SEDIMENTATION STUDY OF THE YAZOO RIVER BASIN

USER MANUAL FOR PROGRAM KUWASER

CONTRACT NO. DACW 38-76-C-0193

Prepared for

U. S. ARMY CORPS OF ENGINEERS
VICKSBURG DISTRICT

Vicksburg, Mississippi

Prepared by

Civil Engineering Department
Engineering Research Center
Colorado State University
Fort Collins, Colorado

D. B. Simons
R. M. Li
G. O. Brown

August, 1979

CER79-80DBS-RML-GOB6

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AUTHORIZATION

The program described here was developed for the U.S. Army Corps of Engineers, Vicksburg District, Lower Mississippi Division, under contract No. DACW38-76-C-0193. Larry Banks and Larry Eckenrod were the authorized Project Managers for the Vicksburg District and Daryl B. Simons and Ruh-Ming Li were the Principal Investigators for Colorado State University.

The purpose of the contract was to determine the extent of sediment problems in the mainstem Yazoo-Tallahatchie-Coldwater River System and principal tributaries excluding the Big Sunflower River Basin. The following model, KUWASER, was developed for use in the study.

In accordance with the contract this User's Manual describes the known discharge, uncoupled sediment routing model developed.

ACKNOWLEDGEMENTS

The writers wish to extend their appreciation to all those who assisted in the development of this model and to express special thanks to Louise Barkau, Jurgen Garbrecht, Lan-Yin Li and Ian O'Neill for their aid in programming and model documentation. Also, Larry Banks and Larry Eckenrod, the Project Managers for the Corps of Engineers, provided valuable guidance in the formation of the model. Without their help it would have been impossible to apply the model to the Yazoo River Basin.

PROGRAM SPECIFICATIONS

A. TITLE OF PROGRAM: KUWASER, known discharge, uncoupled, sediment routing.

B. AUTHORS: Daryl B. Simons, Ruh-Ming Li, and Glenn O. Brown

C. DATE PROGRAM COMPLETED: July 1979

D. PURPOSE OF PROGRAM: To compute the spatially varied flow profile, sediment transport, and aggradation-degradation in rivers. The program can be applied to a single stream or an entire river basin, accomodating divided flow rivers.

E. EQUIPMENT REQUIREMENTS:

Language: ANSI FORTRAN IV

Central Memory Core Storage: Problem dependent (61000_8 on CDC 172, with arrays dimensioned for 100 cross sections, 10 river reaches and 10 tributaries per reach.)
Central-Processor Time: 0.01 to 0.05 c.p. seconds on CDC 172 for one time-space calculation.

Peripheral Equipment: Minimum requirements are printer and one input device, such as a card reader. The program has refined input-output features which utilize up to three input devices and three output devices.

F. SIZE OF OBJECT CODE: 2300, 80 character lines.

G. INPUT: Requirements include digitized channel cross sections, Manning's n values for channel and overbank, river system configuration, downstream stage control, point source tributary sediment rating curves and the known discharge at each cross section.

H. OUTPUT: Output is user controlled. Output options include aggradation-degradation at each cross section, maximum water surface elevations, minimum bed elevations, and cross section hydraulic properties (area, depth, conveyance, velocity, sediment transport, alpha, discharge and water surface elevation) for each time period.

I. GENERAL EQUATIONS: The program solves the spatially varied flow, Manning's and sediment continuity equations. These equations are:

Spatially Varied Flow equation

$$\frac{dD}{dx} = S_o - S_h - \frac{d}{dx} (\alpha \frac{V^2}{2g})$$

Manning's Equation

$$V = \frac{1.486}{n} R^{2/3} S_f^{1/2} \quad \text{(English Units)}$$

Sediment Continuity

$$\frac{\partial Q_s}{\partial x} + (1 - \rho) \frac{\partial A_b}{\partial t} = q_{s\ell}$$

Where D is the thalweg depth, x is the distance along the channel, S_o is the bed slope, S_h is the total head slope, α is the velocity distribution coefficient, g is the acceleration of gravity, V is the average flow velocity, n is the Manning's n-value, S_f is the friction slope, R is the hydraulic radius, Q_s is the volume rate of sediment transport, ρ is the sediment deposit porosity, A_b is the area of bed area deposited or eroded, t is time, and $q_{s\ell}$ is the lateral sediment input per unit length of channel.

J. RANGE OF APPLICATION: The program is presently limited to subcritical flow, and cannot predict channel armoring or two-dimensional flow effects. The known discharge uncoupled formulation limits the model to cases where the change in the bed is small during any one time period, and the rate of change of the water hydrograph is small.

K. ACCURACY: Governed by input data and calibration.

L. DIMENSION SYSTEM: English or metric.

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LIST OF VARIABLES

A_b	bed area
a_n, b_n	coefficients of Manning-n function
a_t, b_t	coefficients of tributary sediment rating curve
D	depth of flow
D_{lob}	left overbank station
D_{rob}	right overbank station
d	depth of flow normal to the bed
g	acceleration of gravity
n	Manning's n-value
n_o	initial Manning's n-value
Q	water discharge
Q_A,Q_B,Q_C	discharge at points A, B, C
Q_ℓ	tributary water discharge
Q_{nps}	non-point source discharge
Q_s	sediment transport
Q_{s_ℓ}	tributary bed material discharge
$q_{s\ell}$	lateral sediment input per unit width of channel
R	hydraulic radius
S_f	friction slope
S_h	total head slope
S_o	bed slope
S_s	sediment specific weight
t	time
V	flow velocity
W	channel width

w	fall velocity
X	particle settling length
X_A, X_C, X_D	river distance at points A, C, and D respectively
x	distance along the channel
Z_{ob}	overbank elevation
α	velocity distribution coefficient
ρ	sediment deposit porosity
ν	water's kinematic viscosity

I. INTRODUCTION

A problem of increasing importance for water resources planning and environmental impact analysis is determining the response of a river system to man's activities. Many rivers have been and continue to be developed for navigation, recreation, flood control, and environmental enhancement. Since rivers are dynamic systems, short- and long-term responses must be determined in order to evaluate the various development alternatives and prevent potential disaster associated with man's activities.

A river's response can be determined by either physical or mathematical physical process models. Physical models are limited by size and cannot model large systems or long periods of time. There are several process models presently in use such as RIVER (Chen, 1975) and HEC-6 (Hydrologic Engineering Center, 1976). While mathematical models do not have a size limitation they are usually limited to simulation periods of a year or two, because of computer costs. With complex problems involved in large basin analysis, it was necessary to develop a new model, KUWASER, in the Sedimentation Study of the Yazoo River Basin for the United States Army Corps of Engineers, Vicksburg District, (Simons, Li, Brown, Chen, Ward, Doung, and Ponce, 1978).

In determining long-term river system response, sediment movement through a river system is of primary concern and detailed information on flood wave movement is of secondary importance. Except when lateral inflow occurs, it is reasonable to assume the discharge is constant along a river reach during an individual computational time-interval. In this case the complete flow routing equations of St. Venant reduce to the equation of spatially varied steady flow. This equation can be solved along traditional lines provided significant changes in bed elevations are not occurring during the time interval. This approach, involving sequential (uncoupled) application of steady flow and sediment equations, is the basis of the present model, KUWASER. Programs of this type are called known discharge uncoupled sediment routing models. The known discharge, uncoupled sediment routing formulation has allowed development of an extremely fast and efficient model, that makes the long-term simulation of sediment movement feasible.

Known-discharge formulation requires the user to identify for the mathematical model water discharge throughout the system for the entire modeling period. Water discharge is determined by either assuming steady flow or using a separate unsteady flow routing model. The model computes the water surface profile by assuming gradually varied steady flow. The time increment used in the input hydrographs may vary from a few hours to a month or longer, depending on the flow conditions and required accuracy of the results. Since it does not linearize the momentum equation, the model accurately simulates unsteady flow profiles when coupled with an acceptable unsteady flow water routing model. Most routing programs presently used, such as HEC-6, utilize a trial and error standard step method to calculate the backwater curve. However, KUWASER differs from these models in that it utilizes channel geometry relationships in an analytical, first order Newton's approximation to solve for the backwater profile. This method is more efficient than the trial and error algorithm.

The program can perform backwater calculations and sediment routing in mainstem and multiple tributaries including divided flow reaches.

With this feature it is possible to determine the response of tributaries to changes on the mainstem, such as channel improvement, realignment, or dredging and to determine response of the mainstem river to tributary modifications. Therefore, the most efficient tributary management procedures can be determined to minimize the mainstem sedimentation problems.

Since the water and sediment calculations are uncoupled, the computations are solved sequentially, i.e., the water surface profile is computed for the current time period assuming a fixed bed and then sediment routing is performed at the end of the time period. Any channel cross sectional changes due to aggradation or degradation are determined before the start of the next time period.

To save computer time, cross section geometry is not changed every time period to reflect increase or decrease of sediment volume at the cross sections due to sediment routing. After a significant amount of sediment has been aggraded or degraded at a cross section, the channel geometry is modified. When the bed elevation has changed more than a threshold value (for example, one-half foot), the area of degradation or aggradation is distributed through the cross section and new channel geometry relationships are calculated to reflect changes in the hydraulic properties of the channel. The model uses a method that relates the change in bed elevation at a point to the flow conveyance above the point. This method predicts more accurately the distribution of aggradation or degradation in the cross section and estimates channel response more adequately than a conventional one-dimensional model.

Unlike other models, KUWASER was developed according to the modularity concept. The model consists of linked components that represent a specific physical process or function. This modularity allows a greater flexibility for updating and improving the various components of the model. The mathematical model is compatible with the data storage and retrieval system developed in the Yazoo Study (Simons, Li, and Doung, 1978). This makes it simple to obtain and format all data required to operate the model.

The following sections describe the application theory of temporal and spatial design's development, program input and output, and an example application. The appendices contain program theory, flow charts, variable definitions, and listings.

II. TEMPORAL AND SPATIAL DESIGNS

GENERAL

Spatial and temporal designs are necessary to provide a realistic representation of the space-time structure for the simulation model. Information on the river and its tributaries, their location, and the location of all pertinent gaging stations, structures and confluences allow the spatial design of a large river basin to be developed. Spatial designs should also consider the purposes of the study. Temporal design of a system is made using the historic hydrologic records of the watershed or river basin. The records should include water flows, river stages, sediment transport, and effect of man's activities, such as reservoir construction, on the hydrologic record. Temporal designs must be compatible with the spatial design. Therefore, only those records pertinent to areas and river reaches included in the spatial design need to be analyzed.

TEMPORAL DESIGN

General

Temporal design refers to the model's representation of changes in water and sediment input to the river system with time as well as the changes in water discharge and the sediment transport throughout the system. Temporal design should be as realistic as possible considering the system being modeled. Because river systems differ greatly in their temporal characteristics and data availability, KUWASER was designed to require that the user supply the water discharge at each cross section for each time period. While this requires additional user time and effort, it allows the user to more accurately model the system.

While the user may define water discharge in any way he chooses, three methods described here to illustrate temporal designs are, constant discharge, flow continuity, and unsteady flow routing.

The program also requires a reasonably accurate sediment rating curve for each point source tributary. Tributary sediment is determined by measurements or by an empirical method. In addition the relationship between the Manning n-value and the discharge is required. The following describes the three methods of computing water discharge, two methods for determining the tributary rating curve, and an explanation of the determination of the Manning n-value relationship.

Computation of Discharge

Constant Discharge

Figure 1 shows a typical river reach. The reach extends from A to C and has a point source of water and sediment at B. When steady flow is assumed, the discharge is considered constant in a river reach except where lateral inflow occurs. In this example, if the discharge is known at two points, the discharge anywhere in the river can be computed. Thus, if Q_A, Q_B and Q_C are the discharges at the respective points and Q_A and Q_B are known, the discharge in the river from point A to B is equal to Q_A and the discharge from point B to C is equal to Q_C and is computed by

$$Q_C = Q_A - Q_B \qquad (1)$$

The flow at each cross section during each time period can thus be determined.

Flow Continuity

If the discharge is known at all three points in Figure 1 the system is over defined for the constant discharge assumption. Usually

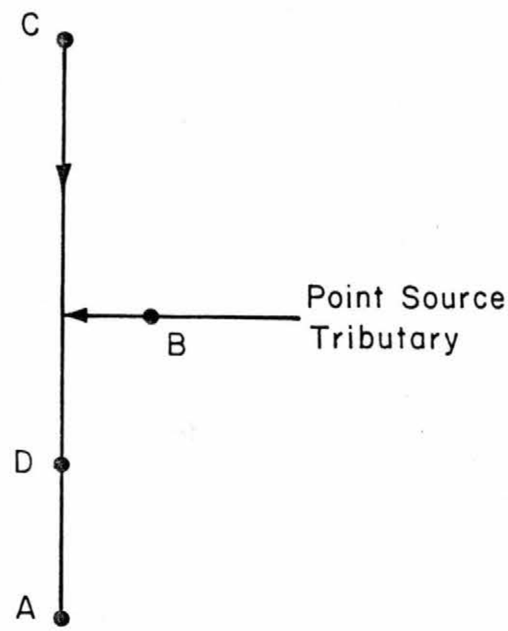


Figure 1. A typical reach of river.

in a natural river $Q_C + Q_B \neq Q_A$. In these cases a non-point source, Q_{NPS} is defined as

$$Q_{NPS} = Q_A - (Q_C + Q_B) \tag{2}$$

The sign of the non-point source is either positive or negative.

Non-point sources are usually distributed throughout the reach in a uniform manner based on the river distance. If X_A and X_C are the river distances of the respective points and X_D is the river distance of a point D, between points A and B, then the discharge at the point, Q_D is computed by

$$Q_D = Q_B + Q_C + \frac{X_D - X_A}{X_C - X_A} \quad Q_{NPS} \tag{3}$$

This type of approach is used in the Sedimentation Study of the Yazoo River Basin (Simons, Li, Ward, and Duong, 1978), that also contains a detailed description of the temporal design used.

Unsteady Routing

Unsteady flow effects can be modeled if the known discharge model is coupled with an acceptable unsteady flow routing model. Acceptable unsteady models include but are not limited to simple storage routing models and kinematic wave models.

When coupling an unsteady flow model to the known discharge model, the user uses a separate program to generate the discharge at each cross section, for each time period. These discharges are then fed to KUWASER which computes the water surface profile for the particular time interval.

Tributary Sediment Rating Curves

Measured Curves

Each point source tributary requires a sediment rating curve of the form

$$Q_{s\ell} = a_t \, Q_\ell^{\,b_t} \tag{4}$$

where $Q_{s\ell}$ is the tributary bed material discharge, Q_ℓ is the tributary water discharge and a_t and b_t are the coefficients of the rating curve.

The best way to determine the rating curve for a stream is to take several measurements of the tributary water and sediment discharge, and then determine by least squares analysis the coefficients of the rating curve. When the rating curve is determined in this manner care must be taken to ensure only bed material is included in the sediment discharge and that measurements cover the full range of tributary flows.

Synthetic Curves

When it is not possible to obtain tributary sediment measurements the rating curve for a particular stream can be determined by a theoretical method using the tributary's cross-sectional shape, thalweg slope, bed material size and estimated Manning's n value. There are five basic steps to the process. First, the range of the tributaries' water discharge is determined for at least ten flow levels over the whole range are selected. Second, Manning's equation is applied using the channel shape and slope, to determine the depth, width, and velocity of flow for each flow level. Third, using a sediment transport equation such as Einstein's or a combination Meyer-Peter, Müller's and Einstein's the bed material transport is determined for each flow level. Fourth, a curve is fitted either by hand or least squares regression, to the computed sediment and water discharge values to obtain the coefficients a_t and b_t. Finally, the coefficient a_t is calibrated by running the model and observing the short term change in the mainstem bed elevation near the tributary. If the bed degrades then the coefficient a_t is probably too low. However, if the bed aggrades a_t should be decreased.

Manning's n-Value Rating Curve

Manning's n-value for an alluvial stream is not constant but is a function of discharge and depth of flow (Simons and Sentürk, 1976). While there are complicated but fairly exact procedures to determine channel roughness in the program Manning's n-value is made a simple function of discharge.

$$n = n_o a_n Q^{b_n} \qquad (5)$$

where n is the actual Manning's n-value, n_o is the initial value of Manning's n that is input with the cross sections, Q is the discharge and a_n and b_n are the coefficients of the relationship. The values of the coefficients are a function of the stream's hydraulics and range of discharge.

To determine the values of a_n and b_n first estimate the n-value for a high and low flow discharge. With the initial n-value, by solving simultaneous equations, the values of a_n and b_n can be determined. The program can then be run for several discharge levels that have known water surface profiles and the error for each discharge determined. New values of a_n and b_n can then be computed which reduce the error in the water surface profile through the whole range of flows. The new value of the coefficients may be either estimated or calculated by least squares analysis. The process is then repeated until no reduction in error is obtained. It should be remembered that the coefficient a_n will be a small positive number and the coefficient b_n should be negative.

SPATIAL DESIGN

General

Spatial design refers to the model's representation of the physical characteristics of the river system. It includes relative information on the location of the various river reaches and tributaries, as well as data on channel properties.

Data required for the spatial design are:

1. digitized channel cross sections with over bank stations and Manning's n values;

2. division of river system into reaches;

3. river distance between cross sections;

4. tributary locations; and

5. locations of any structures.

In addition historical cross section measurements are necessary to calibrate the model.

The following describes considerations to be made in data development of spatial designs.

River Reaches

For program operation a river system is divided into reaches. A river reach is used as a basic computational unit, and as such should represent a single channel with the following hydraulic and sediment properties almost constant:

1. sediment transport,

2. cross section size,

3. channel roughness, and

4. discharge.

The necessary reach divisions required for program operation are described in Section IV.

Tributaries

Tributaries supply water and sediment input to the mainstem river. The program allows for four different types of tributaries

1. point source in,

2. major tributary in,

3. point source out, and

4. major tributary out.

Point source tributaries are tributaries for which no backwater or sediment routing calculations are made. The water discharge (either in or out) is read, and the tributary sediment is computed using a rating curve.

Major tributaries are tributaries to the mainstem that are separate river reaches on which backwater and sediment transport calculations are conducted. There is no limit on the level of tributaries that can be modeled. Therefore the mainstem may have major tributaries, that in turn have major tributaries, and so on.

For divided flow sediment routing, the model assumes that two reaches act as tributaries to one another. The secondary reach will act as a major tributary out of the primary reach at the top, and as a major tributary into the primary reach at the bottom. Likewise the primary reach will act as a major tributary into and out of the secondary reach.

The discharge for each point source tributary is read with the cross section discharges. Point source discharge locations are termed discharge sections and are defined by the user. Discharge sections do not have digitized cross sections associated with them, only a discharge value in the flow array.

Cross Sections

Geometry

Channel cross sections are defined by (x,z) sets of coordinates. Figure 2 shows a typical cross section. To allow for different Manning's n-values across the section three subdivisions are made: Right Over Bank, Main Channel, and Left Over Bank. Subsections are divided by two stations D_{lob} and D_{rob}, as shown in Figure 2. The Manning's n-value at each coordinate point is determined by its location in either the over banks or main channel.

Hydraulic property relationships are computed to relate area of flow, conveyance, alpha, effective depth, and effective width to the thalweg depth. Two separate sets are calculated: one set for main channel flow and a second for overbank flow. The division between main channel and overbank flow is the user defined elevation Z_{ob}. If the overbank elevation is different for the left and right banks the lower of the bank elevations should be used as Z_{ob}. If the water surface is above a coordinate end point (first or last points), the area of flow is determined by extending a vertical line to the water surface from the end point.

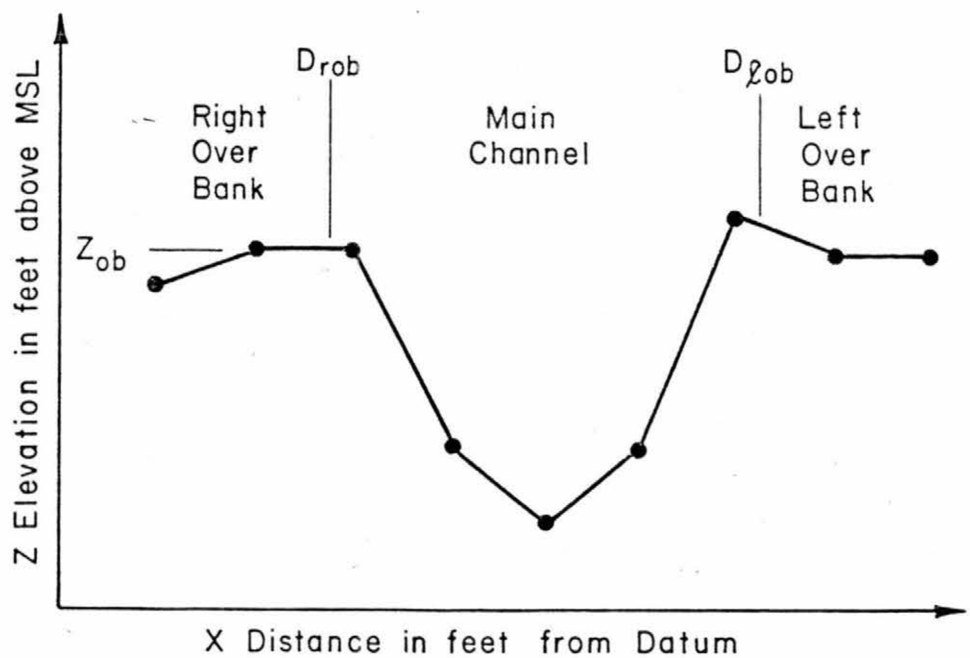


Figure 2. Typical channel cross section with subdivisions.

Cross Section Spacing

To help maintain numerical stability in the sediment routing, channel cross sections should be evenly spaced. Also it should be remembered that the present model cannot simulate differences among actual and potential sediment transport (calculated by Equation 6) as well as sediment dispersion and other processes particular to a small simulation space interval. Therefore the minimum cross section spacing should be based on the river hydraulics and bed material size. Dispersion effects are not usually significant when cross section spacing exceeds the average downstream distance when bed material particles settle if released from the water surface. Generally, the following procedure can be used.

Figure 3 shows the principle used in estimating particle fall distance. First, estimate the average depth and flow velocity. Second, determine fall velocity for the d_{50} bed material particle size (the particle size for which 50% of the sediment mixture is finer). Sediment fall velocity can be determined by several methods (Simons and Suntürk, 1977) but for this purpose Rubey's formula for particles less than 1 mm in size is adequate.

$$w = \frac{\sqrt{\frac{2}{3} g(S_s - 1)\ d_{50}^3 + 36\nu^2} \quad -6\nu}{d_{50}} \qquad (6)$$

where w is the fall velocity, g is the exceleration of gravity, S_s is the sediment specific weight (2.65 for quartz sand), and ν is the kinematic viscosity of water. Particle settling length X, is then computed by

$$X = \frac{D}{w} V \qquad (7)$$

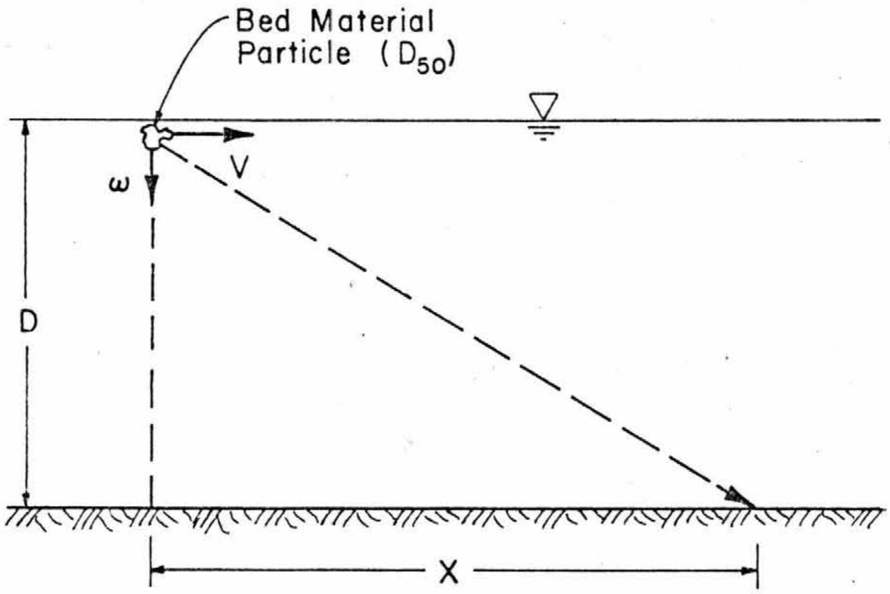


Figure 3. Particle settling length.

The above procedure is only general and as such tighter spacing may be used with discretion. There is no numerical upper limit on spacing but usually for accuracy of the sediment routing, it is recommended that maximum spacing does not exceed 10 X. Cross sections should also be located in areas of interest, control points, and at locations of sudden water surface profile changes.

Weirs

Weirs are represented in the model by a double cross section in a reach with the same river mile. The program computes the water surface elevation at the weir by both backwater and broad crested weir formula, and uses the greater of the two.

The amount of sediment over the weir is computed as a percentage of the sediment transport at the next upstream cross section.

III. INPUT DATA

GENERAL

This section lists important input variables by the data type along with suggested values, while the next section defines structure and format of actual input files. The suggested values for the input variables are presented to help the first time user in operating the program. With experience, the user should be able to determine the best values of the input for his problem.

The program can operate in either English or Metric (SI) unit systems. When using the English system dimensional input variables should be in feet and seconds, except for river distances of cross sections and tributaries that are in miles and time period lengths that are in days. When using the SI system input variables are in meters and seconds, with the exception of river distances that are in kilometers, and time period lengths that are in days.

GENERAL DATA

The following variable must be defined for each run.

TITLE	The job title
IPRNT	The print controls, see Section V
MST	Maximum number of iterations for backwater calculations ($MST \leq 10$)
EPS	The convergence limit for backwater ($EPS \leq 0.10$ ft.)
PORM	The sediment deposit porosity ($PORM \approx .3$)
CE	The coefficient of expansion losses ($CE \approx .3$)
CC	The coefficient of contraction losses ($CC \approx .1$)
IUNIT	The unit system: 1 - ENGLISH; 0 - METRIC

COUNTERS

The following counters must be defined.

NSEC	Number of cross sections
NTIM	Number of time periods
NRIV	Number of river reaches
NQI	Number of input discharges
NCALL	Number of subroutine calling sequence (see following)

SUBROUTINE CALLING SEQUENCE

The program requires the user to input the order in which the various backwater and sediment routing routines are called. The calling sequence is a function of spatial design and thus differs from river to river. To develop the calling sequence the user needs a basic understanding of the program operation. Figure 4 shows the gross program flow and the order that each operation should be carried out. For each subroutine call (NC) the following variables must be defined.

ICALL(NC,1)	Subroutine number code
ICALL(NC,2&3)	Dependent on subroutine

Table 1 gives an explanation of the variable ICALL.

CALLING SEQUENCE ORDER

The following is a set of guidelines for determining the order in which the various subroutines are called. While the sequence of subroutine calls is not strictly order dependent, the user must have a through knowledge of the program operation before attempting to vary from these guidelines.

1. FLOW is called first to determine discharges.

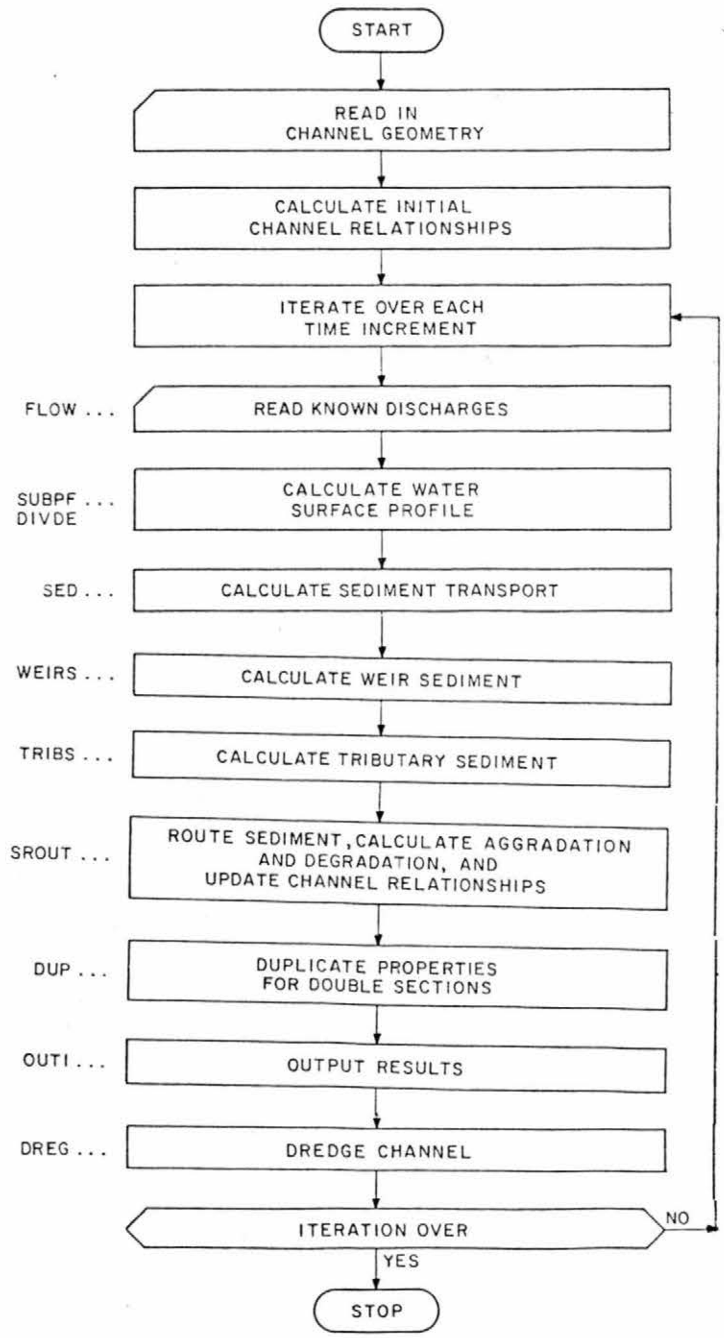


Figure 4. Subroutine used in operations.

Table 1. Subroutine calling sequence.

Value of ICALL(NC,1)	Subroutine Called	Operation Performed	Value of ICALL(NC, 2&3)*	
			2	3
1	FLOW	Determine discharge at each cross section	---	---
2	SUBPF	Calculate water surface profile	A	---
3	DIVIDE	Compute divided flow reach	B	C
4	SED	Calculate sediment transport at each section	---	---
5	WEIRS	Calculate sediment transport over weir	D	E
6	TRIBS	Calculate all tributary sediment transport	---	---
7	SROUT	Route sediment for reach	F	---
8	DUP	Duplicate properties at double cross sections	G	H
9	OUT1	Output results	---	---
10	DREDG	Dredge river reach	I	---

*Explanation of codes

A - Number of reach to compute water surface

B - Number of primary reach in divided flow

Table 1. (continued)

C - Number of secondary reach in divided flow

D - Number of upstream weir cross section

E - Number of cross section upstream of weir

F - Number of reach to computer sediment routing

G - Number of primary cross section

H - Number of duplicate cross section

I - Number of river reach to perform dredging

2. The water surface profile is determined by calling SUBPF or DIVDE, starting with the downstream river reach and working upstream. The profile is calculated for the mainstem first and then for any tributaries.

3. After determining the water surface profiles for all reaches SED is called to calculate sediment transport at each cross section.

4. If there are any weirs in the system WEIRS is called after SED.

5. After SED and WEIRS if there are any tributaries TRIBS is called to calculate sediment transport in tributaries.

6. SROUT is called to route the sediment, starting with the downstream reach and working upstream. The sediment for the mainstem is routed first and then for any tributaries. In cases with divided flow route the sediment for the primary reach is routed first and then for the secondary reach.

7. DUP is called after all sediment routing for each duplicated cross section, if any.

8. If routing results are desired OUT1 is called, after SROUT and DUP.

9. After calling OUT1, if any dredging is to be performed DREDG is called.

10. DUP is called again for any duplicate cross sections in dredged reaches.

RIVER REACH

For each river reach the user must define the following variables.

KUP, KDOWN — The numbers for the upstream and downstream cross sections

NTRIB — The number of tributaries to the reach

ICONT — The type of downstream water surface control

1. Stage-discharge relationship
2. Stage-hydrograph

3. Downstream water surface

4. Greatest of #1 and #2

5. Greatest of #1 and #3

6. Normal depth

KCONT — The number of the downstream control cross section (enter 0 if ICONT $\neq$ 3 or 5)

IROUT — The type of downstream cross section sediment routing

1. Fixed section (use on lowermost reach and for secondary reach in divided flow, bed does not aggrade or degrade).

2. Cross section downstream (use when there is another reach directly downstream).

3. Floating section (use for lowest reach on major tributaries).

AX, BX, CX — The coefficients of the downstream control stage-discharge relationship

$$WS = CX + AX\ TQ^{BX}$$

where TQ is the downstream discharge (set to zero if ICONT $\neq$ 1 or 4)

AN, BN — The coefficients of the reach Manning's n-value function

$$n = n_o\ AN\ TQ^{BN}$$

(set, AN = 1.0 and BN = 0.0 if the function is not known and calibrate on known data)

SB — Normal depth slope (use average bed slope).

TRIBUTARY

For each tributary the user must define the following variables.

RDT — The mainstem river distance at the tributaries' confluence

ITRIB — The type of tributary

1. Point source in

2. Major tributary in

3. Point source out

4. Major tributary out

KTRIB — The tributary's water discharge section

AT, BT — The coefficient of the point source tributary sediment rating curve

$$QSL = AT\ TQ^{BT}$$

(enter zeros for major tributaries)

CROSS SECTION

For each cross section the following variables must be defined.

ND — The number of cross section points (x,z pairs)

RD — The cross section river distance. Must be measured in upstream direction

X — The array of cross section point stations (horizontal distance) negative values are allowed, but the stations cannot decrease in value from one point to the next

Z — The array of cross section point elevations

DROB, DLOB — Overbank stations. To define the start of overbank conditions, the stations do not have to correspond to points in the x array

FROB, FMC, FLOB — Manning's n-value for right overbank, main channel, and left overbank

ZOB — The overbank elevation used to divide main channel and overbank hydraulic properties relationships

FLOW

For each time period the following variables must be defined.

Q — The upstream discharge tons of each river reach

QT — The discharge tons of each point source tributary

DT — The time period length in days

STAGE — The stage at the downstream control(set to 0.0 if not used)

IV. INPUT FORMATS

All input data is read into the program from subroutines IN1 and FLOW. The input data are divided into three files to ease the task of assembling and debugging. When the user is evaluating several alternatives, usually only one or two of the input files need changing for each run. The three files are:

I5 - General Data

I7 - Cross Section Data

I8 - Discharge Data

The user must define the device number for each of these files in the main program.

While it is recommended that the input data are kept separate, all three files can be combined into one file as when cards are used as input. To accomplish this the user defines the three files as the same device and then assembles the data cards with the general data first, cross sections second, and discharge data third.

The following describes order and formats for data input.

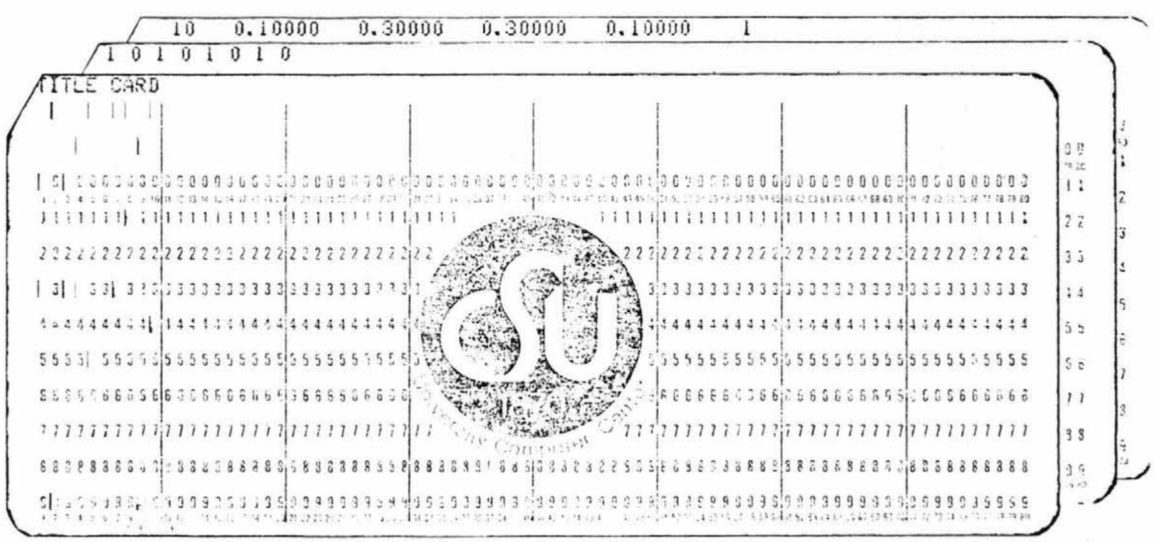
FILE I5--GENERAL DATA

General Information Cards

Three information cards are required for the title, the print controls, and the convergence limits.

Card Number	Format	Description
1	20A4	(TITLE (M2), M2 = 1, 20) Job Title.
2	8I2	(IPRNT (M1), M1 = 1, 8) Print control (see output section for explanation).
3	I5, 4F10.5, I5	MST, EPS, PORM, CE, CC, IUNIT Maximum number of iterations for the backwater curve (MST); maximum error in total head, (EPS). Sediment deposit porosity (PORM), expansion loss coefficient (CE), contraction loss coefficient (CC), and unit system flag (IUNIT).

Example of General Information Cards

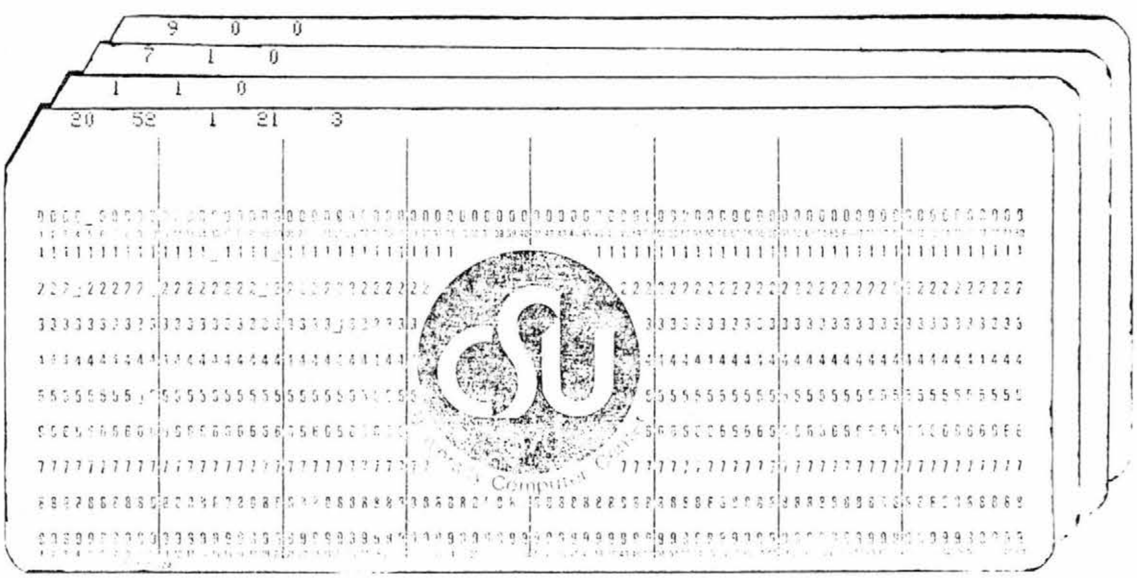


Counter Cards

The two counter cards give the number of elements (cross sections), time periods, river reaches etc.) of the system and the computation sequence.

Card Number	Format	Description
1	5I5	NSEC, NTIM, NRIV, NQI, NCALL Number of cross sections (NSEC); number of time periods, NTIM; the number of river reaches, NRIV; number of input discharges, (NQI); number of subroutine (NCALL).
2	3I5	(ICALL (NC, NN), NN = 1, 3) Sequence of subroutine calls. The number of input cards for ICALL is the same as NCALL. Repeat card 2 for each subroutine call, NC.

Example of Counter Cards

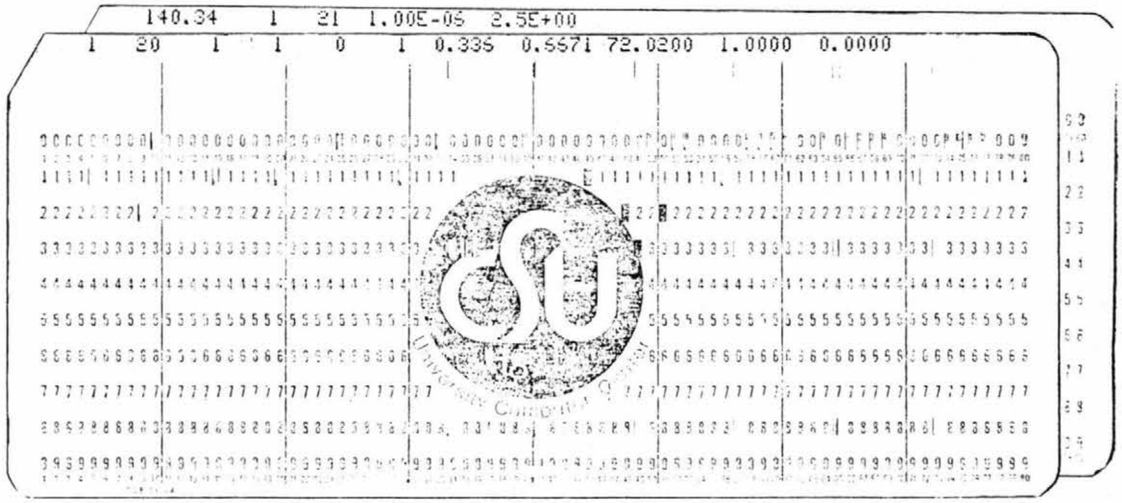


River Reach Cards

The river reach cards give information on each river reach (number of cross sections, number of tributaries, etc.) and on tributaries. The number of river reach cards depends on the number of river reaches and tributaries.

Card Number	Format	Description
1	6I5, 5F8.4, F8.6	KDOWN (NR), KUP (NR), NTRIB(NR), ICONT(NR), KCONT(NR), IROUT(NR), AX(R), BX(NR), CX(NR), AN(NR), BN(NR), SB(NR). Number of downstream cross section, (KDOWN(NR)); Number of tributaires, (NTRIB(R)); type of downstream control, (ICONT(NR)); number of downstream water surface control cross section, (KCONT (NR)); type of downstream sediment routing (IROUT(NR)); the coefficients of the downstream stage discharge relationship, (AX(NR), BX(NR), CX (NR)); coefficients of the conveyance equation, (AN(NR), BN(NR)), the normal depth slope, (SB(NR)).
2	F10.2, 2I5, 2E10.2	RDT(NR,J), ITRIB(NR,J), KTRIB(NR,J). AT(NR,J), BT(NR,T) Main stem river distance of the confluence, (RDT(NR,J)); type of tributary, (ITRIB(NR,J)); number of discharge cross section for tributary, (KTRIB(NR,)). The coefficients of the tributary sediment input (AT(NR,J), BT(NR,J). (Repeated for each tributary in river reach.)
		Repeat cards 1 and 2 for each additional river reach.

Example of River Reach Cards.



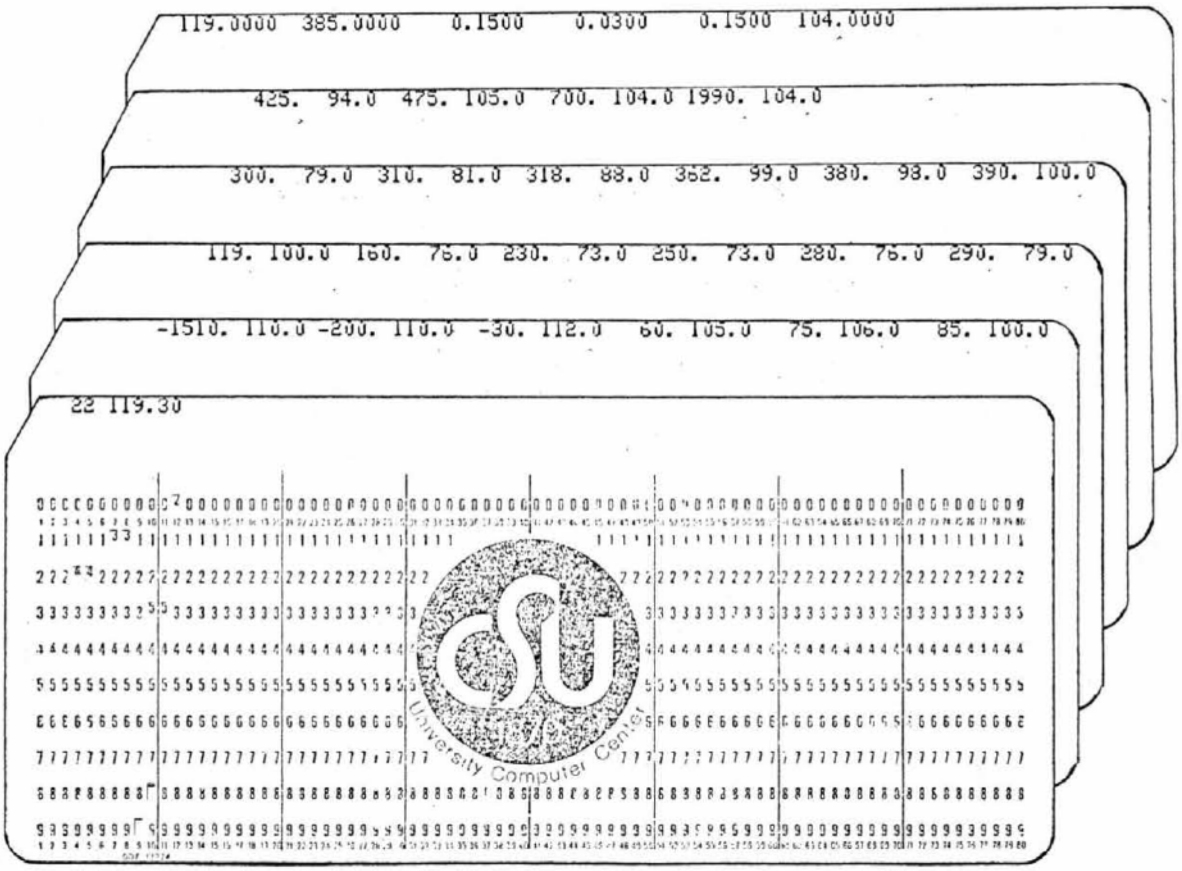
FILE I7--CROSS SECTION DATA

Cross Section Cards

The cross section cards give information on the river cross sections, including the number of cross section points, river distance, and elevation, and station of each point.

Card Number	Format	Description
1	2X, I3, F7.2	ND(K), RD(K) Number of cross section points in this section, (ND(K)); river distance, (RD(K)).
2	8X, 6(F6.0, F6.1)	X(K,L), Z(K,L) Horizontal distance of cross section points, (X(K,L)); elevation of cross section points (Z(K,L)) in pairs. (Card is repeated for each set of six points.)
3	6F10.4	DROB(K), DLOB(K), FROB, FMC, FLOB, ZOB(K) Distance of right and left overbank, (DROB(K), DLOB(K)); Manning's n for right overbank, main channel, left overbank (FROB, FMC, FLOB); overbank elevation, (ZOB(K)). Repeat card 1 to 3 for each additional cross section.

Example of Cross Section Cards.



FILE I8--DISCHARGE AND STAGE DATA

Discharge and Stage Data

The Following cards give the discharges (mainstream and point sources) and the stages (downstream station).

Card Number	Format	Description
1	8F10.0	(Q(K), K=1, NRIV) Upstream discharge for each river reach.
2	F10.2	STAGE. Downstream control stage.
3	F10.0	QT (NR, J), Tributary discharge for the first point source tributary. Repeat Card 3 for the other point source tributary; neglect major tributaries.
4	F10.2	DT Time step in days.

V. RESULTS OUTPUT

GENERAL

Output is user controlled and may vary from no output to output of most intermediate results. Output is controlled by the array IPRNT discussed in this section. An example of the output is found in Section VI. Output is written to three files I6, I9, and I10. File I6 is for printed output and files I9 and I10 are binary files. Binary files are designed so that the detailed intermediate results can be saved. Once the user reviews the printed results, the binary files can be accessed with a used supplied program and any additional information of interest is printed out.

The user must define the device number for each of the output files in the main program.

Print Controls

The following output is controlled by the array IPRNT. The print controls are turned on by inputing a value of 1 for the respective variables. In addition, if at least one of the following print controls IPRNT (1, 2, 3, 4, 5, 6 or 7) is turned on, the title will be printed out.

1. If the print control IPRNT(1) is turned on, all the input data from File I5 and I7 are printed out.

2. If the print control IPRNT(2) is turned on, the following coefficients for the hydraulic properties equation are printed out for the effective width, the effective depth, the total area, the total conveyance, and for alpha, for both flow situations, channel flow and overbank flow:

   - the cross section number
   - the coefficient A of the hydraulic properties equation
   - the power B of the hydraulic property equation
   - the correlation coefficient
   - the standard error

3. If the print control IPRNT(3) is turned on the final bed elevations and the change in elevation at each cross section point is printed out.

4. If the print control IPRNT(4) is turned on, the maximum water elevation and the time period of occurrence at each cross section is output.

5. If the print control IPRNT(5) is turned on, the final minimum bed elevation at each point is printed out.

6. If the print control IPRNT(6) is turned on, following cross section properties are printed out for each cross section and each time period.

   - time period
   - effective width
   - effective depth
   - total area
   - total conveyance
   - alpha
   - velocity
   - water surface
   - discharge
   - sediment transport
   - thalweg elevation

7. If the print control IPRNT (7) is turned on, the following data are output in binary on file I10.

   - effective width
   - effective depth
   - total area
   - total conveyance
   - alpha
   - velocity
   - water surface elevation
   - discharge
   - sediment transport
   - thalweg elevation

   Also the elevation of each cross section point at the end of each year is output in binary to File I9.

8. If the print control IPRNT(8) is turned on, error messages are printed when the backwater or divided flow calculations do not converge. These messages include:

   - the maximum error in total head
   - the number of iterations
   - the cross section number
   - the time period of occurrence

The user should carefully select the desired output and turn off unnecessary output. Generally, print controls IPRNT (1, 2, 6, and 8) provide the best output for initial debugging while IPRNT (1, 3, 4, 5 and 7) provide the best output for production runs. Print controls IPRNT (2 and 6) should not be turned on if a run has several time periods as voluminous amounts of printed output are produced.

VI. EXAMPLE APPLICATION

GENERAL

The following is an example application of the program KUWASER. A portion of the Yazoo River Basin near Greenwood, Mississippi was selected and is shown in Figure 5. In the example, besides the mainstem calculations, there is a divided flow caused by a cutoff, a major tributary, the Yalobusha River, three-point source tributaries, and a weir. The example gives the step by step procedure necessary to model the case. To simplify the example actual temporal and spatial designs used in the Sedimentation Study of the Yazoo River Basin for the area were not used.

Temporal Design

The continuity approach is used in the example temporal design. Locations of known discharge are shown in Figure 6. The discharge at each section (except in divided reaches) is computed by summing all inflows above the section. Any difference between the inflows and the outflows at Belzoni is distributed between Abiaca Creek and Belzoni. Discharge at any cross section between Abiaca Creek and Belzoni is computed by an equation similar to Equation 2.

Point source sediment routing curves were determined by the empirical method.

Spatial Design

Figure 7 shows the example spatial design. The mainstem river is broken into three segments, Reaches I, II, and III. The cutoff where divided flow occurs is Reach IV and the Yalobusha River is Reach V. These divisions were made based on the consistent river characteristics in each reach with consideration of the computational sequence.

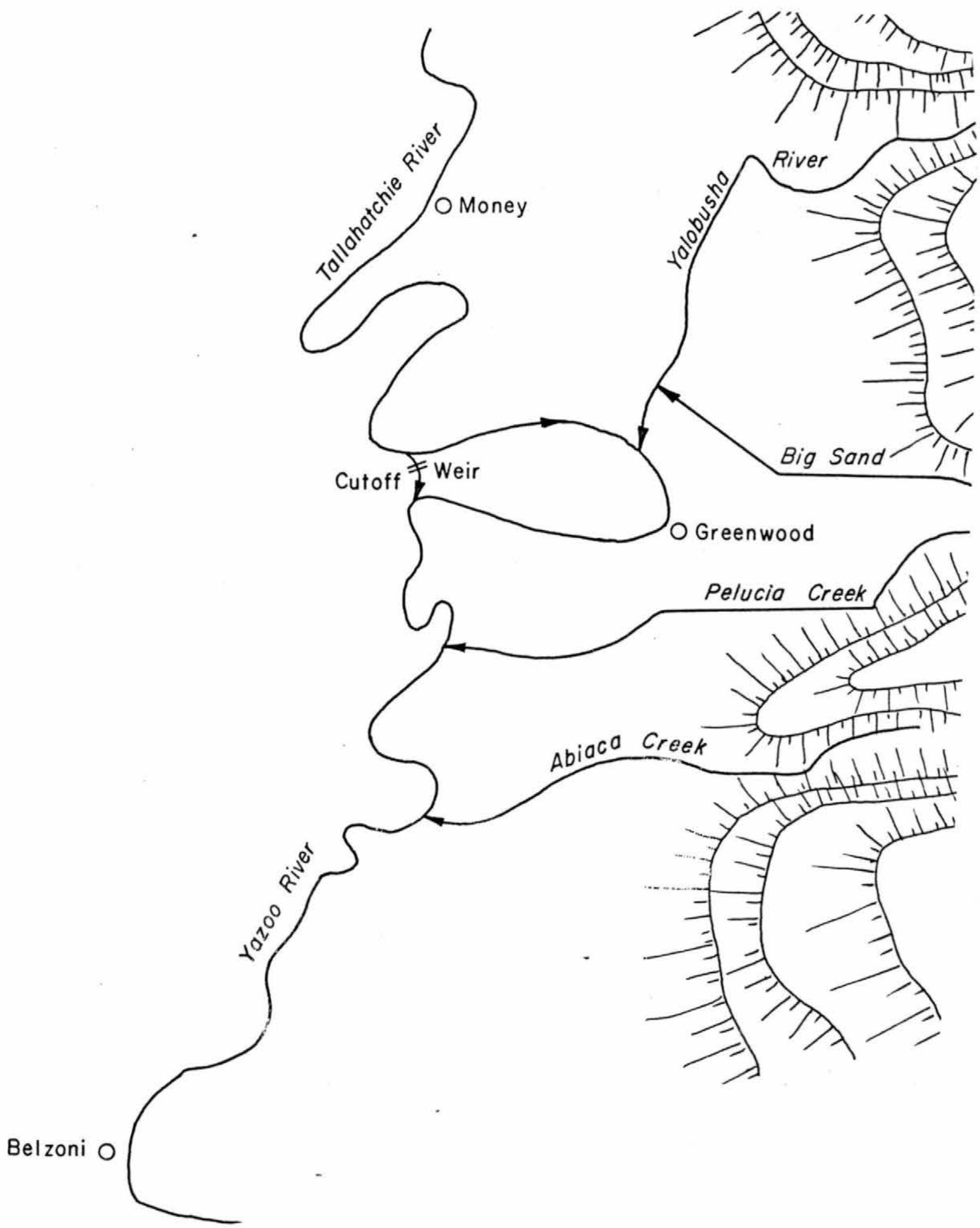


Figure 5. Example case.

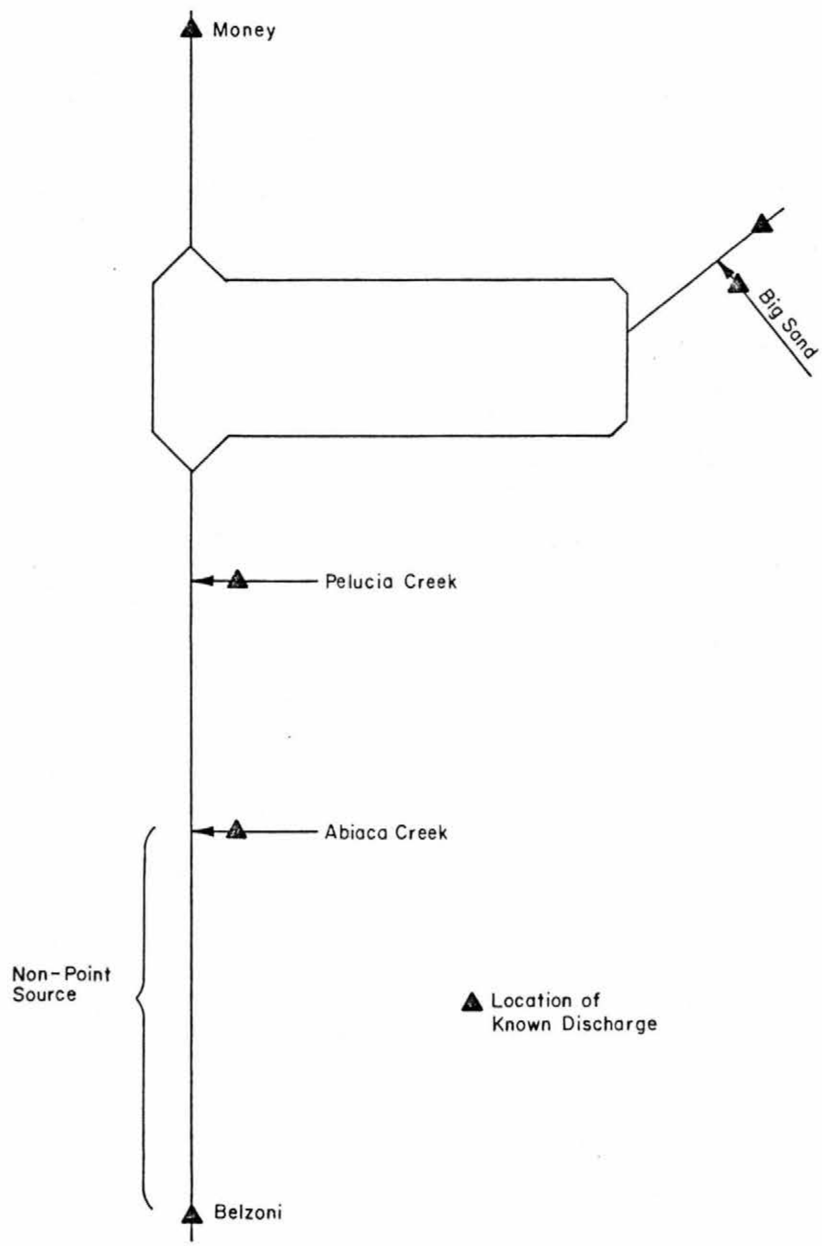


Figure 6. Example temporal design.

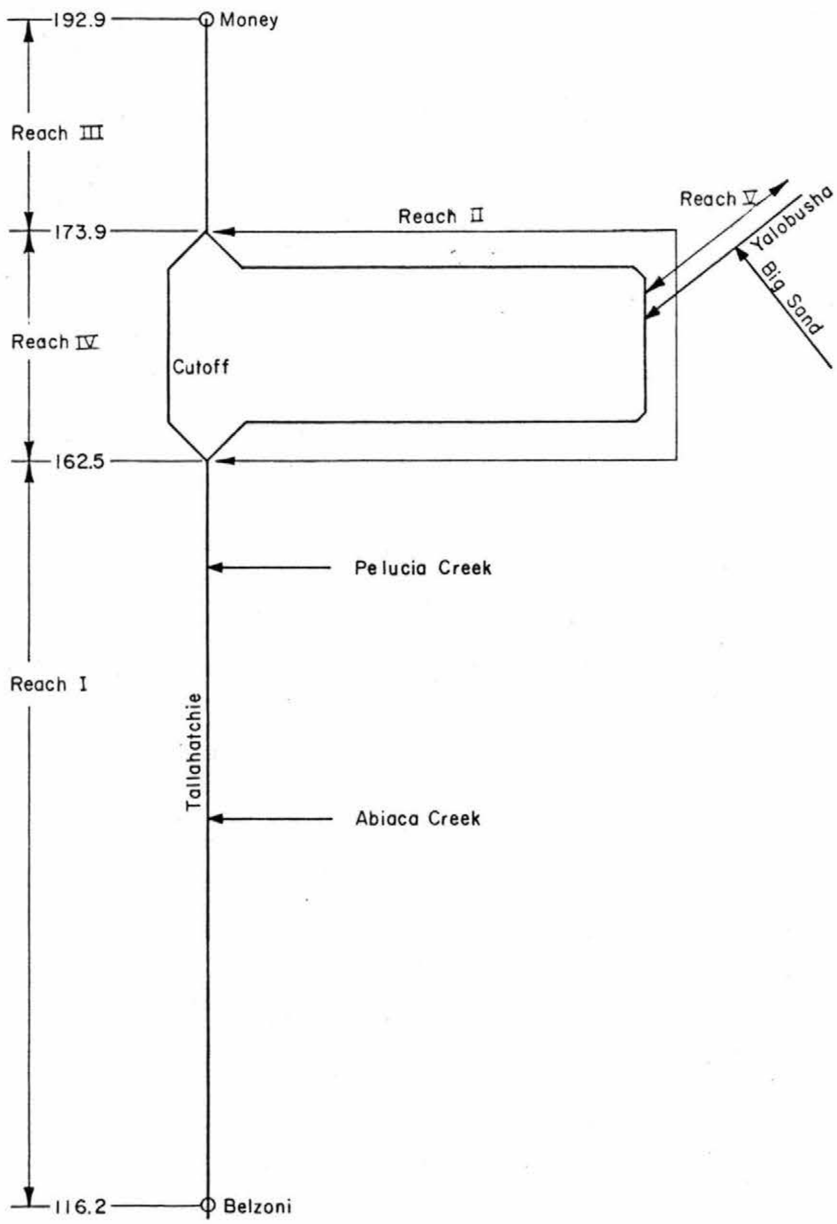


Figure 7. Example spatial design

Figure 8 shows the locations of selected cross sections. The cross sections are identified by river mile and number. The cross sections are fairly even spaced at two to three miles except in the cutoff where the short length of the reach has forced tighter spacing. Figure 8 also shows the discharge section location and number for each point source tributary.

The value of the variables associated with each river reach is shown in Table 2.

The subroutine computation sequence for the example is

1. call FLOW
2. call SUBPF for Reach I
3. call DIVDE for Reach II and IV
4. call SUBPF for Reach III
5. call SUBPF for Reach V
6. call SED
7. call WEIRS
8. call TRIBS
9. call SROUT for Reach I
10. call SROUT for Reach II
11. call SROUT for Reach IV
12. call SROUT for Reach III
13. call SROUT for Reach V
14. call DUP for cross sections 19 and 32
15. call DUP for cross sections 28 and 38
16. call OUTPUT

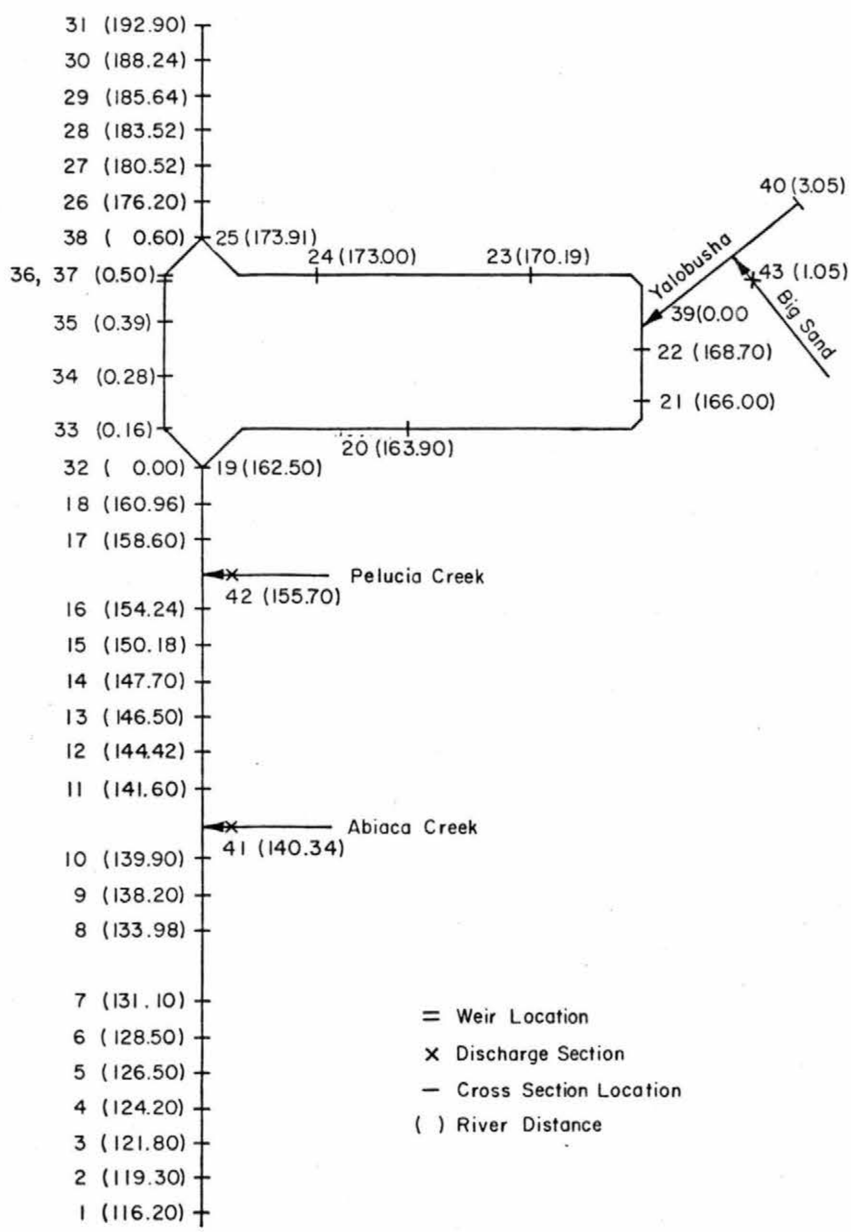


Figure 8. Example cross section locations.

Table 2. Input variable values for example.

Reach	KDOWN	KUP	NTRIB	ICONT	KCONT	AX, BX, CX,	AN, BN	IROUT	SB	TRIBUTARY	RDT	ITRIB	KTRIB	AT	BT
I	1	19	2	1	---	AX = 0.0336	AN = 1.0	1	.00005	1	140.34	1	41	1.5×10^{-8}	2.4
						BX = 0.6868	BN = 0.0			2	155.7	1	42	7.5×10^{-8}	2.3
						CX = 76.02									
II	19	25	3	3	19	---	AN = 1.0	2	.00007	1	162.51	2	33	---	---
							BN = 0.0			2	169.0	2	39	---	---
										3	173.9	4	37	---	---
III	25	31	0	3	25	---	AN = 1.0	2	.0001	4					
							BN = 0.0								
IV	32	38	2	3	19	---	AN = 1.0	1	.0002	1	0.01	2	20	---	---
							BN = 0.0			2	0.59	4	24	---	---
V	39	40	1	3	22		AN = 1.0	3	.0002	1	1.05	1	43	1.0×10^{-8}	2.4
							BN = 0.0								

Example Input

Figures 9, 10 and 11, and Table 3 show input data for the example.

Example Output

Figure 11 shows the output generated by the example run.

```
          E X A M P L E    F O R    P R O G R A M    K U W A S E R
0 0 1 1 1 1 0 0
  10    0.10000    0.30000    0.30000    0.10000     1
  40      1     5    43   16
   1      0     0
   2      1     0
   3      2     4
   2      3     0
   2      5     0
   4      0     0
   5     37    38
   6      0     0
   7      1     0
   7      2     0
   7      4     0
   7      3     0
   7      5     0
   8     19    32
   8     25    38
   9      0     0
   1     19     2     1     0     1   0.0336   0.6868 76.0200   1.0000   0.0000 .000050
    140.34      1    41  1.50E-08  2.40E+00
    155.70      1    42  1.50E-08  2.40E+00
  19     25     3     3    19     2   0.0000   0.0000   0.0000   1.0000   0.0000 .000070
    162.51      2    33       0.00       0.00
    169.00      2    39       0.00       0.00
    173.90      4    37       0.00       0.00
  25     31     0     3    25     2   0.0000   0.0000   0.0000   1.0000   0.0000 .000100
  32     38     2     3    19     1   0.0000   0.0000   0.0000   1.0000   0.0000 .000200
      0.01      2    20       0.00       0.00
      0.59      4    24       0.00       0.00
  39     40     1     3    22     3   0.0000   0.0000   0.0000   1.0000   0.0000 .000200
      1.05      1    43  1.0E-08   2.4E+00
```

Figure 9. Example input data for File I5.

```
CS 22 116.20     0  0  0
PT        8086. 108.2 9542. 108.2 9550. 111.0 9598. 118.5 9598. 118.5 9607. 118.4
PT        9658.  99.7 9662.  96.5 9736.  80.9 9806.  76.9 9836.  75.7 9935.  80.5
PT        9946.  84.1 9946.  86.8 9966.  92.0 9970.  99.6 9979. 104.4 9979. 104.4
PT       10026. 105.910034. 101.210045.  98.511586.  98.5
    9660.00   9979.00    .15000    .03000    .15000     104.00
CS 22 119.30     3 29 72
PT       -1510. 110.0 -200. 110.0  -30. 112.0   60. 105.0   75. 106.0   85. 100.0
PT         119. 100.0  160.  76.0  230.  73.0  250.  73.0  280.  76.0  290.  79.0
PT         300.  79.0  310.  81.0  318.  88.0  362.  99.0  380.  98.0  390. 100.0
PT         425.  94.0  475. 105.0  700. 104.0 1990. 104.0
     119.00    385.00    .15000    .03000    .15000     104.00
CS 22 121.80     3 27 72
PT        -692. 107.0 -580. 107.0 -370. 108.0 -340. 107.0 -328. 104.0 -310. 103.0
PT        -272.  82.0 -262.  82.0 -215.  75.0 -192.  74.0 -120.  79.0 -110.  78.0
PT         -95.  81.0  -85.  81.0  -77.  84.0  -25.  95.0   -5. 106.0   15. 109.0
PT          40. 110.0  175. 106.0  300. 109.0  308. 109.0
    -310.00    -10.00    .15000    .03000    .15000     106.00
CS 22 124.20     3 23 72
PT       -1705. 108.0 -560. 108.0 -550. 101.0 -532.  99.0 -508. 100.0 -475.  86.0
PT        -460.  85.0 -445.  72.0 -425.  68.0 -415.  68.0 -405.  67.0 -380.  78.0
PT        -355.  89.0 -340.  92.0 -318. 100.0 -285. 104.0 -260.  99.0 -240.  98.0
PT        -225.  95.0 -205. 100.0 -190. 110.0  895. 110.0
    -500.00   -320.00    .15000    .03000    .15000     100.00
CS 20 126.50     7 26 62
PT       -1520. 108.0 -500. 108.0 -460. 110.0 -440. 104.0 -420. 102.0 -400. 105.0
PT        -360.  82.0 -350.  89.0 -320.  80.0 -300.  80.0 -260.  78.0 -220.  77.0
PT        -180.  84.0 -140. 106.0 -120. 105.0 -100. 108.0  -60. 108.0  -40. 109.0
PT           0. 108.0 1080. 108.0
    -400.00   -140.00    .15000    .03000    .15000     104.00
CS 19 128.50     7 26 62
PT       -1195. 111.0 -200. 111.0  -90. 109.0  -40. 110.0  -40. 107.0    0. 108.0
PT          10. 110.0   40. 111.0   90.  75.0  120.  75.0  140.  76.0  220.  77.0
PT         270.  99.0  300. 102.0  320. 110.0  340. 108.0  400. 108.0  460. 112.0
PT        1405. 112.0
      40.00    270.00    .15000    .03000    .15000     104.00
CS 16 131.10     3 14 72
PT        -130. 111.0 -130. 111.0 -120. 108.0  -60. 108.0  -30. 110.0   20. 108.0
PT          30. 107.0   80.  90.0  200.  80.0  270.  75.0  350. 100.0  350. 112.0
PT         370. 116.0  600. 116.0  670. 123.0  670. 123.0
      30.00    350.00    .15000    .03000    .15000     108.00
CS 16 133.98    11 23 73
PT       -1642. 116.4 -525. 116.4 -357. 111.0 -344. 107.7 -306. 110.5 -263.  84.6
PT        -221.  77.0 -183.  75.5 -163.  77.1 -142.  73.3 -117.  75.8 -101.  82.2
PT         -71.  92.6  -37. 115.5  201. 116.0 1358. 116.0
    -306.00    -37.00    .15000    .03000    .15000     108.00
CS 13 138.20    11 29 73
PT       -1767. 104.1 -516. 104.1 -341. 118.2 -267.  79.1 -141.  86.3  -67.  91.4
PT         -15. 116.3   25. 115.4   29. 113.7  162. 113.7  169. 115.4  264. 115.2
PT        1233. 115.2
    -341.00    -15.00    .15000    .03000    .15000     115.40
CS 18 139.90     3  3 72
PT       -1130. 124.0  -10. 124.0   20. 118.0   40. 119.0  100. 114.0  130. 115.0
PT         210. 113.0  240.  96.0  270.  95.0  370.  75.0  410.  89.0  440.  89.0
PT         460.  98.0  470. 115.0  560. 113.0  590. 115.0  600. 120.0 1870. 120.0
     210.00    470.00    .15000    .03000    .15000     115.00
CS 18 141.60     3  2 72
PT       -1650. 123.0 -390. 123.0 -370. 114.0 -330. 113.0 -300. 102.0 -250.  95.0
PT        -180.  83.0 -170.  85.0 -160.  81.0 -140.  81.0 -140.  84.0 -110.  85.0
PT         -10.  93.0    0.  97.0   30. 111.0   70. 115.0  140. 114.0 1350. 114.0
    -275.00     30.00    .15000    .03000    .15000     105.00
CS 17 144.42     2 25 72
PT       -1206. 117.3  -37. 117.3   58. 114.7  105.  97.9  170.  93.6  268.  75.8
PT         272.  78.8  277.  78.6  294.  75.6  346. 101.3  364. 104.5  371. 103.1
PT         386. 109.4  417. 107.1  451. 119.2  543. 117.3 1794. 117.3
      60.00    346.00    .15000    .03000    .15000     110.00
CS 18 146.50     2 23 72
PT       -1220. 121.0 -100. 121.0  -10. 121.0    0. 124.0    5. 124.0   10. 123.0
PT          70. 113.0  100. 115.0  140. 112.0  210.  85.0  240.  87.0  260.  84.0
PT         280.  83.0  310.  85.0  390.  96.0  420. 114.0  560. 118.0 1780. 118.0
     140.00    420.00    .15000    .03000    .15000     115.00
CS 15 147.70    11 14 73
PT       -1242. 122.8  -96. 122.8  -29. 122.6  -28. 125.3   64. 115.8  159. 113.7
PT         207. 117.2  258.  83.7  329.  86.7  389.  83.8  414.  84.8  493. 117.4
PT         646. 121.6  727. 121.5 1758. 121.5
     207.00    493.00    .15000    .03000    .15000     113.70
CS 16 150.18    11 13 73
PT       -1376. 123.4 -196. 123.4  -16. 124.1   22. 114.7   65. 116.1  124.  84.2
PT         200.  86.5  279.  88.6  290.  85.6  357. 116.8  422. 117.5  450. 115.6
PT         503. 121.5  543. 122.2  595. 114.0 1624. 114.0
      65.00    357.00    .15000    .03000    .15000     114.70
CS 18 154.24     2 11 72
PT       -1670. 122.0 -570. 122.0 -480. 118.0 -460. 116.0 -420. 116.0 -360.  94.0
PT        -310.  94.0 -300.  93.0 -180.  93.0 -170.  91.0 -160.  92.0 -140.  92.0
PT        -100. 108.0  -70. 116.0  -50. 115.0  -20. 118.0    0. 125.0 1330. 125.0
    -420.00   -100.00    .15000    .03000    .15000     116.00
CS 13 158.60     2  4 72
PT       -1540. 117.0 -500. 117.0 -380. 116.0 -350. 121.0 -320. 120.0 -310. 117.0
PT        -300. 116.0 -240. 100.0  -40.  92.0  -10. 101.0   20. 114.0   30. 124.0
PT        1460. 124.0
    -250.00     20.00    .15000    .03000    .15000     115.00
```

Figure 10. Example input data for File I7.

```
CS 19 160.96     2  1  72
PT       -1700. 133.0 -560. 133.0 -480. 119.0 -420. 118.0 -360.  95.0 -320.  95.0
PT        -270.  94.0 -260.  92.0 -240.  91.0 -230.  93.0 -200.  87.0 -170.  95.0
PT        -140.  96.0  -90. 117.0  -70. 121.0  -40. 119.0  -20. 124.0    0. 127.0
PT        1300. 127.0
  -420.00    -90.00      .15000     .03000     .15000     115.00
CS 19 162.50     3 15  77
PT           0. 130.3   25. 121.3   49. 120.8  101. 125.0  125. 114.8  134. 114.7
PT         145. 103.8  156. 103.7  163.  95.2  215.  83.3  233.  86.9  243.  87.0
PT         294.  92.8  321.  99.7  338. 100.6  347. 103.8  396. 110.9  423. 124.3
PT         448. 122.5
   115.00    396.00      .15000     .03000     .15000     110.00
CS 12 163.9      3 15  77
PT        -443. 121.9 -432. 120.1 -415. 112.1 -406. 109.8 -375.  98.8 -316.  99.4
PT        -264.  96.1 -245.  99.1 -213.  99.9 -207.  97.9 -157. 107.4 -140. 120.8
  -432.00   -140.00      .15000     .03000     .15000     120.00
CS 15 166.0      3 16  77
PT         340. 120.3  364. 108.4  395. 106.1  407. 104.1  437. 104.1  484.  90.0
PT         508.  92.9  526.  90.7  545.  97.2  578.  98.9  616.  98.1  636.  99.0
PT         669. 112.8  674. 121.1  683. 123.4
   340.00    674.00      .15000     .03000     .15000     120.00
CS 12 168.7      3 16  77
PT        -398. 120.3 -360. 123.1 -334. 112.4 -323. 113.2 -297. 102.5 -274. 102.6
PT        -196.  97.4 -182.  97.5 -148.  95.5 -136.  89.2  -84. 125.9    0. 127.3
  -360.00  - 84.00      .15000     .03000     .15000     123.00
CS 12 170.19     3 17  77
PT        -297. 120.3 -290. 120.5 -230. 103.1 -187. 104.6 -181. 102.1 -140. 101.2
PT        -120. 100.0  -76. 101.4  -29. 114.7  -17. 120.7  -11. 118.4    0. 119.0
  -297.00  - 17.00      .15000     .03000     .15000     120.00
CS 12 173.0      3 18  77
PT        -302. 129.0 -286. 121.7 -265. 116.3 -246. 114.7 -217.  99.7 -149.  89.9
PT        -105. 100.1  -66. 104.6  -34. 112.5  -25. 120.2  -15. 123.3    0. 122.8
  -302.00  - 15.00      .15000     .03000     .15000     123.00
CS 15 173.91     3 18  77
PT          21. 125.2   53. 121.1   85. 121.9  124. 108.8  133. 108.8  161.  95.5
PT         228.  94.0  244.  96.5  291.  97.9  311. 101.9  320. 101.2  364. 120.3
PT         374. 120.7  381. 126.2  406. 124.7
    21.00    381.00      .15000     .03000     .15000     125.00
CS 16 176.20     4 13  73
PT       -1040. 126.5  295. 126.5  310. 122.0  360. 122.0  380. 119.0  390. 115.0
PT         400. 107.0  440.  95.0  460.  91.5  500.  92.5  520.  92.5  540.  95.0
PT         560.  95.5  580. 112.0  610. 121.0 1960. 121.0
   385.00    600.00      .15000     .03000     .15000     115.00
CS 16 180.52    12  9  71
PT       -1650. 126.0 -500. 126.0 -390. 127.0 -310. 125.0 -295. 108.0 -250.  99.0
PT        -170.  97.0 -150.  98.0 -130.  97.0 -110.  99.0  -75. 118.0  -50. 122.0
PT         -40. 120.0    0. 132.0  100. 132.0 1350. 132.0
  -300.00   -100.00      .15000     .03000     .15000     115.00
CS 18 183.52    11 30  71
PT       -1180. 136.0 -200. 136.0 -100. 135.0    0. 134.0  140. 124.0  160. 120.0
PT         200. 119.0  235. 122.0  310.  98.0  320.  95.0  390.  99.0  410.  98.0
PT         430. 100.0  480. 122.0  500. 122.0  530. 128.0  600. 127.0 1820. 127.0
   280.00    450.00      .15000     .03000     .15000     120.00
CS 13 185.64    11 22  71
PT       -1338. 124.8  -16. 124.8    1. 125.5   22. 118.4   63. 100.1  111. 100.4
PT         162.  97.5  192.  99.1  222. 115.2  233. 125.8  252. 125.9  270. 124.7
PT        1662. 124.7
     1.00    233.00      .15000     .03000     .15000     124.80
CS 19 188.24    11 16  71
PT       -1270. 135.0 -150. 135.0    0. 132.0   30. 126.0   90. 126.0  120. 122.0
PT         160.  95.0  190.  99.0  210.  92.0  250.  92.0  290. 109.0  300. 108.0
PT         330. 124.0  400. 129.0  430. 125.0  440. 130.0  470. 130.0  500. 129.0
PT        1730. 129.0
   120.00    290.00      .15000     .03000     .15000     125.00
CS 18 192.90    11  8  71
PT       -1323. 130.8   -2. 130.8   35. 127.6   36. 125.5   49. 125.9   65. 119.2
PT          75. 115.7  127.  96.9  177.  96.7  195.  99.6  230.  99.8  264. 115.7
PT         286. 120.4  294. 127.5  336. 126.6  395. 130.0  407. 132.6 1677. 132.6
    -1.00    293.00      .15000     .03000     .15000     125.50
CS 19   0.00     3 15  77
PT           0. 130.3   25. 121.3   49. 120.8  101. 125.0  125. 114.8  134. 114.7
PT         145. 103.8  156. 103.7  163.  95.2  215.  83.3  233.  86.9  243.  87.0
PT         294.  92.8  321.  99.7  338. 100.6  347. 103.8  396. 110.9  423. 124.3
PT         448. 122.5
   115.00    396.00      .15000     .03000     .15000     110.00
CS 14   0.16     5 20  76
PT        -172. 108.0 -165. 105.2 -153. 105.2 -115.  90.7  -93.  89.0  -64.  94.6
PT          -4.  97.5   15.  97.1   57. 100.1   76.  98.0   95.  99.1  128.  96.8
PT         171.  98.5  196. 108.2
  -115.00     57.00      .15000     .03000     .15000      90.70
CS  9   0.28     5 19  76
PT        -152. 109.0  -98. 101.5  -22.  98.8    1.  98.6   55.  99.4  102.  98.9
PT         123.  99.5  129.  98.0  167. 110.1
   -98.00    167.00      .15000     .03000     .15000     101.50
CS 13   0.39     5 18  76
PT         -48. 110.2  -22.  98.8   16.  90.2   32.  82.9   51.  77.7   90.  73.7
PT         100.  77.4  121.  80.8  150.  95.0  160.  94.3  181. 102.6  237. 110.2
PT         264. 131.0
    16.00    121.00      .15000     .03000     .15000      48.00
```

Figure 10. (Continued).

```
CS 13     .50     WEIR
PT       -491. 131.9 -261. 131.9 -209. 132.8 -169. 119.9 -109. 113.2  -74. 113.3
PT        -50. 110.0   31. 110.0   86. 110.0  133. 110.0  150. 110.0  217. 130.4
PT        251. 130.4
   -150.00   217.00    .15000    .03000    .15000    120.00
CS 13     .50     WEIR
PT       -491. 131.9 -261. 131.9 -209. 132.8 -169. 119.9 -109. 113.2  -74. 113.3
PT        -50. 110.0   31. 110.0   86. 110.0  133. 110.0  150. 110.0  217. 130.4
PT        251. 130.4
   -150.00   217.00    .15000    .03000    .15000    120.00
CS 15   0.60     3 18 77
PT         21. 125.2   53. 121.1   85. 121.9  124. 108.8  133. 108.8  161.  95.5
PT        228.  94.0  244.  96.5  291.  97.9  311. 101.9  320. 101.2  364. 120.3
PT        374. 120.7  381. 126.2  406. 124.7
     21.00   381.00    .15000    .03000    .15000    125.00
CS 18   0.0      3 23 77
PT          1. 129.1   30. 121.6   59. 121.3   88. 105.4  108. 104.2  118.  99.8
PT        138.  97.7  162. 105.1  178. 106.8  192. 106.6  197. 109.2  214. 110.5
PT        231. 116.5  250. 117.2  259. 120.7  273. 122.0  283. 126.2  371. 127.6
     80.00   259.00    .15000    .03000    .15000    105.4
CS 20   3.05     5 19 75
PT       -965. 126.0 -600. 126.0 -485. 126.0 -450. 123.0 -370. 123.0 -325. 122.0
PT       -300. 123.0 -260. 124.0 -250. 124.0 -204. 126.0 -190. 117.0 -180. 114.0
PT        -90. 108.0  -41. 127.0   50. 126.0  150. 123.0  250. 122.0  350. 125.0
PT        460. 126.0  785. 126.0
   -204.00   -41.00    .15000    .03000    .15000    124.00
```

Figure 10. (Continued).

```
6560.0    3720.0    3720.0       0.0    2600.0
  92.9
1400.0
  40.0
 240.0
  30.0
```

Figure 11. Example input data for File I8.

Table 3. Example input data for file I8 (* the values of the unformated data appear in this column).

Reach	Discharge or cross Section	Name	Water* Discharge in cfs (and time)	Comments
I	1	116.20	11335	
	2	119.30	11423	
	3	121.80	11494	
	4	124.20	11561	
	5	126.50	11626	NPS = -671 cfs
	6	128.50	11683	
	7	131.10	11757	= 28.3 cfs/mile
	8	133.98	11838	
	9	138.20	11958	
	10	139.90	12006	
			<——	Abiaca Creek
	11	141.60	11529	
	12	144.42	11529	
	13	146.50	11529	
	14	147.70	11529	
	15	150.18	11529	
			<——	Pelucia Creek
	16	154.24	11321	
	17	158.60	11321	
	18	160.96	11321	
II	19	162.50	11321	
	20	163.90	0	
	21	166.00	0	Divided flow
	22	168.70	0	discharges set
	23	170.19	0	to zero
	24	173.00	0	
III	25	173.91	8145	
	26	176.20	8145	
	27	180.52	8145	
	28	183.52	8145	
	29	185.64	8145	
	30	188.24	8145	
	31	192.90	8145	

Table 3. Continued.

Reach	Discharge or cross Section	Name	Water* Discharge in cfs (and time)	Comments
IV	32	0.00	11321	
	33	0.16	0	Divided flow discharges set to zero
	34	0.28	0	
	35	0.39	0	
	36	0.50	0	
	37	0.50	0	
	38	0.60	8145	
V	39	0.00	3176	
			<——	Big Sand Creek
	40	3.05	2884	
TRIBUTARIES	41	ABIACA	477	
	42	PELUCIA	208	
	43	BIG SAND	292	
	DT		7.0	
ADDITIONAL DATA	STAGE		0.0	
	IDRG		0	

```
K U W A S E R
KNOWN DISCHARGE SEDIMENT ROUTING
DEVELOPED BY G.O. BROWN AND R.M. LI
AT COLORADO STATE UNIVERSITY, FOR THE
U.S. ARMY CORPS OF ENGINEERS, VICKSBURG DISTRICT
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*****************************************************************************
*                                                                           *
*          E X A M P L E    F O R    P R O G R A M    K U W A S E R          *
*                                                                           *
*****************************************************************************
```

C R O S S   S E C T I O N   P R O P E R T I E S

TIME 1 30.00

SECTION	EFFECTIVE WIDTH	EFFECTIVE DEPTH	TOTAL AREA	TOTAL CONVEYANCE	ALPHA	VELOCITY	WATER SURFACE	SEDIMENT TRANSPORT	FLOW	THALWEG ELEVATION
1	234.1	13.1	3169.	843428.	1.1500	2.5247	92.08	.231667	8000.00	75.70
2	169.8	17.9	3247.	976874.	1.2641	2.4635	93.34	.209552	8000.00	72.95
3	208.0	16.2	3532.	1044146.	1.1508	2.2653	94.23	.178957	8000.00	74.24
4	99.2	22.5	2425.	839510.	1.2619	3.2986	94.97	.303801	8000.00	65.79
5	187.8	15.9	3123.	908983.	1.1595	2.5613	96.07	.234519	8000.00	75.84
6	170.7	19.7	3509.	1145920.	1.2176	2.2796	96.74	.180286	8000.00	74.94
7	219.9	15.9	3680.	1074722.	1.1534	2.1742	97.41	.163081	8000.00	75.00
8	185.5	20.5	3963.	1370096.	1.1500	2.0189	98.07	.138711	8000.00	73.32
9	228.7	14.3	3564.	830701.	1.5000	2.2445	99.22	.169945	8000.00	79.22
10	169.2	15.3	2688.	770843.	1.1500	2.9760	100.05	.326801	8000.00	75.67
11	235.6	13.7	3449.	895895.	1.1911	1.9135	100.71	.100967	6600.00	81.19
12	177.0	17.6	3309.	1008136.	1.1691	1.9947	101.42	.110134	6600.00	75.63
13	182.1	15.4	2976.	798814.	1.2908	2.2190	101.99	.139313	6600.00	82.95
14	198.2	16.3	3360.	981287.	1.1860	1.9645	102.42	.109356	6600.00	83.68
15	206.7	15.6	3416.	940701.	1.2550	1.9320	103.01	.103845	6600.00	84.24
16	240.7	10.9	2728.	617949.	1.1518	2.4194	104.53	.174060	6600.00	91.03
17	240.3	10.6	2610.	596463.	1.1500	2.5134	107.12	.191006	6560.00	91.93
18	241.1	14.5	3695.	999643.	1.1746	1.7752	108.02	.086488	6560.00	86.90
19	198.4	22.2	4605.	1696626.	1.1500	1.4245	108.24	.053333	6560.00	81.03
20	195.0	9.1	1830.	364604.	1.1564	2.1083	108.27	.076533	3857.33	96.03
21	182.8	14.0	2792.	600766.	1.5000	1.3817	109.02	.028687	3857.33	89.96
22	172.7	25.5	4805.	1746795.	1.3667	.8028	109.17	.008656	3857.33	78.49
23	130.7	8.8	1224.	236610.	1.1902	.8310	109.17	.002620	1017.33	97.17
24	145.4	13.0	1971.	512664.	1.1500	.5161	109.29	.000947	1017.33	89.98
25	175.0	12.8	2339.	603973.	1.1500	1.5903	109.55	.039325	3720.00	94.01
26	154.3	16.0	2555.	770726.	1.1500	1.4559	110.00	.032493	3720.00	91.51
27	177.6	12.4	2275.	566261.	1.1500	1.6352	110.70	.042100	3720.00	97.01
28	145.5	13.3	2093.	486587.	1.4078	1.7776	111.39	.048243	3720.00	95.03
29	156.1	11.8	1909.	471396.	1.1500	1.9482	112.04	.061743	3720.00	97.46
30	128.5	17.4	2397.	685896.	1.3258	1.5518	112.63	.035874	3720.00	92.00
31	148.3	14.2	2192.	603461.	1.1500	1.6972	113.45	.045086	3720.00	96.70
32	198.4	22.2	4605.	1696626.	1.1500	1.4245	108.24	.053333	6560.00	81.03
33	206.4	19.7	4296.	1436331.	1.1577	.6292	108.24	.003740	2702.67	81.31
34	230.2	9.8	2338.	497816.	1.1500	1.1561	108.24	.014568	2702.67	95.76
35	151.4	14.8	2386.	633882.	1.1500	1.1328	108.26	.013403	2702.67	79.41
36	168.2	2.7	462.	43336.	1.1500	5.8488	108.82	.004028	2702.67	106.00
37	168.2	2.7	462.	43336.	1.1500	5.8488	108.82	.004028	2702.67	106.00
38	174.8	12.8	2331.	601057.	1.1500	1.5956	109.51	.039611	3720.00	94.01
39	77.5	8.0	659.	120300.	1.1636	4.3085	109.17	.257744	2840.00	97.59
40	109.5	6.1	681.	109686.	1.1500	3.8202	117.48	.192739	2600.00	108.00

SECTION	MAX WATER ELEVATION	TIME OF MAX
1	92.08	1
2	93.34	1
3	94.23	1
4	94.97	1
5	96.07	1
6	96.74	1
7	97.41	1
8	98.07	1
9	99.22	1
10	100.05	1
11	100.71	1
12	101.42	1
13	101.99	1
14	102.42	1
15	103.01	1
16	104.53	1
17	107.12	1
18	108.02	1
19	108.24	1
20	108.27	1
21	109.02	1
22	109.17	1
23	109.17	1
24	109.29	1
25	109.55	1
26	110.00	1
27	110.70	1
28	111.39	1
29	112.04	1
30	112.63	1
31	113.45	1
32	108.24	1
33	108.24	1
34	108.24	1
35	108.26	1
36	108.82	1
37	108.82	1
38	109.51	1
39	109.17	1
40	117.48	1

Figure 12. Example Output.

SECTION	MIN BED ELEVATION
1	75.70
2	72.95
3	74.24
4	66.79
5	76.84
6	74.94
7	75.00
8	73.32
9	79.22
10	75.67
11	81.19
12	75.63
13	82.95
14	83.68
15	84.24
16	91.03
17	91.93
18	86.90
19	81.03
20	96.03
21	89.96
22	78.49
23	97.17
24	89.98
25	94.01
26	91.51
27	97.01
28	95.03
29	97.46
30	92.00
31	96.70
32	81.03
33	81.31
34	95.76
35	79.41
36	106.00
37	106.00
38	94.01
39	97.59
40	108.00

FINAL BED ELEVATIONS, AND,
TOTAL CHANGE AT EACH POINT

CROSS SECTION NO. 1

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	8086.	108.2	0.0
2	9542.	108.2	0.0
3	9550.	111.0	0.0
4	9598.	118.5	0.0
5	9598.	118.5	0.0
6	9607.	118.4	0.0
7	9658.	99.7	0.0
8	9662.	96.5	0.0
9	9736.	80.9	0.0
10	9806.	76.9	0.0
11	9836.	75.7	0.0
12	9935.	80.5	0.0
13	9946.	84.1	0.0
14	9946.	86.8	0.0
15	9966.	92.0	0.0
16	9970.	99.6	0.0
17	9979.	104.4	0.0
18	9979.	104.4	0.0
19	10026.	105.9	0.0
20	10034.	101.2	0.0
21	10045.	98.5	0.0
22	11586.	98.5	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO; 2

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1510.	110.0	0.0
2	-200.	110.0	0.0
3	-30.	112.0	0.0
4	60.	105.0	0.0
5	75.	106.0	0.0
6	85.	100.0	0.0
7	119.	100.0	-.0
8	160.	76.0	-.0
9	230.	73.0	-.0
10	250.	72.9	-.1
11	280.	76.0	-.0
12	290.	79.0	-.0
13	300.	79.0	-.0
14	310.	81.0	-.0
15	318.	88.0	-.0
16	362.	99.0	-.0
17	380.	98.0	0.0
18	390.	100.0	0.0
19	425.	94.0	0.0
20	475.	105.0	0.0
21	700.	104.0	0.0
22	1990.	104.0	0.0

CROSS SECTION NO; 3

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-692.	107.0	0.0
2	-580.	107.0	0.0
3	-370.	108.0	0.0
4	-340.	107.0	0.0
5	-328.	104.0	0.0
6	-310.	103.0	.0
7	-272.	82.0	.0
8	-262.	82.2	.2
9	-215.	75.2	.2
10	-192.	74.2	.2
11	-120.	79.2	.2
12	-110.	78.2	.2
13	-95.	81.2	.2
14	-85.	81.1	.1
15	-77.	84.0	.0
16	-25.	95.0	.0
17	-5.	106.0	0.0
18	15.	109.0	0.0
19	40.	110.0	0.0
20	175.	106.0	0.0
21	300.	109.0	0.0
22	308.	109.0	0.0

CROSS SECTION NO; 4

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1705.	108.0	0.0
2	-560.	108.0	0.0
3	-550.	101.0	0.0
4	-532.	99.0	0.0
5	-508.	100.0	-.0
6	-475.	86.0	-.0
7	-460.	84.9	-.1
8	-445.	71.8	-.2
9	-425.	67.8	-.2
10	-415.	67.7	-.3
11	-405.	66.8	-.2
12	-380.	77.9	-.1
13	-355.	89.0	-.0
14	-340.	92.0	-.0
15	-318.	100.0	-.0
16	-285.	104.0	0.0
17	-260.	99.0	0.0
18	-240.	98.0	0.0
19	-225.	95.0	0.0
20	-205.	100.0	0.0
21	-190.	110.0	0.0
22	895.	110.0	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO. 5

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1520.	108.0	0.0
2	-500.	108.0	0.0
3	-460.	110.0	0.0
4	-440.	104.0	0.0
5	-420.	102.0	0.0
6	-400.	105.0	-.0
7	-360.	82.0	-.0
8	-350.	88.9	-.1
9	-320.	79.9	-.1
10	-300.	79.8	-.2
11	-260.	77.8	-.2
12	-220.	76.8	-.2
13	-180.	83.9	-.1
14	-140.	106.0	-.0
15	-120.	105.0	0.0
16	-100.	108.0	0.0
17	-60.	108.0	0.0
18	-40.	109.0	0.0
19	0.	108.0	0.0
20	1080.	108.0	0.0

CROSS SECTION NO. 6

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1195.	111.0	0.0
2	-200.	111.0	0.0
3	-90.	109.0	0.0
4	-40.	110.0	0.0
5	-40.	107.0	0.0
6	0.	108.0	0.0
7	10.	110.0	0.0
8	40.	111.0	-.0
9	90.	75.0	-.0
10	120.	74.9	-.1
11	140.	75.9	-.1
12	220.	77.0	-.0
13	270.	99.0	-.0
14	300.	102.0	0.0
15	320.	110.0	0.0
16	340.	108.0	0.0
17	400.	108.0	0.0
18	460.	112.0	0.0
19	1405.	112.0	0.0

CROSS SECTION NO. 7

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-130.	111.0	0.0
2	-130.	111.0	0.0
3	-120.	108.0	0.0
4	-60.	108.0	0.0
5	-30.	110.0	0.0
6	20.	108.0	0.0
7	30.	107.0	-.0
8	80.	90.0	-.0
9	200.	80.0	-.0
10	270.	75.0	-.0
11	350.	100.0	-.0
12	350.	112.0	0.0
13	370.	116.0	0.0
14	600.	116.0	0.0
15	670.	123.0	0.0
16	670.	123.0	0.0

CROSS SECTION NO. 8

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1642.	116.4	0.0
2	-525.	116.4	0.0
3	-357.	111.0	0.0
4	-344.	107.7	0.0
5	-306.	110.5	.0
6	-263.	84.6	.0
7	-221.	77.0	.0
8	-183.	75.5	.0
9	-163.	77.1	.0
10	-142.	73.3	.0
11	-117.	75.8	.0
12	-101.	82.2	.0
13	-71.	92.6	.0
14	-37.	115.5	.0
15	201.	116.0	0.0
16	1358.	116.0	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO; 9

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1767.	104.1	0.0
2	-516.	104.1	0.0
3	-341.	118.2	.0
4	-267.	79.2	.1
5	-141.	86.4	.1
6	-67.	91.5	.1
7	-15.	116.3	.0
8	25.	115.4	0.0
9	29.	113.7	0.0
10	162.	113.7	0.0
11	169.	115.4	0.0
12	264.	115.2	0.0
13	1233.	115.2	0.0

CROSS SECTION NO; 10

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1130.	124.0	0.0
2	-10.	124.0	0.0
3	20.	118.0	0.0
4	40.	119.0	0.0
5	100.	114.0	0.0
6	130.	115.0	0.0
7	210.	113.0	.0
8	240.	96.0	.0
9	270.	95.5	.5
10	370.	75.7	.7
11	410.	89.6	.6
12	440.	89.3	.3
13	460.	98.1	.1
14	470.	115.0	.0
15	560.	113.0	0.0
16	590.	115.0	0.0
17	600.	120.0	0.0
18	1870.	120.0	0.0

CROSS SECTION NO; 11

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1650.	123.0	0.0
2	-390.	123.0	0.0
3	-370.	114.0	0.0
4	-330.	113.0	0.0
5	-300.	102.0	.0
6	-250.	95.0	.0
7	-180.	83.1	.1
8	-170.	85.2	.2
9	-160.	81.2	.2
10	-140.	81.2	.2
11	-140.	84.1	.1
12	-110.	85.1	.1
13	-10.	93.1	.1
14	0.	97.0	.0
15	30.	111.0	.0
16	70.	115.0	0.0
17	140.	114.0	0.0
18	1350.	114.0	0.0

CROSS SECTION NO; 12

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1206.	117.3	0.0
2	-37.	117.3	0.0
3	58.	114.7	.0
4	105.	97.9	.0
5	170.	93.6	.0
6	268.	75.8	.0
7	272.	78.9	.1
8	277.	78.7	.1
9	294.	75.6	.0
10	346.	101.3	.0
11	364.	104.5	.0
12	371.	103.1	0.0
13	386.	109.4	0.0
14	417.	107.1	0.0
15	451.	119.2	0.0
16	543.	117.3	0.0
17	1794.	117.3	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO. 13

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1220.	121.0	0.0
2	-100.	121.0	0.0
3	-10.	121.0	0.0
4	0.	124.0	0.0
5	5.	124.0	0.0
6	10.	123.0	0.0
7	70.	113.0	0.0
8	100.	115.0	0.0
9	140.	112.0	-.0
10	210.	85.0	-.0
11	240.	87.0	-.0
12	260.	84.0	-.0
13	280.	83.0	-.0
14	310.	85.0	-.0
15	390.	96.0	-.0
16	420.	114.0	-.0
17	560.	118.0	0.0
18	1780.	118.0	0.0

CROSS SECTION NO. 14

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1242.	122.8	0.0
2	-96.	122.8	0.0
3	-29.	122.6	0.0
4	-28.	125.3	0.0
5	64.	115.8	0.0
6	159.	113.7	0.0
7	207.	117.2	-.0
8	258.	83.7	-.0
9	329.	86.7	-.0
10	389.	83.8	-.0
11	414.	84.8	-.0
12	493.	117.4	-.0
13	646.	121.6	0.0
14	727.	121.5	0.0
15	1758.	121.5	0.0

CROSS SECTION NO. 15

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1376.	123.4	0.0
2	-196.	123.4	0.0
3	-16.	124.1	0.0
4	22.	114.7	0.0
5	65.	116.1	.0
6	124.	84.2	.0
7	200.	86.6	.1
8	279.	88.7	.1
9	290.	85.6	.0
10	357.	116.8	.0
11	422.	117.5	0.0
12	450.	115.6	0.0
13	503.	121.5	0.0
14	543.	122.2	0.0
15	595.	114.0	0.0
16	1624.	114.0	0.0

CROSS SECTION NO. 16

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1670.	122.0	0.0
2	-570.	122.0	0.0
3	-480.	118.0	0.0
4	-460.	116.0	0.0
5	-420.	116.0	.0
6	-360.	94.0	.0
7	-310.	94.0	.0
8	-300.	93.0	.0
9	-180.	93.0	.0
10	-170.	91.0	.0
11	-160.	92.0	.0
12	-140.	92.0	.0
13	-100.	108.0	.0
14	-70.	116.0	0.0
15	-50.	115.0	0.0
16	-20.	118.0	0.0
17	0.	125.0	0.0
18	1330.	125.0	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO; 17

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1540.	117.0	0.0
2	-500.	117.0	0.0
3	-380.	116.0	0.0
4	-350.	121.0	0.0
5	-320.	120.0	0.0
6	-310.	117.0	0.0
7	-300.	116.0	-.0
8	-240.	99.9	-.1
9	-40.	91.9	-.1
10	-10.	101.0	-.0
11	20.	114.0	-.0
12	30.	124.0	0.0
13	1460.	124.0	0.0

CROSS SECTION NO; 18

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1700.	133.0	0.0
2	-560.	133.0	0.0
3	-480.	119.0	0.0
4	-420.	118.0	-.0
5	-360.	95.0	-.0
6	-320.	94.9	-.1
7	-270.	93.9	-.1
8	-260.	91.9	-.1
9	-240.	90.9	-.1
10	-230.	92.9	-.1
11	-200.	86.9	-.1
12	-170.	94.9	-.1
13	-140.	96.0	-.0
14	-90.	117.0	-.0
15	-70.	121.0	0.0
16	-40.	119.0	0.0
17	-20.	124.0	0.0
18	0.	127.0	0.0
19	1300.	127.0	0.0

CROSS SECTION NO; 19

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1230.	130.0	0.0
2	0.	130.0	0.0
3	10.	129.5	0.0
4	15.	125.0	0.0
5	120.	119.0	.0
6	160.	100.0	.0
7	200.	89.0	.0
8	230.	83.5	.0
9	260.	81.0	.0
10	280.	81.0	.0
11	340.	90.0	.0
12	360.	91.0	.0
13	380.	99.0	.0
14	395.	114.0	.0
15	405.	119.0	0.0
16	1770.	119.0	0.0

CROSS SECTION NO; 20

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1764.	121.9	0.0
2	-443.	121.9	0.0
3	-432.	120.1	0.0
4	-415.	112.1	0.0
5	-406.	109.8	-.0
6	-375.	98.8	-.0
7	-316.	99.3	-.1
8	-264.	96.0	-.1
9	-245.	99.0	-.1
10	-213.	99.8	-.1
11	-207.	97.9	-.0
12	-157.	107.4	-.0
13	-140.	120.8	-.0
14	1236.	120.8	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO; 21

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1016.	120.3	0.0
2	340.	120.3	-.0
3	364.	108.4	-.0
4	395.	106.1	-.0
5	407.	104.1	-.0
6	437.	104.1	-.0
7	484.	90.0	-.0
8	508.	92.8	-.1
9	526.	90.6	-.1
10	545.	97.2	-.0
11	578.	98.9	-.0
12	616.	98.1	-.0
13	636.	99.0	-.0
14	669.	112.8	-.0
15	674.	121.1	0.0
16	683.	123.4	0.0
17	1984.	123.4	0.0

CROSS SECTION NO; 22

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1797.	125.5	0.0
2	-502.	125.5	0.0
3	-468.	122.5	0.0
4	-461.	112.8	.0
5	-436.	105.2	.0
6	-396.	95.3	.0
7	-386.	94.7	.2
8	-381.	91.1	.3
9	-347.	84.3	.3
10	-337.	83.7	.4
11	-324.	80.1	.5
12	-297.	78.5	.5
13	-267.	82.5	.4
14	-229.	94.7	.1
15	-193.	106.0	.0
16	-165.	108.5	.0
17	-163.	119.8	.0
18	-118.	119.8	0.0
19	-80.	126.1	0.0
20	-1.	127.8	0.0
21	1203.	127.8	0.0

CROSS SECTION NO; 23

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1650.	120.6	0.0
2	-299.	120.6	0.0
3	-290.	120.6	.0
4	-250.	105.9	.0
5	-232.	103.0	.0
6	-204.	105.6	.1
7	-172.	97.9	.1
8	-150.	97.2	.2
9	-122.	103.5	.1
10	-109.	103.6	.1
11	-90.	102.2	.1
12	-81.	104.2	.1
13	-72.	104.2	.0
14	-21.	120.3	.0
15	-5.	119.2	0.0
16	1350.	119.2	0.0

CROSS SECTION NO; 24

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1149.	129.0	0.0
2	-302.	129.0	0.0
3	-286.	121.7	0.0
4	-265.	116.3	0.0
5	-246.	114.7	.0
6	-217.	99.8	.1
7	-149.	90.0	.1
8	-105.	100.1	.0
9	-66.	104.6	.0
10	-34.	112.5	.0
11	-25.	120.2	0.0
12	-15.	123.3	0.0
13	0.	122.8	0.0
14	851.	122.8	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO. 25

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	21.	125.2	0.0
2	53.	121.1	0.0
3	85.	121.9	.0
4	124.	108.8	.0
5	133.	108.8	.0
6	161.	95.5	.0
7	228.	94.0	.0
8	244.	96.5	.0
9	291.	97.9	.0
10	311.	101.9	.0
11	320.	101.2	.0
12	364.	120.3	.0
13	374.	120.7	0.0
14	381.	126.2	0.0
15	406.	124.7	0.0

CROSS SECTION NO. 26

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1040.	126.5	0.0
2	295.	126.5	0.0
3	310.	122.0	0.0
4	360.	122.0	0.0
5	380.	119.0	0.0
6	390.	115.0	.0
7	400.	107.0	.0
8	440.	95.0	.0
9	460.	91.5	.0
10	500.	92.5	.0
11	520.	92.5	.0
12	540.	95.0	.0
13	560.	95.5	.0
14	580.	112.0	.0
15	610.	121.0	0.0
16	1960.	121.0	0.0

CROSS SECTION NO. 27

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1650.	126.0	0.0
2	-500.	126.0	0.0
3	-390.	127.0	0.0
4	-310.	125.0	.0
5	-295.	108.0	.0
6	-250.	99.0	.0
7	-170.	97.0	.0
8	-150.	98.0	.0
9	-130.	97.0	.0
10	-110.	99.0	.0
11	-75.	118.0	.0
12	-50.	122.0	0.0
13	-40.	120.0	0.0
14	0.	132.0	0.0
15	100.	132.0	0.0
16	1350.	132.0	0.0

CROSS SECTION NO. 28

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1180.	136.0	0.0
2	-200.	136.0	0.0
3	-100.	135.0	0.0
4	0.	134.0	0.0
5	140.	124.0	0.0
6	160.	120.0	0.0
7	200.	119.0	0.0
8	235.	122.0	.0
9	310.	98.0	.0
10	320.	95.0	.0
11	390.	99.0	.0
12	410.	98.0	.0
13	430.	100.0	.0
14	480.	122.0	.0
15	500.	122.0	0.0
16	530.	128.0	0.0
17	600.	127.0	0.0
18	1820.	127.0	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO. 29

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1338.	124.8	0.0
2	-16.	124.8	0.0
3	1.	125.5	0.0
4	22.	118.4	-.0
5	63.	100.1	-.0
6	111.	100.4	-.0
7	162.	97.5	-.0
8	192.	99.1	-.0
9	222.	115.2	-.0
10	233.	125.8	0.0
11	252.	125.9	0.0
12	270.	124.7	0.0
13	1662.	124.7	0.0

CROSS SECTION NO. 30

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1270.	135.0	0.0
2	-150.	135.0	0.0
3	0.	132.0	0.0
4	30.	126.0	0.0
5	90.	126.0	0.0
6	120.	122.0	.0
7	160.	95.0	.0
8	190.	99.0	.0
9	210.	92.0	.0
10	250.	92.0	.0
11	290.	109.0	.0
12	300.	108.0	.0
13	330.	124.0	.0
14	400.	129.0	0.0
15	430.	125.0	0.0
16	440.	130.0	0.0
17	470.	130.0	0.0
18	500.	129.0	0.0
19	1730.	129.0	0.0

CROSS SECTION NO. 31

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1323.	130.8	0.0
2	-2.	130.8	0.0
3	35.	127.6	0.0
4	36.	125.5	0.0
5	49.	125.9	0.0
6	65.	119.2	0.0
7	75.	115.7	0.0
8	127.	96.9	0.0
9	177.	96.7	0.0
10	195.	99.6	0.0
11	230.	99.8	0.0
12	264.	115.7	0.0
13	286.	120.4	0.0
14	294.	127.5	0.0
15	336.	126.6	0.0
16	395.	130.0	0.0
17	407.	132.6	0.0
18	1677.	132.6	0.0

CROSS SECTION NO. 32

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-1230.	130.0	0.0
2	0.	130.0	0.0
3	10.	129.5	0.0
4	15.	125.0	0.0
5	120.	119.0	.0
6	160.	100.0	.0
7	200.	89.0	.0
8	230.	83.5	.0
9	260.	81.0	.0
10	280.	81.0	.0
11	340.	90.0	.0
12	360.	91.0	.0
13	380.	99.0	.0
14	395.	114.0	.0
15	405.	119.0	0.0
16	1770.	119.0	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO. 33

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-607.	129.9	0.0
2	-192.	129.9	.0
3	-151.	99.6	.1
4	-107.	81.3	.4
5	-28.	88.4	.4
6	-5.	97.2	.1
7	33.	105.0	.0
8	75.	104.0	.0
9	96.	95.1	.2
10	131.	93.2	.2
11	156.	94.2	.1
12	224.	131.5	.0
13	246.	130.3	0.0
14	393.	130.3	0.0

CROSS SECTION NO. 34

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-393.	127.6	0.0
2	-210.	127.6	0.0
3	-163.	115.7	.0
4	-111.	101.1	.0
5	-51.	99.0	.0
6	-8.	98.9	.0
7	50.	98.1	.1
8	107.	95.8	.1
9	130.	97.7	.0
10	151.	112.1	.0
11	194.	126.3	0.0
12	607.	126.3	0.0

CROSS SECTION NO. 35

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-491.	131.9	0.0
2	-261.	131.9	0.0
3	-209.	132.8	0.0
4	-169.	119.9	0.0
5	-109.	113.2	0.0
6	-74.	113.1	-.2
7	9.	79.4	-.3
8	31.	94.8	-.3
9	86.	101.0	-.1
10	133.	102.0	-.1
11	150.	99.1	-.0
12	217.	130.4	-.0
13	251.	130.4	0.0
14	509.	130.4	0.0

CROSS SECTION NO. 36

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-491.	131.9	0.0
2	-261.	131.9	0.0
3	-209.	132.8	0.0
4	-169.	119.9	0.0
5	-109.	113.2	0.0
6	-74.	113.3	0.0
7	9.	106.0	0.0
8	31.	106.0	0.0
9	86.	106.0	0.0
10	133.	106.0	0.0
11	150.	106.0	0.0
12	217.	130.4	0.0
13	251.	130.4	0.0

CROSS SECTION NO. 37

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-491.	131.9	0.0
2	-261.	131.9	0.0
3	-209.	132.8	0.0
4	-169.	119.9	0.0
5	-109.	113.2	0.0
6	-74.	113.3	0.0
7	9.	106.0	0.0
8	31.	106.0	0.0
9	86.	106.0	0.0
10	133.	106.0	0.0
11	150.	106.0	0.0
12	217.	130.4	0.0
13	251.	130.4	0.0

Figure 12. Example Output (continued).

CROSS SECTION NO; 38

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	21.	125.2	0.0
2	53.	121.1	0.0
3	85.	121.9	.0
4	124.	108.8	.0
5	133.	108.8	.0
6	161.	95.5	.0
7	228.	94.0	.0
8	244.	96.5	.0
9	291.	97.9	.0
10	311.	101.9	.0
11	320.	101.2	.0
12	364.	120.3	.0
13	374.	120.7	0.0
14	381.	126.2	0.0
15	406.	124.7	0.0

CROSS SECTION NO; 39

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-737.	129.1	0.0
2	1.	129.1	0.0
3	30.	121.6	0.0
4	59.	121.3	-.0
5	88.	105.4	-.0
6	108.	104.2	-.0
7	118.	99.7	-.1
8	138.	97.6	-.1
9	162.	105.0	-.1
10	178.	106.8	-.0
11	192.	106.6	-.0
12	197.	109.2	-.0
13	214.	110.5	0.0
14	231.	116.5	0.0
15	250.	117.2	0.0
16	259.	120.7	0.0
17	273.	122.0	0.0
18	283.	126.2	0.0
19	371.	127.6	0.0
20	1013.	127.6	0.0

CROSS SECTION NO; 40

POINT	HORIZONTAL	ELEVATION	DELTA ELEV.
1	-965.	126.0	0.0
2	-600.	126.0	0.0
3	-485.	126.0	0.0
4	-450.	123.0	0.0
5	-370.	123.0	0.0
6	-325.	122.0	0.0
7	-300.	123.0	0.0
8	-280.	124.0	0.0
9	-250.	124.0	0.0
10	-204.	126.0	0.0
11	-190.	117.0	0.0
12	-180.	114.0	0.0
13	-90.	108.0	0.0
14	-41.	127.0	0.0
15	50.	126.0	0.0
16	150.	123.0	0.0
17	250.	122.0	0.0
18	350.	125.0	0.0
19	460.	126.0	0.0
20	785.	126.0	0.0

Figure 12. Example Output (continued).

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APPENDIX A

PROGRAM THEORY

A-1 WATER SURFACE PROFILE COMPUTATIONS

General

The water surface profile is computed assuming one-dimensional, spatially varied, steady flow. This implies the following assumptions: 1) the hydraulic characteristics of flow remain constant for the time interval under consideration; 2) the flow streamlines are practically parallel, i.e., a hydrostatic pressure distribution prevails over the channel section, and 3) the secondary flow (lateral or cross-stream) is negligible when compared to the longitudinal flow. A further assumption is that the frictional loss at a section is the same as for uniform flow with the same velocity and hydraulic radius. In addition to these basic assumptions, others will be made when appropriate, the most important being that the slope of the channel is so small that the depth of flow is assumed the same whether vertical or normal to the channel bottom.

Dynamic equations for spatially varied flow can be obtained for three different approaches. These approaches are: 1) momentum, 2) total head, and 3) energy. While the water surface profiles computed by each method are identical, the derived equations themselves are only identical for the special conditions of steady, uniform flow. Because of difficulties in using the momentum and energy equations on non-prismatic channels, the total head approach is used in the program. The following is a brief derivation of the one dimensional dynamic equation for spatially varied flow from the total head equation. Yen and Wenzel (1970) and Li (1972) contain completed derivations of the spatially varied flow equations by all three methods and comparison of the results.

Continuity Equation

Figure A.1 shows an incremental length dx of an open channel with a spatially varied flow profile. The continuity equation for the increment is

$$\frac{dQ}{dx} = q \tag{A-1}$$

where Q is the channel discharge and q is the lateral inflow per unit channel length. Considering the incompressibility of water, Q = VA and

$$\frac{d(VA)}{dx} = q \tag{A-2}$$

Dynamic Equation of Spatially Varied Flow

The total hydraulic head above a selected datum at the upstream section is given by

$$H = Z + d \cos \theta + \alpha \frac{V^2}{2g} \tag{A-3}$$

where H is the total head above the horizontal datum, Z is the elevation of the channel bottom above the datum, d is the depth of flow α is the velocity head correction factor, defined as $\frac{1}{Av^3} \int v^3 \, dA$, where v is the local mean temporal velocity of flow, θ is the bottom slope angle, and g is the acceleration due to gravity. By taking the bottom of the channel as the x axis and differentiating Equation A-3 with respect to x, the following equation is obtained:

$$\frac{dH}{dx} = \frac{dZ}{dx} + \cos \theta \frac{dd}{dx} + \frac{d}{dx} (\alpha \frac{V^2}{2g}) \tag{A-4}$$

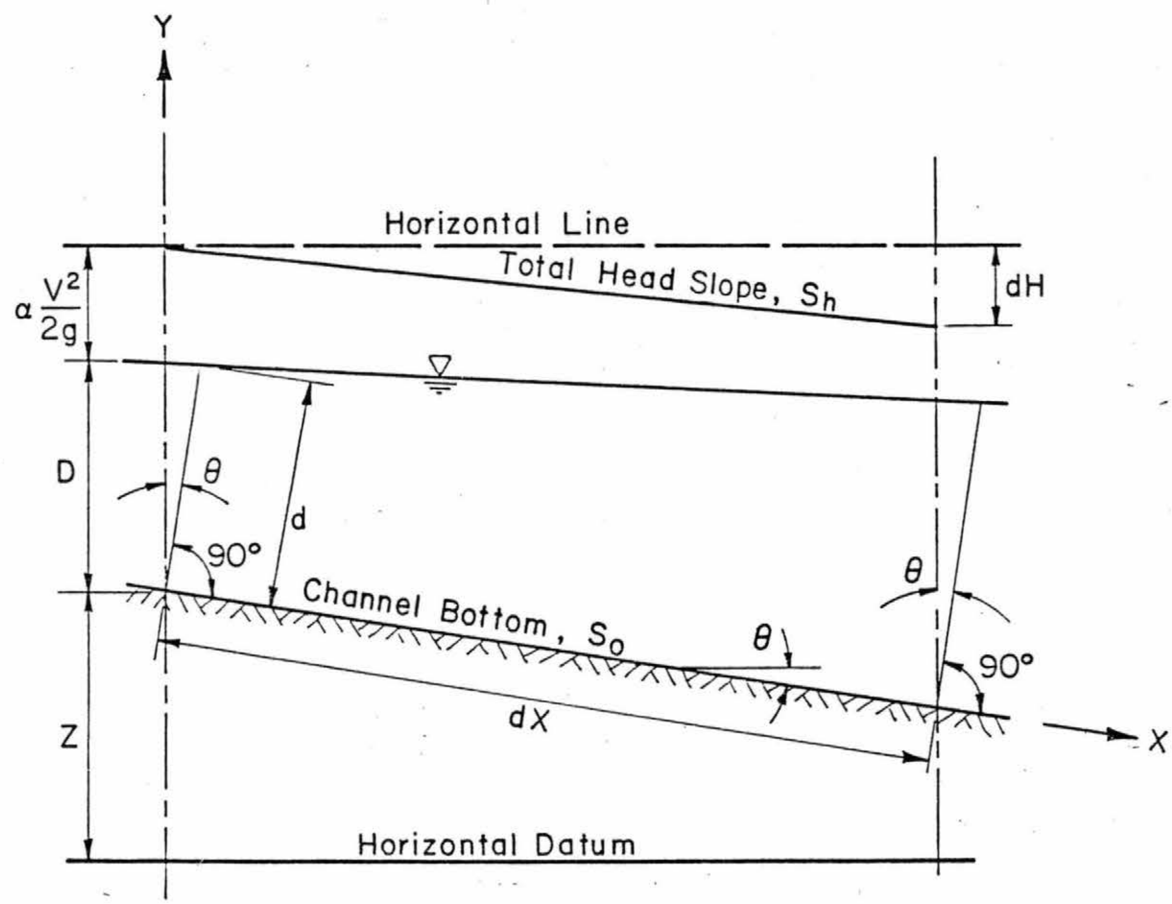

Figure A.1 Incremental length of channel.

The total head slope S_h is then defined as

$$S_h = - \frac{dH}{dx} \tag{A-5}$$

and the bed slope, S_o is expressed as

$$S_o = - \frac{dZ}{dx} \tag{A-6}$$

Substituting Equations A-5 and A-6 into Equation A-4 and solving for dd/dx yields

$$\frac{dd}{dx} = \frac{1}{\cos\theta} \quad [(S_o - S_h - \frac{d}{dx} (\alpha \frac{V^2}{2g})] \tag{A-7}$$

which is the general differential equation for spatially varied steady flow derived from the total head. It represents slope of the water surface with respect to the channel bottom. In most cases the angle θ is so small that $\cos \theta \approx 1$, and $d \approx D$. Placing these approximations into Equation A-7 results in

$$\frac{dD}{dx} = S_o - S_h - \frac{d}{dx} \quad (\alpha \frac{V^2}{2g}) \tag{A-8}$$

where D is the depth of flow measured vertically from the bed Figure A.1).

Chow (1959) and Henderson (1966) present additional spatially and gradually varied flow theories.

Manning's Equation

Total head slope S_h is computed by $S_h = S_f + S_{\ell v}$ where S_f is the friction slope, and $S_{\ell v}$ is the slope of head losses due to other factors.

The friction slope is evaluated using the empirical Manning's equation

$$S_f = \left(\frac{Qn}{1.49A\ R^{2/3}}\right)^2 \qquad \text{(English units)} \qquad \text{(A-9)}$$

where R is the hydraulic radius of flow and n is the Manning's coefficient of channel roughness.

Manning's equation was developed for uniform steady flow, therefore, using Equation A-9 for spatially varied flow produces errors, However, the errors are believed to be small compared with those ordinarily incurred using the uniform-flow formula and in the selection of the roughness coefficient (Chow 1959).

Manning's n-value for alluvial streams is not constant but is a function of discharge and depth (see Simons and Sentürk, 1977). While there are complicated procedures to determine channel roughness, which are fairly exact, in the mathematical model Manning's n-value is made a simple function of discharge, $n = n_o a_n Q^{b_n}$ where a_n and b_n are empirically determined coefficients, and n_o is the initial value of Manning's n.

The channel conveyance is defined by

$$K = \frac{1.49}{n} A\ R^{2/3} \qquad \text{(A-10)}$$

where K is the conveyance. Combining Equations A-10 and A-11 yields

$$S_f = \left(\frac{Q}{K}\right)^2 \qquad \text{(A-11)}$$

Eddy Losses

The slope $S_{\ell v}$ is the slope of the head losses due to all factors except friction and is nominally referred to as the eddy loss slope.

No rational method is available to evaluate eddy losses. Eddy loss depends mainly on velocity head change and may be expressed as a part of it or

$$S_{\ell v} = C_e \; [(\alpha_2 V_2^2 - \alpha_1 V_1^2)/2g] \; dx \tag{A-12}$$

where C_e is an empirical coefficient.

<u>Standard Step Method</u>

The mathematical model uses the finite difference standard step method to solve Equation A-8 for the water surface profile. The computations are carried out moving upstream cross section by cross section from a known water surface. Figure A.2 shows a typical channel reach.

The total head and head loss between the two cross sections are equated

$$Z_2 + D_2 + \alpha_2 \frac{V_2^2}{2g} = Z_1 + D_1 + \alpha_1 \frac{V_1^2}{2g} + H_\ell + H_{\ell v} \tag{A-13}$$

where H_ℓ is the friction loss and may be written as:

$$H_\ell = S_f \; \Delta X \tag{A-14}$$

where ΔX is the horizontal distance between cross sections, and $H_{\ell v}$ is the loss due to all other factors. $H_{\ell v}$ may be written as

$$H_{\ell v} = S_{\ell v} \; \Delta X \tag{A-15}$$

The average of channel conveyance at the two cross sections is used to compute the friction loss. Thus combining Equations A-11 and A-14 results in

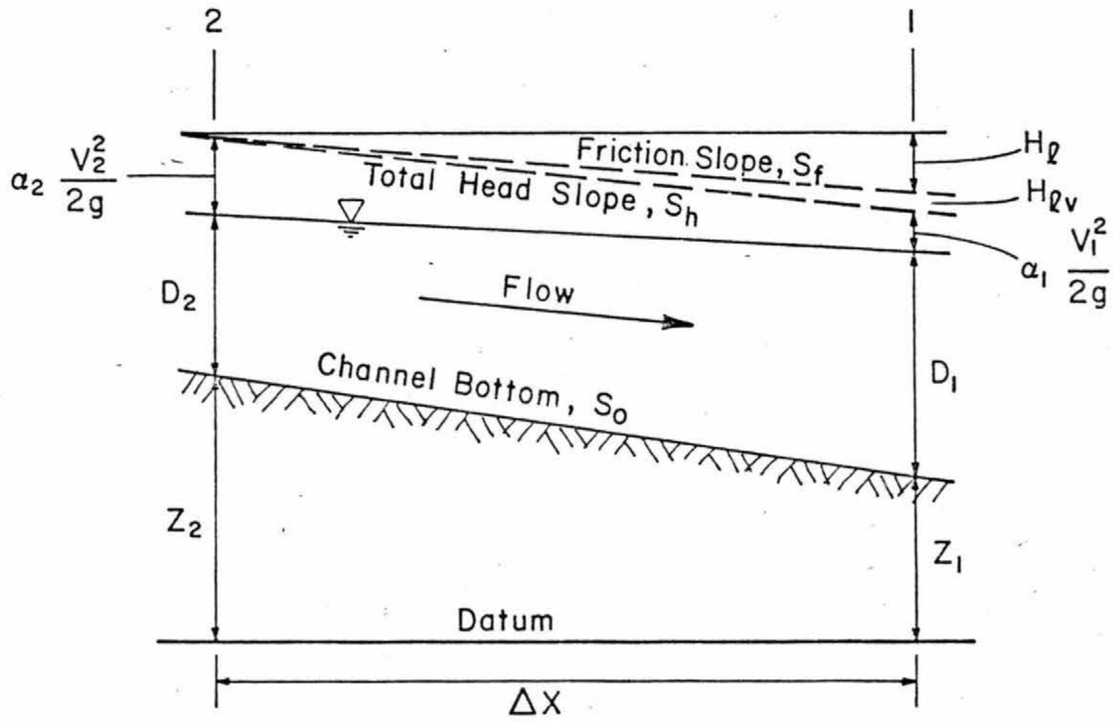

Figure A.2 Channel reach for standard step method.

$$H_{\ell} = \Delta X \left(\frac{Q_2}{(K_1 + K_2)/2} \right)^2 \qquad \text{(A-16)}$$

The continuity equation can be written

$$Q = VA \ . \qquad \text{(A-17)}$$

Total head at the downstream cross section, H_1, is known and is determined by

$$H_1 = Z_1 + D_1 + \alpha_1 \frac{V_1 2}{2g} \qquad \text{(A-18)}$$

Combining Equations A-9, A-12, A-16, A-17 and A-18 yields

$$\alpha_2 \left(\frac{Q_2}{A_2}\right)^2 \frac{1}{2g} + D_2 + Z_2 - \Delta X \left(\frac{Q_2}{(K_1 + K_2)/2}\right)^2 - C_e\left(\frac{\alpha_2 V_2^2 - \alpha_1 V_1^2}{2g}\right) = H_1$$

(A-19)

By starting at a known downstream water surface and proceeding upstream one cross section at a time, the water surface profile is computed.

Computation of Hydraulic Properties

The solution of Equation A-19 requires determination of channel hydraulic properties, area, conveyance, etc., at various depths. In backwater computations the hydraulic properties are computed with relationships developed using digitized channel geometry.

Coordinate Points

Channel cross sections are defined by (x,z) sets of coordinates. Figure A.3 shows a typical cross section. To allow for different Manning's n-values across the section three subdivisions are made: Right Over Bank, Main Channel, and Left Over Bank. The subsections are divided by the two stations D_{lob} and D_{rob}. The Manning's n-value at each coordinate point is set according to its location.

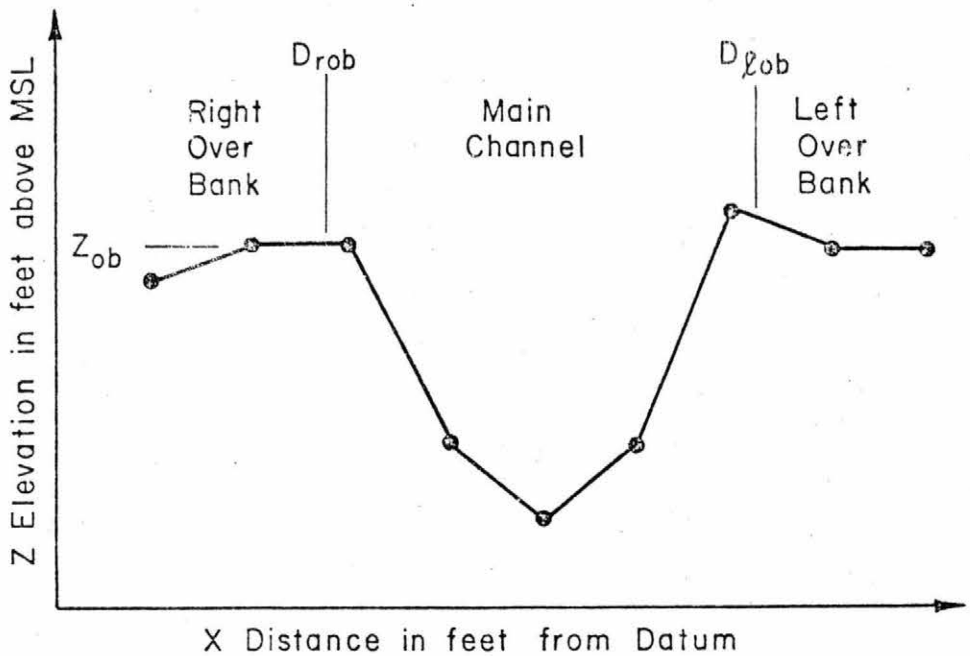

Figure A.3 Typical channel cross section with subdivisions.

Area

Area of flow for a given water surface elevation is computed by summing incremental areas between consecutive coordinates of the cross section. Figure A.4 illustrates this technique. Total area of flow is the summation of the increment areas, a_i.

$$A = \sum_{i=1}^{N} a_i \tag{A-20}$$

where N is the total number of cross section incremental areas. Incremental areas are computed by

$$a_i = X_b D_a \tag{A-21}$$

where X_b is defined in Figure A.5 and D_a is defined as:

$$D_a = \frac{1}{2} (D'_1 + D'_2) \tag{A-22}$$

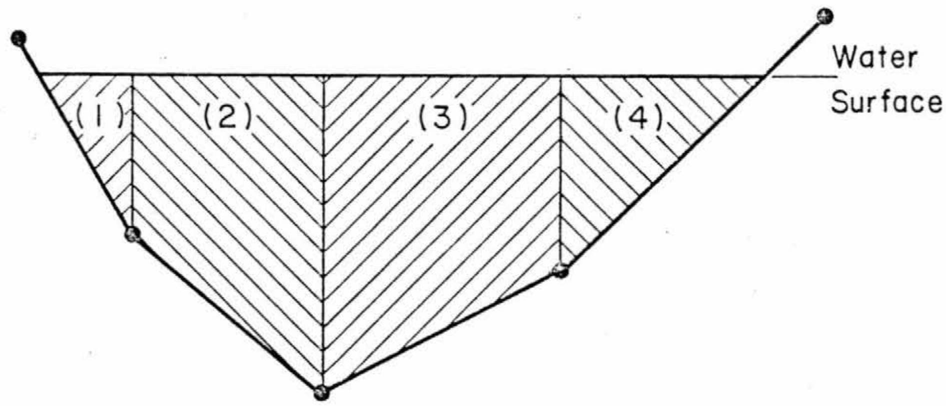

Figure A.4 Incremental areas in a cross section.

where D'_1 and D'_2 are defined in Figure A.5. If the water surface intercepts the cross section between coordinate points as shown by increment 4 in Figure A.4, straight line interpolation between the points is used to compute the triangular area. If the water surface is above a coordinate end point (first or last points), the area of flow is determined by extending a vertical line to the water surface from the end point as shown in Figure A.6.

In many rivers, especially those with small gradients, man-made or natural levees reduce the area of flow until they are topped. Overbank flow area is not considered until the water surface exceeds the elevation Z_{ob} shown in Figure A.3.

Wetted Perimeter

The wetted perimeter p_i is the length of the cross section below the water surface and is computed in increments by

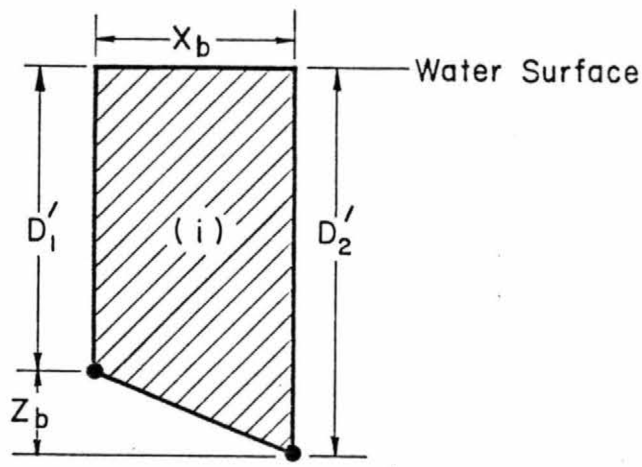

Figure A.5 Incremental cross section area.

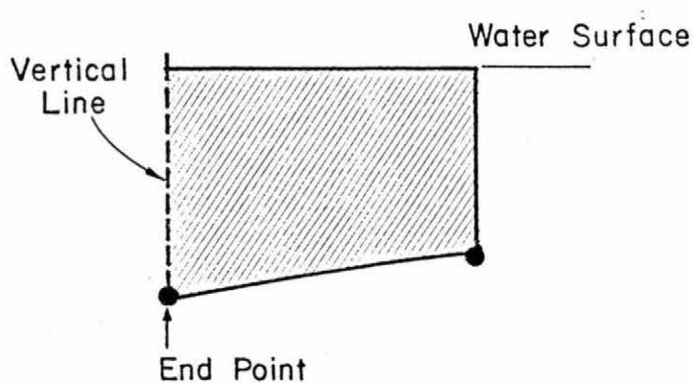

Figure A.6 Flow area at end of cross section.

$$p_i = \sqrt{X_b^2 + Z_b^2} \tag{A-23}$$

where Z_b is defined in Figure A.5.

Hydraulic Radius

The incremental hydraulic radius, r_i, is calculated by

$$r_i = \frac{a_i}{p_i} \tag{A-24}$$

Conveyance

The total cross section conveyance is computed by summing the incremental conveyance

$$K = \sum_{i=1}^{N} k_i \tag{A-25}$$

where k_i is the incremental conveyance and is computed by

$$k_i = \frac{1.49}{n_{a_i}} a_i \, r_i^{2/3} \tag{A-26}$$

where n_{a_i} is the average Manning's n value at the two coordinate points which define the increment.

Alpha

Alpha, the velocity distribution factor, is used to account for distribution of flow across the cross section and not vertical shape of the velocity profile. Alpha is calculated by

$$\alpha = \frac{\sum_{i=1}^{N} \left(\frac{k_i^3}{a_i^2}\right)}{K^3/A^2} \tag{A-27}$$

Effective Depth and Effective Width. Two conveyance weighed parameters, effective depth, D_e, and effective width, W_e, are used in the sediment transport calculations to represent the average hydraulic properties and are calculated as

$$D_e = \frac{\sum_{i=1}^{N} \frac{D_{a_i}^{5/3} a_i}{n_{a_i}}}{\sum_{i=1}^{N} \frac{D_{a_i}^{2/3} a_i}{n_{a_i}}} \tag{A-28}$$

$$W_e = \frac{\sum_{i=1}^{N} D_{a_i}^{2/3} a_i}{D_e^{5/3}} \tag{A-29}$$

The effective depth and effective width values are not used in the water surface profile calculations.

Channel Hydraulic Property Relationship. Hydraulic property relationships are computed to relate area of flow, conveyance, alpha, effective depth, and effective width to the thalweg depth. Two separate sets are calculated: one set for main channel flow and a second for overbank flow. The hydraulic property relations are

Main Channel Flow ($D \leq Z_{ob}$)

$$W_e = a_1 D^{b_1} \tag{A-30}$$

$$D_e = a_2 D^{b_2} \tag{A-31}$$

$$A = a_3 D^{b_3} \tag{A-32}$$

$$K = a_4 D^{b_4} \tag{A-33}$$

$$\alpha = a_5 D^{b_5} \qquad \text{(A-34)}$$

Overbank Flow $(D > Z_{ob})$

$$W_e = a_6 D^{b_6} \qquad \text{(A-35)}$$

$$D_e = a_7 D^{b_7} \qquad \text{(A-36)}$$

$$A = a_8 D^{b_8} \qquad \text{(A-37)}$$

$$K = a_9 D^{b_9} \qquad \text{(A-38)}$$

$$\alpha = a_{10} D^{b_{10}} \qquad \text{(A-39)}$$

where D is the thalweg depth and a_1 to a_{10} and b_1 to b_{10} are computed coefficients. The overbank relationship includes both the overbank and main channel flow for depths greater than Z_{ob}.

Coefficients of the hydraulic properties relations are determined by 1) calculating the hydraulic properties of each cross section for ten evenly spaced incremental depths of flow in the main channel and for ten increments of depths above the overbank elevation, Z_{ob}. Then 2) coefficients of the relations are computed by a least squares regression. To maintain continuity in the backwater computation, overbank relations for area and conveyance are forced to have the same value as the main channel relations at the overbank elevation.

Newton-Raphson Solution for the Total Head Equation

The model solves the equation of spatially varied steady flow by using an analytical first order Newton-Raphson (N-R) method to give successive approximations in the standard step calculation. Combining Equations A-17, A-32, A-33 and A-34 yields the spatially varied flow equation as a sole function of D_2

$$(1 - C_e) \frac{a_5}{a_3^2} \frac{Q_2^2}{2g} D_2^{(b_5 - 2b_3)} + D_2 - \frac{4\Delta X\ Q_2^2}{(K_1^2 + 2K_1\ a_4\ D_2^{b_4} + a_4^2\ D_2^{2b_4})}$$

$$+ C_e \frac{\alpha_1 V_1^2}{2g} + Z_2 - H_1 = 0 \qquad \text{(A-40)}$$

From the Taylor series expansion of an arbitrary function $F(\psi)$, the first order N-R approximation to $F(\psi)$ can be obtained by

$$\psi^* = \psi_0 - \frac{F(\psi_0)}{F'(\psi_0)} \qquad \text{(A-41)}$$

where ψ^* is the root of $F(\psi)$ and ψ_0 is the estimate of ψ^*. When applying Equation A-41 to the solution of the backwater equation ψ is the depth of flow, D_2, at the upstream cross section, and $F(\psi)$ is the total head equation evaluated at that location as computed by Equation A-40. For the N-R solution the first derivative of the total head equation must be obtained.

Differentiating Equation A-40 with respect to D_2 yields

$$(1 - C_e) \frac{Q_2^2}{2g} \left(\frac{a_5}{a_3^2}\right) (b_5 - 2b_3)\ D_2^{(b_5 - 2b_3 - 1)} + 1$$

$$+ \frac{4\Delta X Q_2^2 \quad 2K_1 a_4\ b_4\ D_2^{(b_4 - 1)} + a_4^2\ 2b_4\ D_2^{(2b_4 - 1)}}{(K_1^2 + 2K_1\ a_4\ D_2^{b_4} + a_4^2\ D_2^{2b_4})^2} \qquad \text{(A-42)}$$

Equation A-42 is $F'(\psi)$ in the first order N-R. When Equation A-40 is evaluated at depths other than its roots, the equation is not equal to zero, but is instead equal to the error in the total head. Figure A.7 is a qualitative plot of Equation A-40. The shape of the curve can be verified by consideration of Equation A-19. As the depth

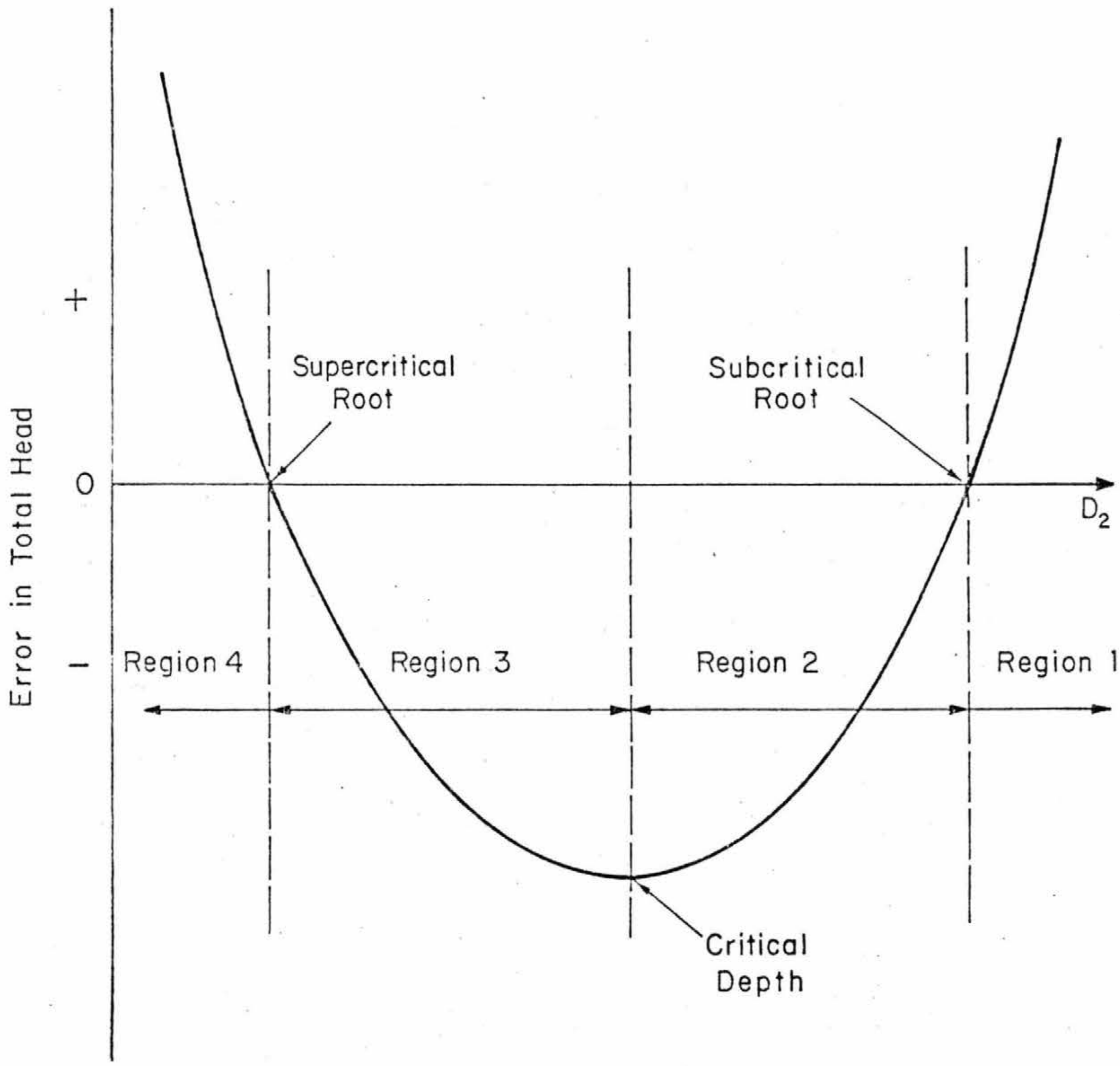

Figure A.7 Error in total head equation as a function of depth of flow.

approaches zero the area of flow goes to zero and the velocity goes to infinity. With a large velocity the velocity head term dominates the equation and causes a large positive error. Conversely, as the depth becomes large the depth itself dominates, and again the error becomes large and positive. At critical depth the specific head is at a minimum and the error is negative.

Care must be taken in using Equation A-41. If the total head equation is not exactly convex, it takes many interactions to converge to a root. Also, if the initial guess is on the supercritical side of the curve, the N-R method drives the solution to the supercritical root, even if the flow is subcritical. By using simple logic the convergence of the N-R method has been greatly improved.

The curve in Figure A.7 is broken into four different regions according to the signs of the error and first derivative. These regions are:

1. error positive, first derivative positive,
2. error negative, first derivative positive,
3. error negative, first derivative negative, and
4. error positive, first derivative negative.

The computer program's simple logic statements can detect in which region the estimate of D_2 is.

In most applications the subcritical root is desired, and logic in the computer program insures it will be found. If the estimate is in region 1 or 2 the N-R method finds the subcritical root, but if it is in regions 3 or 4, the N-R method is forced to the subcritical root. In region 3, simply taking the negative of the first derivative forces the solution to the subcritical root. In region 4, a new estimate is determined by computing critical depth and adding a constant to insure that the new estimate of D_2 is in region 1 or 2.

Divided Flow

In cases where divided flow occurs, the program has the ability to determine the percentage of the total flow going down each of the divided flow reaches. Using an initial guess of the percenage of total flow in each reach the program calculates a water surface profile up each reach. If the upstream water surface elevations match within the defined backwater accuracy tolerance the calculations stop. If not the program uses a numerical second order curve fitting routine developed by Li (1972) to determine new estimates of the flow percentage. The program then repeats itself until the upstream stream water surface converges.

The second order curve fitting routine efficiently and accurately finds the solution to divided flow problems when the flow down the smaller reach is an appreciable percentage of the total flow. In cases when the smaller reach does not carry at least 5% of the total flow the routine may inaccurately set the discharge in the reach to zero. Therefore in cases where this occurs often, the user may wish to modify or replace Subroutine Divide.

Weir Flow

Two flow conditions can occur at a single weir. If the weir height is small compared to the depth of flow the weir has no significant effect and the water surface profile is computed with the standard backwater curve. If the weir is not submerged the depth at the weir is computed by a broad crested weir formula

$$D = {\frac{Q}{W\ I_1}}^{I_2} \qquad \text{(A-43)}$$

where I_1 and I_2 are constants depending on the shape and surface of the weir.

In the program the depth at the weir is computed by both methods and the greater of the two is used.

A-2 SEDIMENT ROUTING

General

Once the backwater profile is determined for a given time period, sediment is routed through the system. Sediment routing is accomplished in three separate steps. The first step is calculation of the sediment transport at each cross section in the river, which requires knowledge of the velocity, depth, and width of flow obtained by the backwater calculations. The second step is routing of the sediment to determine change in cross section area due to sediment movement. The third step is distribution of the change in area through the cross section to obtain a new channel geometry.

Sediment Transport

In the mathematical simulation of stream bed aggradation-degradation, conventional algorithms for calculating sediment transport such as Einstein's procedure require large amounts of computer time. This excessive use of computer time makes these methods impractical. It is also difficult to calibrate conventional methods for observed data. Therefore, empirical relationships are often used in mathematical modeling. In the Sedimentation Study of the Yazoo River Basin (Simons, et al., 1978) a relationship of the following form was used

$$Q_s = 4.48 \times 10^{-6} V^{3.16} D_e^{0.94} W_e \qquad \text{(A-44)}$$

where Q_s is the bed material sediment transport in cfs. Although this equation is not applicable to other rivers, it fits data for the Yazoo River Basin. The coefficients in Equation A-44 were determined by: 1) taking suspended sediment measurements, 2) applying the Modified

Einstein procedure to obtain the bed material load, and 3) using standard least squares regression to obtain the coefficients.

It is important to note that Equation A-44 is only for the bed material load. In most cases the wash load is supply limited and all wash load entering a system will pass through it. An exception to this is when sedimentation behind a large dam is of interest. In this case, calculation of the wash load is required. It is also interesting to note in Equation A-44 that the bed material size does not enter into sediment calculations. This is due to the limited range of data from which the equation was derived. In cases when there is insignificant data to develop relationships such as Equation A-44, Colby's and Meyer-Peter, Müeller's methods have been used with success at minimal cost in computer time.

Sediment Routing

Channel aggradation-degradation is determined by solving the sediment continuity equation.

$$\frac{\partial Q_s}{\partial x} + (1 - \rho)\,\frac{\partial A_b}{\partial t} = q_{s\ell} \qquad \text{(A-45)}$$

where A_b is the cross-sectional area of the bed, $q_{s\ell}$ is the lateral tributary sediment inflow and ρ is the porosity that is the volume of voids per unit volume of sediment in place. The first term in Equation A-45 represents the change in sediment transport along the river, while the second term represents the change in bed area with time. A negative value of the second term signifies degradation while a positive value signifies aggradation.

Interior Sediment Routing

Figure A.8 shows a typical interior sediment routing condition. Equation A-45 is solved by a two step, finite difference algorithm. The first step is calculation of change in sediment volume between cross sections. The change in volume is computed by

$$\Delta V_i = (Q_{s_{i+1}} - Q_{s_i} + q_{s\ell_i})dt \tag{A-46}$$

where ΔV_i is the change in sediment volume between sections i and i+1. The second step in the sediment routing is determination of change in area at each cross section, that requires knowledge of the location of sediment erosion or deposition between cross sections. Modeling of sediment dispersion is required to compute exactly where in the reach between sections the sediment is eroded or deposited. Unfortunately, modeling of sediment dispersion requires excessive amounts of computer time, and considerable effort to calibrate. Therefore, an empirical distribution based on physical reasoning is used. A triangular distribution weighted downstream as shown in Figure A.8, is used. One-quarter of the volume is deposited or eroded in the upstream half of the segment between sections, while three-quarters of the volume is deposited or eroded in the downstream half. This simply places more weight of sediment transport rate at the downstream section for determining the degradation and aggradation. With this assumption the change in bed area at a section is equal to

$$\Delta A_{b_i} = \frac{1}{(1 - \rho)} \frac{\frac{1}{4} \Delta V_{i-1} + \frac{3}{4} \Delta V_i}{\frac{1}{2} (\Delta X_i + \Delta X_{i-1})} \tag{A-47}$$

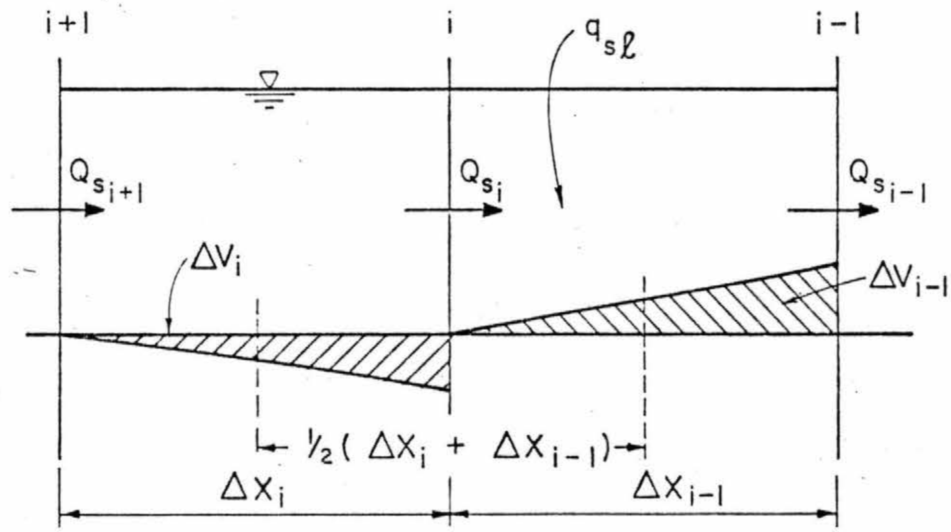

Figure A.8 Finite difference sediment routing scheme.

where ΔA_{b_i} is the change in bed area at the cross section. The physical significance of triangular distribution is seen if Equation A-46 (neglecting lateral sediment inflow) is substituted into Equation A-47.

$$\Delta A_{b_i} = \frac{1}{(1-\rho)} \frac{\frac{1}{4}(Q_{s_i} - Q_{s_{i-1}}) + \frac{3}{4}(Q_{s_{i+1}} - Q_{s_i})}{\frac{1}{2}(\Delta X_{i-1} + \Delta X_i)} dt \qquad \text{(A-48)}$$

$$\Delta A_{b_i} = \frac{1}{(1-\rho)} \frac{(\frac{3}{2} Q_{s_{i+1}} - Q_{s_i} - \frac{1}{2} Q_{s_{i-1}})}{\Delta X_{i-1} + \Delta X_i} dt \qquad \text{(A-49)}$$

As expected, the multiplying factor for sediment inflow, $Q_{s_{i+1}}$ is positive and the factor for the outflow $Q_{s_{i-1}}$ is negative. An important fact to note is that the multiplying factor for the sediment transport at the cross section is negative. This is physically logical. If the upstream and downstream transport is held constant, a reduction in the sediment transport at the section causes the section to aggrade while an increase in the transport causes it to degrade.

Boundary Sediment Routing

At the upstream and downstream boundary cross sections Equation A-47 cannot be used to compute the change in area at the section. This is usually not a problem since the upstream boundaries are always fixed, i.e. unchanged with time, and downstream boundaries are usually fixed to maintain numerical stability in the model. But in cases when a major tributary flows into the mainstem, the tributary's downstream cross section can be allowed to "float". Change in bed area for a downstream tributary section is computed by

$$\Delta A_{bi} = \frac{1}{(1 - \rho)} \frac{\Delta V_i}{\frac{1}{2}\Delta X_i} \quad \text{(A-50)}$$

Distribution of Erosion and Deposition Across the Cross Section

Once the change in area at a cross section is computed the area must be distributed across the section to determine the new channel geometry. With a one dimensional model the exact location of scour or deposition can not be determined since the program does not compute the lateral flow effects. Therefore, empirical procedures are used to distribute the bed area change. One method of distribution is to raise or lower the whole cross section a uniform amount, as shown in Figure A.9. This method is unrealistic because it changes the overbanks as much as the main channel regardless of flow conditions. A method that relates the change in bed elevation at a point to the hydraulic property of conveyance is used in the model. This method as shown in Figure A.10 is considered appropriate because conveyance is directly related to velocity and sediment transport.

A qualitative analysis was performed to test the validity of the sediment distribution scheme based on conveyance (which is directly related to depth if Manning's roughness is the same across the whole cross section). Three cross sections were taken from the Greenwood Bendway of the Yazoo River. At several points in each cross section the percent of maximum depth of flow, and the percent of maximum change in bed elevation (from February 2 to February 18, 1977) were determined. The results are plotted on Figure A.11. As one can see, change in bed elevation is roughly proportional to depth. The sediment distribution method based on the hydraulic properties at each point in the cross section more accurately represents the natural cross-sectional changes.

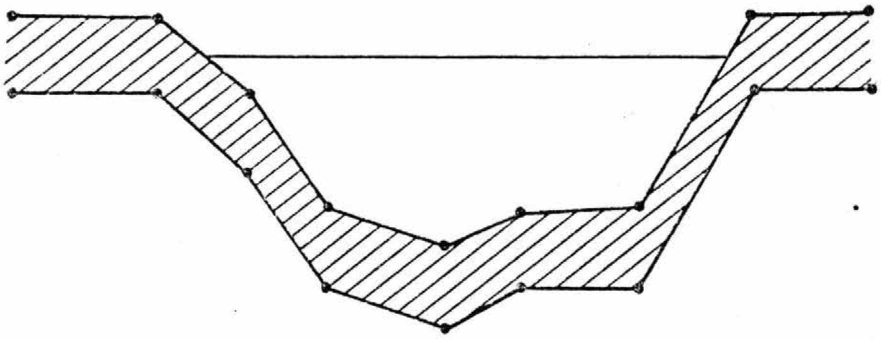

Figure A.9 Uniform sediment distribution.

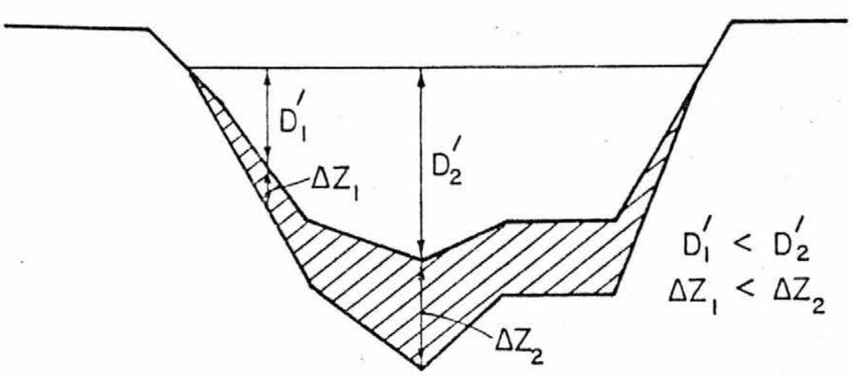

Figure A.10 Sediment distribution based on depth of flow.

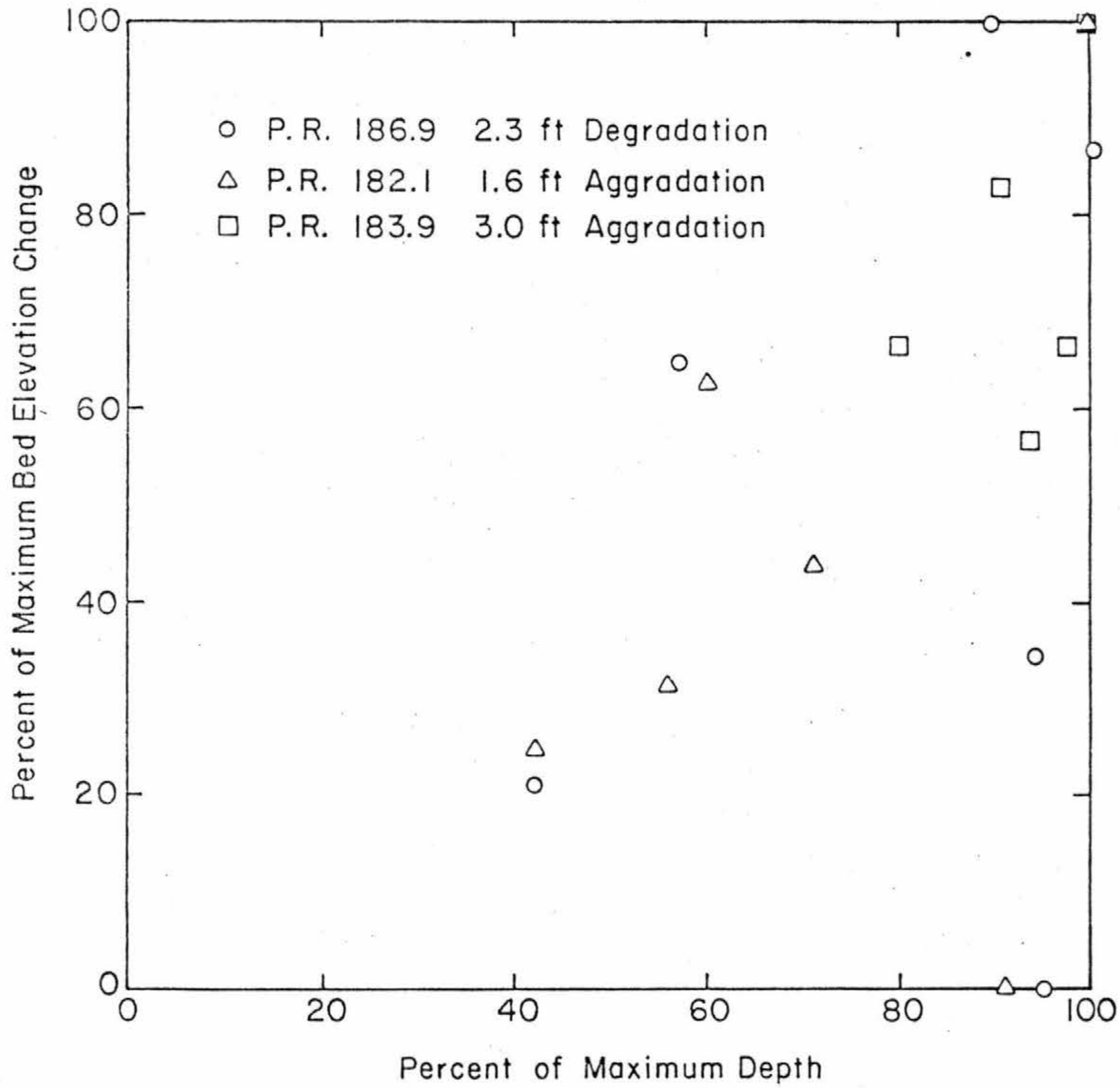

Figure A.11 Percent bed elevation change compared to percent of maximum.

The model computes change in elevation for each cross section point by

$$\Delta Z_j = \frac{k_\ell + k_{\ell+1}}{K_i} \quad \frac{\Delta A_{b_i}}{x_{j+1} - x_{j-1}} \tag{A-51}$$

where ΔZ_j is the change in elevation for point (j), k_ℓ and $k_{\ell+1}$ are the conveyance of the incremental areas to the right and left of the point, and x_{j+1} and x_{j-1} are the horizontal coordinates of the cross section points adjacent to (j) and K_i and ΔA_{b_i} are the total conveyance and bed area change at the ith cross section.

To save computer time sediment is not distributed at a cross section until a significant change in cross section area has occurred. This threshold can be determined according to the physical environment and the objective of study.

Weir Sediment

The sediment transport over a weir is assumed to be a percentage of the upstream sediment transport. The concept used in determining the percentage is shown in Figure A-12. A suspended bed material curve at the cross section directly above the weir is shown. The material in the shaded portion of the curve is assumed to pass over the weir. The percentage is computed using the Lane-Kalinske's relationship (Simons and Sentürk, 1977) for sediment concentration

$$C_y = C_a \exp\left(\frac{6w}{\kappa U_*} \quad \frac{y-a}{D}\right) \tag{A-52}$$

where C_y is the concentration at an arbitrary depth y, C_a is a reference concentration at a depth a, κ is the von Karman constant, w is the particle fall velocity, and U_* is the shear velocity.

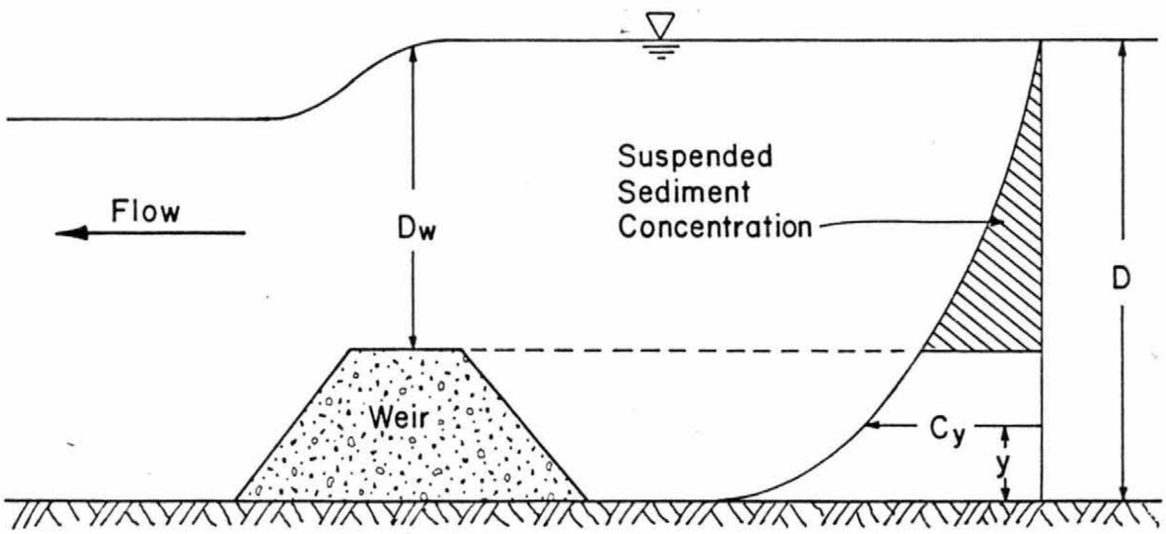

Figure A-12 Sediment transport over weirs.

By assuming a depth a which is close to the bed and much smaller than y, Equation A-52 reduces to

$$C_y = C_a \exp\left(\frac{-6w}{\kappa U_*} \frac{y}{D}\right) \tag{A-53}$$

Integrating Equation A-53 with respect to y yields

$$\int C_y d_y = C_a \frac{\exp\left(\frac{-6w}{\kappa U_*} \frac{y}{D}\right)}{\frac{-6w}{\kappa U_* D}} \tag{A-54}$$

Evaluating Equation A-54 for the shaded portion of the suspended sediment curve results in the percentage of upstream sediment transport P_c, which passes over the weir.

$$P_c = \frac{\int_{(D-D_w)}^{D} C_y d_y}{\int_{0}^{D} C_y d_y} \tag{A-55}$$

where D_w is the depth of flow at the weir. The reference concentration C_a cancels from the equation.

The shear velocity is computed using the Darcy-Weisbach resistance formula.

$$U_* = \frac{V}{\sqrt{8/f}} \tag{A-56}$$

The von Karman constant has a value much higher than in uniform flow, since the weir causes a large vertical turbulence. In the Sedimentation Study of the Yazoo River Basin, κ was set equal to 0.70.

A-3 LIST OF SYMBOLS

A	cross section area of flow
A_b	cross section bed area
a	reference depth
a_i	incremental flow area
a_n	coefficient of Manning's n-value relationship
a_1 - a_{10}	coefficients of hydraulic property relationships
b_n	coefficient of Manning's n-value relationship
b_1 - b_{10}	coefficients of hydraulic property relationships
C	sediment concentration
C_e	coefficient of eddy loss
D	vertical depth of flow, thalweg depth
D_a	average depth for incremental area
D_e	effective depth
D_{lob}	left over bank station
D_{rob}	right over bank station
D'	depth of coordinate point
d	depth of flow normal to the bed
g	acceleration of gravity
H	total hydraulic head
H_ℓ	friction head loss
$H_{\ell v}$	eddy head loss
I_1, I_2	weir coefficients
K	flow conveyance

k_i	incremental conveyance
N	number of cross section area increments
n	Manning's n-value
n_{a_i}	average Manning's n-value
n_o	initial Manning's n-value
p_i	incremental wetted perimeter
Q	water discharge
q	lateral discharge
Q_s	sediment transport
$q_{s\ell}$	lateral sediment inflow
R	hydraulic radius of flow
r_i	incremental hydraulic radius
S_f	friction slope
S_h	head loss slope
$S_{\ell v}$	eddy loss slope
S_o	bed slope
t	time
U_*	shear velocity
V	mean flow velocity
v	local temporal mean velocity of main flow
w	particle fall velocity
W_e	effective width
X_b	width of incremental area
x	distance along channel bottom
y	depth to channel bottom
Z	channel bottom elevation
Z_b	change in depth for incremental area

Z_{ob}	over bank elevation
α	velocity head correction factor
ΔA_b	change in bed cross-sectional area
ΔV	change in sediment volume between cross sections
ΔX	horizontal distance between cross sections
γ	specific weight of fluid
κ	von Karman constant
ρ	sediment deposit porosity
θ	bed angle to horizontal
ψ	arbitrary variable

A-4 REFERENCES

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2. Henderson, F. M., 1966, Open Channel Flow, Macmillan, New York, New York.

3. Li, R. M., 1972, Sheet Flow Under Simulated Rainfall, Thesis (M.S.) Department of Civil Engineering, Colorado State University, Fort Collins, Colorado.

4. Simons, D. B., and Sentürk, 1977, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado.

5. Simons, D. B., Li, R. M., Brown, G. O., Chen, Y. H., Ward, T. J., Duong, N., and Ponce, V. M., 1978, Sedimentation Study of the Yazoo River Basin, Phase I, General Report, Department of Civil Engineering, CER77-78DBS-RML-GOB-YHC-TJW-ND-VMP48, Colorado State University, Fort Collins, Colorado.

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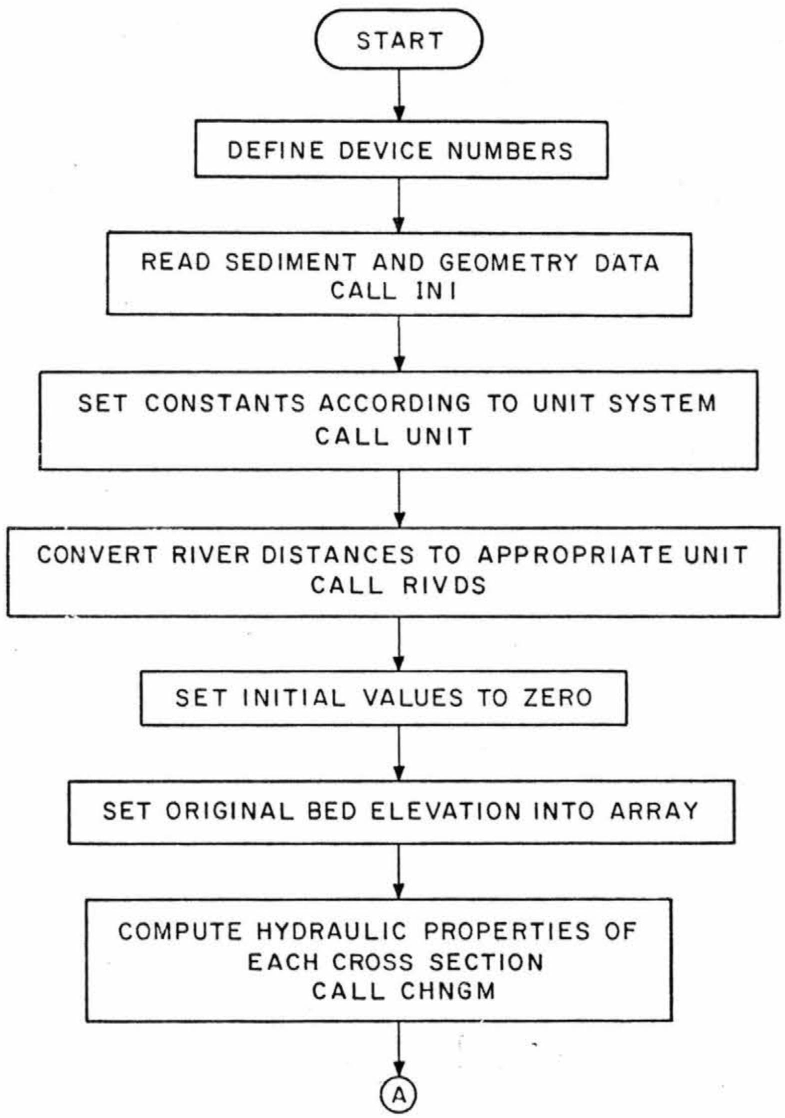
APPENDIX B

PROGRAM FLOW CHARTS

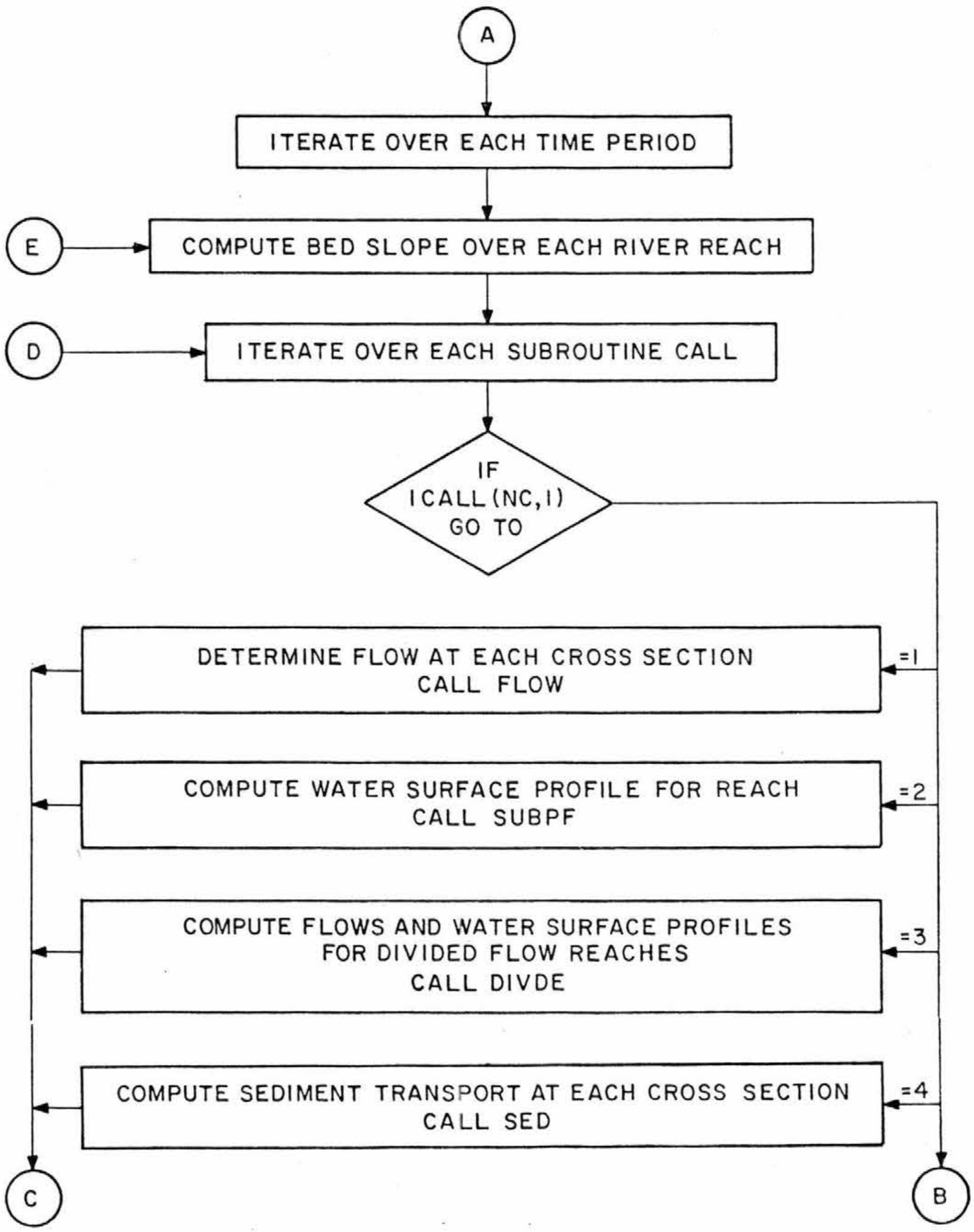
The following are subroutine flow charts for the program KUWASER. To aid the user in understanding the program the flow charts have been designed to show the overall program operation and not the actual FORTRAN statements. The flow charts are presented by subroutine in alphabetical order.

Program KUWASER

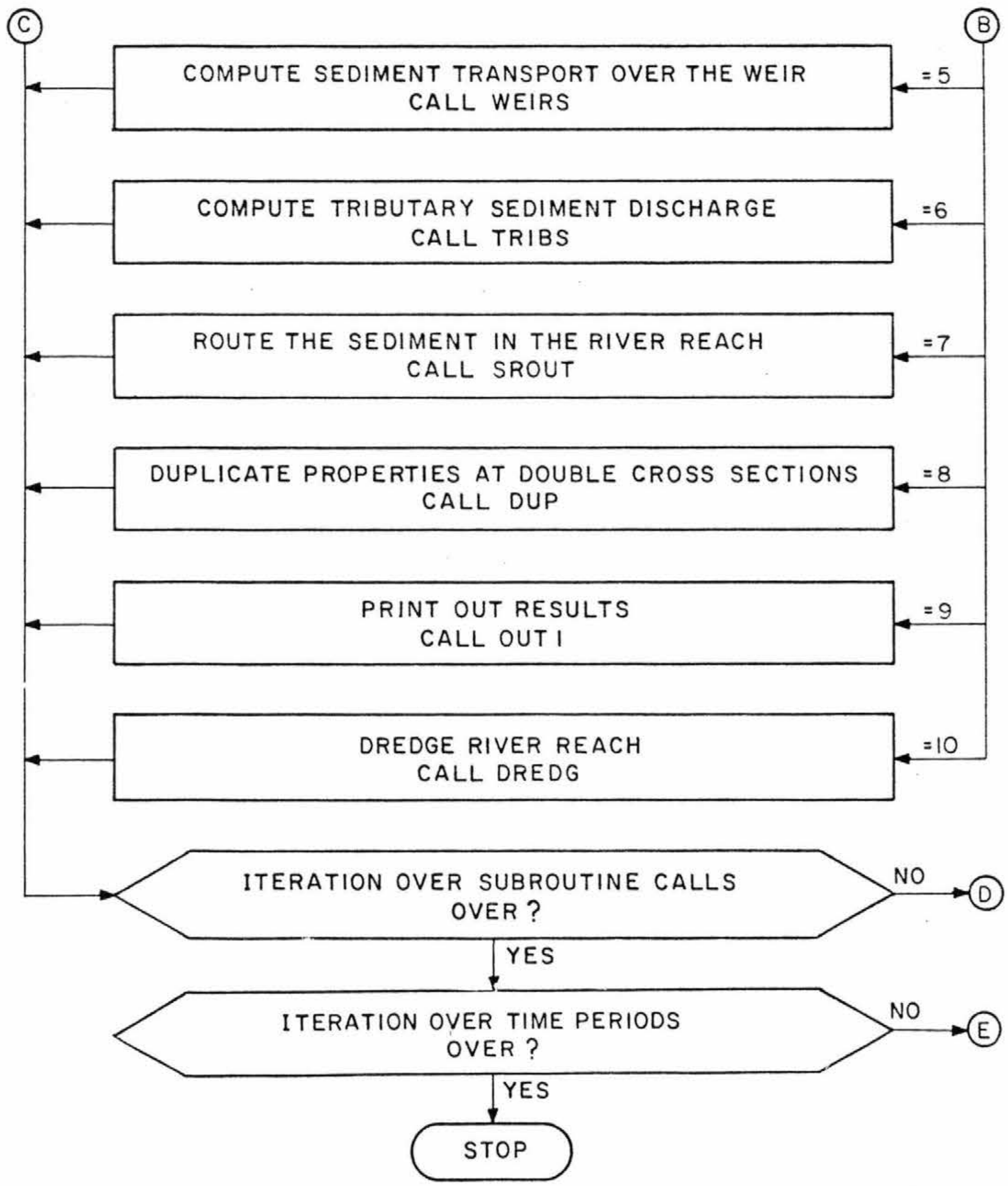
This program is a known discharge, water and sediment routing model.



Program KUWASER (continued)

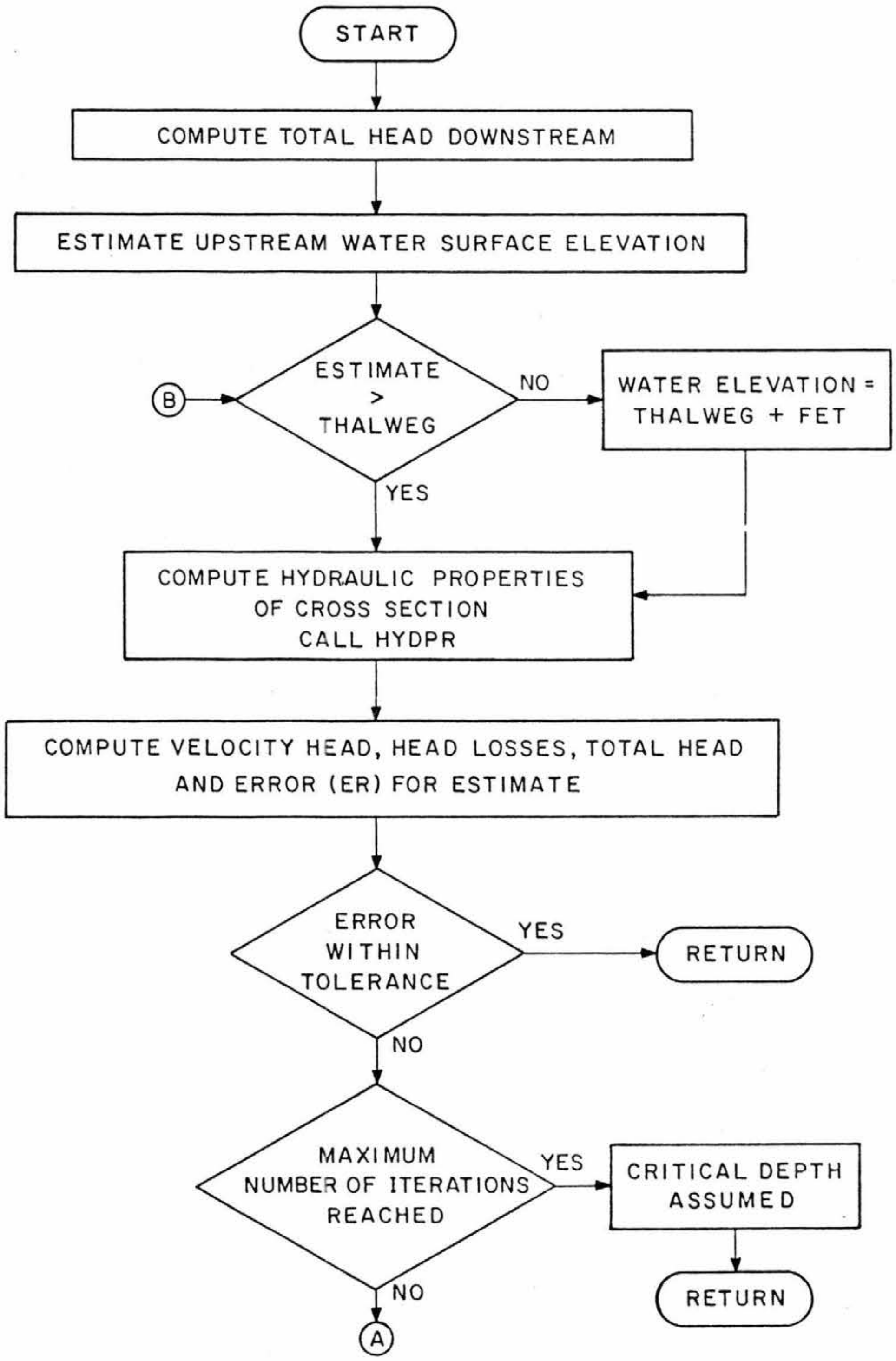


Program KUWASER (continued)

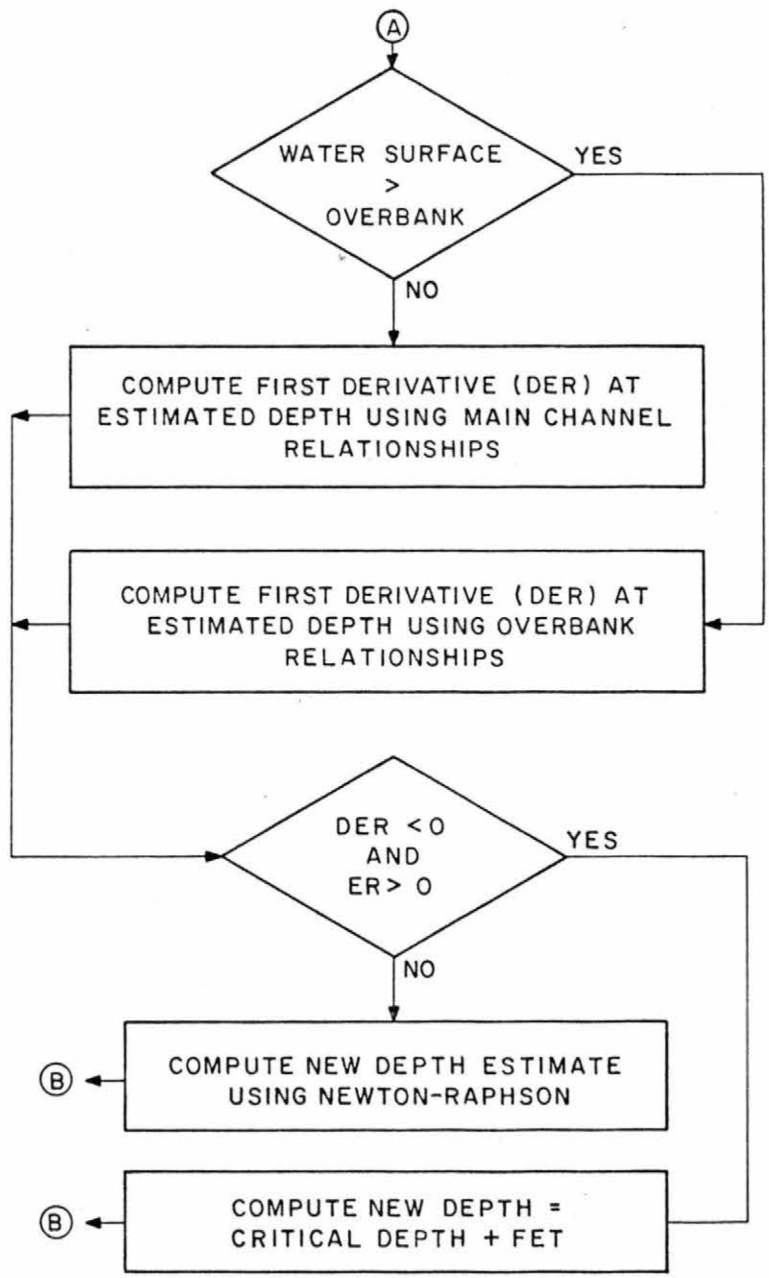


Subroutine BKWAT

This subroutine calculates the water surface elevation at a cross section once the conditions at the downstream section are known. The routine uses a first order Newton-Raphson solution to solve the total head equation.

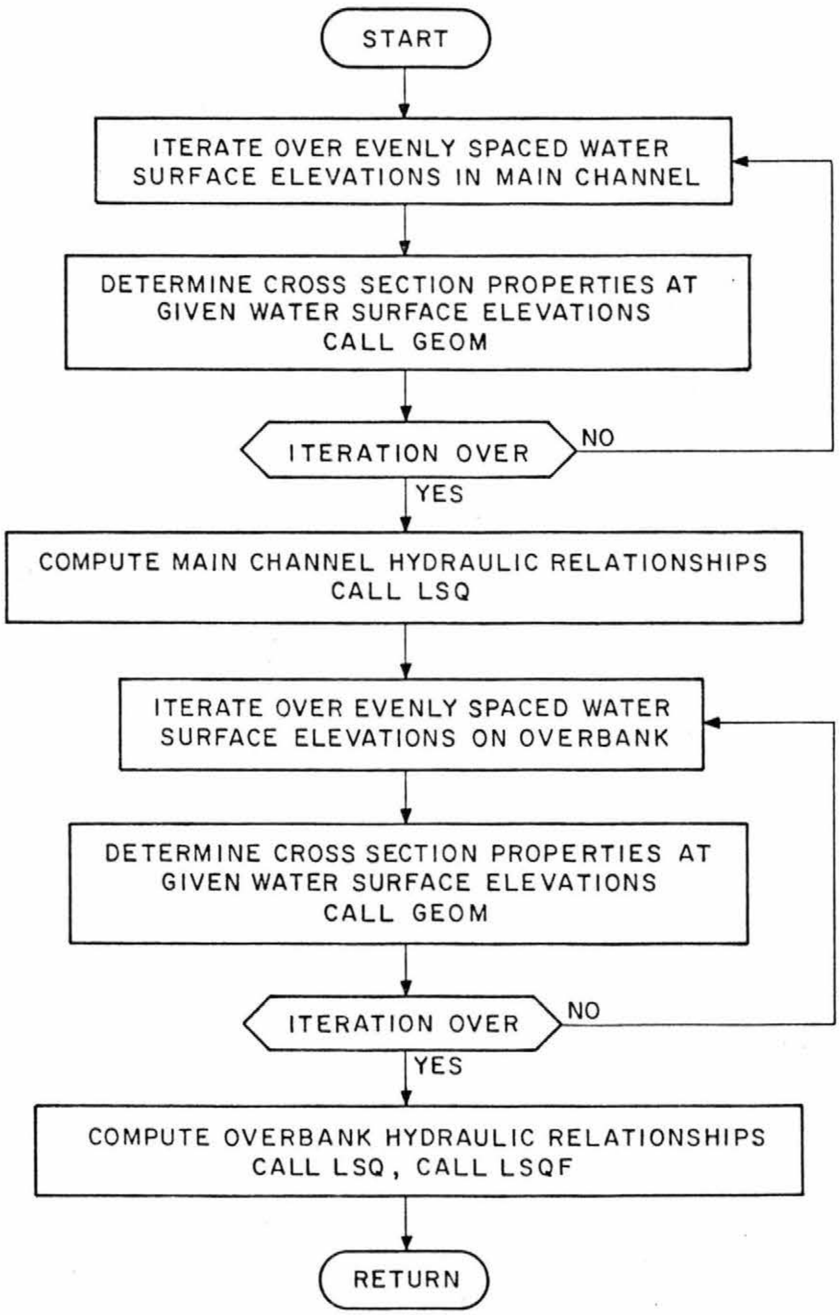


Subroutine BKWAT (continued)



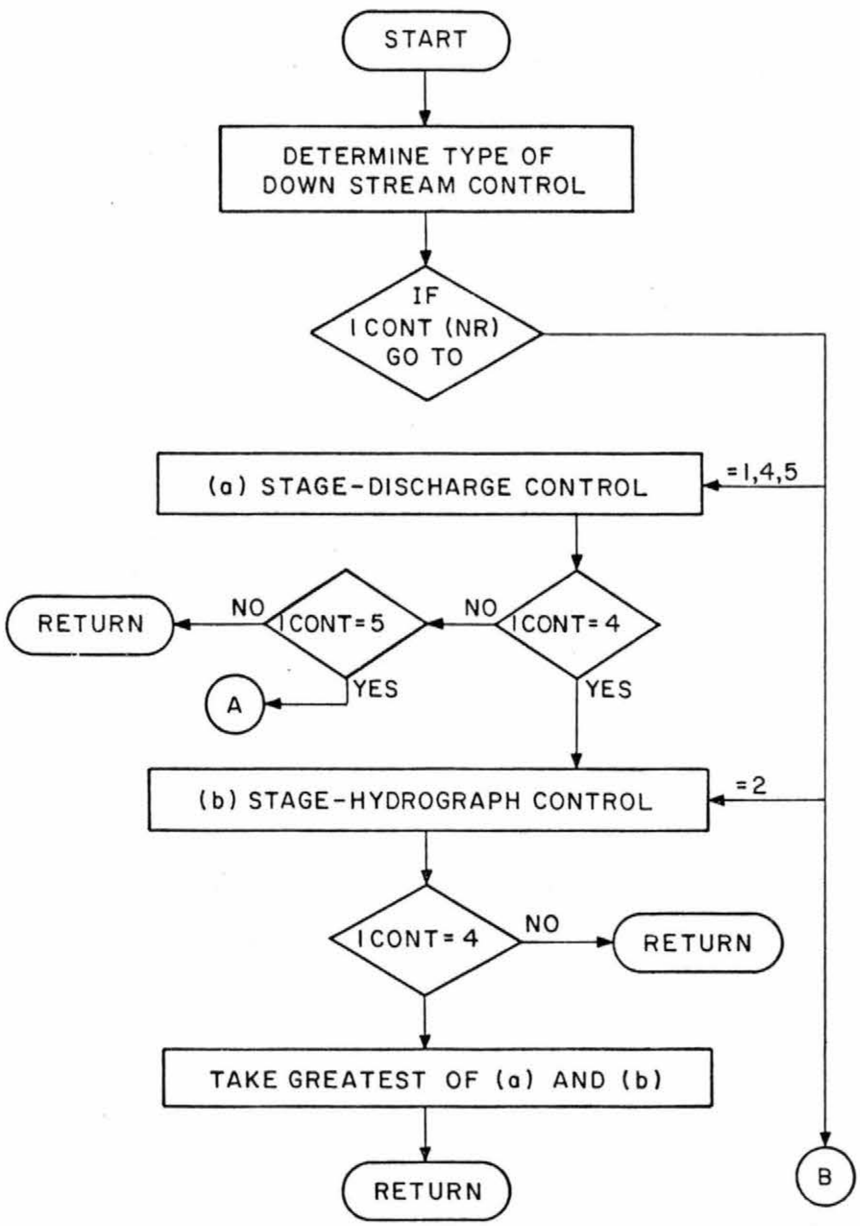
Subroutine CHNGM

This subroutine computes power relations that are used to calculate effective depth (ED), effective width (EW), alpha (ALP), total area (TA), and total conveyance (TK), for a cross section, as a function of the water surface elevation (WS).

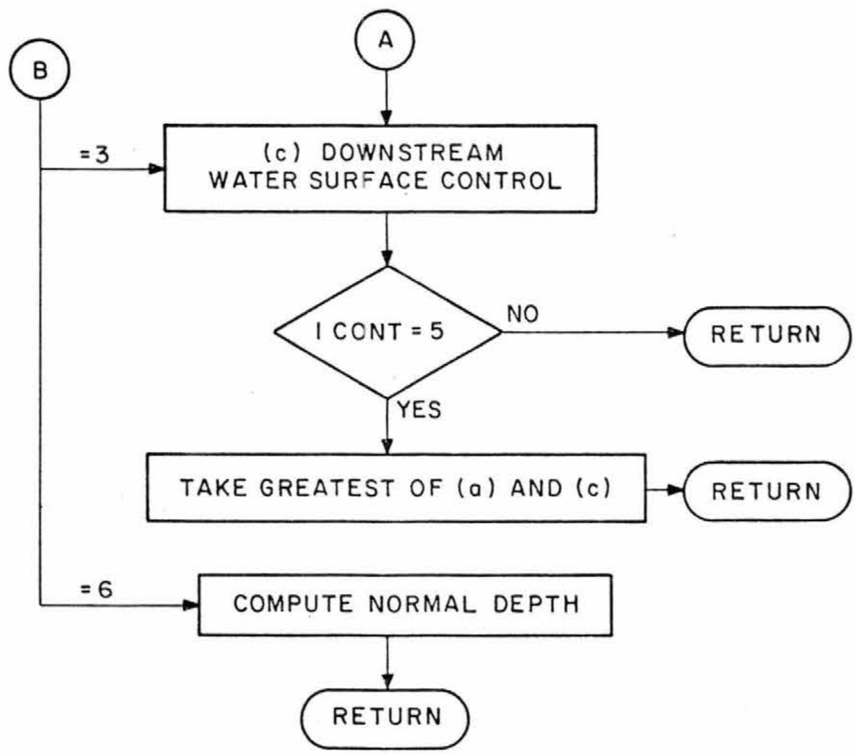


Subroutine CONT

This subroutine is used to compute the water surface elevation at the downstream control.

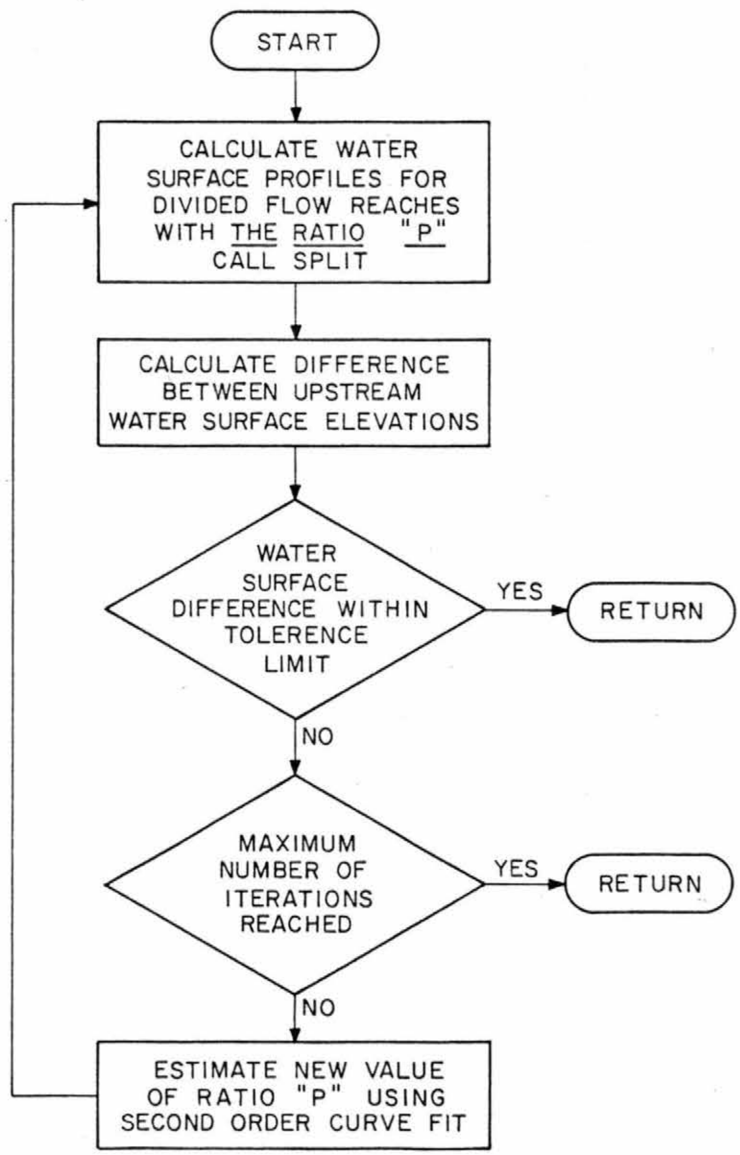


Subroutine CONT (continued)



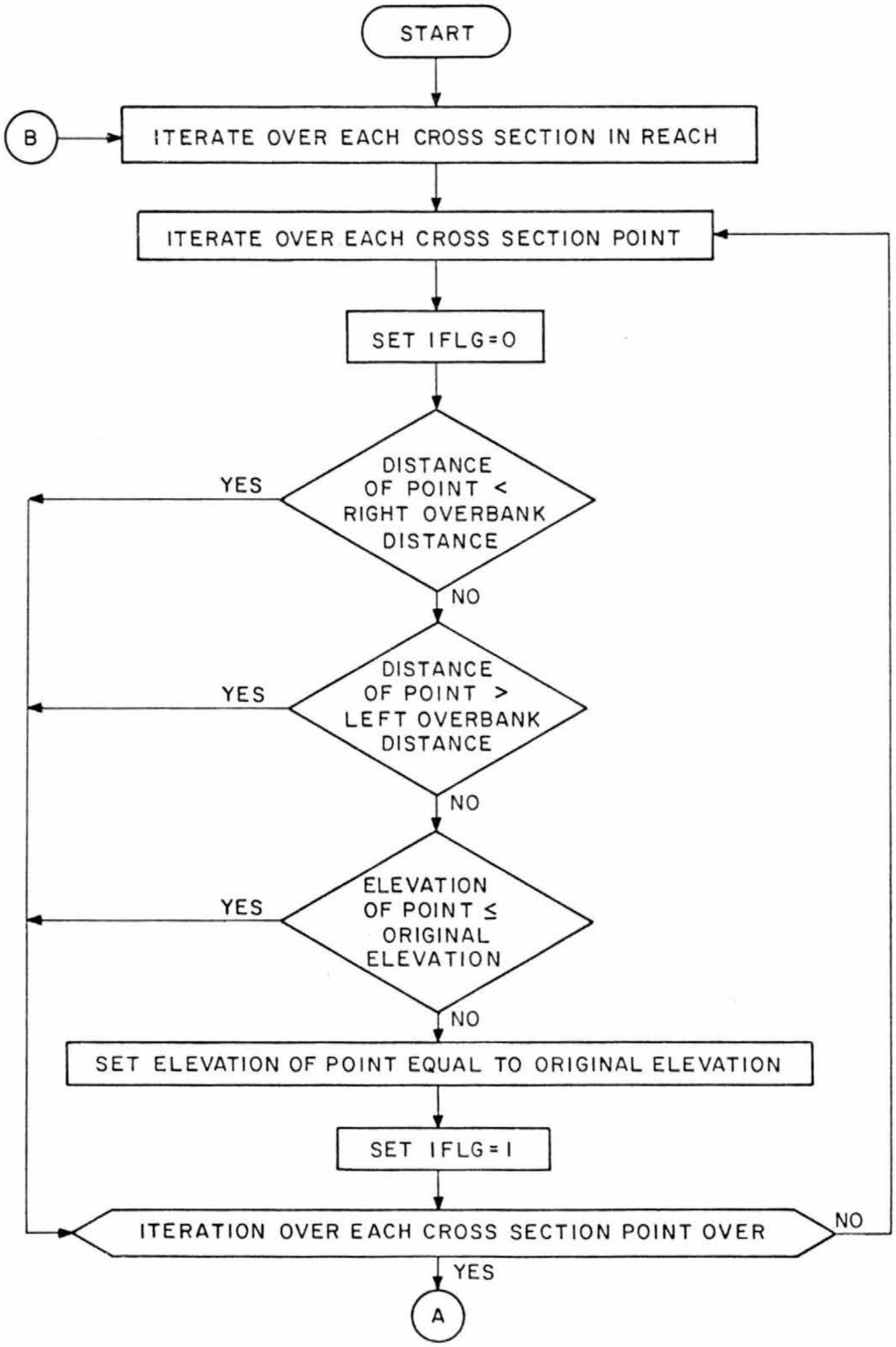
Subroutine DIVDE

This subroutine determines the fraction of the total flow going down each side of divided flow reaches.

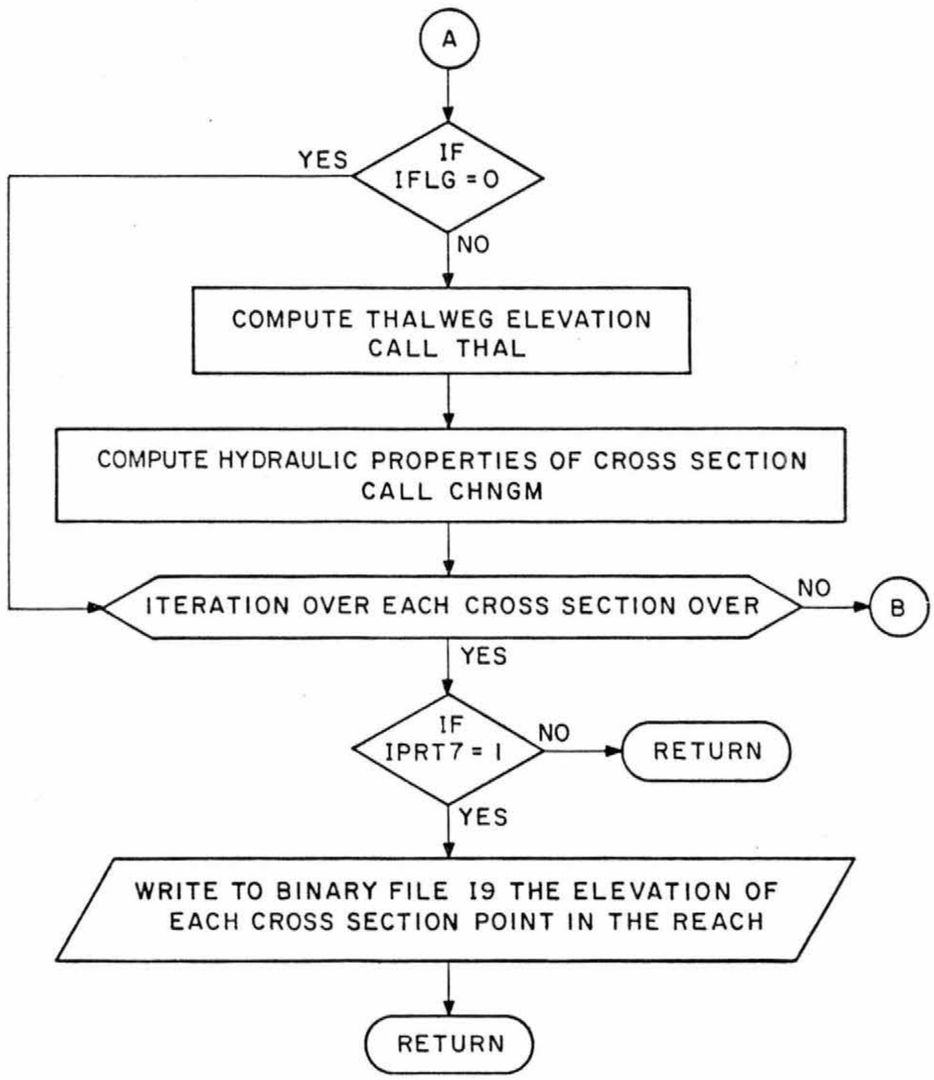


Subroutine DREDG

This subroutine simulates dredging by lowering each cross section in a reach to its original elevation (ZO). Only cross section points in the main channel are lowered.

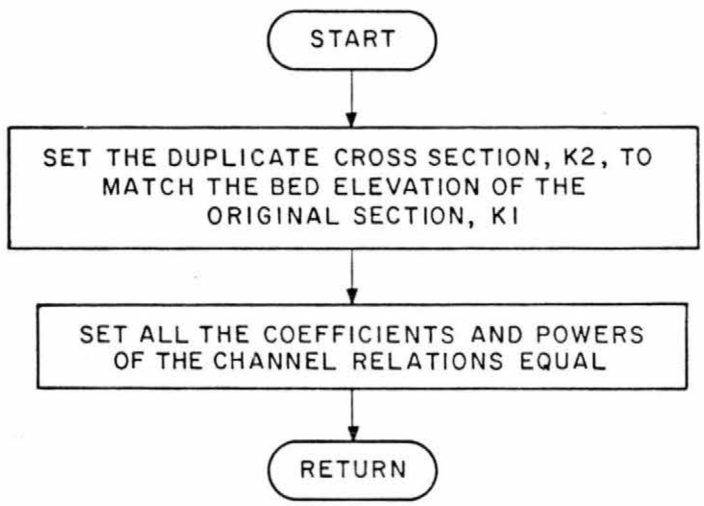


Subroutine DREDG (continued)



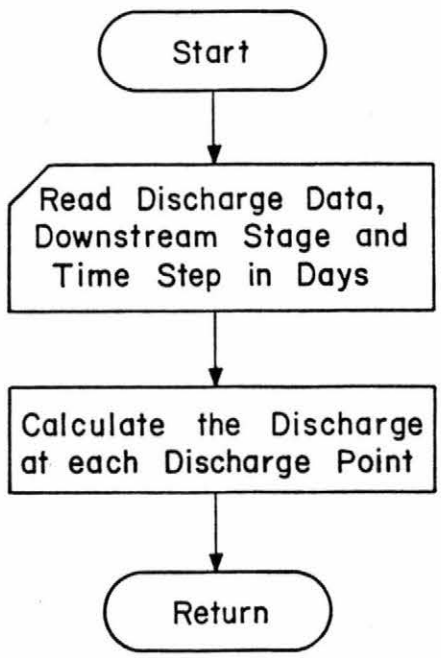
Subroutine DUP

This subroutine is used in divided flow problems when a cross section is used by two different river reaches. It changes the bed elevation of the duplicate cross section, K_2, to match the bed elevation of the original section, (K_1), after sediment routing.



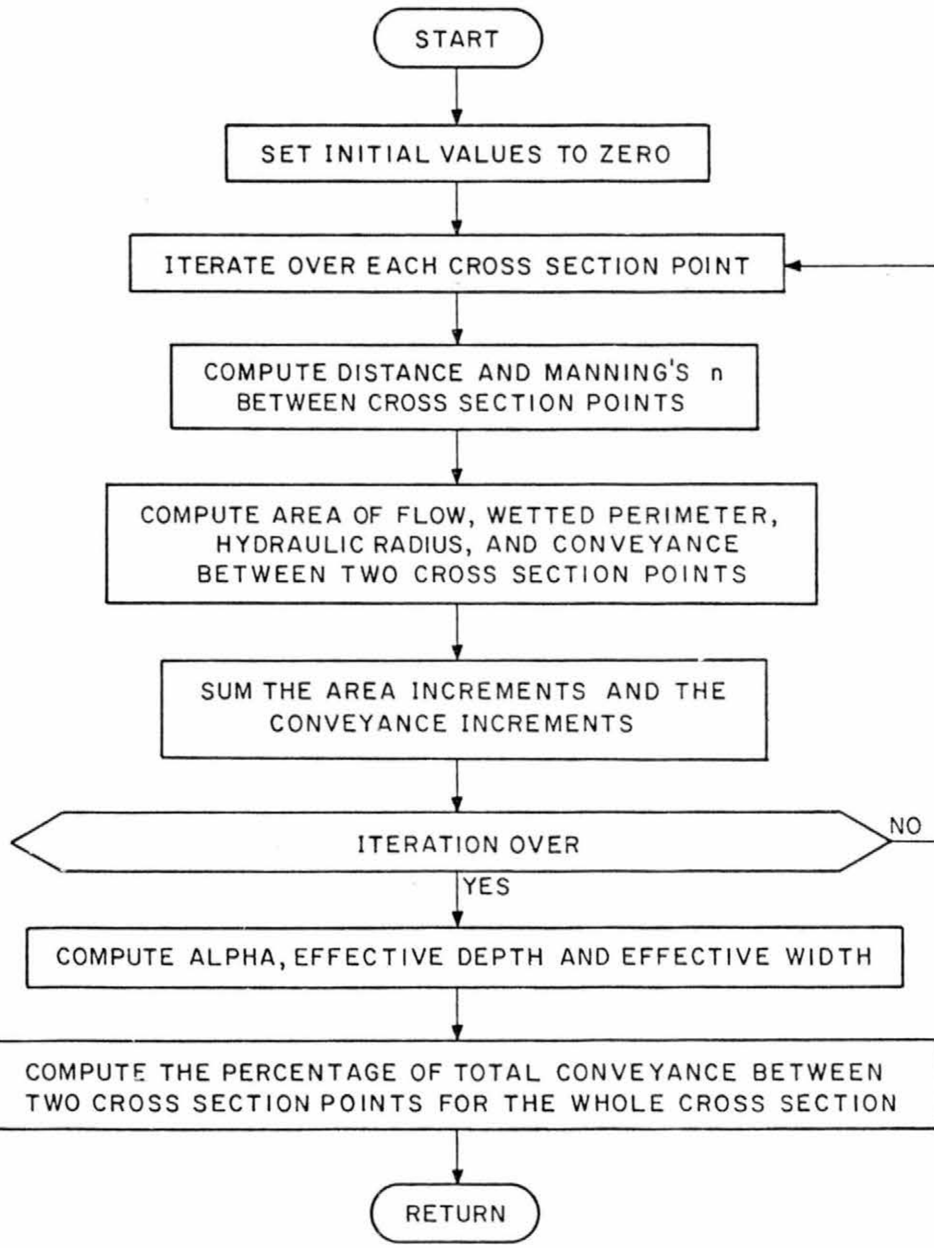
Subroutine FLOW

This subroutine calculates the water discharge at each cross section.



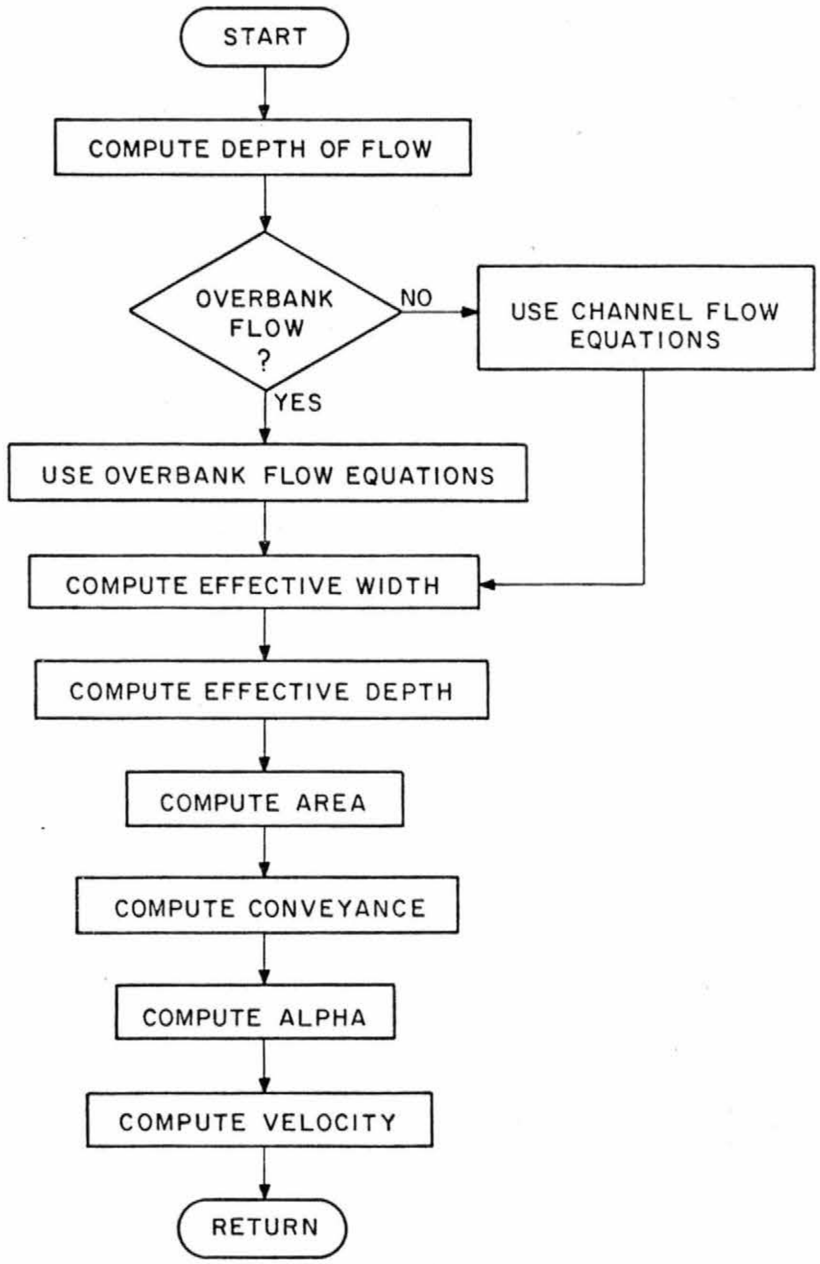
Subroutine GEOM

This subroutine calculates the exact hydraulic properties of a cross section, once given the channel geometry and the water surface elevation.



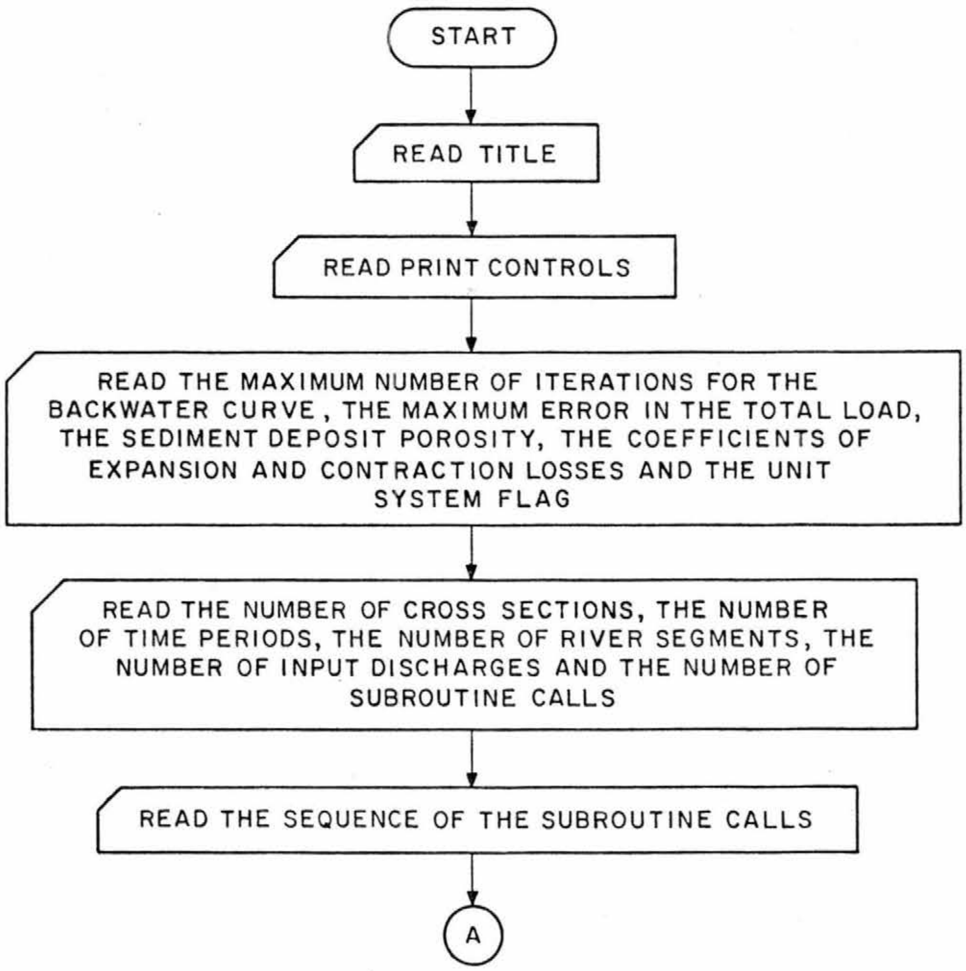
Subroutine HYDPR

This subroutine calculates the hydraulic properties of the (K)TH cross section given the water surface elevation (WS).

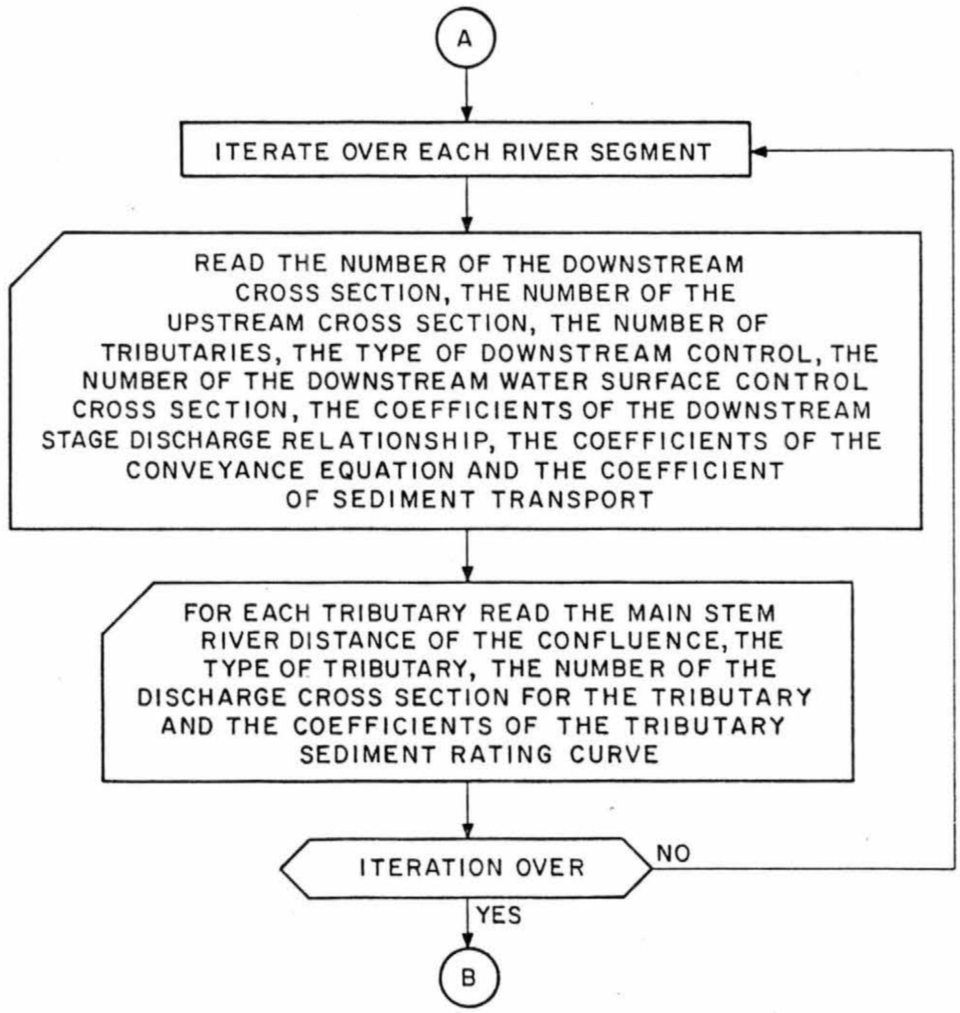


Subroutine IN1

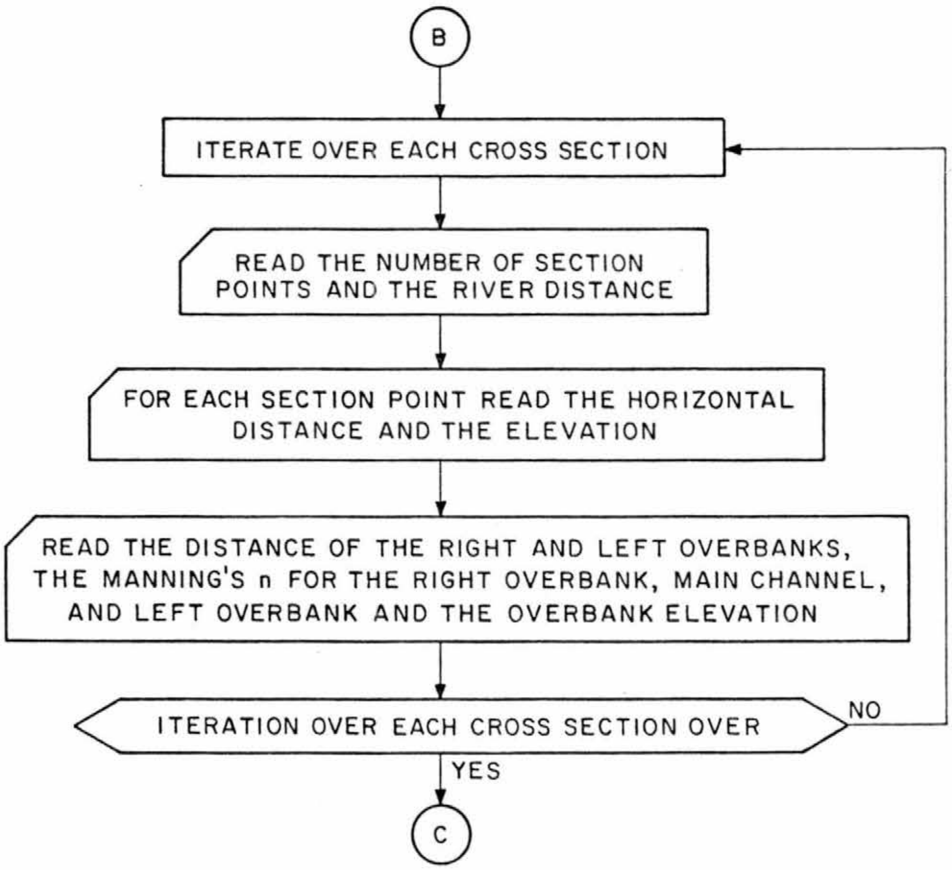
This subroutine reads in the sediment and geometry data.



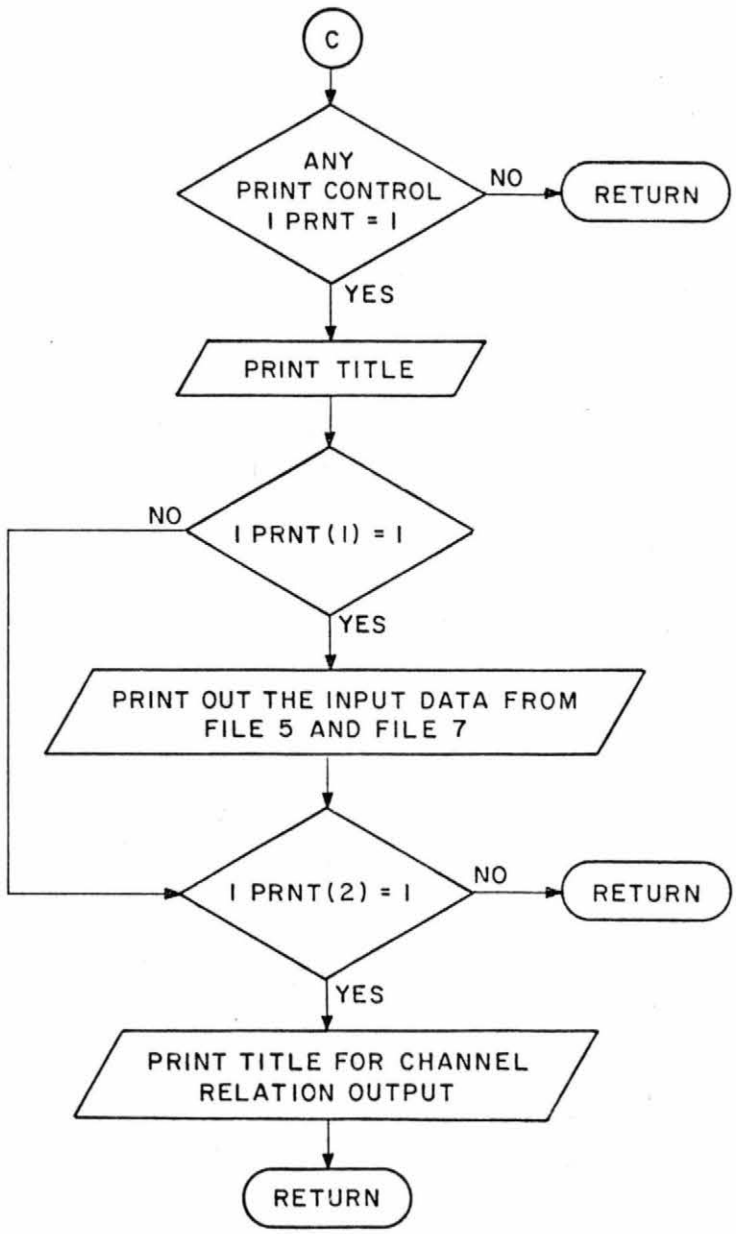
Subroutine IN1 (continued)



Subroutine IN1 (continued)

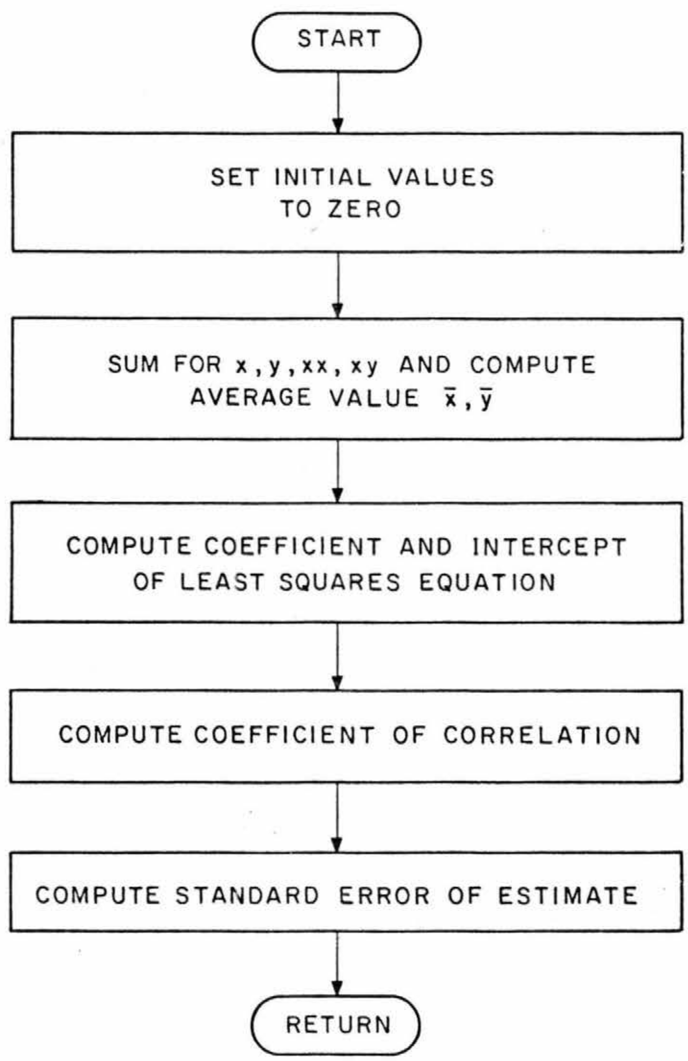


Subroutine IN1 (continued)



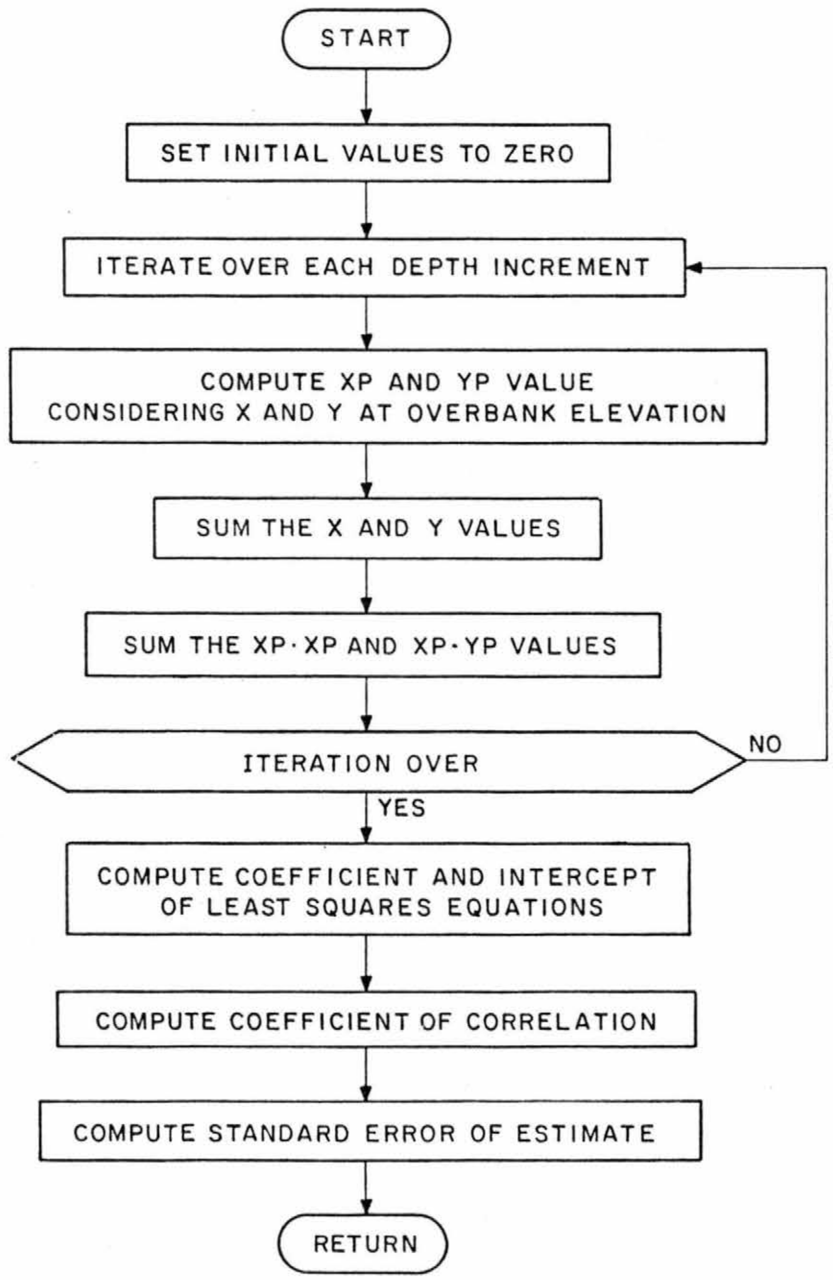
Subroutine LSQ

This subroutine derives the coefficients of the hydraulic power functions, by using a least squares regression.



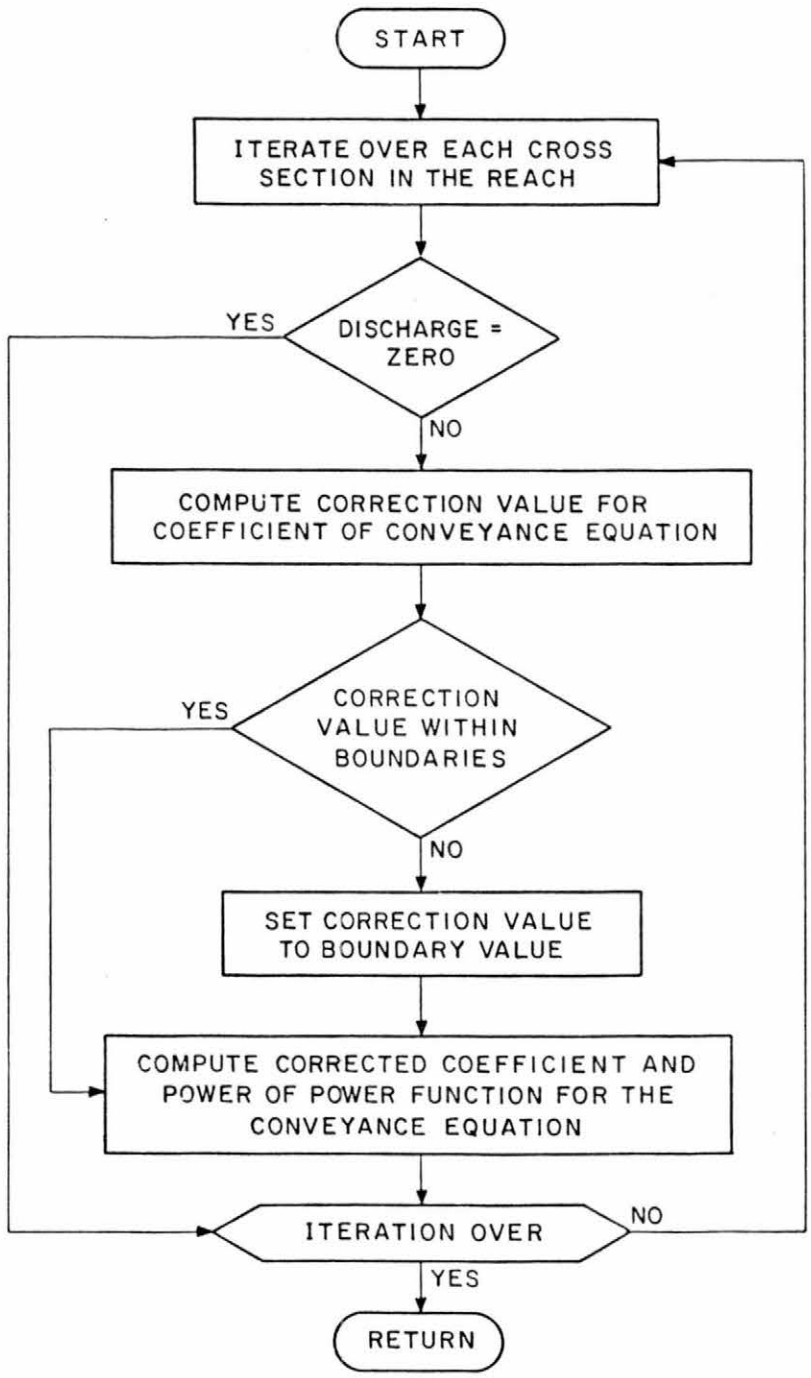
Subroutine LSQF

This subroutine derives the coefficients of the hydraulic power functions, for overbank flow, by using a least squares regression forced through the point (XO, YO).



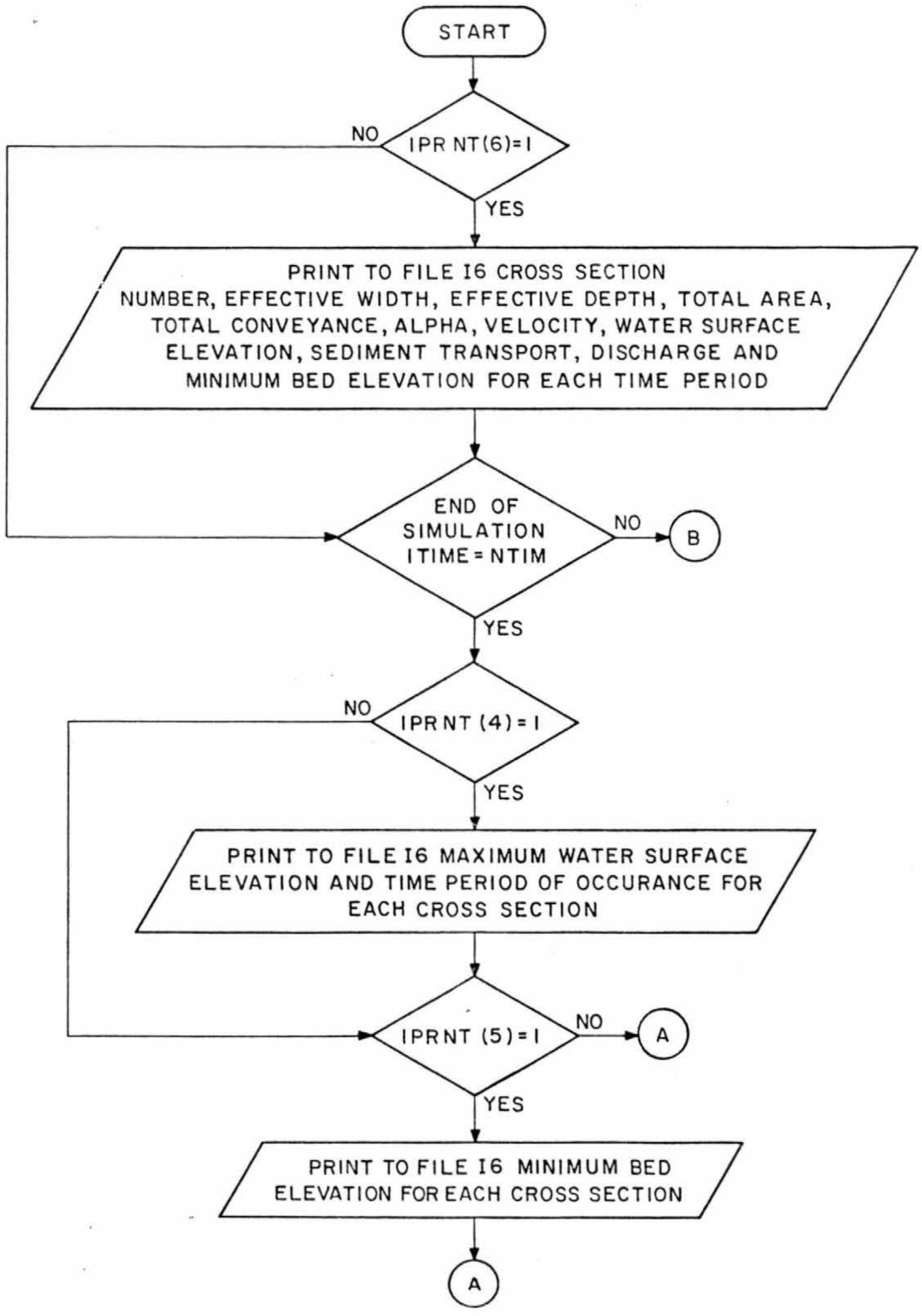
Subroutine NVAL

This subroutine calculates the coefficient of the conveyance equation for the current discharge. This allows Manning's n to be a function of discharge.

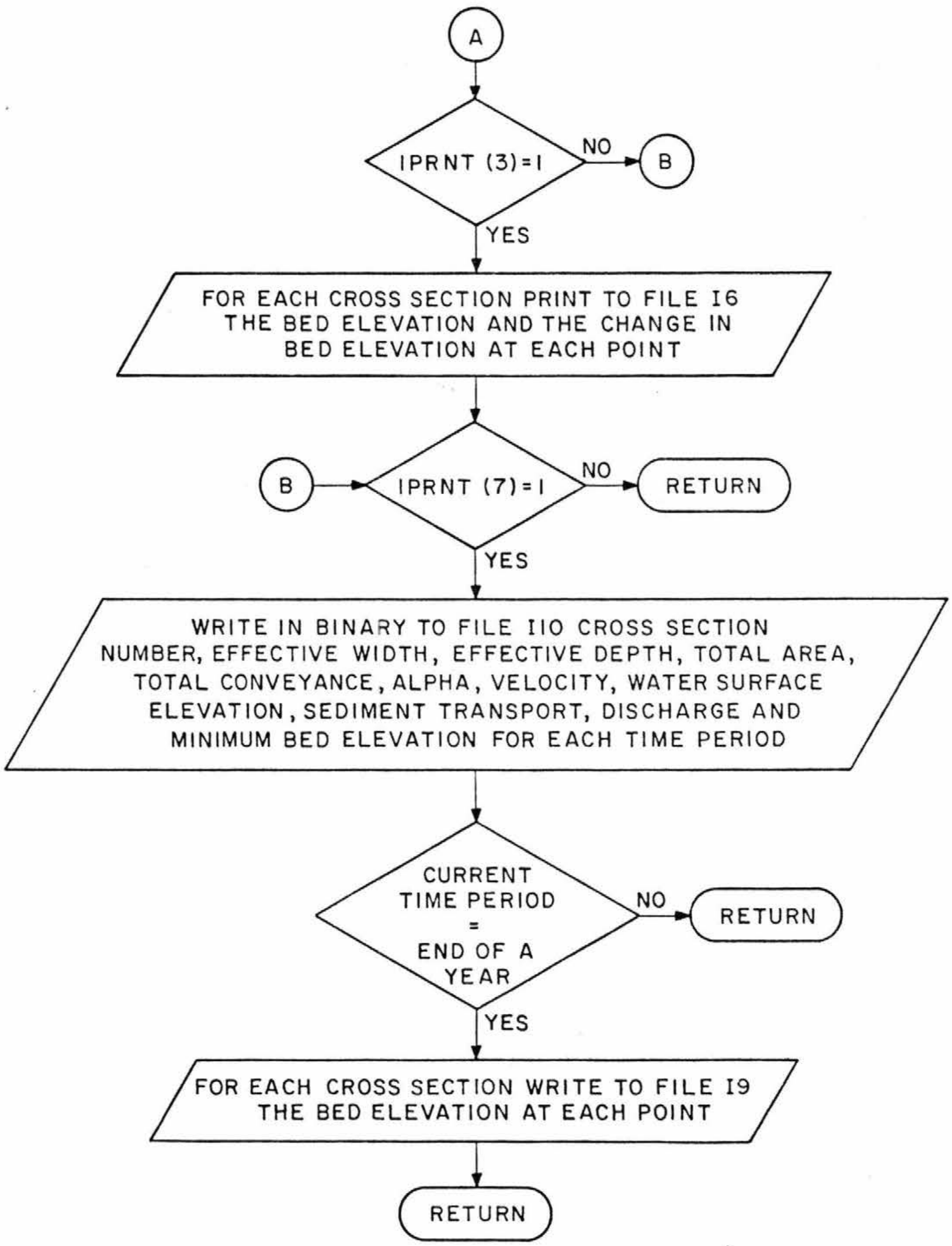


Subroutine OUT1

This subroutine outputs the various results of the simulation model.

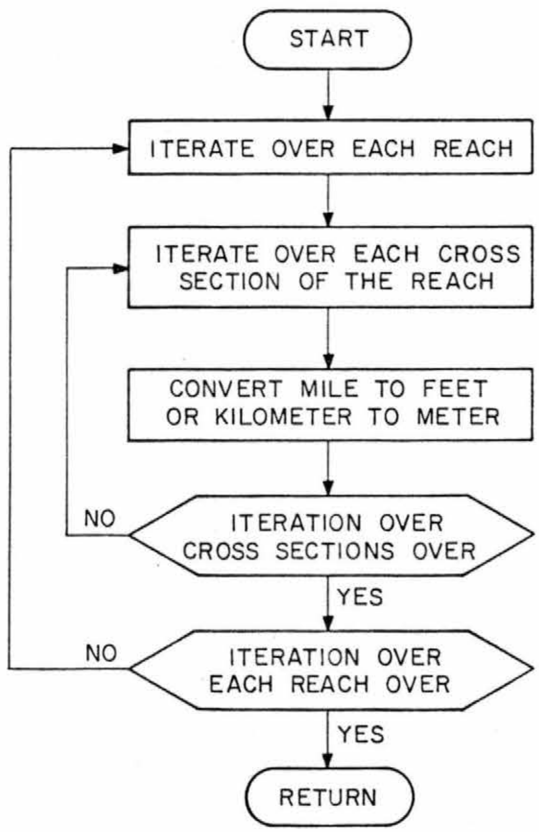


Subroutine OUT 1 (continued)



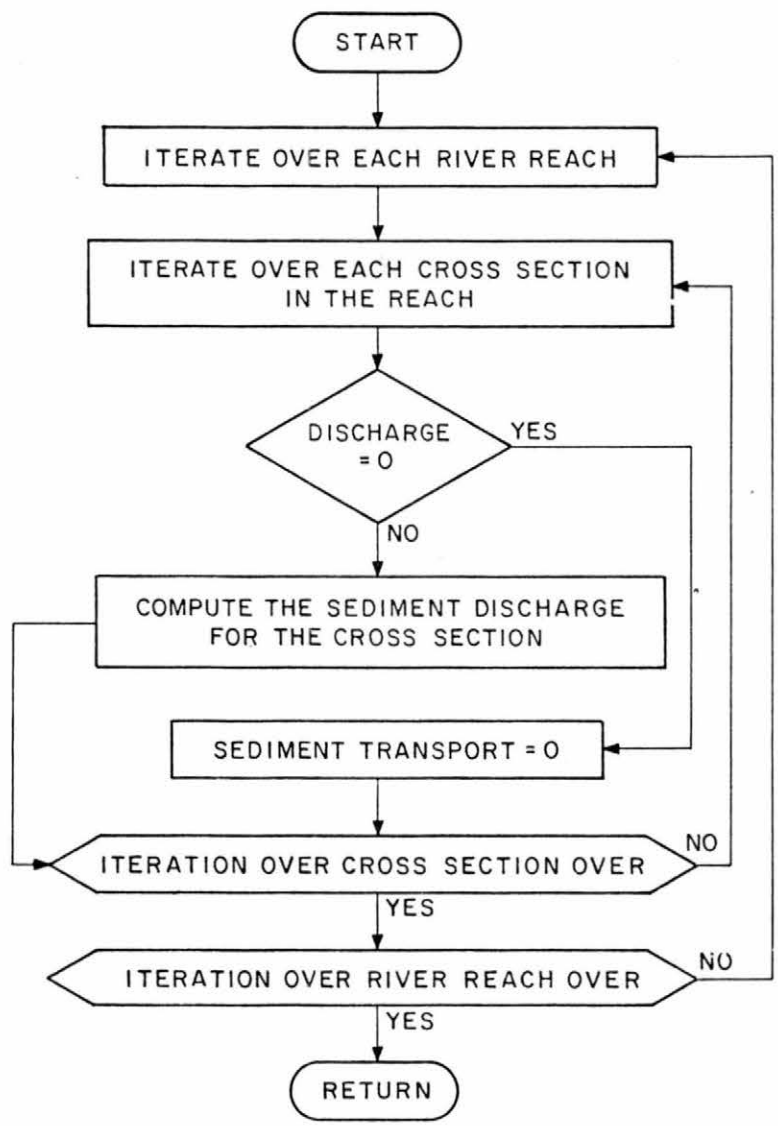
Subroutine RIVDS

This subroutine converts the river distance of each cross section and tributary to proper unit.



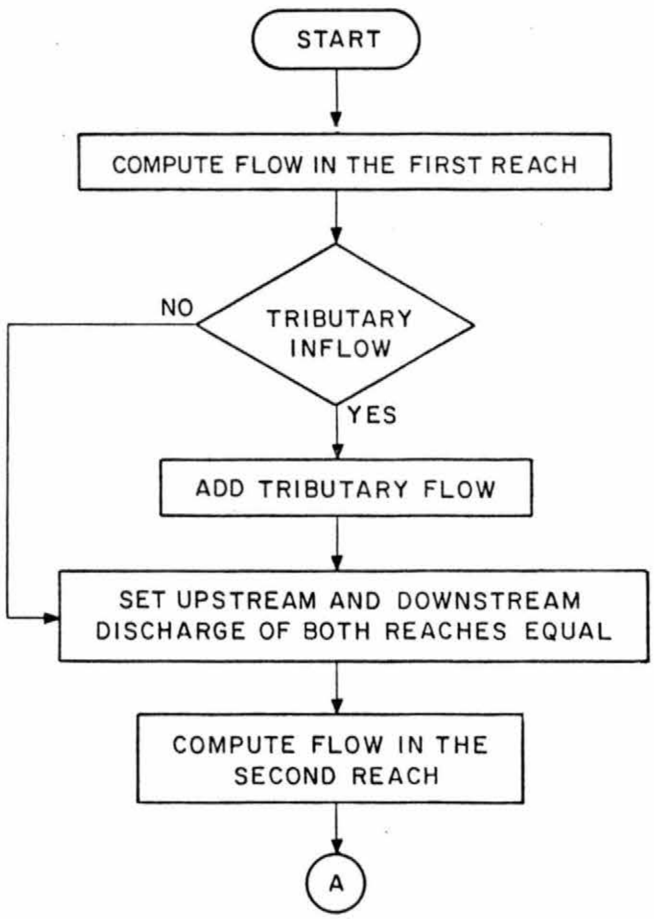
Subroutine SED

This subroutine calculates sediment transport using the generalized formula developed for the Yazoo River.

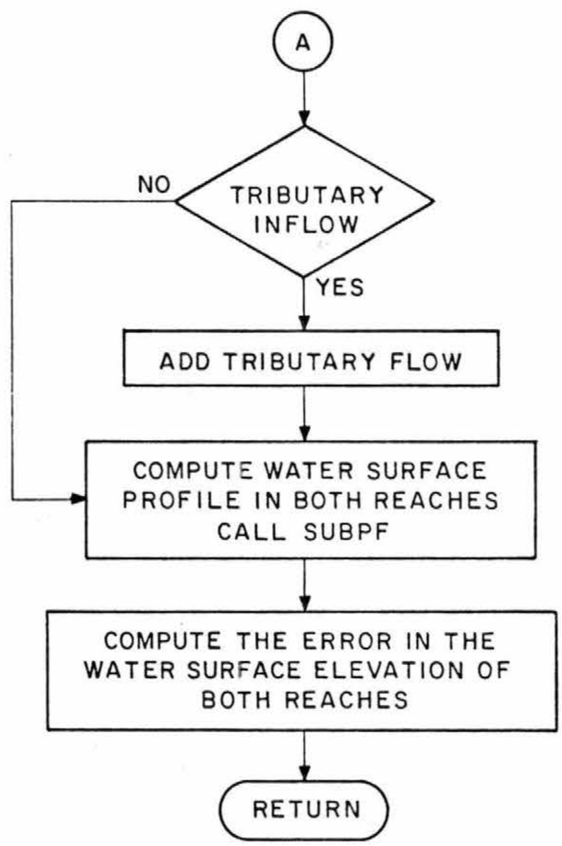


Subroutine SPLIT

This subroutine is used in divided flow problems to split the discharge between two channels.

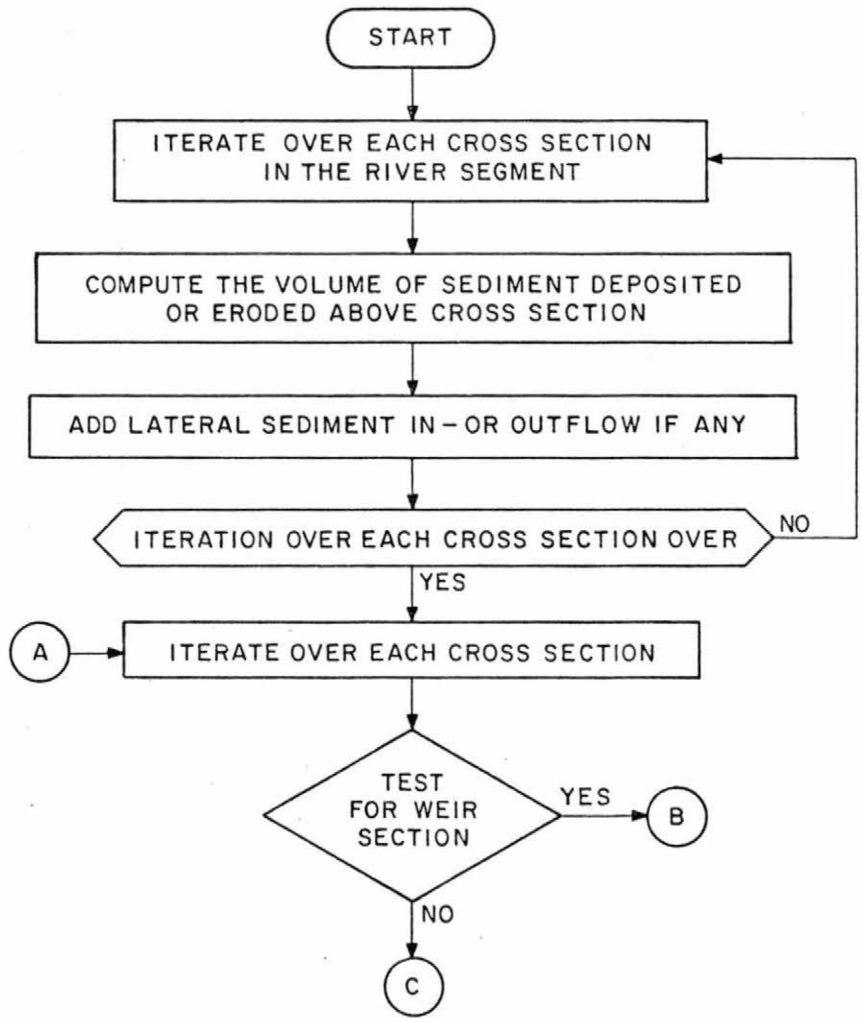


Subroutine SPLIT (continued)



Subroutine SROUT

This subroutine routes the sediment, calculates the approximate bed elevation change, and if necessary, distributes the aggradation or degradation through the cross section.



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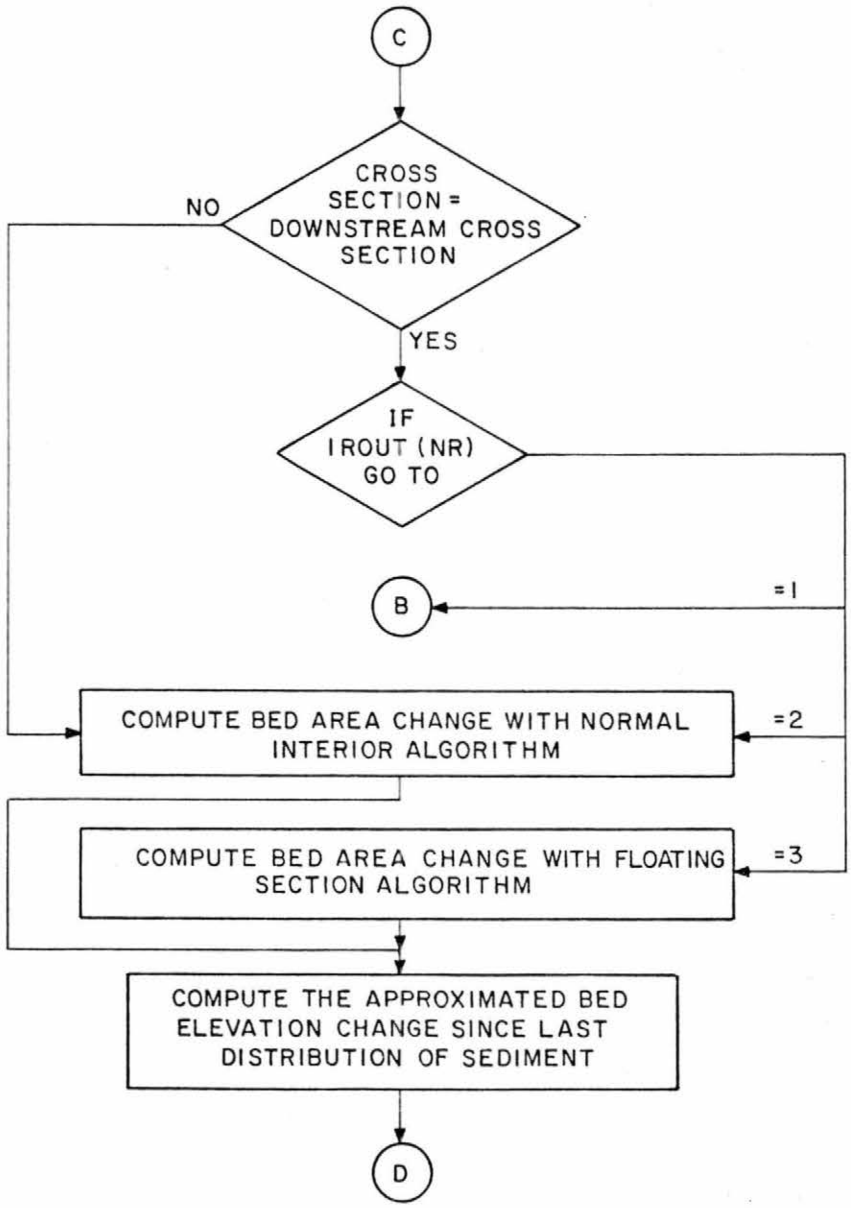

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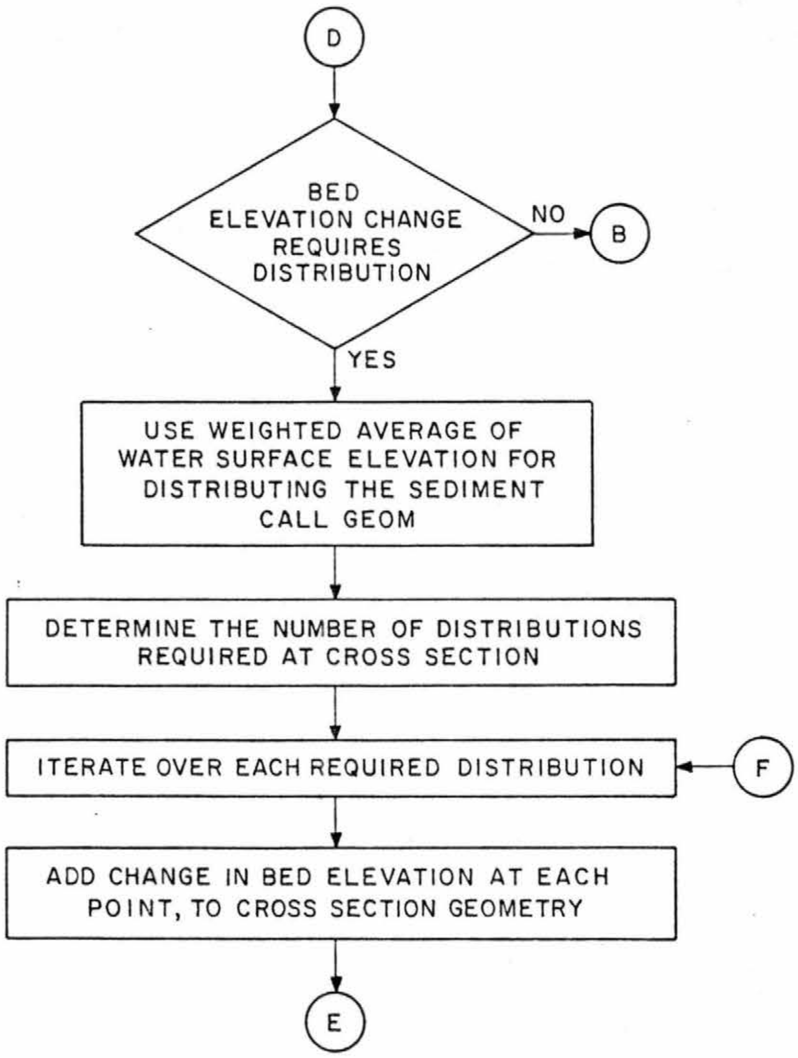
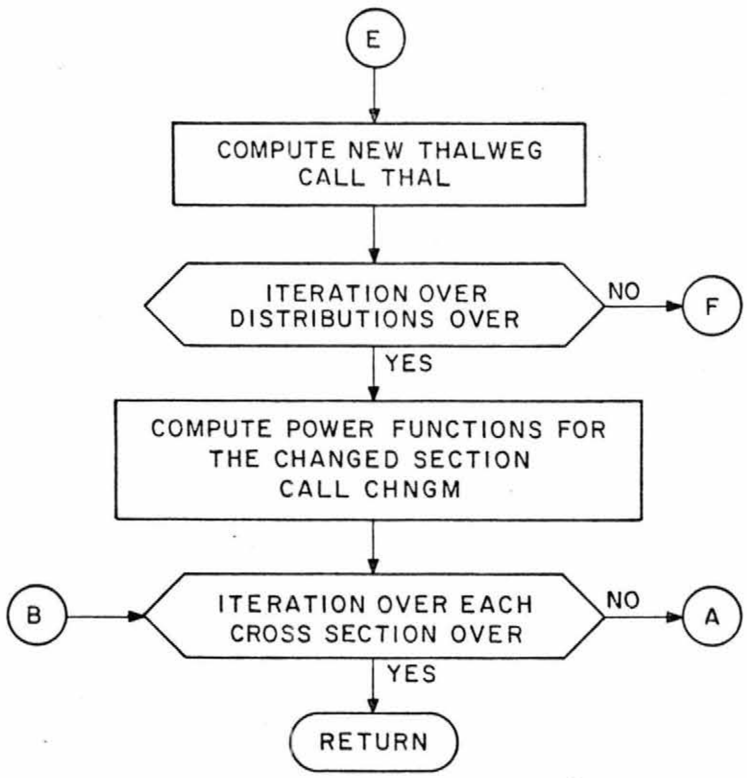
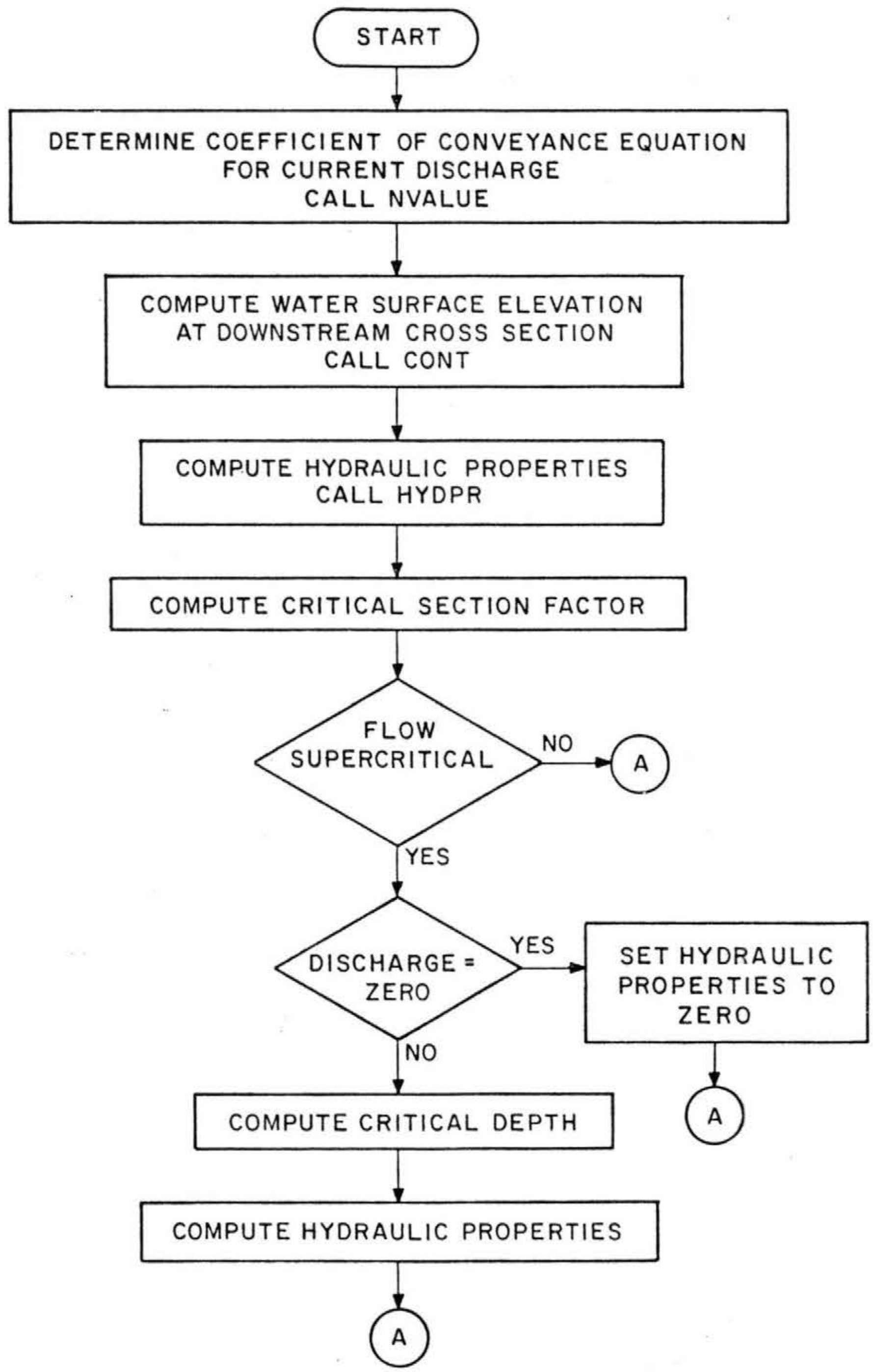


Subroutine SROUT (continued)

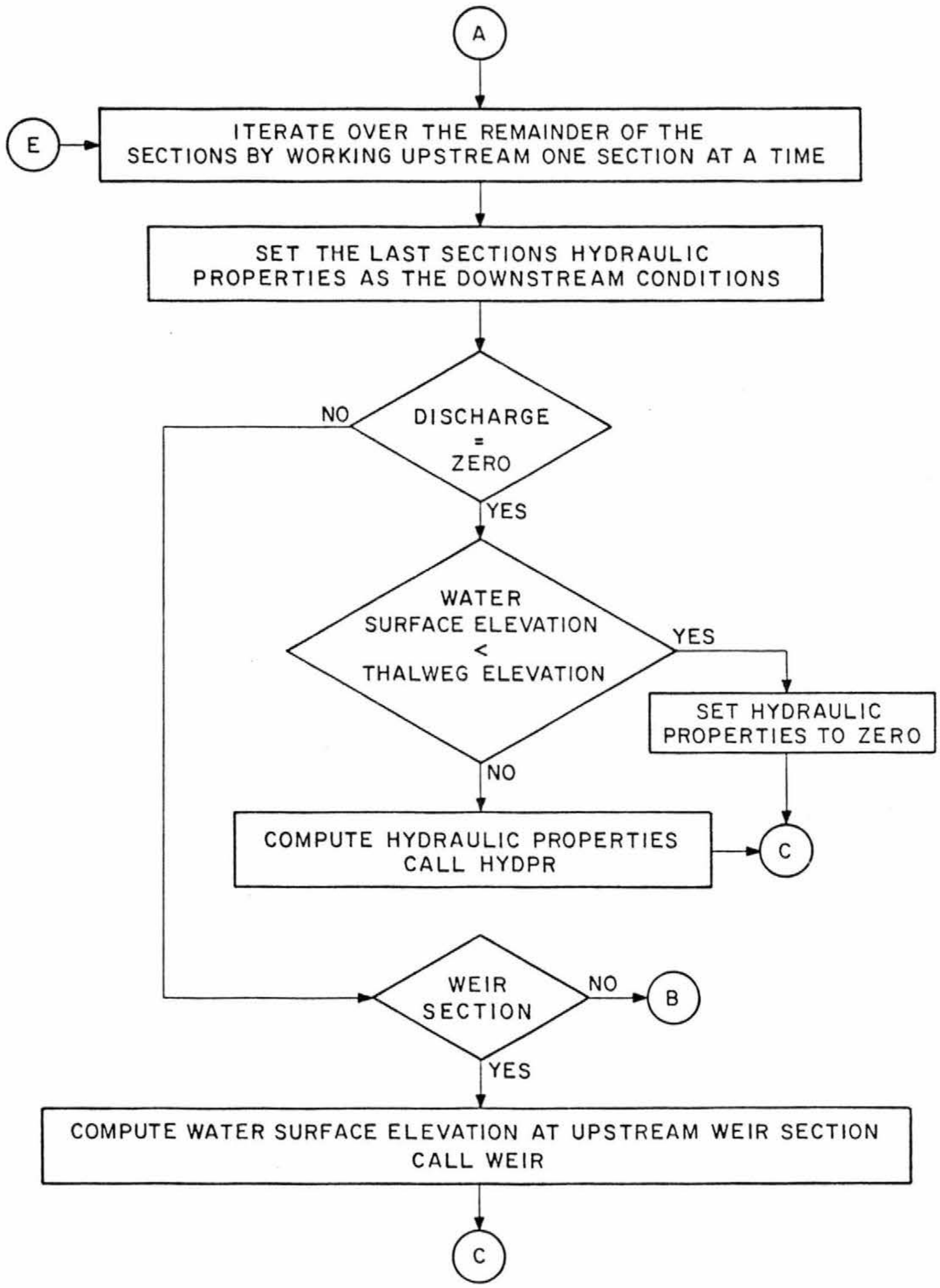


Subroutine SUBPF

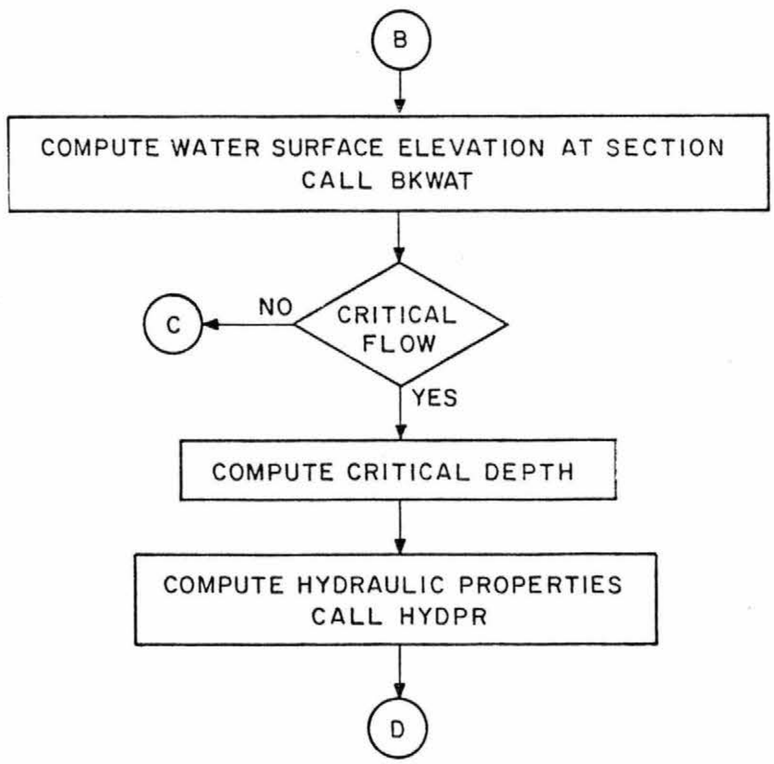
This subroutine calls the various other subroutines needed to calculate the subcritical water surface elevation at each section.



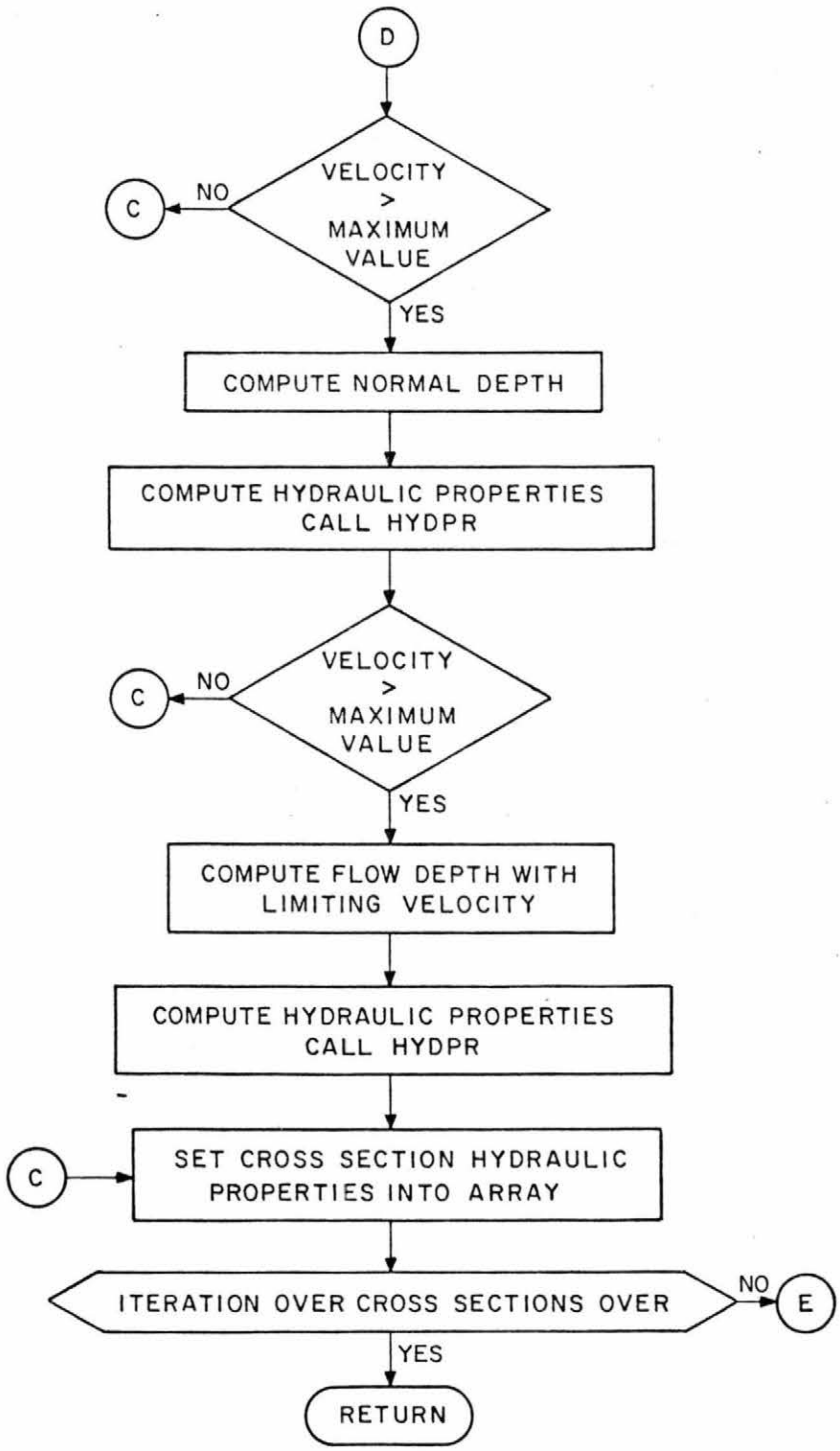
Subroutine SUBPF (continued)



Subroutine SUBPF (continued)

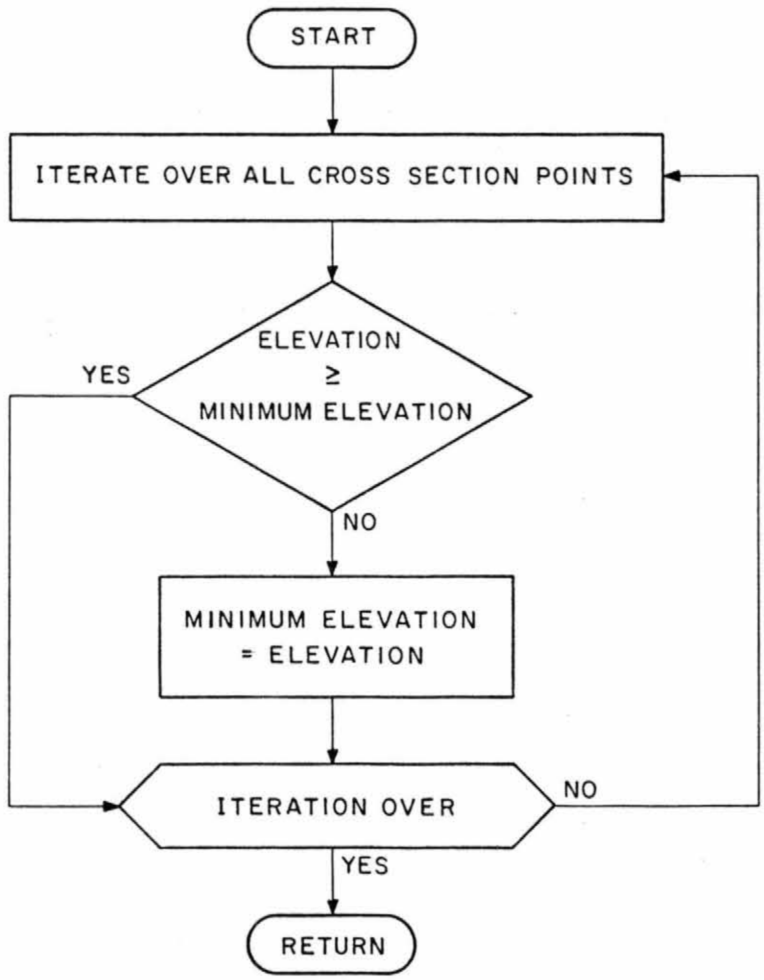


Subroutine SUBPF (continued)



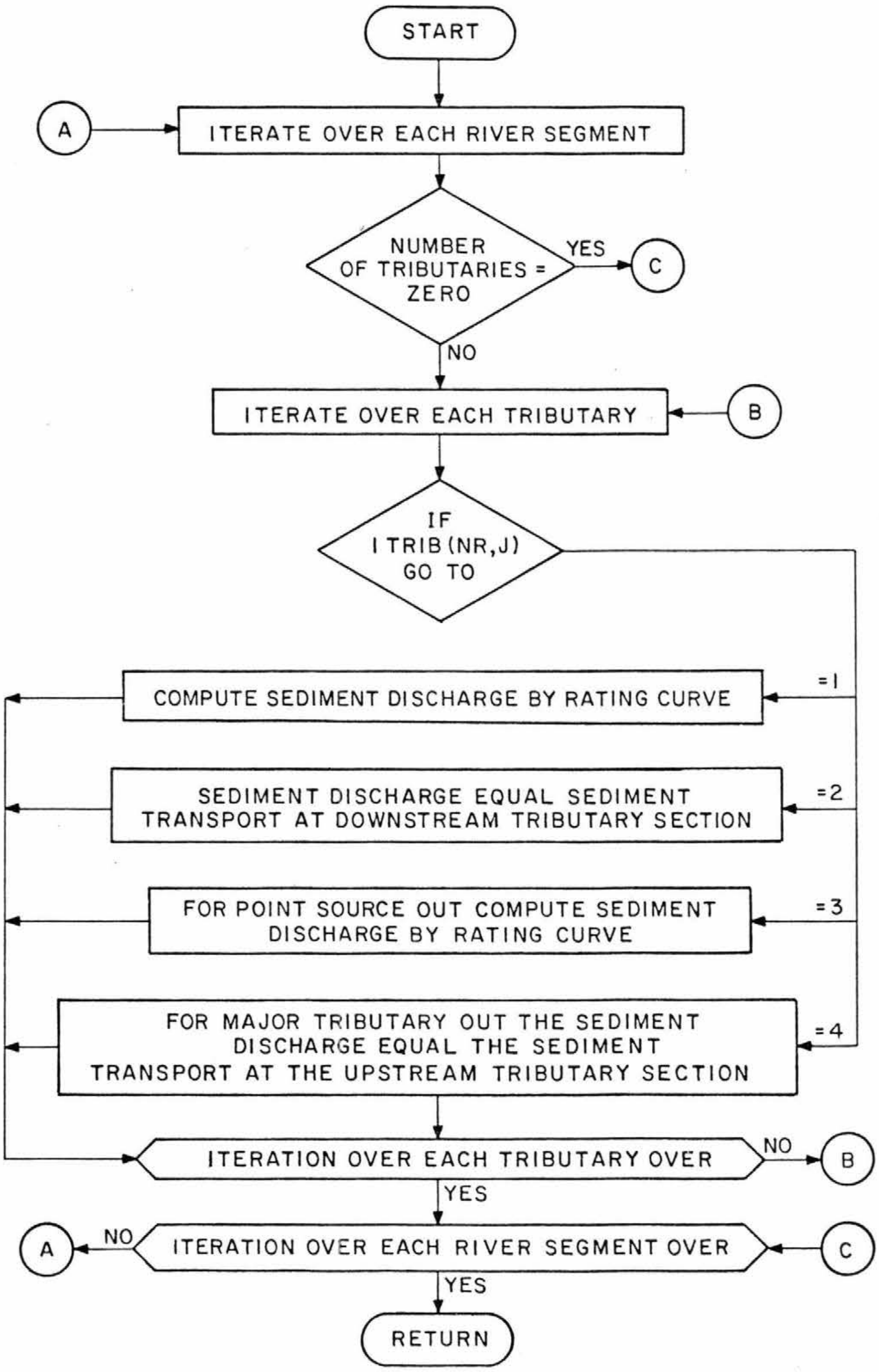
Subroutine THAL

This subroutine determines the cross section thalweg elevation.



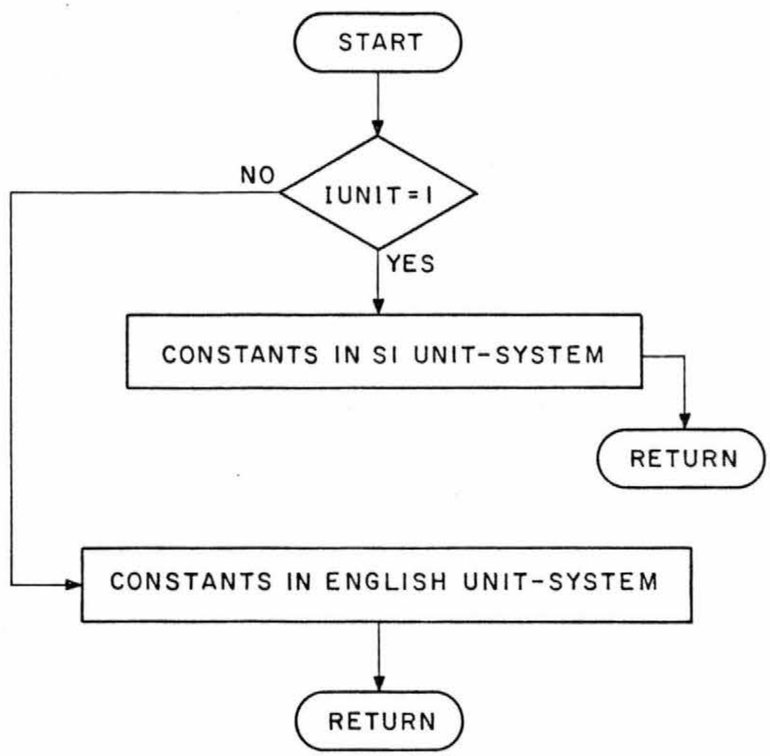
Subroutine TRIBS

This subroutine determines the sediment discharge for each tributary.



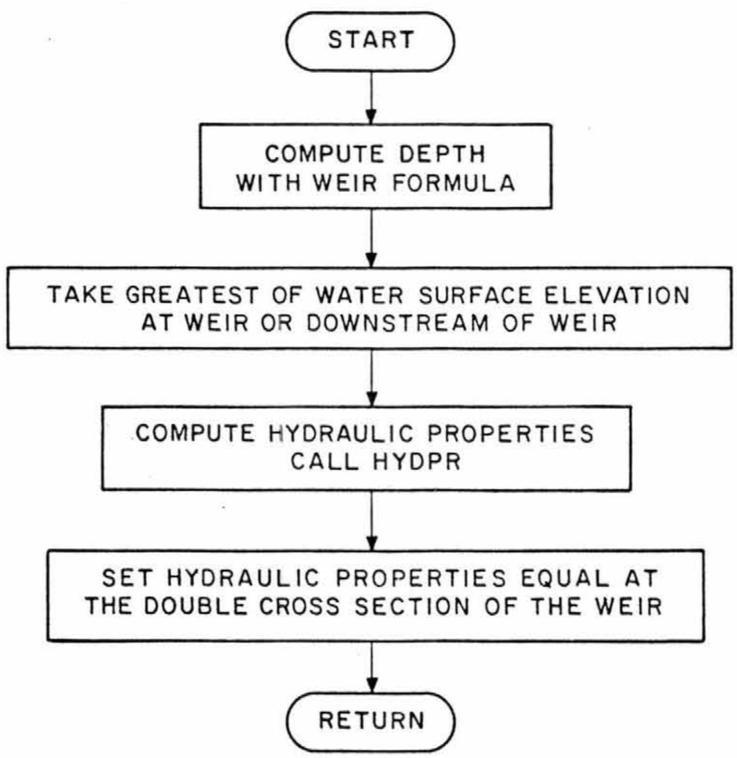
Subroutine UNIT

This subroutine assigns the correct values to the constants according to the unit-system used.



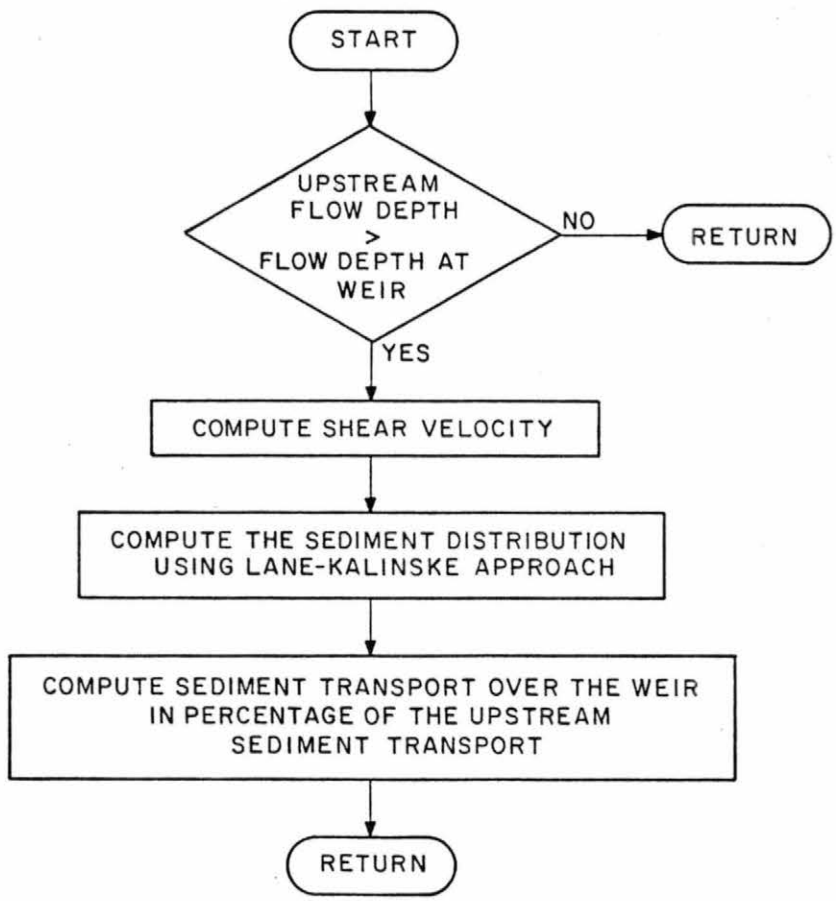
Subroutine WEIR

This subroutine is used to calculate the greater of the downstream water surfaces or the critical depth at the weir.



Subroutine WEIRS

This subroutine calculates the percentage of the upstream sediment transport (G(KU)), which is transported over a weir. It uses the Lane-Kalinske sediment distribution.



APPENDIX C

LIST OF PROGRAM VARIABLES

The following is a list of the variables used in the program KUWASER. For each variable there is a definition, common block name (if applicable) and array size. If the variable is not in a common block, the subroutine(s) in which the variable is used is shown in brackets under the definition. Terms in the definition which appear in parentheses are other variable names. If a variable's dimension is problem dependent, the array size is given as the name of a program variable that the array size should equal or exceed.

Variable	Array size	Common block	Definition
A			Area between two cross section points. [GEOM]
A			Value of intercept. [LSQ]
AALP	10		Log value of alpha (ALP). [CHNGM]
AD	10		Log value of depth. [CHNGM]
ADO			Log value of overbank depth. [CHNGM]
ADZ			Absolute value of approximate bed elevation change. [SROUT]
AED	10		Log value of effective depth (ED). [CHNGM]
AEW	10		Log value of effective width (ED). [CHNCM]
ALP		HYD	Velocity head correction coefficient, for the given cross section and for the given water surface elevation.
ALPK	NSEC	SEC1	Storage array for velocity head correction coefficient.
AN	NRIV	RIV	Coefficient that changes Manning's N value as function of discharge.
AT	NRIV, NTRIB	RIV	Coefficient of tributary sediment rating curve.
ATA	10		Log value of total area (TA). [CHNGM]
ATAO			Log value of area at overbank elevation. [CHNGM]
ATEMP			Temporary value used in equation of first derivative in Newton-Raphson approximation. [BKWAT]
ATK	10		Log value of total conveyance (TK). [CHNGM]
ATKO			Log value of conveyance at overbank. [CHNGM]

Variable	Array size	Common block	Definition
AX	NRIV	RIV	Coefficient of stage-discharge relationship.
A1	NSEC	SEC1	Coefficient of hydraulic power function for effective width in main channel.
A2	NSEC	SEC1	Coefficient of hydraulic power function for effective depth in main channel.
A3	NSEC	SEC1	Coefficient of hydraulic power function for total area in main channel.
A4	NSEC	SEC1	Coefficient of hydraulic power function for total conveyance in main channel.
A5	NSEC	SEC1	Coefficient of hydraulic power function for alpha in main channel.
A6	NSEC	SEC1	Coefficient of hydraulic power function for effective width for overbank flow.
A7	NSEC	SEC1	Coefficient of hydraulic power function for effective depth for overbank flow.
A8	NSEC	SEC1	Coefficient of hydraulic power function for total area for overbank flow.
A9	NSEC	SEC1	Coefficient of hydraulic power function for total conveyance for overbank flow.
A10	NSEC	SEC1	Coefficient of hydraulic power function for alpha for overbank flow.
B			Slope of the least squared regression (log value). [LSQ]
BDEN			Temporary value for calculation of first derivative in Newton-Raphson approximation. [BKWAT]
BN	NRIV	RIV	Power that changes Manning's N value as function of discharge.

Variable	Array size	Common block	Definition
BNUM			Temporary value for calculation of first derivative in Newton-Raphson approximation. [BKWAT]
BT	NIRV, NTRIB	RIV	Power of tributary sediment rating curve.
BX	NRIV	RIV	Power of stage discharge relationship.
B1	NSEC	SEC1	Power of hydraulic power function for effective width in main channel.
B2	NSEC	SEC1	Power of hydraulic power function for effective depth in main channel.
B3	NSEC	SEC1	Power of hydraulic power function for total area in main channel.
B4	NSEC	SEC1	Power of hydraulic power function for total conveyance in main channel.
B5	NSEC	SEC1	Power of hydraulic power function for alpha in main channel.
B6	NSEC	SEC1	Power of hydraulic power function for effective width for overbank flow.
B7	NSEC	SEC1	Power of hydraulic power function for effective depth for overbank flow.
B8	NSEC	SEC1	Power of hydraulic power function for total area for overbank flow.
B9	NSEC	SEC1	Power of hydraulic power function for total conveyance for overbank flow.
B10	NSEC	SEC1	Power of hydraulic power function for alpha for overbank flow.
C			Conveyance. [GEOM], [CONT], [SUBPF]
CC		INF	Coefficient for contraction head loss.
CCE			Coefficient for contraction or expansion losses. [BKWAT]
CE		INF	Coefficient for expansion loss.

Variable	Array size	Common block	Definition
CONV		UNITS	Constant for English or metric units in Manning's N equation.
CORDS		UNITS	Correction factor to convert river distances from miles or kilometer, to feet respectively meters.
CRT			Critical section factor CRT = $Q/\sqrt{g/2}$. [SUBPF]
CX	NRIV	RIV	Constant of stage discharge relationship.
D			Depth used in first derivative calculation in Newton-Raphson approximation. [BKWAT]
D			Critical depth. [SUBPF], [WEIR]
D			Normal depth. [CONT]
DA			Average depth between cross section points. [GEOM]
DA			Change in bed area. [SROUT]
DEPTH			Cross section depth used in calculations for hydraulic properties. [HYDPR]
DER			Temporary derivative value. [BKWAT]
DEX		SYS	River distance between two cross sections.
DEXUP			River distance between cross section and next cross section upstream. [SUBPF]
DF			Darcy-Weisbach fiction factor. [WEIRS]
DIS			River distance. [KUWASER], [RIVDS]
DLOB			Station of left overbank. [IN1]
DO			Depth at overbank. [CHNGM]
DROB			Station of right overbank. [IN1]

Variable	Array size	Common block	Definition
DT		INF	Time period length in days.
DV	NSEC		Change in volume between cross sections. [SROUT]
DWS			Increment of water surface elevation. [CHNGM]
DX			Horizontal distance between cross section points. [SROUT]
DXDWN			River distance to downstream section. [SROUT]
DXUP			River distance to upstream section. [SROUT]
DZF	ND		Change in cross section point elevation. [OUT1]
DZMAX		UNITS	Maximum change in bed elevation allowed before distributing change.
EA			Intercept of the least squared regression (log scale). [LSQ]
ED		HYD	Effective depth for the given cross section and for the given water surface elevation.
EDK	NSEC	SEC1	Storage array for effective depth at cross section.
EO			Temporary value. [WEIRS]
EPS		INF	Maximum allowable error in total head used in backwater calculations.
ER			Error in total head for estimation. [BKWAT]
ERROR			Difference in water surface elevation in divided flow situation. [SPLIT].
EW		HYD	Effective width for the cross section and for the given water surface elevation.
EY			Temporary value. [WEIRS]

Variable	Array size	Common block	Definition
F	NSEC, ND	SEC2	Manning's N for point in a cross section.
FET		UNITS	Increment of water surface elevation.
FLOB			Manning's N for the left overbank. [IN1]
FM			Average Manning's N between cross section points. [GEOM]
FMC			Manning's N for main channel. [IN1]
FROB			Manning's N of right overbank. [IN1]
FX			Average x values in linear regression. [LSQ]
FY			Average y values in linear regression. [LSQ]
G	NSEC	SEC2	Sediment transport in cfs.
GRAV		UNITS	Value of gravitation acceleration.
HL			Head losses. [BKWAT], [BRIDGE]
HLV			Head losses due to contraction and expansion. [BKWAT]
I			Increment and loop counter.
ICALL	(NCALL, 5)	RIV	Sequence of subroutine calls.
ICAL1			ICAL1 = ICALL (NC, 1). [KUWASER]
ICAL2			ICAL2 = ICALL (NC, 2). [KUWASER]
ICANT			ICANT = ICONT (NR). [CONT]
ICONT	NRIV	RIV	Type of downstream control. = 1 stage-discharge relationship. = 2 stage-hydrograph. = 3 downstream water surface.

Variable	Array size	Common block	Definition
			= 4 greatest of #1 and #2.
			= 5 greatest of #1 and #3.
			= 6 Normal depth.
ICRI			Critical flow flag. [BKWAT], [SUBPF]
			ICRI = 0 subcritical flow.
			ICRI = 1 supercritical flow.
IDUMB			Dumbie variable. [KUWASER]
IFLAG			Flag for over bank flow. [GEOM]
IFLG			Flag for dredging. [DREDG]
II			Increment and loop counter. [GEOM]
IMAX	NSEC	SEC1	Time period of maximum water surface at section.
IM1			Increment and loop counter. [GEOM]
IPRINT	8	PRT	Print controls. IPRINT (M1) = 0 or 1. If equal 0 no printout, if equal to 1 printout.
			(1) All input data read from files I5 and I7 are printed.
			(2) Coefficients, correlation coefficient, and standard error of each of the hydraulic property equations are printed for each cross section.
			(3) The final elevation and change in elevation at each cross section point are printed.
			(4) Maximum water surface elevation and the time period of occurrence are printed for each cross section.
			(5) Minimum bed elevation at each cross section is printed at the end of simulation.

Variable	Array size	Common block	Definition
			(6) Cross section properties (time period, effective width, effective depth, total area, total conveyance, alpha, velocity, water surface, elevation, discharge, sediment transport and thalweg level) are printed.
			(7) Binary output for all data.
			(8) Error messages are printed.
IROOT			IROOT = IROUT (NR). [SROUT]
IROUT	NRIV	RIV	Type of downstream cross section sediment routing or river reach.
			IROUT = 1 fixed, no routing.
			IROUT = 2 cross section downstream, normal routing.
			IROUT = 3 floating, no section downstream.
ITIME		INF	Current time period.
ITRIB	NRIV,NTRIB	RIV	Type of tributary.
			= 1 point source in.
			= 2 major tributary in (considered as a segment).
			= 3 point source out.
			= 4 major tributary out (considered as a segment).
ITRYB			ITRYB = ITRIB (NR, J). [TRIBS]
IUNIT		UNITS	Value for selecting unit-system.
			IUNIT = 1 English.
			IUNIT = 2 Metric-SI.
IZMIN	NSEC	SEC2	Cross section thalweg point.
I5		PRT	File used for general data input.
I6		PRT	File used for output to printer.

Variable	Array size	Common block	Definition
I7		PRT	File used for cross sectional data input.
I8		PRT	File used for discharge data input.
I9		PRT	File used for binary output.
I10		PRT	File used for binary output.
J			Increment and loop counter.
JT			Increment and loop counter.
K			Increment and loop counter for cross section number.
K1			Cross section number. [DUP]
K2			Cross section number. [DUP]
KCONT	NRIV	RIV	Number of section which controls water surface.
KD			Number of downstream cross section. [KUWASER], [CONT], [FLOW], [NVAL], [SUBPF]
KDOWN	NRIV	RIV	Downstream cross section for river segment.
KDP1			KDP1 = KD + 1. [SPLIT], [SUBPE], [SROUT]
KDP1			KDP1 = KD + 1. [SPLIT], [SYST]
KD1			Number of downstream cross section of first river segment in divided flow situation. [SPLIT]
KD2			Number of downstream cross section of second river segment in divided flow situation. [SPLIT]
KI			Increment and loop counter. [OUT1]
KM1			KM1 = K - 1. [SUBPF], [WEIR], [SROUT]
KOUNT			Iteration counter. [BKWAT]

Variable	Array size	Common block	Definition
KP1			KP1 = K + 1. [SUBPF], [SROUT]
KT			KT = KTRIB (NR, J). [FLOW], [SPLIT]
KTR			
KTRIB	NRIV,NTRIB	RIV	Discharge cross section for tributary.
KU			Number of upstream cross section. [KUWASER], [FLOW], [NVAL], [SUBPF], [SED], [SROUT], [WEIR]
KUM1			KUM1 = KU - 1. [SPLIT], [SROUT]
KUP	NRIV	RIV	Upstream cross section for river segment.
KU1			Number of upstream cross section for the first river segment in divided flow situation. [DIVDE], [SPLIT]
KU2			Number of upstream cross section for the second river segment in divided flow situation. [SPLIT]
KW			Weir cross section number. [WEIRS]
KWM1			KW - 1. [WEIRS]
L			Increment and loop counter for cross sectional points.
M			Number of cross section points M = ND (K). [IN1], [CHNGM], [KUWASER]
MST		WF	Maximum number of iterations for backwater curve.
M1			Loop counter. [IN1]
M2			Loop counter. [IN1]
N			Increment and loop counter.
NAP			Number of water surface elevations used for linear regression of hydraulic-properties relationship. [CHNGM]

Variable	Array size	Common block	Definition
NC			Increment and loop counter. [KUWASER]
NCALL		INF	Number of subroutine calls for each time period.
ND	NSEC	SEC2	Number of points in each cross section.
NDIS			Number of sediment distributions. [SROUT]
NDS			Loop counter. [SROUT]
NN			Increment and loop counter. [IN1]
NP			Number of incremental subareas. [GEOM], [SROUT]
NQI		INF	Number of discharge sections.
NR			Increment and loop counter for number of river segment.
NRIV		RIV	Number of river segments.
NR1			Number of first river segment in divided flow situation. [DIVDE], [SPLIT]
NR2			Number of second river segment in divided flow situation. [DIVDE], [SPLIT]
NR2			Number of second river segment in divided flow situation. [DIVDE], [SPLIT]
NRM1			NRM1 = NR - 1. [KUWASER], [NVAL]
NR2			Number of second river segment in divided flow situation. [DIVDE], [SPLIT]
NSEC		INF	Number of cross sections.
NT			NT = NTRIB (NR). [IN1], [FLOW], [KUWASER], [SPLIT], [TRIBS]
NTIM		INF	Number of time periods.

Variable	Array size	Common block	Definition
NTRIB	NRIV	RIV	Number of tributaries for each river segment.
OA4	NSEC	SEC1	Initial value of A4.
OA9	NSEC	SEC1	Initial value of A9.
P			Wetter perimeter. [GEOM]
P			Distribution factor for divide flow situation. [KUWASER], [DIVDE], [SLIT]
PC			Percentage of sediment going over the weir. [WEIRS]
PNR	NRIV		Distribution factor for divided flow situation. [KUWASER]
Q	10		Given discharge at upstream station of each reach.
QSL	NRIV,NTRIB	RIV	Tributary sediment discharge.
QT	10,15		Discharge of point source tributary.
R			Hydraulic radius. [GEOM]
RC			Correlation coefficient of hydraulic properties relationships. [CHNGM], [LSQ], [LSQF]
RCK	10		Correlation coefficient for hydraulic properties relationships. [CHNGM]
RD	NSEC	SEC1	River distance for cross section.
RDT	NRIV,NTRIB	RIV	Main stem river distance for each tributary.
RI			RI = FLOAT (I). [OUT1]
RN			Coefficient used to correct the conveyance for the current discharge. [NVAL]
RNMAX			Maximum value for RN. [NVAL]
RNMIN			Minimum value for RN. [NVAL]

Variable	Array size	Common block	Definition
SB	NRIV	RIV	Average river segment slope.
SBAR			Standard error of the estimate for hydraulic properties relationship. [LSQ], [CHNGM], [LSQF]
SD	10		Estimate standard error [CHNGM]
SDA			SDA = SUMDA/NDIS. [SROUT]
SMADA	NSEC	SEC2	Sum of absolute bed area change. [SROUT]
SMZWS	NSEC	SEC2	Sum of water surface elevations. [SROUT]
STAGE		RIV	Value of stage used for downstream control.
SUMA			Sum used in least squares regression $\Sigma(x_i - \bar{x})\cdot(y_i - \bar{y})$. [LSQ]
SUMB			Sum used in least squares regression $\Sigma(x_i - \bar{x})^2$. [LSQ]
SUMC			Sum used in least squares regression $\Sigma(y_i - \bar{y})^2$. [LSQ]
SUMD			Sum used in least squares regression $\Sigma(y_i - A + Bx_i)^2$ or $\Sigma(y_i - y_{icorr})^2$. [LSQ]
SUMDA	NSEC	SEC2	Sum of the bed area change.
SUMDZ			Approximate change in bed elevation. [SROUT]
SUMD1			Sum used to compute effective depth. [GEOM]
SUMD2			Sum used to compute effective depth. [GEOM]
SUMD3			Sum used to compute effective width. [GEOM]
SUMWK			Sum used to calculate alpha. [GEOM]
SUMX			Sum used in least squares regression. [LSQ]

Variable	Array size	Common block	Definition
SUMXX			Sum used in least squares regression. [LSQ]
SUMXY			Sum used in least squares regression. [LSQ]
SUMY			Sum used in least squares regression. [LSQ]
TA		HYD	Total area at the cross section and for the given water surface elevation.
TAK	NSEC	SEC1	Storage array for total area at the cross section (K).
TED1			Temporary value used for derivation of Newton-Raphson approximation. [BKWAT]
TED2			Temporary value used for derivation of Newton-Raphson approximation. [BKWAT]
THD			Total head downstream. [BKWAT]
TITLE	20		Array for the title of the program run. [IN1]
TK		HYD	Total cross section conveyance at the cross section for the given water elevation.
TKA			Average conveyance used in head-loss calculations. [BKWAT]
TKD		SYS	Total conveyance at downstream cross section.
TKK	NSEC	SEC1	Storage array for total conveyance at cross section.
TQ	NQI	SEC	Storage array for total discharge at cross section.
U			Flow velocity. [WEIRS]

Variable	Array size	Common block	Definition
US			Shear velocity. [WEIRS]
V		HYD	Velocity.
VH			Velocity head. [BKWAT]
VHD		SYS	Velocity head at downstream cross section.
VK	NSEC	SEC1	Storage array for velocity at cross section.
WE	NSEC	SEC1	Storage array for effective width at cross section.
WID			Width of the weir. [WEIR]
WS			Water surface elevation. [BKWAT], [CHNGM], [CONT], [GEOM], [HYDPR], [SUBPF], [WEIR]
WSA			Water surface elevation of stage discharge relationship. [CONT]
WSB			Water surface elevation of stage-hydrograph. [CONT]
WSC			Water surface elevation at down-stream cross section. [CONT]
WSD		SYS	Downstream water surface elevation.
WSK	NSEC	SEC1	Storage array for water surface at cross section.
WSMAX	NSEC	SEC1	Maximum water surface elevation at each cross section.
X	NSEC, ND	SEC2	Array of horizontal distances for each cross section.
XB			Increment of channel width. [GEOM]
XO			X-value for forced point. [LSQF]
XP			Temporary value. [LSQF]
XX	10		XX = AD array of log values of depth used in least squares regression. [LSQ]

Variable	Array size	Common block	Definition
Y	10		Array used in least squares regression. [LSQ]
YB	10		Array used in least squares regression. [LSQ]
YO			Y-value for forced point. [LSQF]
YP			Temporary value. [LSQF]
Z	NSEC, ND	SEC2	Array of bed elevation.
ZB			Increment of channel depth. [GEOM]
ZDIF			Difference between maximum and minimum elevation for each cross section. [CHNGM]
ZDIFM		UNITS	Increment of water surface elevation, for the calculation of the hydraulic properties relations.
ZMIN	NSEC	11	Minimum elevation for cross section.
ZMP3			ZMIN + 3.0. [SROUT]
ZO	NSEC, ND	SEC2	Original bed elevations.
ZOB	NSEC	SEC2	Overbank elevation.
ZSQ			Computed section factor. [SUBPF]

APPENDIX D

LISTING OF PROGRAM KUWASER

The following is a list of the program KUWASER. The listings are presented by subroutine in alphabetical order.

Program KUWASER

```
*DECK
      PROGRAM KUWASER
     1(INPUT,OUTPUT=65,TAPE6=OUTPUT,TAPE5=65,TAPE7=65,TAPE8=513,TAPE9=51
     23,TAPE10=513)
C
C     THIS PROGRAM IS A KNOWN DISCHARGE, WATER AND SEDIMENT ROUTING
C     MODEL.
C
C     THIS MODEL WAS DELVELOPED BY GLENN O. BROWN AND RUH-MING LI,
C     AT THE ENGINEERING RESEARCH CENTER, COLORADO STATE UNIVERSITY,
C     FORT COLLINS, COLORADO.
C
      COMMON /SEC1/           WD(22)        , RD(100)       , TQ(125)      ,
     1        WSK(100)      , WE(100)       , ZMIN(100)     , ZOB(100)     ,
     2        A1(100)       , A2(100)       , A3(100)       , A4(100)      ,
     3        A5(100)       , A6(100)       , A7(100)       , A8(100)      ,
     4        A9(100)       , A10(100)      , B1(100)       , B2(100)      ,
     5        B3(100)       , B4(100)       , B5(100)       , B6(100)      ,
     6        B7(100)       , B8(100)       , B9(100)       , B10(100)     ,
     7        DA4(100)      , DA9(100)      , EDK(100)      , TAK(100)     ,
     8        TKK(100)      , ALPK(100)     , VK(100)       , WSMAX(100)   ,
     9        IMAX(100)
      COMMON /SEC2/           X(100,22)     , Z(100,22)     , ZO(100,22)   ,
     1        DLOB(100)     , DROB(100)     , F(100,22)     , ND(100)      ,
     2        SUMDA(100)    , SMADA(100)    , SMZWS(100)    , IZMIN(100)   ,
     3        G(100)
      COMMON /UNITS/          IUNIT         , CORDS         , ZDIFM        ,
     1        GRAV          , VVAL          , FET           , CONV         ,
     2        DZMAX
      COMMON /INF/            NSEC          , NTIM          , DT           ,
     1        IORG          , CE            , CC            , PORM         ,
     2        STAGE         , ITIME         , NQI           , NCALL        ,
     3        ICALL(30,3)   , MST           , EPS
      COMMON /RIV/            NRIV          , KUP(10)       , KDOWN(10)    ,
     1        NTRIB(10)     , ICONT(10)     , QSC(10,5)     , AX(10)       ,
     2        BX(10)        , CX(10)        , RDT(10,5)     , ITRIB(10,5)  ,
     3        KTRIB(10,5)   , AT(10,5)      , BT(10,5)      , KCONT(10)    ,
     4        IROUT(10)     , SB(10)        , AN(10)        , BN(10)
      COMMON /PRT/            IPRNT(8)      , I5            , I6           ,
     1        I7            , I8            , I9            , I10
      DIMENSION               PNR(10)
C
      DATA IDUMB/0/
C
C     DEFINE DEVICE NUMBERS
C
C       I5        INPUT DEVICE FOR GENERAL DATA FILE
C       I6        DEVICE FOR PRINTED OUTPUT
C       I7        INPUT DEVICE FOR CROSS SECTION FILE
C       I8        INPUT DEVICE FOR DISCHARGE FILE
C       I9        OUTPUT DEVICE FOR YEARLY CROSS SECTION ELEVATIONS,
C                 (BINARY OUTPUT)
C      I10        OUTPUT DEVICE FOR CROSS SECTION HYDRAULIC PRPERTIES,
C                 (BINARY OUTPUT)
      I5 = 5
      I6 = 6
      I7 = 7
      I8 = 8
      I9 = 9
      I10 = 10
C
C     READ IN THE SEDIMENT AND GEOMETRY DATA.
C
      CALL INI
C
C     PUTS CORRECT VALUES TO THE CONSTANTS ACCORDING TO THE UNIT-SYSTEM.
C
      CALL UNIT
C
C     CONVERT RIVER DISTANCES.
C
      DO 130 NR = 1,NRIV
         PNR(NR) = 0.5
         KU = KUP(NR)
         KD = KDOWN(NR)
         IF (NR.EQ.1) GO TO 100
         NRM1 = NR - 1
         IF (KD.EQ.KUP(NRM1)) KD = KD + 1
  100    DO 110 K = KD,KU
            DIS = RD(K)
            CALL RIVDS (NR,DIS)
            RD(K) = DIS
  110    CONTINUE
         NT = NTRIB(NR)
         IF (NT.EQ.0) GO TO 130
         DO 120 J = 1,NT
            DIS = RDT(NR,J)
            CALL RIVDS (NR,DIS)
            RDT(NR,J) = DIS
  120    CONTINUE
```

Program KUWASER continued

```
  130 CONTINUE
C
C     SET INITIAL VALUES
C
      DO 150 K = 1,NSEC
         WSMAX(K) = 0.0
         SMZWS(K) = 0.0
         SMADA(K) = 0.0
         SUMDA(K) = 0.0
         WSK(K) = 0.0
         TQ(K) = 0.0
         VK(K) = 0.0
         EDK(K) = 0.0
         WE(K) = 0.0
         ALPK(K) = 0.0
         TKK(K) = 0.0
         TAK(K) = 0.0
C
C     SET ORIGNAL BED ELEVATIONS INTO ZO(K,L) ARRAY.
C
         M = ND(K)
         DO 140 L = 1,M
            ZO(K,L) = Z(K,L)
  140    CONTINUE
  150 CONTINUE
C
C     CALCULATE THE INITIAL HYDRAULIC PROPERTIES OF EACH CROSS SECTION
C
      DO 160 K = 1,NSEC
         CALL THAL (K)
         CALL CHNGM (K)
  160 CONTINUE
C
C     ITERATE OVER EACH TIME PERIOD.
C
      IF (NTIM.NE.0) GO TO 170
      WRITE (I6,310)
      STOP
  170 DO 300 I = 1,NTIM
         ITIME = I
C
C     ITERATE OVER SUBROUTINE CALLS
C
         DO 290 NC = 1,NCALL
         ICAL1 = ICALL(NC,1)
         GO TO (180,190,200,210,220,230,240,250,260,280), ICAL1
C
C     DETERMINE FLOW AT EACH CROSS SECTION
C
  180       CALL FLOW
            GO TO 290
C
C     CALCULATE WATER SURFACE PROFILE FOR REACH
C
  190       CALL SUBPF (ICALL(NC,2))
            GO TO 290
C
C     COMPUTE FLOWS AND WATER SURFACE PROFILES FOR DIVIDED FLOW REACHES
C
  200       ICAL2 = ICALL(NC,2)
            P = PNR(ICAL2)
            IFLAG = 0
            CALL DIVDE (ICALL(NC,2),ICALL(NC,3),IDUMB,IDUMB,IFLAG,P)
            PNR(ICAL2) = P
            GO TO 290
C
C     CALCULATE SEDIMENT TRANSPORT AT EACH CROSS SECTION.
C
  210       CALL SED
            GO TO 290
C
C     CALCULATE SEDIMENT TRANSPORT OVER THE WEIR(S)
C
  220       CALL WEIRS (ICALL(NC,2),ICALL(NC,3))
            GO TO 290
C
C     CALCULATE TRIBUTARY SEDIMENT DISCHARGE.
C
  230       CALL TRIBS
            GO TO 290
C
C     ROUTE THE SEDIMENT IN THE RIVER REACH
C
  240       CALL SROUT (ICALL(NC,2))
            GO TO 290
C
C     DUPLICATE PROPERTIES AT DOUBLE CROSS SECTIONS
C
  250       CALL DUP (ICALL(NC,2),ICALL(NC,3))
            GO TO 290
```

Program KUWASER continued

```
C
C     TEST FOR MAXIMUM WATER SURFACE AT EACH CROSS SECTION
C
  260       DO 270 K = 1,NSEC
               IF (WSK(K).LT.WSMAX(K)) GO TO 270
               WSMAX(K) = WSK(K)
               IMAX(K) = ITIME
  270       CONTINUE
C
C     PRINT OUT THE RESULTS.
C
            CALL OUT1
            GO TO 290
C
C     DREDGE RIVER REACH
C

            CALL DREDG (ICALL(NC,2))
  290    CONTINUE
  300 CONTINUE
C
      STOP
C
C
C
  310 FORMAT (//,10X,38HTHE NUMBER OF TIME PERIODS EQUAL ZERO.,/,10X,42H
     1NO WATER OR SEDIMENT ROUTING IS PERFORMED.)
      END
```

Subroutine BKWAT

```
      SUBROUTINE BKWAT (K,WS,ICRI)
C
C     THIS SUBROUTINE CALCULATES THE WATER SURFACE ELEVATION AT A
C     CROSS SECTION ONCE THE CONDITIONS AT THE DOWNSTREAM SECTION
C     ARE KNOWN.  THE ROUTINE USES A FIRST ORDER NEWTON-RAPHSON
C     SOLUTION TO THE SOLVE THE TOTAL HEAD EQUATION.
C
      COMMON /SEC1/         WD(22)       , RD(100)      , TQ(125)      ,
     1         WSK(100)   , WE(100)      , ZMIN(100)    , ZOB(100)     ,
     2         A1(100)    , A2(100)      , A3(100)      , A4(100)      ,
     3         A5(100)    , A6(100)      , A7(100)      , A8(100)      ,
     4         A9(100)    , A10(100)     , B1(100)      , B2(100)      ,
     5         B3(100)    , B4(100)      , B5(100)      , B6(100)      ,
     6         B7(100)    , B8(100)      , B9(100)      , B10(100)     ,
     7         OA4(100)   , OA9(100)     , EDK(100)     , TAK(100)     ,
     8         TKK(100)   , ALPK(100)    , VK(100)      , WSMAX(100)   ,
     9         IMAX(100)
      COMMON /UNITS/        IUNIT        , CORDS        , ZDIFM        ,
     1         GRAV       , VVAL         , FET          , CONV         ,
     2         DZMAX
      COMMON /INF/          NSEC         , NTIM         , DT           ,
     1         IDRG       , CE           , CC           , PORM         ,
     2         STAGE      , ITIME        , NQI          , NCALL        ,
     3         ICALL(30,3) , MST         , EPS
      COMMON /SYS/          VHD          , WSD          , TKD          ,
     1         DEX
      COMMON /HYD/          V            , ED           , EW           ,
     1         ALP        , TK           , TA
      COMMON /PRT/          IPRNT(8)     , I5           , I6           ,
     1         I7         , I8           , I9           , I10
C
C     CALCULATE THE TOTAL HEAD DOWNSTREAM.
C
      THD = VHD + WSD
C
C     ESTIMATE THE UPSTREAM WATER SURFACE ELEVATION BASED ON THE
C     DOWNSTREAM CONDITIONS.
C
      KOUNT = 0
      WS = WSD + DEX * (TQ(K)/TKD) * (TQ(K)/TKD)
  100 KOUNT = KOUNT + 1
C
C     DETERMINE IF ESTIMATE IS GREATER THAN THALWEG.
C
C
      IF (WS.LE.ZMIN(K)) WS = ZMIN(K) + FET
      CALL HYDPR (K,WS)
      IF (KOUNT.GT.MST) GO TO 140
C
C     CALCULATE VELOCITY HEAD, (VH).
C
      VH = ALP * V * V/(2. * GRAV)
      CCE = CE
      IF (VH.LT.VHD) CCE = CC
C
C     CALCULATE THE HEAD LOSS,(HL).
C
      TKA = (TKD + TK)/2.
      HLV = ABS(VH - VHD) * CCE
      HL = DEX * ((TQ(K) * TQ(K))/(TKA * TKA))
C
C     CALCULATE THE ERROR.
C
      ER = VH + WS - HL - THD - HLV
C
C     TEST FOR ERROR TOLERANCE.
C
```

Subroutine BKWAT continued

```
C
      IF (ABS(ER).LE.EPS) GO TO 150
      IF (KOUNT.GT.MST) GO TO 140
C
C     CALCULATE THE FIRST DERIVATIVE AT THE ESTIMATED DEPTH.
C
      D = WS - ZMIN(K)
      IF (WS.GT.ZOB(K)) GO TO 110
      TED1 = B5(K) - 2.0 * B3(K) - 1.0
      ATEMP = (TQ(K) * TQ(K)/(2. * GRAV)) * ((A5(K)/(A3(K) * A3(K))) * (
     1B5(K) - 2.0 * B3(K))) * D *  * TED1
      ATEMP = (1. - CCE) * ATEMP
      TED1 = B4(K) - 1.0
      TED2 = 2.0 * B4(K) - 1.0
      BNUM = (4.0 * DEX * TQ(K) * TQ(K)) * (2.0 * TKD * A4(K) * B4(K) *
     1D *  * TED1 + (A4(K) * A4(K)) * 2.0 * B4(K) * D *  * TED2)
      TED1 = B4(K)
      TED2 = 2.0 * B4(K)
      BDEN = (TKD * TKD) + 2.0 * TKD * A4(K) * D *  * TED1 + (A4(K) *  *
     1 2) * D *  * TED2
      GO TO 120
  110 TED1 = B10(K) - 2.0 * B8(K) - 1.0
      ATEMP = (TQ(K) * TQ(K)/(2. * GRAV)) * ((A10(K)/(A8(K) * A8(K))) *
     1(B10(K) - 2.0 * B8(K))) * D *  * TED1
      ATEMP = (1. - CCE) * ATEMP
      TED1 = B9(K) - 1.0
      TED2 = 2.0 * B9(K) - 1.0
      BNUM = (4.0 * DEX * TQ(K) * TQ(K)) * (2.0 * TKD * A9(K) * B9(K) *
     1D *  * TED1 + (A9(K) * A9(K)) * 2.0 * B9(K) * D *  * TED2)
      TED1 = B9(K)
      TED2 = 2.0 * B9(K)
      BDEN = (TKD * TKD) + 2.0 * TKD * A9(K) * D *  * TED1 + (A9(K) *  *
     1 2) * D *  * TED2
  120 DER = ATEMP + 1.0 + (BNUM/(BDEN *  * 2))
C
C     ESTIMATE CORRECT WATER SURFACE BY NEWTON-RAPHSON METHOD
C
      IF (DER.LT.0.0.AND.ER.GT.0.0) GO TO 130
      WS = WS - ER/ABS(DER)
      GO TO 100
  130 D = (TQ(K) * TQ(K) * A5(K))/(A3(K) * A3(K) * GRAV)
      D = D *  * (1./(1. + 2. * B3(K) - B5(K)))
      WS = D + ZMIN(K) + FET
      IF (WS.LT.ZOB(K)) GO TO 100
      D = (TQ(K) * TQ(K) * A10(K))/(A8(K) * A8(K) * GRAV)
      D = D *  * (1./(1. + 2. * B8(K) - B10(K)))
      WS = D + ZMIN(K) + FET
      GO TO 100
  140 ICRI = 1
      IF (IPRNT(8).NE.1) GO TO 150
      WRITE (I6,160) EPS,MST,K,ITIME
  150 IF (WS.LT.WSD) WS = WSD
      RETURN
C
C
C
  160 FORMAT (/10X,41HBACKWATER CALCULATION DID NOT CONVERGE TO,F4.1,4H
     1IN ,I3,11H ITERATIONS,/,10X,16HAT CROSS SECTION,I4,19H DURING TIME
     2 PERIOD,I5,/,10X,26HCRITICAL DEPTH IS ASSUMED.)
      END
```

Subroutine CHNGM

```
      SUBROUTINE CHNGM (K)
C
C     THIS SUBROUTINE COMPUTES POWER RELATIONS THAT ARE USED TO
C     CALCULATE EFFECTIVE DEPTH (ED), EFFECTIVE WIDTH (EW),
C     ALPHA (ALP), TOTAL AREA (TA), AND TOTAL CONVEYANCE (TK),
C     FOR A CROSS SECTION, AS A FUNCTION OF THE WATER SURFACE
C     ELEVATION (WS).
C
      COMMON /SEC1/          WD(22)          , RD(100)         , TQ(125)         ,
     1           WSK(100)    , WE(100)       , ZMIN(100)       , ZOB(100)        ,
     2           A1(100)     , A2(100)       , A3(100)         , A4(100)         ,
     3           A5(100)     , A6(100)       , A7(100)         , A8(100)         ,
     4           A9(100)     , A10(100)      , B1(100)         , B2(100)         ,
     5           B3(100)     , B4(100)       , B5(100)         , B6(100)         ,
     6           B7(100)     , B8(100)       , B9(100)         , B10(100)        ,
     7           OA4(100)    , OA9(100)      , EDK(100)        , TAK(100)        ,
     8           TKK(100)    , ALPK(100)     , VK(100)         , WSMAX(100)      ,
     9           IMAX(100)
      COMMON /UNITS/         IUNIT           , CORDS           , ZDIFM           ,
     1           GRAV        , VVAL          , FET             , CONV            ,
     2           DZMAX
      COMMON /HYD/           V               , ED              , EW              ,
     1           ALP         , TK            , TA
      COMMON /PRT/           IPRNT(8)        , I5              , I6              ,
     1           I7          , I8            , I9              , I10
      DIMENSION              AEW(10)         , AALP(10)        , AED(10)         ,
     1           ATA(10)     , ATK(10)       , AD(10)          , RCK(10)         ,
     2           SD(10)
      DATA NAP/10/
C
C     CALCULATE THE RELATIONSHIPS FOR THE MAIN CHANNEL.
C
      ZDIF = ZOB(K) - ZMIN(K)
      IF (ZDIF.LT.ZDIFM) ZDIF = ZDIFM
      DWS = ZDIF/FLOAT(NAP)
      WS = ZMIN(K)
C
C     CALCULATE THE EXACT HYDRAULIC PROPERTIES AT (NAP) EVENLY SPACED
C     WATER SURFACE ELEVATIONS.
C
      DO 100 N = 1,NAP
         WS = WS + DWS
         CALL GEOM (K,WS)
C
C     TAKE THE LOG OF THE HYDRAULIC PROPERTIES.  THESE VALUES WILL BE
C     USED IN THE LINEAR REGRESSION SUBROUTINE, SO THAT A POWER
C     FUNCTION WILL BE OBTAINED.
C
         AEW(N) = ALOG(EW)
         AED(N) = ALOG(ED)
         ATA(N) = ALOG(TA)
         ATK(N) = ALOG(TK)
         AALP(N) = ALOG(ALP)
         AD(N) = ALOG(WS - ZMIN(K))
  100 CONTINUE
C
C     CALL LEAST SQUARES LINEAR REGRESSION SUBROUTINE TO CALCULATE
C     THE HYDRAULIC POWER FUNCTIONS.
C
      CALL LSQ (NAP,AD,AEW,A1(K),B1(K),RCK(1),SD(1))
      CALL LSQ (NAP,AD,AED,A2(K),B2(K),RCK(2),SD(2))
      CALL LSQ (NAP,AD,ATA,A3(K),B3(K),RCK(3),SD(3))
      CALL LSQ (NAP,AD,ATK,A4(K),B4(K),RCK(4),SD(4))
      CALL LSQ (NAP,AD,AALP,A5(K),B5(K),RCK(5),SD(5))
      OA4(K) = A4(K)
      IF (RCK(4).GT.0.8) GO TO 110
      A5(K) = 1.25
      B5(K) = 0.01
C
C     CALCULATE THE RELATIONSHIPS FOR OVERBANK FLOW.
C
  110 DO = ZOB(K) - ZMIN(K)
      IF (DO.LE.0.0) DO = 0.1
      ADO = ALOG(DO)
      ATAO = ALOG(A3(K) * DO *   * B3(K))
      ATKO = ALOG(A4(K) * DO *   * B4(K))
      ZDIF = ZDIFM
      DWS = ZDIF/FLOAT(NAP)
      DO 120 N = 1,NAP
         WS = WS + DWS
         CALL GEOM (K,WS)
C
C     TAKE THE LOG OF THE HYDRAULIC PROPERTIES.  THESE VALUES WILL BE
C     USED IN THE LINEAR REGRESSION SUBROUTINE, SO THAT A POWER
C     FUNCTION WILL BE OBTAINED.
C
         AEW(N) = ALOG(EW)
         AED(N) = ALOG(ED)
         ATA(N) = ALOG(TA)
         ATK(N) = ALOG(TK)
         AALP(N) = ALOG(ALP)
         AD(N) = ALOG(WS - ZMIN(K))
```

Subroutine CHNGM continued

```
  120 CONTINUE
C
C     CALL LEAST SQUARES LINEAR REGRESSION SUBROUTINE TO CALCULATE
C     THE HYDRAULIC POWER FUNCTIONS.
C
      CALL LSQ (NAP,AD,AEW,A6(K),B6(K),RCK(6),SD(6))
      CALL LSQ (NAP,AD,AED,A7(K),B7(K),RCK(7),SD(7))
      CALL LSQF  (NAP,AD,ATA,A8(K),B8(K),RCK(8),SD(8),ADO,ATAO)
      CALL LSQF  (NAP,AD,ATK,A9(K),B9(K),RCK(9),SD(9),ADO,ATKO)
      CALL LSQ (NAP,AD,AALP,A10(K),B10(K),RCK(10),SD(10))
      OA9(K) = A9(K)
      IF (RCK(9).GT.0.8) GO TO 130
      A10(K) = 1.25
      B10(K) = 0.01
  130 IF (IPRNT(2).NE.1) RETURN
      WRITE (I6,140) K,A1(K),B1(K),RCK(1),SD(1),A2(K),B2(K),RCK(2),SD(2)
     1,A3(K),B3(K),RCK(3),SD(3),A4(K),B4(K),RCK(4),SD(4),A5(K),B5(K),RCK
     2(5),SD(5)
      WRITE (I6,140) K,A6(K),B6(K),RCK(6),SD(6),A7(K),B7(K),RCK(7),SD(7)
     1,A8(K),B8(K),RCK(8),SD(8),A9(K),B9(K),RCK(9),SD(9),A10(K),B10(K),R
     2CK(10),SD(10)
C
      RETURN
C
C
C
  140 FORMAT (2X,I3,1X,F6.2,1X,F4.2,1X,F4.2,1X,F5.3,1X,1HI,F7.2,1X,F4.2,
     11X,F4.2,1X,F5.3,1X,1HI,F7.2,1X,F4.2,1X,F4.2,1X,F5.3,1X,1HI,F7.0,1X
     2,F4.2,1X,F4.2,1X,F5.3,1X,1HI,F7.3,1X,F4.2,1X,F4.2,1X,F5.3,1X,1HI)
      END
```

Subroutine CONT

```
      SUBROUTINE CONT (NR,WS)
C
C     THIS SUBROUTINE IS USED TO COMPUTE THE WATER SURFACE ELEVATION
C     AT THE DOWNSTREAM CONTROL
C
C       DEFINITIONS OF TYPES OF CONTROL
C
C       ICONT(NR)              TYPE OF CONTROL
C
C           1                STAGE-DISCHARGE RELATIONSHIP
C           2                STAGE HYDROGRAPH
C           3                DOWNSTREAM WATER SURFACE
C           4                GREATEST OF #1 AND #2
C           5                GREATEST OF #1 AND #3
C           6                NORMAL DEPTH
C
      COMMON /SEC1/         WD(22)       , RD(100)      , TQ(125)      ,
     1         WSK(100)   , WE(100)      , ZMIN(100)    , ZOB(100)     ,
     2         A1(100)    , A2(100)      , A3(100)      , A4(100)      ,
     3         A5(100)    , A6(100)      , A7(100)      , A8(100)      ,
     4         A9(100)    , A10(100)     , B1(100)      , B2(100)      ,
     5         B3(100)    , B4(100)      , B5(100)      , B6(100)      ,
     6         B7(100)    , B8(100)      , B9(100)      , B10(100)     ,
     7         UA4(100)   , UA9(100)     , EDK(100)     , TAK(100)     ,
     8         TKK(100)   , ALPK(100)    , VK(100)      , WSMAX(100)   ,
     9         IMAX(100)
      COMMON /RIV/          NRIV         , KUP(10)      , KDOWN(10)    ,
     1         NTRIB(10)  , ICONT(10)    , QSL(10,5)    , AX(10)       ,
     2         BX(10)     , CX(10)       , RDT(10,5)    , ITRIB(10,5)  ,
     3         KTRIB(10,5), AT(10,5)     , BT(10,5)     , KCONT(10)    ,
     4         IROUT(10)  , SB(10)       , AN(10)       , BN(10)
      COMMON /INF/          NSEC         , NTIM         , DT           ,
     1         IORG       , CE           , CC           , PORM         ,
     2         STAGE      , ITIME        , NQI          , NCALL        ,
     3         ICALL(30,3), MST          , EPS
C
C     DETERMINE TYPE OF DOWNSTREAM CONTROL.
C
      ICANT = ICONT(NR)
      GO TO (100,110,120,100,100,170), ICANT
C
C     STAGE-DISCHARGE CONTROL
C
  100 KD = KDOWN(NR)
      WSA = CX(NR) + AX(NR) * TQ(KD) *  * BX(NR)
      IF (ICONT(NR).EQ.4) GO TO 110
      IF (ICONT(NR).EQ.5) GO TO 120
      WS = WSA
      RETURN
C
C     STAGE HYDROGRAPH CONTROL.
C
  110 WSB = STAGE
      IF (ICONT(NR).EQ.4) GO TO 130
      WS = WSB
      RETURN
C
C     DOWNSTREAM WATER SURFACE CONTROL.
C
  120 KD = KCONT(NR)
      WSC = WSK(KD)
      IF (ICONT(NR).EQ.5) GO TO 150
      WS = WSC
      RETURN
  130 IF (WSB.GT.WSA) GO TO 140
      WS = WSA
      RETURN
  140 WS = WSB
      RETURN
  150 IF (WSC.GT.WSA) GO TO 160
      WS = WSA
      RETURN
  160 WS = WSC
      RETURN
C
C     NORMAL DEPTH CALCULATIONS.
C
  170 KD = KDOWN(NR)
      C = TQ(KD)/(SB(NR) *  * 0.5)
      D = (C/A4(KD)) *  * (1./B4(KD))
      WS = ZMIN(KD) + D
      IF (WS.LE.ZOB(KD)) RETURN
      C = TQ(KD)/(SB(NR) *  * 0.5)
      D = (C/A9(KD)) *  * (1./B9(KD))
      WS = ZMIN(KD) + D
C
      RETURN
      END
```

Subroutine DIVDE

```
      SUBROUTINE DIVDE (NR1,NR2,P)
C
C     THIS SUBROUTINE USES A SECOND ORDER CURVE FITTING ALGORITHM
C     TO FIND THE RATIO OF FLOWS "P" IN DIVIDED FLOW REACHSES
C
      COMMON /INF/        NSEC          , NTIM        , DT          ,
     1        IORG      , CE            , CC          , PORM        ,
     2        STAGE     , ITIME         , NQI         , NCALL       ,
     3        ICALL(30,3) , MST         , EPS
      COMMON /PRT/        IPRNT(8)      , I5          , I6          ,
     1        I7        , I8            , I9          , I10
      DIMENSION           E(3)          , Y(3)
      DATA XLOL,XUPL/0.0,1.0/
      XA = P
      NC = 0
      DX = 0.2
  100 CALL SPLIT (NR1,NR2,VALUE,XA)
      P = XA
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      A = VALUE
      XB = XA + DX
      IF (XB.LE.XUPL) GO TO 110
      XB = XUPL
  110 CALL SPLIT (NR1,NR2,VALUE,XB)
      P = XB
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      B = VALUE
C
C     DETERMINE THE THIRD POINT REQUIRED FOR APPROXIMATION
C
      IF (A.GT.B) GO TO 150
  120 XC = XA - DX
      IF (XC.GE.XLOL) GO TO 130
      XC = XLOL
  130 CALL SPLIT (NR1,NR2,VALUE,XC)
      P = XC
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      C = VALUE
      Y(1) = XC
      Y(2) = XA
      Y(3) = XB
      E(1) = C
      E(2) = A
      E(3) = B
      IF (C.LT.A) GO TO 140
      XINF = XA
      FINF = A
      GO TO 180
  140 XINF = XC
      FINF = C
      GO TO 180
  150 XC = XA + 2. * DX
      IF (XC.LE.XUPL) GO TO 160
      XC = XUPL
  160 CALL SPLIT (NR1,NR2,VALUE,XC)
      P = XC
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      C = VALUE
      Y(1) = XA
      Y(2) = XB
      Y(3) = XC
      E(1) = A
      E(2) = B
      E(3) = C
      IF (C.LT.B) GO TO 170
      XINF = XB
      FINF = B
      GO TO 180
  170 XINF = XC
      FINF = C
C
C     ELIMINATE PREMATURE TERMINATION DUE TO EQUAL VALUES AT TWO END
C     POINTS IN THE FIRST SEARCH
C
  180 YDEF = Y(3) - 2. * Y(2) + Y(1)
      EDEF = E(1) - E(3)
      IF (NC.GT.0.OR.ABS(YDEF).GT.EPS.OR.ABS(EDEF).GT.EPS) GO TO 190
      DX = 0.5 * DX
      Y(2) = Y(1) + DX
      IF (Y(2).GT.XUPL) Y(2) = XUPL
      CALL SPLIT (NR1,NR2,VALUE,Y(2))
      P = Y(2)
C
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      E(2) = VALUE
      Y(3) = XINF
      E(3) = FINF
      EDEF = E(1) - E(3)
      IF (E(2).GT.FINF) GO TO 190
      XINF = Y(2)
      FINF = E(2)
```

Subroutine DIVDE continued

```
C
C     CHECK THE CONVEXITY OF THE QUADRATIC FUNCTION
C
  190 A1 = (Y(1) - Y(2)) * (Y(2) - Y(3)) * (Y(1) - Y(3))
      IF (ABS(A1).EQ.0.) GO TO 200
      A2 = E(1) * (Y(2) - Y(3)) + E(2) * (Y(3) - Y(1)) + E(3) * (Y(1) -
     1Y(2))
      SA = A2/A1
      IF (SA.GE.0.0) GO TO 210
      DX = Y(3) - Y(1)
      XA = Y(1)
      A = E(1)
      XB = Y(3)
      B = E(3)
      IF (EDEF.GT.0.) GO TO 150
      GO TO 120
  200 XSTA = XINF
      FSTA = FINF
      GO TO 270
C
C     DETERMINE THE MINIMUM OF THE QUADRATIC FUNCTION
C
  210 SB = (E(1) - E(2))/(Y(1) - Y(2)) - SA * (Y(1) + Y(2))
      XSTA =  - SB/(2. * SA)
      IF (XSTA.GE.XLOL.AND.XSTA.LE.XUPL) GO TO 230
      IF (EDEF.GT.0.0) GO TO 220
      XSTA = XLOL
      GO TO 230
  220 XSTA = XUPL
  230 NC = NC + 1
      CALL SPLIT (NR1,NR2,VALUE,XSTA)
      P = XSTA
      IF (VALUE.LE.(EPS * EPS)) GO TO 270
      FSTA = VALUE
      XTEM = XSTA
      FTEM = FSTA
      IF (FSTA.LE.FINF) GO TO 240
      XTEM = XINF
      FTEM = FINF
  240 IF (ABS(1. - FSTA/FINF).GT.EPS) GO TO 250
      XSTA = XTEM
      FSTA = FTEM
      GO TO 270
  250 IF (NC.LT.MST) GO TO 260
      IF (IPRNT(8).NE.1) RETURN
      WRITE (16,280) NR1,NR2,ITIME
      RETURN
  260 DL = ABS(XINF - XSTA)
      IF (DL.LT.DX) DX = DL
      XA = XTEM
      GO TO 100
C
C     A MINIMUM HAS BEEN FOUND
C
  270 RETURN
C
C
C
  280 FORMAT (/,10X, 42HDIVIDED FLOW CALCULATIONS DID NOT CONVERGE,/,10X
     1, 11HFOR REACHES,I3,  4H AND,I3, 18HDURING TIME PERIOD,I3)
      END
```

Subroutine DREDG

```
      SUBROUTINE DREDG (NR)
C
C     THIS SUBROUTINE SIMULATES DREDGING BY LOWERING EACH CROSS
C     SECTION IN A REACH TO ITS ORIGINAL ELEVATION (ZO).  ONLY
C     CROSS SECTION POINTS IN THE MAIN CHANNEL ARE LOWERED.
C
      COMMON /SEC1/         WD(22)       , RD(100)      , TQ(125)      ,
     1       WSK(100)     , WE(100)      , ZMIN(100)    , ZOB(100)     ,
     2       A1(100)      , A2(100)      , A3(100)      , A4(100)      ,
     3       A5(100)      , A6(100)      , A7(100)      , A8(100)      ,
     4       A9(100)      , A10(100)     , B1(100)      , B2(100)      ,
     5       B3(100)      , B4(100)      , B5(100)      , B6(100)      ,
     6       B7(100)      , B8(100)      , B9(100)      , B10(100)     ,
     7       OA4(100)     , OA9(100)     , EDK(100)     , TAK(100)     ,
     8       TKK(100)     , ALPK(100)    , VK(100)      , WSMAX(100)   ,
     9       IMAX(100)
      COMMON /SEC2/         X(100,22)    , Z(100,22)    , ZO(100,22)   ,
     1       DLOB(100)    , DROB(100)    , F(100,22)    , ND(100)      ,
     2       SUMDA(100)   , SMADA(100)   , SMZWS(100)   , IZMIN(100)   ,
     3       G(100)
      COMMON /RIV/          NRIV         , KUP(10)      , KDOWN(10)    ,
     1       NTRIB(10)    , ICONT(10)    , QSL(10,5)    , AX(10)       ,
     2       BX(10)       , CX(10)       , RDT(10,5)    , ITRIB(10,5)  ,
     3       KTRIB(10,5)  , AT(10,5)     , BT(10,5)     , KCONT(10)    ,
     4       IROUT(10)    , SB(10)       , AN(10)       , BN(10)
      KU = KUP(NR)
      KD = KDOWN(NR)
      DO 110 K = KD,KU
         IFLG = 0
         M = ND(K)
         DO 100 L = 1,M
            IF (X(K,L).LT.DROB(K)) GO TO 100
            IF (X(K,L).GT.DLOB(K)) GO TO 100
            IF (Z(K,L).LE.ZO(K,L)) GO TO 100
            Z(K,L) = ZO(K,L)
            IFLG = 1
  100    CONTINUE
         IF (IFLG.EQ.0) GO TO 110
         CALL THAL (K)
         CALL CHNGM (K)
  110 CONTINUE
      WRITE (I9) ((Z(K,L),K = KD,KU),L = 1,22)
      RETURN
C
      END
```

Subroutine DUP

```
      SUBROUTINE DUP (K1,K2)
C
C     THIS SUBROUTINE IS USED IN DIVIDE FLOW PROBLEMS WHEN
C     A CROSS SECTION IS USED BY TWO DIFFERENT RIVER REACHES.
C     IT CHANGES THE BED ELEVATION OF THE DUPLICATE CROSS
C     SECTION, (K2), TO MATCH THE BED ELEVATION OF THE ORIGINAL
C     SECTION, (K1), AFTER SEDIMENT ROUTING.
C
      COMMON /SEC1/          WD(22)       , RD(100)      , TQ(125)       ,
     1        WSK(100)     , WE(100)      , ZMIN(100)    , ZOB(100)      ,
     2        A1(100)      , A2(100)      , A3(100)      , A4(100)       ,
     3        A5(100)      , A6(100)      , A7(100)      , A8(100)       ,
     4        A9(100)      , A10(100)     , B1(100)      , B2(100)       ,
     5        B3(100)      , B4(100)      , B5(100)      , B6(100)       ,
     6        B7(100)      , B8(100)      , B9(100)      , B10(100)      ,
     7        OA4(100)     , OA9(100)     , EDK(100)     , TAK(100)      ,
     8        IKK(100)     , ALPK(100)    , VK(100)      , WSMAX(100)    ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)    , Z(100,22)    , ZO(100,22)    ,
     1        ULOB(100)    , DROB(100)    , F(100,22)    , ND(100)       ,
     2        SUMDA(100)   , SMADA(100)   , SMZWS(100)   , IZMIN(100)    ,
     3        G(100)
C
      N = ND(K1)
      DO 100 L = 1,N
         Z(K2,L) = Z(K1,L)
  100 CONTINUE
      ZMIN(K2) = ZMIN(K1)
      IZMIN(K2) = IZMIN(K1)
      A1(K2) = A1(K1)
      A2(K2) = A2(K1)
      A3(K2) = A3(K1)
      A4(K2) = A4(K1)
      A5(K2) = A5(K1)
      A6(K2) = A6(K1)
      A7(K2) = A7(K1)
      A8(K2) = A8(K1)
      A9(K2) = A9(K1)
      A10(K2) = A10(K1)
      B1(K2) = B1(K1)
      B2(K2) = B2(K1)
      B3(K2) = B3(K1)
      B4(K2) = B4(K1)
      B5(K2) = B5(K1)
      B6(K2) = B6(K1)
      B7(K2) = B7(K1)
      B8(K2) = B8(K1)
      B9(K2) = B9(K1)
      B10(K2) = B10(K1)
      OA4(K2) = OA4(K1)
      OA9(K2) = OA9(K1)
C
      RETURN
      END
```

Subroutine FLOW

```
      SUBROUTINE FLOW
C
C     THIS SUBROUTINE CALCULATES THE WATER DISCHARGE AT EACH
C     CROSS SECTION.
C
      COMMON /SEC1/
     1                       WD(22)        , RD(110)       ,
     2          TQ(200)     , WSK(110)     , WE(110)       , ZMIN(110)     ,
     3          ZOB(110)    ,
     4                       A1(110)       , A2(110)       , A3(110)       ,
     5          A4(110)     , A5(110)      , A6(110)       , A7(110)       ,
     6          A8(110)     , A9(110)      , A10(110)      , B1(110)       ,
     7          B2(110)     , B3(110)      , B4(110)       , B5(110)       ,
     8          B6(110)     , B7(110)      , B8(110)       , B9(110)       ,
     9          B10(110)    , OA4(110)     , OA9(110)      , EDK(110)      ,
     0          TAK(110)    , TKK(110)     , ALPK(110)     , VK(110)       ,
     1                       WSMAX(110)    , IMAX(110)
      COMMON /INF/           NSEC          , NTIM          , DT,IDRG       ,
     1          CE       ,CC, PORM         , STAGE         , ITIME         ,
     2          NQI         , NCALL        , ICALL(30,5)   , MST           ,
     3          EPS
      COMMON /RIV/           NRIV          , KUP(10)       , KDOWN(10)     ,
     1          NTRIB(10)   , ICONT(10)    , GC(10)        , QSL(10,10)    ,
     2          AX(10)      , BX(10)       , CX(10)        , RDT(10,10)    ,
     3          ITRIB(10,10), KTRIB(10,10) , AT(10,10)     , BT(10,10)     ,
     4          KCONT(10)   , IROUT(8)     , SB(10)        , AN(10)        ,
     5          BN(10)
      COMMON /PRT/           IPRNT(8)      , I5            , I6            ,
     1          I7          , I8           , I9            , I10
      DIMENSION Q(10),QT(10,5)
C
C     READ UPSTREAM DISCHARGE FOR EACH RIVER REACH
      READ(I8,100)(Q(NR),NR=1,NRIV)
C
C     READ STAGE DATA
      READ(I8,100)STAGE
C
C     READ POINT SOURCE TRIBUTARY FLOW DATA
C
      DO 20 NR=1,NRIV
      NT=NTRIB(NR)
      IF(NT.EQ.0)GO TO 20
      DO 6 J=1,NT
      IT=ITRIB(NR,J)
      IF(IT.EQ.2.OR.IT.EQ.4)GO TO 6
      READ(I8,100)QT(NR,J)
      KT=KTRIB(NR,J)
      TQ(KT)=QT(NR,J)
    6 CONTINUE
   20 CONTINUE
C
C    INITIALIZE THE DISCHARGE AT EACH SECTION WITH THE UPSTREAM DISCHARGE
C     OF THE REACH
      DO 30 M=1,NRIV
      NR=NRIV-M+1
      KU=KUP(NR)
      KD=KDOWN(NR)
      DO 30 K=KD,KU
      TQ(K)=Q(NR)
   30 CONTINUE
```

Subroutine FLOW continued

```
C
C     ADD TRIBUTARY FLOW
      DO 50 M=1,NRIV
      NR=NRIV-M+1
      NT=NTRIB(NR)
      IF(NT.EQ.0)GO TO 50
      KU=KUP(NR)
      KD=KDOWN(NR)
      IDD=0
      KDD=KD
      DO 45 I=1,NRIV
   45 IF(KD.EQ.KUP(I))IDD=1
      IF(IDD.EQ.1)KDD=KD+1
      KU1=KU-1
      DO 40 K=KDD,KU1
      DO 40 J=1,NT
      KT=KTRIB(NR,J)
      IF(RD(K).LT.RDT(NR,J))TQ(K)=TQ(K)+TQ(KT)
   40 CONTINUE
   50 CONTINUE
C
      READ(I8,107) DT
      RETURN
  100 FORMAT(8F10.0)
  105 FORMAT(16I5)
  107 FORMAT(8F10.2)
```

Subroutine GEOM

```
      SUBROUTINE GEOM (K,WS)
C
C     THIS SUBROUTINE CALCULATES THE EXACT HYDRAULIC PROPERTIES OF
C     A CROSS SECTION, ONCE GIVEN THE CHANNEL GEOMETRY AND THE
C     WATER SURFACE ELEVATION.
C
      COMMON /SEC1/          WD(22)          , RD(100)          , TQ(125)          ,
     1        WSK(100)      , WE(100)        , ZMIN(100)        , ZOB(100)         ,
     2        A1(100)       , A2(100)        , A3(100)          , A4(100)          ,
     3        A5(100)       , A6(100)        , A7(100)          , A8(100)          ,
     4        A9(100)       , A10(100)       , B1(100)          , B2(100)          ,
     5        B3(100)       , B4(100)        , B5(100)          , B6(100)          ,
     6        B7(100)       , B8(100)        , B9(100)          , B10(100)         ,
     7        DA4(100)      , DA9(100)       , EDK(100)         , TAK(100)         ,
     8        TKK(100)      , ALPK(100)      , VK(100)          , WSMAX(100)       ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)       , Z(100,22)        , ZO(100,22)       ,
     1        DLOB(100)     , DROB(100)      , F(100,22)        , ND(100)          ,
     2        SUMDA(100)    , SMADA(100)     , SMZWS(100)       , IZMIN(100)       ,
     3        G(100)
      COMMON /UNITS/         IUNIT           , CORDS            , ZDIFM            ,
     1        GRAV          , VVAL           , FET              , CONV             ,
     2        DZMAX
      COMMON /INF/           NSEC            , NTIM             , DT               ,
     1        IORG          , CE             , CC               , PORM             ,
     2        STAGE         , ITIME          , NQI              , NCALL            ,
     3        ICALL(30,3)   , MST            , EPS
      COMMON /HYD/           V               , ED               , EW               ,
     1        ALP           , TK             , TA
C
      N = ND(K)
      NP = N - 1
      IFLAG = 0
      TA = 0.
      TK = 0.
      SUMWK = 0.
      SUMD1 = 0.
      SUMD2 = 0.
      SUMD3 = 0.
      DO 100 I = 1,NP
         WD(I) = 0.
  100 CONTINUE
C
C     ITERATE OVER EACH CROSS SECTION POINT
C
      DO 170 I = 2,N
C
C     CALCULATE DISTANCE AND MANNINGS N BETWEEN CROSS SECTION POINTS.
C
         XB = (X(K,I) - X(K,I - 1)) + 1.0E - 6
         FM = 0.5 * (F(K,I - 1) + F(K,I))
         IF (Z(K,I).GE.WS) GO TO 120
         IF (Z(K,I - 1).GE.WS) GO TO 110
C
C     CALCULATE AREA OF FLOW, WETTED PERIMETER, AND DEPTH.
C
         DA = WS - 0.5 * (Z(K,I - 1) + Z(K,I))
         A = XB * DA
         ZB = ABS(Z(K,I) - Z(K,I - 1))
         P = SQRT(XB * XB + ZB * ZB)
         GO TO 160
  110    ZB = WS - Z(K,I)
         XB = XB * ZB/(Z(K,I - 1) - Z(K,I))
         GO TO 150
  120    IF (Z(K,I - 1).GE.WS) GO TO 170
         IF (I.LT.IZMIN(K).AND.WS.LT.(ZOB(K) + .001)) GO TO 130
         ZB = WS - Z(K,I - 1)
         XB = XB * ZB/(Z(K,I) - Z(K,I - 1))
         IF (WS.LT.(ZOB(K) + .001)) IFLAG = 1
         GO TO 150
C
C     SET OVER BANK FLOWS TO ZERO IF WATER SURFACE IS NOT ABOVE
C     OVER BANK ELEVATION.
C
  130    TA = 0
         TK = 0.
         SUMWK = 0.
         SUMD1 = 0.
         SUMD2 = 0.
         SUMD3 = 0.
         IM1 = I - 1
         DO 140 II = 1,IM1
            WD(II) = 0.
  140    CONTINUE
         GO TO 170
  150    A = 0.5 * XB * ZB
         P = SQRT(XB * XB + ZB * ZB)
         DA = 0.5 * ZB
  160    R = A/P
         C = 1.486 * A * R *  * (2./3.)/FM
C
C     SUM FLOWS BETWEEN CROSS SECTION POINTS.
C
```

Subroutine GEOM continued

```
      TA = TA + A
      TK = TK + C
      SUMWK = SUMWK + C *  * 3./A *  * 2.
      SUMD1 = SUMD1 + DA *  * 1.6666 * A/FM
      SUMD2 = SUMD2 + DA *  * 0.6666 * A/FM
      SUMD3 = SUMD3 + DA *  * 0.6666 * A
      WD(I - 1) = C
      IF (IFLAG.EQ.1) GO TO 180
  170 CONTINUE
  180 ALP = SUMWK * TA *  * 2./TK *  * 3.
      ED = SUMD1/SUMD2
      EW = SUMD3/ED *  * 1.6666
      DO 190 I = 1,NP
      WD(I) = WD(I)/TK
  190 CONTINUE
C
      RETURN
      END
```

Subroutine HYDPR

```
      SUBROUTINE HYDPR (K,WS)
C
C     THIS SUBROUTINE CALCULATES THE HYDRAULIC PROPERTIES OF THE
C     (K)TH CROSS SECTION GIVEN THE WATER SURFACE ELEVATION (WS).
C
      COMMON /SEC1/           WD(22)          , RD(100)        , TQ(125)        ,
     1              WSK(100)     , WE(100)        , ZMIN(100)      , ZOB(100)       ,
     2              A1(100)      , A2(100)        , A3(100)        , A4(100)        ,
     3              A5(100)      , A6(100)        , A7(100)        , A8(100)        ,
     4              A9(100)      , A10(100)       , B1(100)        , B2(100)        ,
     5              B3(100)      , B4(100)        , B5(100)        , B6(100)        ,
     6              B7(100)      , B8(100)        , B9(100)        , B10(100)       ,
     7              DA4(100)     , DA9(100)       , EDK(100)       , TAK(100)       ,
     8              TKK(100)     , ALPK(100)      , VK(100)        , WSMAX(100)     ,
     9              IMAX(100)
      COMMON /HYD/            V               , ED             , EW             ,
     1              ALP          , TK             , TA
C
C      CALCULATE THE DEPTH OF FLOW
C
      DEPTH = WS - ZMIN(K)
C
C     IF THE WATER SURFACE IS ABOVE THE OVERBANK
C     USE THE OVERBANK EQUATIONS.
C
      IF (WS.GT.ZOB(K)) GO TO 100
C
C     CALCULATE EFFECTIVE WIDTH
C
      EW = A1(K) * DEPTH *  * B1(K)
C
C     CALCULATE EFFECTIVE DEPTH
C
      ED = A2(K) * DEPTH *  * B2(K)
C
C     CALCULATE AREA
C
      TA = A3(K) * DEPTH *  * B3(K)
C
C     CALCULATE THE CONVEYANCE
C
      TK = A4(K) * DEPTH *  * B4(K)
C
C     CALCULATE ALPHA
C
      ALP = A5(K) * DEPTH *  * B5(K)
      IF (ALP.GT.1.5) ALP = 1.5
      IF (ALP.LT.1.15) ALP = 1.15
C
C     CALCULATE THE VELOCITY
C
      V = TQ(K)/TA
      RETURN
C
C     CALCULATE EFFECTIVE WIDTH
C
  100 EW = A6(K) * DEPTH *  * B6(K)
C
C     CALCULATE EFFECTIVE DEPTH
C
      ED = A7(K) * DEPTH *  * B7(K)
C
C     CALCULATE AREA
C
      TA = A8(K) * DEPTH *  * B8(K)
C
C     CALCULATE THE CONVEYANCE
C
      TK = A9(K) * DEPTH *  * B9(K)
C
C     CALCULATE ALPHA
C
      ALP = A10(K) * DEPTH *  * B10(K)
      IF (ALP.GT.1.5) ALP = 1.5
      IF (ALP.LT.1.15) ALP = 1.15
C
C     CALCULATE THE VELOCITY
C
      V = TQ(K)/TA
C
      RETURN
      END
```

Subroutine IN1

```
      SUBROUTINE IN1
C
C     THIS SUBROUTINE READS IN THE SEDIMENT AND GEOMETRY DATA.
C
      COMMON /SEC1/           WD(22)          , RD(100)        , TQ(125)        ,
     1         WSR(100)     , WE(100)         , ZMIN(100)      , ZOB(100)       ,
     2         A1(100)      , A2(100)         , A3(100)        , A4(100)        ,
     3         A5(100)      , A6(100)         , A7(100)        , A8(100)        ,
     4         A9(100)      , A10(100)        , B1(100)        , B2(100)        ,
     5         B3(100)      , B4(100)         , B5(100)        , B6(100)        ,
     6         B7(100)      , B8(100)         , B9(100)        , B10(100)       ,
     7         OA4(100)     , OA9(100)        , EDK(100)       , IAK(100)       ,
     8         IKK(100)     , ALPK(100)       , VK(100)        , WSMAX(100)     ,
     9         IMAX(100)
      COMMON /SEC2/           X(100,22)       , Z(100,22)      , ZO(100,22)     ,
     1         DLOB(100)    , DROB(100)       , F(100,22)      , ND(100)        ,
     2         SUMDA(100)   , SMADA(100)      , SMZWS(100)     , IZMIN(100)     ,
     3         G(100)
      COMMON /INF/            NSEC            , NTIM           , DT             ,
     1         IDRG         , CE              , CC             , PORM           ,
     2         STAGE        , ITIME           , NQI            , NCALL          ,
     3         ICALL(30,3)  , MST             , EPS
      COMMON /PRT/            IPRNT(8)        , I5             , I6             ,
     1         I7           , I8              , I9             , I10
      COMMON /RIV/            NRIV            , KUP(10)        , KDOWN(10)      ,
     1         NTRIB(10)    , ICONT(10)       , JSL(10,5)      , AX(10)         ,
     2         BX(10)       , CX(10)          , RDT(10,5)      , ITRIB(10,5)    ,
     3         KTRIB(10,5)  , AT(10,5)        , BT(10,5)       , KCONT(10)      ,
     4         IROUT(10)    , SB(10)          , AN(10)         , BN(10)
      COMMON /UNITS/          IUNIT           , CORDS          , ZDIFM          ,
     1         GRAV         , VVAL            , FET            , CONV           ,
     2         DZMAX
      DIMENSION               TITLE(20)
C
C     READ TITLE
C
      READ (I5,260) (TITLE(M2),M2 = 1,20)
C
C     READ THE PRINT CONTROL.
C
      READ (I5,270) (IPRNT(M1),M1 = 1,8)
C
C     READ IN THE MAXIMUN NUMBER OF ITERATIONS FOR THE BACKWATER
C     CURVE, (MST), THE MAXIMUN ERROR IN TOTAL HEAD, (EPS),
C     THE SEDIMENT DEPOSIT POROSITY, (PORM), THE COEFFICIENTS OF
C     EXPANSION AND CONTRACTION LOSSES, (CE,CC), AND THE UNIT SYSTEM
C     FLAG, (IUNIT).
C
      READ (I5,280) MST,EPS,PORM,CE,CC,IUNIT
C
C     READ IN THE NUMBER OF CROSS SECTIONS, (NSEC), THE NUMBER
C     OF TIME PERIODS,(NTIM), THE NUMBER OF RIVER SEGMENTS,
C     (NRIV), THE NUMBER OF INPUT DISCHARGES, (NQI), AND THE
C     NUMBER OF SUBROUTINE CALLS, (NCALL).
C
      READ (I5,290) NSEC,NTIM,NRIV,NQI,NCALL
C
C     READ IN THE SEQUENCE OF THE SUBROUTINE CALLS, (ICALL(NC,NN)).
C
      DO 100 NC = 1,NCALL
         READ (I5,290) (ICALL(NC,NN),NN = 1,3)
  100 CONTINUE
C
C     ITERATE OVER EACH RIVER SEGMENT.
C
      DO 120 NR = 1,NRIV
C
C     FOR EACH RIVER SEGMENT, READ IN THE NUMBER OF THE DOWNSTREAM
C     CROSS SECTION, (KDOWN(NR)), THE NUMBER OF THE UPSTREAM
C     CROSS SECTION, (KUP(NR)), THE NUMBER OF TRIBUTARIES,
C     (NTRIB(NR)), THE TYPE OF DOWNSTREAM CONTROL, (ICONT(NR)),
C     THE NUMBER OF THE DOWNSTREAM WATER SURFACE CONTROL CROSS SECTION,
C     (KCONT(NR)), THE COEFFICIENTS OF THE DOWNSTREAM STAGE DISCHARGE
C     RELATIONSHIP, (AX(NR),BX(NR),CX(NR)), THE COEFFICIENTS OF THE
C     CONVAYENCE EQUATION, (AN(NR),BN(NR)), AND THE NORMAL DEPTH
C     SLOPE, (SB(NR)).
C
         READ (I5,300) KDOWN(NR),KUP(NR),NTRIB(NR),ICONT(NR),KCONT(NR),I
     1   ROUT(NR),AX(NR),BX(NR),CX(NR),AN(NR),BN(NR),SB(NR)
         NT = NTRIB(NR)
C
C     FOR EACH TRIBUTARY READ IN THE MAINSTEM RIVER DISTANCE
C     OF THE CONFLUENCE, (RDT(NR,J)), THE TYPE OF TRIBUTARY,
C     (ITRIB(NR,J)), THE NUMBER OF THE DISCHARGE CROSS SECTION
C     FOR THE TRIBUTARY, (KTRIB(NR,J)), AND THE COEFFICIENTS OF THE
C     TRIBUTARYS SEDIMENT RATING CURVE, (AT(NR,J),BT(NR,J)).
C
         IF (NT.EQ.0) GO TO 120
         DO 110 J = 1,NT
           READ (I5,310) RDT(NR,J),ITRIB(NR,J),KTRIB(NR,J),AT(NR,J),BT(
     1     NR,J)
  110    CONTINUE
```

Subroutine IN1 continued

```
  120 CONTINUE
C
C     FOR EACH CROSS SECTION READ IN THE NUMBER OF SECTION POINTS,
C     (ND(K)), AND THE RIVER DISTANCE, (RD(K)).
C
      DO 160 K = 1,NSEC
         READ (I7,320) ND(K),RD(K)
         M = ND(K)
C
C     FOR EACH SECTION POINT READ IN THE HORIZONTAL DISTANCE,
C     (X(K,L)), AND THE ELEVATION, (Z(K,L)).
C
         READ (I7,330) (X(K,L),Z(K,L),L = 1,M)
C
C     FOR EACH CROSS SECTION READ IN THE DISTANCE OF THE RIGHT AND LEFT
C     OVERBANKS, (DROB,DLOB), THE MANINGS N FOR THE RIGHT
C     OVERBANK, MAIN CHANNEL, AND LEFT OVERBANK, (FROB,FMC,FLOB).
C     AND THE OVERBANK ELEVATION, (ZOB(K)).
C
         READ (I7,340) DROB(K),DLOB(K),FROB,FMC,FLOB,ZOB(K)
         DO 150 L = 1,M
            IF (X(K,L).GT.DROB(K)) GO TO 130
            F(K,L) = FROB
            GO TO 150
  130       IF (X(K,L).GE.DLOB(K)) GO TO 140
            F(K,L) = FMC
            GO TO 150
  140       F(K,L) = FLOB
  150    CONTINUE
  160 CONTINUE
C
C     PRINT OUT INPUT DATA
C
      IF (IPRNT(1).EQ.1) GO TO 170
      IF (IPRNT(2).EQ.1) GO TO 170
      IF (IPRNT(3).EQ.1) GO TO 170
      IF (IPRNT(4).EQ.1) GO TO 170
      IF (IPRNT(6).EQ.1) GO TO 170
      GO TO 180
  170 WRITE (I6,350)
      WRITE (I6,360) (TITLE(M2),M2 = 1,20)
  180 CONTINUE
      IF (IPRNT(1).NE.1) GO TO 240
      WRITE (I6,370) MST,EPS,PORM,CC,CE,IUNIT
      WRITE (I6,380) NSEC,NTIM,NRIV,NQI,NCALL
      WRITE (I6,390)
      DO 190 NC = 1,NCALL
         WRITE (I6,400) NC,(ICALL(NC,NN),NN = 1,3)
  190 CONTINUE
      DO 210 NR = 1,NRIV
         WRITE (I6,410) NR,KDOWN(NR),KUP(NR),NTRIB(NR),ICONT(NR),KCONT(N
     1   R),IROUT(NR),AX(NR),BX(NR),CX(NR),AN(NR),BN(NR),SB(NR)
         NT = NTRIB(NR)
         IF (NT.EQ.0) GO TO 210
         DO 200 J = 1,NT
            WRITE (I6,420) J,RDT(NR,J),ITRIB(NR,J),KTRIB(NR,J),AT(NR,J),
     1      BT(NR,J)
  200    CONTINUE
  210 CONTINUE
      DO 230 K = 1,NSEC
         WRITE (I6,430) K,ND(K),RD(K),ZOB(K)
         WRITE (I6,440)
         M = ND(K)
         DO 220 L = 1,M
            WRITE (I6,450) L,X(K,L),Z(K,L),F(K,L)
  220    CONTINUE
  230 CONTINUE
  240 CONTINUE
      IF (IPRNT(2).NE.1) GO TO 250
      WRITE (I6,460)
      WRITE (I6,470)
C
  250 RETURN
C
C
C
  260 FORMAT (20A4)
  270 FORMAT (8I2)
  280 FORMAT (I5,4F10.5,I5)
  290 FORMAT (5I5)
  300 FORMAT (6I5,5F8.4,F8.6)
  310 FORMAT (F10.2,2I5,2E10.2)
  320 FORMAT (2X,I3,F7.2)
  330 FORMAT ((8X,6(F6.0,F6.1)))
  340 FORMAT (6F10.4)
  350 FORMAT (1H1,/,10X,13HK U W A S E R,/,10X,25HKNOWN DISCHARGE SEDIME
     1NT ,7HROUTING,/,10X,35HDEVELOPED BY G.O. BROWN AND R.M. LI,/,10X,3
     27HAT COLORADO STATE UNIVERSITY, FOR THE,/,10X,48HU.S. ARMY CORPS O
```

Subroutine IN1 continued

```
     3F ENGINEERS, VICKSBURG DISTRICT)
 360 FORMAT (///,10X,82(1H*),/,10X,1H*,80X,1H*,/,10X,1H*,20A4,1H*,/,10X
     1,1H*,80X,1H*,/,10X,82(1H*),///)
 370 FORMAT (10X,47HMAXIMUM NUMBER OF ITERATIONS FOR CALCULATIONS, ,6HM
     1ST = ,I5,,/,10X,42HACCURACY OF BACKWATER CALCULATIONS, EPS = ,F10.
     25,,/,10X,38HPOROSITY OF SEDIMENT DEPOSITS, PORM = ,F10.5,,/,10X, 5
     33HCOEFFICIENT OF CONTRATION VELOCITY HEAD LOSSES, CC = ,F10.5,/,10
     4X, 52HCOEFFICIENT OF EXPANSION VELOCITY HEAD LOSSES, CE = ,F10.5/,
     510X, 26HUNIT SYSTEM FLAG, IUNIT = ,I5,//)
 380 FORMAT (10X,31HTHE NUMBER OF RIVER SECTIONS = ,I5,/,10X,29HTHE NUM
     1BER OF TIME PERIODS = ,I5,/10X,28HTHE NUMBER OF RIVER SEGMENTS,3H
     2= ,I5,/,10X,33HTHE NUMBER OF INPUT DISCHARGES = ,I5,/,10X,33HTHE N
     3UMBER OF SUBROUTINE CALLS = ,I5)
 390 FORMAT (/,10X,22HNCALL  ICALL (1 TO 3),)
 400 FORMAT (8X,4(2X,I5))
 410 FORMAT (//,10X,14HRIVER SEGMENT ,I5,/,10X,34HDOWNSTREAM CROSS SECT
     1ION NUMBER = ,I5,/,10X,32HUPSTREAM CROSS SECTION NUMBER = ,I5,/,10
     2X,24HNUMBER OF TRIBUTARIES = ,I5,/,10X,39HTYPE OF WATER SURFACE CO
     3NTROL, ICONT = ,I5,/,10X,35HNUMBER OF CONTROL SECTION, KCONT = ,I5
     4,/,10X,44HTYPE OF DOWNSTRAM SEDIMENT ROUTING, IROUT = ,I5,/,10X,45
     5HCOEFFICIENTS OF STAGE DISCHARGE RELATIONSHIP,,/,13X,5HAX = ,F8.4,
     6/,13X,5HBX = ,F8.4,/,13X,5HCX = ,F8.4,/,10X,40HCOEFFICIENTS OF MAN
     7NINGS N RELATIONSHIP,,/,13X,5HAN = ,F8.4,/,13X,5HBN = ,F8.4,/,10X,
     8 25HNORMAL DEPTH SLOPE, SB = ,F8.6)
 420 FORMAT (/,15X,10HTRIBUTARY ,I5,/,15X,17HRIVER DISTANCE = ,F7.2,/,1
     15X,27HTYPE OF TRIBUTARY, ITRIB = ,I5,/,15X,47HNUMBER OF TRIBUTARY
     2DISCHARGE SECTION, KTRIB = ,I5,/,15X,47HCOEFFICIENTS OF TRIBUTARY
     3SEDIMENT RELATIONP    ,/,18X,5HAT = ,E10.3,/,18X,5HBT = ,F10.2)
 430 FORMAT (///,10X,15HSECTION NUMBER ,I4,/,10X,40HTHE NUMBER OF CROSS
     1 SECTION POINTS IS = ,I2,/,10X,24HTHE RIVER DISTANCE IS = ,F10.2,/
     2,10X,25HTHE OVERBANK ELEVATION = ,F10.2)
 440 FORMAT (/,10X,48HPOINT      HORIZONTAL      ELEVATION       N VALUE,
     1/)
 450 FORMAT (10X,I5,3(5X,F10.4))
 460 FORMAT (1H1,/,4H NO.,4X,15HEFFECTIVE WIDTH,6X,1HI,4X,15HEFFECTIVE
     1DEPTH,5X,1HI,6X,10HTOTAL AREA,8X,1HI,4X,16HTOTAL CONVEYANCE,4X,1H
     2,8X,5HALPHA,11X,1HI/29X,1HI,4(24X,1HI))
 470 FORMAT (5X,5(4X,1HA,4X,1HB,2X,13HCO COEF ERR I)/29X,1HI,4(24X,1HI)
     1)
      END
```

Subroutine LSQ

```
      SUBROUTINE LSQ (N,XX,Y,EA,B,RC,SBAR)
C
C     THIS SUBROUTINE DERIVES THE COEFFICIENTS OF THE HYDRAULIC
C     POWER FUNCTIONS, BY USING A LEAST SQUARES REGRESSION.
C
      DIMENSION          XX(10)      , Y(10)        , YB(10)
C
      SUMX = 0.
      SUMXX = 0.
      SUMY = 0.
      SUMXY = 0.
      SUMA = 0.
      SUMB = 0.
      SUMC = 0.
      SUMD = 0.
      DO 100 I = 1,N
         SUMX = SUMX + XX(I)
         SUMY = SUMY + Y(I)
         SUMXX = SUMXX + XX(I) * XX(I)
         SUMXY = SUMXY + XX(I) * Y(I)
  100 CONTINUE
      FX = SUMX/FLOAT(N)
      FY = SUMY/FLOAT(N)
C
C     DERIVE THE EQUATION.
C
      B = (SUMXY - FLOAT(N) * FX * FY)/(SUMXX - FLOAT(N) * FX * FX)
      A = FY - B * FX
C
C     RAISE E TO THE (A) POWER.  THE VALUE, (EA), WILL BE USED IN
C     THE POWER FUNCTIONS.
C
      EA = EXP(A)
C
C     CALCULATE THE COEFFICIENT OF CORRELATION.
C
      DO 110 I = 1,N
         SUMA = SUMA + (XX(I) - FX) * (Y(I) - FY)
         SUMB = SUMB + (XX(I) - FX) *  * 2
         YB(I) = A + B * XX(I)
         SUMC = SUMC + (Y(I) - FY) *  * 2
  110 CONTINUE
      RC = SUMA/SQRT(SUMB * SUMC)
C
C     CALCULATE THE STANDARD ERROR OF ESTIMATE.
C
      DO 120 I = 1,N
         SUMD = SUMD + (Y(I) - YB(I)) *  * 2
  120 CONTINUE
      SBAR = SQRT(SUMD/(FLOAT(N) - 2.))
C
      RETURN
      END
```

Subroutine LSQF

```
      SUBROUTINE LSQF (N,XX,Y,EA,B,RC,SBAR,XO,YO)
C
C     THIS SUBROUTINE DERIVES THE COEFFICIENTS OF THE HYDRAULIC
C     POWER FUNCTIONS, FOR OVERBANK FLOW, BY USING A LEAST
C     SQUARES REGRESSION FORCED THROUGH THE POINT (XO,YO).
C
      DIMENSION            XX(10)        , Y(10)         , YB(10)
C
      SUMX = 0.
      SUMXX = 0.
      SUMY = 0.
      SUMXY = 0.
      SUMA = 0.
      SUMB = 0.
      SUMC = 0.
      SUMD = 0.
      DO 100 I = 1,N
         XP = XX(I) - XO
         YP = Y(I) - YO
         SUMX = SUMX + XX(I)
         SUMY = SUMY + Y(I)
         SUMXX = SUMXX + XP * XP
         SUMXY = SUMXY + XP * YP
  100 CONTINUE
      FX = SUMX/FLOAT(N)
      FY = SUMY/FLOAT(N)
C
C     DERIVE THE EQUATION.
C
      B = SUMXY/SUMXX
      A = YO - B * XO
C
C     RAISE E TO THE (A) POWER.  THE VALUE, (EA), WILL BE USED IN
C     THE POWER FUNCTIONS.
C
      EA = EXP(A)
C
C     CALCULATE THE COEFFICIENT OF CORRELATION.
C
      DO 110 I = 1,N
         SUMA = SUMA + (XX(I) - FX) * (Y(I) - FY)
         SUMB = SUMB + (XX(I) - FX) *  * 2
         YB(I) = A + B * XX(I)
         SUMC = SUMC + (Y(I) - FY) *  * 2
  110 CONTINUE
      RC = SUMA/SQRT(SUMB * SUMC)
C
C     CALCULATE THE STANDARD ERROR OF ESTIMATE.
C
      DO 120 I = 1,N
         SUMD = SUMD + (Y(I) - YB(I)) *  * 2
  120 CONTINUE
      SBAR = SQRT(SUMD/(FLOAT(N) - 1.))
C
      RETURN
      END
```

Subroutine NVAL

```
      SUBROUTINE NVAL (NR)
C
C     THIS SUBROUTINE CALCULATES THE COEFFICIENT OF THE
C     CONVAYENCE EQUATION FOR THE CURRENT DISCHARGE.
C
C     THIS ALLOWS MANNING"S N TO BE A FUNCTION OF DISCHARGE.
C
      COMMON /SEC1/         WD(22)       , RD(100)      , TQ(125)       ,
     1       WSK(100)     , WE(100)      , ZMIN(100)    , ZOB(100)      ,
     2       A1(100)      , A2(100)      , A3(100)      , A4(100)       ,
     3       A5(100)      , A6(100)      , A7(100)      , A8(100)       ,
     4       A9(100)      , A10(100)     , B1(100)      , B2(100)       ,
     5       B3(100)      , B4(100)      , B5(100)      , B6(100)       ,
     6       B7(100)      , B8(100)      , B9(100)      , B10(100)      ,
     7       OA4(100)     , OA9(100)     , EDK(100)     , TAK(100)      ,
     8       TKK(100)     , ALPK(100)    , VK(100)      , WSMAX(100)    ,
     9       IMAX(100)
      COMMON /RIV/          NRIV         , KUP(10)      , KDOWN(10)     ,
     1       NTRIB(10)    , ICONT(10)    , QSC(10,5)    , AX(10)        ,
     2       BX(10)       , CX(10)       , RDT(10,5)    , ITRIB(10,5)   ,
     3       KTRIB(10,5)  , AT(10,5)     , BT(10,5)     , KCONT(10)     ,
     4       IROUT(10)    , SB(10)       , AN(10)       , BN(10)
      DATA RNMAX,RNMIN/1.4,0.67/
C
      KD = KDOWN(NR)
      KU = KUP(NR)
C
C     ITERATE OVER EACH CROSS SECTION IN THE REACH
C
      DO 100 K = KD,KU
         IF (TQ(K).EQ.0.0) GO TO 100
C
C     CALCULATE CORRECTION FACTOR
C
         RN = AN(NR) * ABS(TQ(K)) ** BN(NR)
C
C     TEST FOR VALUE WITHIN LIMITS
C
         IF (RN.GT.RNMAX) RN = RNMAX
         IF (RN.LT.RNMIN) RN = RNMIN
         A4(K) = OA4(K)/RN
         A9(K) = OA9(K)/RN
  100 CONTINUE
C
      RETURN
      END
```

Subroutine OUT1

```
      SUBROUTINE OUT1
C
C     THIS SUBROUTINE OUTPUTS THE VARIOUS RESULTS OF THE SIMULATION
C     MODEL.
C
      COMMON /SEC1/          WD(22)        , RD(100)       , TQ(125)       ,
     1        WSK(100)     , WE(100)       , ZMIN(100)     , ZOB(100)      ,
     2        A1(100)      , A2(100)       , A3(100)       , A4(100)       ,
     3        A5(100)      , A6(100)       , A7(100)       , A8(100)       ,
     4        A9(100)      , A10(100)      , B1(100)       , B2(100)       ,
     5        B3(100)      , B4(100)       , B5(100)       , B6(100)       ,
     6        B7(100)      , B8(100)       , B9(100)       , B10(100)      ,
     7        OA4(100)     , OA9(100)      , EDK(100)      , TAK(100)      ,
     8        TKK(100)     , ALPK(100)     , VK(100)       , WSMAX(100)    ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)     , Z(100,22)     , ZO(100,22)    ,
     1        DLOB(100)    , DROB(100)     , F(100,22)     , ND(100)       ,
     2        SUMDA(100)   , SMADA(100)    , SMZWS(100)    , IZMIN(100)    ,
     3        G(100)
      COMMON /INF/           NSEC          , NTIM          , DT            ,
     1        IORG         , CE            , CC            , PORM          ,
     2        STAGE        , ITIME         , NQI           , NCALL         ,
     3        ICALL(30,3)  , MST           , EPS
      COMMON /RIV/           NRIV          , KUP(10)       , KDOWN(10)     ,
     1        NTRIB(10)    , ICONT(10)     , QSL(10,5)     , AX(10)        ,
     2        BX(10)       , CX(10)        , RDT(10,5)     , ITRIB(10,5)   ,
     3        KTRIB(10,5)  , AT(10,5)      , BT(10,5)      , KCONT(10)     ,
     4        IROUT(10)    , SB(10)        , AN(10)        , BN(10)
      COMMON /PRT/           IPRNT(8)      , I5            , I6            ,
     1        I7           , I8            , I9            , I10
      DIMENSION              DZF(22)
C
C     PRINT CROSS SECTION NUMBER,EFFECTIVE WIDTH,EFFECTIVE DEPTH,TOTAL
C     AREA,TOTAL CONVEYANCE,ALPHA,VELOCITY,WATER SURFACE ELEVATION,
C     SEDIMENT TRANSPORT,DISCHARGE AND MINIMUM BED ELEVATION FOR EACH
C     TIME PERIOD.
C
      IF (IPRNT(6).NE.1) GO TO 100
      WRITE (I6,200) ITIME,DT
      WRITE (I6,210) ((K,WE(K),EDK(K),TAK(K),TKK(K),ALPK(K),VK(K),WSK(K)
     1,G(K),TQ(K),ZMIN(K),K = 1,NSEC))
  100 IF (ITIME.NE.NTIM) GO TO 150
C
C     PRINT MAXIMUM WATER SURFACE ELEVATION AND THE TIME PERIOD OF
C     OCCURANCE FOR EACH CROSS SECTION.
C
      IF (IPRNT(4).NE.1) GO TO 110
      WRITE (I6,220)
      WRITE (I6,230) (K,WSMAX(K),IMAX(K),K = 1,NSEC)
C
C     PRINT MINIMUM BED ELEVATION FOR EACH CROSS SECTION AT THE END OF
C     THE SIMULATION.
C
  110 IF (IPRNT(5).NE.1) GO TO 120
      WRITE (I6,240)
      WRITE (I6,250) (K,ZMIN(K),K = 1,NSEC)
  120 CONTINUE
C
C     PRINT OUT THE BED ELEVATION AND THE CHANGE IN BED ELEVATION
C     AT EACH POINT.

C
      IF (IPRNT(3).NE.1) GO TO 150
      WRITE (I6,190)
      DO 140 K = 1,NSEC
         N = ND(K)
         DO 130 L = 1,N
            DZF(L) = Z(K,L) - ZO(K,L)
  130    CONTINUE
         WRITE (I6,170) K
         WRITE (I6,180) (L,X(K,L),Z(K,L),DZF(L),L = 1,N)
  140 CONTINUE
C
C     BINARY OUTPUT.
C
  150 IF (IPRNT(7).NE.1) RETURN
C
C     PRINT CROSS SECTION NUMBER,EFFECTIVE WIDTH,EFFECTIVE DEPTH,TOTAL
C     AREA,TOTAL CONVEYANCE,ALPHA,VELOCITY,WATER SURFACE ELEVATION,
C     SEDIMENT TRANSPORT,DISCHARGE AND MINIMUM BED ELEVATION FOR EACH
C     TIME PERIOD.
C
      WRITE (I10) ((WE(K),EDK(K),TAK(K),TKK(K),ALPK(K),VK(K),WSK(K),G(K)
     1,ZMIN(K),K = 1,NSEC),(TQ(KI),KI = 1,NQI),((QSL(N,J),J = 1,5),N = 1
     2,NRIV))
C
C     DETERMINE IF THE CURRENT TIME PERIOD IS THE END OF A YEAR
C
      RI = FLOAT(ITIME)
      RI = RI/52.18
      RI = RI - AINT(RI)
      IF (RI.GT.0.9904.OR.RI.LT.0.00958) GO TO 160
      RETURN
```

Subroutine OUT1 continued

```
C
C     PRINT OUT THE BED ELEVATION AT EACH POINT
C
  160 CONTINUE
      WRITE (I9) ((Z(K,L),K = 1,NSEC),L = 1,22)
      RETURN
C
C
C
  170 FORMAT (//,20X,17HCROSS SECTION NO.,I5,/,20X,17HPOINT  HORIZONTAL,
     124H  ELEVATION  DELTA ELEV.,/)
  180 FORMAT (21X,I2,5X,F6.0,5X,F6.1,5X,F6.1)
  190 FORMAT (1H1,19X,46HF I N A L  B E D  E L E V A T I O N S,  A N D,/
     1,20X,47HT O T A L  C H A N G E  A T  E A C H  P O I N T)
  200 FORMAT (//,10X,47HC R O S S  S E C T I O N  P R O P E R T I E S,
     1/,10X,4HTIME,I5,F10.2,/,12X,108HSECTION  EFFECTIVE EFFECTIVE   TOT
     2AL      TOTAL      ALPHA    VELOCITY     WATER   SEDIMENT     FLOW
     3 THALWEG,/,23X,37HWIDTH      DEPTH      AREA   CONVEYANCE,22X,17HSUR
     4FACE TRANSPORT,15X,9HELEVATION,/)
  210 FORMAT (13X,I3,3X,2F10.1,2F10.0,2F10.4,F10.2,F10.6,F10.2,F10.2)
  220 FORMAT (1H1,8X,3HMAX,7X,4HTIME,/,9X,5HWATER,5X,2HOF,/,8H SECTION,1
     1X,9HELEVATION,1X,3HMAX,/)
  230 FORMAT (1H ,I4,F10.2,2X,I4)
  240 FORMAT (1H1,8X,3HMIN,/,9X,3HBED,/,18H SECTION ELEVATION,/)
  250 FORMAT (1H ,I4,3X,F10.2)
      END
```

Subroutine RIVDS

```
      SUBROUTINE RIVDS (NR,DIS)
C
C     THIS SUBROUTINE CONVERTS THE RIVER DISTANCE FROM MILES TO FEET,
C     OR FROM KILOMETERS TO METERS.
C
C     IT MAY BE USED TO CORRECT FOR CUTOFFS OR CHANGES IN RIVER
C     ALIGNMENT BY ADDING SPECIAL LOGIC.
C
      COMMON /UNITS/           IUNIT         , CORDS         , ZDIFM         ,
     1          GRAV         , VVAL          , FET           , CONV          ,
     2          DZMAX
C
      DIS = DIS * CORDS
C
      RETURN
      END
```

Subroutine SED

```
      SUBROUTINE SED
C
C     THIS SUBROUTINE CALULATES SEDIMENT TRANSPORT USING THE
C     GENERALIZED FORMULA DEVELOPED FOR THE YAZOO RIVER.
C
      COMMON /SEC1/          WD(22)        , RD(100)       , TQ(125)       ,
     1        WSK(100)     , WE(100)       , ZMIN(100)     , ZOB(100)      ,
     2        A1(100)      , A2(100)       , A3(100)       , A4(100)       ,
     3        A5(100)      , A6(100)       , A7(100)       , A8(100)       ,
     4        A9(100)      , A10(100)      , B1(100)       , B2(100)       ,
     5        B3(100)      , B4(100)       , B5(100)       , B6(100)       ,
     6        B7(100)      , B8(100)       , B9(100)       , B10(100)      ,
     7        OA4(100)     , OA9(100)      , EDK(100)      , IAK(100)      ,
     8        TKK(100)     , ALPK(100)     , VK(100)       , WSMAX(100)    ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)     , Z(100,22)     , Z0(100,22)    ,
     1        DLOB(100)    , DROB(100)     , F(100,22)     , ND(100)       ,
     2        SUMDA(100)   , SMADA(100)    , SMZWS(100)    , IZMIN(100)    ,
     3        G(100)
      COMMON /RIV/           NRIV          , KUP(10)       , KDOWN(10)     ,
     1        NTRIB(10)    , ICONT(10)     , QSL(10,5)     , AX(10)        ,
     2        BX(10)       , CX(10)        , RDT(10,5)     , ITRIB(10,5)   ,
     3        KTRIB(10,5)  , AT(10,5)      , BT(10,5)      , KCONT(10)     ,
     4        IROUT(10)    , SB(10)        , AN(10)        , BN(10)
      COMMON /INF/           NSEC          , NTIM          , DT            ,
     1        IORG         , CE            , CC            , PORM          ,
     2        STAGE        , ITIME         , NQI           , NCALL         ,
     3        ICALL(30,3)  , MST           , EPS
C
C     ITERATE OVER EACH RIVER REACH
C
      DO 120 NR = 1,NRIV
         KU = KUP(NR)
         KD = KDOWN(NR)
C
C     ITERATE OVER EACH CROSS SECTION IN THE REACH
C
         DO 110 K = KD,KU
            IF (TQ(K).EQ.0.0) GO TO 100
C
C     CALCLATE THE SEDIMENT TRANSPORT FOR THE CROSS SECTION
C
            G(K) = ABS(VK(K)) *  * 3.16 * EDK(K) *  * 0.96 * WE(K) * 4.4
     1      8E - 06
            IF (TQ(K).LT.0.0) G(K) =  - 1. * G(K)
            GO TO 110
  100       G(K) = 0.
  110    CONTINUE
  120 CONTINUE
C
      RETURN
      END
```

Subroutine SPLIT

```
      SUBROUTINE SPLIT (NR1,NR2,NR3,NR4,IFLAG,P,ERROR)
C
C     THIS SUBROUTINE IS USED IN DIVIDED FLOW PROBLEMS TO SPLIT THE
C     DISCHARGE BETWEEN TWO CHANNELS.
C
      COMMON /SEC1/
     1                      WD(22)       , RD(110)       ,
     2             TQ(200)      , WSK(110)     , WE(110)       , ZMIN(110)      ,
     3             ZOB(110)     ,
     4                            A1(110)      , A2(110)       , A3(110)        ,
     5             A4(110)      , A5(110)      , A6(110)       , A7(110)        ,
     6             A8(110)      , A9(110)      , A10(110)      , B1(110)        ,
     7             B2(110)      , B3(110)      , B4(110)       , B5(110)        ,
     8             B6(110)      , B7(110)      , B8(110)       , B9(110)        ,
     9             B10(110)     , OA4(110)     , OA9(110)      , EDK(110)       ,
     0             TAK(110)     , TKK(110)     , ALPK(110)     , VK(110)        ,
     1                            WSMAX(110)   , IMAX(110)
      COMMON /RIV/                NRIV         , KUP(10)       , KDOWN(10)      ,
     1             NTRIB(10)    , ICONT(10)    , GC(10)        , QSL(10,10)     ,
     2             AX(10)       , BX(10)       , CX(10)        , RDT(10,10)     ,
     3             ITRIB(10,10), KTRIB(10,10), AT(10,10)       , BT(10,10)      ,
     4             KCONT(10)    , IROUT(8)     , SB(10)        , AN(10)         ,
     5             BN(10)
      COMMON /PRT/                IPRNT(8)     , I5            , I6             ,
     1             I7           , I8           , I9            , I10
      COMMON /HYD/                V            , ED            , EW             ,
     1             ALP          , TK           , TA
      COMMON/TRI/EPS,MST
      KD1 = KDOWN(NR1)
      KU1 = KUP(NR1)
      KD2=KDOWN(NR2)
      KU2=KUP(NR2)
      KUM1=KU1-1
      KUM2=KU2-1
      NT1=NTRIB(NR1)
      NT2=NTRIB(NR2)
C
C     CHECK THE UPSTREAM DISCHRGES OF NR1 AND NR2 EQUAL OR NOT
      IF(TQ(KU1).EQ.TQ(KU2)) GO TO 310
      PRINT 121,NR2,NR1
      TQ(KU2)=TQ(KU1)
C
C     CHECK IF THE USER COUNTS REACH NR1 AS THE TRIBUTARIES OF
C     REACH NR2 AND VISE VERSA
      IF(NT1.LT.2.OR.NT2.LT.2) PRINT 131,NR1,NR2,NR1
C
  310 QTP1=TQ(KU1)*P
      QTP2=TQ(KU1)*(1-P)
      NT11=NT1-1
      NT21=NT2-1
C
C     CALCULATE THE DISCHARGE AT EACH SECTION OF REACH NR1
      DO 111 K=KD1,KUM1
      TQ(K)=QTP1
      IF(NT11.LT.2)GO TO 111
      DO 101 J=2,NT11
      KT=KTRIB(NR1,J)
  101 IF(RD(K).LT.RDT(NR1,J))TQ(K)=TQ(K)+TQ(KT)
  111 CONTINUE
C
C     CALCULATE THE DISCHARGE AT EACH SECTION OF REACH NR2
      DO 222 K=KD2,KUM2
      TQ(K)=QTP2
      QTRIB2=0.
      IF(NT21.LT.2)GO TO 222
      DO 202 J=2,NT21
      KT=KTRIB(NR2,J)
      IF(K.EQ.KD2)QTRIB2=QTRIB2+TQ(KT)
  202 IF(RD(K).LT.RDT(NR2,J))TQ(K)=TQ(K)+TQ(KT)
  222 CONTINUE
```

Subroutine SPLIT continued

```
C
C     CORRECT DOWNSTREAM DISCHARGES
      TQ(KD1)=TQ(KD1)+QTRIB2+QTP2
      TQ(KD2)=TQ(KD1)
C
C     CALCULATE THE WATER PROFILES IN BOTH REACHES.
      CALL SUBPF (NR1)                                                  SPL 0390
      CALL SUBPF (NR2)                                                  SPL 0400
C
C     COMPUTE THE ERROR IN THE UPSTREAM WATER SURFACE ELEVATION OF
C     BOTH REACHES.
      ERROR = WSK(KU1) - WSK(KU2)
C
C     RESET UPSTERAM WATER SURFACE ELEVATION OF REACH NR2 EQUAL TO THAT
C     OF NR1, IF THE CONVERGENCE CRITERIA HAS BEEN SATISFIED.
      IF(ABS(ERROR).GT.EPS)GO TO 320
      IF(WSK(KU1).LT.WSK(KUM2))GO TO 315
      WSK(KU2)=WSK(KU1)
      TAK(KU2)=TAK(KU1)
      EDK(KU2)=EDK(KU1)
      TKK(KU2)=TKK(KU1)
      ALPK(KU2)=ALPK(KU1)
      VK(KU2)=VK(KU1)
      WE(KU2)=WE(KU1)
      GO TO 320
  315 CONTINUE
      WSK(KU1)=WSK(KU2)
      TAK(KU1)=TAK(KU2)
      EDK(KU1)=EDK(KU2)
      TKK(KU1)=TKK(KU2)
      ALPK(KU1)=ALPK(KU2)
      VK(KU1)=VK(KU2)
      WE(KU1)=WE(KU2)
C
  320 CONTINUE
C
  121 FORMAT(* RESET UPSTREAM DISCHARGE OF REACH*,I4,* TO BE *,
     +*THE SAME AS THAT OF REACH*,I4)
  131 FORMAT(* DID YOU NUMBER REACH*,I4,* AS THE FIRST INFLOW TRIBU*,
     1*TARY AND*,/,* THE LAST OUTFLOW TRIBUTARY OF REACH*,I4,* ?*,
     2,/* ALSO CHECK THE TRIBUTRIES OF REACH*,I4)
      RETURN                                                            SPL 0430
```

Subroutine SROUT

```
      SUBROUTINE SROUT (NR)
C
C     THIS SUBROUTINE ROUTES THE SEDIMENT, CALCULATES THE
C     APPROXIMATE BED ELEVATION CHANGE, AND IF NECESSARY,
C     DISTRIBUTES THE AGGRADATION OR DEGRADATION THROUGH
C     THE CROSS SECTION.
C
      COMMON /SEC1/          WD(22)          , RD(100)         , TQ(125)        ,
     1        WSK(100)     , WE(100)         , ZMIN(100)       , ZOB(100)       ,
     2        A1(100)      , A2(100)         , A3(100)         , A4(100)        ,
     3        A5(100)      , A6(100)         , A7(100)         , A8(100)        ,
     4        A9(100)      , A10(100)        , B1(100)         , B2(100)        ,
     5        B3(100)      , B4(100)         , B5(100)         , B6(100)        ,
     6        B7(100)      , B8(100)         , B9(100)         , B10(100)       ,
     7        DA4(100)     , DA9(100)        , EDK(100)        , TAK(100)       ,
     8        TKK(100)     , ALPK(100)       , VK(100)         , WSMAX(100)     ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)       , Z(100,22)       , ZO(100,22)     ,
     1        DLOB(100)    , DROB(100)       , F(100,22)       , ND(100)        ,
     2        SUMDA(100)   , SMADA(100)      , SMZWS(100)      , IZMIN(100)     ,
     3        G(100)
      COMMON /UNITS/         IUNIT           , CORDS           , ZDIFM          ,
     1        GRAV         , VVAL            , FET             , CONV           ,
     2        DZMAX
      COMMON /INF/           NSEC            , NTIM            , DT             ,
     1        IDRG         , CE              , CC              , PORM           ,
     2        STAGE        , ITIME           , NQI             , NCALL          ,
     3        ICALL(30,3)  , MST             , EPS
      COMMON /RIV/           NRIV            , KUP(10)         , KDOWN(10)      ,
     1        NTRIB(10)    , ICONT(10)       , QSL(10,5)       , AX(10)         ,
     2        BX(10)       , CX(10)          , RDT(10,5)       , ITRIB(10,5)    ,
     3        KTRIB(10,5)  , AT(10,5)        , BT(10,5)        , KCONT(10)      ,
     4        IROUT(10)    , SB(10)          , AN(10)          , BN(10)
      DIMENSION              DV(100)
C
C     ITERATE OVER EACH CROSS SECTION IN THE RIVER SEGMENT.
C
      KU = KUP(NR)
      KD = KDOWN(NR)
      KDP1 = KD + 1
      KUM1 = KU - 1
      DO 120 K = KD,KUM1
         KP1 = K + 1
C
C     CALCULATE  THE VOLUME OF SEDIMENT DEPOSITED, OR ERODED.
C
         DV(K) = (G(KP1) - G(K)) * 86400. * DT
C
C     ADD IN LATERAL SEDIMENT INFLOW IF ANY.
C
         JT = NTRIB(NR)
         IF (JT.EQ.0) GO TO 110
         DO 100 J = 1,JT
            IF (RDT(NR,J).GE.RD(K).AND.RDT(NR,J).LT.RD(KP1)) DV(K) = DV(
     1      K) + QSL(NR,J) * 86400.0 * DT
  100    CONTINUE
  110    DV(K) = (DV(K)/(1.0 - PORM))
  120 CONTINUE
      DXUP = RD(KDP1) - RD(KD)
      DO 210 K = KD,KUM1
         IF (ABS(TQ(K)).EQ.0.0) GO TO 210
         KM1 = K - 1
         KP1 = K + 1
         DXDWN = DXUP
         DXUP = RD(KP1) - RD(K)
C
C     TEST FOR WEIRS
C
         IF ((DXDWN/CORDS).LT.0.001) GO TO 210
         IF ((DXUP/CORDS).LT.0.001) GO TO 210
         IF (K.GT.KD) GO TO 140
         IROOT = IROUT(NR)
         GO TO (210,140,130), IROOT
C
C     CALCULATE THE CHANGE IN THE AREA AT THE CROSS SECTION
C
  130    DA = 0.5 * DV(K)/DXUP
         GO TO 150
  140    DA = (1.5 * DV(K) + 0.5 * DV(KM1))/(DXUP + DXDWN)
  150    SUMDA(K) = SUMDA(K) + DA
C
C     CALCULATE THE APPROXIMATE BED ELEVATION CHANGE
C     SINCE THE LAST DISTRIBUTION OF SEDIMENT.
C
         SUMDZ = SUMDA(K)/WE(K)
         SMZWS(K) = SMZWS(K) + WSK(K) * ABS(DA)
         SMADA(K) = SMADA(K) + ABS(DA)
```

Subroutine SROUT continued

```
C
C     TEST TO SEE IF THE BED ELEVATION HAS CHANGED ENOUGH TO
C     REQUIRE DISTRIBUTING THE SEDIMENT THROUGH THE CROSS SECTION
C
         ADZ = ABS(SUMDZ)
         IF (ADZ.GT.DZMAX) GO TO 160
         IF (ITIME.EQ.NTIM.AND.SMADA(K).GT.0.) GO TO 160
         GO TO 210
C
C     USE THE WEIGHTED AVERAGE OF WATER SURFACE ELEVATIONS FOR
C     DISTRIBUTING THE SEDIMENT.
C
  160    NDIS = IFIX(ADZ/(DZMAX * 4.))
         IF (NDIS.LT.1) NDIS = 1
         SDA = SUMDA(K)/FLOAT(NDIS)
         WS = SMZWS(K)/SMADA(K)
         DO 200 NDS = 1,NDIS
            ZMP3 = ZMIN(K) + 3.
            IF (WS.LT.ZMP3) WS = ZMP3
            CALL GEOM (K,WS)
            N = ND(K)
            NP = N - 1
C
C     ADD IN CHANGE IN BED ELEVATION, AT EACH POINT, TO
C     CROSS SECTION GEOMETRY.
C
            DX = X(K,2) - X(K,1)
            IF (DX.EQ.0.) GO TO 170
            Z(K,1) = Z(K,1) + (SDA * WD(1))/DX
  170       DO 180 L = 2,NP
               DX = X(K,L + 1) - X(K,L - 1)
               IF (DX.EQ.0.) GO TO 180
               Z(K,L) = Z(K,L) + (SDA * (WD(L) + WD(L - 1)))/DX
  180       CONTINUE
            DX = X(K,N) - X(K,N - 1)
            IF (DX.EQ.0.) GO TO 190
            Z(K,N) = Z(K,N) + (SDA * WD(N - 1))/DX
  190       CALL THAL (K)
  200    CONTINUE
C
C     CALCULATE POWER FUNCTIONS FOR THE CHANGED SECTION.
C
         CALL CHNGM (K)
C
C     SET SMADA (K),SMZWS (K), AND SUMDA(K), BACK TO ZERO.
C
         SMADA(K) = 0.
         SMZWS(K) = 0.
         SUMDA(K) = 0.
  210 CONTINUE
C
      RETURN
      END
```

```
 DETAILS     DIAGNOSIS OF PROBLEM
        AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO T
```

Subroutine SUBPF

```
      SUBROUTINE SUBPF (NR)
C
C     THIS SUBROUTINE CALLS THE VARIOUS OTHER SUBROUTINES NEEDED TO
C     CALCULATE THE SUBCRITICAL WATER SURFACE ELEVATION AT EACH SECTION.
C
      COMMON /SEC1/       WD(22)        , RD(100)       , TQ(125)       ,
     1           WSK(100)     , WE(100)       , ZMIN(100)     , ZOB(100)      ,
     2           A1(100)      , A2(100)       , A3(100)       , A4(100)       ,
     3           A5(100)      , A6(100)       , A7(100)       , A8(100)       ,
     4           A9(100)      , A10(100)      , B1(100)       , B2(100)       ,
     5           B3(100)      , B4(100)       , B5(100)       , B6(100)       ,
     6           B7(100)      , B8(100)       , B9(100)       , B10(100)      ,
     7           DA4(100)     , DA9(100)      , EDK(100)      , TAK(100)      ,
     8           TKK(100)     , ALPK(100)     , VK(100)       , WSMAX(100)    ,
     9           IMAX(100)
      COMMON /UNITS/      IUNIT         , CORDS         , ZDIFM         ,
     1           GRAV         , VVAL          , FET           , CONV          ,
     2           DZMAX
      COMMON /HYD/        V             , ED            , EW            ,
     1           ALP          , TK            , TA
      COMMON /RIV/        NRIV          , KUP(10)       , KDOWN(10)     ,
     1           NTRIB(10)    , ICONT(10)     , QSL(10,5)     , AX(10)        ,
     2           BX(10)       , CX(10)        , RDT(10,5)     , ITRIB(10,5)   ,
     3           KTRIB(10,5)  , AT(10,5)      , BT(10,5)      , KCONT(10)     ,
     4           IROUT(10)    , SB(10)        , AN(10)        , BN(10)
      COMMON /SYS/        VHD           , WSD           , TKD           ,
     1           DEX
C
C     DETERMINE THE COEFFICIENT OF THE CONVAYENCE EQUATION
C     FOR THE CURRENT DISCHARGE.
C
      CALL NVAL (NR)
C
C     CALCULATE THE WATER SURFACE ELEVATION AT THE DOWNSTREAM
C     SECTION, BY USING THE CONTROL CONDITIONS.
C
      CALL CONT (NR,WS)
      K = KDOWN(NR)
      IF (WS.LE.ZMIN(K)) GO TO 100
      CALL HYDPR (K,WS)
C
C     TEST FOR CRITICAL FLOW.
C
      CRT = TQ(K)/((GRAV/ALP) * * .5)
      ZSQ = TA * ((TA/EW) * * .5)
      IF (CRT.LT.ZSQ) GO TO 130
C
C     CALCULATE CRITICAL DEPTH.
C
  100 IF (TQ(K).GT.0.0) GO TO 110
      WS = WSD
      ED = 0.0
      EW = 0.0
      TA = 0.0
      TK = 0.0
      ALP = 0.0
      V = 0.0
  110 D = (TQ(K) * TQ(K) * A5(K))/(A3(K) * A3(K) * GRAV)
      D = D * * (1./(1. + 2. * B3(K) - B5(K)))
      WS = D + ZMIN(K)
      IF (WS.LT.ZOB(K)) GO TO 120
      D = (TQ(K) * TQ(K) * A10(K))/(A8(K) * A8(K) * GRAV)
      D = D * * (1./(1. + 2. * B8(K) - B10(K)))
      WS = D + ZMIN(K)
C
C     CALCULATE THE HYDRAULIC PROPERTIES OF THE SECTION.
C
  120 CALL HYDPR (K,WS)
  130 WE(K) = EW
      WSK(K) = WS
      TAK(K) = TA
      EDK(K) = ED
      TKK(K) = TK
      ALPK(K) = ALP
      VK(K) = V
C
C     ITERATE OVER THE REMAINDER OF THE SECTIONS, BY WORKING
C     UPSTREAM ONE SECTION AT A TIME.
C
      KU = KUP(NR)
      K2 = KDOWN(NR) + 1
      DO 220 K = K2,KU
         ICRI = 0
C
C     SET THE LAST SECTIONS HYDRAULIC PROPERTIES AS THE DOWNSTREAM
C     CONDITIONS.
C
```

Subroutine SUBPF continued

```
          KD = K - 1
          DEX = RD(K) - RD(KD)
          VHD = ALP * V * V/(2. * GRAV)
          WSD = WS
          TKD = TK
          IF (TQ(K).GT.0.0) GO TO 150
          WS = WSD
          IF (WS.LE.ZMIN(K)) GO TO 140
          CALL HYDPR (K,WS)
          GO TO 210
  140     EW = 0.0
          ED = 0.0
          TA = 0.0
          TK = 0.0
          ALP = 0.0
          V = 0.0
          GO TO 210
C
C      TEST FOR WEIR SECTION
C
  150     IF (DEX.GT.0.00001) GO TO 160
C
C      CALCULATE THE WATER SURFACE AT THE UPTREAM WEIR SECTION
C
          CALL WEIR (K,WS)
          GO TO 210
C
C      CALCULATE THE WATER SURFACE ELEVATION AT SECTION(K).
C
  160     CALL BKWAT (K,WS,ICRI)
C
C      TEST FOR CRITICAL FLOW.
C
          IF (ICRI.EQ.1) GO TO 170
          CRT = TQ(K)/((GRAV/ALP) *  * .5)
          ZSQ = TA * ((TA/EW) *  * .5)
          IF (CRT.LE.ZSQ) GO TO 210
C
C      CALCULATE CRITICAL DEPTH.
C
  170     D = (TQ(K) * TQ(K) * A5(K))/(A3(K) * A3(K) * GRAV)
          D = D *  * (1./(1. + 2. * B3(K) - B5(K)))
          WS = D + ZMIN(K)
          IF (WS.LT.ZOB(K)) GO TO 180
          D = (TQ(K) * TQ(K) * A10(K))/(A8(K) * A8(K) * GRAV)
          D = D *  * (1./(1. + 2. * B8(K) - B10(K)))
          WS = D + ZMIN(K)
  180     IF (WS.LT.WSD) WS = WSD
          CALL HYDPR (K,WS)
          IF (V.LT.VVAL) GO TO 210
C
C       CALCULATE NORMAL DEPTH
C
          C = TQ(K)/SB(NR) *  * .5
          D = (C/A4(K)) *  * (1./B4(K))
          WS = ZMIN(K) + D + .001
          IF (WS.LT.WSD) WS = WSD
          IF (WS.LT.ZOB(K)) GO TO 190
          D = (C/A9(K)) *  * (1./B9(K))
          WS = ZMIN(K) + D + .001
          IF (WS.LT.WSD) WS = WSD
  190     CALL HYDPR (K,WS)
          IF (V.LT.VVAL) GO TO 210
C
C      VELOCITY LIMITED
C
          D = (TQ(K)/(VVAL * A3(K))) *  * (1.0/B3(K))
          WS = D + ZMIN(K)
          IF (WS.LT.WSD) WS = WSD
          IF (WS.LT.ZOB(K)) GO TO 200
          D = (TQ(K)/(VVAL * A8(K))) *  * (1.0/B8(K))
          WS = D + ZMIN(K)
          IF (WS.LT.WSD) WS = WSD
  200     CALL HYDPR (K,WS)
C
C      SET CROSS SECTION HYDRAULIC PROPERTIES INTO ARRAYS
C
  210     WE(K) = EW
          WSK(K) = WS
          TAK(K) = TA
          EDK(K) = ED
          TKK(K) = TK
          ALPK(K) = ALP
          VK(K) = V
  220 CONTINUE
C
      RETURN
      END
```

Subroutine THAL

```
      SUBROUTINE THAL (K)
C
C     THIS SUBROUTINE DETERMINES THE CROSS SECTION THALWEG ELEVATION
C
      COMMON /SEC1/            WD(22)         , RD(100)        , TQ(125)        ,
     1         WSK(100)      , WE(100)        , ZMIN(100)      , ZOB(100)       ,
     2         A1(100)       , A2(100)        , A3(100)        , A4(100)        ,
     3         A5(100)       , A6(100)        , A7(100)        , A8(100)        ,
     4         A9(100)       , A10(100)       , B1(100)        , B2(100)        ,
     5         B3(100)       , B4(100)        , B5(100)        , B6(100)        ,
     6         B7(100)       , B8(100)        , B9(100)        , B10(100)       ,
     7         OA4(100)      , OA9(100)       , EDK(100)       , TAK(100)       ,
     8         TKK(100)      , ALPK(100)      , VK(100)        , WSMAX(100)     ,
     9         IMAX(100)
      COMMON /SEC2/            X(100,22)      , Z(100,22)      , ZO(100,22)     ,
     1         DLOB(100)     , DROB(100)      , F(100,22)      , ND(100)        ,
     2         SUMDA(100)    , SMADA(100)     , SMZWS(100)     , IZMIN(100)     ,
     3         G(100)
C
C     TEST EACH CROSS SECTION POINT TO FIND THE MINIMUM ELEVATION,
C     (ZMIN(K)).
C
      M = ND(K)
      ZMIN(K) = Z(K,1)
      IZMIN(K) = 1
      DO 100 L = 1,M
         IF (Z(K,L).GE.ZMIN(K)) GO TO 100
         ZMIN(K) = Z(K,L)
         IZMIN(K) = L
  100 CONTINUE
C
      RETURN
      END
```

Subroutine TRIBS

```
      SUBROUTINE TRIBS
C
C     THIS SUBROUTINE DETERMINES THE SEDIMENT DISCHARGE FOR
C     EACH TRIBUTARY.
C
C     DEFINITIONS OF TYPES OF TRIBUTARIES
C
C     ITRIB(NR,J)       TYPE OF TRIBUTARY
C
C         1                 POINT SOURCE IN
C         2                 MAJOR TRIBUTARY IN
C         3                 POINT SOURCE OUT
C         4                 MAJOR TRIBUTARY OUT
C
      COMMON /SEC1/        WD(22)       , RD(100)      , TQ(125)      ,
     1             WSK(100)     , WE(100)      , ZMIN(100)    , ZOB(100)     ,
     2             A1(100)      , A2(100)      , A3(100)      , A4(100)      ,
     3             A5(100)      , A6(100)      , A7(100)      , A8(100)      ,
     4             A9(100)      , A10(100)     , B1(100)      , B2(100)      ,
     5             B3(100)      , B4(100)      , B5(100)      , B6(100)      ,
     6             B7(100)      , B8(100)      , B9(100)      , B10(100)     ,
     7             OA4(100)     , OA9(100)     , EDK(100)     , TAK(100)     ,
     8             TKK(100)     , ALPK(100)    , VK(100)      , WSMAX(100)   ,
     9             IMAX(100)
      COMMON /SEC2/        X(100,22)    , Z(100,22)    , Z0(100,22)   ,
     1             DLOB(100)    , DROB(100)    , F(100,22)    , ND(100)      ,
     2             SUMDA(100)   , SMADA(100)   , SMZWS(100)   , IZMIN(100)   ,
     3             G(100)
      COMMON /INF/         NSEC         , NTIM         , DT           ,
     1             IDRG         , CE           , CC           , PORM         ,
     2             STAGE        , ITIME        , NQI          , NCALL        ,
     3             ICALL(30,3)  , MST          , EPS
      COMMON /RIV/         NRIV         , KUP(10)      , KDOWN(10)    ,
     1             NTRIB(10)    , ICONT(10)    , QSL(10,5)    , AX(10)       ,
     2             BX(10)       , CX(10)       , RDT(10,5)    , ITRIB(10,5)  ,
     3             KTRIB(10,5)  , AT(10,5)     , BT(10,5)     , KCONT(10)    ,
     4             IROUT(10)    , SB(10)       , AN(10)       , BN(10)
C
C     ITERATE OVER EACH RIVER SEGMENT.
C
      DO 150 NR = 1,NRIV
         NT = NTRIB(NR)
         IF (NT.EQ.0) GO TO 150
         DO 140 J = 1,NT
            K = KTRIB(NR,J)
C
C     DETERMINE THE TYPE OF TRIBUTARY.
C
            ITRYB = ITRIB(NR,J)
            GO TO (100,110,120,130), ITRYB
C
C     CALCULATE SEDIMENT DISCHARGE FOR POINT SOURCE BY RATING CURVE
C
  100       QSL(NR,J) = AT(NR,J) * TQ(K) *  * BT(NR,J)
            GO TO 140
C
C     FOR MAJOR TRIBUTARIES SET SEDIMENT DISCHARGE TO SEDIMENT
C     TRANSPORT AT DOWNSTREAM TRIBUTARY SECTION.
C
  110       QSL(NR,J) = G(K)
            GO TO 140
C
C     POINT SOURCE OUT
C
  120       QSL(NR,J) = AT(NR,J) * TQ(K) *  * BT(NR,J)
            QSL(NR,J) =  - QSL(NR,J)
            GO TO 140
C
C     MAJOR TRIBUTARY OUT
C
  130       QSL(NR,J) =  - G(K)
  140    CONTINUE
  150 CONTINUE
C
      RETURN
      END
```

Subroutine UNIT

```
      SUBROUTINE UNIT
C
C     THIS SUBROUTINE ASSIGNES THE CORRECT VALUES TO THE
C     CONSTANTS ACCORDING TO THE UNIT-SYSTEM USED.
C
C        IUNIT        UNITS
C
C        1          ENGLISH UNIT-SYSTEM
C        2          METRIC SYSTEM (SI)
C
C
      COMMON /UNITS/         IUNIT       , CORDS        , ZDIFM        ,
     1         GRAV        , VVAL        , FET          , CONV         ,
     2         DZMAX
C
      IF (IUNIT.NE.1) GO TO 100
      CORDS = 5280.
      ZDIFM = 10.
      GRAV = 32.2
      VVAL = 10.
      FET = 5.
      CONV = 1.486
      DZMAX = 0.5
      RETURN
  100 CORDS = 1000.
      ZDIFM = 3.0
      GRAV = 9.81
      VVAL = 3.3
      FET = 1.5
      CONV = 1.0
      DZMAX = 0.15
C
      RETURN
      END
```

Subroutine WEIR

```
      SUBROUTINE WEIR (K,WS)
C
C     THIS SUBROUTINE IS USED TO CALCULATE THE GREATER OF THE DOWNSTREAM
C     WATER SURFACE OR THE CRITICAL DEPTH AT THE WEIR.
C
      COMMON /SEC1/        WD(22)          , RD(100)         , TQ(125)         ,
     1        WSK(100)    , WE(100)         , ZMIN(100)       , ZOB(100)        ,
     2        A1(100)     , A2(100)         , A3(100)         , A4(100)         ,
     3        A5(100)     , A6(100)         , A7(100)         , A8(100)         ,
     4        A9(100)     , A10(100)        , B1(100)         , B2(100)         ,
     5        B3(100)     , B4(100)         , B5(100)         , B6(100)         ,
     6        B7(100)     , B8(100)         , B9(100)         , B10(100)        ,
     7        OA4(100)    , OA9(100)        , EDK(100)        , TAK(100)        ,
     8        TKK(100)    , ALPK(100)       , VK(100)         , WSMAX(100)      ,
     9        IMAX(100)
      COMMON /SYS/         VHD             , WSD             , TKD             ,
     1        DEX
      COMMON /HYD/         V               , ED              , EW              ,
     1        ALP         , TK              , TA
      DATA WID/200.0/
C
C     CALCULATE DEPTH BY WEIR EQUATION
C
      D = (TQ(K)/(WID * 2.85)) *  * 0.666666
      WS = D + ZMIN(K) + 0.001
C
C     TEST FOR GREATEST OF DOWNSTREAM OR WEIR WATER SURFACE ELEVATIONS
C
      IF (WS.LT.WSD) WS = WSD
      CALL HYDPR (K,WS)
C
C     SET HYDRAULIC PROPERTIES EQUAL AT THE WEIR CROSS SECTIONS
C
      KM1 = K - 1
      WSK(KM1) = WS
      VK(KM1) = V
      TAK(KM1) = TA
      TKK(KM1) = TK
      EDK(KM1) = ED
      WE(KM1) = EW
      ALPK(KM1) = ALP
C
      RETURN
      END
```

Subroutine WEIRS

```
      SUBROUTINE WEIRS (KW,KU)
C
C     THIS SUBROUTINE CALCULATES THE PERCENTAGE OF THE UPSTREAM
C     SEDIMENT TRANSPORT (G(KU)), WHICH IS TRANSPORTED OVER A WEIR.
C     IT USES THE LANE-KALINSKE SEDIMENT DISTRIBUTION.
C
      COMMON /SEC1/          WD(22)          , RD(100)        , TQ(125)        ,
     1        WSK(100)     , WE(100)         , ZMIN(100)      , ZOB(100)       ,
     2        A1(100)      , A2(100)         , A3(100)        , A4(100)        ,
     3        A5(100)      , A6(100)         , A7(100)        , A8(100)        ,
     4        A9(100)      , A10(100)        , B1(100)        , B2(100)        ,
     5        B3(100)      , B4(100)         , B5(100)        , B6(100)        ,
     6        B7(100)      , B8(100)         , B9(100)        , B10(100)       ,
     7        OA4(100)     , OA9(100)        , EDK(100)       , TAK(100)       ,
     8        TKK(100)     , ALPK(100)       , VK(100)        , WSMAX(100)     ,
     9        IMAX(100)
      COMMON /SEC2/          X(100,22)       , Z(100,22)      , ZO(100,22)     ,
     1        DLOB(100)    , DROB(100)       , F(100,22)      , ND(100)        ,
     2        SUMDA(100)   , SMADA(100)      , SMZWS(100)     , IZMIN(100)     ,
     3        G(100)
      DATA DF/0.04/,W/0.075/
C
C     IF THE UPSTREAM BED IS HIGHER THAN THE WEIR, THE TRANSPORT
C     OVER THE WEIR IS EQUAL TO THE POTENTIAL
C
      KWM1 = KW - 1
      IF (EDK(KU).LE.EDK(KW)) RETURN
      D = EDK(KU)
      U = TQ(KU)/TAK(KU)
      US = U/(8./DF) *   * 0.5
      A = ( - 1.0 * 8.57 * W)/(US * D)
      Y = EDK(KU) - EDK(KW)
C
C     EVALUATE THE INTEGRAL
C
      EO = 1.0/A
      EY = EXP(A * Y)/A
      ED = EXP(A * D)/A
      PC = (EY - ED)/(EO - ED)
C
C     ADJUST THE TRANSPORT OVER THE WEIR SECTIONS BY THE COMPUTED
C     PERCENTAGE
C
      G(KW) = PC * G(KW)
      G(KWM1) = G(KW)
C
      RETURN
      END
```