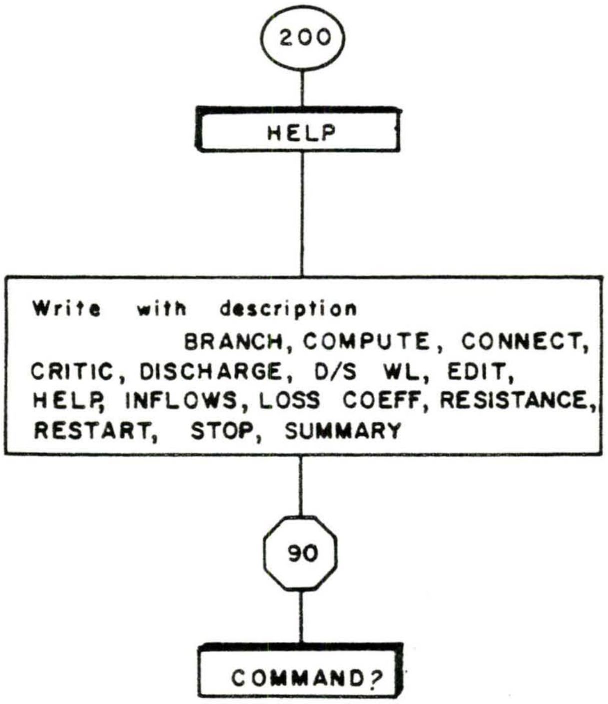

5000 CRITIC 1/1
5000
CRITIC
check if Discharge / Inflow flag is set
IF1 = 0
Yes
2000
DISCHARGE
No
Write " Specify section number"
Read ICRIT
0 < ICRIT ≤ NXSEC
No
Write "Section No. ICRIT out of range, 1 - NXSEC
Yes
find flow value
Q = QAR (ICRIT)
Call FINDXS
ICRIT cross section data
Call CRITIC
HCR - critical energy depth
YCR - critical water depth
Call BOTTOM
BOT - invert
WL = BOT + YCR
EL = BOT + HCR
Write " Critical water level = WL
Critical energy level = EL
90
COMMAND ?

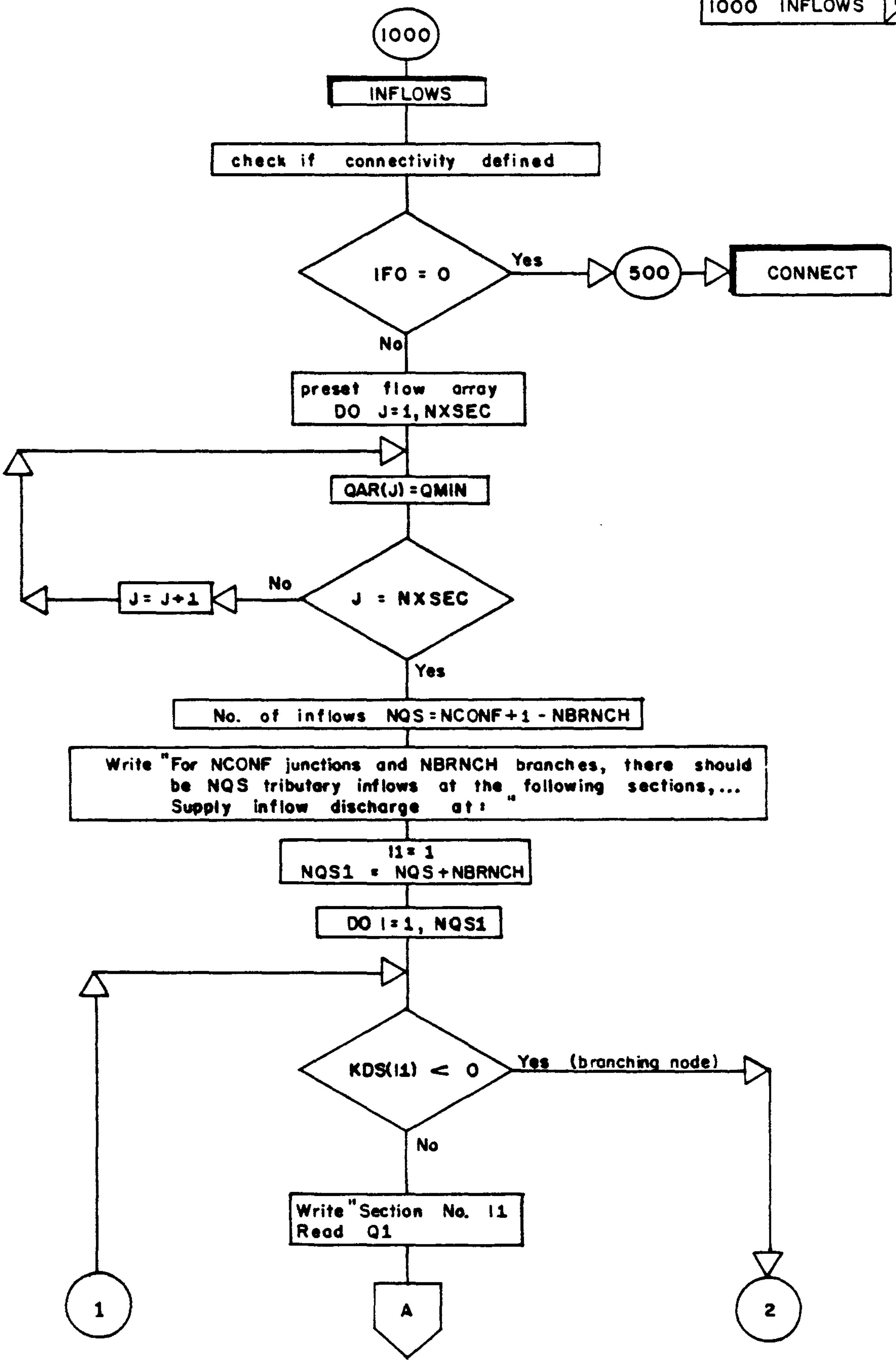

2000
DISCHARGE
DO I=1,NXSEC
QAR(I) = QMIN
I = NXSEC
No
I=I+1
Yes
Write " Enter no. of subreaches with different flows"
Read NQS
Write " For NQS discharges, supply U/S section no. and discharge."
DO J=1,NQS
Write "Reach no. J"
Read I1, Q1
DO K=I1,NXSEC
QAR(K) = Q1
K = NXSEC
No
K=K+1
Yes
J = NQS
No
J = J+1
Yes
Write " Initial flow values at each node going from 1 to NXSEC, inclusive, in order:-"
Write: QAR(J), J = 1, NXSEC
set discharge flag IF1 = 1
90
COMMAND ?

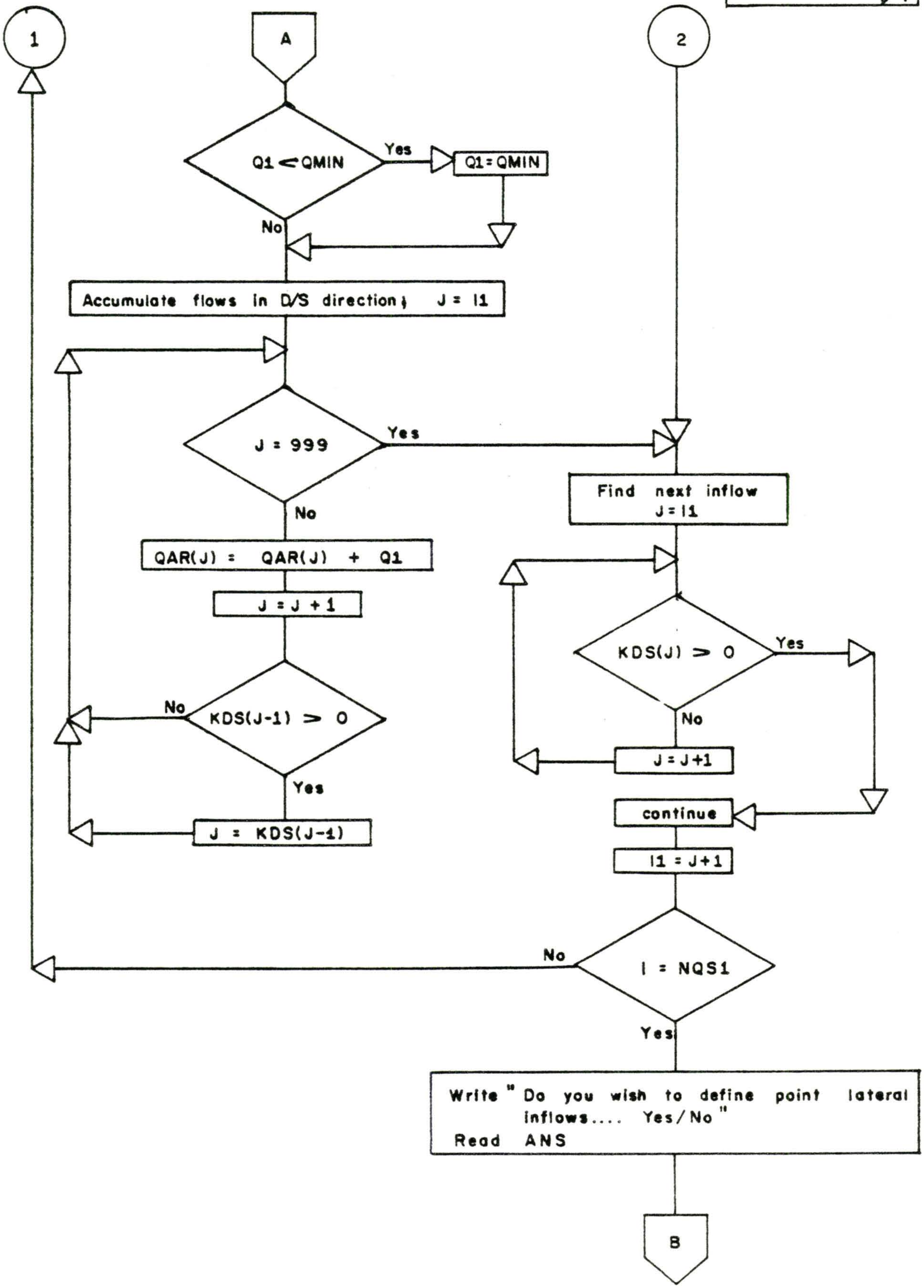
2500 D/S WL 1/1

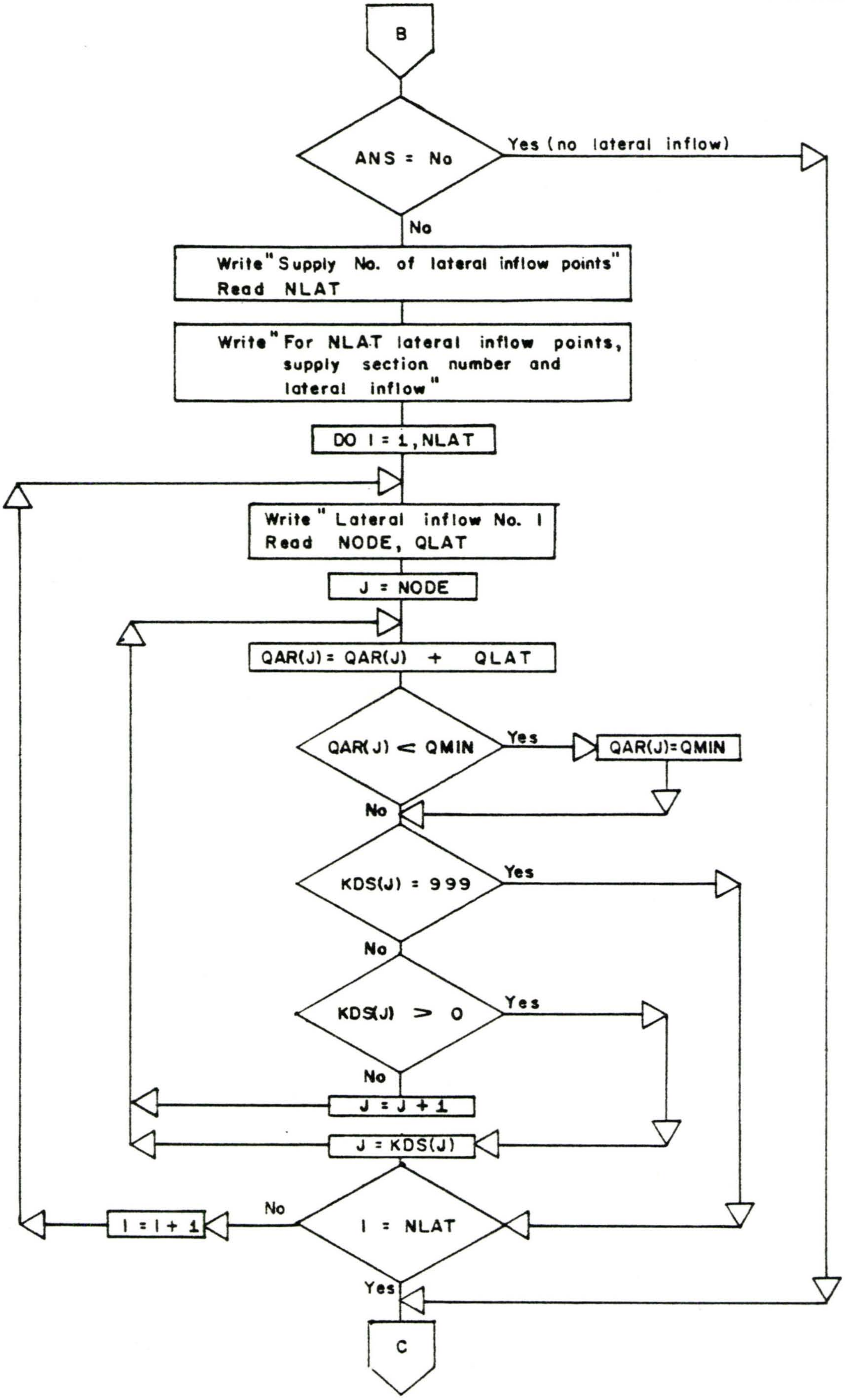

2500
D/S WL
Write " Define section Nº where D/S water level to be defined."
Read NDS1
0 < NDS1 ≤ NXSEC
No
Write "NDS1 out of range"
Yes
Write "Define D/S WL
Read DSWL1
set D/S WL flag
IF2 = 1
90
COMMAND ?

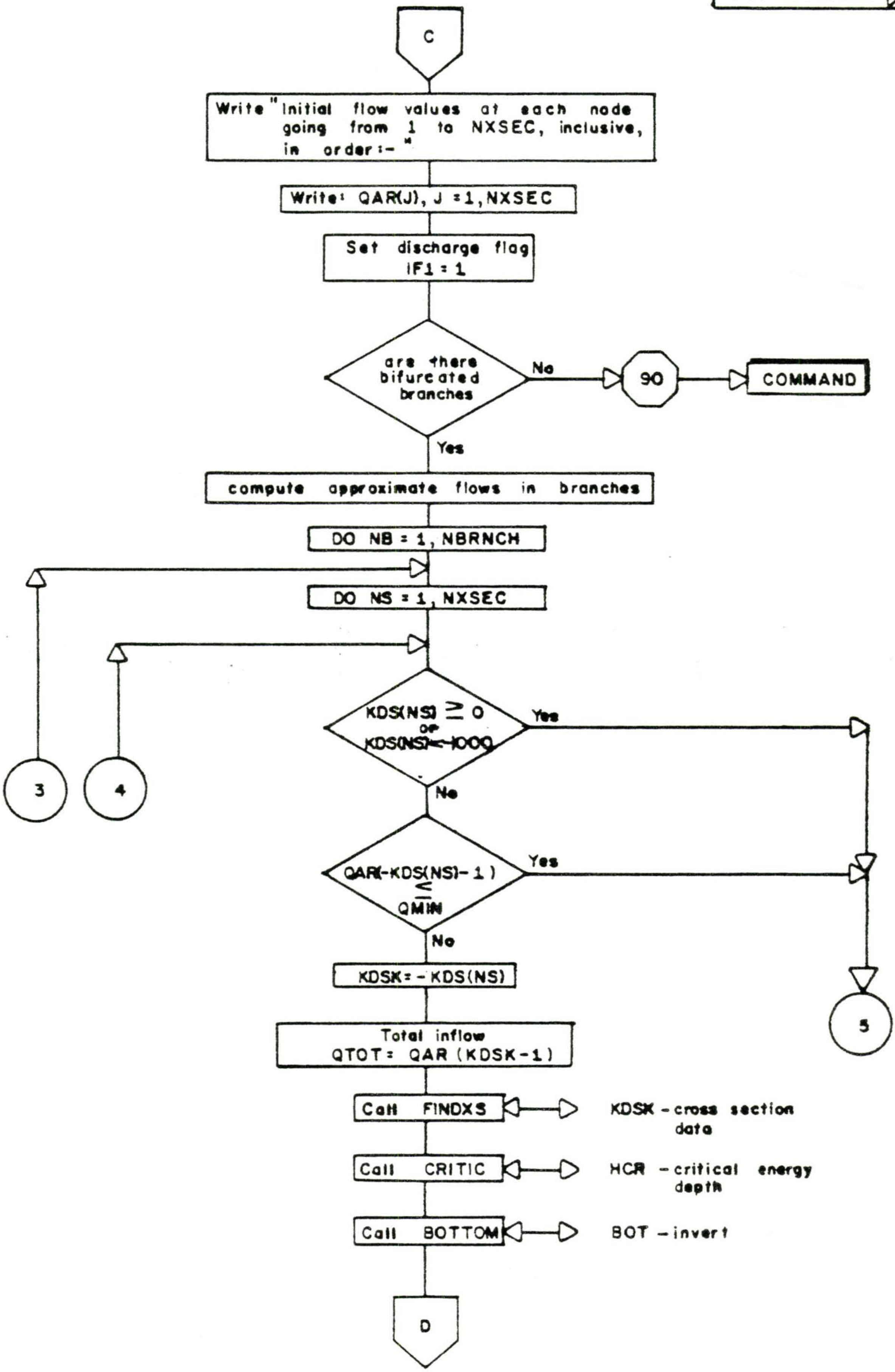

6000
EDIT
Call EDITXS
add or delete sections
change section
properties
return to
Sub'r. RIVER3

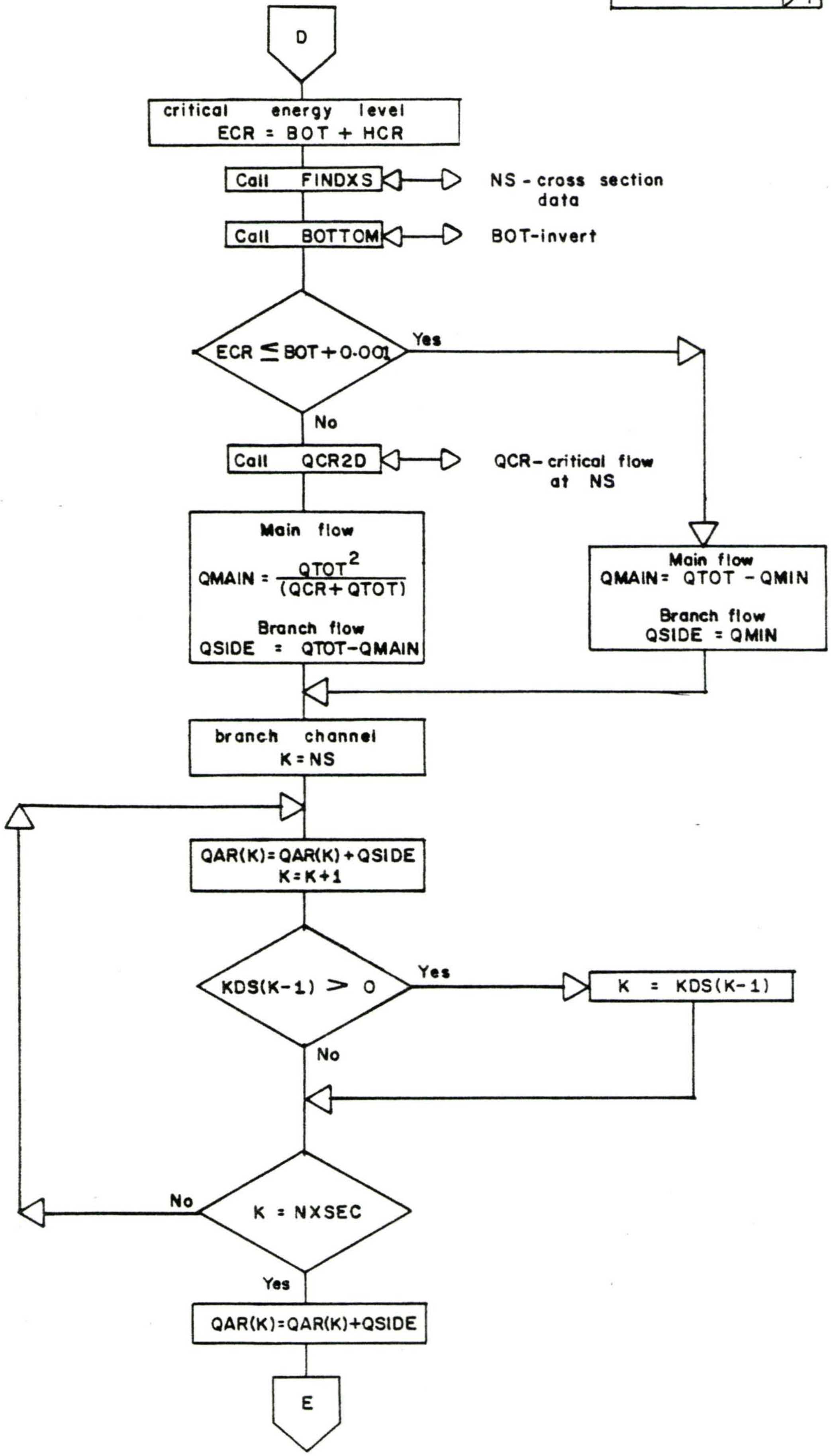

200
HELP
Write with description
BRANCH, COMPUTE, CONNECT,
CRITIC, DISCHARGE, D/S WL, EDIT,
HELP, INFLOWS, LOSS COEFF, RESISTANCE,
RESTART, STOP, SUMMARY
90
COMMAND?

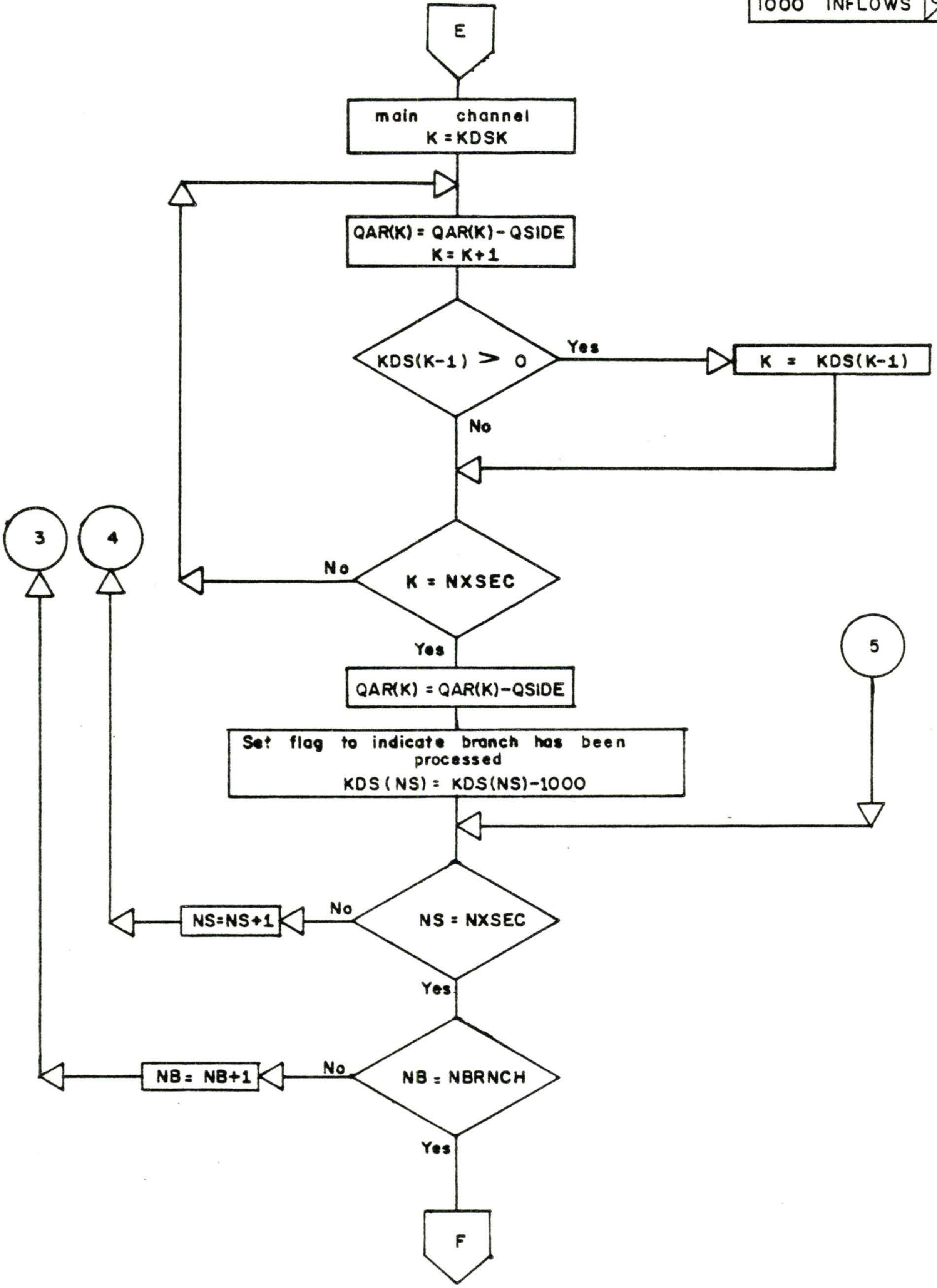

1000
INFLOWS
check if connectivity defined
IFO = 0
Yes
500
CONNECT
No
preset flow array
DO J=1, NXSEC
QAR(J) = QMIN
J = NXSEC
No
J = J+1
Yes
No. of inflows NQS = NCONF+1 - NBRNCH
Write "For NCONF junctions and NBRNCH branches, there should be NQS tributary inflows at the following sections,... Supply inflow discharge at: "
I1 = 1
NQS1 = NQS+NBRNCH
DO I = 1, NQS1
KDS(I1) < 0
Yes (branching node)
No
Write "Section No. I1
Read Q1
1
A
2

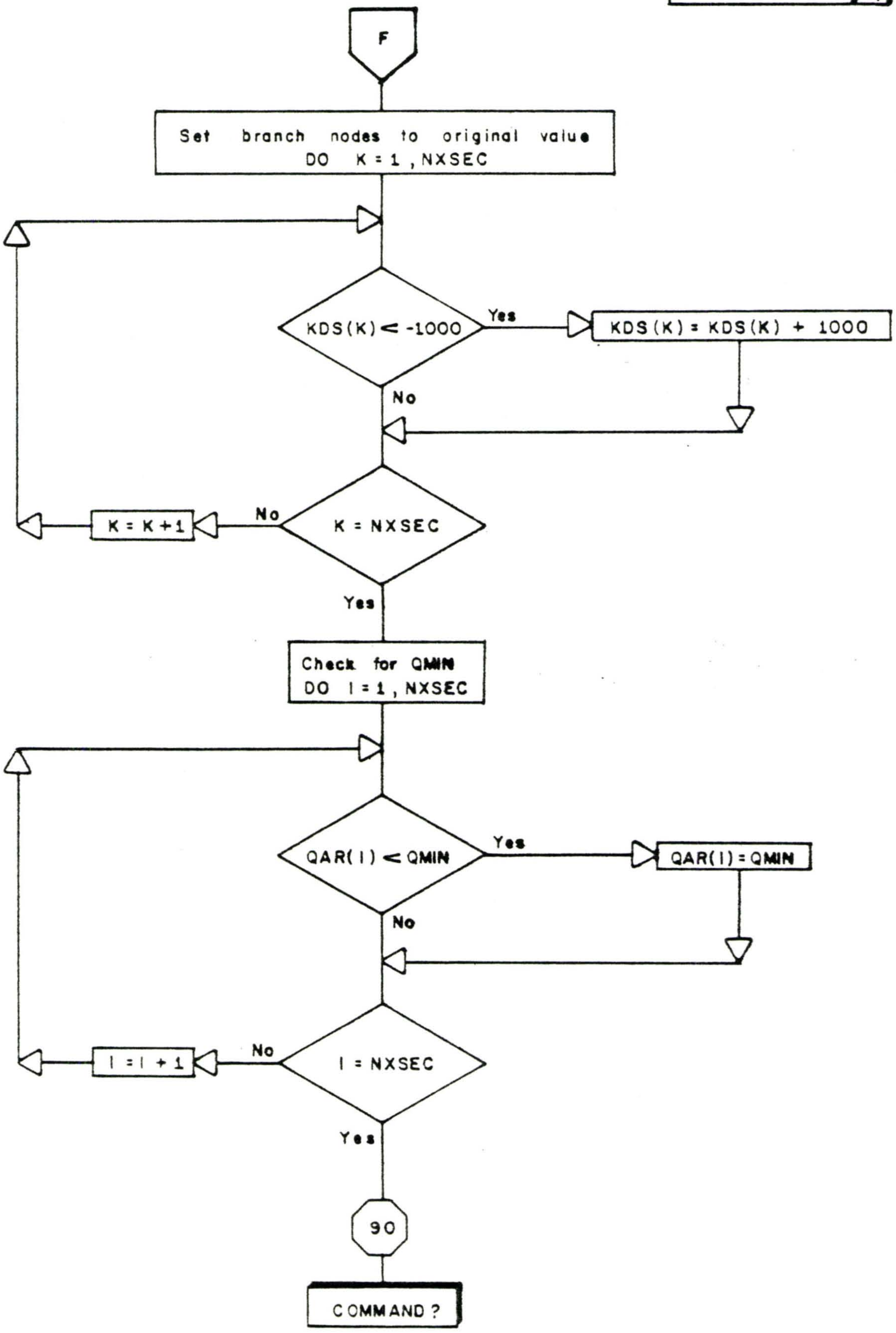

1
A
2
Q1 < QMIN
Yes
Q1 = QMIN
No
Accumulate flows in D/S direction; J = I1
J = 999
Yes
No
QAR(J) = QAR(J) + Q1
J = J + 1
KDS(J-1) > 0
No
Yes
J = KDS(J-1)
Find next inflow
J = I1
KDS(J) > 0
Yes
No
J = J+1
continue
I1 = J+1
I = NQS1
No
Yes
Write " Do you wish to define point lateral inflows.... Yes/No "
Read ANS
B

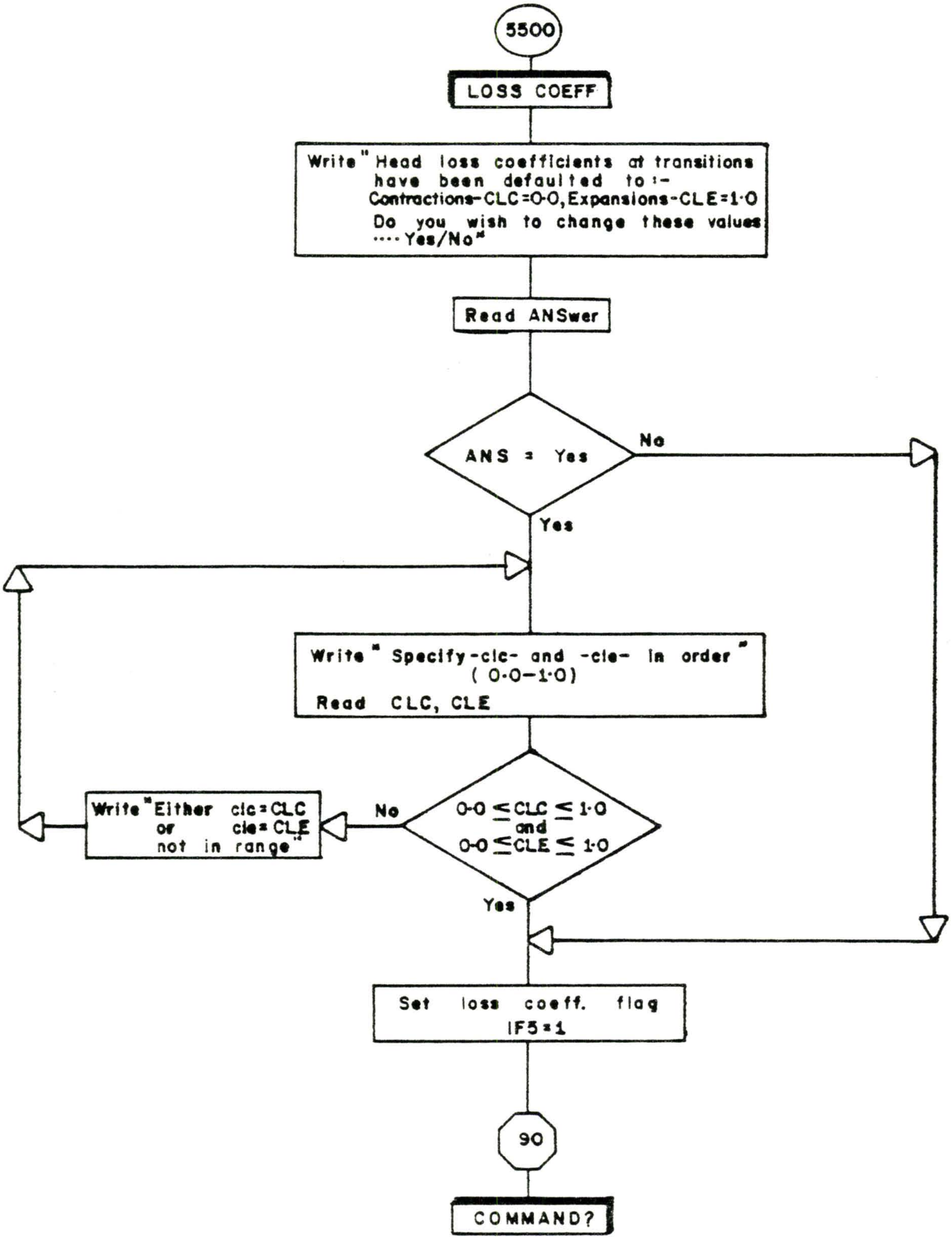

B
ANS = No
Yes (no lateral inflow)
No
Write "Supply No. of lateral inflow points"
Read NLAT
Write "For NLAT lateral inflow points, supply section number and lateral inflow"
DO I = 1, NLAT
Write " Lateral inflow No. I
Read NODE, QLAT
J = NODE
QAR(J) = QAR(J) + QLAT
QAR(J) < QMIN
Yes
QAR(J)=QMIN
No
KDS(J) = 999
Yes
No
KDS(J) > 0
Yes
No
J = J + 1
J = KDS(J)
I = NLAT
No
I = I + 1
Yes
C


C
Write "Initial flow values at each node going from 1 to NXSEC, inclusive, in order:-"
Write: QAR(J), J =1,NXSEC
Set discharge flag IF1 = 1
are there bifurcated branches
No
90
COMMAND
Yes
compute approximate flows in branches
DO NB = 1, NBRNCH
DO NS = 1, NXSEC
KDS(NS) ≥ 0 or KDS(NS) < -1000
Yes
3
4
No
QAR(-KDS(NS)- 1) ≤ QMIN
Yes
No
KDSK = - KDS(NS)
5
Total inflow QTOT = QAR (KDSK-1)
Call FINDXS
KDSK - cross section data
Call CRITIC
HCR - critical energy depth
Call BOTTOM
BOT - invert
D

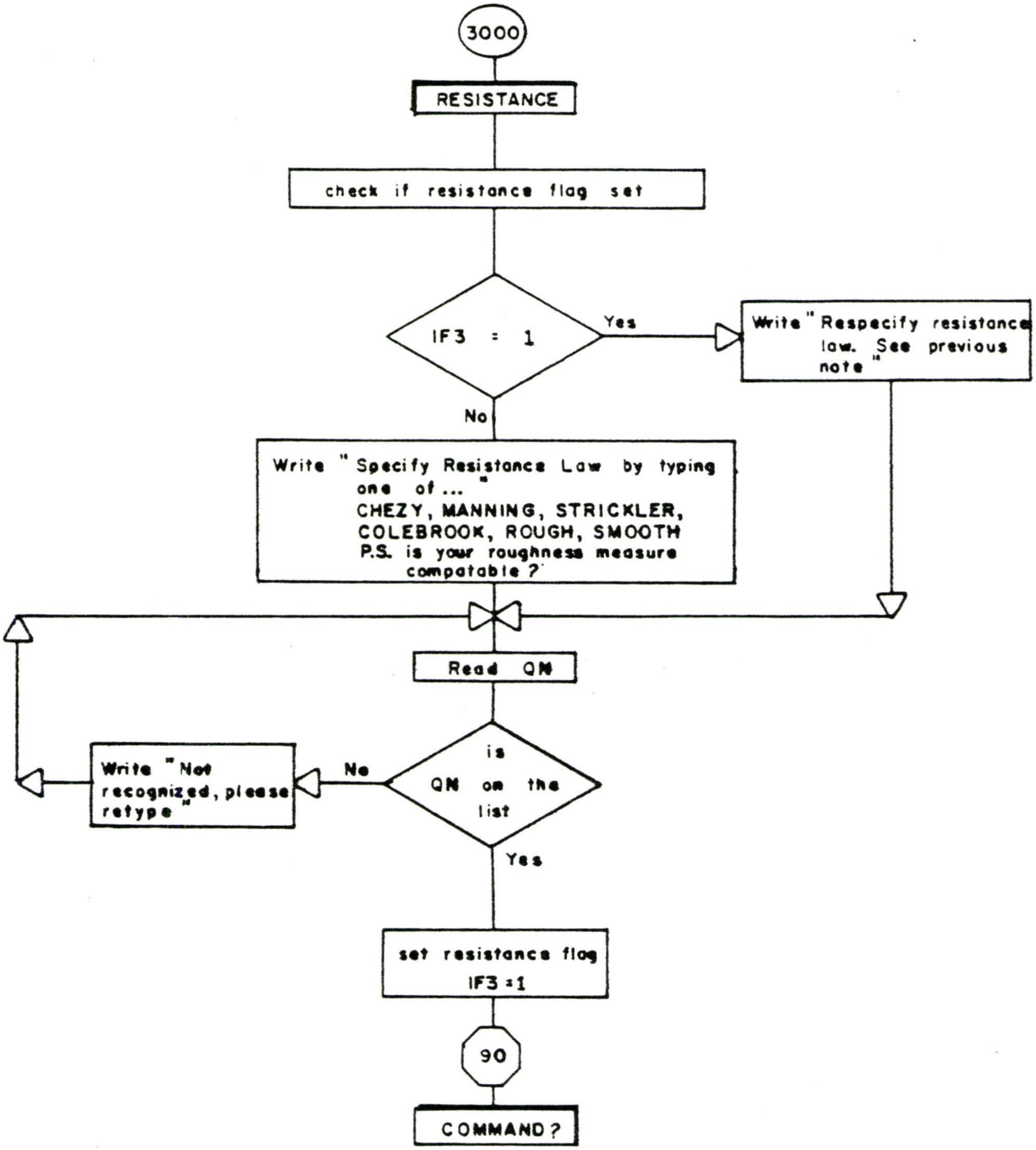

D
critical energy level
ECR = BOT + HCR
Call FINDXS
NS - cross section data
Call BOTTOM
BOT-invert
ECR ≤ BOT + 0.001
Yes
No
Call QCR2D
QCR - critical flow at NS
Main flow
QMAIN = QTOT² / (QCR + QTOT)
Branch flow
QSIDE = QTOT - QMAIN
Main flow
QMAIN = QTOT - QMIN
Branch flow
QSIDE = QMIN
branch channel
K = NS
QAR(K) = QAR(K) + QSIDE
K = K + 1
KDS(K-1) > 0
Yes
K = KDS(K-1)
No
K = NXSEC
No
Yes
QAR(K) = QAR(K) + QSIDE
E


E
main channel
K = KDSK
QAR(K) = QAR(K) - QSIDE
K = K+1
KDS(K-1) > 0
Yes
K = KDS(K-1)
No
3
4
No
K = NXSEC
Yes
5
QAR(K) = QAR(K)-QSIDE
Set flag to indicate branch has been processed
KDS(NS) = KDS(NS)-1000
NS=NS+1
No
NS = NXSEC
Yes
NB = NB+1
No
NB = NBRNCH
Yes
F

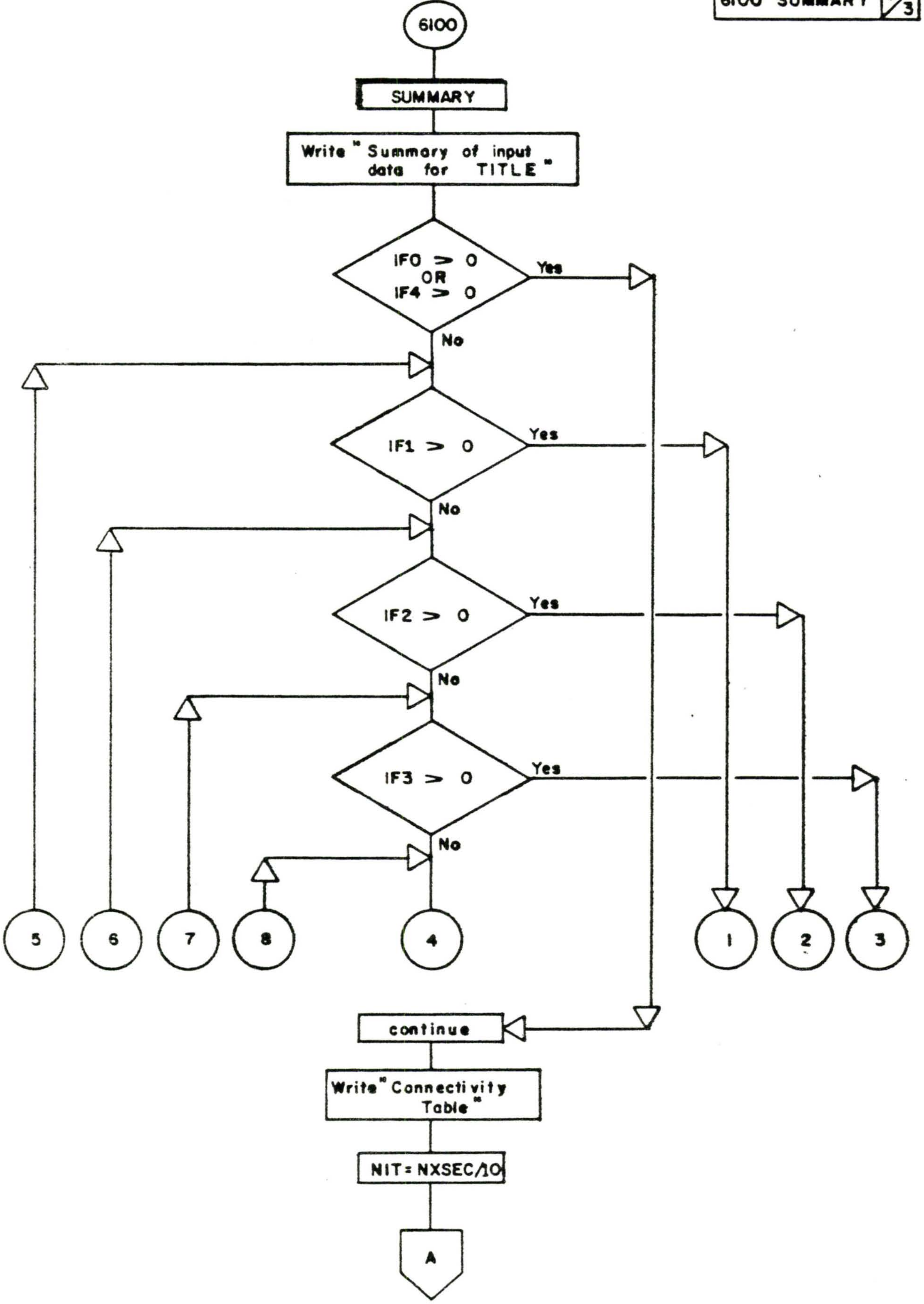

F
Set branch nodes to original value
DO K = 1 , NXSEC
KDS(K) < -1000
Yes
KDS(K) = KDS(K) + 1000
No
K = NXSEC
No
K = K + 1
Yes
Check for QMIN
DO I = 1 , NXSEC
QAR(I) < QMIN
Yes
QAR(I) = QMIN
No
I = NXSEC
No
I = I + 1
Yes
90
COMMAND ?


5500
LOSS COEFF
Write "Head loss coefficients at transitions have been defaulted to :- Contractions-CLC=0·0, Expansions-CLE=1·0 Do you wish to change these values ···· Yes/No"
Read ANSwer
ANS = Yes
No
Yes
Write " Specify -clc- and -cle- in order " (0·0–1·0)
Read CLC, CLE
0·0 ≤ CLC ≤ 1·0 and 0·0 ≤ CLE ≤ 1·0
No
Write "Either clc=CLC or cle=CLE not in range"
Yes
Set loss coeff. flag IF5=1
90
COMMAND?

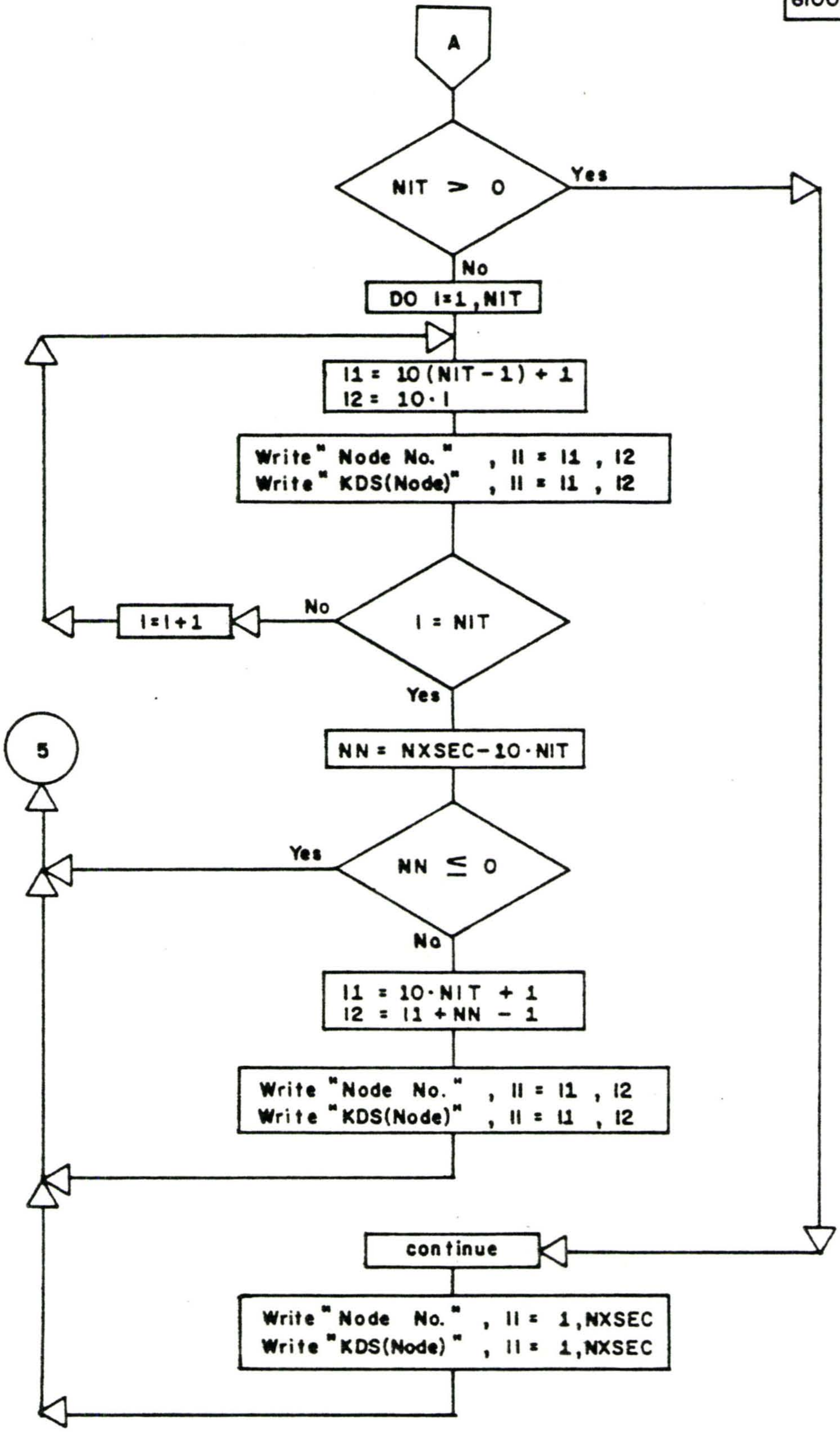
3000 RESISTANCE 1/1

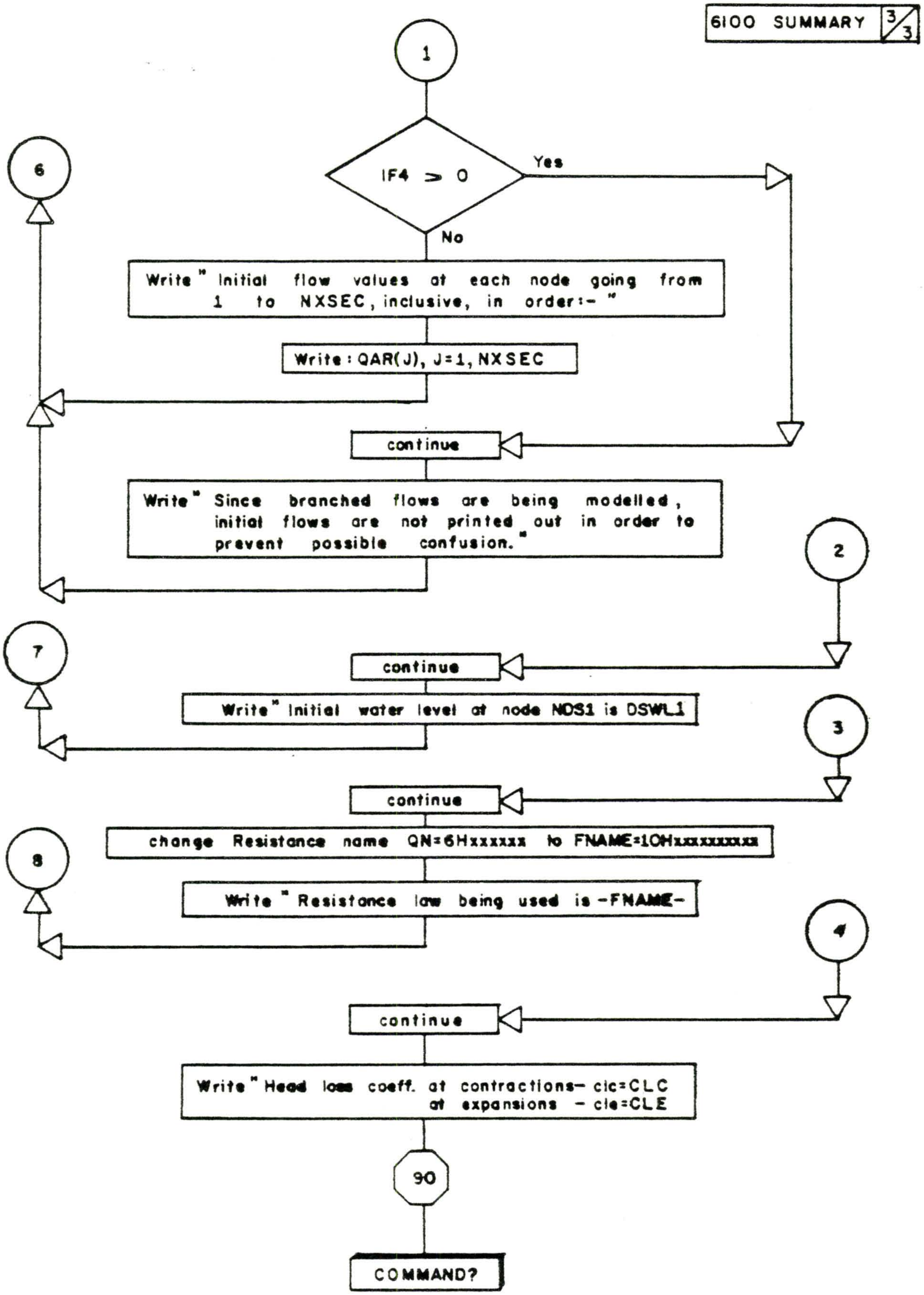


6100 SUMMARY 1/3



C45


A
NIT > 0
Yes
No
DO I=1,NIT
I1 = 10(NIT-1) + 1
I2 = 10·I
Write " Node No. " , II = I1 , I2
Write " KDS(Node)" , II = I1 , I2
No
I=I+1
I = NIT
Yes
5
NN = NXSEC-10·NIT
Yes
NN ≤ 0
No
I1 = 10·NIT + 1
I2 = I1 + NN - 1
Write "Node No. " , II = I1 , I2
Write "KDS(Node)" , II = I1 , I2
continue
Write "Node No. " , II = 1,NXSEC
Write "KDS(Node) " , II = 1,NXSEC


6100 SUMMARY 3/3
1
IF4 > 0
Yes
No
6
Write " Initial flow values at each node going from 1 to NXSEC, inclusive, in order:- "
Write : QAR(J), J=1, NXSEC
continue
Write " Since branched flows are being modelled, initial flows are not printed out in order to prevent possible confusion. "
2
7
continue
Write " Initial water level at node NOS1 is DSWL1
3
continue
change Resistance name QN=6Hxxxxxx to FNAME=10Hxxxxxxxxxx
8
Write " Resistance law being used is -FNAME-
4
continue
Write " Head loss coeff. at contractions- clc=CLC at expansions - cle=CLE
90
COMMAND?

REFERENCES

1. A.A. Smith, "C.E.P.L., A Civil Engineering Program Library", McMaster University, Hamilton, Ontario, 1974.

2. P.B. Ashenhurst, "Computer Analysis of Flow Profiles in Hydraulic Networks", a project report submitted in partial fulfilment of the requirements for the Degree of Master of Engineering, McMaster University, Hamilton, Ontario, 1981.

APPENDIX D

PROGRAM LISTING

Program Listing

The following pages contain the listing of all subroutines modified in the backwater program for this project. They represent only a small part of the complete library of subroutines contained in the C.E.P.L. (Civil Engineering Program Library). Other required routines not listed hereafter may be referenced in the C.E.P.L.

The first listing contains the typical driving programs required for a CDC 6400 computer. Thereafter, the subroutines are listed in alphabetic order as follows:

CONTR2, CRITIC, EDITXS, EZRA, FILEXS, PROFL2, PROPS, RIVER3, RIVER4

Driving program for creating a data file:

```
      PROGRAM TST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,
+                  TAPE2)
C     PROGRAM CARD FOR CDC6400
      DIMENSION ITST(      ),KSREC(100)
C     where ITST() is the value of NXSEC
      NTAPE1=1
      NTAPE2=2
      NXSEC=
      MAXPTS=
      NR=5
      NW=6
      NOCOPY=0
      CALL FILEXS(NTAPE1,KSREC,NXSEC,MAXPTS)
C     THIS ROUTINE INITIALIZES KSREC()
      CALL EDITXS(NTAPE1,NTAPE2,KSREC,ITST,NXSEC,MAXPTS,NR,NW,
+                 NOCOPY)
      END
```

Driving program for profile computations:

```
      PROGRAM TST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,
+                 TAPE2)
C     PROGRAM CARD FOR CDC6400
      DIMENSION WK(    )
      CALL RIVER3(1,2,5,6,32.2,WK)
      END
      where WK(    ) = 5*NXSEC + 4*MAXPTS
      and 32.2 is the value of gravity in imperial units.
```

```
0100      SUBROUTINE CONTR2(HORZ1,VERT1,NPTS1,HORZ2,VERT2,NPTS2,
0110+                  Q1,Q2,G,COEFC,COEFE,WL2,WL1,ENLV2,ENLV1,ICR)
0120C *************************************************************
0130C  THE ROUTINE ANALYZES A TRANSITION DEFINED BY UPSTREAM AND
0140C  DOWNSTREAM CROSS-SECTIONS.   THE DISCHARGE AT THE TWO
0150C  SECTIONS MAY DIFFER.  IF THE TRANSITION IS ACCELERATIVE,
0160C  CONTRACTION LOSSES ARE DEFINED BY:
0170C
0180C    DE = COEFC*ABS(V1**2 - V2**2)/(2.0*G)
0190C
0200C  IF THE TRANSISTION IS DECELERATIVE, EXPANSION LOSSES ARE
0210C  DEFINED BY:
0220C
0230C    DE - COEFE*ABS(V1**2 - V2**2)/(2.0*G)
0240C
0250C  IF THE DOWNSTREAM DISCHARGE EXCEEDS THE UPSTREAM AN
0260C  ADDITIONAL ENERGY LOSS IS COMPUTED AS
0270C
0280C    SPATL  =  (Q2-Q1)*V/(G.A)
0290C  IN WHICH (V/A) IS APPROXIMATED AS THE GEOMETRIC MEAN OF
0300C  THE VALUES AT SECTIONS 1 AND 2.
0310C
0320C  IF THE UPSTREAM SECTION IS FOUND TO BE CRITICAL THE FLAG
0330C  ICR IS SET EQUAL TO 1.
0340C
0350C    HORZ1  = ARRAY (NPTS1) OF HORIZONTAL COORDINATES OF THE
0360C             POINTS DESCRIBING THE UPSTREAM SECTION.
0370C    VERT1  = ARRAY (NPTS1) OF VERTICAL COORDINATES.
0380C    NPTS1  = NO. OF POINTS IN UPSTREAM SECTION 1.
0390C    HORZ2  = )
0400C    VERT2  = ) CORRESPONDING PARAMETERS FOR DOWNSTREAM SEC. 2.
0410C    NPTS2  = )
0420C    Q1     = DISCHARGE AT SECTION 1.
0430C    Q2     = DISCHARGE AT SECTION 2.
0440C    G      = GRAVITATIONAL ACCELERATION.
0450C    COEFC  = ENERGY LOSS COEFFICIENT FOR CONTRACTIONS
0460C    COEFE  = ENERGY LOSS COEFFICIENT FOR EXPANSIONS
0470C    WL2    = DOWNSTREAM WATER SURFACE ELEVATION AT SEC. 2.
0480C    WL1    = COMPUTED WATER SURFACE ELEVATION AT SEC. 1.
0490C    ENLV2  = COMPUTED ENERGY LEVEL AT SEC. 2.
0500C    ENLV1  = COMPUTED ENERGY LEVEL AT SEC. 1.
0510C    ICR    = COMPUTED FLAG WITH VALUE OF:
0520C             0 IF TRANSITION IS FOUND TO BE SUBCRITICAL.
0530C             1 IF UPSTREAM SEC. 1 IS CRITICAL.
0540C
0550C  USES CIVLIB ROUTINES:   BOTTOM   PROPS   CRITIC
0560C *************************************************************
0570       DIMENSION HORZ1(NPTS1),VERT1(NPTS1)
0580       DIMENSION HORZ2(NPTS2),VERT2(NPTS2)
0590C  SET DIMENSION FOR CRITICAL FLOW ANALYSIS
0600       NDIM=2
0610       ICR=0
```

```
00620C  CHECK IF UPSTREAM SECTION IS CRITICAL
00630      CALL CRITIC(NDIM,HORZ1,VERT1,NPTS1,Q1,G,YCR,HCR)
00640      CALL BOTTOM(VERT1,NPTS1,BOT1,WLMAX)
00650      E1CR=BOT1 + HCR
00660      WL1CR=BOT1 + YCR
00670      CALL PROPS(HORZ1,VERT1,NPTS1,WL1CR,A1,T1,P1,AY)
00680      CALL PROPS(HORZ2,VERT2,NPTS2,WL2,A2,T2,P2,AY)
00690      V1CR=Q1/A1
00700      V2=Q2/A2
00710      ENLV2=WL2 + V2*V2/(2.0*G)
00720C  CALC. MAXIMUM ENERGY LOSS IF WL1=WL1CR.
00730      DE=0.0
00740      DV2=V1CR*V1CR -- V2*V2
00750       IF(DV2.GT.0.0) DE=COEFE*DV2/(2.0*G)
00760       IF(DV2.LE.0.0) DE=--COEFC*DV2/(2.0*G)
00770C  CALC. TERM FOR SPATIALLY VARIED FLOW IF PRESENT.
00780      DQDX=0.0
00790      IF(Q1.LT.Q2)DQDX=(Q2--Q1)*SQRT(V2/A2)/G
00800      SPATL=DQDX*SQRT(V1CR/A1)
00810      IF(E1CR.LT.ENLV2+DE+SPATL) GOTO 5
00820C  SECTION 1 IS CRITICAL.
00830      ICR=1
00840      WL1=WL1CR
00850      ENLV1=E1CR
00860      RETURN
00870 5    CONTINUE
00880C  TRIAL ANALYSIS ASSUMING CONVERGENT TRANSITION (CL=COEFC)
00890      WLMIN=WL1CR
00900 30   CONTINUE
00910      WLMAX=WLMIN+YCR
00920      WL=WLMAX
00930      CL=COEFC
00940      MENTRY=1
00950      GOTO 100
00960 11   CONTINUE
00970      IF(FUN.GE.0.0) GOTO 20
00980      WLMIN=WLMAX
00990      GOTO 30
01000 20   CONTINUE
01010C  BEGIN INTERVAL HALVING BETWEEN WLMIN AND WLMAX.
01020      WL=0.5*(WLMIN+WLMAX)
01030      MENTRY=2
01040      GOTO 100
01050 12   CONTINUE
01060      IF(FUN.GT.0.0) WLMAX=WL
01070      IF(FUN.LE.0.0) WLMIN=WL
01080      IF((WLMAX--WLMIN)/YCR.GT.0.0001) GOTO 20
01090      WL1=WL
01100      ENLV1=WL1 + EK1
01110C  TEST TO CHECK IF ASSUMPTION OF CONVERGENCE CORRECT.
01120      IF(V1.LE.V2) RETURN
01130C  DIVERGENT TRANSITION...USE CL==COEFE
```

```
1140C  USE PREVIOUS WL1 AS LOWER LIMIT.
1150       WLMIN=WL1
1160 40    CONTINUE
1170       WLMAX=WLMIN+EK1
1180       WL=WLMAX
1190       CL=COEFE
1200       MENTRY=3
1210       GOTO 100
1220 13    CONTINUE
1230       IF(FUN.GT.0.0) GOTO 50
1240       WLMIN=WLMAX
1250       GOTO 40
1260 50    CONTINUE
1270C  BEGIN INTERVAL HALVING SEARCH.
1280       WL=0.5*(WLMIN+WLMAX)
1290       MENTRY=4
1300       GOTO 100
1310 14    CONTINUE
1320       IF(FUN.GT.0.0) WLMAX=WL
1330       IF(FUN.LE.0.0) WLMIN=WL
1340       IF((WLMAX-WLMIN)/YCR.GT.0.0001) GOTO 50
1350       WL1=WL
1360       ENLV1=WL1+EK1
1370       RETURN
1380C
1390C  THIS SEGMENT OF ROUTINE COMPUTES FUNCTION OF WL.
1400C
1410 100   CONTINUE
1420       CALL PROPS(HORZ1,VERT1,NPTS1,WL,A,T,P,AY)
1430       V1=Q1/A
1440       EK1=V1*V1/(2.0*G)
1450       SPATL=DQDX*SQRT(V1/A)
1460       DV2=ABS(V1*V1 - V2*V2)
1470       FUN=WL+EK1-CL*DV2/(2.0*G)-SPATL-ENLV2
1480       GOTO (11,12,13,14) MENTRY
1490       END
```

```
00100     SUBROUTINE CRITIC(ND,HORZ,VERT,NPTS,Q,G,YCR,HCR)
00110C *************************************************************
00120C   FINDS THE CRITICAL DEPTH AND CRITICAL SPECIFIC
00130C   ENERGY CORRESPONDING TO CRITICAL FLOW OF A SPECIFIED
00140C   FLOW IN A SECTION OF ARBITRARY SHAPE OR PART--FULL PIPE.
00150C     ND     = INTEGER SET EQUAL TO 1 TO SPECIFY ONE
00160C              DIMENSIONAL ANALYSIS OR OTHERWISE (E.G. 2)
00170C              FOR TWO--DIMENSIONAL ANALYSIS.
00180C     HORZ   = ARRAY OF SIZE NPTS HOLDING HORIZL.
00190C              COORDS OF POINTS DESCRIBING SECTION
00200C     VERT   = ARRAY OF VERTICAL COORDS
00210C     NPTS   = NO. OF POINTS DEFINING CROSS--SECTION
00220C     Q      = SPECIFIED FLOW
00230C     G      = GRAV. ACCELN.
00240C     YCR    = COMPUTED CRITICAL DEPTH
00250C     HCR    = COMPUTED CRITICAL SPECIFIC ENERGY
00260C   WHEN ONE--DIMENSIONAL ANALYSIS IS ATTEMPTED ON A
00270C   STEPPED SECTION SIGNIFICANT ERROR MAY RESULT.
00280C   ON THE OTHER HAND, WHEN TWO--DIMENSIONAL ANALYSIS
00290C   IS ATTEMPTED ON A STEPPED SECTION THE COMPUTED
00300C   VALUE OF  YCR  IS ONLY AN APPROXIMATION SINCE
00310C   IN SUCH CASES THE WATER SURFACE IS NOT CONSTANT
00320C   ACROSS THE SECTION (ALTHOUGH THE ENERGY LEVEL IS).
00330C   UNITS USED MUST BE CONSISTENT THROUGHOUT AND
00340C   APPROPRIATE VALUE OF G USED.
00350C   IF NPTS=1 THE ROUTINE ASSUMES THE SECTION TO BE A
00360C   CIRCULAR PIPE IN WHICH:--
00370C     DIAMETER = HORZ(1)
00380C     INVERT   = VERT(1).
00390C   THE CRITICAL DEPTH AND SPECIFIC ENERGY IS THEN COMPUTED
00400C   BY ROUTINE  PICRIT  AND THE  ND  PARAMETER IS IGNORED.
00410C
00420C   USES CIVLIB ROUTINES:
00430C     BOTTOM,  PROPS,   QCR2D,   PICRIT,  AND  PIPROP.
00440C
00450C *************************************************************
00460     DIMENSION HORZ(NPTS),VERT(NPTS)
00470C  SET ARBITRARILY SMALL SLOT WIDTH DEPENDANT ON UNITS USED
00480     TMIN=0.001*G
00490     IF(NPTS.GT.1) GOTO 5
00500C  SECTION IS A CIRCULAR PIPE.
00510     DIA=HORZ(1)
00520     CALL PICRIT(DIA,Q,G,YCR,HCR)
00530     RETURN
00540 5   CONTINUE
00550C  SECTION IS AN ARBITRARY SHAPE
00560     CALL BOTTOM(VERT,NPTS,BOT,WLMAX)
00570C  INITIAYLIZE VARIABLES FOR FALSE POSITION METHOD
00580     Y=0.0
00590     QCR2=0.0
00600     DY=WLMAX--BOT
00610     IF (DY.LT.0.001) DY=0.1
```

```
0620C  START OF ITERATION...CHECK FOR CONVERGENCE
0630 10  Y=Y+DY
0640       IF(ABS(DY/Y).LT.0.0001) GO TO 30
0650C  CHECK FOR NEGATIVE VALUE DURING ITERATION
0660       IF (Y.LE.0.0) GOTO 50
0670       QCR1=QCR2
0680       IF(ND.NE.1) GOTO 20
0690C  GET ONE-DIMENSIONAL VALUE OF QCR
0700       CALL PROPS(HORZ,VERT,NPTS,Y+BOT,AREA,TOPW,PERIN,AY)
0710C  CHECK FOR CLOSED TOP AND APPLY SIMULATED SLOT EFFECT TO
0720C  BOTH AREA AND TOPWIDTH
0730       IF(TOPW.GT.TMIN) GOTO 15
0740       TOPW=TMIN
0750       AREA=AREA+ DY*TMIN
0760  15 CONTINUE
0770       QCR2=AREA*SQRT(AREA*G/TOPW)
0780       GOTO 40
0790 20  CONTINUE
0800C  GET TWO-DIMENSIONAL VALUE OF QCR
0810       CALL QCR2D(HORZ,VERT,NPTS,Y+BOT,G,QCR2,EKCR)
0820 40  CONTINUE
0830       GOTO 60
0840  50 CONTINUE
0850C  NEGATIVE DEPTH GENERATED...REJECT LAST POINT
0860       Y=Y-DY
0870       DY=DY/FAC
0880       GOTO 10
0890C  CALC. CORRECTION BY METHOD OF FALSE POSITION
0900  60 CONTINUE
0910       FAC=(Q-QCR2)/(QCR2-QCR1)
0920       DY=DY*FAC
0930       GOTO 10
0940 30  CONTINUE
0950C  CONVERGED...GET BOTH YCR AND HCR VALUES
0960       IF(ND.NE.1) GOTO 70
0970C  ONE-DIM. SOLUTION...HCR=F(YCR)
0980       YCR=Y
0990       HCR=Y+Q*Q/(2.0*G*AREA*AREA)
1000       RETURN
1010 70  CONTINUE
1020C  TWO-DIM. SOLUTION...YCR=F(HCR)
1030       HCR=Y
1040       YCR=HCR-EKCR
1050       IF(QCR2.LT.Q) HCR=YCR + EKCR*(Q/QCR2)**2
1060C  CHECK FOR CLOSED TOP SECTION
1070       CALL PROPS(HORZ,VERT,NPTS,YCR+BOT,AREA,TOPW,PERIN,AY)
1080       DEPTH=WLMAX-BOT
1090       IF(TOPW.LT.0.001.AND.YCR.GT.DEPTH) GOTO 80
1100       RETURN
```

```
01110C  SECTION HAS CLOSED TOP  IE. YCR.LT. WLMAX
01120  80 CONTINUE
01130      YCR=WLMAX-DDT-0.0001
01140      HCR=YCR+Q*Q/(2.0*G*AREA*AREA)
01150      RETURN
01160      END
```

```
0100      SUBROUTINE EDITXS(NTAPE1,NTAPE2,KSREC,ITST,NXSEC,
0110+                        MAXPTS,NR,NW,NOCOPY)
0120C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
0130C     THIS ROUTINE PROCESSES A FILE CONTAINING THE GEOMETRY OF A
0140C     SERIES OF CHANNEL CROSS SECTIONS, EITHER NATURAL OR MAN-
0150C     MADE.  COMMAND OPTIONS ARE AVAILABLE TO ALLOW THE USER TO
0160C     ADD, CHANGE, DELETE OR EXAMINE A SECTION. THE ROUTINE IS
0170C     INTENDED MAINLY FOR USE WITH ROUTINE RIVER3/4 BUT MAY BE
0180C     USED INDEPENDANTLY TO EDIT GEOMETRY FILES OR TO SPEED FILE
0190C     PREPARATION BY ADDING SECTIONS TO AN INITIALLY EMPTY FILE.
0200C
0210C     NTAPE1 = PERIPHERAL NO. OF INPUT GEOMETRY FILE.
0220C     NTAPE2 = PERIPHERAL NO. OF SCRATCH TAPE FILE FOR EDITING.
0230C     KSREC  = INTEGER ARRAY OF SIZE (100) DEFINING THE RECORD
0240C              OF FILE NTAPE1 AT WHICH A SPECIFIC SECTION
0250C              DESCRIPTION BEGINS.   MAY BE GENERATED BY MEANS
0260C              OF ROUTINE FILEXS.
0270C     ITST   = ARRAY OF SIZE (NXSEC) TO FLAG SECTIONS TO WHICH
0280C              CHANGES HAVE BEEN MADE.
0290C     NXSEC  = NO. OF CROSS-SECTIONS.   MAY BE ALTERED ON EXIT
0300C              IF SECTIONS ADDED OR DELETED.
0310C     MAXPTS = MAXIMUM NO. OF POINTS PER SECTION.   MAY BE
0320C              ALTERED ON EXIT IF SECTIONS CHANGED.
0330C     NR     = PERIPHERAL DEVICE FOR KEYBOARD INPUT.
0340C     NW     = PERIPHERAL DEVICE FOR OUTPUT TO TERMINAL.
0350C     NOCOPY = 0 IF NTAPE1 IS TO BE OVERWRITTEN AT EXIT.
0360C            = 1 IF NTAPE1 IS TO BE LEFT UNALTERED AND NTAPE2
0370C              CONTAINS THE EDITED GEOMETRY FILE.
0380C
0390C     USES CIVLIB ROUTINES FILEXS, PRNTXS
0400C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
0410      DIMENSION KSREC(100),ITST(NXSEC),TEXT(20)
0420      DIMENSION HORZ(100), VERT(100)
0430      COMMON /RECORD/ LAST
0440      REWIND NTAPE1
0450      REWIND NTAPE2
0460    1 FORMAT(8H    (    ))
0470      ICOUNT=0
0480      IEOF=0
0490      LAST=1
0500      MORE=0
0510      MADD=0
0520      NXOLD=NXSEC
0530      WRITE(NW,4) NXSEC,MAXPTS
0540    4 FORMAT(18H OLD FILE CONTAINS,I5,9H SECTIONS,
0550+            20H WITH MAX. NO. PTS =,I5,//)
0560    5 WRITE(NW,10)
0570 10   FORMAT(1X,42HIN ROUTINE EDITXS AVAILABLE COMMANDS ARE:--,/,
0580+            1X,29HADD......TO ADD A NEW SECTION,/,
0590+            1X,38HCHANGE...TO ALTER ANY SECTION PROPERTY,/,
0600+            1X,38HDELETE...TO DELETE AN EXISTING SECTION,/,
0610+            1X,33HEND......TO END THIS EDIT SESSION,/,
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00620+              1X,34HHELP.....TO PRINT LIST OF COMMANDS,/,
00630+              1X,46HPRINT....TO PRINT OUT PROPERTIES OF SECTION(S),/,
00640+              1X,37HRETURN...TO RETURN TO DRIVING ROUTINE)
00650 20  CONTINUE
00660     NUMITR=0
00670     WRITE(NW,25)
00680 25  FORMAT(1X,9HEDIT SEC?)
00690     READ(NR,30)COMND
00700 30  FORMAT(A6)
00710     IC=0
00720     IF(COMND.EQ.6HADD   ) IC=1
00730     IF(COMND.EQ.6HDELETE) IC=2
00740     IF(COMND.EQ.6HCHANGE) IC=3
00750     IF(COMND.EQ.6HPRINT ) IC=4
00760     IF(COMND.EQ.6HEND   ) GOTO 500
00770     IF(COMND.EQ.6HHELP  ) GOTO 5
00780     IF(COMND.EQ.6HRETURN) RETURN
00790     IF(IC.GT.0) GOTO(40,40,40,400)IC
00800     WRITE(NW,35)COMND
00810 35  FORMAT(1X,8HCOMMAND ,A6,31H NOT UNDERSTOOD...PLEASE RETYPE)
00820     GOTO 20
00830 40  CONTINUE
00840     J1=1
00850     IF(IC.EQ.1) GOTO 100
00860     WRITE(NW,45)
00870 45  FORMAT(1X,26HSPECIFY SECTION NO....(I5))
00880     WRITE(NW,1)
00890     READ(NR,50)NSEC
00900 50  FORMAT(I5)
00910     IF(NSEC.LE.NXSEC) GOTO 54
00920     IF(NSEC.GT.NXSEC+1) GOTO 52
00930     IF(IC.EQ.1) GOTO 100
00940C
00950 52  CONTINUE
00960     NUMITR=NUMITR+1
00970     WRITE(NW,53)NSEC
00980 53  FORMAT(1X,11HSECTION NO.,I3,13H OUT OF RANGE)
00990     IF(NUMITR.GE.3) WRITE(NW,55)
01000  55 FORMAT(48H SOMETHING IS WRONG, START OVER AND CHECK FILES.)
01010     IF(NUMITR.GE.3) GOTO 20
01020     GOTO 40
01030 54  CONTINUE
01040     IF(IC.EQ.2) GOTO 200
01050     IF(IC.EQ.3) GOTO 300
01060 70  CONTINUE
01070     IF(NSHIFT.EQ.0) GOTO(130,205,310,400)IC
01080     DO 80 K=1,NSHIFT
01090       READ(NTAPE1,75)ISEC,(TEXT(J),J=1,18)
01100       IF(EOF(NTAPE1).NE.0.0) IEOF=1
01110       IF(IEOF.GT.0) GOTO(130,205,310,400)IC
01120       NEWSEC=ISEC
01130       IF(ISEC.GT.0) NEWSEC=ISEC+NMORE
01140       WRITE(NTAPE2,75)NEWSEC,(TEXT(J),J=1,18)
```

```
1150 75    FORMAT(I5,19A4)
1160 80  CONTINUE
1170     GOTO(130,205,310,400)IC
1180C
1190C  ADD A NEW SECTION
1200 100 CONTINUE
1210     WRITE(NW,105)
1220 105 FORMAT(41H AFTER WHAT SECTION IS THE NEW SECTION(S),
1230+           20H TO BE ADDED?...(I5))
1240     IF(NADD.GT.0) GOTO 115
1250     WRITE(NW,110)
1260 110 FORMAT(39H IF BEFORE THE FIRST SECTION, ENTER...0)
1270 115 CONTINUE
1280     WRITE(NW,1)
1290     READ(NR,120) LSEC
1300 120 FORMAT(I5)
1310     WRITE(NW,125) LSEC
1320 125 FORMAT(42H HOW MANY SECTIONS TO BE ADDED IMMEDIATELY,
1330+           14H AFTER SECTION,I5,8H,...(I5))
1340     WRITE(NW,1)
1350     READ(NR,120) NUMADD
1360     MSEC=LSEC
1370     IF(MSEC.GE.MXOLD) GOTO 170
1380     MSHIFT=KSREC(LSEC+1)-LAST
1390     LAST=KSREC(LSEC+1)
1400     GOTO 70
1410C
1420 130 CONTINUE
1430     DO 165 I=1,NUMADD
1440        WRITE(NW,135) I,NUMADD
1450 135    FORMAT(18H FOR ADDED SECTION,I5,3H OF,I5)
1460        WRITE(NW,45)
1470     WRITE(NW,1)
1480        READ(NR,120) MSEC
1490        WRITE(NW,145) MSEC
1500 145    FORMAT(12H AT SEC. NO.,I5,7H SUPPLY,/,
1510+         34H NO. PTS., CHAINAGE, ROUGH. COEFF.,/,
1520+         20H ...(I5,F10.1,F10.3),/,
1530+         28H   (   )(          )(          ))
1540        READ(NR,150) NPTS,CHAIN,RC
1550 150    FORMAT(I5,F10.1,F10.3)
1560        J2=NPTS
1570        WRITE(NW,155) MSEC,NPTS
1580 155    FORMAT(12H FOR SEC.NO.,I3,7H SUPPLY,I3,16H PRS. COORDS. IN,
1590+         21H ROWS OF 3...(6F10.3),/,23H    (          )(          ),
1600+         40H(          )(          )(          )(          ))
1610        READ(NR,160)(HORZ(J),VERT(J),J=J1,J2)
1620 160    FORMAT(6F10.3)
1630        NEWSEC=MSEC
1640        IF(NADD.GT.0) NEWSEC = MSEC+MORE
1650        CALL PRNTXS(HORZ,VERT,NPTS,CHAIN,RC,NEWSEC,NTAPE2)
1660        MORE=MORE+1
1670        NXSEC=NXSEC+1
```

```
01680 165 CONTINUE
01690     NADD=NADD+1
01700     GOTO 20
01710C
01720C  ADD SECTIONS AT THE END OF THE OLD FILE
01730 170 CONTINUE
01740     ICOUNT=ICOUNT+1
01750     NUNAD1=NUNADD+1
01760     IF(ICOUNT.EQ.NUNAD1) GOTO 20
01770     WRITE(NW,135) ICOUNT,NUNADD
01780     WRITE(NW,45)
01790     WRITE(NW,1)
01800     READ(NR,120) NSEC
01810 175 CONTINUE
01820     IF(IEDF.GT.0) GOTO 185
01830 180 CONTINUE
01840     READ(NTAPE1,75) ISEC,(TEXT(J),J=1,18)
01850     IF(EOF(NTAPE1).NE.0.0) IEDF=1
01860     IF(IEDF.GT.0) GOTO 185
01870     IF(ISEC.GT.0) ISEC=ISEC+NORE
01880     WRITE(NTAPE2,75) ISEC,(TEXT(J),J=1,18)
01890     GOTO 180
01900 185 CONTINUE
01910     WRITE(NW,145) NSEC
01920     READ(NR,150) NPTS,CHAIN,RC
01930     J2=NPTS
01940     WRITE(NW,155) NSEC,NPTS
01950     READ(NR,160) (HORZ(J),VERT(J),J=J1,J2)
01960     IF(NADD.GT.0) NSEC=NSEC+NORE
01970     CALL PRNTXS(HORZ,VERT,NPTS,CHAIN,RC,NSEC,NTAPE2)
01980     IF(IC.EQ.1) GOTO 170
01990     GOTO 20
02000C
02010C  DELETE A SECTION
02020 200 CONTINUE
02030     NSHIFT=KSREC(NSEC)-LAST
02040     LAST=KSREC(NSEC)
02050     GOTO 70
02060 205 CONTINUE
02070     IF(NSEC.EQ.NXOLD) GOTO 220
02080     NDEL=KSREC(NSEC+1) - LAST
02090     DO 210 K=1,NDEL
02100       READ(NTAPE1,50) ISEC
02110 210 CONTINUE
02120     LAST = KSREC(NSEC+1)
02130 215 CONTINUE
02140     IF(IC.EQ.3) GOTO 105
02150     IF(NADD.EQ.0) NADD = 1
02160     NORE=NORE-1
02170     GOTO 20
02180 220 CONTINUE
02190     READ(NTAPE1,50)ISEC
02200     IF(EOF(NTAPE1).NE.0.0) IEDF=1
```

```
2210       IF(IEOF.GT.0) GOTO 215
2220       GOTO 220
2230C
2240C  CHANGE PROPERTIES OF SECTIONS
2250 300 CONTINUE
2260       NSHIFT=KSREC(NSEC)-LAST
2270       LAST=KSREC(NSEC)
2280       GOTO 70
2290 310 CONTINUE
2300       GOTO 205
2310C
2320C  PRINT OUT PROPERTIES OF SECTIONS FOR OLD FILE
2330 400 CONTINUE
2340       WRITE(NW,410)
2350 410 FORMAT(1X,50H SPECIFY FIRST & LAST SEC. NO. OF OLD FILE...(2I5))
2360       WRITE(NW,415)
2370 415 FORMAT(13H   (   )(   ))
2380       READ(NR,420) ISTART,LAST1
2390 420 FORMAT(2I5)
2400       REWIND NTAPE1
2410 430 CONTINUE
2420       READ(NTAPE1,75) ISEC,(TEXT(J),J=1,18)
2430       IF(EOF(NTAPE1).NE.0.0) GOTO 470
2440       IF(ISEC.GT.LAST1) GOTO 470
2450       IF(ISEC.LT.ISTART)GOTO 430
2460       WRITE(NW,75) ISEC,(TEXT(J),J=1,18)
2470       GOTO 430
2480 470 CONTINUE
2490       REWIND NTAPE1
2500       LIMIT=LAST-1
2510       IF(LIMIT.EQ.0) GOTO 20
2520       DO 480 J=1,LIMIT
2530              READ(NTAPE1,420) ISEC
2540 480 CONTINUE
2550       GOTO 20
2560C
2570C  END EDIT SESSION, READ REMAINDER OF TAPE1 AND COPY
2580C  ONTO TAPE2 . THEN COPY TAPE2 TO TAPE1 IF NOCOPY=0
2590 500 CONTINUE
2600       IF(IEOF.GT.0) GOTO 510
2610       READ(NTAPE1,75)ISEC,(TEXT(J),J=1,18)
2620       IF(EOF(NTAPE1).NE.0.0) GOTO 510
2630       NEWSEC=ISEC
2640       IF(ISEC.GT.0) NEWSEC=ISEC+MORE
2650       WRITE(NTAPE2,75)NEWSEC,(TEXT(J),J=1,18)
2660       GOTO 500
2670 510 CONTINUE
2680       MADD=0
2690       IEOF=0
2700       REWIND NTAPE1
2710       REWIND NTAPE2
2720       WRITE(NW,515)
```

```
02730 515 FORMAT(1X,37H DO YOU WANT THE OLD FILE OVERWRITTEN,/,
02740+              1X,30H WITH THE NEW FILE.....YES/NO?)
02750     READ(NR,516)ANS
02760 516 FORMAT(A1)
02770     IF(ANS.EQ.1HY) NOCOPY = 0
02780     IF(ANS.EQ.1HN) NOCOPY = 1
02790     IF(NOCOPY.EQ.1) GOTO 20
02800 520 CONTINUE
02810     READ(NTAPE2,521)(TEXT(J),J=1,20)
02820     IF(EOF(NTAPE2).NE.0.0) GOTO 530
02830     WRITE(NTAPE1,521)(TEXT(J),J=1,20)
02840 521 FORMAT(20A4)
02850     GOTO 520
02860 530 CONTINUE
02870     REWIND NTAPE2
02880     CALL FILEXS(NTAPE1,KSREC,NXSEC,MAXPTS)
02890     WRITE(NW,540) NXSEC,MAXPTS
02900 540 FORMAT(/,19H MAX. NO. OF SEC. =,I5,5X,19H MAX. NO. OF PTS. =,I5)
02910     ICOUNT=0
02920     LAST=1
02930     MORE=0
02940     NXOLD=NXSEC
02950     GOTO 20
02960     END
```

```
00100      SUBROUTINE EZRA(HORZ1,VERT1,NPTS1,CHAIN1,RC1,Q1,
00110+                     HORZ2,VERT2,NPTS2,CHAIN2,RC2,Q2,
00120+                     VISC,G,QNAME,WL2,WL1,ENLV1,ICR)
00130C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
00140C  A SINGLE REACH OF NON-PRISMATIC CHANNEL IS DESCRIBED BY A
00150C  PAIR OF CROSS-SECTIONS EACH OF WHICH IS IN TURN DEFINED BY
00160C  A SERIES OF POINTS THE COORDINATES OF WHICH ARE STORED IN
00170C  ARRAYS (E.G. HORZ1, VERT1).   EACH SECTION IS FURTHER
00180C  DEFINED BY CHAINAGE, ROUGHNESS COEFFICIENT AND THE NO. OF
00190C  POINTS DEFINING EACH SECTION.
00200C  THE DISCHARGE AND RESISTANCE LAW ARE DEFINED AND FOR A
00210C  SPECIFIED DOWNSTREAM WATER SURFACE ELEVATION, THE ROUTINE
00220C  FINDS THE WATER SURFACE AND ENERGY ELEVATIONS AT THE
00230C  UPSTREAM SECTION.
00240C  THE ROUTINE IS INTENDED FOR SUCCESSIVE APPLICATION WORK-
00250C  -ING IN AN UPSTREAM DIRECTION.
00260C    HORZ1  = ARRAY (NPTS1) CONTAINING THE HORIZONTAL COORDS.
00270C             OF POINTS DEFINING THE UPSTREAM SECTION.
00280C    VERT1  = ARRAY (NPTS1) OF VERTICAL COORDS.
00290C    NPTS1  = NO. OF POINTS IN UPSTREAM SECTION.
00300C    CHAIN1 = CHAINAGE OF UPSTREAM SECTION MEASURED POSITIVE
00310C             IN DOWNSTREAM DIRECTION.
00320C    RC1    = ROUGHNESS COEFFICIENT FOR UPSTREAM SECTION.
00330C             MUST BE COMPATIBLE WITH RESISTANCE LAW USED.
00340C    Q1     = DISCHARGE AT UPSTREAM SECTION NO. 1.
00350C    HORZ2  = )
00360C    VERT2  = )
00370C    NPTS2  = )-- CORRESPONDING PARAMETERS FOR DOWNSTREAM
00380C    CHAIN2 = )   CROSS-SECTION.
00390C    RC2    = )
00400C    Q2     = )
00410C    G      = GRAVITATIONAL ACCELERATION.
00420C    VISC   = KINEMATIC VISCOCITY.   IF SET TO ZERO A DEFAULT
00430C             VALUE FOR WATER AT 15 DEG. CELSIUS IS USED.
00440C    QNAME  = HOLLERITH CONSTANT OR STRING VARIABLE SET EQUAL
00450C             TO REQUIRED RESISTANCE LAW.   (SEE S/R NORMLQ)
00460C    WL2    = SPECIFIED WATER SURFACE ELEVATION AT DOWNSTREAM
00470C             SECTION (REFERRED TO SAME DATUM AS VERT1, VERT2)
00480C    WL1    = COMPUTED WATER SURFACE ELEV. AT UPSTREAM SEC.
00490C    ENLV1  = COMPUTED ENERGY LEVEL AT UPSTREAM SECTION.
00500C    ICR    = COMPUTED INTEGER WITH VALUE OF
00510C              0  IF SECTION SUBCRITICAL
00520C              1  IF CRITICAL SECTION ASSUMED.
00530C  IN MAKING ALLOWANCE FOR SPATIALLY VARIED FLOW (Q2.GT.Q1)
00540C  THE INCOMING FLOW IS ASSUMED TO HAVE ZERO COMPONENT OF
00550C  MOMENTUM IN THE DIRECTION OF THE MAIN CHANNEL FLOW.
00560C  UNITS USED MUST BE CONSISTENT THROUGHOUT.
00570C  USES ROUTINES BOTTOM, PROPS, CRITIC, QCR2D, SFROMQ AND
00580C  NORMLQ.
00590C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
00600      DIMENSION HORZ1(NPTS1),VERT1(NPTS1),HORZ2(NPTS2),VERT2(NPTS2)
00610      REAL KE1,KE2
```

```
00620      ICR=0
00630      KE1=Q1*Q1*0.5/G
00640      KE2=Q2*Q2*0.5/G
00650C  GET ENERGY LEVEL AND ENERGY SLOPE AT D/S SEC.
00660      CALL PROPS(HORZ2,VERT2,NPTS2,WL2,AREA,TOPW,PERIN,AY)
00670      QA22=Q2/(AREA*AREA)
00680      CALL SFRONQ(Q2,AREA,PERIN,RC2,VISC,G,QNAME,S2)
00690      DX=CHAIN2-CHAIN1
00700      ENLV2 = WL2 + KE2/(AREA*AREA)
00710      DQDX=0.0
00720      IF(Q2.GT.Q1)DQDX=(Q2-Q1)*SQRT(QA22)/G
00730C
00740C  TEST FOR POSSIBLE CRITICAL SECTION AT UPSTREAM SEC.
00750C
00760      CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
00770      CALL CRITIC(2,HORZ1,VERT1,NPTS1,Q1,G,WDCR,HCR)
00780      NENTRY=1
00790      Y=WDCR
00800      GOTO 90
00810 10   CONTINUE
00820      IF(FUNC.LT.0.0) GOTO 40
00830C  UPSTREAM SECTION PROBABLY CRITICAL.
00840      WL1=WDCR+BOT
00850      ENLV1=HCR+BOT
00860      ICR=1
00870      RETURN
00880C
00890C  UPSTREAM DEPTH  IS SUB-CRITICAL...USE WDCR AS START FOR
00900C  COARSE SEARCH
00910C
00920 40   CONTINUE
00930      Y2=WDCR
00940 50   CONTINUE
00950      Y1=Y2
00960      Y2=1.5*Y2
00970      NENTRY=2
00980      Y=Y2
00990      GOTO 90
01000 20   CONTINUE
01010      IF(FUNC.LT.0.0) GOTO 50
01020 60   CONTINUE
01030      Y=0.5*(Y1+Y2)
01040      NENTRY=3
01050      GOTO 90
01060 30   CONTINUE
01070      IF(FUNC.LE.0.0) GOTO 70
01080      Y2=Y
01090      GOTO 80
01100 70   CONTINUE
01110      Y1=Y
01120 80   CONTINUE
01130      IF(ABS(Y2-Y1)/Y2.GT.0.00001) GOTO 60
```

```
1140      WL1=Y+BOT
1150      ENLV1=WL1 + KE1/(AREA*AREA)
1160C
1170      RETURN
1180C
1190 90   CONTINUE
1200C  THIS SECTION COMPUTES THE MODIFIED ENERGY FUNCTION.
1210      CALL PROPS(HORZ1,VERT1,NPTS1,Y+BOT,AREA,TOPW,PERIN,AY)
1220      CALL SFROMQ(Q1,AREA,PERIN,RC1,VISC,G,QNAME,S1)
1230      AREASQ=AREA*AREA
1240      QA21=Q1/AREASQ
1250      SPATL=DQDX*SQRT(QA21)
1260      HF=DX*SQRT(S1*S2)
1270      FUNC=BOT+Y+KE1/AREASQ -- HF -- SPATL -- ENLV2
1280      GOTO (10,20,30) MENTRY
1290      END
```

```
00100     SUBROUTINE FILEXS(NTAPE,KSREC,MXSEC,MAXPTS)
00110C ************************************************************
00120C  THE ROUTINE PROCESSES A FILE CONTAINING THE GEOMETRY OF A
00130C  SERIES OF NATURAL CHANNEL CROSS-SECTIONS AND CREATES AN
00140C  INTEGER ARRAY DEFINING THE RECORD AT WHICH THE DESCRIPTION
00150C  OF EACH SECTION BEGINS.   THE NUMBER OF SECTIONS AND THE
00160C  MAXIMUM NO. OF POINTS USED IN ANY SECTION ARE ALSO FOUND.
00170C    NTAPE  = PERIPHERAL NO. OF INPUT GEOMETRY FILE.
00180C    KSREC  = COMPUTED INTEGER ARRAY TO STORE THE RECORD OF
00190C             FILE NTAPE AT WHICH SECTION DESCRIPTION BEGINS
00200C             (E.G. SEC. J BEGINS AT RECORD KSREC(J)    )
00210C             DIMENSIONED FOR UP TO 100 SECTIONS ONLY.
00220C    MXSEC  = COMPUTED NO. OF SECTIONS IN THE FILE.
00230C    MAXPTS = COMPUTED MAXIMUM NO. OF POINTS USED TO DESCRIBE
00240C             A SECTION.
00250C  NTAPE IS REWOUND ON EXIT.
00260C ************************************************************
00270     DIMENSION KSREC(100)
00280     MXSEC=0
00290     MAXPTS=0
00300C  SET KSREC() TO ZERO
00310     DO 10 J=1,100
00320       KSREC(J)=0
00330 10  CONTINUE
00340     REWIND NTAPE
00350     ISEC1=0
00360     KOUNT=0
00370 20  CONTINUE
00380     READ(NTAPE,30)ISEC,PTS
00390 30  FORMAT(I5,F5.0)
00400     IF(EOF(NTAPE).NE.0.0) GOTO 40
00410     KOUNT=KOUNT+1
00420     IF(ISEC.EQ.0.OR.ISEC.EQ.ISEC1) GOTO 20
00430C  NEW SECTION LOCATED...RECORD DATA
00440     KSREC(ISEC)=KOUNT
00450     NPTS=IFIX(PTS+0.1)
00460     IF(NPTS.GT.MAXPTS) MAXPTS=NPTS
00470     ISEC1=ISEC
00480     IF(MXSEC.LT.ISEC) MXSEC=ISEC
00490     GOTO 20
00500 40  CONTINUE
00510C  END--OF--FILE READ
00520     REWIND NTAPE
00530     RETURN
00540     END
```

```
00100      SUBROUTINE PROFL2(MTAPE,KSREC,NW,NXSEC,MAXPTS,NUS,NDS,
00110+                       COEFC,COEFF,QNAME,VISC,G,WLDS,QS,
00120+                       HORZ1,VERT1,HORZ2,VERT2,WLS,ENLVS)
00130C ************************************************************
00140C  THE ROUTINE OPERATES ON A NATURAL CHANNEL DEFINED BY A
00150C  SET OF ARBITRARY CROSS-SECTIONS EACH OF WHICH IS IN TURN
00160C  DESCRIBED BY STRAIGHT LINES JOINING POINTS THE COORDINATES
00170C  OF WHICH ARE STORED IN THE FILE MTAPE.
00180C  CHAINAGE AND ROUGHNESS COEFFICIENTS ARE DEFINED FOR EACH
00190C  SECTION.   THE DISCHARGE IS DEFINED FOR EACH REACH IN
00200C  THE CHANNEL.   FLOW RESISTANCE MAY BE DEFINED BY THE USER.
00210C  FOR A SPECIFIED DOWNSTREAM WATER SURFACE ELEVATION, THE
00220C  PROFILES OF WATER SURFACE AND ENERGY ELEVATION ARE
00230C  CALCULATED BETWEEN SPECIFIED DOWNSTREAM AND UPSTREAM
00240C  LIMITS.   PRINTOUT OF THE VALUES MAY BE OBTAINED, SUPPRESSED
00250C  OR ROUTED TO A SCRATCH TAPE FILE.
00260C    MTAPE  = PERIPHERAL NO. OF INPUT GEOMETRY FILE.
00270C    KSREC  = INTEGER ARRAY OF SIZE (100) CONTAINING THE
00280C             RECORD NUMBER AT WHICH DESCRIPTION OF A SECTION
00290C             BEGINS.   MAY BE GENERATED BY ROUTINE FILEXS.
00300C    NW     = OUTPUT CHANNEL FOR PRINTOUT OF PROFILE
00310C           = 6 FOR PRINTOUT AT TERMINAL
00320C           = N FOR OUTPUT TO FILE TAPEN
00330C           = 0 TO SUPPRESS OUTPUT.
00340C    NXSEC  = NO. OF CROSS-SECTIONS.
00350C    MAXPTS = MAXIMUM NO. OF POINTS USED TO DESCRIBE A SECTION.
00360C    NUS    = SECTION NO. DEFINING UPSTREAM LIMIT OF
00370C             DESIRED PROFILE.
00380C    NDS    = SECTION NO. DEFINING DOWNSTREAM LIMIT OF PROFILE.
00390C    COEFF  = HEADLOSS COEFFICIENT
00400C    QS     = ARRAY (NXSEC) CONTAINING IN THE JTH ELEMENT THE
00410C             DISCHARGE IN THE REACH FROM SECTION J TO (J+1).
00420C             QS(NXSEC) IS NOT USED.
00430C    QNAME  = HOLLERITH CONSTANT OR STRING VARIABLE SET EQUAL
00440C             TO REQUIRED RESISTANCE LAW.  (SEE S/R NORMLQ)
00450C    VISC   = KINEMATIC VISCOCITY.   IF SET ZERO A DEFAULT
00460C             VALUE FOR WATER AT 15 DEG. CELSIUS IS USED.
00470C    G      = GRAVITATIONAL ACCELERATION.
00480C    WLDS   = SPECIFIED WATER SURFACE ELEVATION AT DOWNSTREAM
00490C             LIMIT (SECTION NDS).
00500C    HORZ1  = )
00510C    VERT1  = )- WORKING SPACE ARRAYS EACH OF SIZE (MAXPTS)
00520C    HORZ2  = )
00530C    VERT2  = )
00540C    WLS    = ARRAY (NXSEC) FOR COMPUTED VALUES OF WATER SURFACE
00550C             ELEVATION.   UNUSED ELEMENTS SET TO ZERO.
00560C    ENLVS  = ARRAY (NXSEC) FOR COMPUTED VALUES OF ENERGY LEVELS.
00570C             UNUSED ELEMENTS SET TO ZERO.
00580C
00590C  USES CIVLIB ROUTINES: BOTTOM, CONTR2, CRITIC, EZRA,
00600C                        FINDXS, PROPS
00610C ************************************************************
```

```
00620      DIMENSION QS(NXSEC),WLS(NXSEC),ENLVS(NXSEC),KSREC(100)
00630      DIMENSION HORZ1(MAXPTS),VERT1(MAXPTS)
00640      DIMENSION HORZ2(MAXPTS),VERT2(MAXPTS)
00650C  SET UP LOGICAL VARIABLE FOR PRINTOUT
00660      LOGICAL PRNT
00670      PRNT=.FALSE.
00680      IF(NW.GT.0) PRNT=.TRUE.
00690      FLAG=6H
00700C  PRINT HEADING FOR ARRAYS
00710      IF(PRNT)WRITE(NW,10)
00720 10  FORMAT(///,43H SEC.  STATN.  CHAINAGE  DISCH.    W.L.
00730+                        25HEN.LEV.    INV.      VEL.,/)
00740C  ZERO OUTPUT ARRAYS
00750      DO 20 I=NUS,NDS
00760      WLS(I)=0.0
00770      ENLVS(I)=0.0
00780 20  CONTINUE
00790C  DEFAULT LOSS COEFF AND CHECK FOR ALTERNATE VALUES
00800       CLC=0.0
00810       IF(COEFC.GT.0.0.AND.COEFC.LE.1.0) CLC=COEFC
00820       CLE=1.0
00830       IF(COEFE.GE.0.0.AND.COEFE.LT.1.0) CLE=COEFE
00840C  SET DOWNSTREAM VALUES FOR PROFILES
00850      WLS(NDS)=WLDS
00860      CALL FINDXS(NTAPE,KSREC,NDS,HORZ2,VERT2,NPTS2,CHAIN2,RC2)
00870      CALL PROPS(HORZ2,VERT2,NPTS2,WLDS,A,D,D,D)
00880      CALL BOTTOM(VERT2,NPTS2,BOT,WLMAX)
00890      CALL CRITIC(2,HORZ2,VERT2,NPTS2,QS(NDS),G,YCR2,HCR2)
00900      Q=QS(NDS)
00910      V=Q/A
00920      ENLVS(NDS)=WLDS + V*V/(2.0*G)
00930      IF(WLDS.LE.BOT+YCR2) FLAG=6H*CRIT*
00940C  PRINTOUT RESULTS
00950      IF(PRNT)WRITE(NW,30)NDS,CHAIN2,Q,WLDS,ENLVS(NDS),BOT,V,FLAG
00960 30  FORMAT(I4,7X,F9.1,4F10.3,F8.3,A6)
00970      WL2=WLDS
00980      ENLV2=ENLVS(NDS)
00990      NUS1=NUS+1
01000C  START LOOP FOR EACH REACH
01010      DO 70 ISEC=NUS1,NDS
01020      ICR=0
01030      FLAG=6H
01040      I2=NDS + NUS1 - ISEC
01050      I1=I2-1
01060      Q1=QS(I1)
01070      Q2=QS(I2)
01080      CALL FINDXS(NTAPE,KSREC,I1,HORZ1,VERT1,NPTS1,CHAIN1,RC1)
01090      IF(I2.EQ.NDS) GOTO 40
01100      CALL FINDXS(NTAPE,KSREC,I2,HORZ2,VERT2,NPTS2,CHAIN2,RC2)
01110 40  CONTINUE
01120      IF(ABS(CHAIN2-CHAIN1).LT.0.001) GOTO 50
01130      CALL ESRA(HORZ1,VERT1,NPTS1,CHAIN1,RC1,Q1,
```

```
+        HORZ2,VERT2,NPTS2,CHAIN2,RC2,Q1,
+        VISC,G,QNAME,WL2,WL1,ENLV1,ICR)
         GOTO 60
   50    CONTINUE
         CALL CONTR2(HORZ1,VERT1,NPTS1,HORZ2,VERT2,NPTS2,
+        Q1,Q2,G,CLC,CLE,WL2,WL1,ENLV2,ENLV1,ICR)
   60    CONTINUE
C
C   CHECK IF U/S E.L. IS LESS THAN D/S E.L. AND DEFAULT IF NECCESSARY
   65    IF(ENLV1.LT.ENLV2) GOTO 66
         WLS(I1)=WL1
         ENLVS(I1)=ENLV1
         CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
         V=SQRT(2.0*G*(ENLV1-WL1))
         IF(ICR.EQ.1) FLAG=6H*CRIT*
         IF(PRNT)WRITE(NW,30)I1,CHAIN1,Q1,WL1,ENLV1,BOT,V,FLAG
         WL2=WL1
         ENLV2=ENLV1
   70    CONTINUE
         RETURN
C
   66    WL1= WL1 + 0.0005
         CALL PROPS(HORZ1,VERT1,NPTS1,WL1,AREA,TOPW,PERIM,AY)
         KE1=Q1*Q1*0.5/G
         ENLV1 = WL1 + KE1/(AREA*AREA)
         GOTO 65
         END
```

```
00100     SUBROUTINE PROPS(HORZ,VERT,NPTS,WL,AREA,TOPW,PERIN,AY)
00110C ****************************************************************
00120C   CALCULATES THE CROSS-SECTIONAL PROPERTIES IN AN
00130C   OPEN CHANNEL OF ARBITRARY SHAPE OR PART-FULL PIPE.
00140C     HORZ   = ARRAY OF SIZE NPTS HOLDING HORIZL.
00150C              COORDS OF POINTS DEFINING SECTION
00160C     VERT   = ARRAY OF VERTICAL COORDS
00170C     NPTS   = NO. OF POINTS DEFINING SECTION
00180C     WL     = SPECIFIED WATER SURFACE ELEVATION
00190C              REFERRED TO SAME DATUM AS VERT.
00200C     AREA   = COMPUTED CROSS-SECTION AREA
00210C     TOPW   = COMPUTED CROSS-SECTION TOPWIDTH
00220C     PERIN  = COMPUTED WETTED PERIMETER
00230C     AY     = COMPUTED PRODUCT OF AREA AND
00240C              CENTROIDAL DEPTH
00250C   HANDLES OVERHANGING BANKS.   IF WL HIGHER THAN BANKS
00260C   SECTION IS ASSUMED EXTENDED BY VERTICALS THROUGH END
00270C   POINTS, BUT PERIM IS INCREASED ONLY IF TOPW.GT.0.0.
00280C
00290C   IF  NPTS=1  THE ROUTINE ASSUMES THE SECTION TO BE A
00300C   A CIRCULAR PIPE IN  WHICH:-
00310C     DIAMETER = HORZ(1)
00320C     INVERT   = VERT(1)
00330C   PROPERTIES ARE THEN COMPUTED BY ROUTINE PIPROP.
00340C   USES CIVLIB ROUTINES:     PIPROP.
00350C
00360C ****************************************************************
00370     DIMENSION HORZ(NPTS),VERT(NPTS)
00380C  CHECK FOR CIRCULAR SECTION.
00390     IF(NPTS.GT.1) GOTO 1
00400     DIA=HORZ(1)
00410     WD=WL-VERT(1)
00420     CALL PIPROP(DIA,WD,AREA,TOPW,PERIN,AY)
00430     RETURN
00440 1   CONTINUE
00450C  INITIALIZE VARS. FOR
00460C  CALCULATION OF PROPERTIES.
00470     AREA=0.0
00480     TOPW=0.0
00490     PERIN=0.0
00500     AY=0.0
00510     DA=0.0
00520     DT=0.0
00530     DP=0.0
00540     DAY=0.0
00550     DP1=0.0
00560     DP2=0.0
00570     N=NPTS-1
00580     DO 10 I=1,N
00590     IF(WL.GT.VERT(I).AND.WL.GT.VERT(I+1)) GO TO 20
00600     IF(WL.GT.VERT(I).OR.WL.GT.VERT(I+1)) GO TO 40
00610     DA=DT=DP=DAY=0.0
```

```
0620C  WL IS BELOW INVERT OF THIS SEGMENT
0630       GO TO 60
0640 20    CONTINUE
0650C  TRAPEZOIDAL SEGMENT ENCOUNTERED.
0660       DT=HORZ(I+1) - HORZ(I)
0670       X1=WL-VERT(I)
0680       X2=VERT(I)-VERT(I+1)
0690       DA=DT*(X1+X2/2.0)
0700       DP=SQRT(DT*DT+X2*X2)
0710       IF(I.EQ.1) DP1=WL-VERT(1)
0720       IF((I+1).EQ.NPTS) DP2=WL-VERT(NPTS)
0730       DAY=DT*X1*X1/2.0 + 0.5*DT*(X2)*(X1+X2/3.0)
0740       GO TO 60
0750 40    CONTINUE
0760C  TRIANGULAR SEGMENT ENCOUNTERED.
0770       S=(HORZ(I+1)-HORZ(I))/(VERT(I+1)-VERT(I))
0780       X1=VERT(I+1)-WL
0790       IF(X1.GE.0.0)  X1=WL-VERT(I)
0800       DT=S*X1
0810       X2=ABS(X1)
0820       DA=DT*X2/2.0
0830       DP=X2*SQRT(1.0+S*S)
0840       DAY=DA*X2/3.0
0850 60    CONTINUE
0860C  ACCUMULATE PROPERTIES FOR THIS SEGMENT
0870       AREA=AREA+DA
0880       TOPW=TOPW+DT
0890       PERIN=PERIN+DP
0900       AY=AY + DAY
0910 10    CONTINUE
0920C  INCREASE PERIN BY ANY VERTICAL EXTENSION TO END
0930C  POINTS IF TOP WIDTH  FINITE.
0940       IF(TOPW.GT.0.00001) PERIN=PERIN+DP1+DP2
0950       RETURN
0960       END
```

```
00100      SUBROUTINE RIVER3(NTAPE1,NTAPE2,MR,MW,G,WK)
00110C ************************************************************
00120C  THE ROUTINE IS INTENDED AS AN ENCLOSING ROUTINE FOR RIVER4
00130C  TO SAVE THE USER THE INCONVENIENCE OF DIMENSIONING THE
00140C  MANY WORK ARRAYS REQUIRED AND UNWIELDY CALLING STATEMENT.
00150C  ALSO, THE ROUTINE ALLOWS THE INPUT FILE TO BE EDITED BY
00160C  CHANGING THE NUMBER AND SIZE OF RECORDS, BY UPDATING THE
00170C  RECORD MANAGER KSREC() AND RE-PARTITIONING THE ARRAY WK().
00180C    NTAPE1 = PERIPHERAL NO. OF INPUT GEOMETRY FILE.
00190C    NTAPE2 = PERIPHERAL NO. OF SCRATCH TAPE FOR EDITING
00200C             PURPOSES.
00210C    MR     = PERIPHERAL NO. FOR KEYBOARD INPUT.
00220C    MW     = PERIPHERAL NO. FOR OUTPUT AT USER'S TERMINAL.
00230C    WK     = WORK ARRAY WHICH MUST BE DIMENSIONED IN THE
00240C             USER'S CALLING PROGRAM AS A ONE-DIMENSIONAL
00250C             ARRAY OF SIZE (5*MXSEC + 4*MAXPTS)
00260C ************************************************************
00270      DIMENSION WK(1),KSREC(100)
00280      WRITE(MW,10)
00290 10   FORMAT(30X,10H**********,/,
00300+           30X,10H* RIVER3 *,/,30X,10H**********,//,
00310+           14X,42HAN INTERACTIVE SIMULATION MODEL FOR STEADY,/,
00320+           16X,38HSTATE FLOWS IN NATURAL CHANNEL SYSTEMS,//,
00330+           29X,12HALAN A SMITH,/,
00340+           26X,19HMCMASTER UNIVERSITY,//,
00350+           26X,20H(REVISED APRIL 1981),///)
00360      CALL FILEMS(NTAPE1,KSREC,MXSEC,MAXPTS)
00370 12   CONTINUE
00380      MWK = 5*MXSEC + 4*MAXPTS
00390      WRITE(MW,15)NTAPE1,MXSEC,MAXPTS,MWK
00400 15   FORMAT(5X,24HCHANNEL GEOMETRY ON TAPE,I4,4H HAS,I4,
00410+        15H CROSS-SECTIONS,/,
00420+        5X,31HMAX. NO. OF PTS. PER SECTION IS,I4,/,
00430+        5X,44HDIMENSION OF ARRAY WK() IN CALLING PGM. .GE.,I5)
00440      I1=1
00450      I2=MXSEC + I1
00460      I3=MXSEC + I2
00470      I4=MXSEC + I3
00480      I5=MXSEC + I4
00490      I6=MXSEC + I5
00500      I7=MAXPTS + I6
00510      I8=MAXPTS + I7
00520      I9=MAXPTS + I8
00530      CALL RIVER4(NTAPE1,NTAPE2,KSREC,MR,MW,MXSEC,
00540+         MAXPTS,G,WK(I1),WK(I2),WK(I3),WK(I4),WK(I5),
00550+         WK(I6),WK(I7),WK(I8),WK(I9))
00560      GOTO 12
00570      END
```

```
)0100       SUBROUTINE RIVER4(NTAPE1,NTAPE2,KSREC,NR,NW,NXSEC,
)0110+                NAXPTS,G,QAR,WLS,ENLVS,KDS,ITST1,
)0120+                HORZ1,VERT1,HORZ2,VERT2)
)0130C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
)0140C   THE ROUTINE IS INTENDED TO IMPLEMENT AN INTERACTIVE
)0150C   SIMULATION MODEL FOR STUDY OF STEADY STATE RIVER
)0160C   PROFILES IN A TIME SHARING MODE.   THE VARIOUS
)0170C   OPERATIONS ARE COMMAND INITIATED AND ALLOW THE SETTING
)0180C   UP, CALIBRATION, ANALYSIS AND MODIFICATION OF A RIVER
)0190C   SYSTEM.   RIVER GEOMETRY MUST BE STORED IN A PERMANENT
00200C   FILE OR OTHER PERIPHERAL DEVICE IN FORMATS COMPATIBLE
00210C   WITH THOSE IN ROUTINE READXS.   DATA DEFINING FLOW,
00220C   CONTROL LEVELS, ETC IS PROMPTED BY ENTERING THE
00230C   APPROPRIATE COMMAND.   A BRIEF DESCRIPTION OF THESE
00240C   IS GIVEN IN THE BODY OF THE ROUTINE.
00250C     NTAPE1 = PERIPHERAL NO. OF INPUT GEOMETRY FILE.
00260C     NTAPE2 = PERIPHERAL NO. OF SCRATCH TAPE FOR EDITING.
00270C     KSREC  = INTEGER ARRAY OF SIZE (100) CONTAINING THE
00280C              RECORD NUMBER AT WHICH DESCRIPTION OF A SECTION
00290C              BEGINS.   MAY BE GENERATED BY ROUTINE FILEXS.
00300C              IN ORDER TO INCREASE THE NUMBER OF CROSS-SECTIONS,
00310C              KSREC MUST BE REDIMENSIONED IN THE FOLLOWING
00320C              ROUTINES: EDITXS, FILEXS, FINDXS,PROFIL2,
00330C                          RIVER3, RIVER4
00340C     QAR    = ARRAY OF SIZE (NXSEC) HOLDING DISCHARGES IN EACH
00350C              REACH, E.G. FLOW IN  REACH I TO (I+1) IS QAR(I).
00360C              NOTE: QAR(NXSEC) IS NOT USED.
00370C     NXSEC  = NO. OF SECTIONS DEFINING RIVER
00380C     MAXPTS = MAXIMUM NO. OF POINTS USED TO DEFINE SECTION
00390C     G      = GRAV. ACCELN.
00400C     NR     = PERIPH. DEVICE NO. FOR KEYBOARD INPUT
00410C     NW     = PERIPH. DEVICE NO. FOR TERMINAL OUTPUT
00420C     WLS    = WORK ARRAY OF SIZE (NXSEC) TO STORE COMPUTED
00430C              SURFACE PROFILE.
00440C     ENLVS  = WORK ARRAY OF SIZE (NXSEC) TO STORE COMPUTED
00450C              ENERGY PROFILE.
00460C     HORZ1  = )WORK ARRAY OF SIZE (MAXPTS)
00470C     VERT1  = ) "     "     "     "     "
00480C     HORZ2  = ) "     "     "     "     "
00490C     VERT2  = ) "     "     "     "     "
00500C     ITST1  = )WORK ARRAY OF SIZE (NXSEC) TO FLAG CHANGES
00510C     KDS    = INTEGER ARRAY OF SIZE (NXSEC) TO STORE
00520C              CONNECTIVITY INFORMATION.
00530C   ALTHOUGH DESIGNED FOR TIME SHARING MODE THE ROUTINE MAY
00540C   MAY BE USED IN BATCH MODE.   HOWEVER, THE CORRECT SEQUENCE
00550C   OF DATA ITEMS AND COMMANDS MUST BE ANTICIPATED.   REFER
00560C   TO DOCUMENTATION BEFORE USE.
00570C     USES ROUTINES  BOTTOM    CRITIC    EDITXS    FINDXS
00580C                    PROFL2    QCR2D     WLFRE
00590C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
00600       DIMENSION QAR(NXSEC),ITST1(NXSEC),KSREC(100)
00610       DIMENSION WLS(NXSEC),ENLVS(NXSEC),KDS(NXSEC)
```

```
00620       DIMENSION HORZ1(MAXPTS),VERT1(MAXPTS)
00630       DIMENSION HORZ2(MAXPTS),VERT2(MAXPTS)
00640       DIMENSION TITLE(10)
00650       LOGICAL BRANCH, PRNT
00660       BRANCH=.FALSE.
00670       PRNT=.FALSE.
00680       NBRNCH=0
00690C
00700 9001 FORMAT(8H   (    ))
00710 9002 FORMAT(13H   (    )(    ))
00720 9003 FORMAT(13H   (           ))
00730 9004 FORMAT(18H   (    )(           ))
00740 9005 FORMAT(23H   (           )(           ))
00750C
00760   10 CONTINUE
00770       DO 20 I=1,NXSEC
00780        ITST1(I)=0
00790   20 CONTINUE
00800       KDS(NXSEC)=999
00810       WRITE(NW,30)
00820   30 FORMAT(//,47H SUPPLY TITLE FOR PROJECT (UP TO 60 CHARACTERS))
00830       READ(NR,40) TITLE
00840   40 FORMAT(10A6)
00850       WRITE(NW,50)
00860   50 FORMAT(1X,40HDO YOU WANT A LIST OF COMMANDS?...YES/NO)
00870       READ(NR,60)SKIP
00880   60 FORMAT(A3)
00890       IF(SKIP.EQ.3HNO ) GOTO 80
00900       WRITE(NW,70)
00910   70 FORMAT(52H AFTER INVITATION GIVE ONE OF THE FOLLOWING COMMANDS,/
00920+          41H BRANCH........TO DEFINE BRANCHING NODES ,/,
00930+          45H COMPUTE.......TO COMPUTE SURFACE PROFILE(S) ,/,
00940+          57H CONNECT.......TO DEFINE CONNECTIVITY OF NETWORK BRANCHES,
00950+          53H CRITIC........TO COMPUTE CRITICAL DEPTH AT A SECTION,/,
00960+          58H DISCHARGE.....TO SPECIFY FLOW DISTRIBUTION ALONG CHANNELS
00970+          50H D/S WL........TO DEFINE DOWNSTREAM CONTROL LEVEL ,/,
00980+          37H EDIT..........TO EDIT GEOMETRY FILE ,/,
00990+          39H HELP..........TO LIST COMMAND OPTIONS ,/,
01000+          55H INFLOWS.......TO SPECIFY TRIBUTARY INFLOWS TO BRANCHES,/,
01010+          52H LOSS COEFF....TO DEFINE TRANSITION LOSS COEFFICIENT,/,
01020+          45H RESISTANCE....TO DEFINE FLOW RESISTANCE LAW ,/,
01030+          30H RESTART.......TO BEGIN AGAIN ,/,
01040+          32H STOP..........TO TERMINATE RUN ,/,
01050+          47H SUMMARY.......TO PRINT SUMMARY OF INPUT DATA. ,/)
01060C
01070C  SET UP -IF- FLAGS: 0--CONNECTIVITY, 1--INFLOW,DISCHARGE
01080C       2--D/S WL, 3--RESISTANCE, 4--BRANCH, 5--LOSS COEFF
01090   80 IF0=0
01100       IF1=0
01110       IF2=0
01120       IF3=0
01130       IF4=0
01140       IF5=0
```

```
1150C
1160        CLC=0.0
1170        CLE=1.0
1180        QMIN=0.0001
1190C
1200     90 WRITE(NW,100)
1210    100 FORMAT(/,10H COMMAND? ,/)
1220        READ(NR,110) COMMND
1230    110 FORMAT(A6)
1240        IC=0
1250        IF(COMMND.EQ.6HRESTAR) IC=1
1260        IF(COMMND.EQ.6HHELP  ) IC=2
1270        IF(COMMND.EQ.6HCONNEC) IC=3

1280        IF(COMMND.EQ.6HINFLOW) IC=4
1290        IF(COMMND.EQ.6HBRANCH) IC=5
1300        IF(COMMND.EQ.6HDISCHA) IC=6
1310        IF(COMMND.EQ.6HD/S WL) IC=7
1320        IF(COMMND.EQ.6HRESIST) IC=8
1330        IF(COMMND.EQ.6HCOMPUT) IC=9
1340        IF(COMMND.EQ.6HSTOP  ) IC=10
1350        IF(COMMND.EQ.6HCRITIC) IC=11
1360        IF(COMMND.EQ.6HLOSS C) IC=12
1370        IF(COMMND.EQ.6HEDIT  ) IC=13
1380        IF(COMMND.EQ.6HSUMMAR) IC=14
1390        IF(IC.GT.0) GOTO 130
01400       WRITE(NW,120)
01410   120 FORMAT(27H BEG PARDON...PLEASE RETYPE)
01420       GOTO 90
01430   130 CONTINUE
01440       GOTO( 10,200,500,1000,1500,2000,2500,3000,4000,9000,
01450+         5000,5500,6000,6100)IC
01460C
01470C   PRINT OUT COMMAND OPTIONS
01480C
01490   200 CONTINUE
01500       WRITE(NW,70)
01510       GOTO 90
01520C
01530C  DEFINE CONNECTIVITY OF TRIBUTARIES.
01540C
01550   500 CONTINUE
01560       NXSEC1=NXSEC-1
01570       DO 510 J=1,NXSEC1
01580        KDS(J)=0
01590   510 CONTINUE
01600       WRITE(NW,520)
01610   520 FORMAT(53H SUPPLY NO. OF CONFLUENCE POINTS (DEFINED BY A DOUBLE,
01620+        34H SECTION), IN THE NETWORK...(I5)   )
01630       WRITE(NW,9001)
01640       READ(NR,530)NCONF
01650   530 FORMAT(2I5)
```

```
01660       IF(NCONF.EQ.0) GOTO 570
01670       WRITE(NW,540)NCONF
01680  540 FORMAT(4H FOR,I4,42H CONFLUENCES SUPPLY THE SECTION NO. AT THE,/
01690+       55H  DOWNSTREAM LIMIT OF THE TRIBUTARY AND THE INTERMEDIATE,/,
01700+       42H SEC. NO. AT THE RECEIVING STREAM...(2I5) )
01710      DO 560 J=1,NCONF
01720        WRITE(NW,550)J
01730  550  FORMAT(11H CONFLUENCE,I4)
01740        WRITE(NW,9002)
01750        READ(NR,530)K,KDS(K)
01760  560 CONTINUE
01770  570 CONTINUE
01780C  CONNECTIVITY DEFINED...SET FLAG.
01790       IF0=1
01800       GOTO 90
01810C
01820C  DEFINE BRANCHING NODES.
01830C
01840 1500 CONTINUE
01850       DO 1510 K=1,NXSEC
01860           IF(KDS(K).LT.0) KDS(K)=0
01870 1510 CONTINUE
01880       WRITE(NW,1520)
01890 1520 FORMAT(43H SUPPLY NO. OF BIFURCATION BRANCHES...(I5) )
01900       WRITE(NW,9001)
01910       READ(NR,530)NBRNCH
01920       IF(NBRNCH.EQ.0) GOTO 1560
01930       WRITE(NW,1530)NBRNCH
01940 1530 FORMAT(4H FOR,I4,42H BRANCHES, SUPPLY SEC. NO. AT THE UPSTREAM,/
01950+             52H LIMIT OF THE BRANCHING CHANNEL AND THE INTERMEDIATE,/
01960+             38H SEC. NO. OF THE MAIN CHANNEL....(2I5))
01970       DO 1550 NB=1,NBRNCH
01980        WRITE(NW,1540) NB
01990 1540  FORMAT(11H BRANCH NO.,I4)
02000        WRITE(NW,9002)
02010        READ(NR,530)K,KDSK
02020        KDS(K)=-KDSK
02030 1550 CONTINUE
02040       BRANCH=.TRUE.
02050       IF4=1
02060       GOTO 90
02070 1560 CONTINUE
02080       BRANCH=.FALSE.
02090       IF4=0
02100       GOTO 90
02110C
02120C  DEFINE TRIBUTARY INFLOWS...CHECK FIRST IF CONNECTIVITY DEFINED
02130C

02140 1000 CONTINUE
02150       IF(IF0.EQ.0) GOTO 500
02160       DO 1010 J=1,NXSEC
```

```
2170             QAR(J)=QMIN
2180 1010 CONTINUE
2190       NQS=NCONF+1-NBRNCH
2200       WRITE(NW,1020)NCONF,NBRNCH,NQS
2210 1020 FORMAT(4H FOR,I4,14H JUNCTIONS AND,I4,22H BRANCHES THERE SHOULD,/
2220+        3H BE,I4,45H TRIBUTARY INFLOWS AT THE FOLLOWING SECTIONS.,/,
2230+        37H SUPPLY INFLOW DISCHARGE (F10.3 ) AT:)
2240       I1=1
2250       NQS1=NQS+NBRNCH
2260       DO 1090 I=1,NQS1
2270        IF(KDS(I1).LT.0) GOTO 1060
2280        WRITE(NW,1030)I1
2290 1030  FORMAT(12H SECTION NO.,I4)
2300        WRITE(NW,9003)
2310        READ(NR,1040)Q1
2320 1040  FORMAT(F10.3)
2330        IF(Q1.LT.QMIN)Q1=QMIN
2340C
2350C  ACCUMULATE FLOWS IN DOWNSTREAM REACHES.
2360        J=I1
2370 1050  CONTINUE
2380        IF(J.EQ.999) GOTO 1060
2390        QAR(J)=QAR(J) + Q1
2400        J=J+1
2410        IF(KDS(J-1).GT.0) J=KDS(J-1)
2420        GOTO 1050
2430 1060  CONTINUE
2440C
2450C  FIND NEXT INFLOW SECTION.
2460        J=I1
2470 1070  CONTINUE
2480        IF(KDS(J).GT.0) GOTO 1080
2490        J=J+1
02500        GOTO 1070
02510 1080  CONTINUE
02520        I1=J+1
02530 1090 CONTINUE
02540       WRITE(NW,1100)
02550 1100 FORMAT(53H DO YOU WISH TO DEFINE POINT LATERAL INFLOW...YES/NO?)
02560       READ(NR,4050) ANS
02570       IF(ANS.EQ.1HN) GOTO 1200
02580       WRITE(NW,1110)
02590 1110 FORMAT(45H  SUPPLY NO. OF LATERAL INFLOW POINTS.....I5 )
02600       WRITE(NW,9001)
02610       READ(NR,1120) NLAT
02620 1120 FORMAT(I5)
02630       WRITE(NW,1130) NLAT
02640 1130 FORMAT(4H FOR,I5,38H LATERAL INFLOW POINTS, SUPPLY SECTION,/,
02650+           36H NO. AND LATERAL INFLOW....I5,F10.3 )
02660       DO 1190 I=1,NLAT
02670           WRITE(NW,1140) I
02680 1140      FORMAT(19H LATERAL INFLOW NO.,I5)
02690           WRITE(NW,9004)
```

```
02690            WRITE(NW,9004)
02700            READ(NR,1150) NODE, QLAT
02710 1150       FORMAT(I5,F10.3)
02720            J=NODE
02730 1160       CONTINUE
02740            QAR(J)= QAR(J) + QLAT
02750            IF(QAR(J).LE.QMIN) QAR(J)=QMIN
02760            IF(KDS(J).EQ.999) GOTO 1180
02770            IF(KDS(J).GT.0) GOTO 1170
02780            J=J+1
02790            GOTO 1160
02800 1170       CONTINUE
02810            J=KDS(J)
02820            GOTO 1160
02830 1180       CONTINUE
02840 1190 CONTINUE
02850 1200 CONTINUE
02860       WRITE(NW,1210) NXSEC
02870 1210 FORMAT(/,46H  INITIAL FLOW VALUES AT EACH NODE GOING FROM ,/,
02880+            6H  1 TO,I5,24H  INCLUSIVE, IN ORDER:- ,/)
02890       WRITE(NW,1220)(QAR(J),J=1,NXSEC)
02900 1220 FORMAT(5F10.3)
02910       IF1=1
02920       IF(.NOT.BRANCH) GOTO 90
02930 1230 CONTINUE
02940C
02950C COMPUTE APPROXIMATE FLOWS AT BRANCHES.
02960       DO 1320 NB=1,NBRNCH
02970        DO 1310 NS=1,NXSEC
02980          IF(KDS(NS).GE.0.OR.KDS(NS).LT.-1000) GOTO 1310
02990          IF(QAR(-KDS(NS)-1).LE.QMIN) GOTO 1310
03000          KDSK=-KDS(NS)
03010          QTOT=QAR(KDSK-1)
03020          CALL FINDXS(NTAPE1,KSREC,KDSK,HORZ1,VERT1,NPTS1,CHAIN,RC)
03030          CALL CRITIC(2,HORZ1,VERT1,NPTS1,QTOT,G,YCR,HCR)
03040          CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
03050          ECR=BOT+HCR
03060          CALL FINDXS(NTAPE1,KSREC,NS,HORZ1,VERT1,NPTS1,CHAIN,RC)
03070          CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
03080          IF(ECR.LE.(BOT+0.001)) GOTO 1240
03090          CALL QCR2D(HORZ1,VERT1,NPTS1,ECR,G,QCR,EKCR)
03100          QMAIN=QTOT*QTOT/(QTOT+QCR)
03110          QSIDE=QTOT-QMAIN
03120          GOTO 1250
03130 1240     CONTINUE
03140          QMAIN = QTOT-QMIN
03150          QSIDE = QMIN
03160 1250     CONTINUE
03170          K=NS
03180C  BRANCH CHANNEL
03190 1260      CONTINUE
03200           QAR(K)=QAR(K)+QSIDE
```

```
              K=K+1
              IF(KDS(K-1).GT.0) K=KDS(K-1)
              IF(K.EQ.NXSEC) GOTO 1270
              GOTO 1260
 1270         CONTINUE
              QAR(K)=QAR(K)+QSIDE
C  MAIN CHANNEL
              K=KDSK
 1280         CONTINUE
              QAR(K)=QAR(K)-QSIDE
              K=K+1
              IF(KDS(K-1).GT.0) K=KDS(K-1)
              IF(K.EQ.NXSEC) GOTO 1290
              GOTO 1280
 1290         CONTINUE
              QAR(K)=QAR(K) - QSIDE
 1300        CONTINUE
C
C  SET FLAG TO INDICATE BRANCH HAS BEEN PROCESSED.
             KDS(NS)=KDS(NS)-1000
 1310  CONTINUE
 1320 CONTINUE
C
C  RESET BRANCH NODES TO ORIGINAL VALUES.
        DO 1330 K=1,NXSEC
         IF(KDS(K).LT.-1000) KDS(K)=KDS(K)+1000
 1330 CONTINUE
        DO 1340 I=1,NXSEC
            IF(QAR(I).LT.QMIN) QAR(I)=QMIN
 1340 CONTINUE
        GOTO 90
C
C  DEFINE INDIVIDUAL DISCHARGE VALUES...THIS DEFINITION IS
C  INDEPENDANT OF CONNECTIVITY AND BRANCHING.
C
 2000 CONTINUE
        DO 2010 I=1,NXSEC
            QAR(I)=QMIN
 2010 CONTINUE
        WRITE(NW,2020)

 2020 FORMAT(53H ENTER NO. OF SUB-REACHES WITH DIFFERENT FLOWS...(I5))
        WRITE(NW,9001)
        READ(NR,2030)NOS
 2030 FORMAT(I5)
        WRITE(NW,2040)NOS
 2040 FORMAT(4H FOR,I4,39H DISCHARGES SUPPLY UPSTREAM SEC.NO. AND,
+            25H DISCHARGE...(I5,F10.2)  )
        DO 2080 J=1,NOS
         WRITE(NW,2050)J
 2050    FORMAT(10H REACH NO.,I4)
         WRITE(NW,9004)
         READ(NR,2060)I1,Q1
```

```
03730 2060  FORMAT(I5,F10.3)
03740        DO 2070 K=I1,NXSEC
03750          QAR(K)=Q1
03760 2070  CONTINUE
03770 2080 CONTINUE
03780       WRITE(NW,1210) NXSEC
03790       WRITE(NW,1220)(QAR(J),J=1,NXSEC)
03800       IF1=1
03810       GOTO 90
03820C
03830C  DEFINE DOWNSTREAM CONTROL SECTION AND LEVEL.
03840C
03850 2500 WRITE(NW,2510)
03860 2510 FORMAT(44H DEFINE SEC. NO. WHERE D/S WATER LEVEL TO BE,
03870+         18H SPECIFIED...(I5) )
03880       WRITE(NW,9001)
03890       READ(NR,530)NDS1
03900       IF(NDS1.LE.NXSEC.AND.NDS1.GT.0)  GOTO 2530
03910       WRITE(NW,2520)NDS1,NXSEC
03920 2520 FORMAT(1X,7HSEC.NO.,I4,16H OUT OF RANGE 1--,I3)
03930       GOTO 2500
03940 2530 WRITE(NW,2540)
03950 2540 FORMAT(30H DEFINE D/S WATER LEVEL, F10.3)
03960       WRITE(NW,9003)
03970       READ(NR,2550)DSWL1
03980 2550 FORMAT(F10.3)
03990       IF2=1
04000       GOTO 90
04010C
04020C  DEFINE RESISTANCE LAW TO BE USED.
04030C
04040 3000 IF(IF3.EQ.1) GOTO 3020
04050       WRITE(NW,3010)
04060 3010 FORMAT(43H SPECIFY RESISTANCE LAW BY TYPING ONE OF...,/,
04070+       53H CHEZY, MANNING, STRICKLER, COLEBROOK, SMOOTH, ROUGH,,/,
04080+       46H...P.S.  IS YOUR ROUGHNESS MEASURE COMPATIBLE?)
04090       GOTO 3040
04100 3020 WRITE(NW,3030)
04110 3030 FORMAT(27H RESPECIFY  RESISTANCE LAW ,/,
04120+            19H SEE PREVIOUS  NOTE)
04130 3040 READ(NR,3050) QN
04140 3050 FORMAT(A6)
04150       IF(QN.EQ.6HCHEZY .OR.
04160+         QN.EQ.6HMANNIN.OR.
04170+         QN.EQ.6HSTRICK.OR.
04180+         QN.EQ.6HCOLEBR.OR.
04190+         QN.EQ.6HSMOOTH.OR.
04200+         QN.EQ.6HROUGH ) GOTO 3070
04210       WRITE(NW,3060)
04220 3060 FORMAT(31H NOT RECOGNIZED...PLEASE RETYPE)
04230       GOTO 3040
04240 3070 IF3=1
```

```
250        GOTO 90
260C
270C  COMPUTE PROFILES
280C
290 4000 CONTINUE
300        NONE=0
310        NEVERY=0
320        NEND=0
330        NPRNT=0
340        ICOUNT=1
350        IZ=10
360        NUMITR=50
370C
380        IF(IF1.GT.0) GOTO 4020
390        WRITE(NW,4010)
4400 4010 FORMAT(1X,28HFLOWS SHOULD BE SPECIFIED...,
4410+         28HUSE 'INFLOWS' OR 'DISCHARGE')
4420       GOTO 90
4430 4020 CONTINUE
4440       IF(IF2.EQ.0) GOTO 2500
4450       IF(IF3.EQ.0) GOTO 3000
4460C
4470       IF(.NOT.BRANCH) GOTO 4090
4480       WRITE(NW,4030)
4490 4030 FORMAT(/,42H TWO OPTIONS ARE AVAILABLE FOR BRANCH FLOW,/,
4500+      56H COMPUTATION.  EITHER EVERY ITERATION CAN BE PRINTED OUT,/,
4510+      57H IN WHOLE OR PART --OR-- PRINTOUT STARTS AFTER A PREDEFINED,/,
4520+      34H ERROR IN DEPTH HAS BEEN REACHED. ,/)
4530       WRITE(NW,4040)
4540 4040 FORMAT(/,47H DO YOU WANT PROFILES AND/OR ERRORS PRINTED OUT,/,
4550+      33H FOR EVERY ITERATION.....YES/NO? )
4560       READ(NR,4050) ANS
4570 4050 FORMAT(A1)
4580       IF(ANS.EQ.1HN) GOTO 4060
4590       NEVERY=1
4600       GOTO 4090
4610 4060 CONTINUE
4620       WRITE(NW,4070)
4630 4070 FORMAT(54H SUPPLY PERCENT ERROR LIMIT FOR TERMINATION OF INITIAL
4640+      54H COMPUTATION OF WATER LEVELS AT BRANCHES(USUALLY 10.0),/,
4650+      13H ......F10.3 )
4660       WRITE(NW,9003)
4670       READ(NR,4080) PERCNT
4680 4080 FORMAT(F10.3)
4690       NEND=1
04700C
04710 4090 CONTINUE
04720C
04730C  ZERO WLS() AND ENLVS() ARRAYS
04740      DO 4100 J=1,NXSEC
04750       WLS(J)=0.0
04760       ENLVS(J)=0.0
```

```
04770 4100 CONTINUE
04780      NDS=NDS1
04790      DSWL=DSWL1
04800      KDSMAX=999
04810      NW2=NW
04820      IF(NONE.EQ.0) GOTO 4110
04830      IF(NEVERY.GT.0)  GOTO 4140
04840      IF(NEND.GT.0) GOTO 4170
04850 4110 CONTINUE
04860      WRITE(NW,4120)
04870 4120 FORMAT(55H SPECIFY UPSTREAM LIMIT OF PROFILE(S) BY SEC. NO...(I5)
04880      WRITE(NW,9001)
04890      READ(NR,4130)NUS1
04900 4130 FORMAT(I5)
04910      IF(.NOT.BRANCH) GOTO 4180
04920      IF(NEND.GT.0) GOTO 4170
04930C  EVERY ITERATION PRINTED OUT
04940 4140 CONTINUE
04950      NPRNT=1
04960      NONE=1
04970      WRITE(NW,4150) ICOUNT
04980 4150 FORMAT(50H DO YOU WANT PROFILES PRINTED FOR THIS ITERATION.(,
04990+               I5,1H),/,11H.....YES/NO)
05000      READ(NR,4160)ANSW
05010 4160 FORMAT(A1)
05020      IF(ANSW.EQ.1HN) NW2 = 0
05030      GOTO 4180
05040C
05050C  END RESULT PRINTED OUT ONLY
05060 4170 CONTINUE
05070      NW2=0
05080      NONE=1
05090 4180 CONTINUE
05100      PRNT=.FALSE.
05110      IF(NW2.GT.0)PRNT=.TRUE.
05120      IF(PRNT)WRITE(NW2,4190) TITLE
05130 4190 FORMAT(///,1X,10A6)
05140      IF(NUS1.LT.NDS.AND.NUS1.GT.0) GOTO 4200
05150      WRITE(NW,2520)NUS1,NDS
05160      NONE=0
05170      GOTO 4090
05180 4200 CONTINUE
05190C
05200C  START ANOTHER PROFILE
05210      VISC=0.0
05220      J=NDS
05230C
05240C  LOOK FOR UPSTREAM LIMIT OF PROFILE
05250 4210 CONTINUE
05260      J=J-1
05270      IF(J.LT.NUS1) GOTO 4220
05280      IF(KDS(J).LE.0) GOTO 4210
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290 4220 CONTINUE
300        NUS=J+1
310        IF(NUS.LT.NUS1) NUS=NUS1
320        IF(NUS.GE.NDS) GOTO 4230
330        CALL PROFL2(NTAPE1,KSREC,NW2,MXSEC,MAXPTS,NUS,NDS,
5340+          CLC,CLE,QN,VISC,G,DSWL,QAR,HORZ1,VERT1,
5350+          HORZ2,VERT2,WLS,ENLVS)
5360C
5370C   SEARCH FOR D/S SEC. WITH NON-ZERO WL
5380 4230 CONTINUE
5390       NEXT=1
5400       DO 4240 J=1,MXSEC
5410        IF(KDS(J).EQ.0) GOTO 4240
5420        IF(KDS(J).LT.NEXT) GOTO 4240
5430        IF(KDS(J).GE.KDSMAX) GOTO 4240
5440        NEXT=KDS(J)
5450        NDS=J
5460 4240 CONTINUE
5470       KDSMAX=NEXT
5480       CALL FINDXS(NTAPE1,KSREC,NDS,HORZ1,VERT1,NPTS1,CHAIN,RC)
5490       FR=0.5
5500       CALL WLFRE(HORZ1,VERT1,NPTS1,ENLVS(NEXT),QAR(NDS)
5510+       ,G,FR,DSWL)
5520       IF(NEXT.GT.NUS1) GOTO 4200
5530       IF(.NOT.BRANCH) GOTO 90
5540C
5550C   CHECK IF ENERGY LEVELS ARE EQUAL AT BRANCH NODES.
5560C
05570      DELWN=0.0
05580      DO 4420 K=1,MXSEC
05590      IF(KDS(K).GE.0) GOTO 4420
05600C
05610C  FIND U/S CONFLUENCE
05620      NBR=K
05630      KDSJ=-KDS(NBR)
05640C
05650C  GET HEAD LOSS TO BE CORRECTED (U/S MAIN - U/S BRANCH)
05660      DELTAH=WLS(-KDS(NBR)) - WLS(NBR)
05670C
05680C  CALC. CORRECTION TO FLOW BETWEEN BRANCH AND JUNCTION
05690      SUMM=SUMB=0.0
05700C  MAIN CHANNEL
05710      J=KDSJ+1
05720 4250 CONTINUE
05730      CALL FINDXS(NTAPE1,KSREC,J-1,HORZ1,VERT1,NPTS1,CHAIN,RC)
05740      CALL CRITIC(2,HORZ1,VERT1,NPTS1,QAR(J-1),G,YCR,HCR)
05750      CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
05760      IF(ENLVS(J-1).LE.HCR+BOT) GOTO 4260
05770      SUMM= SUMM + (ENLVS(J-1)-ENLVS(J))/QAR(J-1)
05780 4260 J=J+1
05790      IF(KDS(J-1).GT.0) GOTO 4270
05800      IF(J.EQ.MXSEC) GOTO 4290
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05810       GOTO 4250
05820 4270  CONTINUE
05830       CALL FINDXS(NTAPE1,KSREC,J-1,HORZ1,VERT1,NPTS1,CHAIN,RC)
05840       CALL CRITIC(2,HORZ1,VERT1,NPTS1,QAR(J-1),G,YCR,HCR)
05850       CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
05860       IF(ENLVS(J-1).LE.HCR+BOT) GOTO 4280
05870       SUMM=SUMM + (ENLVS(J-1) - ENLVS(KDS(J-1)))/QAR(J-1)
05880 4280  J=KDS(J-1) + 1
05890       IF(J.EQ.NXSEC) GOTO 4290
05900       GOTO 4250
05910 4290  CONTINUE
05920       SUMM = SUMM + (ENLVS(J-1) - ENLVS(J))/QAR(J-1)
05930C  BRANCH CHANNEL
05940       J= NBR + 1
05950 4300  CONTINUE
05960       CALL FINDXS(NTAPE1,KSREC,J-1,HORZ1,VERT1,NPTS1,CHAIN,RC)
05970       CALL CRITIC(2,HORZ1,VERT1,NPTS1,QAR(J-1),G,YCR,HCR)
05980       CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
05990       IF(ENLVS(J-1).LE.HCR+BOT) GOTO 4310
06000       SUMB = SUMB + (ENLVS(J-1) - ENLVS(J))/QAR(J-1)
06010 4310  J=J+1
06020       IF(KDS(J-1).GT.0) GOTO 4320
06030       IF(J.EQ.NXSEC) GOTO 4340
06040       GOTO 4300
06050 4320  CONTINUE
06060       CALL FINDXS(NTAPE1,KSREC,J-1,HORZ1,VERT1,NPTS1,CHAIN,RC)
06070       CALL CRITIC(2,HORZ1,VERT1,NPTS1,QAR(J-1),G,YCR,HCR)
06080       CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
06090       IF(ENLVS(J-1).LE.HCR+BOT) GOTO 4330
06100       SUMB = SUMB + (ENLVS(J-1) - ENLVS(KDS(J-1)))/QAR(J-1)
06110 4330  J=KDS(J-1) + 1
06120       IF(J.EQ.NXSEC) GOTO 4340
06130       GOTO 4300
06140 4340  CONTINUE
06150       SUMB = SUMB + (ENLVS(J-1) - ENLVS(J))/QAR(J-1)
06160C
06170       QNDEX=2.0
06180       DQ=-DELTAH/(QNDEX*(SUMM-SUMB))
06190C
06200C  DETERMINE PERCENT ERROR IN E.L. AND W.L. AND CALCULATE
06210C  A CORRECTION FACTOR FOR DQ
06220       MAIN= -KDS(NBR)
06230       DELTEL=ABS(ENLVS(MAIN) - ENLVS(NBR))
06240       DELTWL=ABS(WLS(MAIN) - WLS(NBR))
06250       N1E=MAIN
06260       N1W=MAIN
06270       CALL FINDXS(NTAPE1,KSREC,MAIN,HORZ1,VERT1,NPTS,CHAIN,RC)
06280       CALL BOTTOM(VERT1,NPTS,BOT,WLMAX)
06290       PCNTEN=DELTEL*100.0/(ENLVS(MAIN)-BOT)
06300       PCNTWN=DELTWL*100.0/(WLS(MAIN)-BOT)
06310       N2E=NBR
06320       N2W=NBR
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      CALL FINDXS(NTAPE1,KSREC,MBR,HORZ1,VERT1,NPTS,CHAIN,RC)
      CALL BOTTOM(VERT1,NPTS,BOT,WLMAX)
      PCNTEB=DELTEL*100.0/(ENLVS(MBR)-BOT)
      PCNTWB=DELTWL*100.0/(WLS(MBR)-BOT)
      PCNTE=PCNTEN
      PCNTW=PCNTWN
      IF(PCNTEB.GT.PCNTEN) PCNTE=PCNTEB
      IF(PCNTWB.GT.PCNTWN) PCNTW=PCNTWB
      IF(DELWN.LT.PCNTW) DELWN=PCNTW
C
      FACTOR=(PCNTE+PCNTW)/200.0
      IF(FACTOR.GT.0.1) FACTOR=0.5
      IF(FACTOR.LT.0.1) FACTOR=FACTOR*5.0
C
C    APPLY -FACTOR- TO CALCULATED DQ
      DQ=SQRT(DQ*DQ)*FACTOR
      IF(ENLVS(MBR).GT.ENLVS(-KDS(MBR))) DQ=-DQ
      IF(DQ.GE.0.0) GOTO 4350
      IF(-DQ.LT.QAR(MBR)) GOTO 4360
      DQ=QMIN-QAR(MBR)
      QAR(MBR)=QMIN
      GOTO 4360
 4350 CONTINUE
      IF(DQ.LT.QAR(-KDS(MBR))) GOTO 4360
      DQ=QAR(-KDS(MBR))-QMIN
      QAR(-KDS(MBR))=QMIN
 4360 CONTINUE
C
C  APPLY CORRECTION TO FLOWS BETWEEN BRANCH AND JUNCTION.
C
C  BRANCH
       J=MBR
 4370 CONTINUE
      QAR(J) = QAR(J) + DQ
      IF(QAR(J).LT.QMIN) QAR(J) = QMIN
      J= J + 1
      IF(KDS(J-1).GT.0) J = KDS(J-1)
      IF(J.EQ.NXSEC) GOTO 4380
      GOTO 4370
 4380 CONTINUE
      QAR(J) = QAR(J) + DQ
C  MAIN CHANNEL
      J = KDSJ
 4390 CONTINUE
      QAR(J) = QAR(J) - DQ
      IF(QAR(J).LT.QMIN) QAR(J) = QMIN
      J = J + 1
      IF(KDS(J-1).GT.0)  J = KDS(J-1)
      IF(J.EQ.NXSEC) GOTO 4400
      GOTO 4390
 4400 CONTINUE
      QAR(J) = QAR(J) - DQ
C
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06860C  RECORD E.L., W.L.  AND DQ FOR THIS BRANCH
06870       IF(NPRNT.EQ.0) GOTO 4420
06880       WRITE(NW,4410)MAIN,MBR,EMLVS(MAIN),EMLVS(MBR),PCNTE,
06890+                        WLS(MAIN),WLS(MBR),PCNTW,DQ
06900 4410 FORMAT(//,7H BRANCH,I5,5H  TO ,I5,/,
06910+        5H E.L.,2F10.3,31H DIFF AS PCNT OF SMALLER DEPTH=,F6.2,/,
06920+        5H W.L.,2F10.3,31H DIFF AS PCNT OF SMALLER DEPTH=,F6.2,/,
06930+       46H CORRECTION TO BRANCH FLOW FOR ENERGY BALANCE=,F10.3)
06940 4420 CONTINUE
06950C
06960       IF(NPRNT.GT.0) GOTO 4460
06970       ICOUNT=ICOUNT+1
06980       IF(ICOUNT.EQ.NUMITR) GOTO 4440
06990       IF(DELWM.LE.PERCNT) NEVERY=1
07000       IF(DELWM.LE.PERCNT) NEND=0
07010       IF(ICOUNT.EQ.IZ.AND.NEND.GT.0) WRITE(NW,4430)
07020 4430 FORMAT(15H  COMPUTING....)
07030       IF(ICOUNT.EQ.IZ) IZ=IZ+10
07040       GOTO 4090
07050 4440 NEVERY=1
07060       NEND=0
07070       WRITE(NW,4450) NUMITR,PERCNT
07080 4450 FORMAT(//,6H AFTER,I5,38H  ITERATIONS, THE MAXIMUM ERROR IN ONE,/,
07090+        34H OR MORE BRANCHES IS GREATER THAN ,F10.2,9H PERCENT.,/,
07100+        34H ONE MORE ITERATION WILL BE TRIED )
07110       GOTO 4090
07120 4460 ICOUNT=ICOUNT+1
07130       WRITE(NW,4470)
07140 4470 FORMAT(//,42H DO YOU WANT PROFILES RECOMPUTED...YES/NO?)
07150       READ(NR,60)ANS
07160       IF(ANS.EQ.3HYES) GOTO 4090
07170       GOTO 90
07180C
07190C  CALCULATE CRITICAL FLOW CONDITIONS AT A SECTION.
07200C
07210 5000 IF(IF1.EQ.0) GOTO 2000
07220 5010 WRITE(NW,5020)
07230 5020 FORMAT(25H SPECIFY SECTION NO.   I5)
07240       WRITE(NW,9001)
07250       READ(NR,5030) ICRIT
07260 5030 FORMAT(I5)
07270       IF(ICRIT.LE.MXSEC.AND.ICRIT.GT.0) GOTO 5040
07280       WRITE(NW,2520) ICRIT,MXSEC
07290       GOTO 5010
07300 5040 CONTINUE
07310       Q=QAR(ICRIT)
07320       CALL FINDXS(NTAPE1,KSREC,ICRIT,HORZ1,VERT1,NPTS1,CHAIN,RC)
07330       CALL CRITIC(2,HORZ1,VERT1,NPTS1,Q,G,YCR,HCR)
07340       CALL BOTTOM(VERT1,NPTS1,BOT,WLMAX)
07350       WRITE(NW,5050) ICRIT,Q,YCR+BOT,HCR+BOT
07360 5050 FORMAT(7H AT SEC,I3,8H WITH Q=,F10.3,/,
07370+          29H      CRITICAL WATER LEVEL  =,F8.3,5H  AND,/,
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7380+          29H      CRITICAL ENERGY LEVEL =,F8.3)
7390      GOTO 90
7400C
7410C  DEFINE HEAD-LOSS COEFFICIENT AT A TRANSITION.
7420C
7430 5500 WRITE(NW,5510) CLC,CLE
7440 5510 FORMAT(33H HEAD LOSS COEFFICIENTS AT TRANSITIONS,/,
7450+        24H ARE PRESENTLY SET AT :--,/,
7460+        19H CONTRACTIONS-- CLC=,F10.3,5X,17H EXPANSIONS-- CLE=,F10.3,/,
7470+        45H DO YOU WISH TO CHANGE THESE VALUES...YES/NO?)
7480      READ(NR,5520)ANS
7490 5520 FORMAT(A1)
7500      IF(ANS.EQ.1HY) GOTO 5530
7510      IF5=1
7520      GOTO 90
7530 5530 WRITE(NW,5540)
7540 5540 FORMAT(33H SPECIFY --CLC-- AND --CLE-- IN ORDER,/,
7550+        27H (0.0 TO 1.0),    2F10.3...)
7560      WRITE(NW,9005)
7570      READ(NR,5550) CLC,CLE
7580 5550 FORMAT(2F10.3)
7590      IF(CLC.GE.0.0.OR.CLC.LE.1.0.AND.CLE.GE.0.0.OR.CLE.LE.1.0)GOTO557
7600      WRITE(NW,5560) CLC, CLE
7610 5560 FORMAT(13H EITHER CLC =,F10.3,9H OR CLE =,F10.3,
7620+            13H NOT IN RANGE)
7630      GOTO 5530
7640 5570 IF5=1
7650      GOTO 90
07660C
07670C   MAKE CHANGES TO CROSS SECTION DATA
07680C
07690 6000 CONTINUE
07700      CALL EDITXS(NTAPE1,NTAPE2,KSREC,ITST1,NXSEC,NAXPTS,
07710+                NR,NW,0)
07720      RETURN
07730C
07740C   SUMMARIZE INPUT DATA
07750C
07760 6100 CONTINUE
07770      WRITE(NW,6105) TITLE
07780 6105 FORMAT(///,27H SUMMARY OF INPUT DATA FOR ,//,1X,10A6,//)
07790      UNIT=10H--IMPERIAL--
07800      IF(G.GT.9.0.AND.G.LT.11.0) UNIT=10H --METRIC--
07810      WRITE(NW,6110) UNIT
07820 6110 FORMAT(/,18H  UNITS USED ARE  ,A10,//)
07830      IF(IF0.GT.0.OR.IF4.GT.0) GOTO 6160
07840 6120 IF(IF1.GT.0) GOTO 6230
07850 6130 IF(IF2.GT.0) GOTO 6240
07860 6140 IF(IF3.GT.0) GOTO 6260
07870 6150 GOTO 6280
07880C
07890 6160 CONTINUE
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07900       WRITE(NW,6170)
07910 6170 FORMAT(/,21H  CONNECTIVITY TABLE )
07920       NIT=NNSEC/10
07930       IF(NIT.GT.0) GOTO 6180
07940       GOTO 6220
07950 6180 CONTINUE
07960       DO 6210 I=1,NIT
07970            I1= 10*(I-1) + 1
07980            I2= 10*I
07990            WRITE(NW,6190)(II,II=I1,I2)
08000 6190       FORMAT(/,10H NODE NO. ,10I5)
08010            WRITE(NW,6200)(KDS(II),II=I1,I2)
08020 6200       FORMAT(10H KDS(NODE),10I5)
08030 6210 CONTINUE
08040       NN=NNSEC- 10*NIT
08050       IF(NN.LE.0) GOTO 6120
08060       I1=10*NIT + 1
08070       I2=I1+NN-1
08080       WRITE(NW,6190)(II,II=I1,I2)
08090       WRITE(NW,6200)(KDS(II),II=I1,I2)
08100       GOTO 6120
08110 6220 CONTINUE
08120       WRITE(NW,6190)(II,II=1,NNSEC)
08130       WRITE(NW,6200)(KDS(II),II=1,NNSEC)
08140       GOTO 6120
08150C
08160 6230 CONTINUE
08170       IF(IF4.GT.0) GOTO 6235
08180       WRITE(NW,1210) NNSEC
08190       WRITE(NW,1220)(QAR(J),J=1,NNSEC)
08200       GOTO 6130
08210 6235 CONTINUE
08220       WRITE(NW,6236)
08230 6236 FORMAT(/,42H SINCE BRANCHED FLOWS ARE BEING MODELLED, ,/,
08240+                38H INITIAL FLOWS ARE NOT PRINTED OUT IN ,/,
08250+                37H ORDER TO PREVENT POSSIBLE CONFUSION.,/)
08260       GOTO 6130
08270C
08280 6240 CONTINUE
08290       WRITE(NW,6250) NDS1, DSWL1
08300 6250 FORMAT(/,28H INITIAL WATER LEVEL AT NODE,I5,4H  IS,F10.3)
08310       GOTO 6140
08320C
08330 6260 CONTINUE
08340       IF(QN.EQ.6HCHEZY ) FNAME=10H  CHEZY
08350       IF(QN.EQ.6HMANNIN) FNAME=10H MANNING
08360       IF(QN.EQ.6HSTRICK) FNAME=10HSTRICKLER
08370       IF(QN.EQ.6HCOLEBR) FNAME=10HCOLEBROOK
08380       IF(QN.EQ.6HSMOOTH) FNAME=10H  SMOOTH
08390       IF(QN.EQ.6HROUGH ) FNAME=10H  ROUGH
08400       WRITE(NW,6270) FNAME
08410 6270 FORMAT(/,31H RESISTANCE LAW BEING USED IS --,A10,1H-)
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08420       GOTO 6150
08430C
08440 6280 CONTINUE
08450       WRITE(NW,6290) CLC, CLE
08460 6290 FORMAT(/,39H HEAD LOSS COEFF. AT CONTRACTIONS CLC =,F10.3,/,
08470+            39H                    AT EXPANSIONS   CLE =,F10.3,//)
08480       GOTO 90
08490C
08500 9000 STOP
08510C
08520       END
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