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URBAN HIGHWAY STORM DRAINAGE MODEL

Research, Development, and Technology

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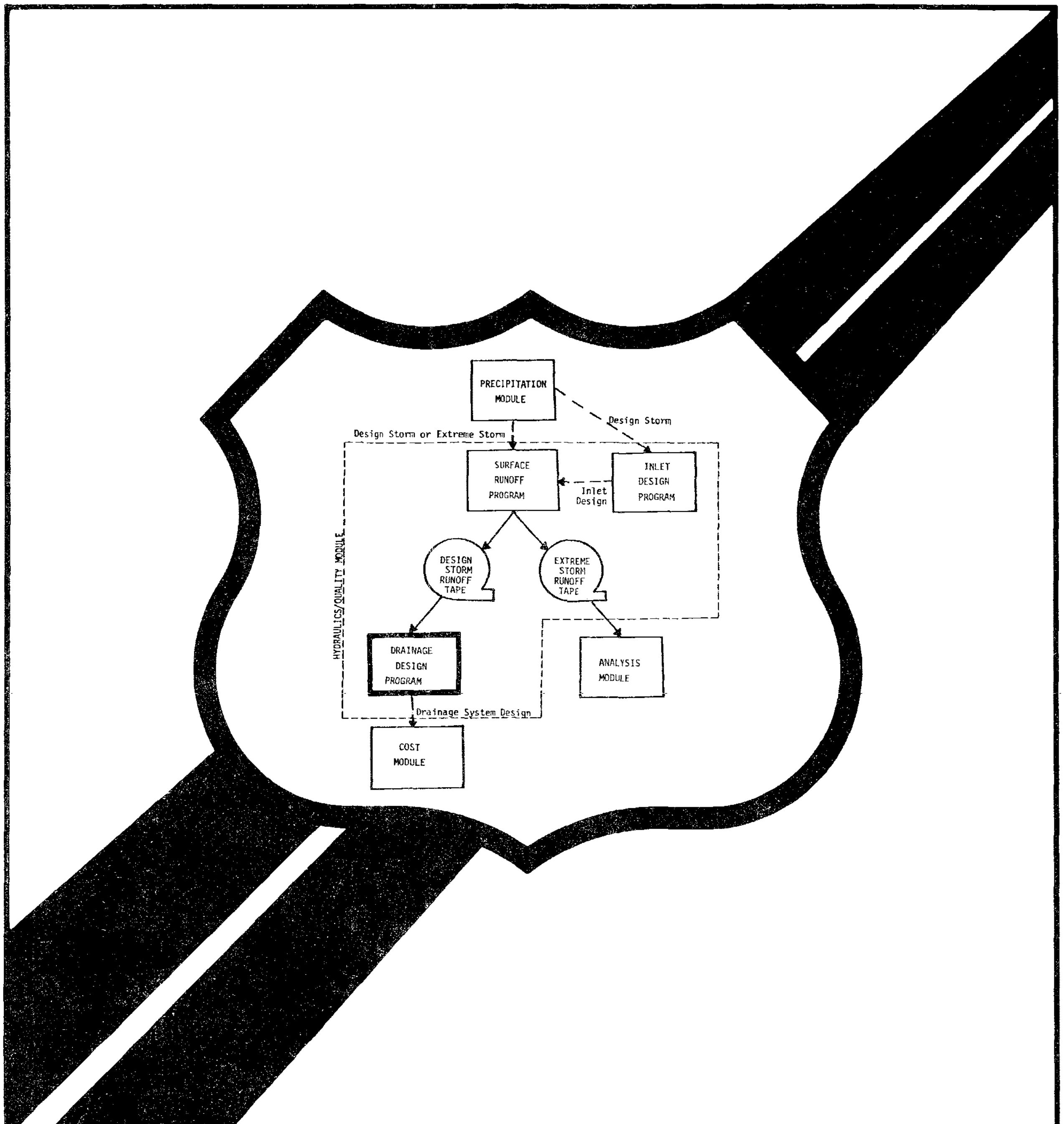

FOREWORD

This report documents the development and presents the user's manual for the Drainage Design Program of the Hydraulics/Quality Module of this computer model. Based on the inlet hydrographs and the inlet pollutographs computed by the Surface Runoff Program, this program sizes the storm sewers and estimates the stormwater quantity and quality at the sewer outfalls.

Research and development in urban and rural highway storm drainage is included in the Federally Coordinated Program of Highway Research, Development, and Technology Project 5H "Highway Drainage and Flood Protection." Dr. Roy E. Trent is the Project Manager and Dr. D. C. Woo is the Contracting Officer's Technical Representative for this study.

This report is being distributed on request only due to the specialized nature of the contents.

Richard E. Hay, Director
Office of Engineering
and Highway Operations
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16. Abstract

A package of six user-oriented computer programs has been developed and tested for the analysis and design of urban highway drainage systems and related nonpoint source pollution problems. These programs are organized into four related but independent Modules.

This report consists of the documentation and user's manual for the Drainage Design Program of the Hydraulics/Quality Module. This program takes the inlet flows and their qualities which were predicted by the Surface Runoff Program and routes them through the underground drainage system to one or more outfalls.

This report is the fifth in a series. The others in the series are:

Vol. No.	FHWA No.	Short Title
-	83/040	Executive Summary
1	83/041	Model Development and Test Applications
2	83/042	Precipitation Module
3	83/043	Inlet Design Program
4	83/044	Surface Runoff Program
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7	83/047	Cost Estimation Module

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

OVERVIEW OF THE URBAN HIGHWAY STORM DRAINAGE MODEL

The Urban Highway Storm Drainage Model consists of four modules in six computer programs, developed for the Federal Highway Administration, U.S. Department of Transportation by the Water Resources Division of Camp Dresser & McKee Inc. The basic purpose of this package of programs is to provide the engineer with computational tools to assist in the analysis and design of highway drainage systems. Due to the nature of the problem, this model is not intended to fully automate the design process. Each module or program can be used separately to suit the designer's purpose.

The programs of the model are organized into four related but independent modules, as follows:

- Precipitation Module
- Hydraulics/Quality Module
  - Surface Runoff Program
  - Inlet Design Program
  - Drainage Design Program
- Analysis Module
- Cost Module

The Precipitation Module can perform a variety of statistical analyses on long-term hourly precipitation data and generate design storm hyetographs. The Hydraulics/Quality Module is the basic design tool in the package. This module simulates time-varying runoff quantity and quality, locates stormwater inlets and sizes the conduits of the major drainage system. The Analysis Module simulates unsteady gradually-varied flow in the drainage system and can be used to analyze complex hydraulic conditions, such as surcharge and backwater, that may be encountered during extreme storm events. The Cost Module can be used to estimate construction, operation and maintenance, and total annual costs associated with the drainage system.

The interrelationships among the computer programs are illustrated by Figure I-1. As can be seen from this figure, there are a variety of ways in which these programs can be used independently or in conjunction with each other. This flexibility should allow the engineer to apply one or more of these programs to a wide variety of common stormwater-related problems. The major features of each of the programs are summarized in Tables I-1 through I-4.

This chapter is intended only to give the reader a broad overview of the Urban Highway Storm Drainage Model. To gain an understanding of the potential applications, the capabilities and the limitations of a particular program in the package, the engineer will need to study the appropriate User's Manual and Documentation Report.

This report is the User's Manual and Documentation Report for the Drainage Design Program of the Hydraulics/Quality Module. Chapter II of the report is an introduction to this program, describing the general approach used in the program and how the program fits into the drainage design process. The technical approach employed in the program is presented in some detail in Chapter III. Finally, Chapter IV is a complete user's manual for the program including input requirements and a Fortran listing of the program.

Based on the inlet hydrographs computed by the Surface Runoff Program (SRO) and the arrangement of the drains to be designed, this Drainage Design Program will size the drains, either closed pipes or trapezoid open channels. If runoff quality analysis is needed, the inlet runoff pollutographs generated by the Surface Runoff Program (SRO) are routed through the drainage system, either newly designed or existing

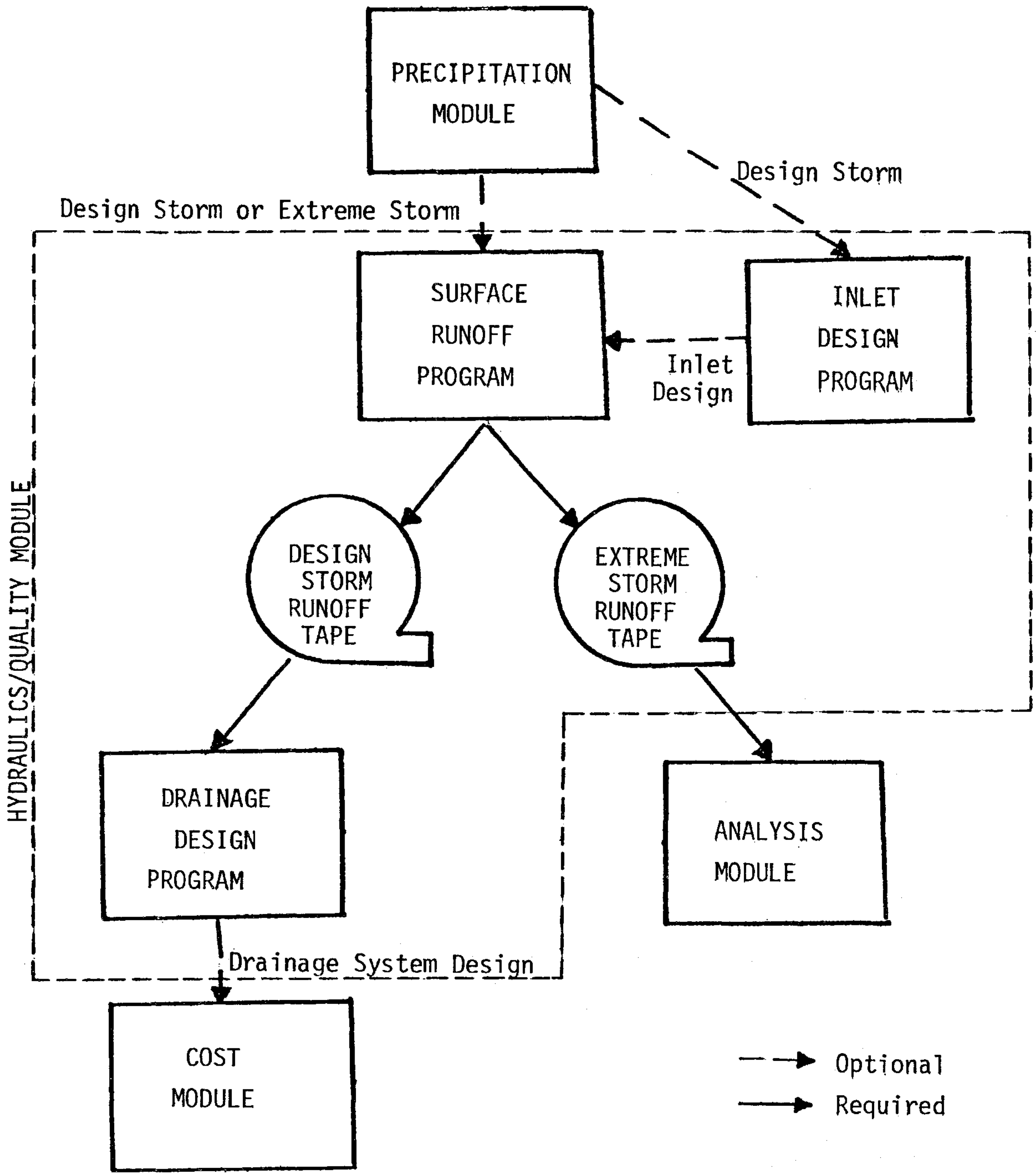

FIGURE I-1. Urban Highway Storm Drainage Model

TABLE I-1

MAJOR FEATURES OF THE PRECIPITATION MODULE

- Derivation of Hyetographs of Selected Return Frequency, Duration, and Skew
- Statistical Analysis of Hourly Rainfall Records to Generate Intensity-Duration-Frequency Curves
- Frequency of Occurrence Analysis of Hourly Rainfall Records for Peak Rainfall Intensity, Storm Duration, and Dry Period Duration
- Statistical Analysis of Hourly Rainfall Records for Storm Skew

TABLE I-2

MAJOR FEATURES OF HYDRAULICS/QUALITY MODULE PROGRAMS

INLET DESIGN PROGRAM (INLET)

- Simulation of Time-Varying Runoff and Gutter/Channel Flow
- Spacing of Fixed-Size Inlets in Gutters or Channels
- Prespecification of Inlet Locations if Required
- Simulation of Six Basic Inlet Types

SURFACE RUNOFF PROGRAM (SRO)

- Simulation of Time-Varying Runoff and Gutter/Channel Flow
- Simulation of Accumulation and Washoff of Suspended Solids and Associated Pollutants
- Simulation of All Inlet Types Considered in Inlet Design Program
- Simulation of Four Types of Gutters/Channels
- Generation of Runoff Tape (Inlet Hydrographs and Pollutographs)

DRAINAGE DESIGN PROGRAM (DRAIN)

- Standard Pipe Sizing
- Sizing of Trapezoidal Open Channels
- Routing of Pollutants Through Drainage System
- Simulation of Treatment at Outfalls (Suspended Solids Removal)

TABLE I-3

MAJOR FEATURES OF THE ANALYSIS MODULE

- Analysis of Extreme Storm Event Hydraulic Conditions in the Major Drainage System Such as Surcharge, Backwater, and Surface Flooding

- Simulation of Unsteady Gradually-Varied Flow in the Major Drainage System

- Simulation of Channels and Pipes of Five Different Cross-Sections

- Simulation of Pumping Station Operation

TABLE I-4

MAJOR FEATURES OF THE COST ESTIMATION MODULE

- Calculation of Capital Costs for Construction of Major Drainage Systems
- Calculation of Operation and Maintenance Costs and Total Annual Costs for Major Drainage Systems
- Estimation of Excavation and Backfill Volumes Associated with Construction of Major Drainage Systems

ones. The Program can also simulate treatment at outfalls for suspended solids removal.

This program will not design an optimized drainage system because too many parameters are involved. However, the user can make use of this Program and the Cost Estimation and Analysis Modules for a risk analysis to select the best design. This Program can size the drains for various arrangements, then the Cost Estimation Module is applied to compute their relative costs, and the Analysis Module to estimate their potential flooding conditions for excessive storms and the associated damages.

CHAPTER II

INTRODUCTION TO THE DRAINAGE DESIGN PROGRAM

This report deals with the Drainage Design Program of the Hydraulics/Quality Module. The primary purpose of the Drainage Design Program (DRAIN) is to size the conduits of the highway major drainage system. The program uses as input a card deck describing the drainage system to be designed and a tape or disc file containing inlet hydrographs computed by the Surface Runoff Program (SRO). If runoff quality has been simulated with SRO, then the inlet pollutographs generated are also read by DRAIN and pollutants are routed through the major drainage system.

This chapter of the report is intended to provide the potential user with a basic understanding of the capabilities of this program and the manner in which it may be used. Topics discussed below include the general approach embodied in the program, its capabilities and limitations, and the computer requirements of the program.

GENERAL APPROACH

Figure II-1 shows a section of typical urban highway including the major components of the drainage system. As can be seen in the figure, runoff from the highway surface and the surface of the right-of-way is collected in roadside drainage channels. The runoff is routed to a series of inlets, such as those in Figure II-2, located to remove runoff so as to prevent flooding of the highway surface. The runoff so collected is then routed through the underground conduit system, generally to a nearby stream or other body of water.

The Drainage Design Program is intended primarily to size the underground drainage system. Each of the major steps involved in applying the program is discussed briefly below.

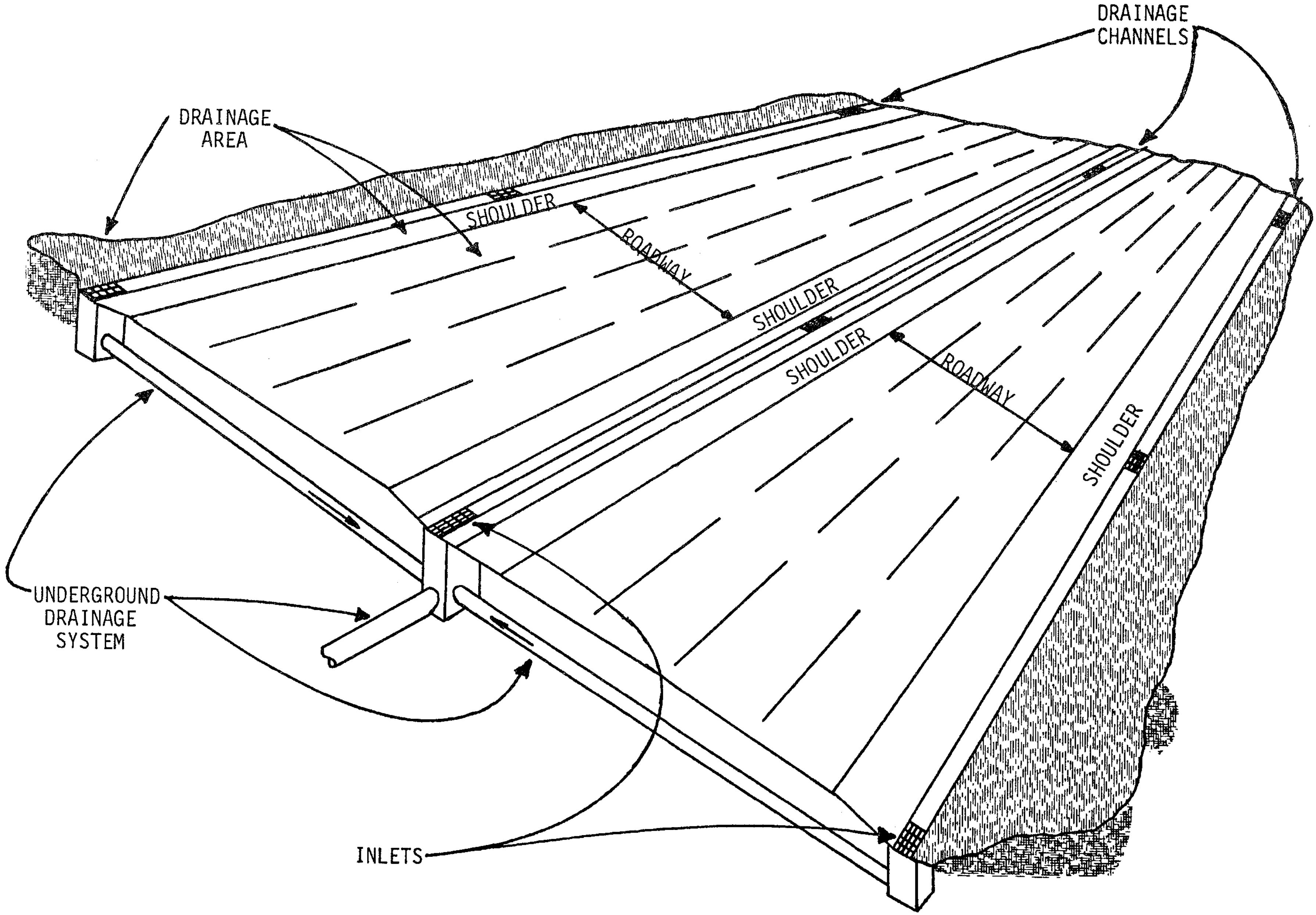

FIGURE II-1. Typical Urban Highway Drainage System

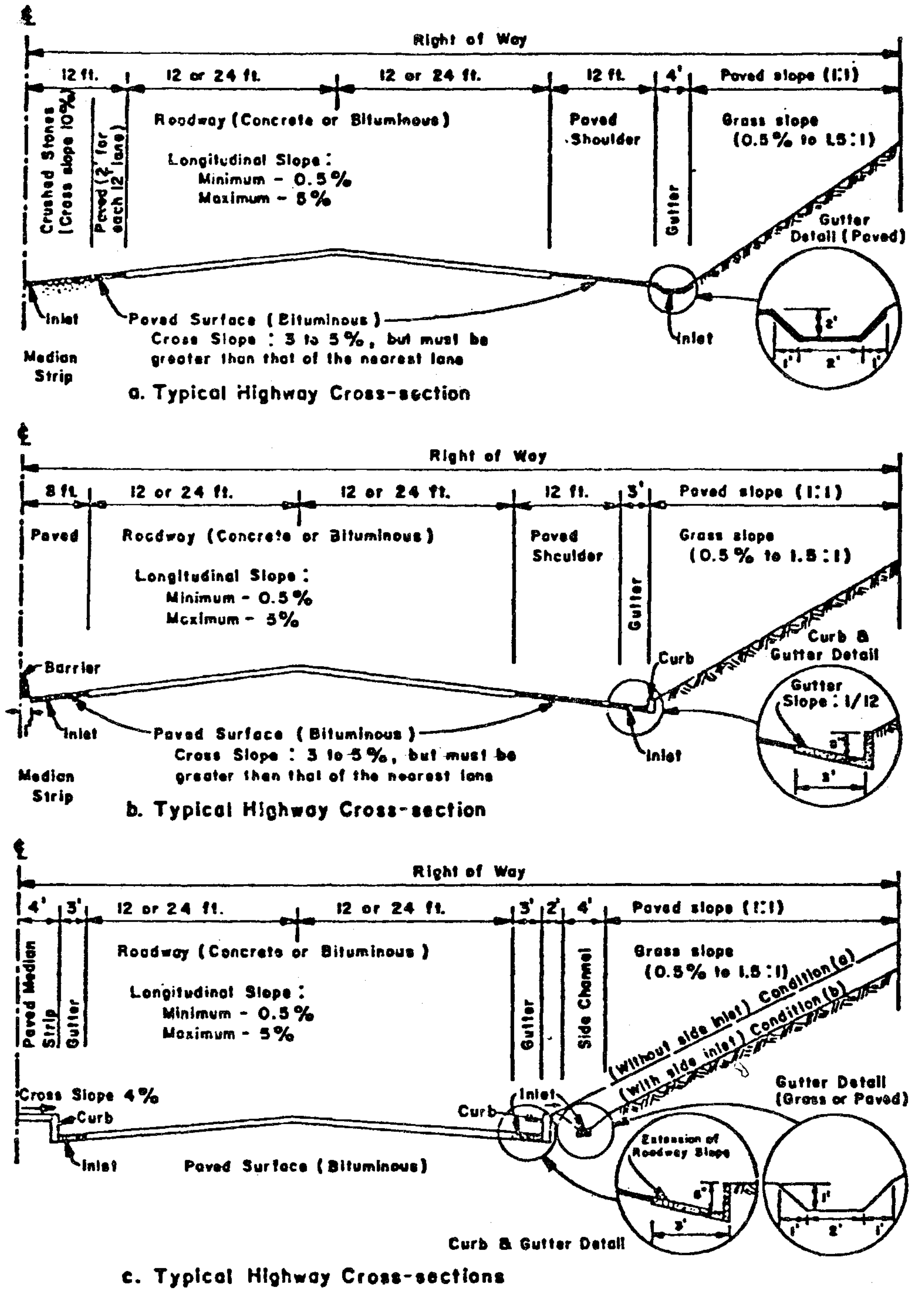

Figure II-2. Schematic Diagrams of Typical Urban Highway Cross-Sections.

Design Storm Runoff

As with design of the underground drainage system by conventional techniques, the engineer must begin design of the drainage system with this program by calculating runoff from a design storm event (or events), in accordance with the appropriate design criteria. These runoff computations must be done with the Surface Runoff Program of the Urban Highway Storm Drainage Model. The output from this program includes a computer file containing the inlet hydrographs from the design storm event.

Use of the Surface Runoff Program is described in a separate User's Manual and Documentation Report. The engineer should really study the Surface Runoff Program Report and the Drainage Design Program Report together to understand how the entire highway drainage system--surface and subsurface--can be addressed with these programs.

Drainage System Elements

The user must begin application of this program by dividing the drainage system to be simulated into a series of discrete elements, each element having apporoximately constant geometric and hydraulic characteristics. The elements here will be lengths of conduit, each with constant cross-sectional shape and area, constant slope, and constant roughness. The user may select some or all of the system elements to be sized by the program, to flow full with the design storm runoff. For each element to be sized, the user must still supply an initial size which will be increased by the program, if necessary, to accommodate the runoff. The program will not, however, decrease the size of a pipe or channel below the initial size specified by the user.

Chapter IV explains how these conduit characteristics are to be coded for input to the program. Also required for each conduit is an external number. The user must assign an external numbering scheme to the major drainage system elements for identification purposes. Generally, it is advisable to number elements consecutively, with each type of element being identified by a certain series of numbers (e.g., underground conduits could be numbered consecutively in the 500's). This type of scheme is especially helpful since the Surface Runoff Program elements will also need to be numbered when that program is used and the same scheme can be used (e.g., gutters could be numbered in the 200's, surface channels in the 300's, inlets in the 400's).

When dividing the drainage system into elements and numbering the elements, the user should be aware of some general features of the Drainage Design Program. First, an inlet structure can only be located at the upstream end of an underground conduit. Second, the first conduit downstream of an inlet must have the same external number as the inlet did in the Surface Runoff Program simulation. (This allows the program to input the inlet hydrographs from the Surface Runoff Program file into the correct points in the drainage system.) Third, junctions cannot be located in the middle of a drainage system element. For example, one drainage element on a major trunk line must end and a new downstream element begin at every location where a lateral line ties into the trunk line. Fourth, a new element should begin at every location where there is a major change in element characteristics (such as slope) and not only at inlet and junction locations.

Runoff Quality

The accumulation and washoff of selected surface pollutants in the highway right-of-way can be simulated with the Surface Runoff Program. When this is done, inlet pollutographs as well as inlet hydrographs are saved in a file to be used as input by the Drainage Design Program. The pollutants so generated are routed through the drainage system, after the program has completed the conduit design calculations. Pollutants are routed conservatively, i.e., with the assumption that no physical, chemical or biological changes to the pollutant species occur from the time they are washed off the right-of-way surface to the time they reach drainage system outfalls.

If nonpoint source pollution or erosion from the highway right-of-way is a problem in the user's study area, he may examine alternative control facilities with this program. Facilities for removal of suspended solids at drainage system outfalls such as detention basins can be simulated with the Drainage Design Program. As part of the input, the user must quantify the performance of the facility in terms of a flow versus removal efficiency curve (see Chapter IV). The program will then calculate the reduction in suspended solids and associated pollutants during the storm event simulated.

CAPABILITIES AND LIMITATIONS

As described above the major drainage system of the urban highway can be designed with the assistance of DRAIN. The design algorithm operates on an element-by-element basis, so the user can prespecify the sizes of selected pipes and open channels, if necessary. Output available from the program includes both design summaries and detailed hydrographs.

As also discussed above, the quality response in the major drainage system may be simulated. Conservative routing of suspended solids and associated runoff pollutants can be performed and physical treatment at system outfalls can be simulated. The engineer may choose to first use the program to obtain a satisfactory hydraulic design and then proceed to analyze quality problems. In some cases, the user analyzing an existing system may wish to proceed directly to quality simulations.

Program DRAIN, as presently structured, has several limitations of which the user should be aware:

- The maximum number of pipe and open channel elements that can be simulated with a single run is 200;
- The maximum number of pollutants that can be simulated is 13 (the same pollutants as in the Surface Runoff Program); and
- The maximum number of system outfalls at which treatment can be simulated is 50.

- Program DRAIN will accept either English or metric units.

COMPUTATIONAL REQUIREMENTS

Program DRAIN has been developed on a shared CDC 6600/6700 computer at the Naval Ship Research and Development Center in Carderock, Maryland. The program as currently dimensioned requires approximately 115,000 octal words of storage. A drainage system consisting of 14 elements required 58 seconds central processing time for a real time simulation of five hours.

CHAPTER III

TECHNICAL APPROACH

This chapter describes the mathematical formulations and assumptions upon which the Drainage Design Program is based. The discussion that follows is divided into four sections: pipe/channel flow routing; pipe/channel sizing; quality routing; and outfall treatment. All equations presented in the chapter are given in terms of the British system of units, for the sake of simplicity. Conversions to or corresponding equations in metric units are contained in the program for use when the metric units option is selected.

PIPE/CHANNEL FLOW ROUTING

The surface runoff hydrographs calculated with program SRO are routed through the pipes and channels of the major drainage system as follows. Consider the typical trapezoidal channel shown in Figure III-1. (Note that flow calculations for circular pipes are done in identical fashion to the calculations for the channel described below.) The outflow from each channel, Q, is determined beginning with the most upstream channel and working downstream, the outflow from each channel then serving as inflow to the next downstream channel.

The two unknowns at the end of each time step are Q and d_1. The known quantities are inflow Q_i and depth d_o, where

d_o = depth at time t;
d_1 = depth at time $t + \Delta t$;
Q_i = inflow from upstream pipe or channel; and
Q = outflow from pipe or channel.

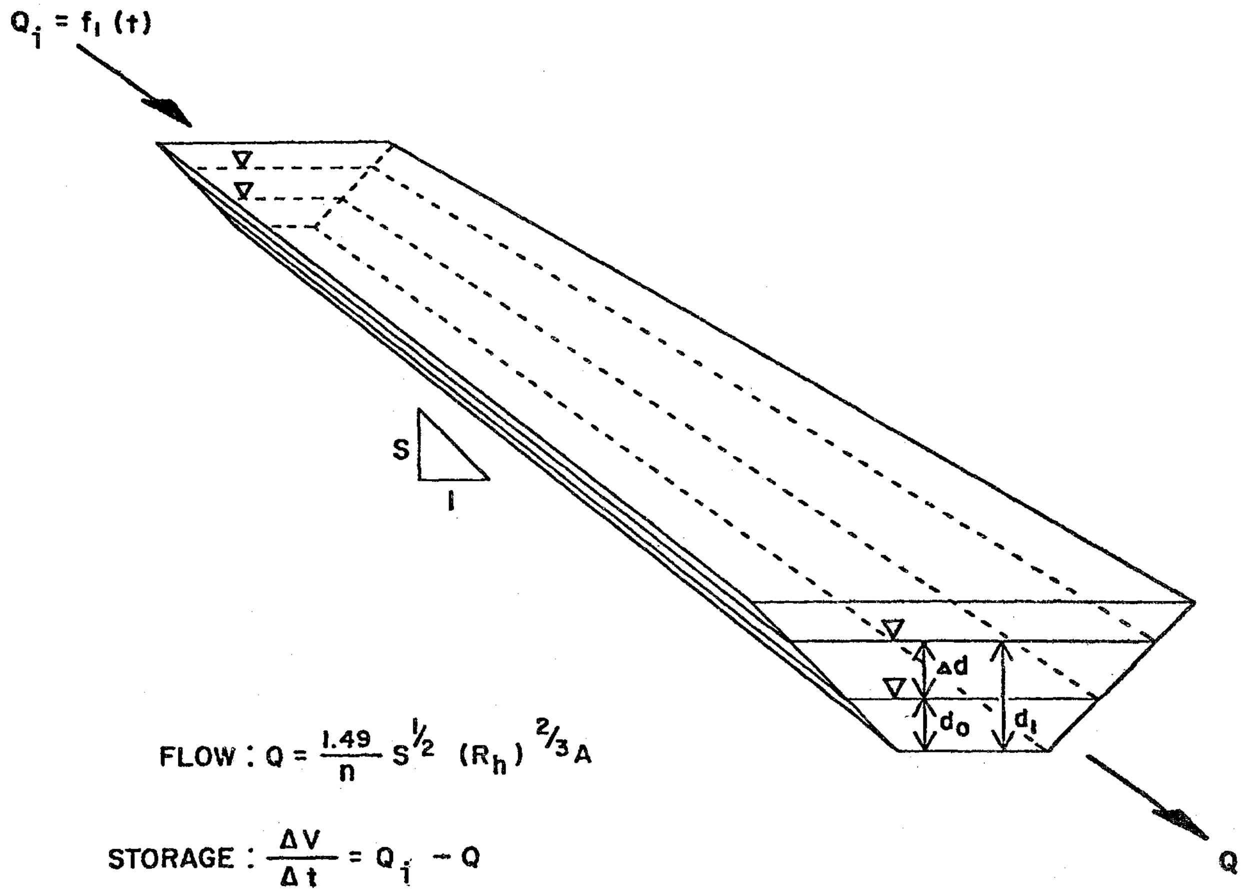

FIGURE III-1. Basic Flow Calculations for Typical Channel

The kinematic wave approximation is made, and the equations of continuity and uniform flow are solved simultaneously at each time step. The continuity equation is:

$$\frac{\Delta V}{\Delta t} = Q_i - Q \qquad \text{(III-1)}$$

where

ΔV = volume change associated with Δd.

The outflow Q is determined from the Manning equation:

$$Q^* = \frac{1.49}{n} S^{1/2} R_h^{2/3} A \qquad \text{(III-2)}$$

where

S = slope of channel bottom

n = Manning coefficient

R_h = hydraulic radius (A/wetted perimeter)

A = cross-sectional area of flow.

Q* is computed for both d_o and d_1 and the average taken as Q. The Newton-Raphson iterative technique is employed to solve equations III-1 and III-2. These equations are combined and Newton's function F is formed as follows:

$$F = \Delta V + \Delta t(Q - Q_i) = 0 \qquad \text{(III-3)}$$

in which ΔV and Q are expressed in terms of d_o and d_1. The Newton's function F is differentiated with respect to d and the following iterative formula used:

$$(\Delta d)_{n+1} = (\Delta d)_n - \frac{F_n}{\frac{d F_n}{d(\Delta d)}} \qquad \text{(III-4)}$$

The subscripts refer to the n^{th} and $(n+1)^{th}$ iterations. The following convergence criterion is used and has proven to be stable and efficient:

$$\left| Q_{n+1} - Q_n \right| < 0.001 \; (Q_{n+1}) \qquad \text{(III-5)}$$

After a solution for d_1 and Q is reached, the procedure is repeated for the next pipe or channel downstream, Q becoming Q_i for that element.

PIPE/CHANNEL SIZING

A pipe or channel in a drainage system can be either sized by the Drainage Design Program or set by the user at a fixed size. If a fixed size is set and the capacity is exceeded during the simulation, DRAIN prints a surcharge volume history to show the severity of the problem. Such an approach may be useful in analyzing existing systems, parts of systems, or cases where a certain pipe size must be used or retained. When the user wants a pipe or channel to be sized he must set initial starting dimensions. Since the program can not decrease the dimensions of a pipe or channel being sized, it is wise to use the smallest size desired as a starting point. During execution, DRAIN checks to see if the capacity of any pipe being sized is exceeded. If this occurs, the following algorithms are used.

Pipe Sizing

When a pipe is being sized, the flow-routing algorithm described above estimates the angle θ, shown in Figure III-2, at the end of each time step. This angle, $\theta_{t + \Delta t}$, where t is the time and Δt is the time step, is a function of the volume of flow at this time, $V_{t + \Delta t}$. If during the time step the pipe capacity (defined in Figure III-2 as θ_f = 2.62 radians) is exceeded, the pipe is resized using the continuity equation:

$$\frac{\Delta V}{\Delta t} = Q_i - Q_o \qquad \text{(III-6)}$$

where

Δt = time step (sec);
ΔV = change in the volume of flow over Δt (ft^3);
Q_i = inflow to the pipe during Δt (cfs); and
Q_o = outflow from the pipe during Δt (cfs).

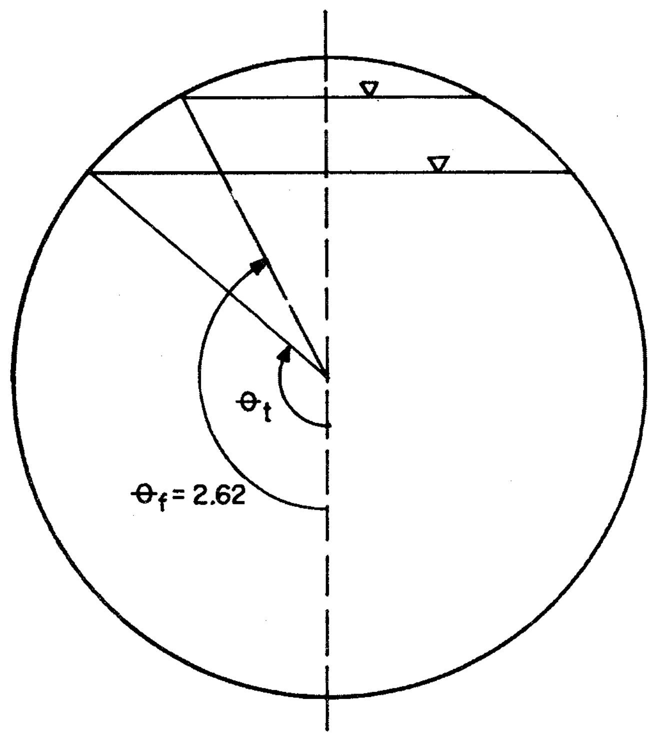

FIGURE III-2. Pipe Hydraulic Conditions at Time t

ΔV is represented as the difference between the volume of flow at the beginning (V_t) and the end ($V_{t+\Delta t}$) of the time step, and Q_o is the average of the outflow at the beginning (Q_t) and the end ($Q_{t+\Delta t}$) of the time step. Now if we assume that $V_{t+\Delta t} = V_{cr}$, the capacity volume of the pipe at its old dimensions, we can rewrite Equation III-6 as:

$$\frac{V_{cr} - V_t}{\Delta t} = Q_i - \frac{Q_t + Q_{t+\Delta t}}{2} \qquad \text{(III-7)}$$

Since continuity must be maintained, the outflow from the resized pipe, Q_e, must equal $Q_{t+\Delta t}$. Solving Equation III-7 for Q_e, then, gives:

$$Q_e = 2Q_i - Q_t - 2\frac{V_{cr} - V_t}{\Delta t} \qquad \text{(III-8)}$$

Q_e can then be used in the Manning equation to determine the new pipe diameter D_e:

$$D_e = 4\,\frac{Q_e}{4\pi K}^{3/8} \qquad \text{(III-9)}$$

where

$$K = \frac{1.49\ S^{1/2}}{n} \qquad \text{(III-10)}$$

Open Channel Sizing

The program can also be used to determine the bottom width of trapezoidal channels so that the channels have sufficient capacity to carry the routed flow. The user-specified side slopes and full depth of the channel are not altered by the sizing algorithm, described below.

For a given width trapezoidal open channel, the continuity equation as written in Equation III-6 is again used. Consider a trapezoidal open channel of width W as shown in Figure III-3. For a given depth d, the flow area, the wetted perimeter and the flow in the channel may be determined by the following equations:

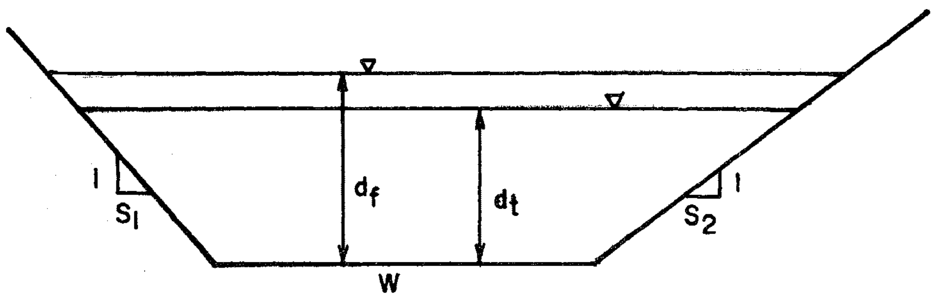

FIGURE III-3. Trapezoidal Open Channel Hydraulic Conditions at Time t

$$A = Wd + \frac{1}{2}(S_1 + S_2)d^2 \qquad \text{(III-11)}$$

$$WP = [\sqrt{1 + S_1^2} + \sqrt{1 + S_2^2}]\, d + W \qquad \text{(III-12)}$$

$$Q = \frac{1.49}{n} S^{1/2} R_h^{2/3} A = K R_h^{2/3} A \qquad \text{(III-13)}$$

where

$K = \frac{1.49}{n} S^{1/2}$

S_1 = reciprocal side slope 1 (ft/ft)

S_2 = reciprocal side slope 2 (ft/ft)

W = channel width (ft)

WP = wetted perimeter

The flow routing procedure described above estimates $d_{t+\Delta t}$ and hence $Q_{t+\Delta t}$ for the open channel. If $d_{t+\Delta t}$ is greater than d_f (i.e., the capacity of the channel is exceeded), then the channel sizing algorithm, using the equations for channel hydraulics given above, is employed. The new bottom width cannot be determined directly; therefore, the sizing algorithm employs the Newton-Raphson iterative technique to solve for the new width.

QUALITY ROUTING

The Drainage Design Program has the capability of routing total suspended solids and associated pollutants through pipes and channels as conservative constituents. A mass balance for each pipe or channel can be written:

$$\frac{dM}{dt} = \sum_{i=1}^{n} s_i \qquad \text{(III-14)}$$

where

M = the total mass of pollutant in the pipe or channel

s_i = a flux of pollutant mass into or out of the pipe or channel

n = the number of mass fluxes associated with the pipe or channel.

If we further define

$$M = \forall\, C \qquad \text{(III-15)}$$

where

$\forall$ = the volume of water in the pipe or channel

C = the concentration of pollutant

and

$$\frac{dM}{dt} = \frac{d(\forall C)}{dt} = C\,\frac{d\forall}{dt} + \forall\,\frac{dC}{dt} \qquad \text{(III-16)}$$

or

$$\forall\,\frac{dC}{dt} = \sum_{i=1}^{n} s_i - C\,\frac{d\forall}{dt} \qquad \text{(III-17)}$$

For simplicity, let $dC/dt = \dot{C}$ and $d\forall/dt = \dot{\forall}$. Equation III-34 becomes

$$\forall\dot{C} = \sum_{i=1}^{n} s_i - C\,\dot{\forall} \qquad \text{(III-18)}$$

To achieve an integration of Equation III-18 with respect to time, we shall make the following assumption concerning the behavior of concentration in time:

$$C_{t+\Delta t} = C_t + \frac{\Delta t}{2}\left(\dot{C}_t + \dot{C}_{t+\Delta t}\right) \qquad \text{(III-19)}$$

where

C_t, $C_{t+\Delta t}$ = pollutant concentration at a time, t, and at a later time $t+\Delta t$.

$\dot{C}_t$, $\dot{C}_{t+\Delta t}$ = the rate of change of concentration at times t and $t+\Delta t$, respectively.

Solving Equation III-19 for $\dot{C}_{t+\Delta t}$ we obtain:

$$\dot{C}_{t+\Delta t} = \frac{2}{\Delta t} C_{t+\Delta t} - (\frac{2}{\Delta t} C_t + \dot{C}_t) \quad \text{(III-20)}$$

In the general case, C_t and $\dot{C}_t$ are known from initial conditions or the previous time step and can be treated as constants. Accordingly, we shall define:

$$\beta = \frac{2}{t} C_t + \dot{C}_t \quad \text{(III-21)}$$

$$\alpha = \frac{2}{\Delta t} \quad \text{(III-22)}$$

which substituted in Equation III-20 give:

$$\dot{C}_{t+\Delta t} = \alpha C_{t+\Delta t} - \beta \quad \text{(III-23)}$$

Equations III-18 and III-23 can be combined as follows:

$$\dot{C}\forall + \forall (\alpha C - \beta) = \sum_{i=1}^{n} s_i \quad \text{(III-24)}$$

or

$$\dot{C}\forall + C\alpha\forall - \beta\forall = \sum_{i=1}^{n} s_i \quad \text{(III-25)}$$

The term $\sum_{i=1}^{n} s_i$ may contain several mass inflows and generally contains one mass outflow, QC, from the pipe or channel. This being the case, Equation III-25 is finally written as:

$$\dot{C}\forall + C\alpha\forall - \beta\forall = \sum_{i=1}^{n} s_i - QC \quad \text{(III-26)}$$

This equation can be solved for the concentration at the end of the time step Δt in the form:

$$C = \frac{\sum_{i=1}^{n} s_i + \beta \forall}{\dot{\forall} + \alpha \forall + Q} \qquad \text{(III-27)}$$

Equation III-27 is the form used in the quality routing and is solved sequentially for each pipe or channel. The outflow from each pipe or channel becomes the inflow to the next.

OUTFALL TREATMENT

Facilities for removal of suspended solids at system outfalls can be simulated with program DRAIN. Suspended solid removal efficiencies are assumed to be a function of flow and to obey the following equations:

$$R = R_{max} \quad \text{when} \quad Q \leq Q_{min} \qquad \text{(III-28)}$$

$$R = aQ^{-b} \quad \text{when} \quad Q > Q_{min} \qquad \text{(III-29)}$$

where

R = suspended solids removal fraction

Q = flow rate through the treatment device (cfs)

a,b = design constants (a,b>o)

The variation of treatment efficiency is as shown in Figure III-4. The user specifies two points on the treatment curve-(Q_{min}, R_{max}) and (Q_2, R_2) where $Q_2 > Q_{min}$. The following equations are then employed to compute a and b above from the two specified points:

$$a = \sqrt{R_2 R_{max} Q_{min}{}^b Q_2{}^b} \qquad \text{(III-30)}$$

$$b = \frac{\ln\left(\frac{R_{max}}{R_2}\right)}{\ln\left(\frac{Q_2}{Q_{min}}\right)} \qquad \text{(III-31)}$$

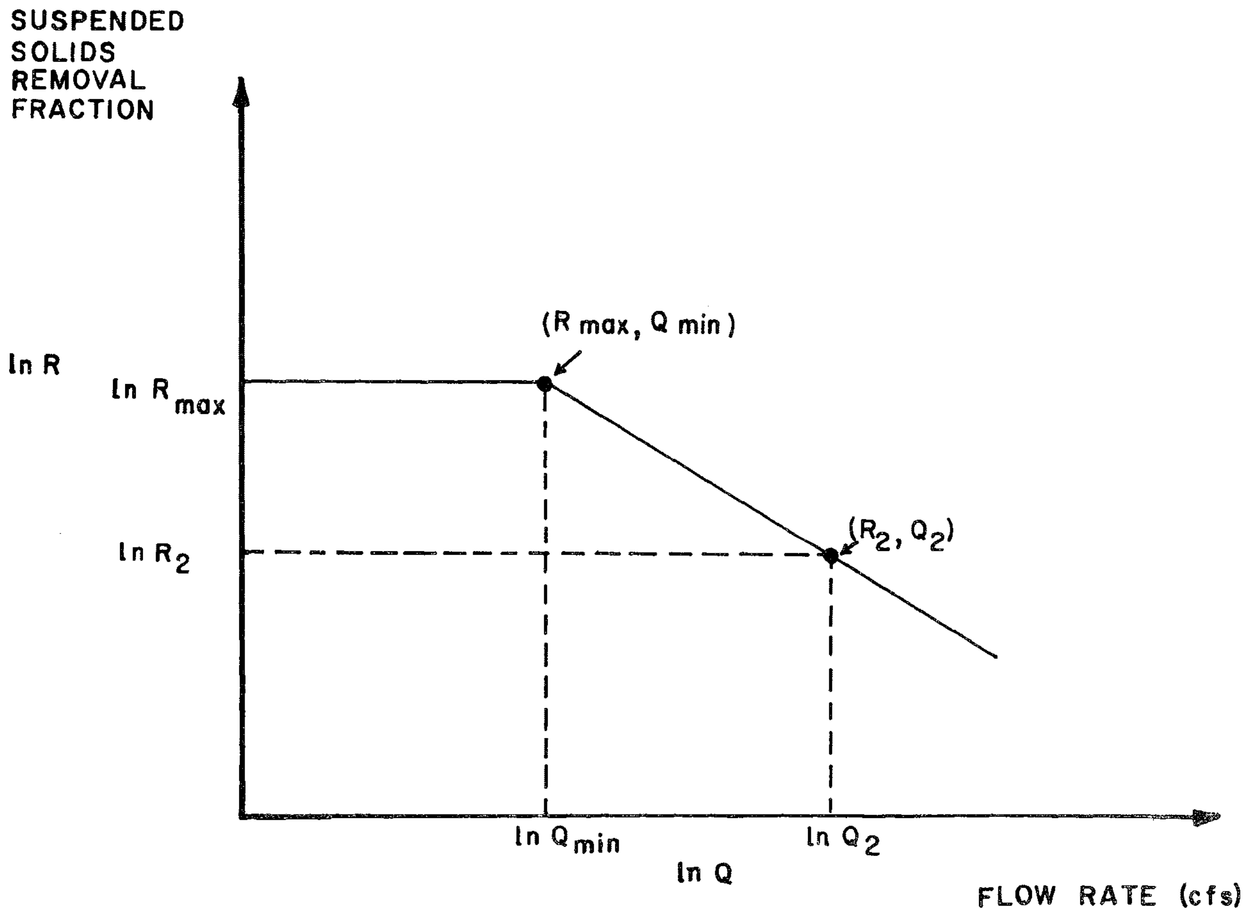

FIGURE III-4. Suspended Solids Treatment Device Operating Curve

When $Q \leq Q_{min}$, the removal efficiency is taken as R_{max}. When $Q > Q_{min}$, the removal efficiency is found with Equation III-29, using the constants calculated as shown above.

CHAPTER IV

USER'S MANUAL

This chapter of the report serves as a user's manual for the Drainage Design Program. The first section of the chapter is devoted to a detailed presentation of the input requirements of the program. The second section presents a description of the computer program itself, including flowcharts and Fortran listings of all the subroutines. Finally, an example problem is presented as the last section of the chapter.

INPUT REQUIREMENTS

The Drainage Design Program requires as input a series of cards describing the hydraulic and geometric characteristics of the major drainage systems. Also required as input is the inlet hydrograph/pollutograph file generated by the Surface Runoff Program, described in a separate documentation report. The input data cards required and the formats in which the data must be supplied are presented in Table IV-1. Input data are divided into the following five card groups:

- Card Group One: Simulation Control Data
- Card Group Two: Channel Data
- Card Group Three: Pipe Data
- Card Group Four: Outfall Data
- Card Group Five: Output Control Data

Following are discussions of the data required in each card group. The user should refer to the text below for clarification of any input item in Table IV-1 that is not self-explanatory.

TABLE IV-1

PROGRAM DRAIN INPUT DATA REQUIREMENTS

Card Group	Format	Card Column	Description	Variable Name	Default Value
			SIMULATION CONTROL CARDS		
1A	2I10	1-10	Inlet Hydrograph File Number	JTAPE(1)	-
		11-20	Print File Number (scratch file)	JTAPE(2)	-
1B	20A4	1-80	Title Information (2 Cards)	TITLE	-
1C	I5	1-5	Basin Number	BASIN	-
	I5	6-10	Number of Time Steps Simulated	NSTEP	-
	I3	11-13	Start Hour	NHR	-
	I2	14-15	Start Minute	NMN	-
	F5.1	16-20	Time Step Length (Minutes)	DELT	-
1D	2I5	1-5	Design Option (1=Do not design) (2=Design and rerun)	NOPT	-
		6-10	Units Option (0=British units) (1=Metric units)	IMET	0
			CHANNEL CARDS		
		Repeat Card Group 2 for Each Open Channel Drainage Element			
2A	I8	1-8	Channel Number	NAMEG(N)	-
	I8	9-16	Downstream Pipe or Channel Number	NGTO(N)	-
	I8	17-24	Resize Option (+1 = Resize this channel) (-1 = Do not resize)	NGP(N)	-
	I5,1X	33-37	Station 1 (Hundreds of ft or m)	ISTA1A(N)	-
	I2	39-40	Station 1 (Tens and units ft or m)	ISTA1B(N)	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	I5,1X	41-45	Station 2 (Hundreds of ft or m)	ISTA2A(N)	-
	I2	47-48	Station 2 (Tens and units ft or m)	ISTA2B(N)	-
	2X,F10.0	51-60	Station 1 Elevation (ft or m)	ELEVA1(N)	
	F10.0	61-70	Station 2 Elevation (ft or m)	ELEVA2(N)	-
2B	5F10.0	1-10	Reciprocal Side Slope 1	GS1(N)	
		11-20	Reciprocal Side Slope 2	GS2(N)	-
		21-30	Channel Width (ft or m)	GWIDTH(N)	-
		31-40	Manning Roughness Coefficient	GN(N)	-
		41-50	Maximum Depth (ft or m)	DFULL(N)	-
		This card group must be terminated with two blank cards. If there are no channels to be simulated, then two blank cards must be supplied.			
		PIPE CARDS			
		Repeat Card Group 3 for Each Pipe Drainage Element			
3	3I8	1-8	Pipe Number	NAMEG(N)	-
		9-16	Downstream Pipe or Channel Number	NGTO(N)	-
		17-24	Resize Option (+2 = Resize this pipe) (-2 = Do not resize)	NPG(N)	
	2(I5,1X,I2)	25-29	Station 1 (Hundreds of ft or m)	ISTA1A(N)	-
		31-32	Station 1 (Tens and units ft or m)	ISTA1B(N)	-
		33-37	Station 2 (Hundreds of ft or m)	ISTA2A(N)	-

TABLE IV-1

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
		39-40	Station 2 (Tens and units ft or m)	ISTA2B(N)	-
	5F8.0	41-48	Station 1 Elevation (ft or m)	ELEVA1(N)	-
		49-56	Station 2 Elevation (ft or m)	ELEVA2(N)	-
		57-64	Pipe Diameter (ft or m)	GWIDTH(N)	-
		65-72	Manning Roughness Coefficient	GN(N)	.014
		This card group must be terminated by a single blank card. If there are no pipes to be simulated, one blank card must be supplied.			
			OUTFALL CARDS		
		Supply Card Group 4 at each outfall for which treatment occurs. If quality is not to be simulated or no outfall treatment facilities are to be simulated, skip Card Group 4.			
4	I5	1-5	Outfall Number	NME	-
	F10.0	6-15	Maximum SS Removal Percentage (at Q1)	PRR1	-
	F10.0	16-25	Minimum flow Q1 (cfs or cms)	Q1	-
	F10.0	26-35	SS Removal Percentage (at Q2)	PRR2	-
	F10.0	36-45	Flow Q2 (cfs or cms)	Q2	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			OUTPUT CONTROL CARDS		
5A	2I5	1-5	Number of Pipes and Channels for which Flows are to be Printed (maximum of 100)	NPRNT	-
		6-10	Number of Time Steps Between Printings	INTERV	-
			If NPRNT = 0, Skip Card 5B		
5B	16I5	1-5	Pipe and Channel Numbers for which Flows are to be Printed	IPRNT(1)	-
		6-10	⋮	IPRNT(2)	-
		11-15		IPRNT(3)	-
		⋮		⋮	
				IPRNT (NPRNT)	-

Card Group One: Simulation Control Data

Card Group One consists of five cards that specify several control variables and select several options of the program.

Card Group 1A identifies the unit numbers on the user's computer system corresponding to the two disc files used by the program. The first file is the inlet hydrograph file, which should be generated with the Surface Runoff Program and saved for access by this program. The second file is a scratch file used for interim storage of output. The user may require the assistance of an operator of his computer system to properly identify these unit numbers.

Card Group 1B consists of two cards used to identify the run. The user should supply an appropriate two-line title here.

Card Group 1C is a single card used to identify several control variables. The first variable BASIN is an optional variable with which the user may supply a basin number, if this type of identifier is used. The second variable, NSTEP, gives the number of time steps in the simulation. Generally, the user should specify a simulation period greater than the duration of the storm event so that the entire runoff event will be computed. The next two variables are used to specify the clock time at which the simulation starts. If the storm event being simulated is not an historical event, this start time may be selected arbitrarily. The last variable on this card, DELT, is the time step length in minutes. This time step should be the same time step used in computing the inlet hydrographs with the Surface Runoff Program.

Card Group 1D is a single card used to select two options of the program. The first variable NOPT is used to select the basic design option of the program. If NOPT is set equal to one, the program will not size any pipes and channels, but will only route runoff through the major drainage system as input by the user. If NOPT is set equal to two, then the program will size the pipes and channels of the major drainage system and route flows through the system so designed. (Under this option, the user may specify individual pipe and open channel elements that are not to be sized; the discussion of Card Groups Two and Three below explains how this can be done.)

The second option selected with Card Group 1D is the units option. If IMET is set equal to zero, the British system of units is used; if IMET is set equal to one, the metric system of units is used. Note that the same system of units used in the Surface Runoff Program to generate the inlet hydrographs must also be used in the Drainage Design Program.

Card Group Two: Channel Cards

Card Group Two is used to describe the hydrogeometric characteristics of the open channels of the major drainage system. Two cards must be supplied for each open channel element.

Card Group 2A gives nine variables required for each open channel. The first variable, NAMEG(N), is the external number used to identify the channel. (The user should identify the channels being simulated with a consecutive numbering scheme that he finds convenient.) Note that each open channel element that is to receive an inlet hydrograph from the Surface Runoff Program should have the same external number as the corresponding inlet in the Surface Runoff Program simulation and that there must be either an open channel or a pipe for every inlet simulated in Program SRO. If one of these inlets does not empty into the drainage system being simulated, then a dummy channel or pipe must be set up using the same external number and emptying to a dummy outfall.

The second variable on Card Group 2A NGTO(N) is the identifying external number of the next downstream pipe or channel element. (If NAMEG(N), the open channel element being described, is the last channel upstream of an outfall, then the user should assign an identifying number to the outfall itself with NGTO(N).)

The third variable, NPG(N), tells the program whether or not to resize this open channel. If NPG(N) is set equal to +1, then the program will resize this channel. If NPG(N) is set equal to -1, then this channel will not be resized. Note that the design option on Card Group 1D must be selected (NOPT = 2) if any of the open channels are to be resized.

The next four variables on Card Group 2A give the highway stations of the upstream and downstream ends of the channel element. These stations are used in the program to calculate the length of the channel element. In the special case where one or more of the channel elements run perpendicular to the centerline of the highway, the user will need to employ a stationing scheme other than the highway stationing to denote the length of these particular channels. (Distance to the left or right of the centerline is generally a convenient alternate scheme.) The last two variables on Card Group 2A give the upstream and downstream elevations of the channel. These elevations are used in the program only to calculate the channel slope.

Card Group 2B specifies five additional characteristics of the open channel. The first two variables give the reciprocal side slopes of the channel (horizontal : vertical). The next variable is the bottom width of the channel. For channels that are to be sized, an arbitrary non-zero initial width must be specified here. (One foot is a reasonable choice.) The last two variables are the Manning roughness coefficient and the full depth of the channel.

Card Group Three: Pipe Cards

Card Group Three consists of a single card for each pipe element to be simulated; eleven variables must be specified on each card.

The first variable, NAMEG(N), is the external number used to identify the pipe, assigned according to a consecutive numbering scheme selected by the user. As with channels, each pipe element that is to receive an inlet hydrograph from the Surface Runoff Program must have the same external number as the corresponding inlet in the Surface Runoff Program. The second variable on this card, NGTO(N), is the external number of the next downstream pipe or channel. (Outfalls should be identified with NGTO(N), as explained above for Card Group Two.) The third variable tells the program whether or not to resize this pipe. If NPG(N) is set equal to +2, this pipe will be resized. If NPG(N) is set equal to -2, then this pipe will not be resized. Again, note that the design option on Card Group 1D must be selected (NOPT=2) if any pipes are to be resized.

The next four variables give the stations of the upstream and downstream ends of the pipe. As with channels, these stations are used in the program to calculate the length of the pipe element. In those instances where one or more of the pipe elements run perpendicular to the centerline of the highway, the user will have to rely on a stationing scheme other than the highway stationing to denote the length of these particular pipes. (Again, distance to the left or right of the centerline is generally a convenient scheme.)

The next two variables on the card give the elevation of the upstream and downstream ends of the pipe. These elevations are only used by the program to calculate the slope of the pipe element. Following these two elevations is the pipe diameter GWIDTH(N). If the pipe is to be resized, an arbitrary non-zero initial diameter must be specified here. (One foot has proven to be a reasonable initial value.) The last variable on this card is the Manning roughness coefficient for the pipe.

Card Group Four: Outfall Cards

Card Group Four is supplied only if a runoff treatment facility is to be simulated at one or more system outfalls. One card is to be supplied for each outfall at which the treatment occurs. The efficiency of the treatment device is assumed to be a function of flow, as described in Chapter III. (Equations III-28 and III-29 and Figure III-4).

The first variable on Card Group Four is the external number of the outfall channel or outfall pipe. (The outfall must have been previously identified in either Card Group Two or Three.) The remaining four variables on this card are the coordinates of the two points that define the flow-treatment efficiency relationship shown in Figure III-4.

Card Group Five: Output Control Cards

Card Group Five allows the user to select those pipes and channels for which full hydrographs (and full pollutographs when quality is simulated) are to be printed out. The first variable on Card Group 5A, NPRNT, is the total number of pipes and channels for which hydrographs (and pollutographs) are to be output. The second variable is the number of time steps between printings of hydrograph values.

If no hydrographs are to be output (i.e., NPRNT = 0 on Card Group 5A), then Card Group 5B should not be supplied. Otherwise, the pipe and channel numbers for which hydrographs are to be output should be given with Card Group 5B, 16 values per card, as many cards as are required.

Note that the program will automatically print out an echo of the input data, a tabulation of the designed pipes and channels, and a summary of peak hydraulic conditons in the system. This basic output is not affected by Card Group Five.

PROGRAM DESCRIPTION

General Structure

Program DRAIN is structured into a main program and seven subroutines - Subroutine HYDRO, Subroutine RHYDRO, Subroutine GUTTER, Subroutine GQUAL, Subroutine NEWDIA, Subroutine SUMSTAT, and Subroutine RECAP.

The interrelationships among these units are illustrated in Figure IV-1. The main program DRAIN controls the computational sequence. The primary function of each routine is as follows:

- Subroutine HYDRO - Controls the time and space sequencing of the hydraulic and quality computations
- Entry HYDRO2 (in Subroutine HYDRO) - Controls the repetition of the hydraulic and quality computations for the resized system
- Subroutine RHYDRO - Reads all input data required for the simulation
- Entry RHYDRO2 (in Subroutine RHYDRO) - Sets up output tape files
- Subroutine GUTTER - Performs hydraulic computations in each pipe and channel for each time step
- Subroutine GQUAL - Performs quality computations in each pipe and channel for each time step
- Subroutine NEWDIA - Resizes pipe diameter for each pipe to be resized as necessary
- Entry NEWWID (in Subroutine NEWDIA) - Computes new width for each trapezoidal channel to be resized as necessary
- Entry NEWPRT (in Subroutine NEWDIA) - Prints resized hydraulic elements and performs system reinitialization
- Subroutine SUMSTAT - Prints hydraulic response in design summary form
- Subroutine RECAP - Prints detailed hydraulic and quality drainage element time responses

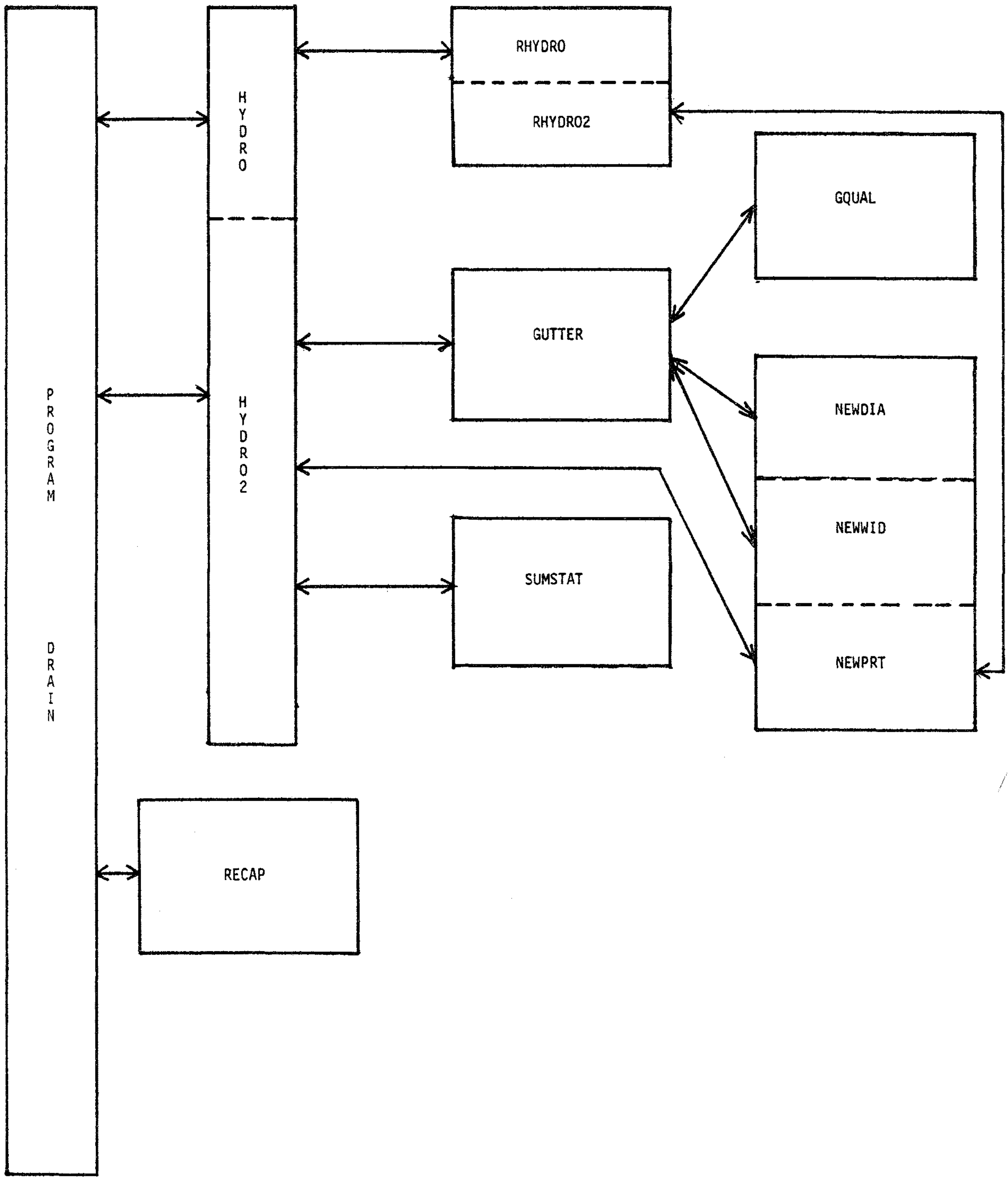

FIGURE IV-1. Program DRAIN General Structure

The main program and each of these routines is discussed in turn below. A complete definition of all common block variables is given at the end of the chapter.

Main Program DRAIN

The following routines are called from the main program:

- Subroutine HYDRO
- Entry HYDRO2
- Subroutine RECAP

The computational sequence is controlled by the main program. Subroutine HYDRO is called to control the hydraulic computations during pass one. Quality is not considered on this pass. Entry HYDRO2 is called to control the hydraulic and quality routing functions during pass two after the necessary pipes and open channels have been sized during the first pass. Subroutine RECAP is called to print detailed hydraulic and quality responses within individual drainage elements. BLOCK DATA is called prior to execution to perform variable initialization. Two disc or tape files are employed: the surface runoff transfer file and a print file. File numbers are read and assigned in the main program. The flowchart for main program DRAIN is presented in Figure IV-2 followed by the computer listing.

Subroutine HYDRO

HYDRO calls the following routines:

- GUTTER
- NEWPRT
- RHYDRO
- SUMSTAT

All of the above subroutines except RHYDRO are also called in Entry HYDRO2.

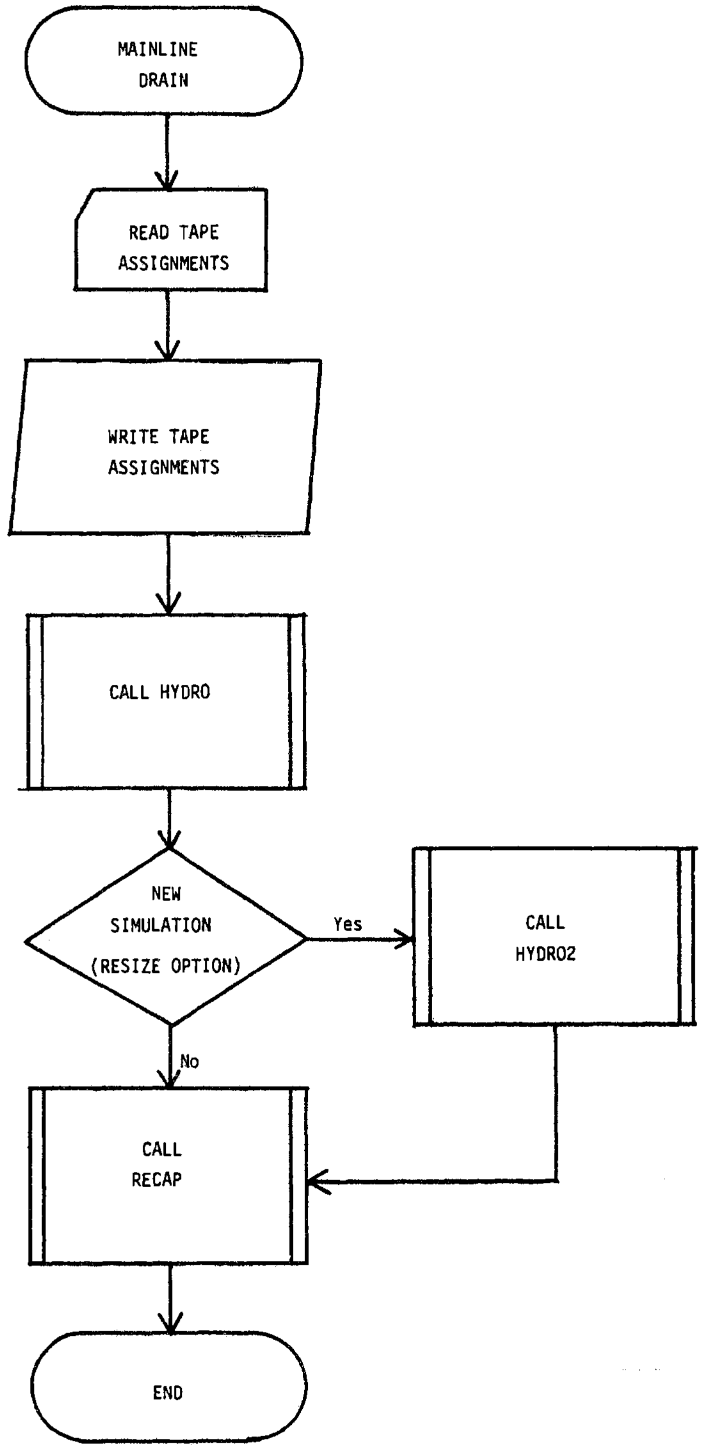

FIGURE IV-2. Flowchart of Mainline DRAIN

```
      PROGRAM DRAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,TAPE8,
     2 TAPE9,TAPE10)
C***********************************************************************
C          DRAINAGE DESIGN PROGRAM
C          FHWA URBAN HIGHWAY STORM DRAINAGE MODEL
C***********************************************************************
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON/RESIZ/NOPT,NEWSIZ,NEW(200),OLDWID(200)
      N5=5
      N6=6
      WRITE(N6,2999)
2999  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,4H****,32X,4H****,8X,
     4*CAMP DRESSER AND MCKEE             */* *,*WASHINGTON, D.C.*,28X,4H
     5****,4X,*DRAINAGE DESIGN PROGRAM*,5X,4H****,8X,*ANNANDALE, VIRGINI
     6A*)
C
C******** READ AND WRITE TAPE ASSIGNMENTS
C
      READ(N5,5010) (JTAPE(J),J=1,3)
      WRITE(N6,6010) (JTAPE(J),J=1,3)
5010  FORMAT(6I10)
6010  FORMAT(////10X,*TAPE ASSIGNMENTS*//
     2 2X,* RUNOFF     PRINT     PLOT*,/,
     3 2X,*  INPUT      FILE     FILE*,/,
     4 I7,2I10)
      CALL HYDRO
      IF(NEWSIZ.EQ.2) CALL HYDRO2
      CALL RECAP
      WRITE(N6,6020)
6020  FORMAT(1H1/// 30X,*........DRAINAGE SIMULATION ENDED NORMALLY.....
     2.....*)
      STOP
      END
```

The following common blocks are employed in both Subroutine HYDRO and Entry HYDRO2:

- BLANK COMMON
- TAPES
- ABLK
- RESIZ
- MAX

Subroutine HYDRO initializes hydraulic variables for the first pass and calls Subroutine RHYDRO to read all necessary input data. From this point on, Subroutine HYDRO and Entry HYDRO2 contain exactly the same statements. Subroutine HYDRO statements are employed during the first pass. If the sizing option is selected, a new simulation (second pass) is made to simulate the hydraulic and quality response of the resized system and a call to Entry HYDRO2 is made in the main program. For each time step in both the first and second passes, the surface runoff transfer file is read to obtain inlet inflow and mass influx information. Subroutine GUTTER is called to perform hydraulic and supervise quality computations in each drainage element. All outfall flows are next summed for use in the continuity balance. A continuity check is made on the hydraulic computation and the results printed to flag the design engineer of any computational problems. If the drainage system has been resized and a second simulation is to be performed, Entry NEWPRT is called to print the resized drainage elements and the routine is exited. Subroutine SUMSTAT is next called to print the simulation results in the form of a design summary.

The flow chart for Subroutine HYDRO and Entry HYDRO2 is presented in Figure IV-3. All key variables are included in the above listed common areas. A listing of these routines follows.

Subroutine RHYDRO

No routines are called from RHYDRO. The following common blocks are employed in the routines:

- TAPES
- BLANK COMMON

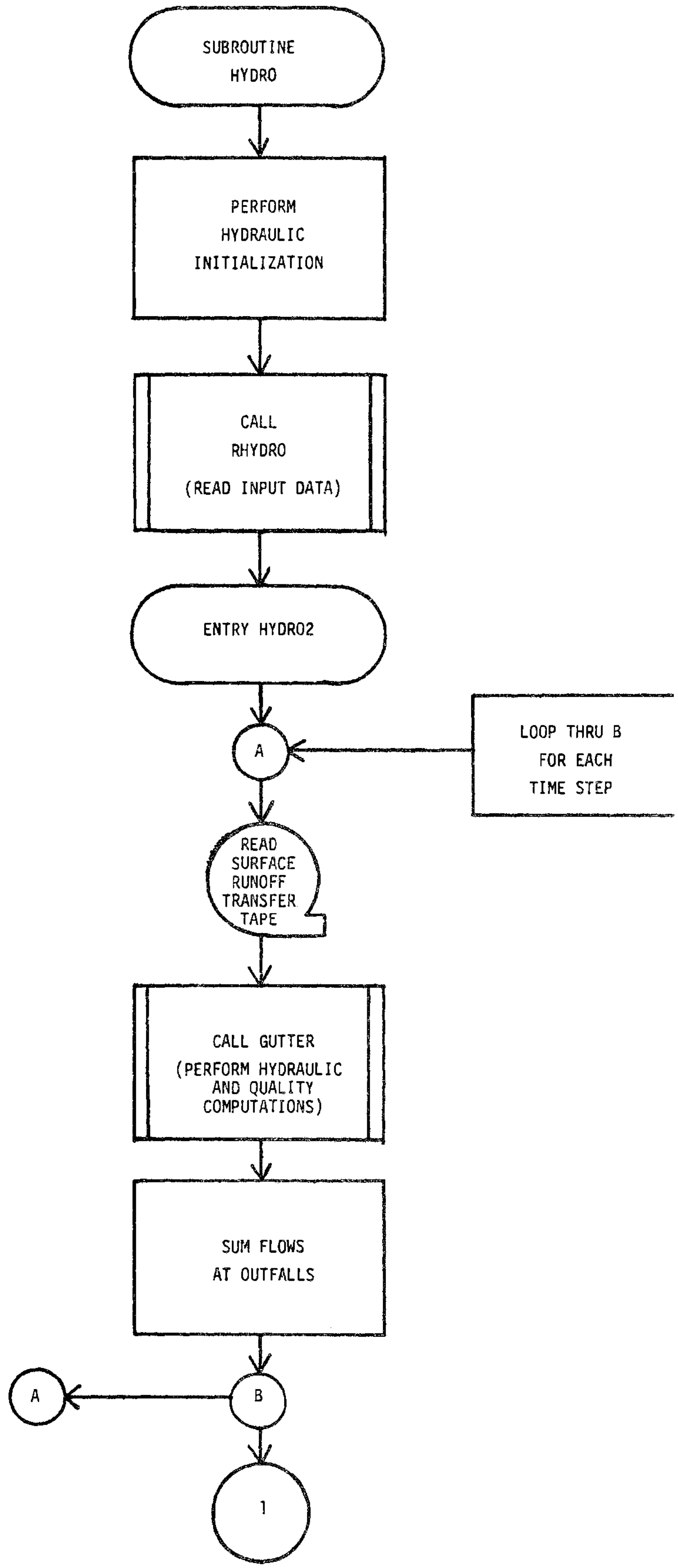

FIGURE IV-3. Flowchart of Subroutine HYDRO and Entry HYDRO2

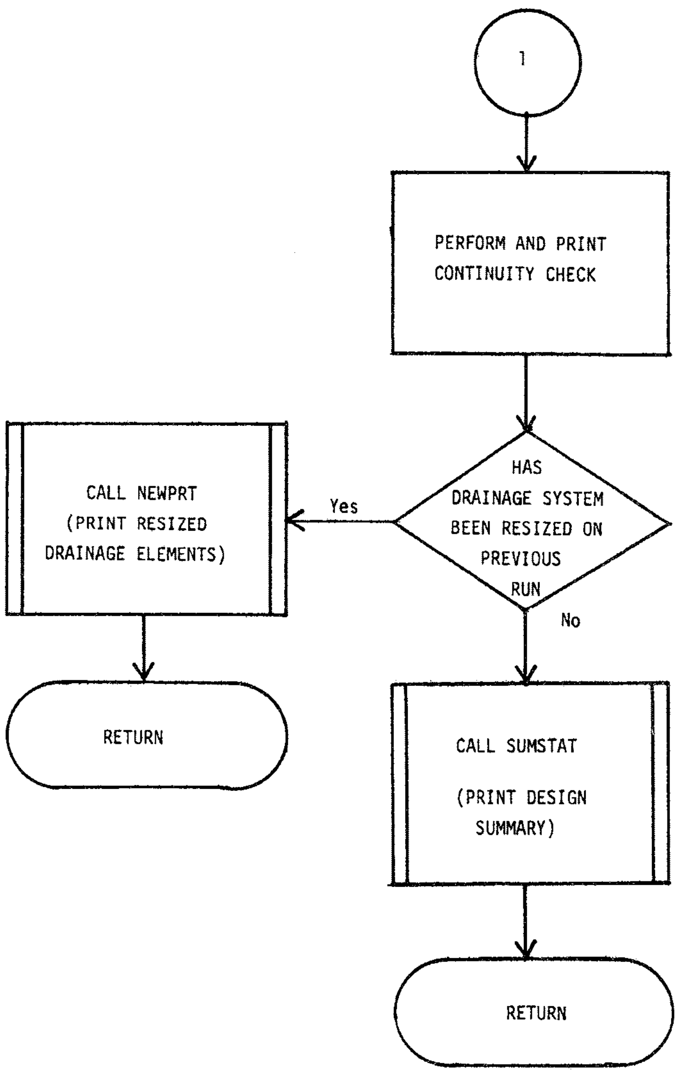

Figure IV-3
(Continued)

```
      SUBROUTINE HYDRO
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT,TITLE(40),IPLOT(200),ICODE(25),NPLOT
      COMMON HGRAPH(200),HTIME(200)
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON/ABLK/ NQS,
     2             C(200,5),CDOT(200,5),POFF(200,13),QFACT(5,13)
      COMMON/INFIL/ RAININ(200),DEPIN(200)
      COMMON/RESIZ/ NOPT,NEWSIZ,NEW(200),OLDWID(200)
      COMMON/MAX/ MAXFLW(200),MAXHR(200),MAXMIN(200),MAXDEP(200),
     2SURLEN(200)
      REAL MAXFLW,MAXDEP
      INTEGER BASIN
C
C******** INITIALIZATION
C
      NW=200
      NG=200
      NING=200
      NRANVL=200
      NIN=10
      INTCNT=0
      DO 4000 I=1,200
      MAXFLW(I)=0.0
      MAXHR(I)=0
      MAXMIN(I)=0
      MAXDEP(I)=0.0
4000  SURLEN(I)=0.0
      DO 220 I=1,NW
      RAININ(I)=0.0
      WFLOW(I)=0.0
      WWIDTH(I)=0.
      WDEPTH(I,1)=0.
      WDEPTH(I,3)=0.
220   WDEPTH(I,2)=0.
      DO 240 I=1,NG
      NPG(I)=0
      NGUT(I)=0.
      QSUR(I)=0.0
      DELD(I)=0.0
      QIN(I)=0.0
      GFLOW(I)=0.0
      GDEPTH(I)=0.
240   GLEN(I)=0.
      DO 250 J=1,NING
250   NGTOI(J)=0
```

```
      DO 260 J=1,NIN
      NWTOI(J)=0
      DO 260 I=1,NG
      NWTOG(I,J)=0
260   NGTOG(I,J)=0
      DO 280 I=1,NRANVL
      HGRAPH(I)=0.
      HTIME(I)=0.
      DO 280 J=1,10
280   RAIN(I,J)=0.
      SUMR=0.0
      SUMI=0.0
      SUMOFF=0.0
      SUMST=0.0
C
C******** CALL INPUT SUBROUTINE
C
      CALL RHYDRO(BASIN)
      TIME=TZERO
      NTX=JTAPE(1)
C
C******** CALCULATE INLET HYDROGRAPHS
C
      ENTRY HYDRO2
      M=(NSTEP+99)/100
      I=1
      HTIME(1)=TZERO/3600.
      DO 440 II=1,NSTEP,M
      I=I+1
      DO 430 IJ=1,M
      TIME=TIME+DELT
      TIME2=TIME-DELT2
      HTIME(I)=TIME/3600.
C
C******** READ SURFACE RUNOFF PROGRAM INPUT TAPE
C
      IF(NQS.GT.0) GO TO 500
      READ(NTX) T2,(WFLOW(N),N=1,NOW)
      GO TO 505
500   READ(NTX) T2,(WFLOW(N),N=1,NOW),((POFF(K,N),N=1,5),K=1,NOW)
505   DO 510 N=1,NOW
      IF(IMET.EQ.1) WFLOW(N)=WFLOW(N)*35.31
510   SUMR=SUMR+WFLOW(N)*DELT
C
C******** GUTTER ELEMENTS
C
      IF(NOG.GT.0) CALL GUTTER
340   CONTINUE
C
C******** HYDROGRAPH CONSTRUCTION
C
      HGRAPH(I)=0.0
C
C**** SUM INLET FLOWS OVER THE BASIN
380   IF(NOG.EQ.0) GO TO 420
      DO 400 JK=1,NING
      IF(NGTOI(JK).EQ.0) GO TO 420
```

```
      NX=NGTOI(JK)
400   HGRAPH(I)=HGRAPH(I)+GFLOW(NX)
420   CONTINUE
C
C**** SUM FOR CONTINUITY CHECK
      SUMOFF=SUMOFF+HGRAPH(I)*DELT
430   CONTINUE
440   CONTINUE
C
C**** CONTINUITY CHECK
      ERROR=(SUMR-SUMOFF)*100./SUMR
      WRITE(N6,9000) K6,SUMR,K6,SUMOFF,ERROR
9000  FORMAT(*1*,*TOTAL INFLOW  *,A5,1X,E12.6//
     2* TOTAL OUTFLOW  *,A5,1X,E12.6//
     3* ERROR IN CONTINUITY, PERCENTAGE OF INFLOW, *,F10.5)
C
C******** CLOSE OUTPUT FILES
C
      NT1=JTAPE(2)
      IF(NT1.LT.1) GO TO 470
      IEOF=-1
      IF(IMET.LT.1) GO TO 7030
      DO 7010 N=1,NPRINT
      OUTFLW(N)=OUTFLW(N)/35.31
 7010 CONTINUE
 7030 CONTINUE
      WRITE(NT1) IEOF,IEOF,(OUTFLW(N),N=1,NPRNT)
470   CONTINUE
C
C******** OUTPUT
C******** PRINT OUT RESIZED PIPES
C
      IF(NEWSIZ.NE.1) GO TO 475
      CALL NEWPRT(0,0.,0.)
      RETURN
475   CONTINUE
      CALL SUMSTAT
      RETURN
      END
```

- NEW
- REMOVE
- ABLK
- RESIZE
- NEWGUT

All input data necessary for program execution are read in Subroutine RHYDRO. If the drainage system is to be resized, a return is made to HYDRO prior to entering Entry RHYDR2, since it is not necessary to set up output tape files during the first pass. All key variables are contained in the above common blocks. The flowchart is given in Figure IV-4 followed by the computer listing.

Subroutine GUTTER

The following routines are called from GUTTER:

- GQUAL
- NEWDIA
- NEWWID

Gutter employs the following common blocks:

- TAPES
- BLANK COMMON
- ABLK
- NEW
- RESIZ
- MAX

Subroutines GUTTER loops through each drainage element. Elements may be of two types: trapezoidal open channels and pipes. Inputs to each drainage element are summed, and the change in depth within the element during the current time step is computed using a Newton-Raphson technique. A check is made to see if the maximum or full depth in the element has been exceeded. If this is the case and the given element is to be resized, the appropriate routines are called depending on the element type to perform the resizing.

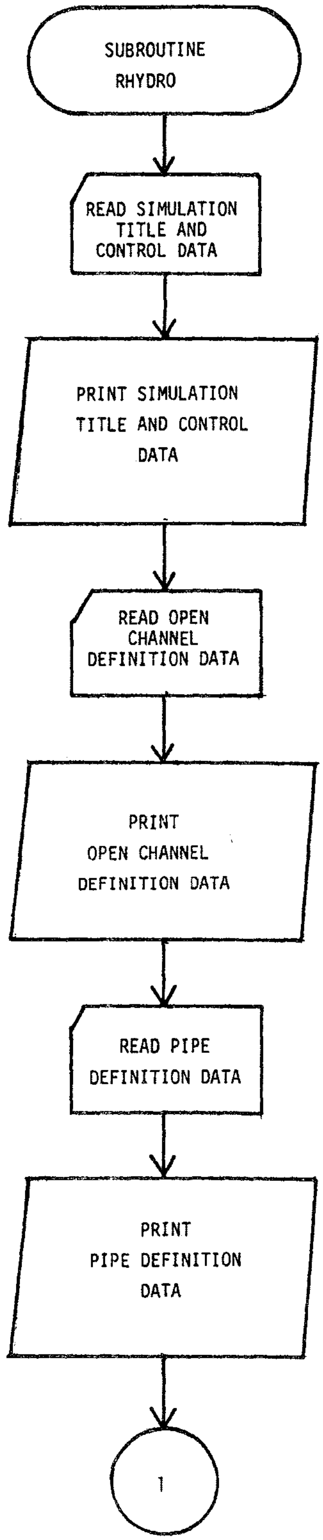

FIGURE IV-4. Flowchart of Subroutine RHYDRO and Entry RHYDR2

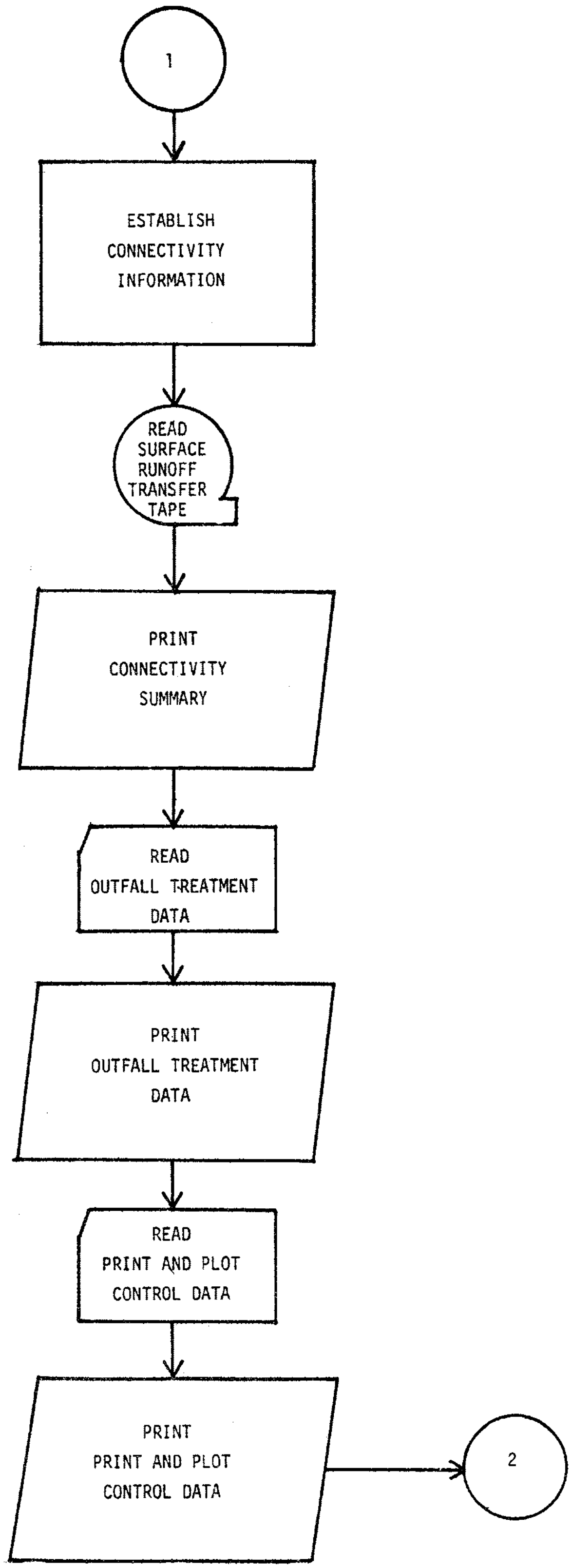

Figure IV-4
(Continued)

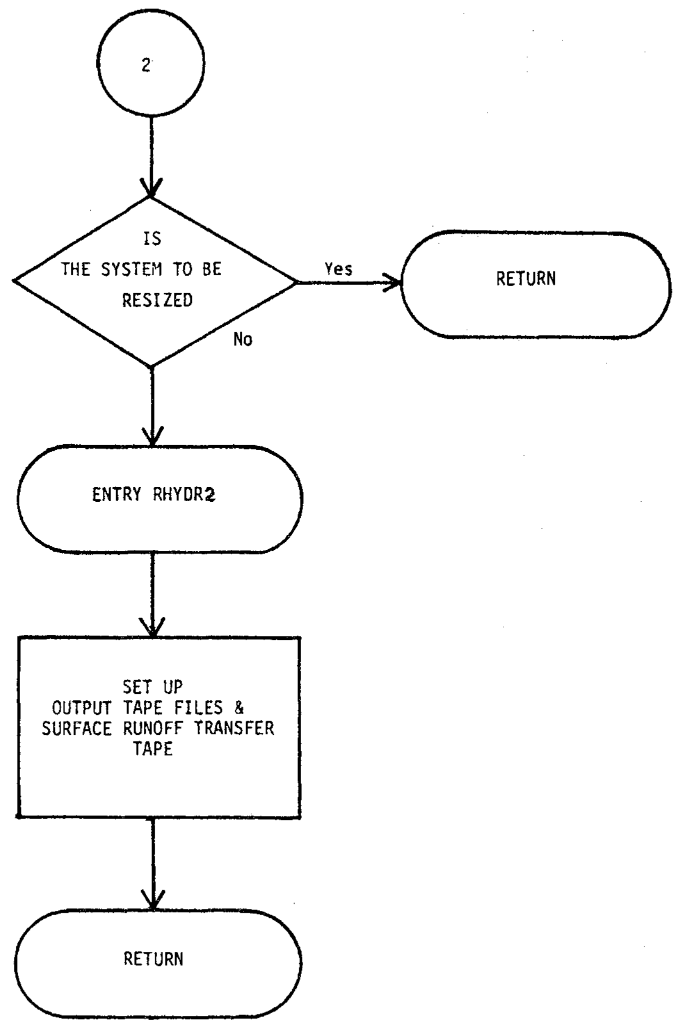

Figure IV-4
(Continued)

```
      SUBROUTINE RHYDRO(BASIN)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT,TITLE(40),IPLOT(200),ICODE(25),NPLOT
      COMMON/ABLK/ NQS,
     2             C(200,5),CDOT(200,5),POFF(200,13),QFACT(5,13)
      COMMON/REMOVE/ PRRA(50),PRRB(50),QMIN(50)
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON/NEW/ NAMEG(200),NGTO(200)
      COMMON/INFIL/ RAININ(200),DEPIN(200)
      COMMON/RESIZ/ NOPT,NEWSIZ,NEW(200),OLDWID(200)
      COMMON/NEWGUT/ NOGUTTR,XSLOPE(200),INTYP(200),ISTA1A(200),
     2ISTA1B(200),ISTA2A(200),ISTA2B(200),ELEVA1(200),ELEVA2(200),
     3MGTO(200)
C
C******** GENERAL INFORMATION
C
      NDIM=200
      DO 210 N=1,NDIM
210   OUTFLW(N)=0.0
      READ(N5,1005) TITLE
1005  FORMAT(20A4)
      READ(N5,1000) BASIN,NSTEP,NHR,NMN,DELT
1000  FORMAT(2I5,I3,I2,F5.1)
      TZERO=3600.*FLOAT(NHR)+60.*FLOAT(NMN)
C
C******* SET UNITS FOR OUTPUT TABLES
C
      IF(IMET.EQ.1) GO TO 7200
      K1=4H(IN)
      K2=4H(FT)
      K3=7H(FT/FT)
      K4=5H(FPS)
      K5=5H(CFS)
      K6=5H(FT3)
      GO TO 7210
7200  K1=4H(CM)
      K2=3H(M)
      K3=5H(M/M)
      K4=5H(CMS)
      K5=5H(CMS)
      K6=4H(M3)
7210  CONTINUE
C
C******** READ DRAINAGE CHANNEL RESIZE CONTROL
C******** NOPT=1 - DO NOT RESIZE
C******** NOPT=2 - RESIZE INPUT SYSTEM AND RERUN
```

```
C
C
      READ(N5,1000) NOPT,IMET
      NEWSIZ=0
      IF(NOPT.EQ.2) NEWSIZ=1
      WRITE(N6,2999)
2999  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,4H****,32X,4H****,8X,
     4*CAMP DRESSER AND MCKEE          */* *,*WASHINGTON, D.C.*,28X,4H
     5****,4X,*DRAINAGE DESIGN PROGRAM*,5X,4H****,8X,*ANNANDALE, VIRGINI
     6A*)
      WRITE(N6,4000) TITLE
4000  FORMAT(///* *,24X,20A4/* *,24X,20A4)
      WRITE(N6,4001)
4001  FORMAT(////* *,46(1H-),* GENERAL INPUT / OUTPUT INFORMATION *,46(1
     2H-))
      WRITE(N6,4002) N5,N6,BASIN,NSTEP,DELT
4002  FORMAT(///////////////* *,50X,*CARD READER UNIT NO. (N5)=*,I2/*0*,5
     22X,*PRINTER UNIT NO. (N6)=*,I2/*0*,52X,*BASIN NUMBER (BASIN)=*,I3/
     3*0*,47X,*NUMBER OF TIME STEPS (NSTEP)=*,I4/*0*,39X,*INTEGRATION TI
     4ME INTERVAL IN MINUTES (DELT)=*,F6.2)
      IF(NOPT.EQ.1) WRITE(N6,4003) NOPT
      IF(NOPT.EQ.2) WRITE(N6,4004) NOPT
4003  FORMAT(*0*,34X,*PIPE RESIZE OPTION (NOPT)=*,I2,* - DO NOT RESIZE T
     2HE INPUT SYSTEM*)
4004  FORMAT(*0*,37X,*PIPE RESIZE OPTION (NOPT)=*,I2,* - RESIZE THE INPU
     2T SYSTEM*)
      DELT=DELT*60.
      DELT2=DELT/2.
      ICHK=1
      NOGUTTR=0
C
C********* READ GUTTER INFORMATION
C
      DO 480 N=1,NG
      IF((N/39*39).EQ.N) GO TO 4020
4021  READ(N5,1115) NAMEG(N),NGTO(N),NPG(N),INTYP(N),ISTA1A(N),ISTA1B(N)
     2,ISTA2A(N),ISTA2B(N),ELEVA1(N),ELEVA2(N),XSLOPE(N),GS1(N),GS2(N),
     3GWIDTH(N),GN(N),DFULL(N),GLEN(N)
1115  FORMAT(4I8,2(I5,1X,I2),2X,3F10.0/6F10.0)
      IF(IMET.LT.1) GO TO 7000
      ISTA1A(N)=ISTA1A(N)*3.281
      ISTA1B(N)=ISTA1B(N)*3.281
      ISTA2A(N)=ISTA2A(N)*3.281
      ISTA2B(N)=ISTA2B(N)*3.281
      ELEVA1(N)=ELEVA1(N)*3.281
      ELEVA2(N)=ELEVA2(N)*3.281
      GWIDTH(N)=GWIDTH(N)*3.281
      DFULL(N)=DFULL(N)*3.281
      GLEN(N)=GLEN(N)*3.281
7000  CONTINUE
      IF(NAMEG(N).EQ.0) GO TO 4020
      IF(GN(N).EQ.0.0) GN(N)=0.014
      IF(N.GT.1.AND.XSLOPE(N).EQ.0.0.AND.GS2(N).EQ.0.0) XSLOPE(N)=XSLOPP
      IF(XSLOPE(N).NE.0.0) GO TO 4013
      GO TO 4014
```

```
4013  GS1(N)=0.0
      GS2(N)=1/XSLOPE(N)
      GWIDTH(N)=0.0
      XSLOPP=XSLOPE(N)
C
C******** CALCULATE GUTTER LENGTH AND GRADE SLOPE
C
4014  IF(GLEN(N).GT.0.0) GO TO 4070
      GLEN(N)=ABS((ISTA2A(N)-ISTA1A(N))*100.0+(ISTA2B(N)-ISTA1B(N)))
4070  GSLOPE(N)=ABS((ELEVA2(N)-ELEVA1(N))/GLEN(N))
      IF(N.EQ.1.OR.(N/39*39).EQ.N) GO TO 4016
      GO TO 4017
C
C******** PRINT GUTTER/CHANNEL DATA
C
4016  WRITE(N6,2999)
      WRITE(N6,4018)
4018  FORMAT(//* *,42X,*INPUT DATA FOR ABOVE-GROUND GUTTERS/CHANNELS*/*
     2*,42X,44(*=*)//)
      WRITE(N6,4019) K2,K2,K3
4019  FORMAT(* *,18X,*CONNECTED TO*,8X,*INLET*,52X,*ELEVATION*,14X,*GRAD
     2E*/* *,4X,*GUTTER*,9X,*GUTTER/PIPE*,9X,*TYPE*,12X,*STATIONS*,12X,
     3*LENGTH*,16X , A4 , 17X,*SLOPE*/* *,4X,*NUMBER*,11X,*NUMBER*,12X,
     4*NO.*,11X,*1*,10X,*2*,11X , A4 , 9X,*UPSTREAM*,2X,*DOWNSTREAM*,
     5    8X , A7 /* *,4X,6(*-*),8X,12(*-*),8X,5(*-*),8X,16(*-*),8X,
     66(*-*),8X,20(*-*),8X,7(*-*)/)
      IF(IMET.LT.1) GO TO 7010
      ISTA1A(N)=ISTA1A(N)/3.281
      ISTA1B(N)=ISTA1B(N)/3.281
      ISTA2A(N)=ISTA2A(N)/3.281
      ISTA2B(N)=ISTA2B(N)/3.281
      GLEN(N)=GLEN(N)/3.281
      ELEVA1(N)=ELEVA1(N)/3.281
      ELEVA2(N)=ELEVA2(N)/3.281
7010  CONTINUE
4017  WRITE(N6,4025) NAMEG(N),NGTO(N),INTYP(N),ISTA1A(N),ISTA1B(N),
     2ISTA2A(N),ISTA2B(N),GLEN(N),ELEVA1(N),ELEVA2(N),GSLOPE(N)
4025  FORMAT(* *,5X,I4,13X,I4,14X,I1,10X,I4,*+*,I2,2X,I4,*+*,I2,8X,F6.1,
     28X,F8.3,3X,F8.3,9X,F7.3)
      MGTO(N)=NGTO(N)
      GO TO 480
4020  MN=N-1
      IF(MN.EQ.0) GO TO 4015
      WRITE(N6,2999)
      WRITE(N6,4031)
4031  FORMAT(///* *,36X,*INPUT DATA FOR ABOVE-GROUND GUTTERS/CHANNELS (C
     2ONTINUED)*/* *,36X,56(*=*)//)
      WRITE(N6,4032) K3,K3,K2,K2,K4,K5
4032  FORMAT(* *,22X,*CROSS*,13X,*TRAPEZOIDAL CHANNEL*,12X,*MAXIMUM*/* *
     2,7X,*GUTTER*,9X,*SLOPE*,10X,*SLOPES * , A7 , 6X,*WIDTH*,10X,
     3*DEPTH*,9X,*MANNINGS*,8X,*V FULL*,8X,*Q FULL*/* *,7X,*NUMBER*,8X,
     4     A7 , 10X,*LEFT*,4X,*RIGHT*,7X , A4 , 11X , A4 , 13X,*N*,12X,
     5   A5 , 9X , A5 , /* *,7X,6(*-*),8X,7(*-*),8X,27(*-*),8X,7(*-*),
     68X,8(*-*),8X,6(*-*),8X,6(*-*)/)
      DO 4040 NN=ICHK,MN
C
C******** COMPUTE V FULL AND Q FULL
```

```
C
      GA=DFULL(NN)*(GWIDTH(NN)+0.5*DFULL(NN)*(GS1(NN)+GS2(NN)))
      GP=GWIDTH(NN)+DFULL(NN)*(SQRT(1.0+GS1(NN)**2)+SQRT(1.0+GS2(NN)**2)
     2)
      GR=GA/GP
      GV=1.486/GN(NN)*SQRT(GSLOPE(NN))*GR**0.666667
      GQ=GA*GV
      IF(XSLOPE(NN).NE.0.0) GS2(NN)=0.0
      IF(IMET.LT.1) GO TO 7020
      GWIDTH(NN)=GWIDTH(NN)/3.281
      DFULL(NN)=DFULL(NN)/3.281
      GV=GV/3.281
      GQ=GQ/35.31
7020  CONTINUE
      WRITE(N6,4033) NAMEG(NN),XSLOPE(NN),GS1(NN),GS2(NN),GWIDTH(NN),
     2DFULL(NN),GN(NN),GV,GQ
4033  FORMAT(* *,8X,I4,9X,F7.3,8X,F7.3,2X,F7.3,4X,F7.3,8X,F7.3,9X,F6.3,
     28X,F6.2,9X,F6.2)
      IF(IMET.LT.1) GO TO 7030
      ISTA1A(N)=ISTA1A(N)*3.281
      ISTA1B(N)=ISTA1B(N)*3.281
      ISTA2A(N)=ISTA2A(N)*3.281
      ISTA2B(N)=ISTA2B(N)*3.281
      GLEN(N)=GLEN(N)*3.281
      ELEVA1(N)=ELEVA1(N)*3.281
      ELEVA2(N)=ELEVA2(N)*3.281
      GWIDTH(NN)=GWIDTH(NN)*3.281
      DFULL(NN)=DFULL(NN)*3.281
      GV=GV*3.281
      GQ=GQ*35.31
7030  CONTINUE
      IF(XSLOPE(NN).NE.0.0) GS2(NN)=1/XSLOPE(NN)
C
C******** SET KEY FOR GUTTERS/CHANNELS THAT WILL NOT BE RESIZED
C
      IF(NPG(NN).GT.0) GO TO 310
      NPG(NN)=(-1)*NPG(NN)
      NEW(NN)=-1
310   OLDWID(NN)=GWIDTH(NN)
      IF(DFULL(NN).LE.0.0) DFULL(NN)=10.0
      GCON(NN)=(1.486/GN(NN))*SQRT(GSLOPE(NN))
4040  CONTINUE
      IF(NAMEG(N).EQ.0) GO TO 4015
      ICHK=N
      GO TO 4021
480   CONTINUE
C
C******** READ PIPE DATA
C
4015  NOGUTTR=N-1
      WRITE(N6,1151) NOGUTTR
1151  FORMAT(//* *,45X,*TOTAL NUMBER OF GUTTERS/CHANNELS=*,I4)
      NOGUTR=N
      DO 4050 N=NOGUTR,NG
      READ(N5,4051) NAMEG(N),NGTO(N),NPG(N),ISTA1A(N),ISTA1B(N),
     2ISTA2A(N),ISTA2B(N),ELEVA1(N),ELEVA2(N),GWIDTH(N),GN(N),GLEN(N)
4051  FORMAT(3I8,2(I5,1X,I2),5F8.0)
```

```
      IF(IMET.LT.1) GO TO 7040
      ISTA1A(N)=ISTA1A(N)*3.281
      ISTA1B(N)=ISTA1B(N)*3.281
      ISTA2A(N)=ISTA2A(N)*3.281
      ISTA2B(N)=ISTA2B(N)*3.281
      ELEVA1(N)=ELEVA1(N)*3.281
      ELEVA2(N)=ELEVA2(N)*3.281
      GWIDTH(N)=GWIDTH(N)*3.281
      DFULL(N)=DFULL(N)*3.281
      GLEN(N)=GLEN(N)*3.28181
7040  IF(NAMEG(N).EQ.0) GO TO 500
      IF(GN(N).EQ.0.0) GN(N)=0.014
      INTYP(N)=0
      XSLOPE(N)=0.0
      GS1(N)=0.0
      GS2(N)=0.0
      DFULL(N)=0.0
C
C******** CALCULATE PIPE LENGTH AND SLOPE
C
      GLEN(N)=ABS((ISTA2A(N)-ISTA1A(N))*100.0+(ISTA2B(N)-ISTA1B(N)))
      GSLOPE(N)=ABS((ELEVA2(N)-ELEVA1(N))/GLEN(N))
C
C******** COMPUTE V FULL AND Q FULL
C
      GA=0.7854*GWIDTH(N)**2
      GP=3.14159*GWIDTH(N)
      GR=GA/GP
      GV=1.486/GN(N)*SQRT(GSLOPE(N))*GR**0.666667
      GQ=GA*GV
C
C******** PRINT PIPE DATA
C
      IF(N.EQ.NOGUTR.OR.((N-NOGUTR)/38*38).EQ.(N-NOGUTR)) GO TO 4052
      GO TO 4053
4052  WRITE(N6,2999)
      WRITE(N6,4054)
4054  FORMAT(///* *,44X,*INPUT DATA FOR UNDERGROUND DRAINAGE PIPES*/* *,
     244X,41(*=*)//)
      WRITE(N6,4055) K2,K2,K3,K2,K4,K5
4055  FORMAT(* *,10X,*CONNECTED TO*,24X,*      *,6X,*CROWN ELEVATIONS*,
     27X,*GRADE*,6X,*PIPE*/* *,1X,*PIPE*,6X,*PIPE/OUTLET*,8X,*STATIONS*,
     38X,*LENGTH*,12X , A4 , 13X,*SLOPE*,5X,*DIAM.*,4X,*MANNINGS*,4X,
     4*V FULL*,4X,*Q FULL*/* *,*NUMBER*,7X,*NUMBER*,9X,*1*,10X,*2*,7X,
     5  A4 ,5X,*UPSTREAM*,2X,*DOWNSTREAM* , 4X , A7 , 5X , A4 , 8X ,
     6*N* , 8X , A5 , 5X , A5  /* *,6(*-*),4X,12(*-*),4X,16(*-*),4X,
     76(*-*),4X,20(*-*),4X,7(*-*),4X,5(*-*),4X,8(*-*),4X,6(*-*),4X,
     86(*-*)/)
      IF(IMET.LT.1) GO TO 7050
      ISTA1A(N)=ISTA1A(N)/3.281
      ISTA1B(N)=ISTA1B(N)/3.281
      ISTA2A(N)=ISTA2A(N)/3.281
      ISTA2B(N)=ISTA2B(N)/3.281
      GLEN(N)=GLEN(N)/3.281
      ELEVA1(N)=ELEVA1(N)/3.281
      ELEVA2(N)=ELEVA2(N)/3.281
      GWIDTH(N)=GWIDTH(N)/3.281
```

```
      DFULL(N)=DFULL(N)/3.281
      GV=GV/3.281
      GQ=GQ/35.31
7050  CONTINUE
4053  WRITE(N6,4056) NAMEG(N),NGTO(N),ISTA1A(N),ISTA1B(N),ISTA2A(N),
     2ISTA2B(N),GLEN(N),ELEVA1(N),ELEVA2(N),GSLOPE(N),GWIDTH(N),
     3GN(N),GV,GQ
4056  FORMAT(* *,1X,I5,7X,I5,8X,I4,*+*,I2,2X,I4,*+*,I2,4X,F6.1,4X,F8.3,
     23X,F8.3,5X,F7.3,4X,F5.2,5X,F6.3,5X,F6.2,5X,F6.2)
      IF(IMET.LT.1) GO TO 7055
      ISTA1A(N)=ISTA1A(N)*3.281
      ISTA1B(N)=ISTA1B(N)*3.281
      ISTA2B(N)=ISTA2B(N)*3.281
      ISTA2A(N)=ISTA2A(N)*3.281
      GLEN(N)=GLEN(N)*3.281
      ELEVA1(N)=ELEVA1(N)*3.281
      ELEVA2(N)=ELEVA2(N)*3.281
      GWIDTH(N)=GWIDTH(N)*3.281
      DFULL(N)=DFULL(N)*3.281
      GV=GV*3.281
      GQ=GQ*35.31
7055  CONTINUE
      MGTO(N)=NGTO(N)
C
C******** SET KEY FOR PIPES THAT WILL NOT BE RESIZED
C
      IF(NPG(N).GT.0) GO TO 4057
      NPG(N)=NPG(N)*(-1)
      NEW(N)=-1
4057  OLDWID(N)=GWIDTH(N)
      DFULL(N)=2.62
      GCON(N)=(1.486/GN(N))*SQRT(GSLOPE(N))
4050  CONTINUE
C
C******** SET UP GUTTER CONNECTIVITY TABLES
C
500   NOG=N-1
      NOGUTR=NOG-NOGUTTR
      WRITE(N6,1150) NOGUTR,NOG
1150  FORMAT(//* *,51X,*TOTAL NUMBER OF PIPES=*,I4/* *,40X,*TOTAL NUMBER
     2 OF CHANNELS AND PIPES=*,I4)
      INLETS=0
      DO 390 N=1,NOG
      NN=NOG+INLETS
      DO 350 NGOTO=1,NN
      IF(NGTO(N).EQ.NAMEG(NGOTO)) GO TO 370
350   CONTINUE
C
C******** CREATE DUMMY GUTTERS AS NEEDED
C
      INLETS=INLETS+1
      NGOTO=NOG+INLETS
      IF(NGOTO.GT.NG) GO TO 440
      NAMEG(NGOTO)=NGTO(N)
      NPG(NGOTO)=3
      NGTOI(INLETS)=NGOTO
370   CONTINUE
```

```
      DO 380 J=1,NIN
      IF(NGTOG(NGOTO,J).GT.0) GO TO 380
      NGTOG(NGOTO,J)=N
      GO TO 390
380   CONTINUE
390   CONTINUE
      GO TO 510
C
C******** ERROR IN DATA
C
440   WRITE(N6,1130) NGOTO,NG
1130  FORMAT(*  ERROR - - THE ASSIGNED GUTTER NUMBERS *,I5,*WHICH INCLUD
     2E DUMMIES EXCEED THE COMMON STORAGE BLOCK*,I5)
      STOP
510   CONTINUE
C
C******** ORDER THE GUTTER SYSTEM
C
      NOGS=NOG+INLETS
      DO 800 N=1,NOG
      DO 790 NN=1,NOGS
      IF(NAMEG(NN).NE.NGTO(N)) GO TO 790
      NGTO(N)=NN
      GO TO 800
790   CONTINUE
800   CONTINUE
      KOUNT=0
      NINLET=1
      NTRY=1
810   IF(NGTOG(NTRY,1).EQ.0) GO TO 820
      NTRY=NGTOG(NTRY,1)
      GO TO 810
820   DO 920 KOUNT=1,NOG
      NGUT(KOUNT)=NTRY
      NTRY=NGTO(NTRY)
      NDUM=NTRY
83    NGSAVE=0
      DO 86 J=1,10
      IF(NGTOG(NTRY,J).EQ.0) GO TO 870
      DO 84 JJ=1,KOUNT
      IF(NGTOG(NTRY,J).EQ.NGUT(JJ)) GO TO 86
84    CONTINUE
      NGSAVE=NGTOG(NTRY,J)
      IF(NGSAVE.NE.NDUM) GO TO 86
      WRITE(N6,85) NAMEG(NGSAVE)
85    FORMAT(* *,*       ERROR     CHANNEL  *,I6 ,* LOOPS BACK ON ITSELF*)
      STOP
86    CONTINUE
870   CONTINUE
      IF(NGSAVE.EQ.0) GO TO 880
      NTRY=NGSAVE
      GO TO 83
880   IF(NTRY.LE.NOG) GO TO 920
      K=NOG+NINLET
      NGUT(K)=NTRY
      NINLET=NINLET+1
      IF(K.NE.NOGS) GO TO 890
```

```
      GO TO 930
890   CONTINUE
      DO 910 L=1,NOG
      IF(NGTOG(L,1).GT.0) GO TO 910
      DO 900 LL=1,KOUNT
      IF(NGUT(LL).EQ.L) GO TO 910
900   CONTINUE
      NTRY=L
      GO TO 920
910   CONTINUE
920   CONTINUE
930   CONTINUE
C
C******** READ SURFACE RUNOFF PROGRAM INPUT TAPE
C
      NTX=JTAPE(1)
      REWIND NTX
      READ(NTX) TITLE
      READ(NTX) NSTP,NOW,NQS,D1,D2,D3
      IF(IMET.EQ.1) D3=D3*2.471
      READ(NTX) (NGTO(K),K=1,NOW)
      IF(NQS.GT.0) GO TO 1060
      READ(NTX) T1,(WFLOW(N),N=1,NOW)
      GO TO 1070
1060  READ(NTX) ((QFACT(L,M),L=1,5),M=1,13)
      READ(NTX) T1,(WFLOW(N),N=1,NOW),((POFF(K,N),N=1,5),K=1,NOW)
1070  IF(NQS.LE.0) WRITE(N6,6010)
      IF(IMET.LT.1) GO TO 7070
      DO 7060 N=1,NOW
7060  WFLOW(N)=WFLOW(N)*35.31
7070  CONTINUE
C
C******** SET UP CONNECTIVITY TABLES
C
      DO 255 N=1,NOW
      NAMEW(N)=NGTO(N)
      NN=NOG+INLETS
      DO 245 NGOTO=1,NN
      IF(NGTO(N).EQ.NAMEG(NGOTO)) GO TO 250
245   CONTINUE
      WRITE(N6,1) NGTO(N)
1     FORMAT(* INLET NUMBER *,I4,*, USED IN THE SURFACE RUNOFF PROGRAM,
1    2IS NOT INCLUDED IN THE DATA SET FOR DRAIN*)
      STOP
250   CONTINUE
C
C**** GUTTER CONNECTION
      DO 240 J=1,NIN
      IF(NWTOG(NGOTO,J).GT.0) GO TO 240
      NWTOG(NGOTO,J)=N
      GO TO 255
240   CONTINUE
255   CONTINUE
C
C**** PRINT CONNECTIVITY SUMMARY
      WRITE(N6,1190)
1190  FORMAT(*1*,*ARRANGEMENT OF INLETS AND CHANNELS/PIPES*//
```

```
     2*        CHANNEL*,5X,*TRIBUTARY CHANNEL/PIPE*,40X,
     3*INLET*,/,7X,*OR PIPE*)
      DO 620 NN=1,NOG
      J=NGUT(NN)
      DO 605 N=1,NIN
      IF(NGTOG(J,N)) 604,606,604
604   INUM=NGTOG(J,N)
      NGTO(N)=NAMEG(INUM)
605   CONTINUE
606   N=N-1
      IF(N) 607,607,608
607   WRITE(N6,1200) NAMEG(J)
      GO TO 609
608   WRITE(N6,1200) NAMEG(J),(NGTO(K),K=1,N)
1200  FORMAT(/I10,5X,10I5)
609   DO 610 N=1,NIN
      IF(NWTOG(J,N)) 611,615,611
611   INUM=NWTOG(J,N)
      NGTO(N)=NAMEW(INUM)
610   CONTINUE
615   N=N-1
      IF(N) 620,620,616
616   WRITE(N6,1230) (NGTO(K),K=1,N)
1230  FORMAT(1H+,74X,10I5)
620   CONTINUE
      WRITE(N6,1240)
1240  FORMAT(*0*,*      OUTFALL*,6X,*TRIBUTARY CHANNELS AND/OR PIPES*)
      DO 640 I=1,INLETS
      N=NGTOI(I)
      JG=0
      JW=10
      DO 630 J=1,NIN
      IF(NGTOG(N,J)) 622,625,622
622   JG=JG+1
      INUM=NGTOG(N,J)
      NGTO(JG)=NAMEG(INUM)
625   IF(NWTOG(N,J)) 627,630,627
627   JW=JW+1
      INUM=NWTOG(N,J)
      NGTO(JW)=NAMEW(INUM)
630   CONTINUE
      WRITE(N6,1200) NAMEG(N)
      IF(JG.GT.0) WRITE(N6,1201) (NGTO(J),J=1,JG)
1201  FORMAT(1H+,15X,10I5)
      IF(JW.GT.10) WRITE(N6,1230) (NGTO(J),J=11,JW)
640   CONTINUE
C
C******** INFO. TO CONTROL INLETS SAVED AND PRINTED
C
      NSAVE=INLETS
      DO 705 J=1,INLETS
      N=NGTOI(J)
      ISAVE(J)=NAMEG(N)
705   CONTINUE
      WRITE(N6,1210) INLETS,(ISAVE(K),K=1,INLETS)
1210  FORMAT(*0*,*HYDROGRAPHS WILL BE STORED FOR THE FOLLOWING*,I5,
     2* OUTFALLS*/(8I10))
```

```
6010  FORMAT(///10X,*.....QUALITY SIMULATION NOT INCLUDED IN THIS RUN...
     2..*)
      WRITE(N6,1720)
1720  FORMAT(///55(1H-),*OUTFALL TREATMENT*,55(1H-),/,36X,*MAXIMUM*,
     216X,*FLOW AT*,14X,*ALTERNATE*,16X,*FLOW AT*,/,36X,*REMOVAL*,
     316X,*MAXIMUM*,15X,*REMOVAL*,16X,*ALTERNATE*,/,14X,*OUTFALL*,
     414X,*EFFICIENCY*,14X,*REMOVAL*,2(14X,*EFFICIENCY*),/,14X,7(1H-),
     514X,10(1H-),14X,7(1H-),2(14X,10(1H-)),/)
      DO 1705 J=1,INLETS
      READ(N5,1721) NME,PRR1,Q1,PRR2,Q2
1721  FORMAT(I5,4F10.0)
      IF(NME.EQ.0) GO TO 650
      WRITE(N6,1722) NME,PRR1,Q1,PRR2,Q2
1722  FORMAT(14X,I5,19X,F5.2,13X,F10.2,17X,F5.2,13X,F10.2)
      IF(IMET.EQ.1) Q1=Q1*35.31
      IF(IMET.EQ.1) Q2=Q2*35.31
      PRR1=PRR1/100.
      PRR2=PRR2/100.
      DO 1706 K=1,INLETS
      N=NGTOI(K)
      IF(NME.EQ.NAMEG(N)) GO TO 1707
1706  CONTINUE
      WRITE(N6,1710) NME
1710  FORMAT(* ERROR - - POLLUTANT REMOVAL RATE SPECIFIED AT OUTFALL*,I6
     1,*, WHICH IS NOT DEFINED*,/,* CHECK INPUT DATA*,/)
      STOP
1707  IF(PRR1.EQ.PRR2) GO TO 1725
      PRRB(K)=ALOG(PRR1/PRR2)/ALOG(Q2/Q1)
      PRRA(K)=SQRT(PRR1*PRR2*(Q1*Q2)**PRRB(K))
      GO TO 1705
1725  PRRB(K)=1.
      PRRA(K)=1.
1705  QMIN(K)=Q1
      WRITE(N6,1726)
1726  FORMAT(//,14X,*NOTE - EFFICIENCIES EXPRESSED AS PERCENTS AND FLOWS
     1 IN CFS*)
650   READ(N5,1204) NPRNT,INTERV
1204  FORMAT(2I5)
      IF(NPRNT.LT.1) GO TO 680
      READ(N5,1205) (IPRNT(K),K=1,NPRNT)
1205  FORMAT(16I5)
      WRITE(N6,1220) (IPRNT(K),K=1,NPRNT)
1220  FORMAT(*1*,*HYDROGRAPHS AND POLLUTOGRAPHS WILL BE LISTED FOR THE F
     2OLLOWING CHANNELS OR INLETS*,//,* LOCATION *,10I10/(10X,10I10))
680   CONTINUE
      READ(N5,1204) NPLOT
      IF(NPLOT.EQ.0) GO TO 690
      READ(N5,1205) (IPLOT(K),K=1,NPLOT)
      READ(N5,1206) (ICODE(K),K=1,25)
      WRITE(N6,1245) (IPLOT(K),K=1,NPLOT)
      WRITE(N6,1250) (ICODE(K),K=1,25)
1206  FORMAT(25I1)
1245  FORMAT(*0*,*HYDROGRAPHS AND POLLUTOGRAPHS WILL BE PLOTTED FOR THE
     2FOLLOWING CHANNELS OR OUTFALLS*//* LOCATION *,10I10/(10X,10I10))
1250  FORMAT(*0*,* PLOT CODES ARE*,/1X,25I2)
690   CONTINUE
      IF(NEWSIZ.EQ.1) RETURN
```

```
C
C******** SET UP OUTPUT FILES
C
      ENTRY RHYDR2
      DO 3000 N=1,NDIM
3000  POFF(N,6)=0.
      NSTP=NSTEP+1
      NQT=NQS
      IF(NQT.EQ.0) NQT=1
      DO 860 J=2,3
      IF(JTAPE(J).LT.1)  GO TO 860
      NTX=JTAPE(J)
      REWIND NTX
      WRITE(NTX) TITLE
      IF(IMET.EQ.1) TAREA=TAREA/2.471
      IF(J.EQ.3) GO TO 850
      WRITE(NTX) NSTP,NPRNT,NQS,DELT,TZERO,TAREA
      WRITE(NTX) (IPRNT(K),K=1,NPRNT)
      XMIN=NMN
      IF(IMET.LT.1) GO TO 7090
      DO 7080 K=1,NPRINT
7080  OUTFLW(K)=OUTFLW(K)/35.31
7090  CONTINUE
      WRITE(NTX) NHR,XMIN,(OUTFLW(K),K=1,NPRNT)
      IF(NQS.GT.0) WRITE(NTX) NHR,XMIN,((POFF(K,6),N=1,NQT),K=1,NPRNT)
      GO TO 860
850   WRITE(NTX) NSTP,NPLOT,NQS,DELT,TZERO,TAREA
      WRITE(NTX) (IPLOT(K),K=1,NPLOT)
      IF(IMET.LT.1) GO TO 7110
      DO 7100 K=1,NPLOT
7100  OUTFLW(K)=OUTFLW(K)/35.31
7110  CONTINUE
      WRITE(NTX) TZERO,(OUTFLW(K),K=1,NPLOT),((POFF(K,6),N=1,NQT),
     2K=1,NPLOT)
  860 CONTINUE
      IF(NPLOT.EQ.0) GO TO 770
      NN=NOG+INLETS
      DO 760 N=1,NPLOT
      DO 750 J=1,NN
      IF(IPLOT(N).EQ.NAMEG(J)) GO TO 755
750   CONTINUE
      WRITE(N6,1260) IPLOT(N)
1260  FORMAT(*  ERROR - - CANNOT MATCH PLOT REQUEST*,I5,* WITH GUTTER*)
      STOP
755   IPLOT(N)=J
760   CONTINUE
770   CONTINUE
      IF(NPRNT.EQ.0) GO TO 1098
      NN=NOG+INLETS
      DO 1090 N=1,NPRNT
      DO 1095 J=1,NN
      IF(IPRNT(N).EQ.NAMEG(J)) GO TO 1096
1095  CONTINUE
      WRITE(N6,1097) IPRNT(N)
1097  FORMAT(*  ERROR - - CANNOT MATCH PLOT REQUEST*,I5,* WITH GUTTER*)
      STOP
1096  IPRNT(N)=J
```

```
1090  CONTINUE
1098  CONTINUE
      NTX=JTAPE(1)
      REWIND NTX
      READ(NTX) TITLE
      READ(NTX) NSTP,NOW,NQS,D1,D2,D3
      IF(IMET.EQ.1) D3=D3*2.471
      READ(NTX) (D1,N=1,NOW)
      IF(NQS.GT.0) GO TO 1080
      READ(NTX) T1,(WFLOW(N),N=1,NOW)
      GO TO 1085
1080  READ(NTX) ((QFACT(L,M),L=1,5),M=1,13)
      READ(NTX) T1,(WFLOW(N),N=1,NOW),((POFF(K,N),N=1,5),K=1,NOW)
1085  CONTINUE
      IF(IMET.LT.1) GO TO 7130
      DO 7120 N=1,NOW
7120  WFLOW(N)=WFLOW(N)*35.31
7130  CONTINUE
      RETURN
      END
```

If the full depth has not been exceeded or if it has and the element is not to be resized, a check is made directly to see if quality is being considered. If so, a call is made to Subroutine GQUAL to perform the conservative quality routing computations. After each drainage element in upstream to downstream order has been considered, a check is made to determine if the drainage system is being resized during this pass. If this is the case, GUTTER is exited. If the system has already been resized on a previous program pass or if it is not to be resized, detailed surcharge results are printed for all pipes and channels in surcharge during the current time step. A print file is also written for subsequent access by Subroutine RECAP and the routine is exited.

The computational sequence is indicated in flowchart form in Figure IV-5. Major variables not contained in the above referenced common blocks are presented in Table IV-2. The computer listing follows.

Subroutine NEWDIA

Subroutine RHYDRO2 is called by Entry NEWPRT in Subroutine NEWDIA. No other routines are called by NEWDIA. The following common blocks are employed in the routine:

- TAPES
- BLANK COMMON
- NEW
- RESIZ
- NEWGUT

Subroutine NEWDIA employs the approach described in Chapter IV for sizing pipes and open channels. Entry NEWPRT is called to print the results of the first pass. Resized drainage elements sizes are printed; for pipes, diameters are corrected to standard sizes and printed again. Parameters for the second pass are initialized, and the revised trapezoidal open channel and pipe sizes printed with revised design flow characteristics. A call is made to Entry RHYDRO2 to reposition the necessary tape files and NEWPRT is exited.

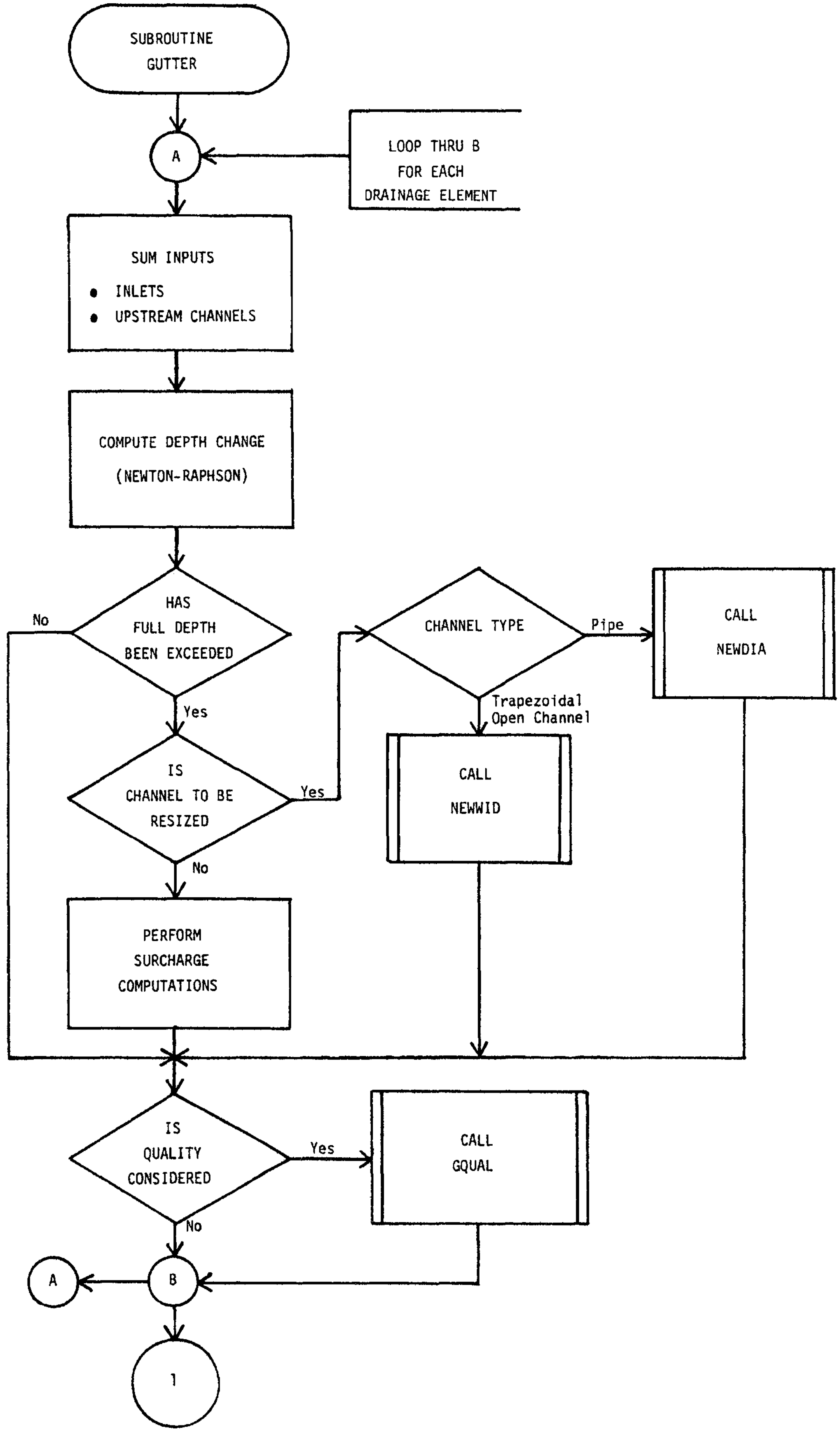

FIGURE IV-5. Flowchart of Subroutine GUTTER

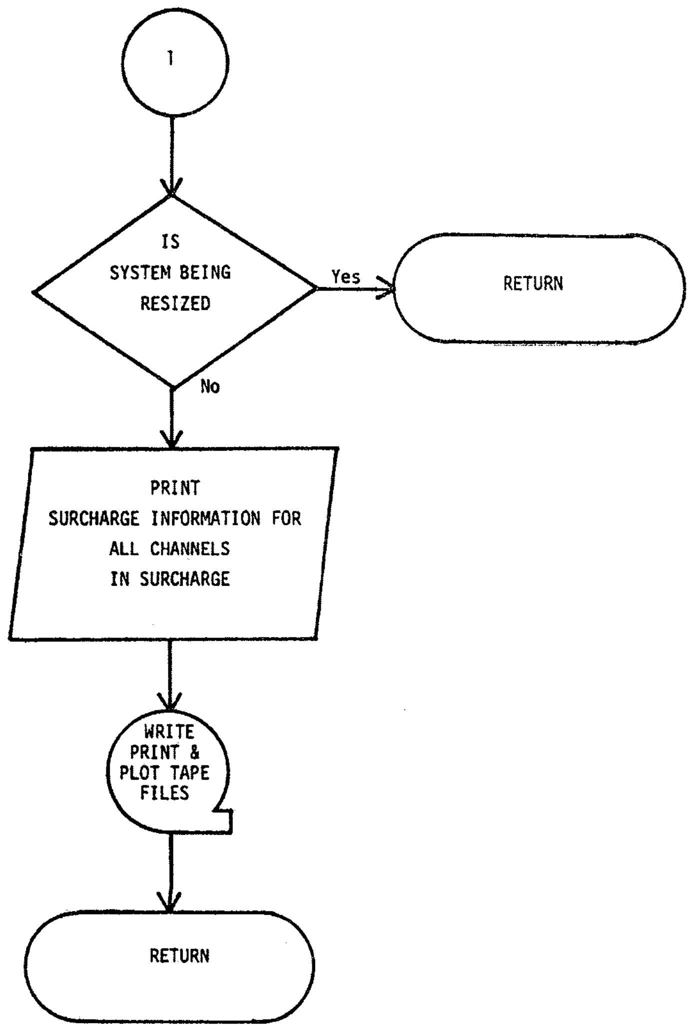

Figure IV-5
(Continued)

TABLE IV-2

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE GUTTER

Fortran Variable	Description	Units
AXØ	Channel flow area at start of time step	ft^2
AX1	Channel flow area at end of time step	ft^2
DAX1	Derivative of flow area with respect to depth change	ft
DDELV	Derivative of flow volume with respect to depth change	ft^2
DEL	Change in depth	ft
DELV	Channel in volume as a function of depth change	ft^3
DF	Derivative of Newton-Raphson F function	ft^2
DFLOW1	Derivative of flow at end of time step with respect to depth change	cfs/ft
DWP1	Derivative of wetted perimeter with respect to depth change	ft/ft
DØ	Channel depth at beginning of the time step	ft
D1	Channel depth at end of the time step	ft
F	Newton-Raphson F function	ft^3
FLOW	Average flow during the time step length	ft^3
FLOWØ	Flow at depth at beginning of the time step	ft^3
FLOW1	Flow at depth at end of the time step	ft^3
FLOW1Ø	Flow at depth at beginning of the previous time step	ft^3
IFLG	Surcharge indicator	-
NSUR	Number of surcharged channels	-
NTIMEH	Time in hours	hrs
NT1	Print tape number	-
RAD1	Hydraulic radius at end of the time step	ft
TIMEM	Time in minutes	min
TMSUR	Surcharge volume rate	ft^3/sec
VOL	Channel volume	ft^3

Table IV-2
(Continued)

Fortran Variable	Description	Units
VOLØ	Volume at the beginning of the time step	ft^3
WP	Wetted perimeter as a function of depth change	ft
WPØ	Wetted perimeter at depth at beginning of the time step	ft
WP1	Wetted perimeter at depth at end of the time step	ft

```
      SUBROUTINE GUTTER
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT,TITLE(40),IPLOT(200),ICODE(25),NPLOT
      COMMON HGRAPH(200),HTIME(200)
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON/ABLK/ NQS,
     2             C(200,5),CDOT(200,5),POFF(200,13),QFACT(5,13)
      COMMON/RESIZ/ NOPT,NEWSIZ,NEW(200),OLDWID(200)
      COMMON/MAX/ MAXFLW(200),MAXHR(200),MAXMIN(200),MAXDEP(200),
     2SURLEN(200)
      COMMON/NEW/NAMEG(200),NGTO(200)
      REAL MAXFLW,MAXDEP
      NT1=JTAPE(2)
      NOUT=JTAPE(3)
      NOGG=NOG+NSAVE
      DO 410 N=1,NOGG
      J=NGUT(N)
C
C******** INPUTS FROM ADJACENT WATERSHED AREAS
C
      SUMQW(J)=0.
      DO 220 JK=1,NIN
      IF(NWTOG(J,JK).EQ.0) GO TO 240
      NX=NWTOG(J,JK)
220   SUMQW(J)=SUMQW(J)+WFLOW(NX)
C
C******** INPUTS FROM UPSTREAM GUTTERS
C
240   QIN(J)=SUMQW(J)
      DO 260 JK=1,NIN
      IF(NGTOG(J,JK).EQ.0) GO TO 280
      NX=NGTOG(J,JK)
260   QIN(J)=QIN(J)+GFLOW(NX)
280   D0=GDEPTH(J)
      IF(QIN(J).NE.0) GO TO 290
      IF(GDEPTH(J).EQ.0) GO TO 391
290   IF(NPG(J).EQ.3) GO TO 391
      IFLG=0
      DELD(J)=0.
      FLOW1=0.
      DO 360 I=1,30
      FLOW10=FLOW1
      TMSUR=0.
C
C******** COMPUTE CHANGE IN DEPTH (NEWTON-RAPHSON)
C******** ESTIMATED FINAL DEPTH
```

```
C
      D1=GDEPTH(J)+DELD(J)
      IF(NPG(J).EQ.2) GO TO 295
C
C******** TRAPEZOIDAL GUTTER
C
      IF(D1.LT.0.) D1=0.
C
C**** VOLUME
      DELV=GLEN(J)*DELD(J)*((GS1(J)+GS2(J))*(D0+0.5*DELD(J))+GWIDTH(J))
      DDELV=GLEN(J)*((GS1(J)+GS2(J))*D1+GWIDTH(J))
C
C**** CROSS-SECTIONAL AREA
      AX0=0.5*(GS1(J)+GS2(J))*D0**2+GWIDTH(J)*D0
      AX1=0.5*(GS1(J)+GS2(J))*D1**2+GWIDTH(J)*D1
      DAX1=(GS1(J)+GS2(J))*D1+GWIDTH(J)
C
C**** WETTED PERIMETER
      WP0=SQRT(GS1(J)**2+1.)*D0+SQRT(GS2(J)**2+1.)*D0+GWIDTH(J)
      WP1=SQRT(GS1(J)**2+1.)*D1+SQRT(GS2(J)**2+1.)*D1+GWIDTH(J)
      DWP1=SQRT(GS1(J)**2+1.)+SQRT(GS2(J)**2+1.)
      GO TO 315
C
C******** CIRCULAR PIPE
C
295   IF(I.GT.1) GO TO 307
      D1=1.5707963
      DELD(J)=D1-GDEPTH(J)
307   IF(D1.GT.0) GO TO 308
      D1=0.
      DELD(J)=-GDEPTH(J)
308   IF(D1.LE.DFULL(J)) GO TO 310
      D1=DFULL(J)
      DELD(J)=D1-GDEPTH(J)
C
C**** VOLUME
310   DELV=GLEN(J)*(GWIDTH(J)**2/4.)*(DELD(J)-0.5*SIN(2.*D1)+0.5*SIN(2.*
     2D0))
      DDELV=GLEN(J)*(GWIDTH(J)**2/4.)*(1.-COS(2.*D1))
C
C**** CROSS-SECTIONAL AREA
      AX0=(GWIDTH(J)**2/4.)*(D0-0.5*SIN(2.*D0))
      AX1=(GWIDTH(J)**2/4.)*(D1-0.5*SIN(2.*D1))
      DAX1=(GWIDTH(J)**2/4.)*(1.-COS(2.*D1))
C
C**** WETTED PERIMETER
      WP0=GWIDTH(J)*D0
      WP1=GWIDTH(J)*D1
      DWP1=GWIDTH(J)
C
C******** HYDRAULIC RADIUS (ALL CROSS-SECTIONS)
C
315   IF(AX0.LT.0) AX0=0.
      IF(AX1.LT.0) AX1=0.
      IF(WP0.LE.0.) WP0=0.001
      IF(WP1.LE.0.) WP1=0.001
      RAD1=AX1/WP1
```

```
C
C******** FLOW
C
      FLOW0=GCON(J)*(AX0**1.6666667)/(WP0**0.6666667)
      FLOW1=GCON(J)*(AX1**1.6666667)/(WP1**0.6666667)
      OUTFLW(J)=FLOW1
      FLOW=0.5*(FLOW0+FLOW1)
      DFLOW1=0.5*GCON(J)*(1.6666667*(RAD1**0.6666667)*DAX1
     2 -0.6666667*(RAD1**1.6666667)*DWP1)
C
C******** NEWTON-RAPHSON CORRECTION
C
      F=DELV+DELT*(FLOW-QIN(J))-QSUR(J)
      DF=DDELV+DELT*DFLOW1
      IF(DF.GT.0.) GO TO 320
C
C**** ZERO SLOPE
      DEL=0.01
      GO TO 340
C
C**** NON-ZERO SLOPE
320   DEL=DELD(J)-F/DF
C
C**** CONVERGENCE CHECK (INDIVIDUAL GUTTER)
340   IF(I.EQ.1) GO TO 360
      IF(GDEPTH(J)+DEL.LT.DFULL(J)) GO TO 355
C
C**** ALLOW CHANNELS BEING RESIZED TO OVERFILL
      IF(NEWSIZ-1) 350,342,350
342   IF(NEW(J)) 350,345,345
345   IF(NPG(J).EQ.1) GO TO 355
350   CONTINUE
      IF(IFLG.EQ.1) GO TO 390
      DEL=DFULL(J)-GDEPTH(J)
      IFLG=1
      GO TO 360
355   IFLG=0
C
C**** NO SURCHARGE
      IF(FLOW10.GT..001) GO TO 363
      IF(ABS(FLOW1-FLOW10).LT.0.001) GO TO 380
      GO TO 360
363   CONTINUE
      IF(ABS(FLOW1-FLOW10).LT..001*FLOW1) GO TO 380
360   DELD(J)=DEL
C
C******** NON-CONVERGENT SOLUTION
C******** CHECK IF OUTFLOW EXCEEDS AVAILABLE WATER
C
      VOL0=AX0*GLEN(J)+QSUR(J)
      IF((FLOW0*.5*DELT).GT.(VOL0+QIN(J)*DELT)) GO TO 366
      IF(IMET.EQ.1) GDEPTH(J)=GDEPTH(J)/3.281
      IF(IMET.EQ.1) DELD(J)=DELD(J)/3.281
      WRITE(N6,1000) TIME,NAMEG(J),GDEPTH(J),DELD(J)
      IF(IMET.EQ.1) GDEPTH(J)=GDEPTH(J)*3.281
      IF(IMET.EQ.1) DELD(J)=DELD(J)*3.281
1000  FORMAT(* CHECK RESULTS.  NOT CONVERGED IN GUTTER*,F8.0,I6,2E12.5)
```

```
      FLOW=QIN(J)
      DEL=.01*DFULL(J)-GDEPTH(J)
      GO TO 380
366   WRITE(N6,1001) NAMEG(J),TIME
1001  FORMAT(* *,*OUTFLOW EXCEEDS AVAILABLE WATER IN CONDUIT  *,I4,*  AT
     2 TIME  *,F8.0)
      FLOW=QIN(J)+VOL0/DELT
      DEL=-GDEPTH(J)
C
C******** NEW DEPTH AT END OF TIME INTERVAL
C
380   DELD(J)=DEL
      GDEPTH(J)=GDEPTH(J)+DELD(J)
C
C******** RESIZE BOTTOM WIDTH OF TRAP. CHANNELS IF REQUESTED
C
      IF(NEWSIZ-1) 385,382,385
382   IF(NPG(J)-1) 385,383,385
383   IF(GDEPTH(J).GT.DFULL(J)) CALL NEWWID(J,FLOW1,0.0)
385   CONTINUE
      QSUR(J)=0.
C
C******** AVERAGE FLOW DURING TIME INTERVAL
C
      IF(FLOW.LT.1.0E-10) FLOW=0.0
      GFLOW(J)=FLOW
      OUTFLW(J)=GFLOW(J)
      GO TO 400
C
C******** SURCHARGE
C
390   GDEPTH(J)=DFULL(J)
C
C******** RESIZE PIPES IF REQUESTED
C
      IF(NEWSIZ-1) 393,392,393
392   IF(NEW(J).EQ.-1) GO TO 393
      CALL NEWDIA(J,FLOW0,DELV)
      GO TO 400
393   CONTINUE
      GFLOW(J)=FLOW1
      TMSUR=QIN(J)-FLOW1
      QSUR(J)=QSUR(J)+TMSUR*DELT
      IF(NEWSIZ.NE.1.AND.QSUR(J).GT.0) SURLEN(J)=SURLEN(J)+DELT/60.0
      IF(QSUR(J).GT.0) GO TO 400
      GFLOW(J)=GFLOW(J)+QSUR(J)/2.
      QSUR(J)=0.
      OUTFLW(J)=GFLOW(J)+QSUR(J)/2.
391   GFLOW(J)=QIN(J)
400   IF(NQS.GT.0.AND.NEWSIZ.NE.1) CALL GQUAL(J,AX1,OUTFLW,TMSUR)
410   CONTINUE
      IF(NEWSIZ.EQ.1) RETURN
C
C******** WRITE OUTPUT TAPE
C
      NTIMEH=TIME/3600.
      TIMEM=TIME/60.-FLOAT(NTIMEH)*60.
```

```
      DO 500 N=1,NOG
      IF(GFLOW(N).GT.MAXFLW(N)) GO TO 4200
      GO TO 500
4200  MAXFLW(N)=GFLOW(N)
      MAXHR(N)=NTIMEH
      MAXMIN(N)=TIMEM+0.5
      MAXDEP(N)=GDEPTH(N)
500   CONTINUE
      NQT=NQS
      INTCNT=INTCNT+1
      IF(INTCNT.LT.INTERV) GO TO 510
      INTCNT=0
      DO 780 N=1,NPRNT
      J=IPRNT(N)
780   OUTFLW(N)=GFLOW(J)
      IF(IMET.LT.1) GO TO 7010
      DO 7000 N=1,NPRINT
      OUTFLW(N)=OUTFLW(N)/35.31
 7000 CONTINUE
 7010 CONTINUE
      WRITE(NT1) NTIMEH,TIMEM,(OUTFLW(N),N=1,NPRNT)
      IF(NQT.LT.1) GO TO 510
      DO 710 J=1,NPRNT
      N=IPRNT(J)
      DO 700 K=1,NQS
      POFF(J,K)=0.
      DO 790 L=1,5
790   POFF(J,K)=C(N,L)*QFACT(L,K)+POFF(J,K)
700   CONTINUE
710   POFF(J,1)=8.
      WRITE(NT1) NTIMEH,TIMEM,((POFF(J,K),K=1,NQS),J=1,NPRNT)
510   DO 505 N=1,NOG
      J=NGUT(N)
      IF(QSUR(J).LE.0.0) GO TO 505
      NTSCP=NTSCP+1
      IF(MOD(NTSCP,36).EQ.1) WRITE(N6,5003) K5,K6
5003  FORMAT(1H1/5X,*SUMMARY OF SURCHARGE HISTORY*//5X,
     2  *TOTAL              GUTTER   CUM VOL*/*  HOUR MIN    GUTTER
     3FLOW   SURCHAR* /  3X, *(HOURS)      NUMBER      *,A5,6X,A5)
      WRITE(N6,9000) NTIMEH,TIMEM,NAMEG(J),GFLOW(J),QSUR(J)
9000  FORMAT(I5,F5.0,I10,F10.1,F10.0)
505   CONTINUE
      WRITE(N6,5004)
5004  FORMAT( )
C
C******** WRITE INLETS TO BE SAVED
C
      IF(NOUT.LT.1) GO TO 670
      DO 600 N=1,NPLOT
      J=IPLOT(N)
      IF(NQT.EQ.0) GO TO 600
      DO 7500 K=1,NQT
      POFF(N,K)=0.
      DO 7490 L=1,5
7490  POFF(N,K)=POFF(N,K)+C(J,L)*QFACT(L,K)
      IF(K.EQ.4) GO TO 7500
      POFF(N,K)=POFF(N,K)*GFLOW(J)*0.225
```

```
7500   CONTINUE
       POFF(N,1)=8.
600    OUTFLW(N)=GFLOW(J)
       IF(IMET.LT.1) GO TO 7030
       DO 7020 N=1,NPLOT
       OUTFLW(N)=OUTFLW(N)/35.31
 7020  CONTINUE
 7030  CONTINUE
       WRITE(NOUT) TIME,(OUTFLW(N),N=1,NPLOT),((POFF(N,K),K=1,NQT),
      2N=1,NPLOT)
670    CONTINUE
       RETURN
       END
```

The computational steps employed in the routine are presented in flowchart form in Figure IV-6. Key variables not contained in the above common areas are listed in Table IV-3 followed by a listing of the routine.

Subroutine SUMSTAT

This routine calls no other computational routines and employs the following common blocks:

- BLANK COMMON
- MAX
- NEWGUT
- NEW

The routine formats the results of the simulation as a convenient design summary. The design flow and velocity, pipe diameter, maximum computed flow, velocity, depth and their time of occurrence, length of surcharge, ratio of maximum computed flow to design flow, and ratio of maximum computed depth to design depth are printed for each pipe in the major drainage system. The computational steps are presented in flowchart form in Figure IV-7. A listing of key variables not contained in common is presented in Table IV-4. The listing of the routine follows.

Subroutine RECAP

The following common blocks are employed in this routine:

- ABLK
- TAPES
- BLANK COMMON

The subroutine reads the output tapes written in GUTTER and writes a flow time history, and if quality is considered, a concentration time history for each drainage element specified. The flow chart is in Figure IV-8. The computer listing follows.

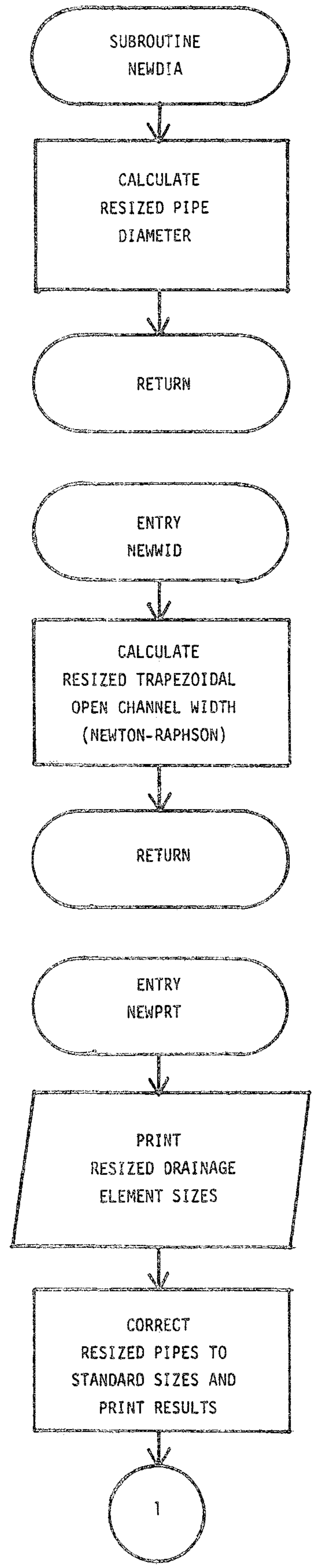

FIGURE IV-6. Flowchart of Subroutine NEWDIA, Entry NEWWID, and Entry NEWPRT

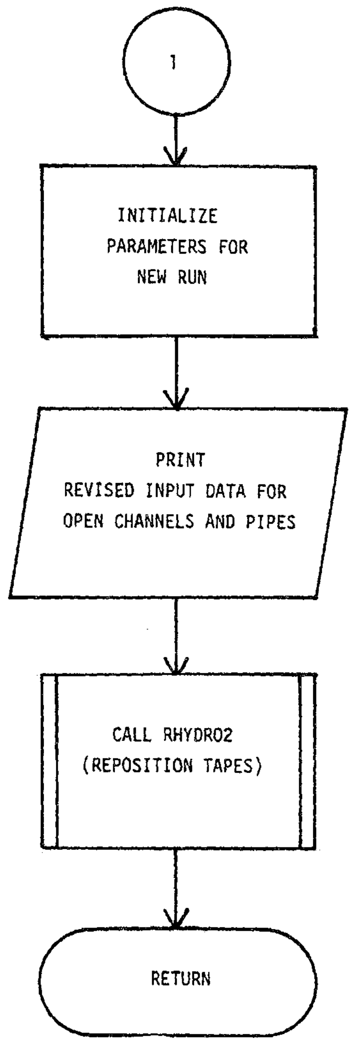

Figure IV-6
(Continued)

TABLE IV-3

KEY VARIABLES NOT IN COMMON FOR
SUBROUTINE NEWDIA, ENTRY NEWWID, AND ENTRY NEWPRT

Fortran Variable	Description	Units
A	Pipe flow area	ft^2
AKON	Area constant	ft
AX	Trapezoidal open channel flow area	ft^2
BASIN	Basin number	-
D	Full pipe depth	radians
DELV	Volume change	ft^3
DF	Derivative of trapezoidal open channel flow with respect to width	ft^2/sec
DIA	Pipe diameter	in/ft
F	Newton-Raphson F function	ft^3/sec
FLOW	Flow in trapezoid open channel	ft^3/sec
GA	Pipe area at full flow	ft^2
GKON	Pipe friction constant	$sec^{-1}ft^{-2/3}$
GP	Pipe wetted perimeter at full flow	ft
GQ	Pipe maximum (full) flow	ft^3/sec
GR	Pipe hydraulic radius at full flow	ft
GV	Pipe maximum velocity	fps
G1	Width or diameter	ft
G2	Drainage element length	ft
G3	Drainage element slope	ft/ft
G4	Side slope 1 (trapezoidal open channel)	ft/ft
G5	Side slope 2 (trapezoidal open channel)	ft/ft
G6	Manning's roughness	$ft^{1/6}$
G7	Maximum depth	ft
J	Drainage element internal number	-
NP	Drainage element type	-

TABLE IV-3
(cont.)

Fortran Variable	Description	Units
QNEW	New full pipe flow at end of time step	ft^3/sec
QO	Original pipe flow at beginning of time step	ft^3/sec
QP	Necessary parallel pipe flow	ft^3/sec
QT	Total necessary pipe flow	ft^3/sec
RAD	Trapezoidal open channel hydraulic radius	ft
W	Trapezoidal open channel trial width	ft
WP	Wetted perimeter	ft
WPKON	Trapezoidal open channel wetted perimeter constant	ft

```
      SUBROUTINE NEWDIA(J,Q0,DELV)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT,TITLE(40),IPLOT(200),ICODE(25),NPLOT
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON HGRAPH(200),HTIME(200)
      COMMON/NEW/NAMEG(200),NGTO(200)
      COMMON/INFIL/RAININ(200),DEPIN(200)
      COMMON/RESIZ/NOPT,NEWSIZ,NEW(200),OLDWID(200)
      COMMON/NEWGUT/NOGUTTR,XSLOPE(200),INTYP(200),ISTA1A(200),
     2ISTA1B(200),ISTA2A(200),ISTA2B(200),ELEVA1(200),ELEVA2(200),
     3MGTO(200)
      REAL ISTA1A,ISTA2A,ISTA1B,ISTA2B
C
C******** SET NEW DIAMETER FOR CIRCULAR PIPE
C
      QNEW=2.*(QIN(J)-DELV/DELT)-Q0
      GWIDTH(J)=1.0*4.*(QNEW/(GCON(J)*4.*3.14159))**0.375
      GFLOW(J)=(QNEW+Q0)/2.
      OUTFLW(J)=GNEW
      NEW(J)=1
      RETURN
C
C******** ENTRY NEWWID
C******** SET NEW WIDTH FOR TRAPEZOIDAL CHANNEL
C
      ENTRY NEWWID
      FLOW=Q0
      D=DFULL(J)
      W=GWIDTH(J)
      GKON=GCON(J)
      AKON=0.5*(GS1(J)+GS2(J))*D
      WPKON=(SQRT(GS1(J)**2+1.)+SQRT(GS2(J)**2+1.))*D
      DO 40 I=1,30
      AX=(AKON+W)*D
      WP=WPKON+W
      RAD=AX/WP
C
C******** NEWTON-RAPHSON CORRECTION
C
      F=-FLOW+GKON*AX*RAD**0.6667
      DF=GKON*(1.66667*D*RAD**0.66667-0.66667*RAD**1.6667)
      IF(DF.GT.0) GO TO 20
      W=0.01
      GO TO 40
20    W=W-F/DF
      IF(ABS(F).LT.0.1) GO TO 60
```

```
40    CONTINUE
      WRITE(N6,45) J,W,F,TIME
45    FORMAT(* WIDTH NOT CONVERGED IN CHANNEL*,I6,*WIDTH =*,E12.5,* FLOW
     2 ERROR = *,E12.5,* TIME = *,F8.0)
60    GWIDTH(J)=W
      GDEPTH(J)=D
      NEW(J)=1
      RETURN
C
C******** ENTRY NEWPRT
C******** PRINT OUT NEW CONDUIT SIZES
C
      ENTRY NEWPRT
      WRITE(N6,100)
100   FORMAT(1H1,*---  THE CONDUITS LISTED BELOW WERE RESIZED DURING THI
     2S RUN ---*,/,7X,*DIAMATERS WERE INCREASED FOR PIPES, BOTTOM WIDTHS
     3 FOR TRAP. CHANNELS*//)
C
C******** PRINT CHANNEL/PIPE DATA
C
      WRITE(N6,105) K1,K2,K2,K3,K2,K4,K5
105   FORMAT(1H0,3X,
     2 *        GUT  PIPE DIA   WIDTH    LENGTH     SLOPE         SIDE SLO
     3PES   MANNING      DEPTH      V FULL     Q FULL* / 4X,
     4 *        NUM    *,A4,6X,A4,6X,A4,3X,A7, *      LEFT      RIGHT*,
     5 6X,*N*,6X,A4,6X,A5,5X,A5)
      NEWT=0
      DO 120 N=1,NOG
      IF(NEW(N)) 120,120,110
110   NEWT=NEWT+1
      NP=NPG(N)
      G1=GWIDTH(N)
      W=0.
      IF(NPG(N).EQ.2) W=12.*G1
      G2=GLEN(N)
      G3=GSLOPE(N)
      G4=GS1(N)
      G5=GS2(N)
      G6=GN(N)
      G7=DFULL(N)
      IF(NPG(N).EQ.2) G7=0.
C
C******** COMPUTE V FULL AND Q FULL
C
      IF(NP.EQ.2) GO TO 307
      GA=G7*(G1+0.5*G7*(G4+G5))
      GP=G1+G7*(SQRT(1.0+G4**2)+SQRT(1.0+G5**2))
      GO TO 309
307   GA=0.7854*G1**2
      GP=3.14159*G1
309   GR=GA/GP
      GV=1.486/G6*SQRT(G3)*GR**0.666667
      GQ=GA*GV
C
C******** PRINT GUTTER/PIPE DATA
C
      IF(IMET.LT.1) GO TO 7000
```

```
      W=W*2.54
      G1=G1/3.281
      G2=G2/3.281
      G7=G7/3.281
      GV=GV/3.281
      GQ=GQ/35.31
 7000 WRITE(N6,1120) NAMEG(N),W,G1,G2,G3,G4,G5,G6,G7,GV,GQ
1120  FORMAT(6X,I7,F8.1,F9.2,F10.0,F10.5,2F10.1,F10.3,3F10.1)
      IF(NP.EQ.2) WRITE(N6,1122)
1122  FORMAT(1H+,13X,1H*)
120   CONTINUE
      WRITE(N6,130) NEWT
130   FORMAT(*0*,*TOTAL NUMBER OF RESIZED CHANNELS/PIPES *,I4)
      WRITE(N6,1151)
1151  FORMAT(*0*,*ASTERISK DENOTES CIRCULAR PIPE.(WIDTH COLUMN SHOWS DIA
     2METER.)*)
C
C******** CORRECT NEW SIZED PIPES TO STANDARD SIZES
C
      WRITE(N6,131)
131   FORMAT(1H1,*       RESIZED PIPES IN STANDARD SIZES AND*/,7X,
     2*REQUIRED PIPE SIZE FOR PARALLEL RELIEF LINES*,//,6X,
     3* NOTE - PIPE DIAMETERS ARE IN INCHES*)
      WRITE(N6,135) K5,K5,K5
135   FORMAT(1H0,3X,
     2*       GUT          EXISTING  CAPACITY          PARALLEL  CAPACITY
     3  RESIZED  CAPACITY*/,4X,
     4*       NUM          PIPE          *,A5,12X,*PIPE*,6X,A5,8X,*PIPE*,
     55X,A5)
      DO 170 N=1,NOG
      IF(NEW(N)) 170,170,140
140   IF(NPG(N)-1) 170,170,145
145   GK=GCON(N)
      DO 160 I=1,3
      GO TO (151,152,153),I
151   DIA=OLDWID(N)*12.
      GO TO 155
152   A=3.14159*(GWIDTH(N)/2.)**2
      WP=3.14159*GWIDTH(N)
      QT=GK*A*(A/WP)**0.6667
      A=3.14159*(OLDWID(N)/2.)**2
      WP=3.14159*OLDWID(N)
      QO=GK*A*(A/WP)**0.6667
      QP=QT-QO
      DIA=12.*4.*(QP/(GK*4.*3.14159))**0.375
      GO TO 154
153   DIA=GWIDTH(N)*12.
154   MULT=3
      IF(DIA.GT.36.) MULT=6
      IF(DIA.GT.96.) MULT=12
      ID=IFIX(DIA)/MULT
      IF(DIA-ID*MULT.GT.0.) DIA=MULT*(ID+1)
      IF(I.EQ.3) GWIDTH(N)=DIA/12.
155   DELD(I)=DIA
      DIA=DIA/12.
      A=3.14159*(DIA/2.)**2
      WP=3.14159*DIA
```

```
      GFLOW(I)=GK*A*(A/WP)**0.6667
160   CONTINUE
      IF(IMET.LT.1) GO TO 7020
      DO 7010 K=1,3
      GFLOW(K)=GFLOW(K)/35.31
 7010 CONTINUE
 7020 CONTINUE
      WRITE(N6,165) NAMEG(N),(DELD(K),GFLOW(K),K=1,3)
165   FORMAT(6X,I7,3(F13.1,F10.1,2X))
170   CONTINUE
C
C******** INITIALIZE FOR NEW RUN
C
      NEWSIZ=NEWSIZ+1
      TIME=TZERO
      DO 210 I=1,NW
      RAININ(I)=0.
      WFLOW(I)=0.
      WDEPTH(I,1)=0.
      WDEPTH(I,2)=0.
      WDEPTH(I,3)=0.
210   CONTINUE
      DO 215 I=1,NG
      QSUR(I)=0.
      DELD(I)=0.
      QIN(I)=0.
      OUTFLW(I)=0.
      GFLOW(I)=0.
      GDEPTH(I)=0.
215   CONTINUE
      DO 220 I=1,200
      HGRAPH(I)=0.
      HTIME(I)=0.
220   CONTINUE
      SUMR=0.
      SUMI=0.
      SUMOFF=0.
      SUMST=0.
      TITLE(15)=4H --
      TITLE(16)=4H RES
      TITLE(17)=4HIZED
      TITLE(18)=4H CON
      TITLE(19)=4HDUIT
      TITLE(20)=4HS --
C
C******** PRINT REVISED INPUT DATA FOR GUTTER/CHANNELS
C
      IF(NOGUTTR.LE.0) GO TO 5000
      ICHK=1
      DO 340 N=1,NOGUTTR
      IF(N.EQ.1.OR.(N/39*39).EQ.N) GO TO 4000
      GO TO 4017
4000  WRITE(N6,2999)
2999  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL   ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,4H****,32X,4H****,8X,
     4*CAMP DRESSER AND MCKEE             */* *,*WASHINGTON, D.C.*,28X,4H
```

```
     5****,4X,*DRAINAGE DESIGN PROGRAM*,5X,4H****,8X,*ANNANDALE, VIRGINI
     6A*)
      WRITE(N6,4002)
4002  FORMAT(///* *,38X,*REVISED INPUT DATA FOR ABOVE-GROUND GUTTERS/CHA
     2NNELS*/* *,38X,52(*=*)//)
      WRITE(N6,4019) K2,K2,K3
4019  FORMAT(* *,18X,*CONNECTED TO*,8X,*INLET*,52X,*ELEVATION*,14X,*GRAD
     2E*/* *,4X,*GUTTER*,9X,*GUTTER/PIPE*,9X,*TYPE*,12X,*STATIONS*,12X,
     3*LENGTH* , 16X, A4 ,17X,*SLOPE*/* *,4X,*NUMBER*,11X,*NUMBER*,12X,
     4*NO.*,11X,*1*,10X,*2*, 11X, A4, 9X, *UPSTREAM*,2X,*DOWNSTREAM*,
     5 8X, 7X     /* *,4X,6(*-*),8X,12(*-*),8X,5(*-*),8X,16(*-*),8X,
     66(*-*),8X,20(*-*),8X,7(*-*)/)
      IF(IMET.LT.1) GO TO 4017
      ISTA1A(N)=ISTA1A(N)/3.281
      ISTA1B(N)=ISTA1B(N)/3.281
      ISTA2A(N)=ISTA2A(N)/3.281
      ISTA2B(N)=ISTA2B(N)/3.281
      GLEN(N)=GLEN(N)/3.281
      ELEVA1(N)=ELEVA1(N)/3.281
      ELEVA2(N)=ELEVA2(N)/3.281
4017  WRITE(N6,4025) NAMEG(N),MGTO(N),INTYP(N),ISTA1A(N),ISTA1B(N),
     2ISTA2A(N),ISTA2B(N),GLEN(N),ELEVA1(N),ELEVA2(N),GSLOPE(N)
4025  FORMAT(* *,5X,I4,13X,I4,14X,I1,10X,I4,*+*,I2,2X,I4,*+*,I2,8X,F6.1,
     28X,F8.3,3X,F8.3,9X,F7.3)
      IF(NEW(N).LE.0) GO TO 4037
      WRITE(N6,4008)
4008  FORMAT(*+*,9X,1H*)
4037  IF(N.EQ.NOGUTTR.OR.(N/38*38).EQ.N) GO TO 5010
      GO TO 340
5010  WRITE(N6,4009)
4009  FORMAT(//* *,42X,*ASTERISK INDICATES GUTTER/CHANNEL HAS BEEN RESIZ
     2ED*)
      DO 4003 NN=ICHK,N
      IF(NN.EQ.1.OR.(NN/39*39).EQ.NN) GO TO 4010
      GO TO 4011
4010  WRITE(N6,2999)
      WRITE(N6,4012)
4012  FORMAT(///* *,32X,*REVISED INPUT DATA FOR ABOVE-GROUND GUTTERS/CHA
     2NNELS (CONTINUED)*/* *,32X,64(*=*)//)
      WRITE(N6,4032) K3,K3,K2,K2,K4,K5
4032  FORMAT(* *,22X,*CROSS*,13X,*TRAPEZOIDAL CHANNEL*,12X,*MAXIMUM*/* *
     2,7X,*GUTTER*,9X,*SLOPE*,10X,*SLOPES * , A7 , 6X,*WIDTH*,10X,
     3*DEPTH*,9X,*MANNINGS*,8X,*V FULL*,8X,*Q FULL*/* *,7X,*NUMBER*,8X,
     4       A7, 10X,*LEFT*,4X,*RIGHT*,7X , A4 , 11X , A4 , 13X,*N*,12X,
     5   A5 , 9X , A5   /* *,7X,6(*-*),8X,7(*-*),8X,27(*-*),8X,7(*-*),
     68X,8(*-*),8X,6(*-*),8X,6(*-*)/)
C
C******** COMPUTE V FULL AND Q FULL FOR GUTTERS/CHANNELS
C
4011  GA=DFULL(NN)*(GWIDTH(NN)+0.5*DFULL(NN)*(GS1(NN)+GS2(NN)))
      GP=GWIDTH(NN)+DFULL(NN)*(SQRT(1.0+GS1(NN)**2)+SQRT(1.0+GS2(NN)**2)
     2)
      GR=GA/GP
      GV=1.486/GN(NN)*SQRT(GSLOPE(NN))*GR**0.66667
      GQ=GA*GV
      IF(IMET.LT.1) GO TO 7030
      GWIDTH(NN)=GWIDTH(NN)/3.281
```

```
      DFULL(NN)=DFULL(NN)/3.281
      GV=GV/3.281
      GQ=GQ/35.31
 7030 WRITE(N6,4033) NAMEG(NN),XSLOPE(NN),GS1(NN),GS2(NN),GWIDTH(NN),
     2DFULL(NN),GN(NN),GV,GQ
4033  FORMAT(* *,8X,I4,9X,F7.3,8X,F7.3,2X,F7.3,4X,F7.3,8X,F7.3,9X,F6.3,
     28X,F6.2,9X,F6.2)
      IF(NEW(NN).LE.0) GO TO 4003
      WRITE(N6,4004)
4004  FORMAT(*+*,12X,1H*)
4003  CONTINUE
      WRITE(N6,4009)
      ICHK=N+1
340   CONTINUE
C
C******** PRINT REVISED INPUT DATA FOR PIPES
C
5000  MN=NOGUTTR+1
      DO 4020 N=MN,NOG
      IF(N.EQ.MN.OR.((N-MN)/38*38).EQ.(N-MN)) GO TO 4021
      GO TO 4022
4021  WRITE(N6,2999)
      WRITE(N6,2023)
2023  FORMAT(///* *,39X,*REVISED INPUT DATA FOR UNDERGROUND DRAINAGE SYS
     2TEM*/* *,39X,50(*=*)//)
      WRITE(N6,4055) K2,K2,K3,K1,K4,K5
4055  FORMAT(* *,10X,*CONNECTED TO*,24X,*        *,6X,*CROWN ELEVATIONS*,
     27X,*GRADE*,6X,*PIPE*/* *,1X,*PIPE*,6X,*PIPE/OUTLET*,8X,*STATIONS*,
     38X,*LENGTH*,12X , A4 , 13X,*SLOPE*,5X,*DIAM.*,4X,*MANNINGS*,4X,
     4*V FULL*,4X,*Q FULL*/* *,*NUMBER*,7X,*NUMBER*,9X,*1*,10X,*2*,7X,
     5   A4, 5X,*UPSTREAM*,2X,*DOWNSTREAM* , 4X , A7 , 5X , A4 , 8X ,
     6*N*,8X , A5 , 5X , A5    /* *,6(*-*),4X,12(*-*),4X,16(*-*),4X,
     76(*-*),4X,20(*-*),4X,7(*-*),4X,5(*-*),4X,8(*-*),4X,6(*-*),4X,
     86(*-*)/)
C
C******** CALCULATE V FULL AND Q FULL FOR PIPES
C
4022  GA=0.7854*GWIDTH(N)**2
      GP=3.14159*GWIDTH(N)
      GR=GA/GP
      GV=1.486/GN(N)*SQRT(GSLOPE(N))*GR**0.666667
      GQ=GA*GV
      W=12.0*GWIDTH(N)
      IF(IMET.LT.1) GO TO 7040
      W=W*2.54
      GV=GV/3.281
      GQ=GQ/35.31
7040  WRITE(N6,4056) NAMEG(N),MGTO(N),ISTA1A(N),ISTA1B(N),ISTA2A(N),
     2ISTA2B(N),GLEN(N),ELEVA1(N),ELEVA2(N),GSLOPE(N),W,
     3GN(N),GV,GQ
4056  FORMAT(* *,1X,I4,9X,I4,8X,I4,*+*,I2,2X,I4,*+*,I2,4X,F6.1,4X,F8.3,
     23X,F8.3,5X,F7.3,4X,F5.1,5X,F6.3,5X,F6.2,5X,F6.2)
      IF(NEW(N).LE.0) GO TO 4024
      WRITE(N6,4026)
4026  FORMAT(*+*,5X,1H*)
4024  IF(N.EQ.NOG.OR.(N/38*38).EQ.N) WRITE(N6,4049)
4049  FORMAT(//* *,69X,1H*,* INDICATES PIPE HAS BEEN RESIZED*)
```

```
4020  CONTINUE
      IF(NPLOT.EQ.0) GO TO 530
      DO 520 I=1,NPLOT
      J=IPLOT(I)
      IPLOT(I)=NAMEG(J)
520   CONTINUE
C
C******** REPOSITION OUTPUT TAPES
C
530   CALL RHYDR2(BASIN)
      RETURN
      END
```

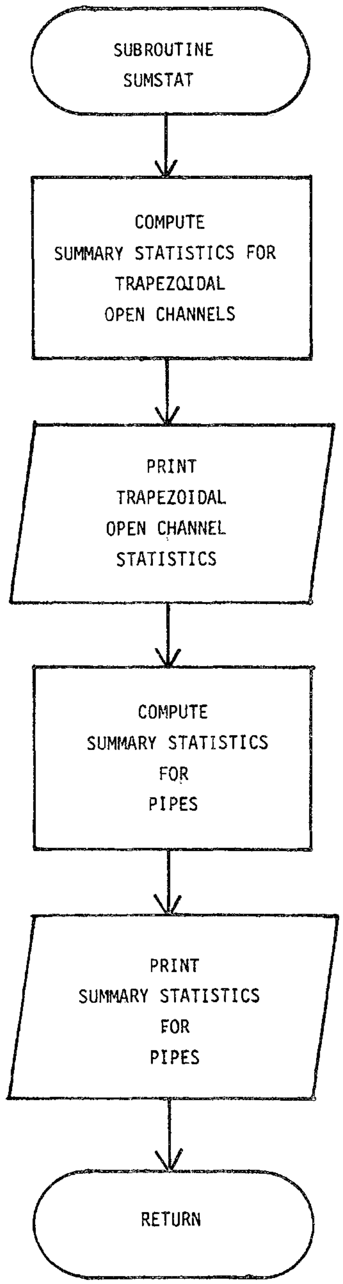

FIGURE IV-7. Flowchart of Subroutine SUMSAT

TABLE IV-4

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE SUMSTAT

Fortran Variable	Description	Units
DR	Ratio of maximum computed depth to design depth	-
GA	Design flow area	ft^2
GAA	Maximum computed flow area	ft^2
GP	Design flow wetted perimeter	ft
GR	Design hydraulic radius	ft
GQ	Design flow	ft^3/sec
GV	Design velocity	ft/sec
GVV	Maximum computed velocity	ft/sec

```
      SUBROUTINE SUMSTAT
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT,TITLE(40),IPLOT(200),ICODE(25),NPLOT
      COMMON HGRAPH(200),HTIME(200)
      COMMON/MAX/ MAXFLW(200),MAXHR(200),MAXMIN(200),MAXDEP(200),
     2SURLEN(200)
      COMMON/NEWGUT/ NOGUTTR,XSLOPE(200),INTYP(200),ISTA1A(200),
     2ISTA1B(200),ISTA2A(200),ISTA2B(200),ELEVA1(200),ELEVA2(200),
     3MGTO(200)
      COMMON/NEW/ NAMEG(200),NGTO(200)
      COMMON/TAPES/ JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      REAL MAXFLW,MAXDEP,ISTA1A,ISTA2A,ISTA1B,ISTA2B
C
C******** COMPUTE SUMMARY STATISTICS FOR ABOVE GROUND GUTTERS/CHANNELS
C
      IF(NOGUTTR.LE.0) GO TO 400
      DO 100 I=1,NOGUTTR
      IF(I.EQ.1.OR.(I/36*36).EQ.I) GO TO 200
      GO TO 201
200   WRITE(N6,2999)
2999  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL   ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,4H****,32X,4H****,8X,
     4*CAMP DRESSER AND MCKEE            */* *,*WASHINGTON, D.C.*,28X,4H
     5****,4X,*DRAINAGE DESIGN PROGRAM*,5X,4H****,8X,*ANNANDALE, VIRGINI
     6A*)
      WRITE(N6,300)
300   FORMAT(///* *,38X,*SUMMARY STATISTICS FOR ABOVE-GROUND GUTTERS/CHA
     2NNELS*/* *,38X,52(*=*)//)
      WRITE(N6,301) K5,K4,K2,K5,K4,K2
301   FORMAT(* *,52X,*DESIGN*,4X,3(3X,*MAXIMUM*),14X,*TIME*,8X,
     2*RATIO OF*/* *,14X,*DESIGN*,2(7X,*DESIGN*),7X,*FLOW*,5X,3(2X,*COMP
     3UTED*),2X,*FEET OF*,6X,*OF*,10X,*MAX. TO*/* *,2X,*GUTTER*,7X,
     4*FLOW*,7X,*VELOCITY*,7X,*DEPTH*,6X,*SPREAD*,8X,*FLOW*,4X,
     5*VELOCITY*,4X,*DEPTH*,3X,*HIGHWAY*,2X,*OCCURENCE*,7X,*DESIGN*/
     6* *,2X,*NUMBER*,7X,A5,8X,A5,2(8X,A5),9X,A5,5X,A5,5X,A4,4X,*FLOODED
     7*,2X,*HR.  MIN.*,8X,*DEPTH*/* *,2X,6(*-*),6X,6(*-*),6X,8(*-*),2(6X
     8,6(*-*)),6X,48(*-*),6X,8(*-*)/)
C
C******** COMPUTE DESIGN FLOW AND DESIGN VELOCITY
C
201   GA=DFULL(I)*(GWIDTH(I)+0.5*DFULL(I)*(GS1(I)+GS2(I)))
      GP=GWIDTH(I)+DFULL(I)*(SQRT(1.0+GS1(I)**2)+SQRT(1.0+GS2(I)**2))
      GR=GA/GP
      GV=1.486/GN(I)*SQRT(GSLOPE(I))*GR**0.6666667
      GQ=GA*GV
```

```
C
C******** COMPUTE MAXIMUM VELOCITY FOR RUN
C
      GAA=MAXDEP(I)*(GWIDTH(I)+0.5*MAXDEP(I)*(GS1(I)+GS2(I)))
      GVV=MAXFLW(I)/GAA
C
C******** COMPUTE RATIO OF MAX. DEPTH TO DESIGN DEPTH
C
      DR=MAXDEP(I)/DFULL(I)
C
C******** PRINT GUTTER/CHANNEL STATISTICS
C
      IF(IMET.LT.1) GO TO 7000
      GQ=GQ/35.31
      GV=GV/3.281
      DFULL(I)=DFULL(I)/3.281
      MAXFLW(I)=MAXFLW(I)/35.31
      GVV=GVV/3.281
      MAXDEP(I)=MAXDEP(I)/3.281
 7000 CONTINUE
      WRITE(N6,302) NAMEG(I),GQ,GV,DFULL(I),MAXFLW(I),GVV,MAXDEP(I),
     2MAXHR(I),MAXMIN(I),DR
302   FORMAT(* *,3X,I4,7X,F6.2,7X,F6.2,8X,F4.2,20X,F6.2,4X,F6.2,5X,
     2F4.2,13X,I3,3X,I2,8X,F6.2)
      IF(IMET.EQ.1) MAXFLW(I)=MAXFLW(I)*35.31
      IF(IMET.EQ.1) MAXDEP(I)=MAXDEP(I)*3.281
100   CONTINUE
400   NPIPE=NOGUTTR+1
      DO 110 I=NPIPE,NOG
      IF(I.EQ.NPIPE.OR.((I-NPIPE)/35*35).EQ.(I-NPIPE)) GO TO 210
      GO TO 211
210   WRITE(N6,2999)
      WRITE(N6,310)
310   FORMAT(///* *,39X,*SUMMARY STATISTICS FOR UNDERGROUND DRAINAGE SYS
     2TEM*/* *,39X,50(*=*)//)
      WRITE(N6,311) K5,K4,K1,K5,K4,K1
311   FORMAT(* *,44X,3(3X,*MAXIMUM*),5X,*TIME*,9X,*LENGTH*,2(6X,*RATIO O
     2F*)/* *,12X,*DESIGN*,6X,*DESIGN*,7X,*PIPE*,3X,3(2X,*COMPUTED*),
     36X,*OF*,12X,*OF*,9X,*MAX. TO*,5X,*MAX. DEPTH*/* *,2X,*PIPE*,
     47X,*FLOW*,6X,*VELOCITY*,5X,*DIAM.*,7X,*FLOW*,4X,*VELOCITY*,
     54X,*DEPTH*,3X,*OCCURENCE*,5X,*SURCHARGE*,6X,*DESIGN*,8X,*TO PIPE*/
     6* *,1X,*NUMBER*,6X,A5,7X,A5,7X,A4,7X,A5,5X,A5,5X,A4,4X,*HR.  MIN.*
     7,7X,*(MIN)*,9X,*(FLOW)*,8X,*DIAMETER */* *,1X,6(*-*),5X,6(*-*),
     85X,8(*-*),5X,5(*-*),5X,39(*-*),5X,9(*-*),5X,8(*-*),5X,10(*-*))
C
C******** COMPUTE DESIGN FLOW AND DESIGN VELOCITY
C
211   GA=0.7854*GWIDTH(I)**2
      GP=3.14159*GWIDTH(I)
      GR=GA/GP
      GV=1.486/GN(I)*SQRT(GSLOPE(I))*GR**0.66666667
      GQ=GA*GV
C
C******** COMPUTE MAXIMUM VELOCITY FOR RUN
C
      GAA=(GWIDTH(I)**2/4.)*(MAXDEP(I)-0.5*SIN(2.*MAXDEP(I)))
      GVV=MAXFLW(I)/GAA
```

```
C
C******** COMPUTE FLOW AND DEPTH RATIOS
C
      FR=MAXFLW(I)/GQ
      PIPDEP=GWIDTH(I)/2*(1-COS(MAXDEP(I)))
      DR=PIPDEP/GWIDTH(I)
      DIAM=12.0*GWIDTH(I)
      PIPDEP=PIPDEP*12.0
C
C******** PRINT UNDERGROUND DRAINAGE SYSTEM STATISTICS
C
      IF(IMET.LT.1) GO TO 7010
      GQ=GQ/35.31
      GV=GV/3.281
      DIAM=DIAM*2.54
      MAXFLW(I)=MAXFLW(I)/35.31
      GVV=GVV/3.281
      PIPEDEP=PIPEDEP*2.54
 7010 CONTINUE
      WRITE(N6,312) NAMEG(I),GQ,GV,DIAM,MAXFLW(I),GVV,PIPDEP,MAXHR(I),
     2MAXMIN(I),SURLEN(I),FR,DR
312   FORMAT(* *,2X,I4,2(6X,F6.2),6X,F4.0,7X,F6.2,4X,F6.2,4X,F6.2,3X,
     2I3,2X,I3,8X,F5.1,2(8X,F6.2))
110   CONTINUE
      RETURN
      END
```

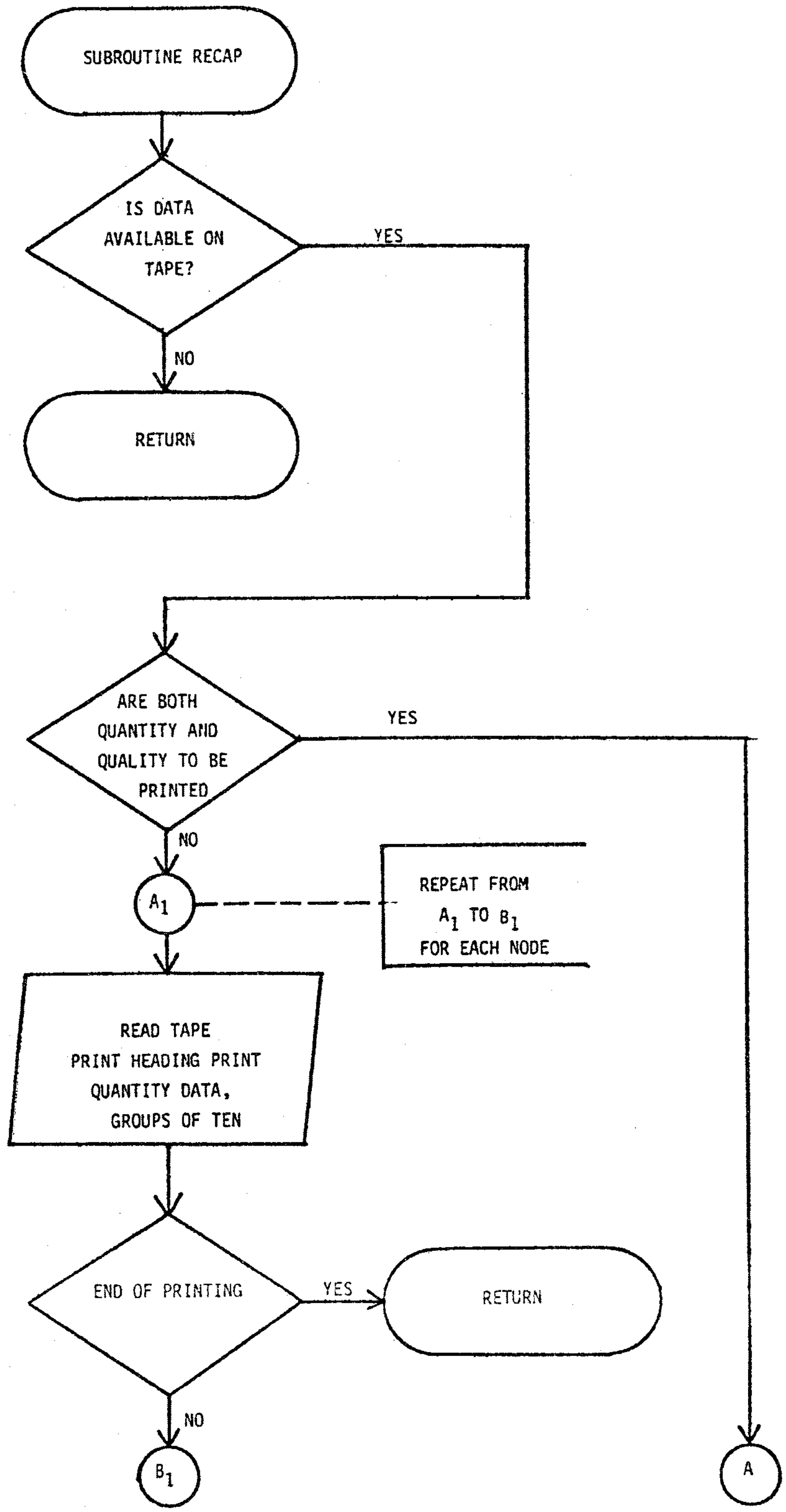

FIGURE IV-8. Flowchart of Subroutine RECAP

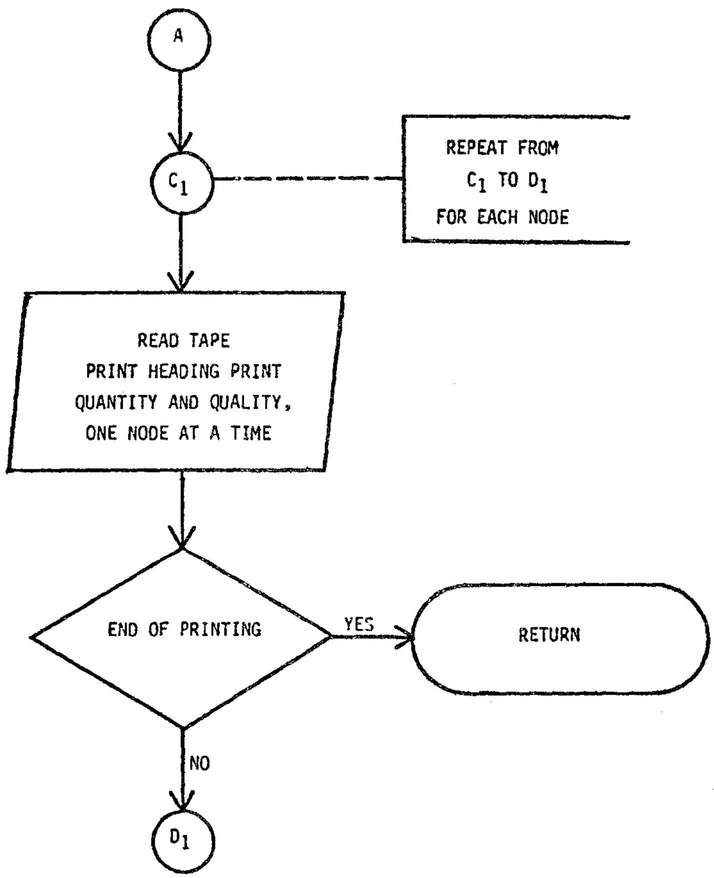

Figure IV-8
(Continued)

```
      SUBROUTINE RECAP
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      COMMON/ABLK/NQS,C(200,5),CDOT(200,5),POFF(200,13),QFACT(5,13)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON FLOW(200),QUAL(200,24),IPRNT(200),TITLE(40),
     2 NHR(100),TMIN(100),OUT(100,13),FLOWOT(13)
C
C******** READ TAPE HEADERS
C
      IF(JTAPE(2).LT.1) RETURN
      NT1=JTAPE(2)
      REWIND NT1
      READ(NT1) TITLE
      READ(NT1) NSTEP,NPTS,NQS,DELT,TZERO,TAREA
      IF(IMET.EQ.1) TAREA=TAREA*2.471
      READ(NT1) (IPRNT(K),K=1,NPTS)
      IF(NQS.LT.1) GO TO 150
      NREAD=NSTEP
      DO 140 J=1,NPTS
      REWIND NT1
      READ(NT1) TITLE
      READ(NT1) NTX
      READ(NT1) NTX
      WRITE(N6,10) TITLE,IPRNT(J)
10    FORMAT(1H1/10X,20A4/10X,20A4//10X,*SUMMARY OF QUANTITY AND QUALITY
     2 RESULTS AT LOCATION*,I5//10X,*QUALITY IN*,* (MG/L) EXCEPT COLIFOR
     3MS IN (1000/100ML)*,//6X,*TIME*,9X,*FLOW*,9X,*DO      BOD    TOT-SS
     4   COLI    CL*,*       NH3    NO2+NO3  ORG-N  TOT-PHOS  PO4    GREASE
     5  H-METALS*,/,15X,*CMS       CFS*)
      NRD=NREAD
      DO 90 K=1,NREAD
      READ(NT1) NTIMEH,TIMEM,(FLOW(N),N=1,NPTS)
      IF(IMET.LT.1) GO TO 7010
      DO 7000 N=1,NPTS
      FLOW(N)=FLOW(N)*35.31
 7000 CONTINUE
 7010 CONTINUE
      IF(NTIMEH.NE.-1) GO TO 20
      NRD=K-1
      GO TO 100
20    IF(NQS.LT.1) GO TO 40
      READ(NT1) NTIMEH,TIMEM,((QUAL(M,N),N=1,NQS),M=1,NPTS)
      IF(NQS.LT.15) GO TO 40
      DO 30 N=15,NQS
30    OUT(K,N-14)=QUAL(J,N)
      FLOWOT(K)=FLOW(J)
      NHR(K)=NTIMEH
      TMIN(K)=TIMEM
40    CONTINUE
      IF(NQS.GE.8) GO TO 50
      NLT=NQS
      GO TO 70
50    NLT=NQS-1
      IF(NQS.GT.13) NLT=12
      QUAL(J,7)=QUAL(J,7)+QUAL(J,8)
      DO 60 JJ=8,12
```

```
      JK=JJ+1
60    QUAL(J,JJ)=QUAL(J,JK)
70    CONTINUE
C
C**** CONVERT FLOW TO CMS
      QCMS=FLOW(J)*0.02832
C
C**** CONVERT COLIFORMS TO 1000/100ML
      QUAL(J,4)=QUAL(J,4)/1000.
      WRITE(N6,80) NTIMEH,TIMEM,QCMS,FLOW(J),(QUAL(J,N),N=1,NLT)
80    FORMAT(I4,F6.2,F9.3,F9.2,12F8.1)
90    CONTINUE
100   CONTINUE
      IF(NQS.LT.15) GO TO 140
      WRITE(N6,110) TITLE,IPRNT(J)
110   FORMAT(1H1/10X,20A4/10X,20A4//10X,*SUMMARY OF QUANTITY AND QUALITY
     2 RESULTS AT LOCATION*,I5//10X,*FLOW IN CMS AND QUALITY IN (MG/L)*,
     3//6X,*TIME      FLOW  NO3+NO2  T-HYD-P ORTH-PO4       HG      CU
     4   ZN       PB       CR       CD       AS*)
      NLT=NQS-14
      DO 130 K=1,NRD
C
C**** CONVERT FLOW TO CMS
      QCMS=FLOWOT(K)*0.02832
      WRITE(N6,120) NHR(K),TMIN(K),QCMS,FLOWOT(K),(OUT(K,N),N=1,NLT)
120   FORMAT (I4,F6.2,13F9.2)
130   CONTINUE
140   CONTINUE
      RETURN
150   DO 200 J=1,NPTS,10
      MAX=J+9
      IF(MAX.GT.NPTS) MAX=NPTS
      WRITE(N6,160) TITLE
160   FORMAT(1H1/10X,20A4/10X,20A4//10X,*SUMMARY OF FLOWS..... NO QUALIT
     2Y SIMULATION....*)
      WRITE(N6,170) (IPRNT(K),K=J,MAX)
170   FORMAT(/10X,10I10/)
      REWIND NT1
      READ(NT1) TITLE
      READ(NT1) NTX
      READ(NT1) NTX
      DO 190 K=1,NSTEP
      READ(NT1) NTIMEH,TIMEM,(FLOW(N),N=1,NPTS)
      IF(NTIMEH.EQ.-1) GO TO 200
      WRITE(N6,180) NTIMEH,TIMEM,(FLOW(N),N=J,MAX)
180   FORMAT(I4,F6.2,10F10.2)
190   CONTINUE
200   CONTINUE
      RETURN
      END
```

Subroutine GQUAL

The subroutine calls no other subroutines and employs the following common blocks:

- REMOVE
- ABLK
- TAPES
- BLANK COMMON

The routing computations are as described in Chapter III. At the outfall, suspended solids removal is computed based on a user-specified treatment curve of the form $R = aQ^b$, where R is the removal fraction rate; Q, the flow rate (cfs); and a and b are computed from two user-specified points on the curve. The flowchart is in Figure IV-9. The major variables not contained in the above common areas are itemized in Table IV-5. The computer listing of the routine follows.

Variables in Common

Program DRAIN employs separate common blocks as itemized below:

- BLANK COMMON
- TAPES
- NEW
- RESIZ
- NEWGUT
- REMOVE
- ABLK
- MAX

Variable definitions for the common blocks listed above are presented in Tables IV-6 through IV-13, respectively.

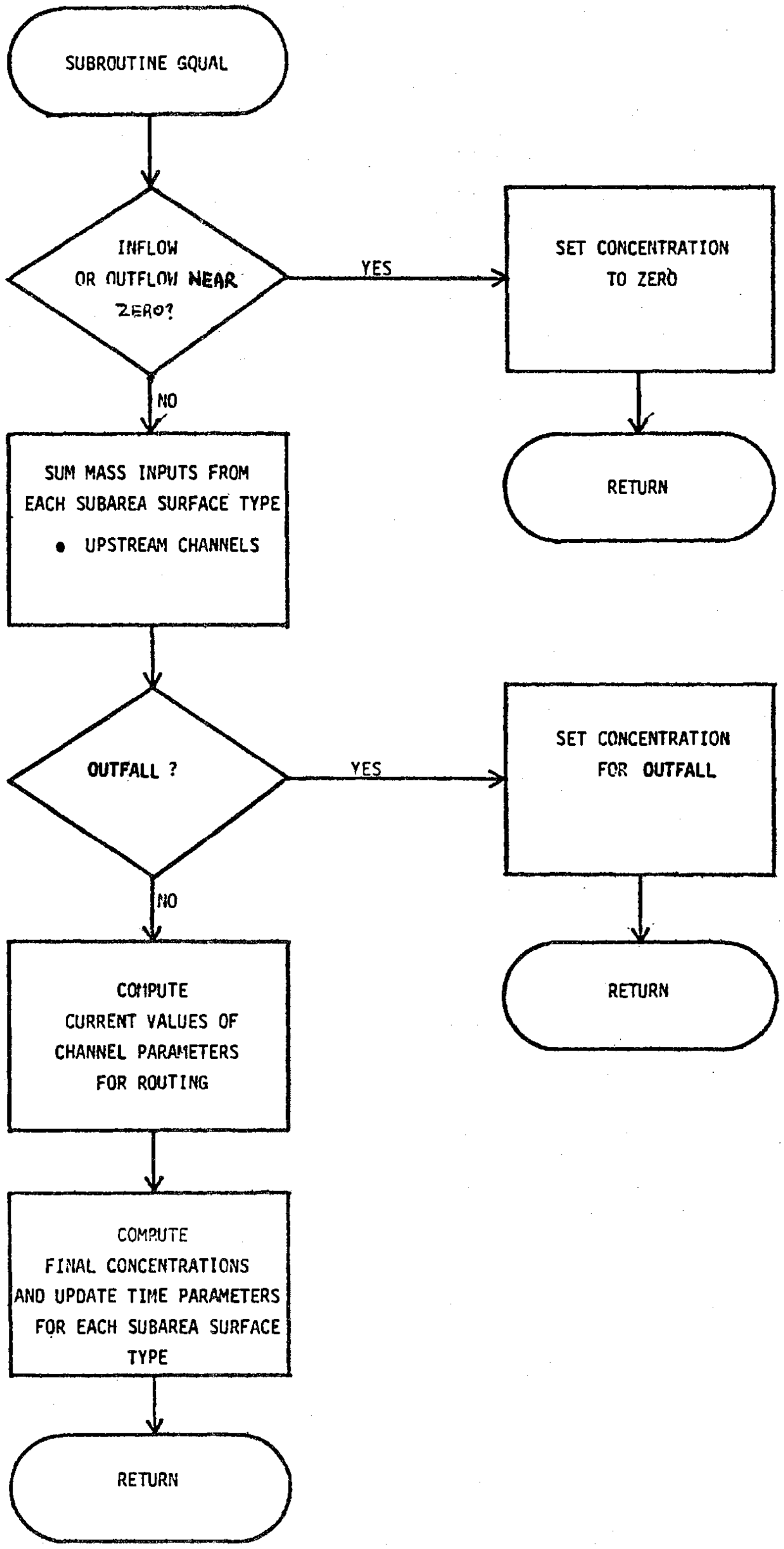

FIGURE IV-9. Flowchart of Subroutine GQUAL

TABLE IV-5

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE GQUAL

Fortran Variable	Description	Units
ALFA	Auxiliary variable	sec^{-1}
BETA	Auxiliary variable	gm/1/sec
J	Channel number (internal)	-
PREM	Surcharge mass flux	gm/sec
QT	Channel flow plus surcharge rate	ft^3/sec
RR	Suspended solids removal fraction	-
STORPL(13,5)	Surcharge mass in channel for each suspended solid type	gm
TEMP	Auxiliary variable	gm
V	Channel volume	sec/ft^3
VDOT	Time derivative of channel volume	ft^3/sec

```
      SUBROUTINE GQUAL(J,AREA,QOUT,TMSUR)
C
C******** THIS SUBROUTINE ROUTES QUALITY IN GUTTER J FOR THE FLOW VALUES
C******** COMPUTED IN SUBROUTINE GUTTER.  NQS QUALITIES ARE CALCULATED.
C
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,SUMR,SUMI,SUMOFF,SUMST,TZERO,NING
      COMMON WFLOW(200),WWIDTH(200),WAREA(200),WSLOPE(200),WN(200),
     2 WSTORE(200,3),WLMAX(200),WLMIN(200),DECAY(200),WDEPTH(200,3),
     3 WCON(200,3),NAMEW(200),PCIMP(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),NPG(200),DFULL(200),
     3 NGUT(200),SUMQW(200),PCTZER
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10),NGTOI(200)
      COMMON RAIN(200,10),NHYET(200),NRAIN,NRGAG,NHISTO,THISTO
      COMMON QSUR(200),DELD(200),QIN(200)
      COMMON IPRNT(200),ISAVE(200),NPRNT,NSAVE,OUTFLW(200),INTERV,
     2 INTCNT
      COMMON/ABLK/ NQS,
     2              C(200,5),CDOT(200,5),POFF(200,13),QFACT(5,13)
      COMMON/REMOVE/ PRRA(50),PRRB(50),QMIN(50)
      COMMON/TAPES/JTAPE(3),IMET,N5,N6,K1,K2,K3,K4,K5,K6
      DIMENSION QOUT(200),FLUX(20)
      DIMENSION STORPL(200,5)
      DATA STORPL/1000*0./
C
C******** CHECK FLOW AND SET ZEROS IF BELOW MINIMUM
C
      IF(GFLOW(J).GT.0.005) GO TO 150
      DO 130 K=1,5
      CDOT(J,K)=0.0
      C(J,K)=0.0
130   CONTINUE
      RETURN
150   CONTINUE
C
C******** COMPUTE INPUTS FROM UPSTREAM GUTTERS
C
      ALFA=2.0/DELT
      DO 200 M=1,5
      FLUX(M)=0.
      IF(TMSUR.GE.0) GO TO 200
      PREM=-TMSUR*STORPL(J,M)/(QSUR(J)-TMSUR*DELT)
      FLUX(M)=FLUX(M)+PREM
      STORPL(J,M)=STORPL(J,M)-PREM*DELT
200   CONTINUE
      DO 240 K=1,NIN
      L=NGTOG(J,K)
      IF(L.EQ.0) GO TO 245
      DO 220 M=1,5
      FLUX(M)=FLUX(M)+C(L,M)*QOUT(L)
220   CONTINUE
240   CONTINUE
245   CONTINUE
C
C******** ADD MASS INPUT FROM ADJACENT WATERSHEDS (POFF IN LBS)
C
```

```
      DO 280 K=1,NIN
      L=NWTOG(J,K)
      IF(L.EQ.0) GO TO 285
      DO 260 M=1,5
      FLUX(M)=FLUX(M)+POFF(L,M)
260   CONTINUE
280   CONTINUE
285   CONTINUE
      IF(NPG(J).NE.3) GO TO 286
      DO 1706 K=1,NSAVE
      N=NGTOI(K)
      IF(N.EQ.J) GO TO 1707
1706  CONTINUE
1707  QR=AMAX1(QMIN(K),QOUT(J))
      PR=PRRA(K)/QR**PRRB(K)
      DO 287 M=1,5
287   FLUX(M)=FLUX(M)*(1.-PR)
286   CONTINUE
C
C******** COMPUTE CURRENT VALUES OF GUTTER PARAMETERS FOR ROUTING
C
      V=AREA*GLEN(J)
      VDOT=QIN(J)-QOUT(J)-TMSUR
      QT=QOUT(J)
      IF(TMSUR.GT.0) QT=QT+TMSUR
      TEMP=1./(VDOT+ALFA*V+QT)
C
C******** COMPUTE FINAL CONCENTRATION AND UPDATE TIME PARAMETERS
C
      DO 290 K=1,5
      BETA=ALFA*C(J,K)+CDOT(J,K)
      C(J,K)=TEMP*(FLUX(K)+V*BETA)
      CDOT(J,K)=ALFA*C(J,K)-BETA
      IF(TMSUR.GT.0) STORPL(J,K)=STORPL(J,K)+TMSUR*C(J,K)*DELT
290   CONTINUE
      RETURN
      END
```

TABLE IV-6

BLANK COMMON

Variable Name	Description	Unit
DELD	Trial change in flow depth	feet
DELT	Integration time step	sec, min
DELT2	One half of a time step	sec, min
DFULL	Maximum depth of channel	feet
FLOW	Hydrograph flow value	cfs
FLOWOT	Temporary variable for printing flow	cfs
GCON	Manning's equation less hydraulic radius term	none
GDEPTH	Depth of flow in channel	feet
GFLOW	Average channel outflow over time step	cfs
GLEN	Length of channel	feet
GN	Manning's roughness coefficient	none
GSLOPE	Slope of channel	ft/mi, ft/ft
GS1, GS2	Channel side slopes, left and right (H/V)	ft/ft
GWIDTH	Pipe diameter or channel bottom width	ft
INTCNT	Printing counter	none
INTERV	Number of time steps between printed hydrograph values	none
IPRNT	External numbers of channels for which hydrographs will be printed	none
NG	Maximum number of channels	none
NGTOC	Channel connections	none
NGUT	Array ordering channels from upstream to downstream	none
NHISTO	Number of rainfall time intervals	none
NHR	Hour for hydrograph output	hr
NOG	Total number of channels	none
NPG	Control switch for type of channel	none
NPRNT	Number of channels to be printed	none

TABLE IV-6
(Continued)

Variable Name	Description	Unit
NSTEP	Number of time steps in simulation	none
OUT	Temporary variable for printing concentration	mg/1
OUTFLW	Flow out of the channel	cfs
QUAL	Concentration of quality constituents	mg/1
QIN	Inflow to channel	cfs
QSUR	Surcharge volume	ft^3
TIME	Current time	sec
TIME2	Current time minus half step	sec
TMIN	Minutes for hydrograph output	min
TZERO	Starting time of simulation	sec

TABLE IV-7
COMMON BLOCK TAPES

Fortran Variable	Description	Units
JTAPE(3)	Tape File Number Array	-
IMET	Units Option Control Variable	-
N5	Input device number	-
N6	Output device number	-
K1 through K6	Labels for units in output titles	-

TABLE IV-8
COMMON BLOCK NEW

Fortran Variable	Description	Units
NAMEG(200)	Drainage Element External Number	-
NGTO(200)	Drainage Element Downstream Drainage Number	-

TABLE IV-9

COMMON BLOCK RESIZ

Fortran Variable	Description	Units
NOPT	Resize Option Indicator	-
NEWSIZ	Simulation Control Variable	-
NEW(200)	Resize Indicator by Drainage Element	-
OLDWID(200)	Original Size by Drainage Element	ft

TABLE IV-10

COMMON BLOCK NEWGUT

Fortran Variable	Description	Units
NOGUTTER	Number of open channels	-
XSLOPE(200)	Not used presently	-
INTYP(200)	Not used presently	-
ISTA1A(200)	Station 1 (Hundreds)	ft
ISTA1B(200)	Station 1 (Units)	ft
ISTA2A(200)	Station 2 (Hundreds)	ft
ISTA2B(200)	Station 2 (Units)	ft
ELEVA1(200)	Station 1 Elevation	ft
ELEVA2(200)	Station 2 Elevation	ft
MGTO(200)	Not used presently	-

TABLE IV-11

COMMON BLOCK REMOVE

Fortran Variable	Description	Units
PRRA(50)	Outfall Treatment Constant a	
PRRB(50)	Outfall Treatment Constant b	-
QMIN(50)	Minimum Treatment flow	cfs

TABLE IV-12

COMMON BLOCK ABLK

Fortran Variable	Description	Units
NQS	Number of quality constituents considered	-
C(200,5)	Concentration of conservative constituent	g/l
CDOT(200,5)	Time derivative of constituent concentration	g/l/sec
POFF(200,13)	Inlet loadagraph, later concentration	g/sec,mg/l
QFACT(5,13)	mg constituent per g of suspended solids	mg/l

TABLE IV-13

COMMON BLOCK MAX

Fortran Variable	Description	Units
MAXFLW(200)	Maximum Computed Flow	cfs
MAXHR(200)	Time Maximum Computed Flow (Minutes)	min
MAXMIN(200)	Time Maximum Computed Flow (Hours)	hrs
MAXDEP(200)	Maximum Computed Depth	ft
SURLEN(200)	Length of Surcharge	sec

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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

B 27