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URBAN HIGHWAY STORM DRAINAGE MODEL

Research, Development, and Technology

Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101

VOL. 4 SURFACE RUNOFF PROGRAM

U.S. Department of Transportation

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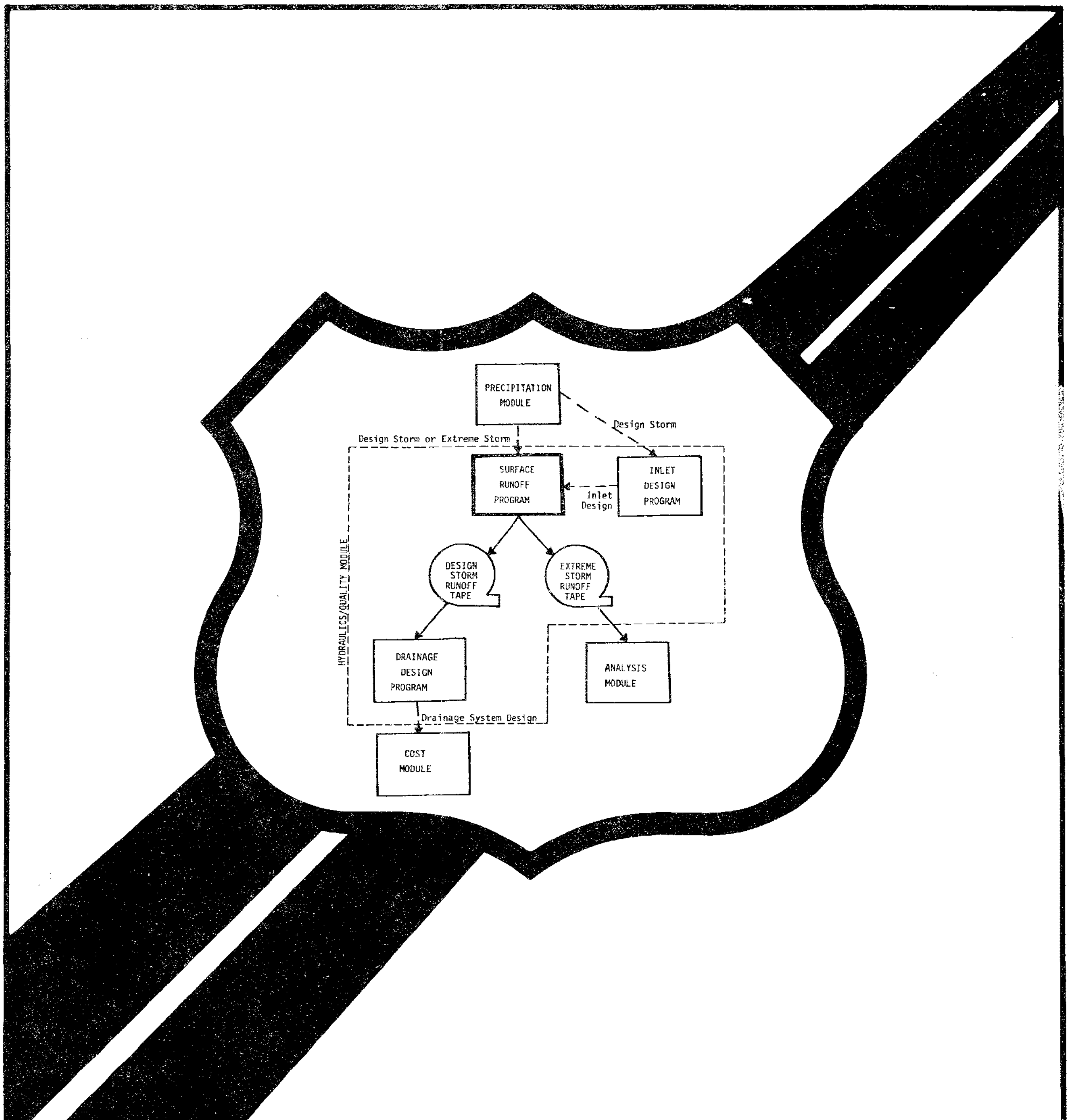

FOREWORD

This report documents the development and presents the user's manual for the Surface Runoff Program of the Hydraulics/Quality Module of this computer model. This program is an event model for both stormwater quantity and quality simulation. From the local design storms, either derived from the Precipitation Module or from other sources, this program computes the inlet hydrographs and estimates the inlet pollutographs. The computation scheme employed is a real area routing procedure.

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
Research and Development
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R. J. Dever, Jr., L.A. Roesner, and J.A. Aldrich

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16. Abstract

A package of six user-oriented computer programs has been develoepd and tested for the analysis and design of urban highway drainage systems and related non-point 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 Surface Runoff Program of the Hydraulics/Quality Module. This program simulates the runoff quantity and quality from the highway and its surroundings and routes the flow through the surface conveyance system to detention basins and inlets to the underground conduit system.

This report is the fourth 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
5	83/045	Drainage Design Program
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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 Analysis Module. Chapter 2 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 3. Finally, Chapter 4 is a complete user's manual for the program including input requirements, a Fortran listing of the program, and an example problem.

This Program is an event model for both stormwater quantity and and quality simulation. For stormwater quantity, it is used for design of new drainage system in the Inlet Design Program in determining locations of the selected inlets and in calculating the inlet hydrographs, or for anlaysis of existing drainage systems in deriving the inlet hydrographs. For stormwater quality, it is used to compute the accumulation and washoff

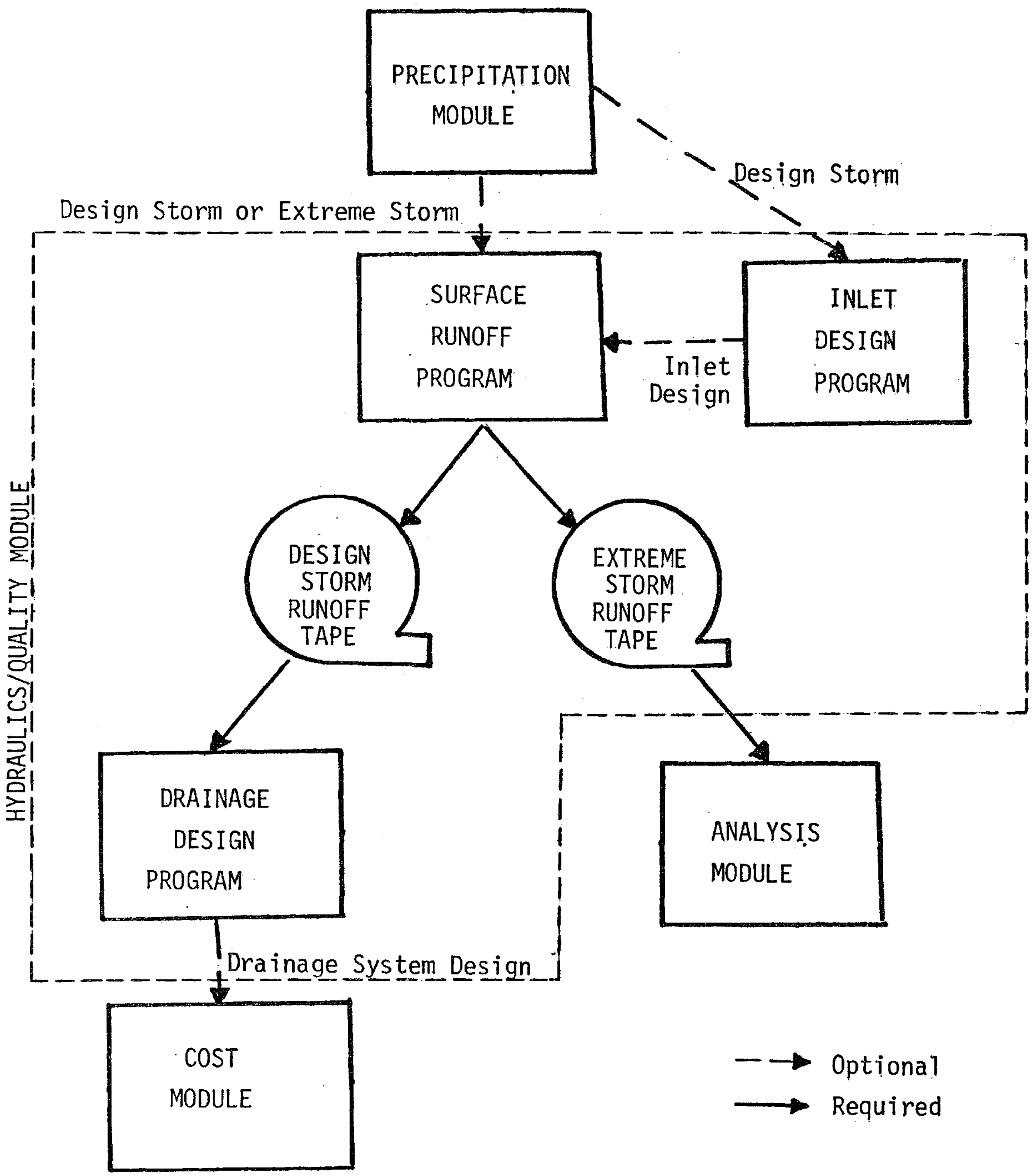


FIGURE I-1 Urban Highway Storm Drainage Model

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

of surface pollutants in deriving the inlet pollutographs. The computation scheme employed in this Program is a real-area routing procedure, not a conceptual one. The user must first divide his study area into homogeneous subareas, then route the stormwater into the inlets.

CHAPTER II

INTRODUCTION TO THE SURFACE RUNOFF PROGRAM

The highway storm drainage system consists of a surface runoff conveyance system and a major drainage system. The Surface Runoff Program (SRO) is a powerful and flexible computer program for simulating the surface runoff conveyance system for either analysis or design purposes. Both time-varying quantity and quality of runoff can be simulated. Additionally, output from the Surface Runoff Program can be used as input either to the Drainage Design Program of the Hydraulics/Quality Module or to the Analysis Module.

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 gutters and channels. The runoff is routed to a series of inlets, 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.

In the design or analysis of highway drainage systems, such as illustrated in Figure II-1, the first basic step is the computation of surface runoff from a selected storm event. Often, this computation has consisted of no more than calculating a peak runoff flow for each drainage area using the rational formula. The Surface Runoff Program provides a more sophisticated tool that can compute full runoff hydrographs, route these hydrographs through the surface drainage system, and calculate inlet hydrographs. In addition, this program can simulate the accumulation and washoff of surface pollutants in the highway right-of-way.

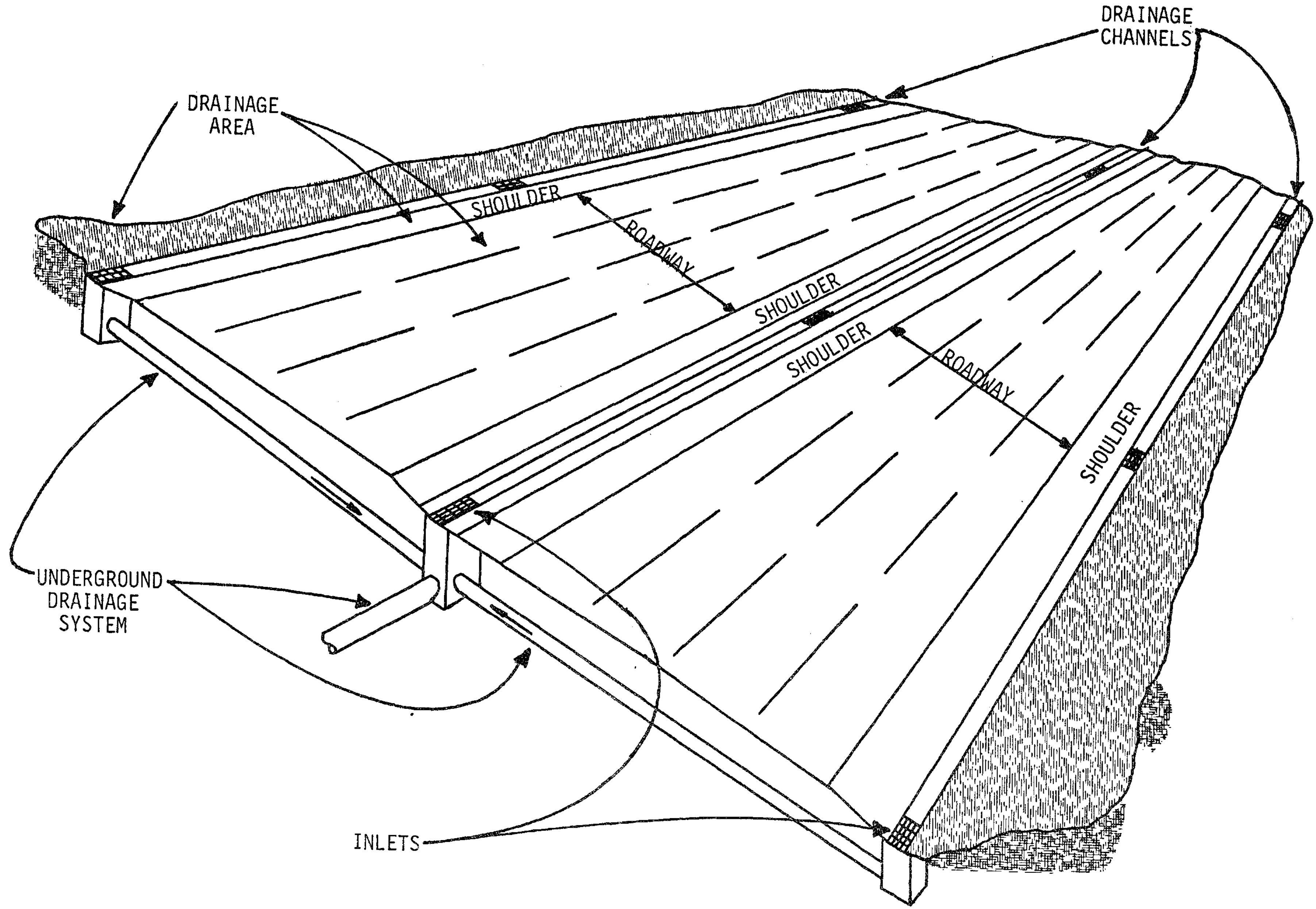


FIGURE II-1. Typical Urban Highway Drainage System

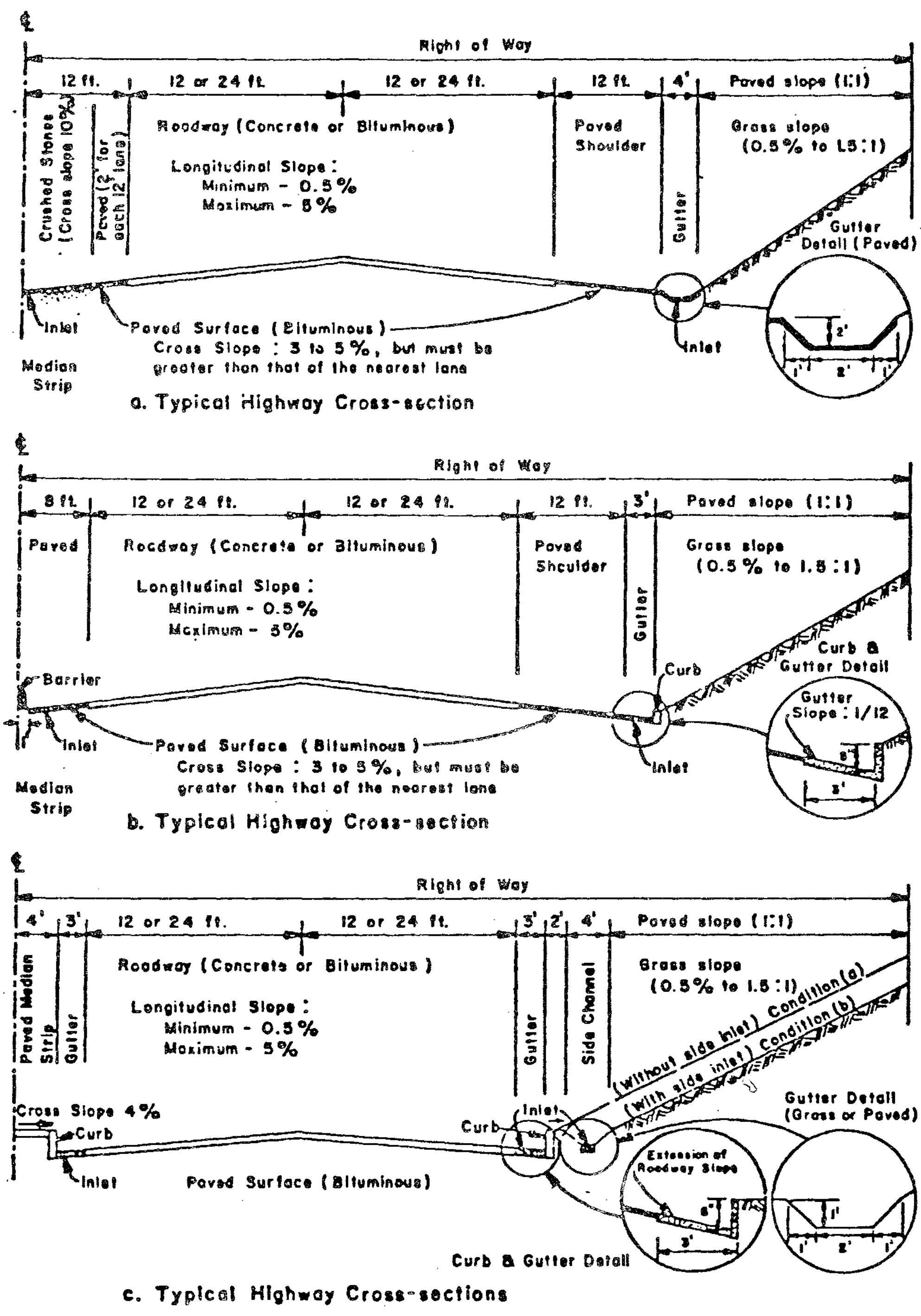


Figure II-2. Schematic Diagrams of Typical Urban Highway Cross-sections

The Surface Runoff Program is an event model, that is, it simulates runoff from an individual storm event, described by a complete hyetograph. To apply the program, the user must first divide his study area into homogeneous subareas that can be represented by a given area, width, slope, roughness coefficient and infiltration type. Similarly, the gutters and channels of the surface drainage system must be represented by sections of constant slope, cross-sectional area and roughness. The performance of inlets in the surface drainage system can be characterized by inlet efficiency curves input by the user or inlet efficiency equations built into the program. If runoff quality is to be simulated, then the user must select parameters describing the rate of accumulation of suspended solids and associated pollutants in the highway right-of-way.

In general, the Surface Runoff Program can be applied in two ways. First, the program can be used to analyze the performance of an existing or proposed surface drainage system during selected storm events. Second, the program can be used to compute inlet hydrographs and pollutographs for purposes of analysis or design of the subsurface drainage system. These hydrographs and pollutographs can be saved as a disc or tape file for subsequent use by the Drainage Design Program or the Analysis Module. The Drainage Design Programs can be used to size the subsurface drainage system and to analyze suspended solids removal facilities at system outfalls. The Analysis Module can be used to analyze the hydraulic performance of the subsurface drainage system during extreme storm events.

CAPABILITIES AND LIMITATIONS

Program SRO will simulate time-varying runoff quantity and quality from a selected storm event and route these flows and pollutants through gutters,channels, pipes, and detention basins of the highway right-of-way. The program is capable of simulating the following types of surface drainage structures:

- Circular pipes
- Trapezoidal open channels
- Overbank channels (double trapezoidal channels)
- Gutters (special case of trapezoidal channels)
- Detention basins with weir outflow control
- Detention basins with channel outflow control

The hydraulics of the following six basic inlet types may be simulated:

- Curb Opening Inlet
- Depressed Curb Opening Inlet
- Grate Inlet
- Depressed Grate Inlet
- Combination Inlet
- Depressed Combination Inlet

The accumulation, washoff, and transport of total suspended solids and the following associated pollutants may be modeled, if the user so desires:

- Dissolved Oxygen
- Biochemical Oxygen Demand
- Fecal Coliforms
- Chloride
- Ammonia
- Nitrite
- Nitrate
- Organic Nitrogen
- Total Phosphorus
- Dissolved Orthophosphates
- Oil and Grease
- Heavy Metals

The program will compute inlet hydrographs and pollutographs and write this information to a disc or tape file for subsequent use by the Drainage Design Program or the Analysis Module.

There are several limitations imposed on the user by the program as presently structured. These limitations include:

- The number of gutter or channel sections plus the number of inlets must be less than or equal to 150;
- The number of watersheds must be less than or equal to 200;
- The number of subareas per watershed must be less than or equal to three;
- The number of raingages must be less than or equal to 13;
- The number of infiltration types must be less than or equal to four (not including impervious surfaces);
- The number of detention basins must be less than or equal to three;
- The number of pollutants simulated must be less than or equal to 13; and
- The number of pollutant accumulation rates (for different

land surface types) must less than or equal to five.

- The detention basin computation is for evaluation of fixed-size basins only. For sizing a new detention basin several sizes will have to be assumed and their effects evaluated.

COMPUTATIONAL REQUIREMENTS

Program SRO was developed on a shared CDC 6600/6700 computer at the Naval Ship Research and Development Center in Carderock, Maryland. The program as presently dimensioned requires approximately 250000_8 words of storage. A drainage system consisting of five gutters, one detention basin, and seven watersheds required approximately 85 seconds for a simulation of both quantity and quality conditions over a three hour and twenty minute period.

CHAPTER III

TECHNICAL APPROACH

This chapter describes the formulation and mathematical structure of the surface runoff system as it is simulated in SRO. The discussion is divided into seven parts dealing with the major computational topics: computational elements; surface runoff; gutter/channel flow routing; detention basins; inlet hydraulics; runoff quality; and quality routing. All equations presented in this chapter are given in terms of the British system of units, for the sake of simplicity. Corresponding equations in metric units are contained in the program.

COMPUTATIONAL ELEMENTS

The gutters/channels and watersheds of the drainage area being simulated must be discretized into a series of computational elements by the user. The gutters or channels being simulated are divided into a series of sections having constant hydraulic and geometric characteristics.

The drainage area along either side of the gutters and channels must also be discretized into a series of watersheds of constant hydraulic and geometric characteristics. Each watershed must drain to a gutter or channel; however, each watershed may be divided into as many as three subareas. Runoff is thus allowed to cascade from subarea to subarea before draining to a gutter or channel.

SURFACE RUNOFF

As stated above, each watershed may contain up to three subareas. The Surface Runoff Program considers the flow from the upstream subarea to cascade to the immediate downstream subarea. The basic flow routing algorithm in the program is the kinematic wave approximation which assumes that the friction slope is equal to the slope of the plane. For this condition, the equations of continuity and uniform flow must be solved simultaneously to define at each time step the depth of flow and the outflow for each of the subareas in the watershed. The flow routing algorithm is applied sequentially to each subarea in the cascade.

A typical watershed is shown in Figure III-1; the three-plane runoff computation sequence can be generalized for an arbitrary subarea as shown in Figure III-2. At the end of each time step, Δt, we have two unknowns, Q and d_1, and two equations as indicated in Figure III-1. Three flow depths are shown in the figure:

d_o = depth at time t;
d_1 = depth at time $t + \Delta t$; and
d_s = average depth of depression storage.

The objective of the calculations which pertains to this subarea is to find the new depth, d_1, determining, in the process, the outflow, Q, and maintaining mass continuity at all times. To accomplish this, two equations must be solved simultaneously. The first is the continuity, or storage, equation:

$$\frac{\Delta d}{\Delta t} = R - I + \frac{(Q_i - Q)}{A_s} \qquad \text{(III-1)}$$

where

$\Delta d = d_1 - d_o$;
R = rainfall intensity during Δt;
I = infiltration rate during Δt;
Q = outflow from subarea;
Q_i = inflow from upstream subarea; and
A_s = surface area of plane.

The second is the Manning equation for overland flow with the hydraulic radius set equal to average depth (wide channel assumption):

$$Q = \frac{1.49}{n} S^{1/2} W \left\{ \left(\frac{d_o + d_1}{2} \right) - d_s \right\}^{5/3} \qquad \text{(III-2)}$$

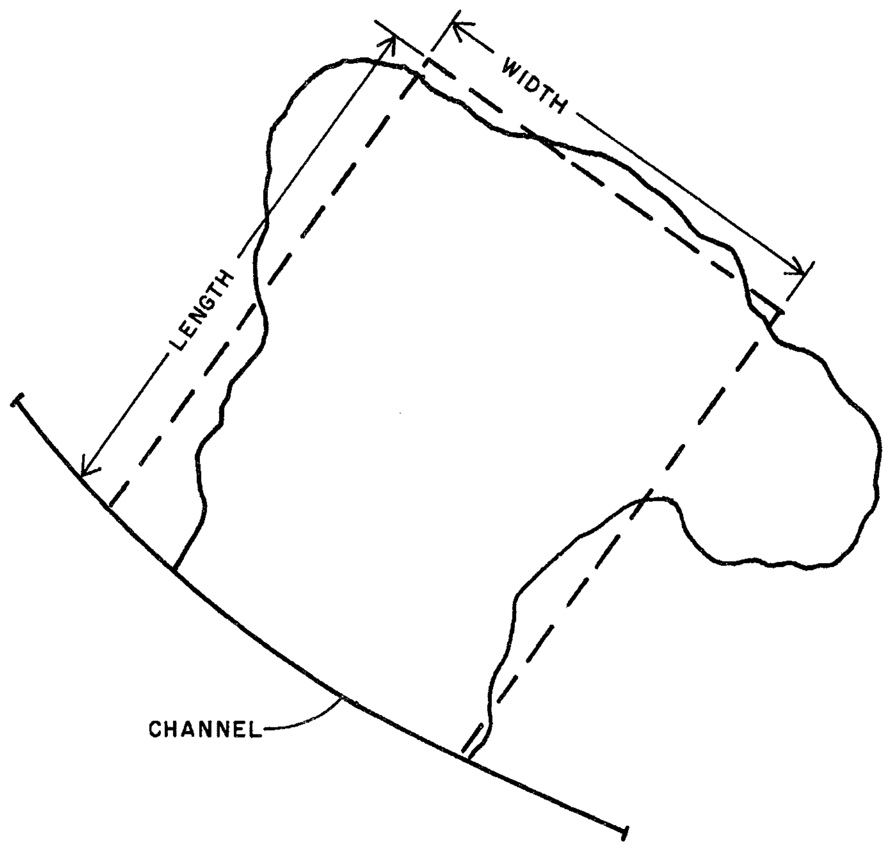
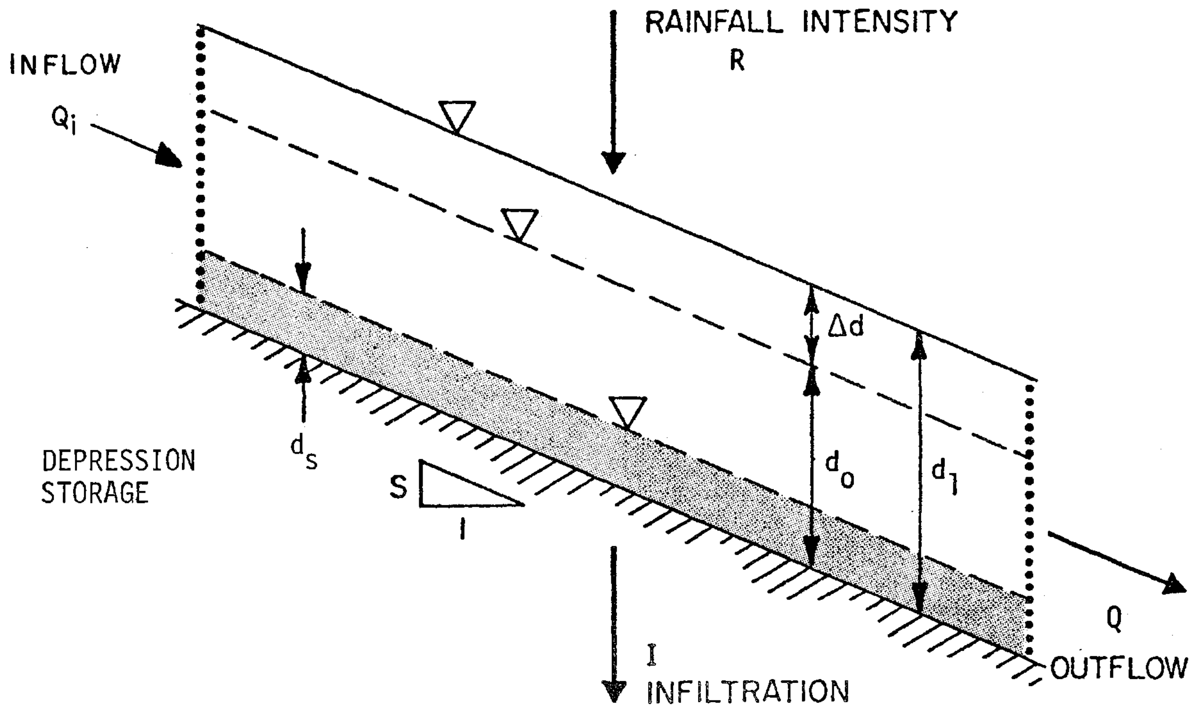


FIGURE III-1. Representation of Typical Watershed



$$\text{INFILTRATION: } I = k_1 + (k_2 - k_1)e^{-k_3 t}$$

$$\text{OUTFLOW: } Q = \frac{1.49}{n} S^{1/2} w \left(\frac{d_o + d_1}{2} - d_s\right)^{5/3}$$

$$\text{INFLOW: } Q_i$$

$$\text{STORAGE: } \frac{\Delta d}{\Delta t} = R - I + \frac{(Q_i - Q)}{A_s}$$

FIGURE III-2. Basic Flow Calculations for Typical Watershed Subarea

where

S = slope of ground surface;

n = Manning coefficient; and

w = width of the plane.

Here, we have two equations in two unknowns, Q and d_1. Note that the flow computation is based on the average depth during Δt, and that surface detention is not included in the effective depth of flow. Rainfall intensity is an input quantity, variable in time, but considered constant during each time interval Δt. Infiltration is computed by a modified Horton formula written as:

$$I = k_1 + (k_2 - k_1)e^{-k_3 t} \qquad \text{(III-3)}$$

where

I = infiltration loss rate, inches per hour;

k_1, k_2 = minimum and maximum infiltration rates, respectively;

k_3 = exponential rate loss in infiltration capacity; and

t = time in hours.

During periods of light or zero rainfall, the net precipitation value, R-I, could become negative. Traps in the computer program prevent this occurrence.

The equations III-1 and III-2 are nonlinear algebraic equations and their simultaneous solution is performed by the Newton-Raphson iterative technique. First, these two equations are combined and rearranged in the form:

$$F = \Delta d - \Delta t\ (k\tilde{d}^{5/3} + R_{net}) = 0 \qquad \text{(III-4)}$$

where

F = Newton's function

$$k = -\frac{1.49}{n} S^{1/2} w \ / A_s$$

$$\tilde{d} = \frac{d_o + d_1}{2} - d_s = d_o - d_s + \frac{\Delta d}{2}$$

$$R_{net} = (R + \frac{Q_i}{A_s} - I)$$

Then, differentiating F with respect to Δd yields

$$\frac{dF}{d(\Delta d)} = 1 - \Delta t \frac{5}{6} k\tilde{d}^{2/3} \qquad \text{(III-5)}$$

The Newton-Raphson technique then uses the following interative calculation to find Δd:

$$(\Delta d)_{n+1} = (\Delta d)_n - \frac{F_n}{\frac{dF_n}{d(\Delta d)}} \qquad \text{(III-6)}$$

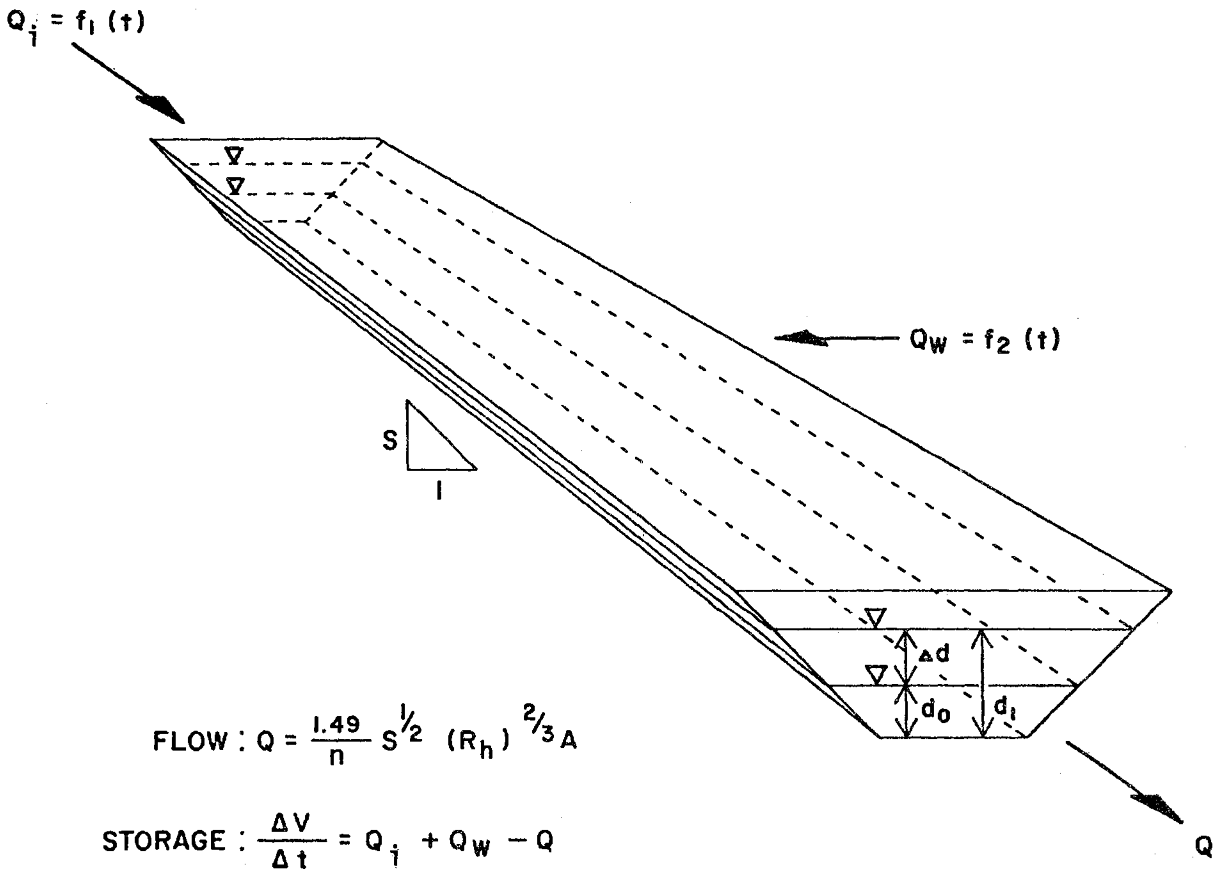
The subscripts refer to the n^{th} and $(n+1)^{th}$ iterations. Repeated application of this expression coverges upon F = 0. However, because of the possibility of truncation when subtracting numbers that are very close to each other, F may never converge upon 0 on some computers, although an adequate solution has been reached. For this reason, the convergence check is based on the percentage change in Δd from the previous iteration reaching some small value. The convergence criterion used is:

$$|(\Delta d)_{n+1} - (\Delta d)_n| < |0.01(\Delta d)_n| \qquad \text{(III-7)}$$

The corresponding value of Δd gives the final depth, d_1, and the outflow, Q, can then be calculated from equation IV-2. The solution is then repeated for the next subarea in the cascade. The outflow from the downstream-most subarea is considered the outflow from the watershed and is input to the channel draining this watershed. The entire sequence is repeated for all time steps in the surface runoff simulation period.

GUTTER/CHANNEL FLOW ROUTING

The surface runoff calculated as described above is next routed through the gutters, channels, and pipes of the highway right-of-way. Consider the typical trapezoidal channel shown in Figure III-3. (Note that flow calculations for gutters and 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



FLOW : $Q = \frac{1.49}{n} S^{1/2} (R_h)^{2/3} A$

STORAGE : $\frac{\Delta V}{\Delta t} = Q_i + Q_W - Q$

Figure III-3. Basic Flow Calculations For Typical Channel outflow from each channel then serving as inflow to the next downstream channel if no inlet is located at the end of the upstream channel. If an inlet is located there, the appropriate carryover flow is calculated as described later in this chapter.

As with watershed subareas, the two unknowns at the end of each time step are Q and d_1. The known quantities are inflows Q_i, Q_W, and depth d_o, where

d_o = depth at time t;
d_1 = depth at time t + Δt;
Q_i = inflow from upstream gutter or channel;
Q_W = inflow from adjacent watershed subareas; and
Q = outflow from channel.

Note that Q_W is the outflow from the downstream-most plane of the cascaded subareas of the given watershed, as discussed above.

The solution for d_1 and Q is similar to that used to compute flow off watershed subareas. Again, 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:

$$\frac{\Delta V}{\Delta t} = Q_i + Q_W - Q \qquad \text{(III-8)}$$

where

ΔV = volume change associated with Δd.

The outflow Q is determined from the Manning equation:

$$Q^* = \frac{1.49}{n} S^{1/2} R_h^{2/3} A \qquad \text{(III-9)}$$

where

Q^* = outflow at d_o or d_1

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-8 and III-9. These equations are combined and Newton's function F is formed as follows:

$$F = \Delta V + \Delta t(Q - Q_i - Q_W) = 0 \qquad \text{(III-10)}$$

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 Δd and the following iterative formula used:

$$(\Delta d)_{n+1} = (\Delta d)_n - \frac{F_n}{\frac{d\,F_n}{d(\Delta d)}} \qquad \text{(III-11)}$$

The subscripts refer to the n^{th} and $(n+1)^{th}$ iterations. As in the subarea calculations, a convergence criterion other than F = 0 is required. The following criterion is used and has proven to be stable and efficient:

$$\left|Q_{n+1} - Q_n\right| < 0.001\ (Q_{n+1}) \qquad \text{(III-12)}$$

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

Normal gutters and channels (types 1 and 2) will surcharge. The volume of surcharge,

$$V_{SUR} = (Q_i + Q_W - Q_{FULL})\Delta t \qquad \text{(III-13)}$$

where

V_{SUR} = surcharge volume for time step

Q_{FULL} = outflow from channel at full depth

is set aside. Since V_{SUR} may be positive or negative, the total volume in surcharge may increase or decrease with time. Each channel has its own surcharge volume which is handled separately from any other.

Overbank Channels

The flow in overbank channels, or double trapezoidal channels, Figure III-4, is handled normally until the depth reaches full channel depth for the base channel. At that point, if inflow exceeds outflow, i.e.,

$$Q_i + Q_W > Q_{FULL} \tag{III-14}$$

then the excess, $Q_i + Q_W - Q_{FULL}$, is entered into the overbank channel as the sole inflow and the depth and flow from the overbank channel are found by iteration as for standard channels. The only difference in the calculations is that the wetted perimeter of the overbank channel does not include the top width of the base channel when full; cross-sectional areas, however, are computed in the normal fashion. In addition, length and slope are assumed to be the same for base and overbank channels.

The outflow from the overbank channel is then added to the outflow from the full base channel to arrive at the total outflow from the double trapezoidal channel. The outflow from the double trapezoidal channel then serves as inflow to the next channel in the system. When the volume in the overbank channel (V_{OVR}) is small enough such that the following condition is met:

$$Q_i + Q_W + \frac{V_{OVR}}{\Delta t} < Q_{FULL} \tag{III-15}$$

then the overbank channel is emptied completely and the depth in the base channel falls below full depth. Of course, the overbank channel may flow again if the total inflow into the base channel later exceeds Q_{FULL}.

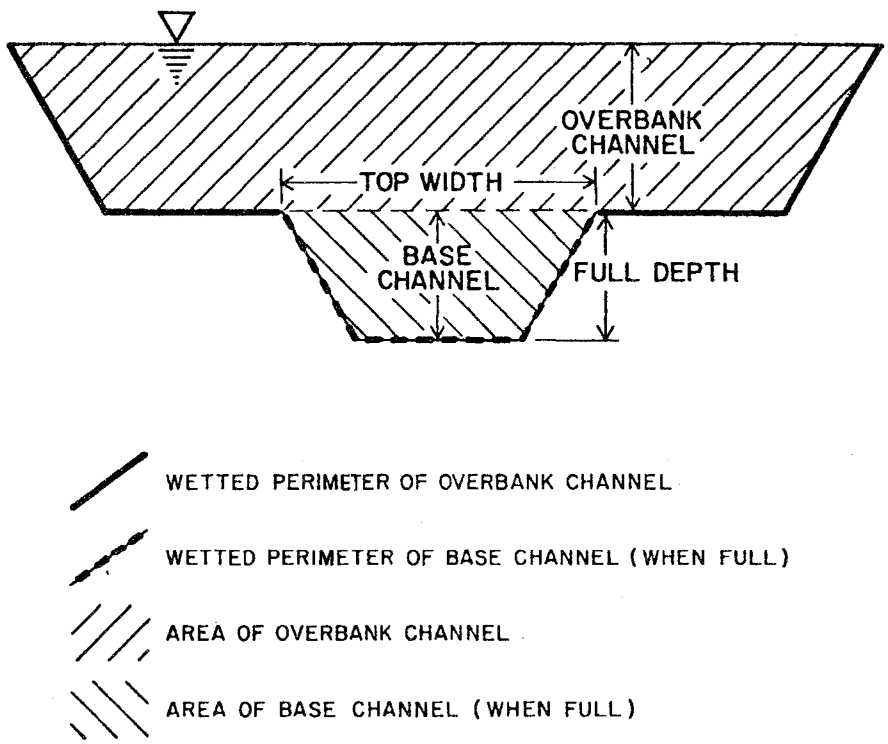


Figure III-4. Double-Trapezoidal Channel

Overbank channels do not surcharge in the manner described above. If the flow depth exceeds the full depth specified for the overbank channel, the banks are extended at the same side slopes to handle the excess flow, and a message is printed informing the user that this condition has occurred.

DETENTION BASINS

The computations for detention basins are made on the assumption that the change in depth of the detention basin over one time step will not significantly affect the outflow, which is controlled by either a weir or an outlet channel. It is also assumed that the surface area of the detention basin is constant. Thus, there is no need for an iterative solution technique. Figure III-5 shows a typical detention basin.

The outflow from a weir-controlled basin is computed from the discharge equation for flow over a sharp-crested rectangular weir:

$$Q = K\ W\ d_o^{3/2} \tag{III-16}$$

where

K = weir coefficient (=3.33)
W = length along weir crest
d_o = depth over weir crest at time t

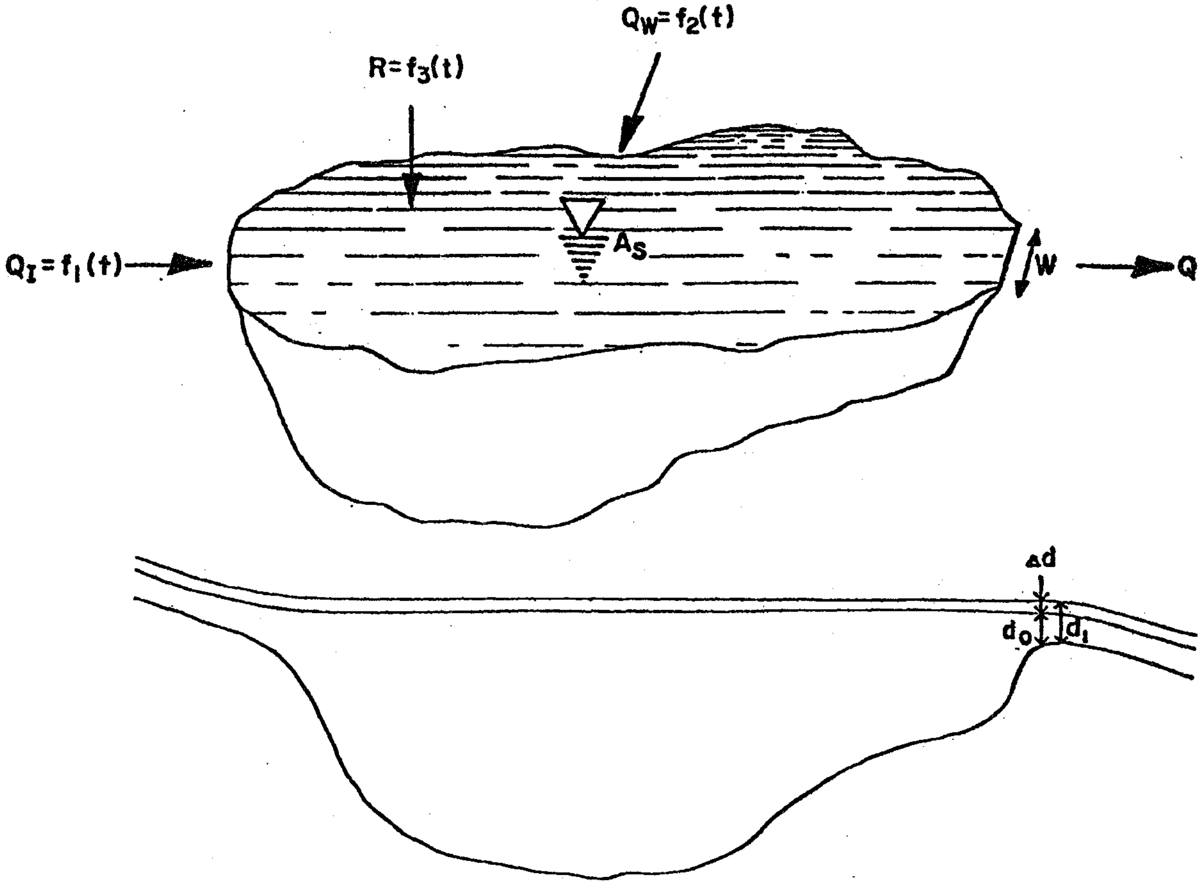
The outflow from an outlet channel-controlled basin is computed from the Manning equation:

$$Q = \frac{1.49}{n}\ s^{1/2}(R_h)^{2/3}A \tag{III-17}$$

where n, s, R_h, and A describe the outlet channel at time t ($d=d_o$). The new depth in both cases is found from the continuity equation:

$$\frac{\Delta d}{\Delta t} = R + (Q_i + Q_W - Q)/A_s \tag{III-18}$$

where d, R, Q_i, Q_W and Q are as previously defined, and A_s = surface area of basin (constant with time).



FLOW : $Q = kW d_o^{3/2}$ (WEIR)

$Q = \frac{1.49}{n} S^{1/2} (R_h)^{2/3} A$ (OUTLET CHANNEL)

STORAGE : $\frac{\Delta d}{\Delta t} = R + (Q \quad + Q_W - Q)/A_s$

Figure III-5. Basic Flow Calculations for a Detention Basin

INLET HYDRAULICS

The Surface Runoff Program is structured to allow the user to simulate six basic types of inlets:

- Curb Opening Inlet;
- Depressed Curb Opening Inlet;
- Grate Inlet;
- Depressed Grate Inlet;
- Combination (Curb Opening and Grate) Inlet; and
- Depressed Combination Inlet.

The hydraulics of an inlet on grade may be simulated by either an equation approach or by an inlet efficiency curve approach. Equations developed by Izzard and described below are available in the program to simulate the hydraulics of FHWA depressed curb opening inlets. At present, no other inlet equations are in the program, but the Fortran code is structured to allow easy addition of equations for the other inlet types. (See the description of Subroutine Carry in the following chapter.)

As an alternative to the equation approach, inlet efficiency curves supplied as input can be used by the program to compute flow interception by inlets. Efficiency curves which give percent interception versus total gutter flow or channel depth can be input for a fixed-size inlet of any of the six types listed above.

For sump inlets, the program assumes that all remaining flow is intercepted.

FHWA Depressed Curb Opening Inlets on Continuous Grades - Izzard Methodology (1)

A methodology has been developed by Izzard to determine the flow properties of the FHWA depressed curb opening inlet in gutters, as shown in Figure III-6. The methodology proceeds as follows.

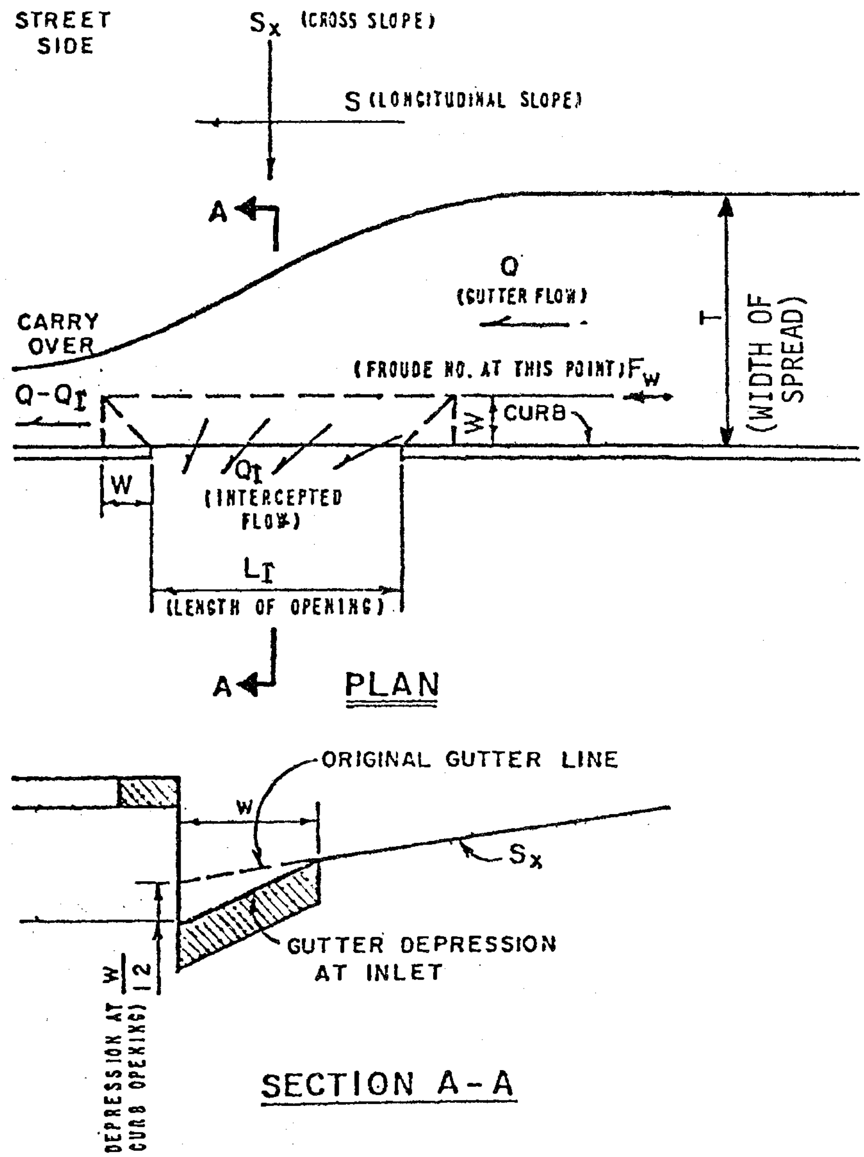


FIGURE III-6. FHWA Depressed Curb Opening Inlet

Based upon the depth of flow in the gutter and the cross-sectional properties of the gutter, the flow spread T (ft) and the flow Q (cfs) may be determined. The design engineer is required to specify the depression width W (ft). The depression depth is assumed to be equal to W/12 (feet). The following steps are then followed to compute the flow characteristics.

Step 1: Compute Froude Number:

$$F_W = \frac{0.262}{n} \{ (T - W)S_x\}^{1/6} S^{1/2} \qquad \text{(III-19)}$$

where

F_W = Froude Number at a distance W from the curb face
n = Manning coefficient for the gutter
W = Depression width (ft)
S_x = Cross slope of the pavement section (ft/ft)
S = Longitudinal slope of the pavement (ft/ft)
T = Width of spread of approach flow (ft)

Step 2: Compute L_1:

$$L_1 = 2.79\, W^{-1/6}\, S_x^{\;0.3} F_W T \qquad \text{(III-20)}$$

where L_1 is a characteristic inlet length given by the above equation.

Step 3: Compute maximum inlet length for weir flow:

$$L_{max} = 3.67 W^{-1/6}\, S_x^{\;0.5} F_W T \qquad \text{(III-21)}$$

where L_{max} is the maximum length for weir flow (ft).

Step 4: Compute inlet length for complete interception:

$$L_{100} = 1.85\ W^{1/6}\ F_w\ T \qquad \text{(III-22)}$$

where L_{100} is the length for complete interception (ft).

Step 5: Computer flow intercepted and carryover flow:

$$Q_I = \left(\frac{L_I}{L_1} Q\right) \text{ when } L_I \leq L_{max} \qquad \text{(III-23)}$$

$$Q_I = \left(\frac{L_1}{L_{100}}\right) Q \text{ when } L_I \geq L_{max} \qquad \text{(III-24)}$$

$$Q_c = Q - Q_I \qquad \text{(III-25)}$$

where

Q = total gutter flow at inlet (cfs)
Q_I = flow intercepted by inlet (cfs)
Q_C = carryover flow (cfs)
L_I = length of inlet (ft)

The equations presented are most accurate for W = 2 ft. and are reliable for W <2 ft. For W >2 ft., results obtained from the equations have not been confirmed.

Inlet Efficiency Curves

The simulation of inlet hydraulics by means of inlet efficiency curves proceeds as follows.. The user supplies as input a group of inlet efficiency curves for the size and type of inlet in question, as shown in Figure III-7. (Actually, the user supplies the coordinates of points that define the curves.) The curves give the percentage of gutter or channel flow intercepted by the inlet as a function of the total gutter or channel flow at a given point

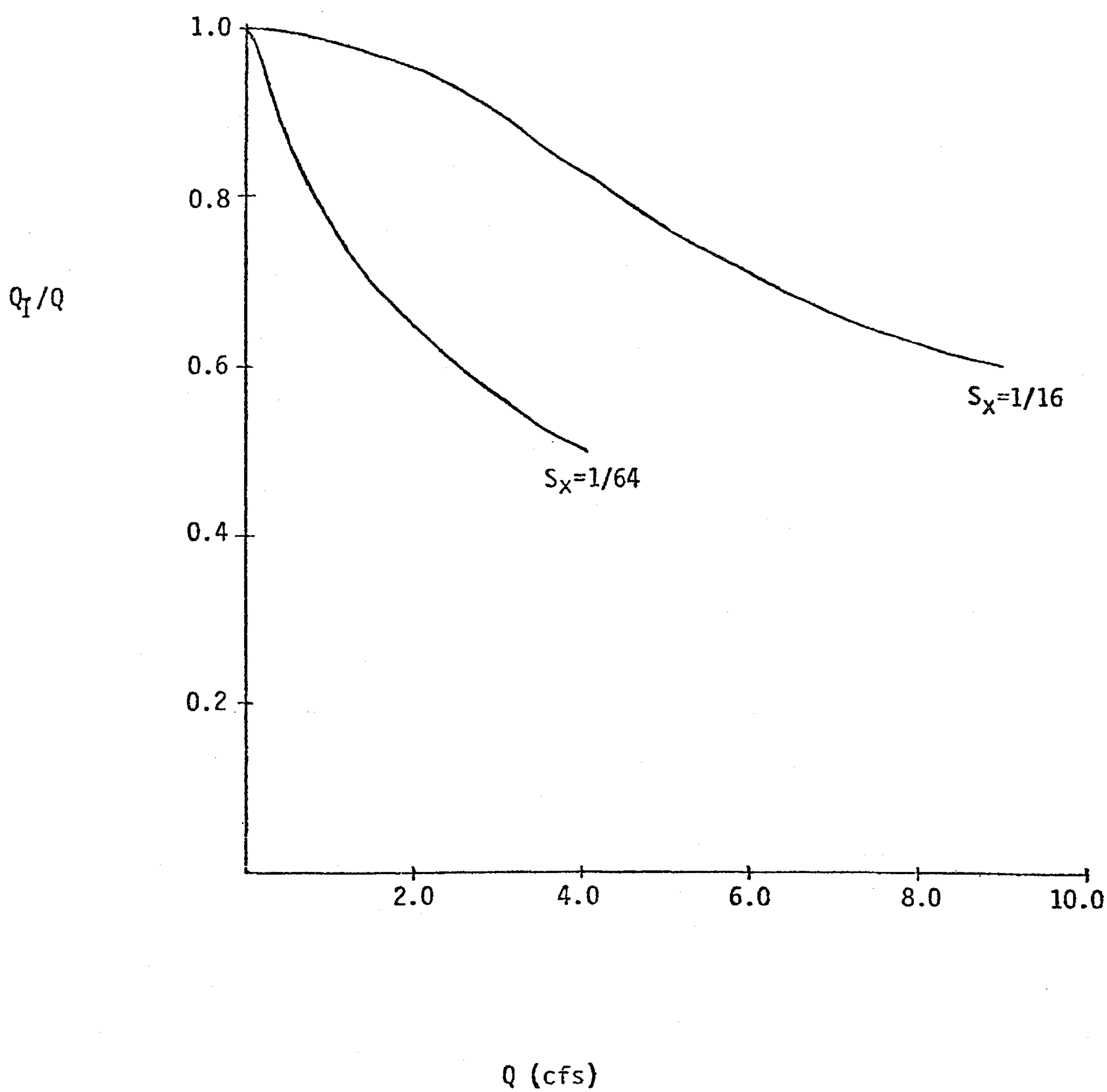


FIGURE III-7. Inlet Efficiency Curves for 2' X 4' Parallel Bar Grate Inlet with Gutter Slope = 0.02 (2) in time or the percentage of channel flow intercepted as a function of depth of flow at a given point in time. For inlets in gutters, the flow interception capacity is a function of both the longitudinal slope and the cross-slope of the highway surface; thus, a family of curves, one curve for each of several typical longitudinal slopes and the cross-slopes, must be supplied. For inlets in channels, the flow interception capacity is a function of the channel slope; a family of curves for typical channel slopes must be input by the user. In the example curves of Figure IV-7, Q_I is the flow intercepted by the inlet, Q is the gutter/channel flow, and S_x is the cross-slope of the highway.

For a given inlet, the program will select the appropriate inlet efficiency curve to use based on the slope of the gutter/channel section where the inlet is located and the cross-slope of the highway, if appropriate. At each time step, the program then calculates the gutter/channel flow, determines the inlet efficiency from the curve, and computes the flow intercepted by the inlet and the flow carried over to the next gutter/channel section.

RUNOFF QUALITY

The basis of the runoff quality computations in the Surface Runoff Program are numerous studies in which pollutant washoff rates have been related to antecedent surface buildup and runoff intensities by empirical functions. Antecedent surface buildup of pollutants can be expressed as a function of total suspended solids (TSS) buildup. TSS accumulation in turn can be written in the form:

$$P_{NL} = SSU_L \times \frac{N_D}{HAFSAT_L + N_D} \times A^*_N \qquad \text{(III-26)}$$

where

P_{NL} = TSS accumulation at the start of the storm on watershed subarea N having surface type L (lbs)

SSU_L = Ultimate TSS load for surface type L (lbs/acre)

N_D = Equivalent number of dry days since the last storm

$HAFSAT_L$ = Number of dry days required for TSS load to reach one-half the ultimate TSS load for surface type L

A^*_N = Subarea area (acres)

The resultant TSS accumulation with time is illustrated in Figure III-8.

The values of SSU_L, the ultimate TSS load for surface type L, and $HAFSAT_L$, the number of dry days required for the TSS load to reach one-half of SSU_L, are user-supplied values that define the TSS accumulation curve for each land surface type. At present, typical values for these parameters for five land surface types are supplied in the program in Block Data. If the user has site-specific runoff quality data available, he may wish to adjust these parameters accordingly. The user should refer to the Block Data section of Chapter IV for more information.

The actual number of dry days since the last storm must be modified to account for the number of times maintenance has occurred since the last rainfall. The corrected value for N_D, the equivalent number of dry days, is:

$$N_D = N_S \times [1 + (1-E)^1 + \ldots + (1-E)^n] \qquad \text{(III-27)}$$

where

N_S = number of days between maintenance
n = number of times maintenance was performed since the last storm
E = efficiency of the maintenance practice

Once the TSS load, P_{NL}, on all the watershed subareas by surface type has been determined, the rate of washoff to the surface drainage system can be expressed by a first order rate equation as:

$$\frac{d P^*_{NL}}{dt} = K P^*_{NL} \qquad \text{(III-28)}$$

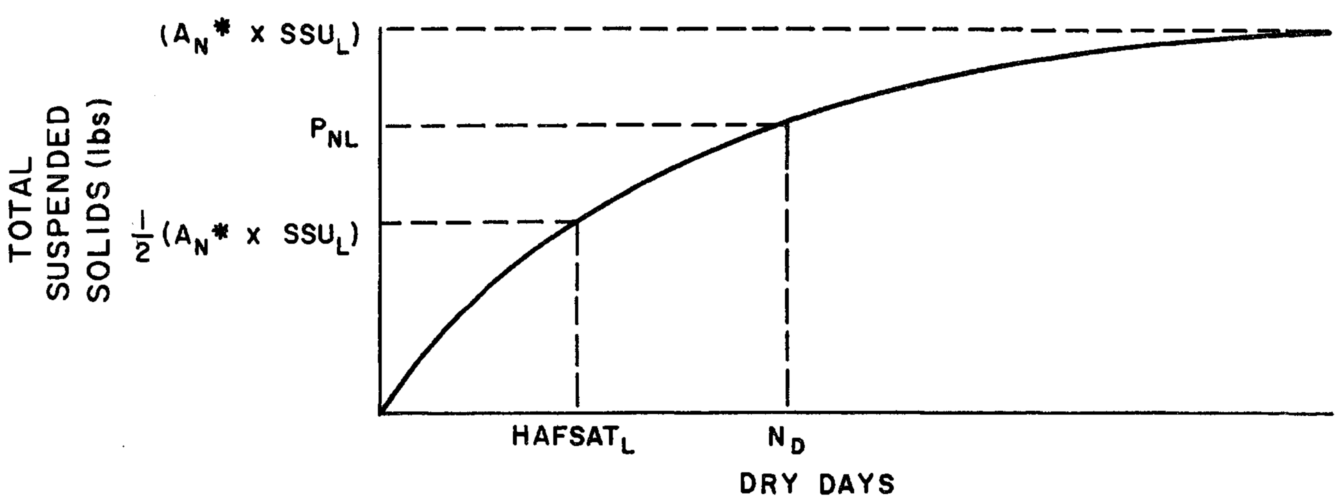


FIGURE III-8 .. TSS Accumulation vs. Dry Days

where

P^*_{NL} = TSS load available for washoff = P_{NL} x AVAIL

K = decay rate related to runoff intensity

AVAIL = availability factor related to runoff intensity

The decay rate K is assumed to be directly proportional to runoff rate. AVAIL is assumed to increase from some small value at low runoff intensities to 1.0 at the runoff intensity level at which essentially all the remaining load is available for washoff at the set decay rate.

Comparisons with measured data in the Detroit, Michigan area, suggested use of the following expression for AVAIL (3):

$$AVAIL = 0.03 + 33R^2 \qquad \text{(III-29)}$$

where

R = subarea runoff (in/hr)

At intensities greater than about 0.17 in/hr., AVAIL is equal to 1.0.

For the Detroit area, a value of K equal to 2.0 was found to give good results and is used here. This value implies a removal of 63 percent of the TSS load in 1 hour at 0.5 inches per hour or 86 percent in 5 hours at 0.3 inches per hour. The values of K and AVAIL should be considered to be somewhat site-specific and caution should be exercised in applying them without measured data for verification.

Figure III-9 illustrates the relation between time t and runoff R, TSS load remaining on watershed P, and rate of mass removal M. For simplicity, the availability factor is assumed here to be 1.0.

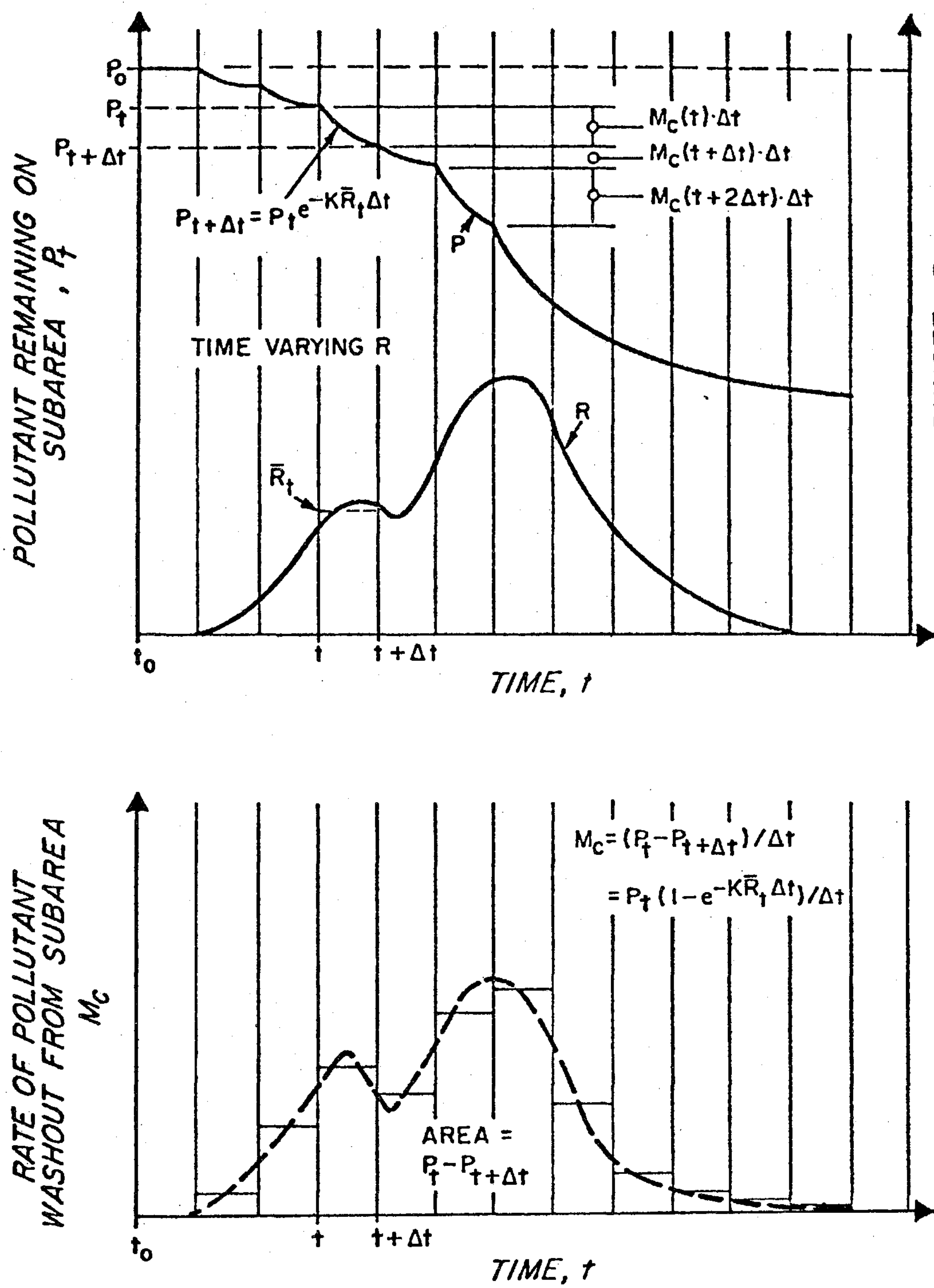


FIGURE III-9. Development of Pollutograph (M_c vs. t) From Time History of P_t

The conservative routing routine routes the TSS load through the gutters, channels and pipes and, just before printing output, converts the resulting concentrations to concentrations of various constituents on the basis of measured relationships between TSS load and mass of these constituents. For the purpose of providing input to the drainage design program, DRAIN, the mass rate of each constituent entering each inlet at each time step is also calculated. These pollutographs are computed as:

$$P_C = M_{NL} \times F_{LC} \tag{III-30}$$

where

P_C = mass rate of constituent C over Δt

M_{NL} = mass rate of TSS load from surface type L in channel N over Δt

F_{LC} = mass of constituent C per unit mass of TSS load from surface type L

The P_C values for each inlet and each constituent are written on tape or disc at every time step for later use by the drainage design program. Typical values of F_{LC} for five land surface types and twelve pollutants are included in Block Data. If the user has site-specific data he wishes to use, he should refer to the Block Data section of the next chapter.

The next section of this chapter describes the conservative routing of pollutants in the drainage area. To determine the concentration of a pollutant in the runoff as a function of time, it is necessary to consider a mass balance for each subarea. This mass balance may be written in a form similar to that considered for pollutant routing in gutters and channels. As a result, the mass balance techniques for the kinematic cascaded watersheds are described below following the description of pollutant routing in gutters and channels.

QUALITY ROUTING

As noted previously, the Surface Runoff Program has the capability of routing the TSS load through gutters and channels as a conservative constituent. A mass balance for each gutter/channel can be written:

$$\frac{dM}{dt} = \sum_{i=1}^{n} s_i \qquad \text{(III-31)}$$

where

M = the total mass of pollutant in the gutter/channel

s_i = a flux of pollutant mass in or out of the gutter/channel

n = the number of mass fluxes associated with the channel. (This consists of upstream channel inflow, inlet carryover, and tributary watershed washoff.)

If we further define

$$M = \mathcal{V} C \qquad \text{(III-32)}$$

where

$\mathcal{V}$ = the volume of water in the gutter/channel

C = the concentration of pollutant

and

$$\frac{dM}{dt} = \frac{d(\mathcal{V}C)}{dt} = C \frac{d\mathcal{V}}{dt} + \mathcal{V} \frac{dC}{dt} \qquad \text{(III-33)}$$

or

$$\mathcal{V} \frac{dC}{dt} = \sum_{i=1}^{n} s_i - C \frac{d\mathcal{V}}{dt} \qquad \text{(III-34)}$$

for simplicity, let $dc/dt = \dot{C}$ and $d\mathcal{V}/dt = \dot{\mathcal{V}}$. Equation III-34 becomes

$$\mathcal{V}\dot{C} = \sum_{i=1}^{n} s_i - C \dot{\mathcal{V}} \qquad \text{)III-35)}$$

To achieve an integration of Equation III-35 with respect to time, we shall make the following assumption concerning the behavior of concentration in time:

$$C_{t+\Delta t} = C_t + \frac{\Delta t}{2}\left(\dot{C}_t + \dot{C}_{t+\Delta t}\right) \qquad \text{(III-36)}$$

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-36 for $\dot{C}_{t + \Delta t}$ we obtain

$$\dot{C}_{t+\Delta t} = \frac{2}{\Delta t} C_{t+\Delta t} - \left(\frac{2}{\Delta t}C_t + \dot{C}_t\right) \qquad \text{(III-37)}$$

In the general case C_t and C_t are known from initial conditions or the previous time step and can be treated as constants. Accordingly, we shall define:

$$\beta = \frac{2}{\Delta t} C_t + \dot{C}_t \qquad \text{(III-38)}$$

$$\alpha = \frac{2}{\Delta t} \qquad \text{(III-39)}$$

which substituted in Equation III-37 give:

$$\dot{C}_{t+\Delta t} = \alpha\, C_{t+\Delta t} - \beta \qquad \text{(III-40)}$$

Equations III-35 and III-40 can be combined as follows:

$$\dot{C}\mathcal{V} + \mathcal{V}\,(\alpha C - \beta) = \sum_{i=1}^{n} s_i \qquad \text{(III-41)}$$

or

$$\dot{C}\mathcal{V} + C\alpha\mathcal{V} - \beta\mathcal{V} = \sum_{i=1}^{n} s_i \qquad \text{(III-42)}$$

Usually, the term $\sum_{i=1}^{n} s_i$ contains several mass inflows and one mass outflow, QC, from the gutter/channel. This being the case, Equation III-42 is finally written as:

$$C\dot{V} + C \alpha V - \beta V = \sum_{i=1}^{n} s_i - QC \qquad \text{(III-43)}$$

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

$$C = \frac{\sum_{i=1}^{n} s_i + \beta V}{\dot{V} + \alpha V + Q} \qquad \text{(III-44)}$$

Equation III-44 is the form used in the quality routing and is solved sequentially for each gutter/channel. The outflow from each gutter/channel becomes the inflow to the next and total mass flux is summed using gutter/channel and watershed contributions. If an inlet is located at the end of the gutter/channel, the carryover is computed and becomes the inflow to the next downstream gutter/channel.

The mass routed is total suspended solids in each gutter/channel by surface type. Thus, as noted previously, the resulting concentrations must be multiplied by the F_{LC} factors of Equation III-30 prior to output.

Special Conditions

In the event of gutter/channel surcharge, the new concentration is computed for the full channel and the mass rate entering surcharge is simply the product of this concentration and the flow into surcharge storage. The surcharge is assumed to be fully mixed. The mass reentering the gutter/channel (when inflow drops below full outflow) is in the same ratio to the total mass in surcharge as the volume leaving surcharge is to the total surcharge volume.

For double trapezoidal channels, the combined volume of both base and overbank channels is used to compute concentration and assumed to be fully mixed.

For detention basins, suspended solids removal is determined by the following relations for each time step in the simulation:

$$D_t = \frac{V_t}{Q_t} \tag{III-45}$$

$$RR_t = \frac{D_t}{D + D_t} \tag{III-46}$$

where

D_t = Detention time at time t

V_t = Volume at time t

Q_t = Outflow at time t

D = Detention time for 50% suspended solids removal (input factor)

RR_t = Suspended solids removal factor at time t

If the outflow is zero at time t, all suspended solids entering the basin at that time are removed. If the outflow is non-zero, RR_t of the suspended solids entering the basin at that time are removed.

Watershed Quality Routing

Since watersheds may be divided into as many as three consecutive subareas, pollutants must be routed overland in a kinematic cascade. This is done as follows.

A mass balance of the form in Equation III-31 may be written for each watershed subarea, namely:

$$\frac{dM}{dt} = \sum_{i=1}^{n} s_i \tag{III-47}$$

where

M = total pollutant mass in the volume of water on the subarea

s_i = pollutant mass flux into or out of the subarea volume

n = number of mass fluxes.

Using the same procedures employed in the gutter/channel routing, we may obtain the following relationship:

$$C_t = \frac{\sum_{i=1}^{n} s_i + \beta \forall_t}{\dot{\forall}_t + \alpha \forall_t + Q_t} \text{ with } \alpha = \frac{2}{\Delta t} \text{ and } \beta = \alpha C_t + \dot{C}_t \qquad \text{(III-48)}$$

where

C_t = subarea outflow concentration at time t

Q_t = subarea outflow at time t

$\forall_t$ = subarea volume at time t

$\dot{\forall}_t$ = subarea volume time derivative at time t

Δt = time step length

$\dot{C}_t$ = subarea outflow concentration time derivative at time t

s_i = subarea mass influx at time t

n = number of mass influxes.

The subarea outflow at time t, Q_t, is as previously determined in Equation III-2. The mass influxes consist of the mass flux entering from the upstream subarea and the mass washoff rate from the surface of the given subarea. The subarea volume V_t at time t is computed from the following relationship:

$$V_t = (d_1 - d_s)\, A_s \qquad \text{(III-49)}$$

where

d_1 = subarea depth at the end of time step

d_s = detention storage depth

A_s = subarea area.

The subarea volume time derivative $\dot{V}_t$ at time t is determined from the following equation:

$$\dot{V}_t = Q_{it} - Q_t + \max(0, (R_I - R_L)A_s) \qquad \text{(III-50)}$$

where

Q_{it} = inflow from upstream subarea at time t

Q_t = outflow at time t

R_I = rainfall intensity at time t

R_L = infiltration rate at time t

A_s = subarea area.

Suspended solids concentration for each of the five different surface types are routed in the above manner over the watershed and into the appropriate drainage element.

CHAPTER IV

USER'S MANUAL

The Surface Runoff Program requires, as input, a series of cards describing the characteristics of the drainage area and the storm event to be simulated. Several simulation control parameters must also be specified in the input deck. The printed output from the program includes a rainfall-runoff continuity summary, peak hydraulic conditions in each gutter, channel, or pipe and complete hydrographs and pollutographs for those drainage system elements selected by the user. In addition to printed output, the program writes all inlet hydrographs and pollutographs to a disc or tape file that can be used as input to other programs of the Urban Highway Storm Drainage Model.

This chapter gives a detailed description of the input requirements, a detailed program description and an example problem.

INPUT REQUIREMENTS

The input data required by the Surface Runoff program and the formats in which the data must be supplied are presented in Table IV-1. Input data are divided into the following ten card groups:

- Card Group 1: Simulation Control Data
- Card Group 2: Rainfall Data
- Card Group 3: Infiltration Data
- Card Group 4: Inlet Data
- Card Group 5: Gutter/Channel Data
- Card Group 6: Overbank Channel Data
- Card Group 7: Storage Basin Data
- Card Group 8: Watershed Data
- Card Group 9: Runoff Quality Data
- Card Group 10: Output Control Data

TABLE IV-1
PROGRAM SRO INPUT DATA REQUIREMENTS

Card Group	Format	Card Column	Description	Variable Name	Default Value
			SIMULATION CONTROL CARDS		
1A	4I4	1-4	Upstream Hydrograph File Number	JIN(1)	-
		5-8	Inlet Hydrographs File Number	JOUT(1)	-
		9-12	Print File Number (scratch file)	JOUT(2)	-
		13-16	Plot File Number (scratch file)	JOUT(3)	-
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	-
	I5	21-25	Number of Raingages	NRGAG	-
	I5	26-30	Units Option 0 - British Units 1 - Metric Units	IMET	0
			RAINFALL CARDS		
2A	I5	1-5	Number of Rainfall Intervals	NHISTO	-
	F5.0	6-10	Duration of Rainfall Interval (minutes)	THISTO	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
2B		Repeat Card Group 2B for each raingage (J=1, NRGAG). Place up to 5 rainfall intensities per card.			
	4F10.0	1-10	Rainfall Intensity (in/hr or mm/hr)	RAIN(1,J)	-
		11-20	Rainfall Intensity (in/hr or mm/hr)	RAIN(2,J)	-
		21-30	Rainfall Intensity (in/hr or mm/hr)	RAIN(3,J)	-
		31-40	Rainfall Intensity (in/hr or mm/hr)	RAIN(4,J)	-
		41-50	Rainfall Intensity (in/hr or mm/hr)	RAIN(5,J)	-
			INFILTRATION CARDS		
3A	I10	1-10	Number of Infiltration Types	INFIL	-
3B		Repeat Card Group 3B for each infiltration type (K=1, INFIL, INFIL $\leq$ 4).			
	4F10.0	1-10	Maximum Infiltration Rate (in/hr or mm/hr)	WLMAX(K)	-
		11-20	Minimum Infiltration Rate (in/hr or mm/hr)	WLMIN(K)	-
		21-30	Decay Rate (hour^{-1})	DECAY(K)	-
		31-40	Maximum infiltration (inches or millimeters)	DEPIN(K)	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			INLET CARDS		
4A			Inlet Types (ITYPG, ITYPC) 1= Curb Opening Inlet 2= Depressed Curb Opening Inlet 3= Grate Inlet 4= Depressed Grate Inlet 5= Combination Inlet 6= Depressed Combination Inlet		
	4I10	1-10	Type of Inlet in Gutters (1-6)	ITYPG	-
		11-20	Type of Inlet in Channels (1-6)	ITYPC	-
			Inlet Simulation Option (INOMG, INOMC) 0= Supply Efficiency Curves as Input 1= Supply Efficiency Curves in Block Data 2= Use Design Equations in Program		
		21-30	Inlet in Gutter Simulation Option	INOMG	0
		31-40	Inlet in Channel Simulation Option	INOMC	0
4B		Efficiency Curves for Inlets in Gutters (Omit Card Group 4B if INOMG ≠ 0) 24 curves, one curve per card. First six cards for cross-slope of 1/64 with gutter slopes of 0.5, 1, 2, 4, 6, and 9%, respectively; second six cards for cross-slope of 1/48 with same gutter slopes of 0.5-9%; third six cards for cross-slope of 1/24 with same six gutter slopes; last six cards for 1/16 cross-slope and same gutter slopes.			
	12F6.2	1-6	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,1)	1.0

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
		7-12	Gutter Flow (cfs or cms)	QINLG(I,J,2)	0.0
		13-18	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,3)	-
		19-24	Gutter Flow (cfs or cms)	QINLG(I,J,4)	-
		25-30	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,5)	-
		31-36	Gutter Flow (cfs or cms)	QINLG(I,J,6)	-
		37-42	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,7)	-
		43-48	Gutter Flow (cfs or cms)	QINLG(I,J,8)	-
		49-54	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,9)	-
		55-60	Gutter Flow (cfs or cms)	QINLG(I,J,10)	-
		61-66	Ratio of Flow Intercepted to Gutter Flow	QINLG(I,J,11)	-
		67-72	Gutter Flow (cfs or cms)	QINLG(I,J,12)	-
4C		Include Card Group 4C only if ITYPG = 2 (depressed curb opening inlet) and INOMG = 2 (design equation in program to be used)			
	2F10.0	1-10	Apron Depression Width (feet or meters)	W	-
		11-20	Inlet Length (ft or m)	GLI	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
4D			Efficiency Curves for Inlets in Channels (Omit Card Group 4D if INOMC $\neq$ 0)		
			6 curves, one curve per card for channel slopes of 0.5, 1, 2, 4, 6, and 9%, respectively.		
	12F6.2	1-6	Ratio of Flow Intercepted to Channel Flow	QINLC(J,1)	
		7-12	Depth (ft or m)	QINLC(J,2)	
		13-18	Ratio of Flow Intercepted to Channel Flow	QINLC(J,3)	
		19-24	Depth (ft or m)	QINLC(J,4)	
		25-30	Ratio of Flow Intercepted to Channel Flow	QINLC(J,5)	
		31-36	Depth (ft or m)	QINLC(J,6)	
		37-42	Ratio of Flow Intercepted to Channel Flow	QINLC(J,7)	
		43-48	Depth (ft or m)	QINLC(J,8)	
		49-54	Ratio of Flow Intercepted to Channel Flow	QINLC(J,9)	
		55-60	Depth (ft or m)	QINLC(J,10)	
		61-66	Ratio of Flow Intercepted to Channel Flow	QINLC(J,11)	
		67-72	Depth (ft or m)	QINLC(J,12)	

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
4E	FI0.0	1-10	Inlet Capacity Reduction Factor	RD	1.0
			GUTTER/CHANNEL CARDS		
			Repeat Card Group 5 for each gutter or channel, two cards per element		
5A	I10	1-10	Gutter/Channel Number	NAMEG(N)	-
	I7	11-17	Upstream Station (hundreds of feet or meters)	ISTA1A(N)	-
	I2	19-20	Upstream Station (tens and units of feet or meters)	ISTA1B(N)	-
	I7	21-27	Downstream Station (hundreds of feet or meters)	ISTA2A(N)	-
	I2	29-30	Downstream Station (tens and units of feet or meters)	ISTA2B(N)	-
	F10.0	31-40	Width of Gutter/Channel; Diameter of Pipe (ft or m)	GWIDTH(N)	-
	F10.0	41-50	Gutter/Channel Slope (ft/ft or m/m)	GSLOPE(N)	-
	F10.0	51-60	Reciprocal Side Slope 1 (ft/ft or m/m; 1 must be the highway side)	GS1(N)	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	F10.0	61-70	Reciprocal Side Slope 2 (ft/ft or m/m)	GS2(N)	-
	F10.0	71-80	Manning Roughness Coefficient	GN(N)	0.014
5B	10X,I10	11-20	Gutter/Channel Number for Drainage	NGTO(N)	-
	I10	21-30	Inlet Number for Drainage	NGSTO(N)	-
			Gutter/Channel Type (NPG(N)) 1= Gutter 2= Trapezoidal Channel 3= Circular Pipe 4= Double Trapezoidal Channel		
	I10	31-40	Gutter/Channel Type	NPG(N)	-
	F10.0	41-50	Channel Depth When Full (Not required if NPG(N)=1 or 3; feet or meters)	DFULL(N)	-
	F10.0	51-60	Design Flow Spread (required only if NPG(N) = 1; feet or meters)	SPMAX(N)	-
			Terminate this card group with two blank cards.		
			OVERBANK CHANNEL CARDS		
			Repeat Card Group 6 for each overbank channel, one card per channel.		
6	I10	1-10	Drainage Basin Number	NBASIN	-
	I10	11-20	Overbank Channel Number (same number as corresponding base channel)	IDENT	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	F10.0	21-30	Overbank Channel Base Width (feet or meters; must be greater than bottom width of corresponding base channel)	OVRWTH(N)	-
	F10.0	31-40	Overbank Channel Reciprocal Side Slope 1 (ft/ft or m/m)	OVRGS1(N)	-
	F10.0	41-50	Overbank Channel Reciprocal Side Slope 2 (ft/ft or m/m)	OVRGS2(N)	-
	F10.0	51-60	Overbank Channel Manning Roughness Coefficient	GN(N)	-
	F10.0	61-70	Overbank Channel Depth When Full (feet or meters; measured from top of base channel)	OVRDFL(N)	-
			Terminate this card group with one blank card. (If there are no overbank channels, supply one blank card.)		
			STORAGE BASIN CARDS		
			Repeat Card Group 7 for each surface storage basin, two cards per basin.		
7A	6I5	1-5	Drainage Basin Number	NBASIN	-
		6-10	Storage Basin Number	NAMEG(N)	-
		11-15	Downstream Gutter/Channel Number for Drainage	NGTO(N)	-
		16-20	Inlet Number for Drainage	NGSTO(N)	-
		Outlet Control Type (NP) 5= Weir Control 6= Outlet Channel Control			

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
		21-25	Outlet Control Type	NP	-
		26-30	Raingage Number	IG	-
7B	9F8.0	1-8	Weir Length or Bottom Width of Outlet Channel (feet or meters)	GWIDTH(N)	-
		9-16	Basin Surface Area (acres or hectares)	AREALK(N)	-
		17-24	Outlet Channel Slope (ft/ft or m/m; required only if NP=6)	GSLOPE(N)	-
		25-32	Outlet Channel Reciprocal Side Slope 1 (ft/ft or m/m; required only if NP=6)	GS1(N)	-
		33-40	Outlet Channel Reciprocal Side Slope 2 (ft/ft or m/m; required only if NP = 6)	GS2(N)	-
		41-48	Weir Coefficient or Outlet Channel Manning Roughness Coefficient	GN(N)	-
		49-56	Basin Length (feet or meters)	GLEN(N)	-
		57-64	Basin Volume (acre-feet or cubic meters)	VOLMLK(N)	-
		65-72	Initial Depth in Basin (feet or meters; measured from crest of weir or bottom of outlet channel; may be negative)	GDEPTH(N)	-
			Terminate this card group with two blank cards. (If there are no surface storage basins, supply two blank cards.)		

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			WATERSHED CARDS		
			Repeat Card Group 8 for each Watershed		
8A	I10	1-10	Name of Watershed (external number)	NAMEW(N)	-
	I10	11-20	Gutter/Channel Number for Drainage	NGTO(N)	-
	I10	21-30	Raingage Number	JK	-
	F10.0	31-40	Watershed Area (acres or hectares)	AREA	-
	I70	41-50	Number of Watershed Subareas	NW3	-
	F10.0	51-60	Watershed Width (feet or meters)	WWIDTH(N)	-
		Immediately after the corresponding 8A card, repeat card 8B NW3 times (i.e., one 8B card for each subarea).			
8B	5F10.0	1-10	Fraction of Watershed Area	WAREA(N,K)	-
		11-20	Infiltration Type (leave blank for impervious areas)	WTYPE(N,K)	-
		21-30	Slope (ft/ft or m/m)	WSLOPE(N,K)	-
		31-40	Depression Storage Depth (inches or millimeters)	WSTORE(N,K)	-
		41-50	Manning Roughness Coefficient	W4	
		Terminate this card group with one blank card.			

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			RUNOFF QUALITY CARDS		
9		Enter a value for NQS to select the runoff quality simulation option. The program will simulate the following list of constituents, up to and including the constituent corresponding to the NQS chosen. (For example, if NQS=5, the first five constituents in the list will be simulated.) 0 = No Quality Simulation 1 = Dissolved Oxygen 2 = BOD_5 3 = Suspended Solids 4 = Fecal Coliforms 5 = Chloride 6 = Ammonia-Nitrogen 7 = Nitrite-Nitrogen 8 = Nitrate-Nitrogen 9 = Organic Nitrogen 10 = Total Phosphorus 11 = Dissolved Orthophosphate 12 = Grease 13 = Heavy Metals			
	I10	1-10	Number of Quality Constituents Simulated	NQS	-
		If NQS = 0, the remaining variables on Card Group 9 need not be supplied			
	F10.0	11-20	Dry Days Since Last Storm	DRYDAY	-
		21-30	Maintenance Frequency (days between street cleanings)	CLFREQ	-
		31-40	Maintenance Efficiency	REFF	-
		41-50	Detention Time Required for 50% suspended solids removal in surface storage basins (hours; not required if no storage basins are simulated)	DET	-

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			OUTPUT CONTROL CARDS		
10A	2I5	1-5	Number of Gutters, Channels and Inlets for which Flows and Quality Constituents are to be Printed.	NPRNT	-
		6-10	Number of Time Steps between Printings	INTERV	-
			Omit Card Group 10B if NPRNT=0.		
10B	16I5		Gutter, Channel and Inlet Numbers for which Flows and Quality Constituents are to be Printed (16 values per card)	IPRNT(N)	-
10C	I5		Number of Gutters, Channels and Inlets for which Flow and/or Quality Constituents are to be Plotted	NPLOT	-
			Omit Card Groups 10D and 10E if NPLOT=0.		
10D	16I5		Gutter, Channel and Inlet Numbers for which Flow and/or Quality Constituents are to be Plotted (16 values per card)	IPLOT(N)	-
			Enter 1 in the appropriate columns of Card Group 10E for those constituents to be plotted (0 = no plot; 1 = plot)		

TABLE IV-1
(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
10E	14I1	1	Flow		
		2	Dissolved Oxygen		
		3	BOD_5		
		4	Suspended Solids		
		5	Fecal Coliforms		
		6	Chloride		
		7	Ammonia-nitrogen		
		8	Nitrite-nitrogen		
		9	Nitrate-nitrogen		
		10	Organic Nitrogen		
		11	Total Phosphorus		
		12	Dissolved Orthophosphate		
		13	Grease		
		14	Heavy Metals		

Data required in each of these card groups are discussed below.

Card Group One: Simulation Control Data

Card Group 1A consists of a single card that identifies the unit numbers on the user's computer system corresponding to the four disc files used by the program. The first file, which is optional, contains any hydrographs which may flow into the system being analyzed. These hydrographs may be needed if the total drainage area is so large that SRO must be run for each of several sub-drainage areas. In this case, the SRO simulated flow at the downstream end of a gutter or channel in one of these sub-areas can be used as an input hydrograph to the upstream end of a connecting gutter or channel in another sub-area. The next disc file, an inlet hydrograph file, stores the results from the present run of SRO for use in the Drainage Design Program. If the latter program is to be used, then this file is required. Print and plot file numbers should be included if the user desires a printed or plotted output, respectively, of the resulting hydrographs.

Card Group 1B consists of two title cards which can be used to describe the drainage project being analyzed or designed.

Card Group 1C contains several simulation control parameters. The first variable is a basin number that can be assigned by the user for identification purposes. The next four variables control the duration of the simulation, giving the number of time steps, the hour and minute of the simulation start time, and the time step length in minutes. The next variable, NRGAG, gives the number of raingages to be employed. This allows the user to input more than one hyetograph if spatial variation of rainfall is considered significant for his project. For most applications of this program, one raingage will be sufficient. The last variable selects the units option. If IMET is set equal to zero, all input and output will be in British units. If IMET equals one, metric units will be used.

A few additional words should be said about the selection of the time step length. Time steps ranging from one minute to five minutes have been used successfully with this program. In cases where the drainage system includes steep channels immediately downstream of inlets, there is a possibility that all water will empty out of the channel in less than a time step and a problem in the solution for open channel flow will arise, signalled by an error message that the program is calculating a negative depth. If this occurs, the time step length should be shortened.

Card Group Two: Rainfall Data

This card group is used to input the design hyetograph(s), the duration and return frequency of which must be selected by the user in accordance with local design criteria. Card Group 2A consists of a single card that specifies the number of rainfall intervals, NHISTO, and the duration of the rainfall interval in minutes, THISTO. The design hyetograph and the number of dry days can be obtained from the results of the Precipitation Module or from whatever local sources of design storm information the user has.

Card Group 2B consists of as many cards as are required for the hyetograph(s) to be specified. Five rainfall intensities should be placed on each card. (If the number of rainfall intervals NHISTO is not an integral multiple of five, then the last card for each hyetograph will have fewer than five rainfall intensities.)

When more than one hyetograph is input (i.e., NRGAG >1 in Card Group One), all the cards for a given hyetograph should be fully specified before input of the next hyetograph is begun. Each hyetograph should begin on a new card and must have the same interval duration and number of intervals as every other hyetograph.

Card Group Three: Infiltration Data

This card group is used to specify the infiltration characteristics of up to four types of pervious surfaces in the drainage area being simulated. Card Group 3A gives the number of infiltration types, INFIL, to be specified. (The impervious surface type is included in the program itself and need not be specified here as input.)

Card Group 3B, a single card, is supplied for each infiltration type. The four variables given by this card are the four constants in the Horton infiltration formula, equation III-3 in the previous chapter of this report. The Horton formula defines an infiltration curve, examples of which are given in Figure IV-1 and Table IV-2.

If no land types other than impervious surfaces are to be specified, then INFIL should be set equal to zero on Card Group 3A and Card Group 3B should be omitted.

Card Group Four: Inlet Data

This card group is used to specify the types of inlets in the highway right-of-way, the hydraulic characteristics of the inlets, and related information.

Card Group 4A is used to specify the types of inlets found in the drainage area being simulated. Variables ITYPG and ITYPC are used to specify the inlet types in gutters and in channels, respectively, using the key for inlet types shown in Table IV-1. Note that only one inlet type may be used for all the inlets in gutters and one for all the inlets in channels in a single run. Three options for inlet capacity computation are available. The last two variables on this card, INOMG and INOMC, are used to select these options, (INOMG for inlets in gutters and INOMC for inlets in channels). If the user supplies inlet efficiency curves as input, then the appropriate variable should be set equal to zero. If inlet efficiency curves stored in Block Data of the program are to be used, then the variable should be set equal to one. If inlet capacity equations in the program are used, then the variable should be set equal to two. (Note that the only equations presently in the code are those for depressed curb opening inlets in gutters.)

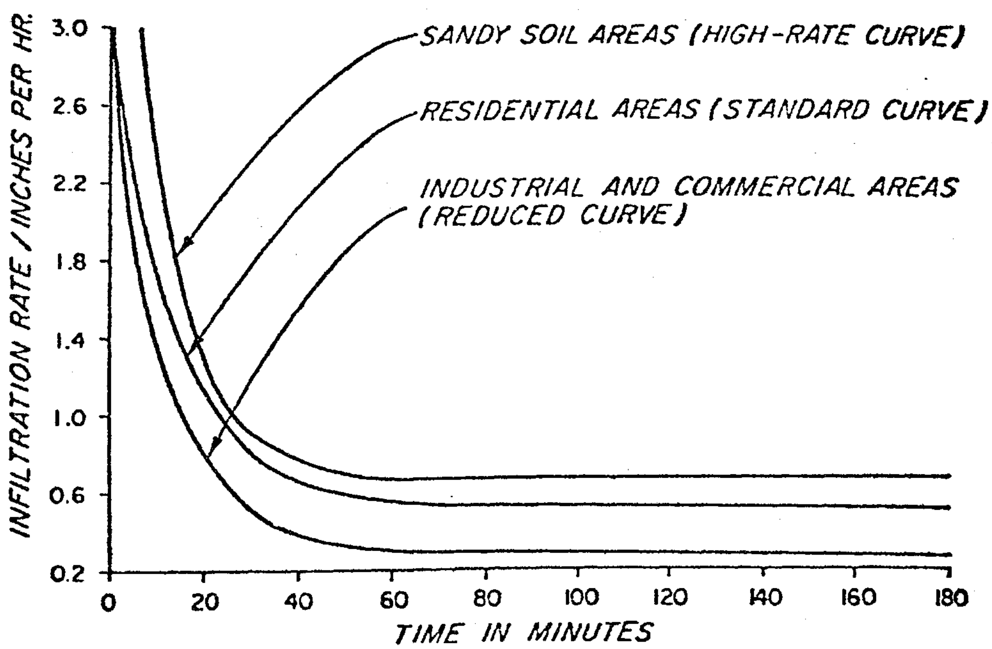


FIGURE IV-1. Example Infiltration Curves (4)

TABLE IV-2

TYPICAL VALUES FOR HORTON INFILTRATION FORMULA FOR GRASSED AREAS (5)

SCS Hydrologic Soil Group	Minimum Infiltration Rate, WLMIN(K)[1] (in/hr)	Maximum Infiltration Rate, WLMAX(K)[2] (in/hr)	Exponential Infiltration Rate Loss, DECAY(K)[3] ($hour^{-1}$)	Maximum Infiltration DEPIN(K)[4] (inches)
A	1.00	10.0	2.0	4.3
B	0.50	8.0	2.0	3.4
C	0.25	5.0	2.0	2.3
D	0.10	3.0	2.0	1.3

[1] k_1 in Equation III-3

[2] k_2 in Equation III-3

[3] k_3 in Equation III-3

[4] For bone-dry conditions, i.e., zero rainfall in the five days preceding the storm.

When inlet efficiency curves are to be supplied for inlets in gutters, Card Group 4B is used to supply these curves. Inlet efficiency is given by these curves as a function of longitudinal slope of the gutter, cross-slope of the gutter, and flow. Use of the curves is explained in Chapter III and example curves are shown in Figure III-7. Twenty-four cards are required, one efficiency curve per card, as specified in Table IV-1. Each card contains twelve values, the two coordinates of six points on each curve. The points should proceed in order from zero gutter flow to the highest gutter flow. The first point on the curve should be (1,0); if the user does not supply this point, the program will.

Card Group 4C is supplied only if the surface conveyance system includes gutters, if the inlet in the gutters is a depressed curb opening inlet, and if the capacity equations for this inlet type are to be used. The only variables required here are the apron depression width, and the inlet length.

Card Group 4D is used to supply efficiency curves for inlets in channels. Inlet efficiency is given by these curves as a function of longitudinal slope of the channel and depth of flow. Six cards are required, one efficiency curve per card, as specified in Table IV-1. Otherwise, these cards are analogous to Card Group 4B.

Card Group 4E consists of a single card used to specify the inlet capacity reduction factor, RD. The flow intercepted by each on-grade inlet will be multiplied by this factor. RD allows the user to account for inlet capacity reduction by debris clogging, etc. The value of RD should be in the range $0 < RD \leq 1$.

Card Group Five: Gutter/Channel Cards

The gutters or channels which make up the surface conveyance system are described with these cards; two cards are required for each gutter or channel. The conveyance system must be divided by the user into a series of gutter/channel lengths, each with constant geometric and hydraulic properties as given on these cards.

Four general types of channels can be simulated:

- Type 1: Gutters (special case of trapezoidal channel)
- Type 2: Trapezoidal Channels
- Type 3: Circular Pipes
- Type 4: Overbank Channels (double trapezoidal channels)

Card Group 5A is a single card with ten variables. The first variable is the external number used to identify the gutter/channel. (The user should identify the gutters or channels being simulated with a consecutive numbering scheme which he finds convenient.) The next four variables define the upstream and downstream stations of the gutter or channel.

Hydrogeometric properties of the gutter/channel are given by the next five variables. The bottom width of the gutter/channel is given by variable GWIDTH(N); if the cross-section is triangular (i.e., a gutter) then GWIDTH(N) equals zero. In the case of a circular pipe, GWIDTH(N) is used to specify the diameter. The longitudinal slope of the gutter/channel is supplied as GSLOPE(N). The next two variables define the reciprocal slopes, (horizontal/vertical) of the sides of the gutter/channel. (These are not required for circular pipes.) The first slope, GS1(N), should be the slope on the highway side. The last variable on this card is the Manning roughness coefficient of the gutter/channel.

Card Group 5B is a single card used to specify the remaining characteristics of the gutter/channel. The first two variables are used to specify the drainage structure or structures downstream of the gutter/channel. If the next downstream structure is another gutter/channel section, then its external number is given as NGTO(N), the first variable on this card, and no value is given for NGSTO(N), the second variable on this card. If the next downstream structure is an inlet, then its external number is given as NGSTO(N) and the gutter/channel section downstream of the inlet is given as NGTO(N). If the next downstream structure is a sump inlet, then its external number is given us NGSTO(N) and no value is given for NGTO(N). The gutter/channel type number, as listed above, is specified by the third variable, NPG(N).

The final item required on this card is a characteristic dimension of the gutter/channel section when flowing full. If the section is a trapezoidal channel, then the channel depth when flowing full is given as DFULL(N). If the section is an overbank channel (double trapezoidal channel), then the depth of the base channel when flowing full is given as DFULL(N) (see Figure III-4). If the section is a gutter (triangular cross-section), then the flow spread corresponding to the gutter flowing full (which is controlled by the curb height) should be given as SPMAX(N). If the section is a circular pipe, then no further information need be given, since the pipe diameter given in Card Group 5A is also the depth when flowing full for this channel type.

Note that for each gutter/channel section, the 5B card must follow immediately after the corresponding 5A card.

Card Group Six: Overbank Channel Cards

Card Group Six should be supplied only if the drainage system includes overbank channels, i.e., only if one or more gutter/channel sections in Card Group Five were identified as overbank channels (NPG(N)=4). If no overbank channels are included, then a single blank card should be supplied here.

Card Group Six consists of a single card used to specify the characteristics of the overbank portion of this channel type. The first variable, IDENT, is the external number of the overbank channel; this must be the same as the external number of the base channel, previously identified in Card Group Five. The remaining five variables specify the hydrogeometric characteristics of the overbank channel.

Card Group Seven: Storage Basin Cards

Card Group Seven consists of two cards used to specify the characteristics of stormwater detention basins that may be part of the surface drainage system. If no such basins are included, then two blank cards should be supplied here.

Card Group 7A is used to specify up to five variables identifying the basin. The first variable NAMEG(N) is the user-assigned external number of the basin. The next two variables, NGTO(N) and NGSTO(N), are used to identify the drainage structure or structures downstream of the basin; the use of these two variables is described under Card Group 5B. The basin outlet control type is given by the next variable, NP; NP equal to five indicates weir control, NP equal to six indicates outlet channel control. The final variable on this card, IG, identifies the number of the raingage assigned to the area in which the basin is situated; this must be in the range $1 \leq IG \leq NRGAG$, where NRGAG is given on Card Group 1C.

Card Group 7B gives the hydrogeometric characteristics of the basin. The first variable GWIDTH(N) is used to specify the outlet weir length or the outlet channel bottom width, depending on the type of outlet control. The next variable, AREALK(N), gives the surface area of the basin when full. If the outlet is a channel, then the next three variables are used to specify its longitudinal slope and the reciprocals of its side slopes. If the outlet control is a weir, then the next variable GN(N) is used to specify the weir coefficient for the standard formula for flow over a sharp-crested rectangular weir (equation III-16). If the outlet control is a channel, then GN(N) is used to specify the Manning roughness coefficient of the outlet channel. The next two variables GLEN(N) and VOLMLK(N) give the basin length and volume, respectively. The last variable on this card, GDEPTH(N), specifies the initial depth of water in the basin, measured from the crest of the outlet weir or the bottom of the outlet channel. (The user may simulate either wet or dry detention basins.)

Card Group Eight: Watershed Cards

Characteristics of the drainage area being simulated are specified on these cards. The drainage area must be divided into a series of watersheds, each with constant hydraulic and geometric characteristics. In addition, each watershed may be divided into as many as three subareas, as explained in the discussion of surface runoff in Chapter III. Card Groups 8A and 8B must be provided for each watershed.

Card Group 8A contains six variables describing the watersheds being simulated. The first variable gives the external number of the watershed, selected by the user for purposes of identification. The second variable, NGTO(N), identifies the gutter/channel to which the watershed drains. Note that one or more watersheds may drain to the same gutter/channel, but a given watershed may not drain to more than one gutter/channel. The number of the raingage to be used for the watershed is given next as JK. JK corresponds to the number of the hyetograph as input in Card Group Two; the first hyetograph corresponds to JK equal to one, the second to JK equal to two, etc. If only one raingage is used, as will usually be the case, then JK must equal one for all watersheds.

The watershed area is specified by the next variable, AREA. The number of subareas in the watershed is specified next as NW3; this variable must be in the range $1 \leq NW3 \leq 3$. The last variable on this card, WWIDTH(N), is the watershed width, as shown in Figure III-1.

Card Group 8B is supplied once for each subarea; thus, there can be from one to three 8B cards following each 8A card. The first variable on this card, WAREA(N,K) is the fraction of the total watershed area in the subarea (given as a decimal). The second variable, WTYPE(N,K), identifies the infiltration type of the subarea. WTYPE(N,K) set equal to zero denotes impervious areas; WTYPE(N,K) set equal to an integer from one to four corresponds to the infiltration curves input as Card Group 3B. The average slope of the subarea, WSLOPE(N,K), is given next. The average depression storage depth for the subarea is supplied as WSTORE(N,K). Typical values of depression storage have been found to be on the order of 0.05 inches for impervious areas and 0.2 inches for pervious areas (3). The final value on this card is the Manning roughness coefficient for the subarea. Typical values of this coefficient for overland flow are shown in Table IV-3.

Card Group Nine: Runoff Quality Cards

Card Group Nine consists of a single card used to provide runoff quality information. If runoff quality is not to be simulated, then the first variable NQS should be set equal to zero and no further information need be supplied on this card.

TABLE IV-3

TYPICAL VALUES FOR MANNING COEFFICIENT FOR OVERLAND FLOW (6)

Groundcover	Manning's n for Overland Flow
Smooth asphalt	0.012
Asphalt or concrete paving	0.014
Packed clay	0.030
Light turf	0.200
Dense turf	0.350
Dense shrubbery and forest litter	0.400

If runoff quality is to be simulated, then NQS should be set equal to an integer from one to thirteen, corresponding to the list of thirteen water quality parameters given in Table IV-1. The program will then simulate the first NQS parameters in the list. With the next three variables, the user should supply the number of dry days since the last significant storm, DRYDAY, which can be obtained from the Path 3 computation in the Precipitation Module, the frequency of maintenance such as street-sweeping, CLFREQ, and the efficiency of the maintenance, REFF (0<REFF<1). If any storage basins are included in the simulation, then a value should be given for the last variable on this card, DET. This variable defines the detention time required for 50% removal of suspended solids in the storage basins.

All assumptions with regards to simulation of runoff quality are explained in Chapter III. If the user has site-specific runoff quality information that he would like to use, he should refer to Chapter III for guidance.

Card Group Ten: Output Control Cards

Card Group Ten is used to select several options related to program output. The first variable on Card Group 10A, NPRNT, is used to specify the total number of gutters, channels, and inlets for which hydrographs and pollutographs (if quality was simulated) are to be printed. The number of time-steps between output values should be specified by the second variable on this card, INTERV. If NPRNT equals zero, then no value need be supplied for INTERV and Card Group 10B may be skipped.

Card Group 10B is used to list the external numbers of the NPRNT gutters, inlets, and channels for which output is requested. As many cards as are required may be used, 16 values per card. (Note that each card should be filled with 16 values before a subsequent card is started.)

The only variable on Card Group 10C, NPLOT, is the total number of gutters, channels, and inlets for which hydrographs and pollutographs (if quality was simulated) are to be plotted. If NPLOT equals zero, Card Groups 10D and 10E should be skipped.

Card Group 10D is used to list the external numbers of the NPLOT gutters, channels, and inlets for which plots are to be produced. Card Group 10E is used to list the parameters to be plotted. As shown in Table IV-1, a zero placed in the appropriate column means do not plot the parameter; a one in the appropriate column means plot the parameter.

PROGRAM DESCRIPTION

General Structure

Program SRO is structured into 17 computational units--Main Program SRO, BLOCK DATA, Subroutine CURVE, Subroutine GQUAL, Subroutine GRAPH, Subroutine GUTTER, Subroutine HCURVE, Subroutine HYDRO, Subroutine OVRBNK, Subroutine PINE, Subroutine PPLOT, Subroutine QSHED1, Subroutine RECAP, Subroutine RHYDRO, Subroutine WSHED, Subroutine CARRY, and Subroutine SUMSTAT. The interrelationship among these units is illustrated in Figure IV-2. The Main Program SRO controls the computational sequence. The primary function of each routine is as follows:

- BLOCK DATA - Initializes variables prior to execution
- Subroutines CURVE, PINE, and PPLOT - Perform graphical functions
- Subroutine GRAPH - Sets up information for hydrograph and pollutograph plots
- Subroutine HCURVE - Sets up information for hyetograph and total outflow plots
- Subroutine GQUAL - Performs gutter/channel quality routing
- Subroutine GUTTER - Performs gutter/channel hydraulic routing
- Subroutine HYDRO - Controls time sequencing of quantity and quality calculations
- Subroutine OVRBNK - Performs hydraulic computations for overbank channels
- Subroutine QSHED1 - Performs pollutant buildup and washoff computations by subarea
- Subroutine RECAP - Outputs detailed simulation results
- Subroutine RHYDRO - Reads input data
- Subroutine WSHED - Computes watershed subarea flows
- Subroutine CARRY - Computes inlet interception and carryover
- Subroutine SUMSTAT - Outputs simulation results in summary format.

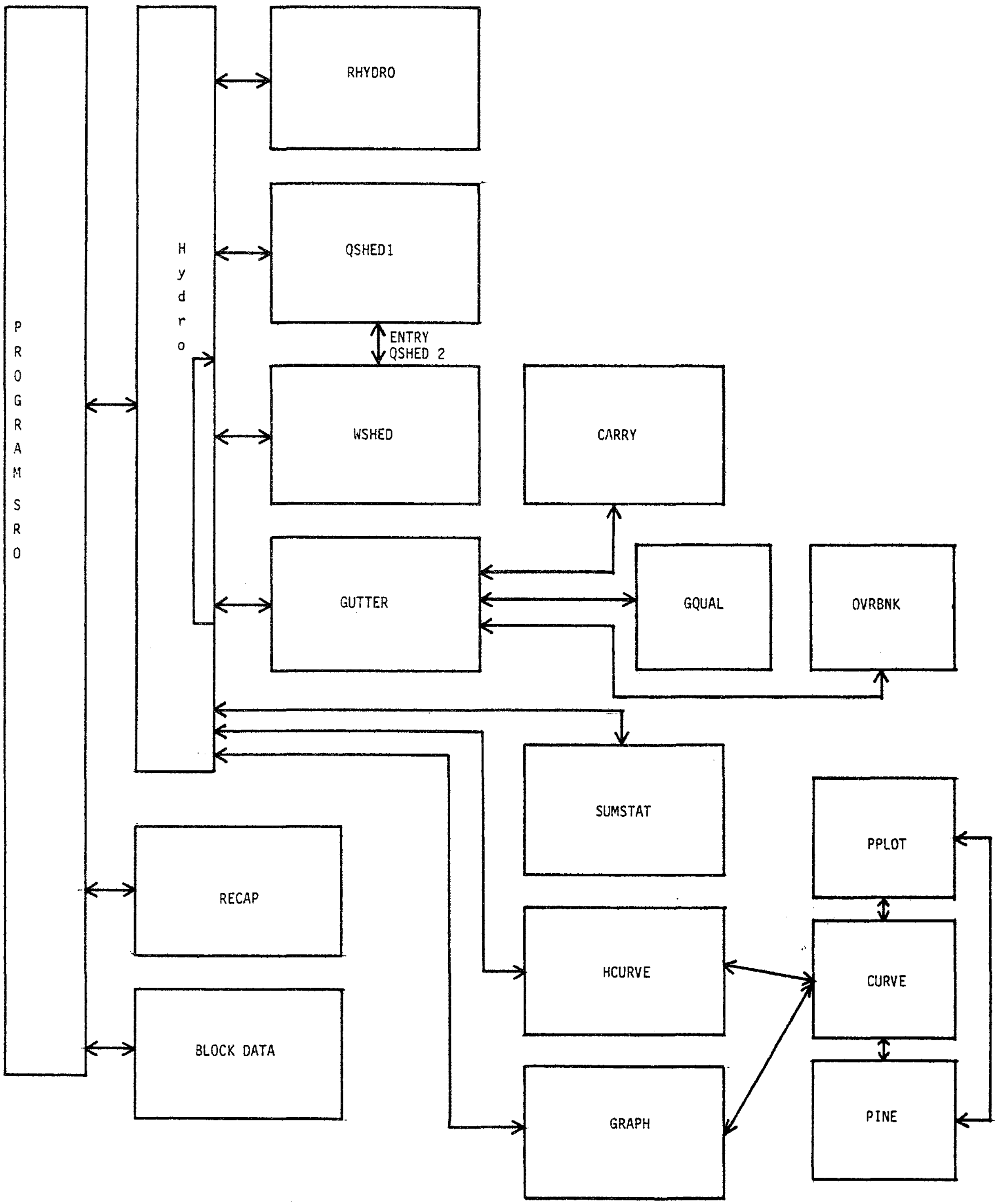


FIGURE IV-2. Program SRO
General Structure

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 section.

Main Program SRO

The following routines are called from the main program:

- HYDRO
- RECAP

Common Block TAPES is the only common block employed in the main program, which is presented in flowchart form in Figure IV-3. After tape assignments have been made, Subroutine HYDRO is called to perform the computations. Subroutine RECAP is then called to print the detailed simulation results on a gutter/channel basis. There are no key variables not contained in common; a listing of the main program follows.

Block Data

This routine is used to initialize key variables in common blocks SLOPES, LAB, ABLK, and CON. For each of the five land surface types, the ulitmate load in lbs/acre, the half saturation constant in days and the pollutant ratios to suspended solids are defined. Also given are axes labeling information.

The user who wishes to calibrate the runoff quality portion of the model with site-specific data must do so by modifying the values of the variables initialized in BLOCK DATA. The relevant variables for each land surface type are the ultimate suspended solids load, SSU_L, the time to reach half the ultimate suspended solids load, $HAFSAT_L$, and the ratio of each pollutant to suspended solids, F_{Ld}, all of which are defined in Chapter IV. The values presently in BLOCK DATA were obtained from a study in the Detroit, Michigan area (3).

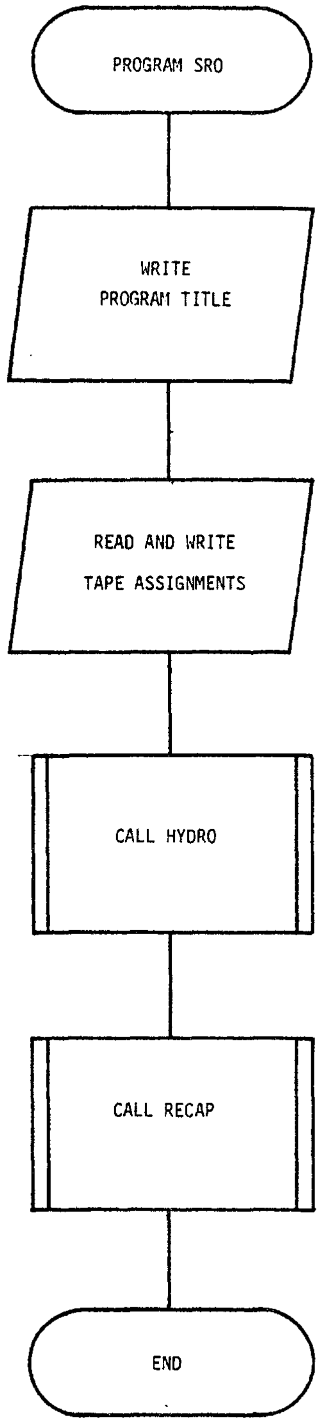


FIGURE IV-3. Flowchart for Program SRO

```
      PROGRAM SRO(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     2TAPE10,TAPE11,TAPE12)
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      N5=5
      N6=6
      WRITE(6,2999)
 2999 FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2** URBAN HIGHWAY DRAINAGE PROGRAM ****,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,*SURFACE RUNOFF PROGRAM *,5X,4H****,8X,*ANNANDALE, VIRGINA
     6*)
      READ(N5,20)(JIN(I),I=1,1),(JOUT(I),I=1,3)
   20 FORMAT(2 I4)
      WRITE(N6,30)
   30 FORMAT(*0*,*  ENTRY MADE TO SURFACE RUNOFF PROGRAM*)
      WRITE(N6,40)(JIN(I),I=1,1),(JOUT(K),K=1,3)
   40 FORMAT(////25X,*TAPE ASSIGNMENTS*//,
     210X,*INFLOW TAPE*,T60,I5,/,
     310X,*INLET TAPE*,T60,I5,/,
     410X,*PRINT TAPE*,T60,I5,/,
     510X,*PLOT TAPE*,T60,I5)
      CALL HYDRO
      CALL RECAP
      WRITE(6,50)
   50 FORMAT(1H1///30X,*SURFACE RUNOFF PROGRAM ENDED NORMALLY*)
      END
```

The ultimate suspended solids load and the half-saturation constants in array SSFACT (5,2) are initialized by a DATA statement. The ratio of each pollutant mass to suspended solids mass for each land type are contained in array QFACT (5,13) and are also initialized by a data statement.

A listing of BLOCK DATA follows.

Subroutine GRAPH

Subroutine CURVE is called from this routine to control the graphical functions. The following common blocks are contained in Subroutine GRAPH:

- BLANK COMMON
- TAPES
- LAB

The graphing subroutines enable hydrographs and pollutographs to be plotted on the printer for selected locations on the data file. GRAPH is the driving subroutine, and it calls CURVE to produce the actual page of plotted output. The flow sequence is presented in flowchart form in Figure IV-4. The logic sequence is essentially as follows:

1. Information is read from the data file indicating the structure of that file;
2. All hydrograph and pollutograph information is read from the data file; and
3. For each type of hydrograph and pollutograph, individual curves are selected, transferred into plotting arrays, and output in a final plotted form by Subroutine CURVE.

There are no key variables not contained in common. The computer listing of this routine follows.

Subroutine HCURVE

Subroutine CURVE is called by HCURVE to produce the plotted results. The following common blocks are employed in Subroutine HCURVE:

- BLANK COMMON
- LAB

```
      BLOCK DATA
      COMMON/ABLK/ NGS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2             C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
     3             SSFACT(5,2),QFACT(5,13)
      COMMON/CON/ICTTL(13)
      COMMON/LAB/ TITLE(18),XLAB(11),YLAB(6),HORIZ(20),VERT(7,6),IT,
     2            VERTM(7,6)
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMC,QINLG(4,6,12),DINLG(12,6,4),QINLC(6,12),
     2DINLC(12,6)
      DATA ICTTL/4HDO   ,4HBOD ,4HTSS ,4HFCOL,4HCL   ,4HNH3 ,4HNO2 ,4HNO3
     2,4HORGN,4HTOTP,4HOPO4,4HO+G ,4HPB  /
      DATA SSFACT/
C**** SS ULTIMATE LOAD, LB/ACRE
     2 31.,41.,52.,74.,90.,
C**** HALF-SAT. CONSTANTS, DAYS
     3 1.0,1.0,1.0,1.5,1.5/
C
C******** MG OF CONSTITUENT PER GRAM OF TSS (DERIVED FROM SEMCOG)
C
      DATA QFACT/
C**** DO
     1  5*0.0,
C**** BOD
     2  2*34.,3*45.,
C**** TSS
     3  5*1000.,
C**** F. COLI.
     5  2*8700.,3*37000.,
C**** CL
     6  2*0.0,3*0.0,
C**** NH3
     7  4*0.8,1*2.4,
C**** NO2
     8  5*0.0,
C**** NO3
     9  2*1.7,3*6.4,
C**** ORG-N
     1  2*4.3,3*4.1,
C**** TOT P
     2  2*1.9,3*1.7,
C**** O-PO4
     3  2*.24,3*.47,
C**** O+G
     4  2*25.,3*8.,
C**** PB
     5  2*1.8,3*1.4/
      DATA VERT/4HRAIN,4HFALL,4H   I,4HN   ,4HIN /,4H  HR,4H    ,
     2          4H RUN,4HOFF ,4H   I,4HN   ,4H    ,4HCFS ,4H    ,
     3          4H SPE,4HCIES,4H  CO,4HNC. ,4H  MG,4H/L  ,4H    ,
     4          4H  MA,4HSS  ,4HEMIS,4HSION,4H  LB,4H/HR ,4H    ,
     5          4H SPE,4HCIES,4H  CO,4HNC. ,4HNO/1,4H00ML,4H    ,
     6          4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    /
      DATA VERTM/4HRAIN,4HFALL,4H   I,4HN   ,4HMM /,4H  HR,4H    ,
     2           4HRUN ,4HOFF ,4H   I,4HN   ,4H    ,4HCMS ,4H    ,
     3           4H SPE,4HCIES,4H  CO,4HNC. ,4H  MG,4H/L  ,4H    ,
     4           4H  MA,4HSS  ,4HEMIS,4HSION,4H  LB,4H/HR ,4H    ,
```

```
      5           4H SPE,4HCIES,4H  CO,4HNC. ,4HNO/1,4HOOML,4H    ,
      6           4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    /
       DATA ISLOP/64,48,24,16/
       DATA SLOP/.005,.01,.02,.04,.06,.09/
       DATA DINLG/1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      20.0,.99,.30,.96,.50,.92,.60,.89,.80,.60,5.0,1.0,0.0,.99,.70,.98,
      31.0,.93,1.5,.87,2.1,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.89,2.9,.82,
      44.2,.60,9.0,1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      50.0,.99,.30,.96,.50,.89,.80,.81,1.1,.60,5.0,1.0,0.0,.99,.70,.98,
      61.0,.93,1.5,.78,3.3,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.82,4.2,.76,
      75.5,.60,9.0,1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      80.0,.99,.30,.96,.50,.89,.80,.81,1.1,.60,5.0,1.0,0.0,.99,.70,.93,
      91.5,.82,2.7,.74,4.1,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.82,4.2,.76,
      15.5,.60,9.0,1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      20.0,.99,.30,.96,.50,.85,1.5,.70,2.2,.60,5.0,1.0,0.0,.99,.70,.93,
      31.5,.79,3.8,.70,5.6,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.87,3.8,.79,
      45.6,.60,9.0,1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      50.0,.99,.30,.96,.50,.73,1.9,.66,2.6,.60,5.0,1.0,0.0,.99,.70,.93,
      61.5,.82,3.2,.71,5.5,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.87,4.2,.81,
      75.5,.60,9.0,1.0,0.0,.99,.10,.90,.40,.78,1.0,.66,1.8,.50,4.0,1.0,
      80.0,.99,.30,.96,.50,.72,2.0,.66,3.0,.60,5.0,1.0,0.0,.99,.70,.93,
      91.5,.83,3.2,.73,5.4,.60,7.0,1.0,0.0,.99,1.2,.96,1.8,.87,4.2,.81,
      15.5,.60,9.0/
       DATA DINLC /1.0,0.0,.99,.08,.96,.12,.92,.14,.89,.16,.60,.48,
      2           1.0,0.0,.99,.08,.96,.10,.89,.14,.81,.16,.60,.40,
      3           1.0,0.0,.99,.06,.96,.08,.89,.10,.81,.13,.60,.32,
      4           1.0,0.0,.99,.05,.96,.07,.85,.13,.70,.16,.60,.26,
      5           1.0,0.0,.99,.04,.96,.06,.73,.13,.66,.16,.60,.23,
      6           1.0,0.0,.99,.04,.96,.05,.72,.12,.66,.15,.60,.20/
       END
```

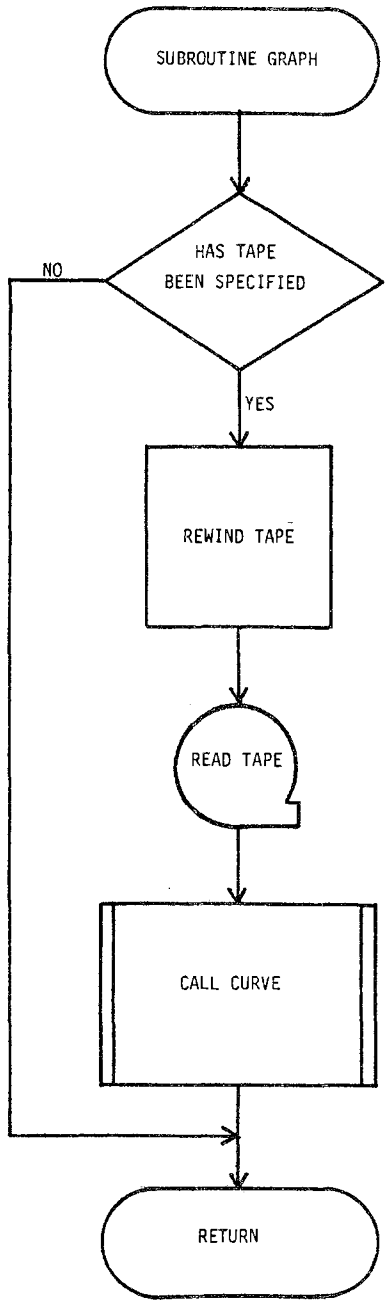


FIGURE IV-4. Flowchart for
Subroutine GRAPH

```
      SUBROUTINE GRAPH (IC)
      DIMENSION IC(25)
      DIMENSION CONST(5,25)
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON DUMMY(50)
      COMMON X(105,5),Y(105,5),NLOC(13),YT(101,25),NPT(5),YS(13,25)
      COMMON/LAB/ TITL(18),XLAB(11),YLAB(6),HORIZ(20),VERT(7,6),IT,
     1VERTM(7,6)
      DATA TITL14,TITL15,TITL16,TITL17,TITL18/
     24H CHA,4HNNEL,4H  OR,4HINLE,4HT NO/
      DATA CONST/4H    ,4H    ,4HFLOW,4H    ,4H    ,4HDISS,4HOLVE,
     24HD OX,4HYGEN,4H    ,4H    ,4H    ,4HBOD ,4H    ,4H    ,4HTOTA,
     34HL SU,4HSP. ,4HSOLI,4HDS  ,4HFECA,4HL CO,4HLIFO,4HRMS ,4H    ,
     44H    ,4HCHLO,4HRIDE,4HS   ,4H    ,4HAMMO,4HNIA ,4HNITR,4HOGEN,
     54H    ,4HNITR,4HITE ,4HPLUS,4HNITR,4HATE ,4HORGA,4HNIC ,4HNITR,
     64HOGEN,4H    ,4HTOTA,4HL PH,4HOSPH,4HORUS,4H    ,4HDISS,4H, OR,
     74HTHOP,4HHOSP,4HHATE,4HOIL ,4HAND ,4HGREA,4HSE  ,4H    ,4H    ,
     84HHEAV,4HY ME,4HTALS,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     94H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     14H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     24H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     34H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     44H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     54H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     64H    /
      TITL(14)=TITL14
      TITL(15)=TITL15
      TITL(16)=TITL16
      TITL(17)=TITL17
      TITL(18)=TITL18
      NTAPE=JOUT(3)
      IF(NTAPE.LT.1) RETURN
      REWIND NTAPE
      READ (NTAPE)
      READ (NTAPE) NSTEPS,NCURVE,NQUAL,TDELT,TZERO,TAREA
      READ (NTAPE) (NLOC(M),M=1,NCURVE)
      NQP=NQUAL+1
      NQT=NQP
      IF(NQT.EQ.1) NQT=2
      MST=(NSTEPS-1)/101+1
      NCV=1
      DO 60 J=1,NCURVE
      REWIND NTAPE
      READ (NTAPE)
      READ (NTAPE)
      READ (NTAPE)
      MLOC=0
      DO 20 N=1,NSTEPS
      READ (NTAPE) TIME,(YS(I,1),I=1,NCURVE),((YS(I,M),M=2,NQT),I=1,NCUR
     2VE)
      IF(MOD(N-1+MST,MST).NE.0) GO TO 20
      MLOC=MLOC+1
      DO 10 M=1,NQP
      YT(MLOC,M)=YS(J,M)
   10 CONTINUE
      X(MLOC,1)=TIME/3600.
   20 CONTINUE
```

```
      NPT(1)=MLOC
      DO 50 N=1,25
      IF(IC(N).EG.0) GO TO 50
      DO 30 I=3,7
   30 TITL(I)=CONST(I-2,N)
      IT=3
      IF(N.EG.1) IT=2
      IF(N.EQ.5) IT=4
      DO 40 M=1,MLOC
   40 Y(M,1)=YT(M,N)
      CALL CURVE(X,Y,NPT,NCV,NLOC(J))
   50 CONTINUE
   60 CONTINUE
      RETURN
      END
```

HCURVE arranges rainfall hyetograph data or the total inlet inflow data for subsequent processing by Subroutine CURVE. The logic sequence is presented in Figure IV-5 in flowchart form, followed by the computer listing.

Subroutines CURVE, PINE AND PPLOT

These routines form a standard plot package and will be considered here as one computational unit. Subroutine CURVE is called to enter the plot package and employs common block LAB to define axis labeling information. Subroutine PPLOT also employs common block LAB while PPLOT contains no common block. Each routine is disussed in turn below.

Subroutine CURVE

The Subroutine CURVE performs the following operations:

1. Determines maximum and minimum of arrays to be plotted;
2. Calculates the range of values and selects appropriate scale intervals;
3. Computes vertical axis labels based upon the calculated scales;
4. Computes horizontal axis labels based upon the calculated scales;
5. Joins individual parts of the curve by Subroutine PINE; and
6. Outputs final plot.

Subroutine PINE

This subroutine joins two coordinate locations with appropriate characters in the output image array A of PPLOT.

Subroutine PPLOT

This subroutine initializes the plotting array, stores individual locations, and outputs the final image array A for the printer plot.

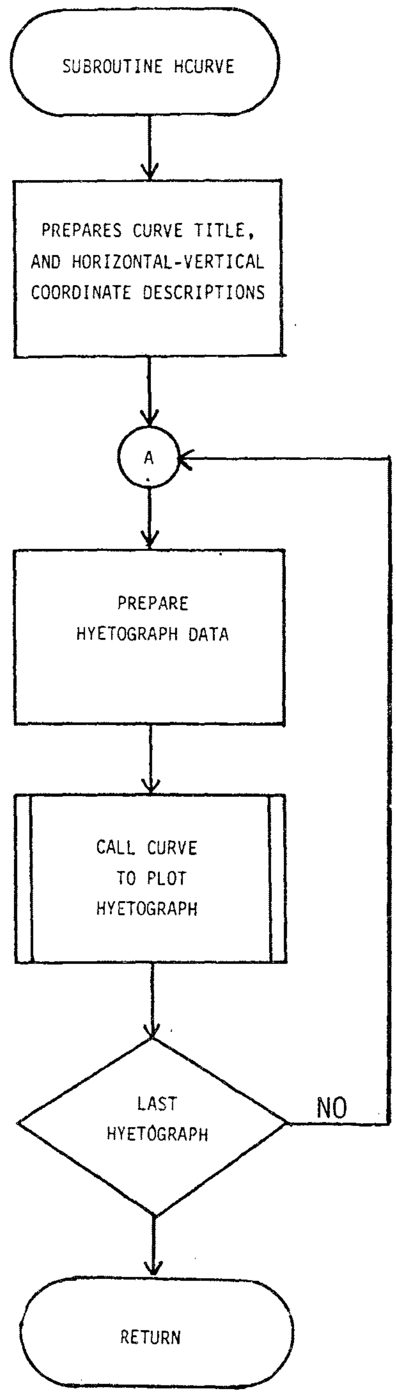


FIGURE IV-5. Flowchart for Subroutine HCURVE

```
      SUBROUTINE HCURVE(NTYPE,INLET)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMGW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),OIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,DUMMY(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/LAB/ TITLE(18),XLAB(11),YLAB(6),HORIZ(20),VERT(7,6),IT,
     2             VERTM(7,6)
      DIMENSION X(105,5),Y(105,5),NPT(5)
      DIMENSION VER(7,2),TITL(7,2),VERM(7,2)
      DIMENSION TITEL(18),ORIZ(20)
      DATA TITL /4HRAIN,4HFALL,4H HYE,4HTOGR,4HAPH ,4H    ,4H    ,
     2 4HINLE,4HT HY,4HDROG,4HRAPH,4H SUM,4HMATI,4HON  /
      DATA TITEL / 16*4H    ,4HBASI,4HN NO/
      DATA ORIZ/8*4H    ,4HTIME,4H IN ,4HHOUR,4HS   ,8*4H    /
      DATA VER/4HRAIN,4HFALL,4H   I,4HN   ,4HIN /,4H  HR,4H    ,
     24H RUN,4HOFF ,4H   I,4HN   ,4H  CF,4HS   ,4H    /
      DATA VERM/4HRAIN,4HFALL,4H   I,4HN   ,4HMM /,4H  HR,4H    ,4H RUN,
     2          4HOFF ,4H   I,4HN   ,4H  CM,4HS   ,4H    /
      DO 10 I=1,18
   10 TITLE(I)=TITEL(I)
      DO 20 I=1,20
   20 HORIZ(I)=ORIZ(I)
C
C******** RAINFALL HYETOGRAPH OR INLET HYDROGRAPH
C
      DO 30 I=1,7
      J=I+2
      IT=NTYPE
      IF(IMET.EQ.0) GO TO 21
      VERT(I,IT)=VERM(I,NTYPE)
      GO TO 25
   21 VERT(I,IT)=VER(I,NTYPE)
   25 TITLE(J)=TITL(I,NTYPE)
   30 CONTINUE
      NGAGP=5
      TMAX=FLOAT(NSTEP)*DELT+TZERO
      I=0
      DO 80 J=1,NRGAG,NGAGP
      DO 50 K=1,NGAGP
      I=I+1
      IF(I.GT.NRGAG) GO TO 60
      TIME=TZERO
      N=0
      DO 40 L=1,NHISTO
      N=N+1
      X(N,K)=TIME/3600.
      IF(IMET.EQ.0) GO TO 35
C
```

```
C**** CONVERT RAINFALL FROM FT/SEC TO MM/HR
      Y(N,K)=RAIN(L,I)*0.3048*3600000.
      GO TO 36
C
C**** CONVERT RAINFALL FROM FT/SEC TO IN/HR
35    Y(N,K)=RAIN(L,I)*43200.
36    TIME=TIME+HISTOG
      IF(TIME.GT.TMAX) GO TO 59
      IF(NHISTO.GT.50) GO TO 40
      N=N+1
      X(N,K)=TIME/3600.
      IF(IMET.EQ.0) GO TO 37
C
C**** CONVERT RAINFALL FROM FT/SEC TO MM/HR
      Y(N,K)=RAIN(L,I)*0.3048*3600000.
      GO TO 40
C
C**** CONVERT RAINFALL FROM FT/SEC TO IN/HR
37    Y(N,K)=RAIN(L,I)*43200.
40    CONTINUE
      N=N+1
      X(N,K)=TMAX/3600.
      Y(N,K)=0.
50    NPT(K)=N
      K=NGAGP+1
60    K=K-1
      CALL CURVE (X,Y,NPT,K,INLET)
80    CONTINUE
      RETURN
      END
```

The key variables in each routine not in common are presented in Table IV-4. The computer listing for these routines follows.

Subroutine GQUAL

GQUAL computes a mass balance for each gutter/channel at each time step. The routine is called from GUTTER and returns the concentration of conservative constituents in the gutter/channel. Mass inputs include upstream gutters and channels, tributary watersheds, and inlet carryover. This quality routing routine also handles surcharge quality. It does not contain any provision for decay of non-conservative constituents. Suspended solids removal in detention basins is also computed in this routine. The following common blocks are employed in this routine:

- BLANK COMMON
- ABLK
- NEW
- POLUT
- INFIL
- REMOV
- TEST

The computational sequence is shown in flowchart form in Figure IV-6. Key variables not in common are presented in Table IV-5, followed by a listing of this subroutine.

Subroutine GUTTER

Subroutine GUTTER calls Subroutine GQUAL and Subroutine CARRY. The following common blocks are employed in GUTTER:

- BLANK COMMON
- TAPES
- ABLK
- NEW
- MAX

TABLE IV-4

PLOT PACKAGE VARIABLES NOT IN COMMON

Variable Name	Description	Unit
	SUBROUTINE CURVE	
A	The log base 10 of the range of values of y coordinate to be plotted	
FRANG	Expanded range (even intervals) of y coordinates of curve to be plotted	
K	Subscript counter	
L	Subscript counter	
M	Subscript counter	
N	Subscript counter	
NCV	Number of curves/plot	
NPLOT	Number of plots	
NPOINT	Number of points on a plot	
NPT	Number of points/curve (array)	
NPTM	Numerical value of NPT	
RANGE	Range of y values to be plotted	
X	X coordinate array	
XINT	Label interval for X	
XMAX	Maximum X value	
XMIN	Minimum X value	
XO	Start point of line (X coordinate)	
XSCAL	X scale factor	
XT	End point of line (X coordinate)	
M	Subscript counter	
MC	Do loop counter	
MM	Subscript counter	
N	Subscript counter	
NCURVE	Number of curves to be plotted	

TABLE IV-4
(cont.)

Variable Name	Description	Unit
NCV	Number of curves/plot	
NLOC	Node number of hydrograph point	
NLP	Number of types of plot (hydrographs and pollutographs)	
NN	Subscript counter	
NPCV	Maximum number of curves/plot	
NPLOT	Number of plots	
NPT	Array containing number of points to be plotted (GRAPH)	
NQP	Number of quality constituents to be plotted	
NQUAL	Number of quality constituents on data file	
NR	Subscript counter	
NSTEPS	Number of steps in plot	
NTAPE	Input tape number for plotting	
NVAL	Number of points/data record on a file	
TAREA	Total area	Acres
TDELT	Time-step interval	
TIMES	Time-step interval	
TZERO	Zero time	
X	X coordinate array (GRAPH)	
Y	Y coordinates of curves to be drawn	
YT	Hydrograph-pollutograph information on data file	
	SUBROUTINE PINE	
AXA	X coordinate of value previously plotted	
AXG	X coordinate of value to be plotted	
AYA	Y coordinate of value previously plotted	

TABLE IV-4
(cont.)

Variable Name	Description	Unit
AYB	Y coordinate of value to be plotted	
IXA	Integer value of AXA	
IXB	Integer value of AXB	
IYA	Integer value of AYA	
IYB	Integer value of AYB	
N	Subscript counter	
NCT	Number of plots	
NSYM	Plot number	
XA	X increment used for interpolation	
X1	Same as X0	
X2	Same as XT	
YA	Y increment used for interpolation	
Y1	Same as Y0	
Y2	Same as YT	
	SUBROUTINE PPLOT	
A	Transfer array for plotting	
I	Subscript counter	
II	Subscript counter	
IX	Start point of line	
IY	Start point of line	
J	Subscript counter	
JJ	Subscript counter	
NCT	Number of plots	
SYM	Plot symbol array	

```
      SUBROUTINE CURVE(X,Y,NPT,NCV,NPLOT)
      DIMENSION X(105,10),Y(105,10),NPT(10)
      COMMON/LAB/ TITLE(18),XLAB(11),YLAB(6)
     2,HORIZ(20),VERT(7,6),IT,VERTM(7,6)
      XMAX=X(1,1)
      XMIN=XMAX
      YMIN=Y(1,1)
      YMAX=YMIN
      DO 20 L=1,NCV
      NPTM=NPT(L)
      IF(NPTM.EQ.0) GO TO 20
      DO 10 N=1,NPTM
      IF(X(N,L).LT.XMIN) XMIN=X(N,L)
      IF(X(N,L).GT.XMAX) XMAX=X(N,L)
      IF(Y(N,L).LT.YMIN) YMIN=Y(N,L)
      IF(Y(N,L).GT.YMAX) YMAX=Y(N,L)
   10 CONTINUE
   20 CONTINUE
      RANGE=(YMAX-YMIN)/5.
      IF(RANGE.GT.0) GO TO 30
      IF(YMAX.GT.0.) YMIN=0.
      IF(YMAX.LT.0.) YMAX=0.
      RANGE=(YMAX-YMIN)/5.
      IF(RANGE.LE.0) RETURN
   30 CONTINUE
      A=ALOG10(RANGE)
      IF(A.LT.0) GO TO 70
      N=A
      RANGE=RANGE/(10.**N)
      L=RANGE+1.001
   40 CONTINUE
      IF(L.EQ.2) GO TO 60
      IF(L.GT.4) GO TO 50
      L=4
   50 IF(L.GT.5) L=10
   60 CONTINUE
      FRANG=L*10.**N
      GO TO 110
   70 M=A-0.9999
      N=-M
      RANGE=RANGE*10.**N
      L=RANGE+1.001
   80 CONTINUE
      IF(L.EQ.2) GO TO 100
      IF(L.GT.4) GO TO 90
      L=4
   90 CONTINUE
      IF(L.GT.5) L=10
  100 CONTINUE
      FRANG=L/10.**N
  110 CONTINUE
      K=YMIN/FRANG
      IF(YMIN.LT.0) K=K-1
      IF(YMAX.LE.(K+5)*FRANG) GO TO 130
      L=L+1
      IF(L.LT.11) GO TO 120
      L=2
```

```
      N=N+1
      IF(A.LE.0.) N=N-2
120   CONTINUE
      IF(A) 80,40,40
130   YMIN=K*FRANG
      YMAX=(K+5)*FRANG
      XSCAL=100./(XMAX-XMIN)
      YSCAL=50./(YMAX-YMIN)
      XINT=(XMAX-XMIN)/10.
      YINT=(YMAX-YMIN)/5.
      XLAB(1)=XMIN
      DO 140 N=1,10
140   XLAB(N+1)=XLAB(N)+XINT
      YLAB(6)=YMIN
      DO 150 N=1,5
150   YLAB(6-N)=YLAB(7-N)+YINT
      CALL PPLOT(0,0,100,NPLOT)
      K=1
      DO 180 L=1,NCV
      IF(NPT(L).EQ.0) GO TO 170
      XO=XSCAL*(X(1,L)-XMIN)
      YO=YSCAL*(Y(1,L)-YMIN)
      NPOINT=NPT(L)
      DO 160 N=2,NPOINT
      XT=XSCAL*(X(N,L)-XMIN)
      YT=YSCAL*(Y(N,L)-YMIN)
      CALL PINE (XO,YO,XT,YT,K,NPLOT)
      XO=XT
      YO=YT
160   CONTINUE
170   K=K+1
180   CONTINUE
      CALL PPLOT(0,0,99,NPLOT)
      RETURN
      END
```

```
      SUBROUTINE PINE(X1,Y1,X2,Y2,NSYM,NCT)
      AXA=X1
      AXB=X2
      AYA=Y1
      AYB=Y2
      N=1
      IF(ABS(AXB-AXA).LT.ABS(AYB-AYA)) GO TO 50
C
C     SET PARAMETERS FOR X DIRECTION
C
      IF(AXB-AXA) 10,100,20
10    CONTINUE
      AXA=X2
      AXB=X1
      AYA=Y2
      AYB=Y1
   20 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
   30 CONTINUE
      IF(IXA.LT.0.OR.IXA.GT.100) GO TO 40
      IF(IYA.LT.0.OR.IYA.GT.50) GO TO 40
      CALL PPLOT(IXA,IYA,NSYM,NCT)
   40 CONTINUE
      IXA=IXA+1
      YA=(N*(AYB-AYA))/(AXB-AXA)
      IYA=AYA+YA+0.5
      N=N+1
      IF(IXA.LE.IXB) GO TO 30
      GO TO 100
C
C     SET PARAMETERS FOR Y DIRECTION
C
   50 CONTINUE
      IF(AYB.GT.AYA)   GO TO 60
      AYB=Y1
      AXB=X1
      AYA=Y2
      AXA=X2
   60 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
   70 CONTINUE
      IF(IXA.LT.0.OR.IXA.GT.100) GO TO 80
      IF(IYA.LT.0.OR.IYA.GT.50) GO TO 80
      CALL PPLOT(IXA,IYA,NSYM,NCT)
   80 CONTINUE
      IYA=IYA+1
      XA=(N*(AXB-AXA))/(AYB-AYA)
      IXA=XA+AXA+0.5
```

```
      N=N+1
      IF(IYA-IYB) 70,90,100
   90 IXA = IXB

      GO TO 70
  100 RETURN
      END
```

```
      SUBROUTINE PPLOT(IX,IY,K,NCT)
      DIMENSION A(51,101),SYM(9)
      COMMON /TAPES/ JIN(1),JOUT(3),N5,N6
      COMMON /LAB/ TITLE(18),XLAB(11),YLAB(6)
     1,HORIZ(20),VERT(7,6),IT,VERTM(7,6)
      DATA SYM / 4H****,4H++++, 4H    , 4HXXXX, 4H...., 4H2222,
     1 4H    , 4HIIII, 4H---- /
      IF(K-99) 10,20,160
   10 A(51-IY,IX+1)=SYM(K)
      RETURN
   20 CONTINUE
      I=0
      WRITE(N6,120) TITLE,NCT
  120 FORMAT(1H1,20X,18A4,I6)
      DO 70 II=1,6
      I=I+1
      WRITE(N6,100) YLAB(II),(A(I,J),J=1,101)
  100 FORMAT(* *,1PE16.2,1X,101A1)
      IF(II.EQ.6) GO TO 80
      DO 60 JJ=1,9
      I=I+1
      IF(I.NE.28) GO TO 30
  223 WRITE(N6,150) VERT(5,IT),VERT(6,IT),VERT(7,IT),(A(I,J),J=1,101)
  150 FORMAT(3X,3A4,3X,101A1)
      GO TO 60
   30 IF(I.NE.24) GO TO 40
      WRITE(N6,140) VERT(1,IT),VERT(2,IT),(A(I,J),J=1,101)
      GO TO 60
   40 IF(I.NE.26) GO TO 50
      WRITE(N6,140) VERT(3,IT),VERT(4,IT),(A(I,J),J=1,101)
  140 FORMAT(3X,2A4,7X,101A1)
      GO TO 60
   50 WRITE(N6,90) (A(I,J),J=1,101)
   90 FORMAT(18X,101A1)
   60 CONTINUE
   70 CONTINUE
   80 CONTINUE
      WRITE(N6,110) XLAB
      WRITE(N6,130) HORIZ
  110 FORMAT(* *,F19.1,10F10.1)
  130 FORMAT(/30X,20A4)
  160 DO 180 I=1,50
      DO 170 J=1,101
  170 A(I,J)=SYM(7)
      A(I,1)=SYM(8)
  180 CONTINUE
      DO 190 J=1,101
  190 A(51,J)=SYM(9)
      DO 200 I=1,101,10
  200 A(51,I)=SYM(8)
      DO 210 I=11,41,10
      A(I,1)=SYM(9)
  210 CONTINUE
      RETURN
      END
```

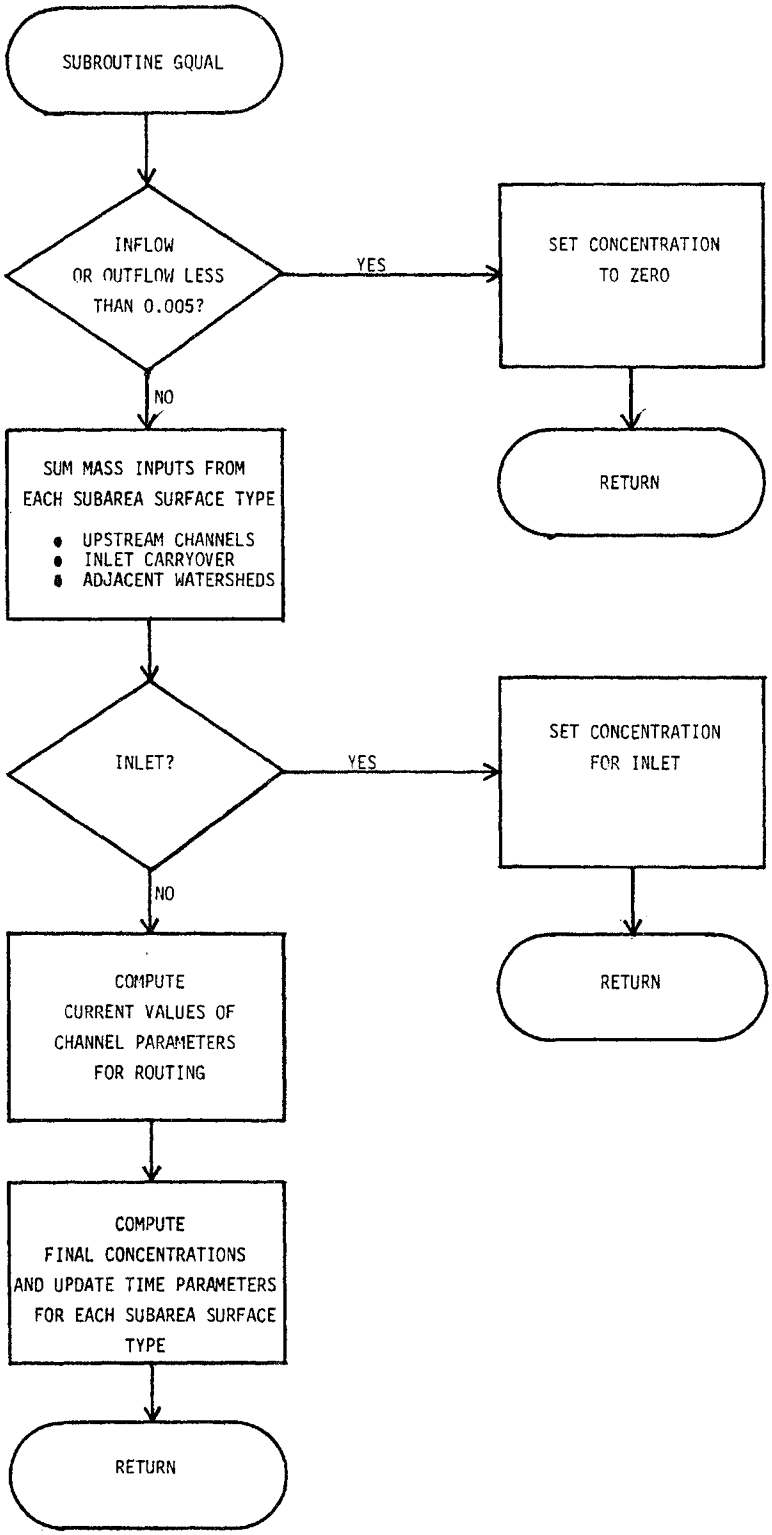


FIGURE IV-6. Flowchart for Subroutine GQUAL

TABLE IV-5

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE GQUAL

Fortran Variable	Description	Units
ALFA	Auxiliary variable	sec^{-1}
BETA	Auxiliary variable	gm/l/sec
DT	Detention time	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	sec/ft^3
V	Channel volume	ft^3
VDOT	Time derivative of channel volume	ft^3/sec

```
      SUBROUTINE GQUAL(J,V,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,
     1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),GIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON/INFIL/RAININ(200,3),DEPIN( 5 ),TIMEW(200),WTYPE(200,3),
     2NC(200)
      COMMON/POLUT/WFLO(200,3),WDOT(200,3,5),W(200,3,5)
      COMMON/ABLK/ NQS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2            C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
     3            SSFACT(5,2),QFACT(5,13)
      COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
     1          GDEPT(3),QI(3),VOL1(150),VOL2(150),XFLOW(150),
     2          NGSTO(200),NGSUR(150),QINLET(150),PINLET(150,13),
     3          ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
     4          OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
     5          OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
      COMMON/REMOVE/DET
      COMMON/TEST/SJMT1
      DIMENSION FLUX(5)
      DIMENSION STORPL(13,5)
      DATA STORPL/65*0./
C
C******** CHECK FLOW AND SET ZEROS IF BELOW MINIMUM
C
      IF(GIN(J).GT.0.005.OR.GFLOW(J).GT.0.005) GO TO 20
      DO 10 K=1,5
      CDOT(J,K)=0.0
      C(J,K)=0.0
   10 CONTINUE
      RETURN
   20 CONTINUE
C
C******** COMPUTE INPUTS FROM UPSTREAM GUTTERS
C
      ALFA=2.0/DELT
      DO 30 M=1,5
      FLUX(M)=0.
      IF(TMSUR.GE.0) GO TO 30
      PREM=-TMSUR*STORPL(J,M)/(QSUR(J)-TMSUR*DELT)
      FLUX(M)=FLUX(M)+PREM
      STORPL(J,M)=STORPL(J,M)-PREM*DELT
   30 CONTINUE
```

```
      DO 50 K=1,NIN
      L=NGTOG(J,K)
      IF(L.EQ.0) GO TO 60
      DO 40 M=1,5
      FLUX(M)=FLUX(M)+C(L,M)*GFLOW(L)
40    CONTINUE
50    CONTINUE
60    CONTINUE
C
C******** ADD MASS FROM INLETS
C
      IF(INLET2.EQ.0) GO TO 110
      DO 100 IN=1,INLET2
      IF(J.NE.ISAVE(IN)) GO TO 100
      DO 90 M=1,13
90    FLUX(M)=FLUX(M)+PINLET(IN,M)
100   CONTINUE
110   CONTINUE
C
C******** ADD MASS INPUT FROM ADJACENT WATERSHEDS
C
      DO 130 K=1,NIN
      L=NWTOG(J,K)
      IF(L.EQ.0) GO TO 140
      DO 120 M=1,5
      FLUX(M)=FLUX(M)+WFLOW(L)*W(L,NC(L),M)
C
C******** FLUX IS GRAM-CUBIC FEET/LITER-SECOND
C
      SUMT1=SUMT1+WFLOW(L)*W(L,NC(L),M)*DELT*.0283
120   CONTINUE
130   CONTINUE
140   CONTINUE
      IF(NPG(J).EQ.10) GO TO 160
      IF(NPG(J).EQ.9) GO TO 160
      IF(NPG(J).NE.4.AND.NPG(J).NE.5) GO TO 175
      RR=1.
      IF(GFLOW(J).LE.0.) GO TO 180
      DT=VOL2(J)/GFLOW(J)*60.
      RR=DT/(DT+DET)
160   DO 185 M=1,5
185   FLUX(M)=FLUX(M)*(1.-RR)
C
C******** COMPUTE CURRENT VALUES OF GUTTER PARAMETERS FOR ROUTING
C
175   VDOT=QIN(J)-GFLOW(J)-TMSUR
      QT=GFLOW(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 150 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
```

```
  150 CONTINUE
      RETURN
C
C**** COMPUTE FINAL CONCENTRATION FOR INLET
  160 DO 170 K=1,5
  170 C(J,K)=FLUX(K)/QIN(J)
      RETURN
      END
```

The function of Subroutine GUTTER is very similar to that of WSHED; it calculates a complete set of water depths and flows for gutters and channels and calls GQUAL to route conservative pollutants. If an inlet is encountered, CARRY is called to compute the carryover to the downstream gutter/channel.

The computation proceeds one gutter/channel at a time. For a gutter/channel, first the inflows are summed, then Newton's iterative procedure is used to determine the depth and outflow based on continuity and uniform flow equations. Individual calculations are made for trapezoidal gutters and channels, pipes, and overbank channels (by calling OVRBNK). Detention basin outflows are determined from a weir equation or the uniform flow equation for an outlet channel. If the gutter/channel becomes filled and surcharge occurs or if an overbank channel begins to flow, a message is printed. Inlet hydraulic and quality information is written to tape or disc for later access by the drainage design program. Hydrographs and pollutographs are written to an output file. The computational sequence is shown in the flowchart of Figure IV-7. Key variables not included in common are presented in Table IV-6 followed by a listing of the subroutine.

Subroutine OVRBNK

When a channel has been input as a double trapezoidal channel and the base channel overflows, OVRBNK is called to route the flows in the overbank channel. The structure of this subroutine is virtually identical with the portion of GUTTER that calculates flow from trapezoidal channels. The inflow to the overbank channel is the overflow from the base channel and again Newton's method is used to compute depth and outflow. The overbank channel outflow is added to the full flow of the base channel computed in GUTTER to arrive at the total outflow.

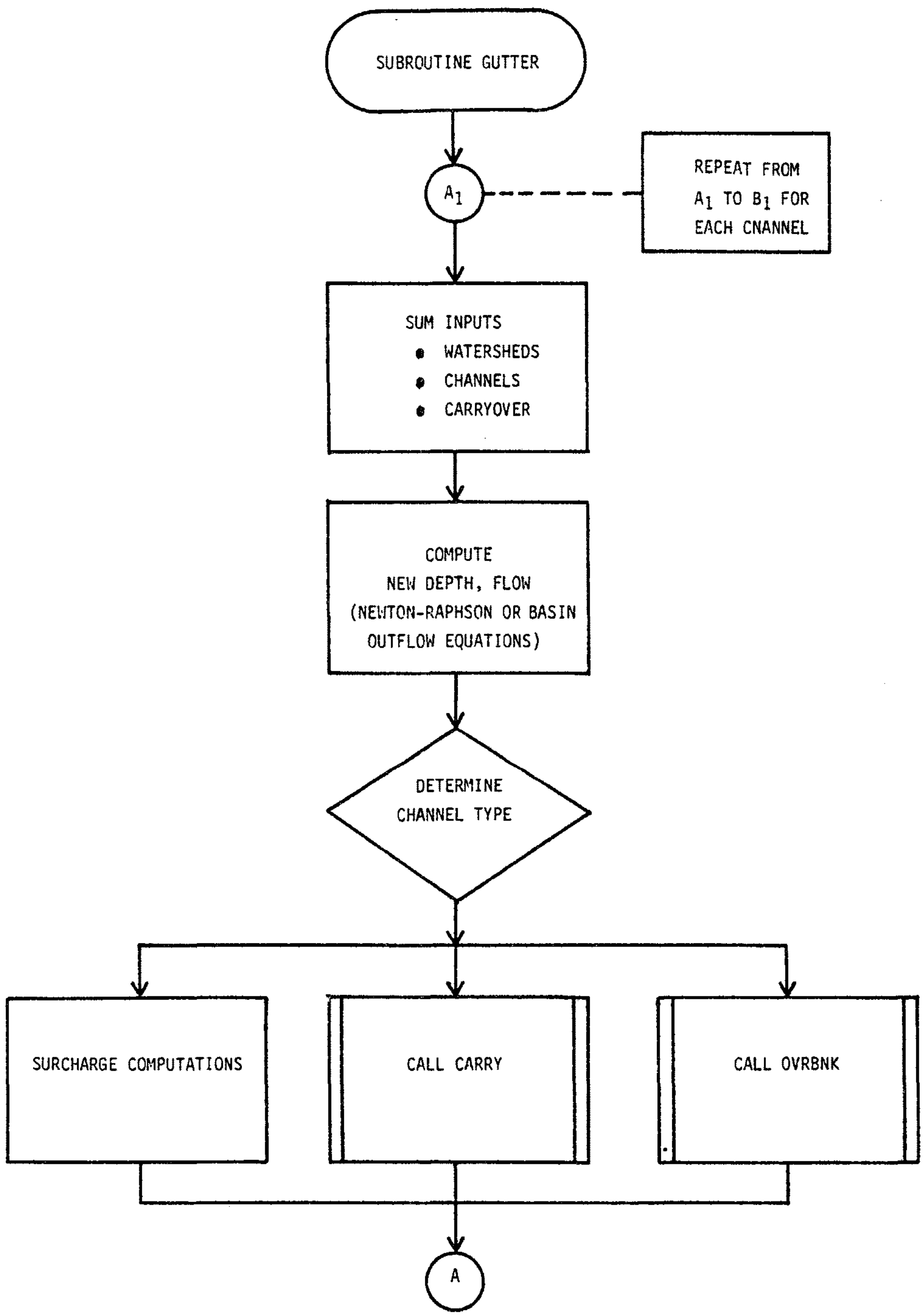


FIGURE IV-7. Flowchart for Subroutine GUTTER

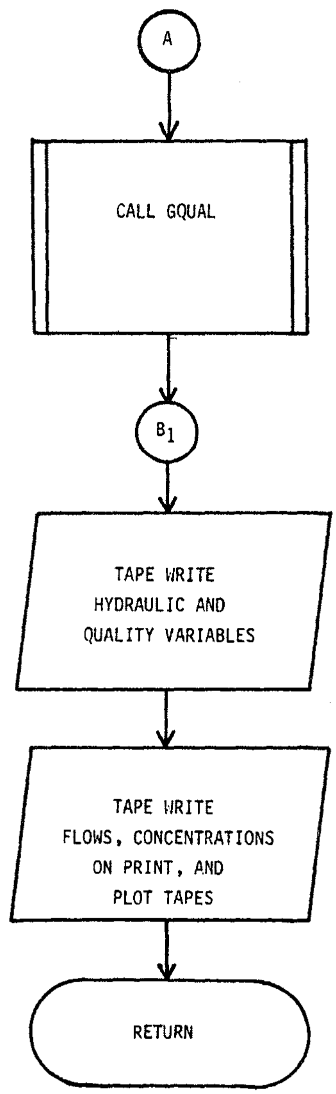


Figure IV-7
(Continued)

TABLE IV-6

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE GUTTER

Fortran Variable	Description	Units
AR23	Detention basin flow calculation auxiliary variable	$ft^{8/3}$
AX	Detention basin flow area	ft^2
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 has a function depth change	ft^3
DEPTH	Depth of flow at inlet	ft
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
DO	Detention basin depth at the beginning of the time step	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	-

TABLE IV-6
(cont.)

Fortran Variable	Description	Units
IND	Rainfall array pointer	-
INLETS	Number of inlets	-
NGAG	Raingage number	-
NOGG	Number of channels and inlet channels	-
NOUT	Plot tape number	-
NPGJ	Channel type	-
NSUR	Number of surcharged channels	-
NTIMEH	Time in hours	hrs
NTS2	Transfer tape number	-
NT1	Print tape number	-
NUP	Channel number above inlet (internal)	-
NX	Contributary watershed number (internal)	-
OVRAXØ	Overbank flow area at beginning of time step	ft^2
OVRAX1	Overbank flow area at end of time step	ft^2
OVRDEL	Overbank channel change in depth	ft
OVROUT	Overbank channel outflow	ft^3/sec
OVRQIN	Overbank channel inflow	ft^3/sec
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
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,
         1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
          COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
         2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
         3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
          COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
         2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMGW(150),
         3NGUT(200),PCTZER,NPG(150),SPMAX(150)
          COMMON DELD(150),QIN(150),QSUR(150)
          COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
          COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
          COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
         2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
          COMMON/TAPES/JIN(1),JOUT(3),N5,N6
          COMMON/ABLK/ NOS,CLFREG,DRYDAY,REFF,NQO,PLAND(200,3),
         2              C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
         3              SSFACT(5,2),OFACT(5,13)
          COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
         1            GDEPT(3),QI(3),VOL1(150),VOL2(150),XFLOW(150),
         2            NGSTO(200),NOSUR(150),QINLET(150),PINLET(150,13),
         3            ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
         4            OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
         5            OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
          COMMON/MAX/MAXFLW(150),MAXHR(150),MAXMIN(150),MAXDEP(150),
         2SURLEN(150)
          REAL MAXFLW,MAXDEP
    C
          DATA NTSCP/0/
          NTS2=JOUT(1)
          NT1=JOUT(2)
          NOUT=JOUT(3)
    C
    C******** DETERMINE RAINFALL INTERVAL FOR LAKES
    C
          IND=1.+(TIME2-TZERO)/HISTOG
    C
          INLETS=NSAVE
          NOGG=NOG+NSAVE
    C
    C******** INPUT FROM UPSTREAM GUTTERS
    C
          DO 10 J=1,NOGG
          DO 10 JK=1,NIN
          IF(NGTOG(J,JK).EQ.0) GO TO 10
          NX=NGTOG(J,JK)
          GIN(J)=GIN(J)+GFLOW(NX)
    10    CONTINUE
    C
          DO 340 N=1,NOGG
          J=NGUT(N)
          OUTFLW(J)=0.
    C
    C******** INPUTS FROM ADJACENT WATERSHED AREAS
    C
          SUMGW(J)=0.
          DO 20 JK=1,NIN
```

```
          IF (NWTOG(J,JK).EQ.0) GO TO 30
          NX=NWTOG(J,JK)
   20     SUMQW(J)=SUMQW(J)+WFLOW(NX)
   30     QIN(J)=QIN(J)+SUMQW(J)
C
C**** CHECK GUTTER TYPE
C           1 = TRAPEZOIDAL GUTTER
C           2 = TRAPEZOIDAL CHANNEL
C           3 = CIRCULAR PIPE
C           4 = DOUBLE TRAPEZOIDAL CHANNEL
C           5 = BASIN, WEIR CONTROL
C           6 = BASIN, OUTLET CHANNEL CONTROL
C
   50     NPGJ=NPG(J)
          IF(NPGJ.LE.0) WRITE(N6,51)
   51     FORMAT(/5X,*ERROR IN CONNECTIVITY - CHECK THE FOLLOWING:*/10X,
         2 *ONLY ONE ELEMENT CAN DRAIN INTO EACH INLET*/10X,*CATCHMENTS DRAI
         3NING DIRECTLY INTO INLETS NEED DUMMY CHANNELS SPECIFIED*//)
          GO TO(70,70,70,70,280,280,80,80,55,60) NPGJ
   55     TMSUR=0.
          GO TO 325
   60     TMSUR=0.
          GO TO 320
C
   70     D0=GDEPTH(J)
C
C**** CHECK FOR ZERO FLOW
          IF(QIN(J).NE.0.) GO TO 80
          IF(GDEPTH(J).NE.0.) GO TO 80
          AX0=0.
          AX1=0.
          FLOW=0.
          DELD(J)=0.
          TMSUR=0.
          VOL=0.
          GO TO 320
C
C******** COMPUTE CHANGE IN DEPTH (NEWTON-RAPHSON)
C
   80     IFLG=0
          DELD(J)=0.
          FLOW1=0.
          DO 180 I=1,30
          FLOW10=FLOW1
          TMSUR=0.
C
C**** ESTIMATED FINAL DEPTH
          D1=GDEPTH(J)+DELD(J)
          IF(NPG(J).EQ.3) GO TO 90
C
C******** TRAPEZOIDAL GUTTER/CHANNEL
C
          IF(D1.GE.0.) GO TO 85
          D1=0.
          DELD(J)=-GDEPTH(J)
C
C**** VOLUME CHANGE
```

```
85    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 (TRAPEZOIDAL CROSS-SECTION)
      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 TRAP CROSS SECTION
      DWP1=SQRT(GS1(J)**2+1.)+SQRT(GS2(J)**2+1.)
      WP0=DWP1*D0+GWIDTH(J)
      WP1=DWP1*D1+GWIDTH(J)
      GO TO 130
C
C******** CIRCULAR PIPE
C
90    IF(I.GT.1) GO TO 100
      D1=1.5707963
      DELD(J)=D1-GDEPTH(J)
100   IF(D1.GT.0) GO TO 110
      D1=0.
      DELD(J)=-GDEPTH(J)
110   IF(D1.LE.DFULL(J)) GO TO 120
      D1=DFULL(J)
      DELD(J)=D1-GDEPTH(J)
C
C**** VOLUME CHANGE
120   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******** ALL CROSS-SECTIONS
C
C**** HYDRAULIC RADIUS
130   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
      FLOW0=GCON(J)*(AX0**1.6666667)/(WP0**0.6666667)
      FLOW1=GCON(J)*(AX1**1.6666667)/(WP1**0.6666667)
      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
      F=DELV+DELT*(FLOW-QIN(J))-QSUR(J)
      DF=DDELV+DELT*DFLOW1
      IF(DF.GT.0) GO TO 140
C
C**** ZERO SLOPE
      DEL=0.01
      GO TO 150
C
C**** NON-ZERO SLOPE
140   DEL=DELD(J)-F/DF
C
C**** CONVERGENCE CHECK
150   IF(I.EQ.1) GO TO 180
      IF(GDEPTH(J)+DEL.LT.DFULL(J)) GO TO 160
      IF(IFLG.EQ.1) GO TO 240
      DEL=DFULL(J)-GDEPTH(J)
      IFLG=1
      GO TO 180
160   IFLG=0
      IF(FLOW10.GT..001) GO TO 170
      IF(ABS(FLOW1-FLOW10).LT..001) GO TO 220
      GO TO 180
170   CONTINUE
      IF(ABS(FLOW1-FLOW10).LT..001*FLOW1) GO TO 220
180   DELD(J)=DEL
C
C******** NON-CONVERGENT SOLUTION
C******** CHECK IF OUTFLOW EXCEEDS AVAILABLE WATER
C
      VOLO=AXO*GLEN(J)+QSUR(J)
      IF((FLOWO*.5*DELT).GT.(VOLO+QIN(J)*DELT)) GO TO 200
      WRITE(6,1000) TIME,NAMEG(J),GDEPTH(J),DELD(J)
1000  FORMAT(*  CHECK RESULTS. NOT CONVERGED IN GUTTER *,
     2 F8.0,I6,2E12.5)
      FLOW=QIN(J)
      DEL=.01*DFULL(J)-GDEPTH(J)
      GO TO 220
200   WRITE(6,1001) NAMEG(J),TIME
1001  FORMAT(*   OUTFLOW EXCEEDS AVAILABLE WATER IN GUTTER  *,I4,
     2    * AT TIME   *,F8.0)
      FLOW=QIN(J)+VOLO/DELT
      DEL=-GDEPTH(J)
C
C******** NEW DEPTH AT END OF TIME INTERVAL
C
220   DELD(J)=DEL
      GDEPTH(J)=GDEPTH(J)+DELD(J)
      IF(GDEPTH(J).GE.0.0) GO TO 225
      WRITE(N6,1) GDEPTH(J),NAMEG(J),TIME
1     FORMAT(* A NEGATIVE DEPTH OF *,F8.2,* HAS OCCURRED IN CHANNEL *,
     2I4,* AT TIME *,F8.0,* SEC.*/*   THE DEPTH AND FLOW IN THIS CHANNEL
     3 HAVE BEEN SET TO ZERO.*/*   THIS MAY INDICATE THAT THE TIME STEP
     4USED MAY BE TOO LONG.*)
      GDEPTH(J)=0.
      FLOW=0.
225   QSUR(J)=0.
```

```
      C
      C******** AVERAGE FLOW DURING TIME INTERVAL
      C
            IF(FLOW.LT.1.E-10) FLOW=0.0
            GFLOW(J)=FLOW
            VOL=0.5*(AX0+AX1)*GLEN(J)
            IF(TIME.GT.TZERO+DELT) GO TO 230
            VOL1(J)=AX0*GLEN(J)
      230   VOL2(J)=AX1*GLEN(J)
            OUTFLW(J)=FLOW
            GO TO 330
      C
      C******** OVERBANK OR SURCHARGED GUTTER
      C
      240   GDEPTH(J)=DFULL(J)
            IF(NPG(J).NE.4) GO TO 250
      C
      C**** OVERBANK CASE
            OVRQIN=QIN(J)-FLOW1
            CALL OVRBNK (J,OVRQIN,OVROUT,OVRAX0,OVRAX1,OVRDEL)
            JUP=JOVER(J)
            GFLOW(J)=FLOW1+OVROUT
      C
      C**** QSUR IS OVERBANK VOLUME AT END OF TIME STEP
            QSUR(J)=OVRAX1*GLEN(J)
            VOL=(AX1+((OVRAX0+OVRAX1)/2.))*GLEN(J)
            OUTFLW(J)=GFLOW(J)
            GO TO 330
      C
      C**** SURCHARGE CASE
      250   GFLOW(J)=FLOW1
            TMSUR=QIN(J)-FLOW1
            QSUR(J)=QSUR(J)+TMSUR*DELT
            IF(QSUR(J).GT.0.) GO TO 270
            GFLOW(J)=GFLOW(J)+QSUR(J)/(2.*DELT)
            QSUR(J)=0.
      270   VOL=AX1*GLEN(J)
            OUTFLW(J)=FLOW1
            GO TO 330
      C
      C******** COMPUTE OUTFLOW FROM AND CHANGE IN STORAGE IN DETENTION BASINS
      C
      280   DO=GDEPTH(J)
      C
      C**** DO CAN BE NEGATIVE IF BASIN LEVEL IS BELOW OUTLET ELEVATION
            GFLOW(J)=0.
            IF(DO.LE.0.) GO TO 300
            IF(NPG(J).EQ.6) GO TO 290
      C
      C**** OUTFLOW FROM BASINS WITH OUTLET WEIR CONTROL - NPG(J)=5
            GFLOW(J)=GCON(J)*DO**1.5
            GO TO 300
      C
      C**** OUTFLOW FROM BASINS WITH OUTLET CHANNEL CONTROL - NPG(J)=6
      290   AX=0.5*(GS1(J)+GS2(J))*DO**2+GWIDTH(J)*DO
            WP=SQRT(GS1(J)**2+1.)*DO+SQRT(GS2(J)**2+1.)*DO+GWIDTH(J)
            AR23=AX*(AX/WP)**.6667
```

```
      GFLOW(J)=GCON(J)*AR23
C
C**** CHANGE IN LAKE STORAGE
300   NGAG=LKHYET(J)
      RI=0.
      IF(TIME2.LE.TRAIN) RI=RAIN(IND,NGAG)
      DELD(J)=(RI+(QIN(J)-GFLOW(J))/AREALK(J))*DELT
      GDEPTH(J)=GDEPTH(J)+DELD(J)
      VOL=VOLMLK(J)+(GDEPTH(J)-DELD(J)/2.)*AREALK(J)
      IF(TIME.GT.TZERO+DELT) GO TO 310
      VOL1(J)=(GDEPTH(J)-DELD(J))*AREALK(J)
310   VOL2(J)=GDEPTH(J)*AREALK(J)
      VOLMLK(J)=VOL2(J)
C
C**** SUM FOR CONTINUITY CHECK
      SUMRL=SUMRL+RI*AREALK(J)*DELT
      TMSUR=0.
      OUTFLW(J)=GFLOW(J)
      IF(OUTFLW(J).EQ.0) OUTFLW(J)=0.0011
      GO TO 330
C
C******** COMPUTE INTERCEPTION AND CARRYOVER FOR INLETS
C
325   NUP=NGTOG(J,1)
      DEPTH=GDEPTH(NUP)
      ISUMP=0
      CALL CARRY(DEPTH,ISUMP,NUP,XFLOW(J),GFLOW(J))
      GO TO 330
320   GFLOW(J)=QIN(J)
330   IF(NQS.GT.0) CALL GQUAL (J,VOL,TMSUR)
C
C**** END OF DO LOOP ON GUTTERS
340   CONTINUE
      NTIMEH=TIME/3600.
      TIMEM=TIME/60.-FLOAT(NTIMEH)*60.
      DO 1500 N=1,NOG
      IF(GFLOW(N).LE.MAXFLW(N)) GO TO 1500
      MAXFLW(N)=GFLOW(N)
      MAXHR(N)=NTIMEH
      MAXMIN(N)=TIMEM+.5
      MAXDEP(N)=GDEPTH(N)
1500  CONTINUE
C
C******** PRINT TAPE
C
      NQT=NQS
      IF(NQT.LT.1) NQT=1
      IF(NPRNT.LT.1) GO TO 480
      INTCNT=INTCNT+1
      IF(INTCNT.LT.INTERV) GO TO 480
      INTCNT=0
      DO 380 N=1,NPRNT
      J=IPRNT(N)
      OUTFLW(N)=GFLOW(J)
      IF (NPG(J).EQ.9) OUTFLW(N)=XFLOW(J)
380   CONTINUE
      WRITE (NT1) NTIMEH,TIMEM,(OUTFLW(N),N=1,NPRNT)
```

```
      IF(NGS.LT.1) GO TO 420
      DO 410 J=1,NPRNT
      N=IPRNT(J)
      DO 400 K=1,NOS
      POFF(J,K)=0.0
      DO 390 L=1,5
      POFF(J,K)=C(N,L)*QFACT(L,K)+POFF(J,K)
390   CONTINUE
400   CONTINUE
      POFF(J,1)=8.0
410   CONTINUE
      WRITE (NT1) NTIMEH,TIMEM,((POFF(J,K),K=1,NGS),J=1,NPRNT)
420   CONTINUE
      NSUR=0
      DO 460 N=1,NOG
      J=NGUT(N)
      IF(QSUR(J).LE.0.0) GO TO 460
      NSUR=1
      NTSCP=NTSCP+1
      IF(MOD(NTSCP,36).EQ.1.AND.IMET.EQ.0) WRITE(N6,430)
430   FORMAT(1H1/,5X,*SUMMARY OF SURCHARGE HISTORY*//5X,*TOTAL
     2    GUTTER   CUM VOL*/*  HOUR MIN    GUTTER      FLOW   SURCHAR*/3X
     3,*(HOURS)    NUMBER      (CFS)       (FT3)*)
      IF(MOD(NTSCP,36).EQ.1.AND.IMET.EQ.1) WRITE(N6,431)
431   FORMAT(1H1/,5X,*SUMMARY OF SURCHARGE HISTORY*//5X,*TOTAL
     2    GUTTER   CUM VOL*/*  HOUR MIN    GUTTER      FLOW   SURCHAR*/3X
     3,*(HOURS)    NUMBER      (CMS)        (M3)*)
      IF(IMET.EQ.0) GO TO 432
C
C**** METRIC OUTPUT
      GFLOW(J)=GFLOW(J)/35.3
      QSUR(J)=QSUR(J)/35.3
432   WRITE(6,440) NTIMEH,TIMEM,NAMEG(J),GFLOW(J),QSUR(J)
440   FORMAT(I5,F5.0,I10,F10.1,F10.0)
      IF(IMET.EQ.0) GO TO 441
      QSUR(J)=QSUR(J)*35.3
      GFLOW(J)=GFLOW(J)*35.3
441   IF(NPG(J).NE.4) GO TO 460
      JUP=JOVER(J)
      IF(IMET.EQ.0) GO TO 449
C
C**** METRIC OUTPUT
      OVRDEP(JUP)=OVRDEP(JUP)/3.281
      WRITE(N6,448) OVRDEP(JUP)
448   FORMAT(1H+,40X,*OVERBANK*,F8.2,*M.*)
      OVRDEP(JUP)=OVRDEP(JUP)*3.281
      GO TO 460
449   WRITE(N6,450)OVRDEP(JUP)
450   FORMAT(1H+,40X,*OVERBANK*,F8.2,* FT.*)
460   CONTINUE
      IF(NSUR.EQ.1) WRITE(N6,470)
470   FORMAT()
C
C******** PLOT TAPE
C
480   IF(NOUT.LT.1) GO TO 520
      DO 510 N=1,NPLOT
```

```
      J=IPLOT(N)
      OUTFLW(N)=GFLOW(J)
      IF(NPG(J).EQ.9) OUTFLW(N)=XFLOW(J)
      IF(NQS.EQ.0) GO TO 510
      DO 500 K=1,NQT
      POFF(N,K)=0.0
      DO 490 L=1,5
  490 POFF(N,K)=POFF(N,K)+C(J,L)*QFACT(L,K)
      IF(K.EQ.4) GO TO 500
      POFF(N,K)=POFF(N,K)*OUTFLW(N)*0.225
  500 CONTINUE
      POFF(N,1)=8.0
  510 CONTINUE
      WRITE(NOUT) TIME,(OUTFLW(N),N=1,NPLOT),((POFF(N,K),K=1,NQT),N=1,NP
     2LOT)
  520 CONTINUE
C
C******** WRITE PERMANENT QUANTITY AND QUALITY TAPES
C
      IF(INLETS.LT.1) GO TO 550
C
C******** INLET FLOWS AND QUALITY TAPE
C
      IF(NTS2.LT.1) GO TO 550
      DO 540 N=1,INLETS
      J=NGTOI(N)
      OUTFLW(N)=GFLOW(J)
      IF(NPG(J).EQ.9) OUTFLW(N)=XFLOW(J)
      IF(NQS.LT.1) GO TO 540
      DO 530 K=1,5
      POFF(N,K)=C(J,K)*OUTFLW(N)
  530 CONTINUE
  540 CONTINUE
      IF(NQS.LT.1) GO TO 560
      WRITE(NTS2) TIME,(OUTFLW(N),N=1,INLETS),((POFF(N,K),K=1,5),N=1,INL
     2ETS)
      GO TO 550
  560 WRITE(NTS2) TIME,(OUTFLW(N),N=1,INLETS)
  550 CONTINUE
      RETURN
      END
```

The following common blocks are employed:

- BLANK COMMON
- NEW

The structure of the routine is shown in the flowchart of Figure IV-8. Key variables not in common are a subset of those presented in Table IV-6. The computer listing follows.

Subroutine HYDRO

As shown in Figure IV-2, HYDRO links most of the subroutines in the runoff program and calls them sequentially to execute a complete runoff simulation. It initializes certain variables to zero before calling RHYDRO to read in the control, rainfall, watershed subarea, land use, gutter/channel, and quality data. A call to QSHED1 initializes suspended solids loadings in the watershed subareas.

A DO-loop is formed to compute the hydrograph coordinate and concentration for each gutter/channel and for each time step. In each time step, subroutine WSHED is first called to calculate the flow and quality of water off the watershed subareas. GUTTER is then called to route the flow and conservative constituents through the gutters and channels and into the inlets. Inlet inflow and the pollutant influx is stored on a tape or disc file for subsequent access by the drainage design program DRAIN.

During the process of computation, an accounting is made for the quantity of all water entering and leaving each watershed subarea and the disposition of water currently in the watershed. A continuity balance is then performed and printed. The pollutant mass washed off each watershed subarea is also printed for reference.

Finally, the rainfall hyetograph, the sum of all inlet hydrographs, and desired gutter/channel outflow hydrographs and concentration-time curves are plotted by calling HCURVE and GRAPH. Subroutine SUMSTAT is

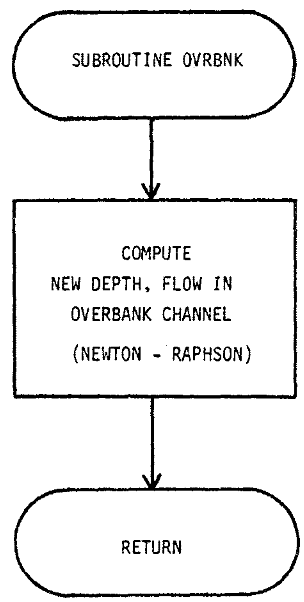


FIGURE IV-8. Flowchart of Subroutine OVRBNK

```
      SUBROUTINE OVRBNK (J,OVRQIN,OVROUT,OVRAX0,OVRAX1,OVRDEL)
C
C******** THIS SUBROUTINE COMPUTES THE INSTANTANEOUS WATER DEPTH AND
C******** FLOW RATE FOR TRAPEZOIDAL OVERBANK GUTTERS
C
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),QIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI( 10),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
     1            GDEPT(3),QI(3),VOL1(150),VOL2(150),XFLOW(150),
     2            NGSTO(200),NGSUR(150),QINLET(150),PINLET(150,13),
     3            ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
     4            OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
     5            OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
      JUP=JOVER(J)
      D0=OVRDEP(JUP)
      IF(OVRQIN.NE.0) GO TO 10
      IF(OVRDEP(JUP).NE.0) GO TO 10
      OVRAX0=0.
      OVRAX1=0.
      OVROUT=0.
10    OVRDEL=0.
      FLOW1=0.
      DO 70 I=1,30
      FLOW10=FLOW1
C
C******** COMPUTE CHANGE IN DEPTH
C
C**** ESTIMATED FINAL DEPTH
      D1=OVRDEP(JUP)+OVRDEL
      IF(D1.LT.0) D1=0.
C
C**** VOLUME CHANGE
      DELV=GLEN(J)*OVRDEL*((OVRGS1(JUP)+OVRGS2(JUP))*(D0+0.5*OVRDEL)+OVR
     1WTH(JUP))
      DDELV=GLEN(J)*((OVRGS1(JUP)+OVRGS2(JUP))*D1+OVRWTH(JUP))
C
C**** CROSS-SECTIONAL AREA
      OVRAX0=0.5*(OVRGS1(JUP)+OVRGS2(JUP))*D0**2+OVRWTH(JUP)*D0
      OVRAX1=0.5*(OVRGS1(JUP)+OVRGS2(JUP))*D1**2+OVRWTH(JUP)*D1
      DAX1=(OVRGS1(JUP)+OVRGS2(JUP))*D1+OVRWTH(JUP)
C
C**** WETTED PERIMETER
      WP0=SQRT(OVRGS1(JUP)**2+1.)*D0+SQRT(OVRGS2(JUP)**2+1.)*D0+OVRWTH(J
     1UP)-TWIDTH(J)
      WP1=SQRT(OVRGS1(JUP)**2+1.)*D1+SQRT(OVRGS2(JUP)**2+1.)*D1+OVRWTH(J
```

```
     1UP)-TWIDTH(J)
      DWP1=SQRT(OVRGS1(JUP)**2+1.)+SQRT(OVRGS2(JUP)**2+1.)
C
C**** HYDRAULIC RADIUS
      IF(OVRAX0.LT.0) OVRAX0=0.
      IF(OVRAX1.LT.0) OVRAX1=0.
      IF(WP0.LE.0) WP0=0.001
      IF(WP1.LE.0) WP1=0.001
      RAD1=OVRAX1/WP1
C
C**** FLOW
      FLOW0=OVRCON(JUP)*(OVRAX0**1.6666667)/(WP0**0.6666667)
      FLOW1=OVRCON(JUP)*(OVRAX1**1.6666667)/(WP1**0.6666667)
      FLOW=0.5*(FLOW0+FLOW1)
      DFLOW1=0.5*OVRCON(JUP)*(1.66666667*(RAD1**0.6666667)*DAX1-0.666666
     17*(RAD1**1.6666667)*DWP1)
C
C**** NEWTON-RAPHSON CORRECTION
      F=DELV+DELT*(FLOW-OVRQIN)
      DF=DDELV+DELT*DFLOW1
      IF(DF.GT.0) GO TO 20
C
C**** ZERO SLOPE
      DEL=0.01
      GO TO 30
C
C**** NON-ZERO SLOPE
20    DEL=OVRDEL-F/DF
C
C**** CONVERGENCE CHECK (INDIVIDUAL GUTTER)
30    IF(I.EQ.1) GO TO 70
      IF(OVRDEP(JUP)+DEL.LT.OVRDFL(JUP)) GO TO 50
      WRITE(N6,40) NAMEG(J)
40    FORMAT(*0*,*WARNING - OVERBANK GUTTER*,I6,* IS SURCHARGING*)
50    IF(FLOW10.GT.0.001) GO TO 60
      IF(ABS(FLOW1-FLOW10).LT.0.001) GO TO 90
      GO TO 70
60    CONTINUE
      IF(ABS(FLOW1-FLOW10).LT.0.001*FLOW1) GO TO 90
70    OVRDEL=DEL
      WRITE(N6,80) TIME,J,OVRDEP(JUP),OVRDEL
80    FORMAT(* CHECK RESULTS. NOT CONVERGED IN OVRBNK*,F8.0,I6,2E12.5)
      OVROUT=OVRQIN
      DEL=0.01*OVRDFL(JUP)-OVRDEP(JUP)
C
C**** NEW DEPTH AT END OF TIME INTERVAL
90    OVRDEL=DEL
      OVRDEP(JUP)=OVRDEP(JUP)+OVRDEL
C
C******** AVERAGE FLOW DURING TIME INTERVAL
C
      IF(FLOW.LT.1.0E-10) FLOW=0.0
      OVROUT=FLOW
      RETURN
      END
```

called to output simulation results in a summary format. The control is then returned to main program SRO.

The following common blocks are employed in Subroutine HYDRO:

- BLANK COMMON
- TAPES
- ABLK
- INFIL
- NEW
- CON
- MAX
- TEST

The computation steps are presented in flowchart form in Figure IV-9. Key variables not in common areas are presented in Table IV-7. The computer listing follows.

Subroutine QSHED1

Subroutine QSHED1 is used to estimate the initial mass of pollutants on each watershed subarea at the beginning of a storm. This is done by applying empirically determined pollutant buildup factors for the number of dry days prior to a storm and then reducing the total by the amount taken up by maintenance. QSHED1 is also called at entry point QSHED2 by WSHED for each time step to compute the amount of suspended solids washed off of each subarea surface type. Washoff mechanisms are simulated by using an exponential runoff function.

The following common blocks are employed:

- BLANK COMMON
- ABLK
- POLUT
- INFIL

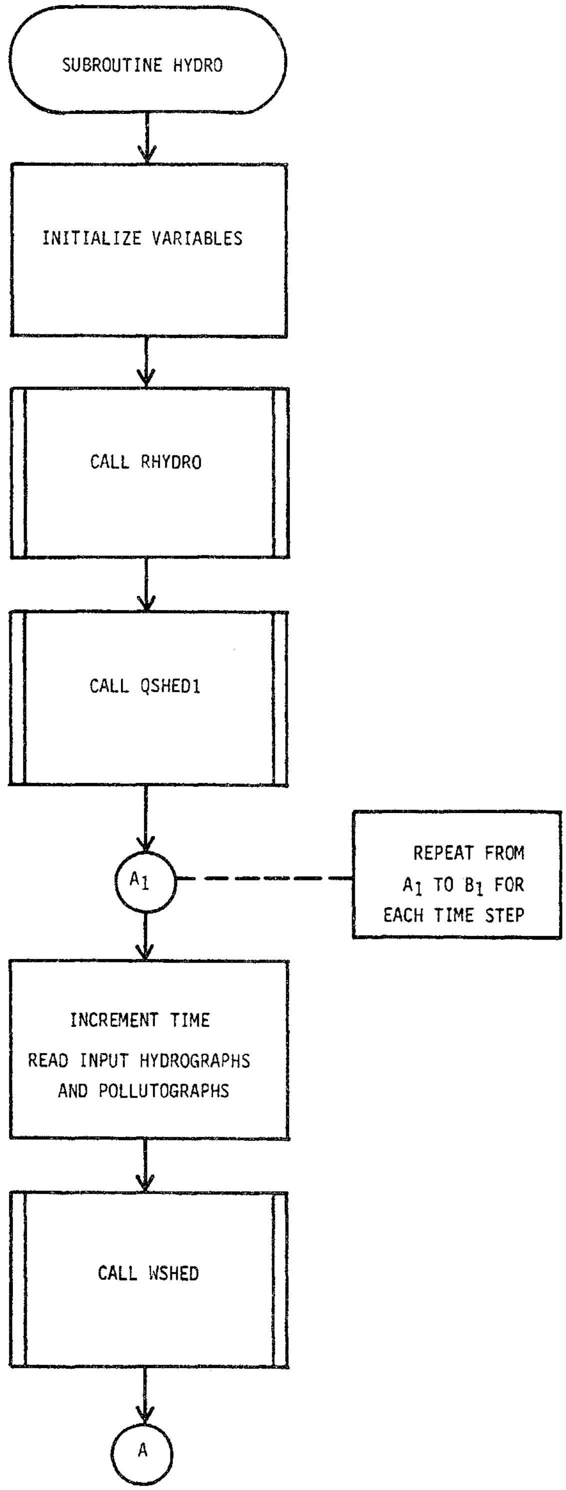


FIGURE IV-9. Flowchart of Subroutine HYDRO

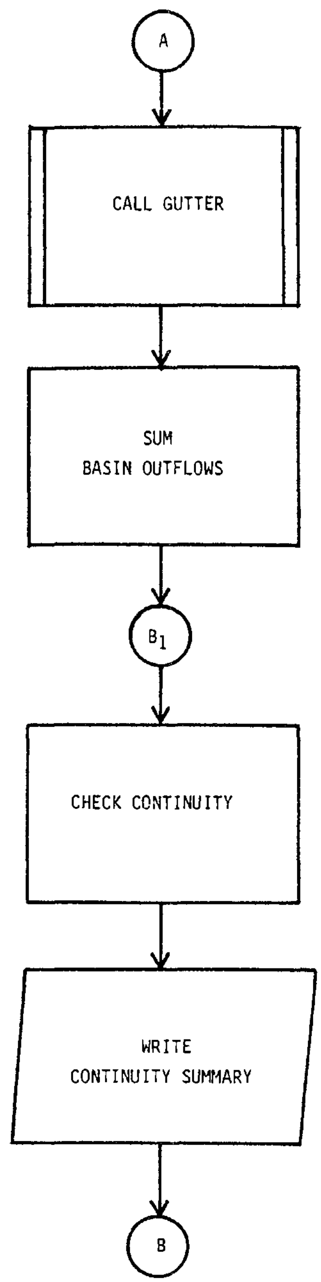


Figure IV-9
(Continued)

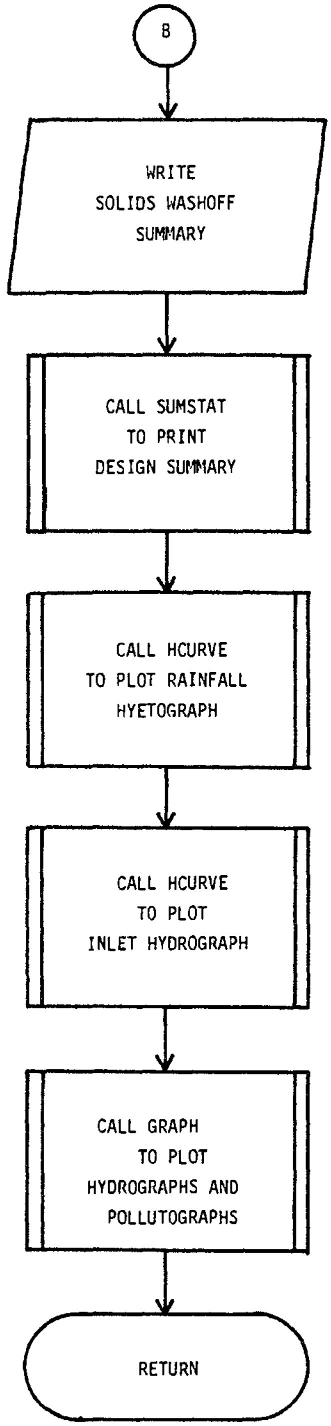


Figure IV-9
(Continued)

TABLE IV-7

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE HYDRO

Fortran Variable	Description	Units
BASIN	Basin number	-
ERROR	Error in continuity as a percent of inflow volume	-
FLOW	Inlet flow	ft^3/sec
NOGG	Number of channels and inlets	-
PK	Inlet load by constituent	kg, No. of organisms
PR	Percent load reduction by surface storage	-
PSUM	Total inlet load	kg
PTOT	Total washoff by subarea	kg
SUMCHL	Sum of change in channel volumes	ft^3
SUMSUR	Sum of change in surcharge volumes	ft^3
TOTIN	Total inlet volume	ft^3
TOTOUT	Total runoff volume plus change in channel storage	ft^3
WASH	Total washoff	kg

```
      SUBROUTINE HYDRO
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),QIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON/ABLK/ NQS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2              C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
     3              SSFACT(5,2),QFACT(5,13)
      COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
     1            GDEPT(3),QI(3),VOL1(150),VOL2(150),XFLOW(150),
     2            NGSTO(200),NQSUR(150),QINLET(150),PINLET(150,13),
     3            ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
     4            OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
     5            OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
      COMMON/MAX/MAXFLW(150),MAXHR(150),MAXMIN(150),MAXDEP(150),
     2SURLEN(150)
      COMMON/INFIL/RAININ(200,3),DEPIN( 5 ),TIMEW(200),WTYPE(200,3),
     2NC(200)
      COMMON/CON/ICTTL(13)
      COMMON/TEST/SUMT1
      DIMENSION PLOAD(5)
      DIMENSION WOFF(13,24)
      REAL MAXFLW,MAXDEP
      INTEGER BASIN
C
C********* INITIALIZATION
C
      NW=200
      NG=150
      NING=150
      NRANVL=100
      NIN=10
      INTCNT=0
      DO 10 I=1,NW
      DO 3 J=1,13
    3 POFF(I,J)=0.
      DO 5 J=1,3
      RAININ(I,J)=0.0
      PLAND(I,J)=0.0
      PSHED(I,J)=0.0
      WAREA(I,J)=0.0
    5 WDEPTH(I,J)=0.0
      TIMEW(I)=0.0
      WFLOW(I)=0.0
   10 WWIDTH(I)=0.
      DO 20 I=1,NG
      NGSTO(I)=0
```

```
      NPG(I)=0
      NGUT(I)=0.
      CSUR(I)=0.
      VOL1(I)=0.
      VOL2(I)=0.
      OUTFLW(I)=0.
      DO 15 J=1,5
      C(I,J)=0.
15    CDOT(I,J)=0.
      DELD(I)=0.
      QIN(I)=0.
      GFLOW(I)=0.
      MAXFLW(I)=0.
      MAXHR(I)=0
      MAXMIN(I)=0
      MAXDEP(I)=0.
      SURLEN(I)=0.
      XFLOW(I)=0.0
      GDEPTH(I)=0.0
20    GLEN(I)=0.
      DO 30 J=1,NING
30    NGTOI(J)=0
      DO 40 J=1,NIN
      NWTOI(J)=0
      DO 40 I=1,NG
      NWTOG(I,J)=0
40    NGTOG(I,J)=0
      DO 50 I=1,NRANVL
      DO 50 J=1,13
50    RAIN(I,J)=0.
      DO 412 I=1,5
412   PLOAD(I)=0.
      SUMR=0.
      SUMI=0.
      SUMOFF=0.
      SUMST=0.
      SUMRL=0.
      SUMGWI=0.
      SUMINL=0.
      SUMCHL=0.
      SUMLK=0.
      SUMSUR=0.
      NT1=JIN(1)
C
C******** CALL INPUT SUBROUTINE
C
      CALL RHYDRO(BASIN)
      TIME=TZERO
C
C**** READ INITIAL INLET FLOWS, QUALITY
      IF(NT1.EQ.0) GO TO 60
      READ (NT1) TIMET,(QINLET(N),N=1,INLET2),((PINLET(N,K),K=1,13),N=1,
     2INLET2)
60    CONTINUE
C
C******** INITIALIZE WATERSHED POLLUTION LOADS
C
```

```
      IF(NQS.GT.0) CALL QSHED1(0,0,0.)
C
C******** CALCULATE INLET HYDROGRAPHS
C
      M=(NSTEP+100)/100
      I=1
C
C**** SUM INLET FLOWS FOR INITIAL CONDITIONS
80    CONTINUE
      DO 270 II=1,NSTEP,M
      DO 260 IJ=1,M
      TIME=TIME+DELT
      TIME2=TIME-DELT2
      NOGG=NOG+NSAVE
      DO 100 N=1,NOGG
      DO 90 NQ=1,14
90    WOFF(N,NQ)=0.
100   QIN(N)=0.
C
C**** READ INLET HYDROGRAPHS AND POLLUTOGRAPHS
      IF(NT1.EQ.0) GO TO 150
      READ (NT1) TIMET,(QINLET(N),N=1,INLET2),((PINLET(N,K),K=1,13),N=1,
     2INLET2)
C
C**** ADD INLET FLOWS, QUALITIES
      DO 140 K=1,NOGG
      J=NGUT(K)
      DO 130 IN=1,INLET2
      IF(J.NE.ISAVE2(IN)) GO TO 130
      QIN(J)=QINLET(IN)
      WOFF(K,1)=QINLET(IN)*8.0
      DO 120 NQ=2,13
      DO 110 LUSE=1,5
      WOFF(K,NQ)=WOFF(K,NQ)+PINLET(IN,LUSE)*QFACT(LUSE,NQ)
110   CONTINUE
120   CONTINUE
      GO TO 140
130   CONTINUE
140   CONTINUE
150   CONTINUE
C
C******** WATERSHED ELEMENTS (OVERLAND FLOW)
C
      CALL WSHED(NQS)
C
C******** GUTTER ELEMENTS
C
      IF(NOG.GT.0) CALL GUTTER
C
C******** HYDROGRAPH CONSTRUCTION
C
C**** SUM INLETS OVER THE BASIN
      IF(NOG.EQ.0) GO TO 230
      DO 220 JK=1,NING
      IF(NGTOI(JK).EQ.0) GO TO 230
      NX=NGTOI(JK)
      FLOW=GFLOW(NX)
```

```
      IF(NPG(NX).EQ.9) FLOW=XFLOW(NX)
      DO 480 MX=1,5
480   PLOAD(MX)=PLOAD(MX)+FLOW*C(NX,MX)*DELT*0.0283
220   SUMOFF=SUMOFF+FLOW*DELT
230   CONTINUE
C
C**** SUM FOR CONTINUITY CHECK
      IF(NT1.EQ.0) GO TO 250
      DO 240 J=1,INLET2
240   SUMINL=SUMINL+QINLET(J)*DELT
250   CONTINUE
260   CONTINUE
270   CONTINUE
C
C**** CONTINUITY CHECK
      DO 300 J=1,NOS
      IF(NPG(J).EQ.4.OR.NPG(J).EQ.5) GO TO 280
      SUMCHL=SUMCHL+VOL2(J)-VOL1(J)
      IF(NPG(J).EQ.3) GO TO 290
      SUMSUR=SUMSUR+QSUR(J)
      GO TO 300
280   SUMLK=SUMLK+VOL2(J)-VOL1(J)
      GO TO 300
290   SUMCHL=SUMCHL+QSUR(J)
300   CONTINUE
      DO 310 J=1,NOW
      NCA=NC(J)
      DO 310 JJ=1,NCA
      SUMST=SUMST+WDEPTH(J,JJ)*WAREA(J,JJ)
310   CONTINUE
      TOTIN=SUMR+SUMRL+SUMGWI+SUMINL
      TOTOUT=SUMI+SUMOFF+SUMST+SUMSUR+SUMCHL+SUMLK
      ERROR=(TOTIN-TOTOUT)*100./TOTIN
      WRITE(N6,430) SUMR,SUMRL,SUMINL,TOTIN,SUMI,SUMOFF,SUMST,
     1SUMSUR,SUMCHL,SUMLK,TOTOUT,ERROR
430   FORMAT(*1*,T40,*RAINFALL ON WATERSHED (FT3)*,E12.6,/,
     1T40,*RAINFALL ON STORAGE (FT3)*,E12.6,/,
     2T40,*INFLOW VOLUME (FT3)*,E12.6,/,
     3T40,*------ TOTAL INPUT VOLUME (FT3) ------*,E12.6,///,
     4T40,*INFILTRATION (FT3)*,E12.6,/,
     5T40,*INLET VOLUME (FT3)*,E12.6,/,
     6T40,*WATERSHED STORAGE (FT3)*,E12.6,/,
     7T40,*SURCHARGE STORAGE (FT3)*,E12.6,/,
     8T40,*CHANNEL STORAGE (FT3)*,E12.6,/,
     9T40,*RETENTION STORAGE (FT3)*,E12.6,/,
     1T40,*------ TOTAL OUTFLOW STORAGE (FT3) ------*,E12.6,////,
     2T50,*      ERROR IN CONTINUITY, PERCENTAGE OF INFLOW   *,F10.5)
C
C******** CLOSE OUTPUT FILES
C
      NT1=JOUT(2)
      IF(NT1.LT.1) GO TO 330
      IEOF=-1
      WRITE (NT1) IEOF,IEOF,(OUTFLW(N),N=1,NPRNT)
330   CONTINUE
C
C******** OUTPUT
```

```
C
      IF(NOS.EQ.0) GO TO 420
      WASH=0.0
      DO 390 N=1,NOW
      WRITE(N6,340) NAMEW(N)
  340 FORMAT(*1*,*TOTAL SUSPENDED SOLIDS WASHOFF BY SUBAREA TYPE,*,
     2* IN KILOGRAMS*,//,21X,*WATERSHED*,I5)
      PTOT=0.0
      N1=NC(N)
      DO 350 J=1,N1
      JJ=WTYPE(N,J)+1
      PLAND(N,J)=PLAND(N,J)*QFACT(JJ,3)/1.E6
      PSHED(N,J)=PSHED(N,J)*QFACT(JJ,3)/1.E6
      POFF(J,3)=PLAND(N,J)-PSHED(N,J)
      WRITE(N6,370) J,JJ,PLAND(N,J),PSHED(N,J),POFF(J,3)
  370 FORMAT(* *,15X,*SUBAREA*,I2,* TYPE*,I2,/,10X,
     1*ORIGINAL AMOUNT *,G10.4,/,10X,
     2*AMOUNT REMAINING *,G10.4,/,10X,
     3*AMOUNT WASHED OFF *,G10.4,/)
  350 PTOT=PTOT+POFF(J,3)
      WRITE(N6,380) PTOT
  380 FORMAT(* SUBAREA TOTAL*,G10.4,//)
      WASH=WASH+PTOT
  390 CONTINUE
      WRITE(N6,410) WASH
  410 FORMAT(*0*,*TOTAL HIGHWAY LOAD*,G10.4,/)
      PSUM=0.
      DO 470 J=1,5
  470 PSUM=PSUM+PLOAD(J)
      PR=(WASH-PSUM)/WASH*100.
      WRITE(N6,411) PSUM,PR
  411 FORMAT(*0*,*TOTAL INLET LOAD*,G10.4,//,
     2*0*,*PERCENT LOAD REDUCTION BY SURFACE STORAGE*,F6.2,//)
      WRITE(N6,485) SUMT1
  485 FORMAT(*0*,*TOTAL WATERSHED INPUT LOAD*,G10.4,/)
      WRITE(N6,466)
  466 FORMAT(* *,10X,*INLET LOAD IN KG EXCEPT FOR FECAL COLIFORM*,/,11X,
     2*EXPRESSED AS NO. ORGANISMS*,//)
      DO 460 K=1,NQS
      PK=0.
      DO 450 J=1,5
      IF(K.EQ.4) GO TO 451
      PK=PK+PLOAD(J)*QFACT(J,K)*.001
      GO TO 450
  451 PK=PK+PLOAD(J)*QFACT(J,K)*10.
  450 CONTINUE
      WRITE(N6,465) ICTTL(K),PK
  465 FORMAT(* *,20X,A4,5X,E10.2)
  460 CONTINUE
  420 CALL SUMSTAT
      CALL HCURVE(1,BASIN)
C*****CALL HCURVE(2,BASIN)
      CALL GRAPH(ICODE)
      RETURN
      END
```

The computational sequence is depicted in flowchart form in Figure IV-10. Key variables not contained in common are presented in Table IV-8. The subroutine listing follows.

Subroutine RECAP

This subroutine reads the output tapes written in GUTTER and writes a summary report. The report consists of either hydraulic results alone or of hydraulic and quality results for inlets, gutters and channels, as specified for that run. The following common blocks are employed:

- BLANK COMMON
- ABLK
- TAPES

The flowchart is presented in Figure IV-11 followed by the computer listing.

Subroutine RHYDRO

This subroutine is called by HYDRO to read input data and perform some preparatory work, such as unit conversion, input error detection, and set-up of the gutter/channel connectivity array. RHYDRO is called only once and provides virtually all the necessary information for the complete run-off quantity and quality simulation.

There are several categories of input data read by RHYDRO. These include basic control information, rainfall hyetographs, inlet data, data for gutters, trapezoidal channels, pipes, overbank channels and detention basins, watershed data, and runoff quality data. All input data are echo printed.

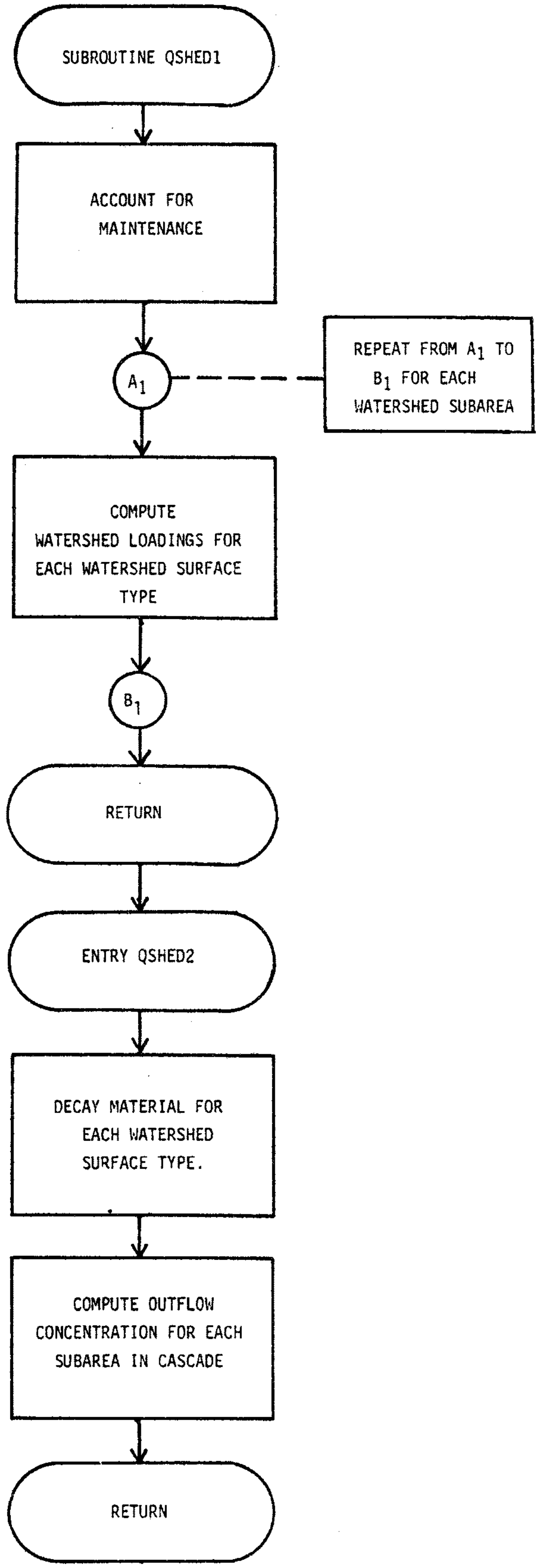


FIGURE IV-10. Flowchart of Subroutine QSHED1

TABLE IV-8

KEY VARIABLES NOT CONTAINED IN COMMON FOR SUBROUTINE QSHED1

Fortran Variable	Description	Units
ALFA	Auxiliary computational variable	sec^{-1}
AVAIL	Washoff availability factor	-
BETA	Auxiliary computational variable	gm/l/sec
DFACT	Decay factor	-
DORG	Rainfall minus infiltration	ft
DRY	Effective dry days	days
J	Watershed number (internal)	-
K	Subarea number	-
NCLEAN	Number of times maintenance performed	-
PO	Material available for washoff from subarea	gm
QIW	Subarea inflow	ft^3/sec
QT	Subarea outflow	ft^3/sec
R	Runoff	ft
SS	Suspended solids initial accumulation	lbs
TEMP	Temporary variable	sec/ft^3
TGS	Effective maintenance efficiency	-
V	Subarea volume	ft^3
VDOT	Subarea volume time derivative	ft^3/sec
NGSAVE	Number of inlets	-
NHR	Number of hours	-
NHRR	Temporary variable	-
NINLET	Number of inlets on grade	-
NLAKE	Number of detention basins	-
NMN	Number of minutes	-
NMNN	Temporary variable	-
NOGG	Number of channels and inlets on grade	-

TABLE IV-8
(cont.)

Fortran Variable	Description	Units
NOGS	Number of channels and inlets on grade	-
NOVR	Number of overbank channels	-
NP	Type channel	-
NSTP	Number of time steps simulated	-
NTRY	Temporary internal channel number	-
NW3	Number of subareas in the given watershed	-
N5	Read unit number	-
N6	Write unit number	-
OVRGQ	Overbank channel maximum flow	ft^3/sec
OVRGV	Overbank channel maximum velocity	ft/sec
W4	Subarea Manning's roughness factor	$ft^{1/6}$
XSLOPP	Cross slope	ft/ft

```
      SUBROUTINE QSHED1(J,K,DORG)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     1 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMGW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),QIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON/INFIL/RAININ(200,3),DEPIN( 5 ),TIMEW(200),WTYPE(200,3),
     2NC(200)
      COMMON/POLUT/WFLO(200,3),WDOT(200,3,5),W(200,3,5)
      COMMON/ABLK/ NOS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2              C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
     3              SSFACT(5,2),QFACT(5,13)
      DIMENSION FLUX(5)
C
C******** SET INITIAL POLLUTANT LOADINGS
C
      DRY=DRYDAY
      IF(CLFREQ.GT.DRYDAY.OR.CLFREQ.LT.1.0) GO TO 60
      NCLEAN=DRYDAY/CLFREQ
C
C******** ACCOUNT FOR STREET-SWEEPING
C
      TGS=1.0
      DO 50 J=1,NCLEAN
      TGS=TGS+(1.0-REFF)**J
   50 CONTINUE
      DRY=CLFREQ*TGS
C
C******** COMPUTE WATERSHED LOADINGS
C
   60 DO 110 N=1,NOW
      N1=NC(N)
C
C**** URBAN LOAD, PSHED IN GRAMS
      DO 80 J=1,N1
      JJ=WTYPE(N,J)+1
   70 SS=SSFACT(JJ,1)*(DRY/(SSFACT(JJ,2)+DRY))*WAREA(N,J)/43560.
      PSHED(N,J)=SS*453.8
      PLAND(N,J)=PSHED(N,J)
      DO 80 L=1,5
      W(N,J,L)=0.
   80 WDOT(N,J,L)=0.
  110 CONTINUE
      RETURN
C
C******** ENTRY QSHED2 PERFORMS TIME-DEPENDENT ROUTING OF POLLUTANTS
C******** FROM THE WATERSHED SUBAREAS
C
```

```
      ENTRY GSHED2
      IF(WFLO(J,K).GT..005) GO TO 20
      DO 10 L=1,5
      WDOT(J,K,L)=0.
10    W(J,K,L)=0.
      RETURN
C
C******** COMPUTE INPUT FROM UPSTREAM SUBAREA
C******** (FLUX IN GM-CU FT/L-SEC)
C
20    ALFA=2./DELT
      DO 30 M=1,5
30    FLUX(M)=0.
      IF(K.EQ.1) GO TO 250
      DO 40 M=1,5
40    FLUX(M)=FLUX(M)+W(J,K-1,M)*WFLO(J,K-1)
C
C******** COMPUTE RUNOFF AND DECAY COEFFICIENTS
C
250   R=12.*WFLO(J,K)/WAREA(J,K)
      DFACT=EXP(-2.0*R*DELT)
      AVAIL=0.03+33.*(3600.*R)**2.
      AVAIL=AMIN1(1.0,AVAIL)
C
C******** DECAY MATERIAL FROM EACH URBAN AREA AND COMPUTE THE
C******** RATE OF MASS RUNOFF (GM-CU FT/L-SEC)
C
      JJ=WTYPE(J,K)+1
      POFF(J,K)=0.
      PO=PSHED(J,K)
      IF(PO.LE.0.) GO TO 260
      POFF(J,K)=AVAIL*PO*(1.-DFACT)/DELT
      PSHED(J,K)=PSHED(J,K)-POFF(J,K)*DELT
260   FLUX(JJ)=FLUX(JJ)+POFF(J,K)/28.317
      QT=WFLO(J,K)
      QIW=0.
      IF(K.GT.1) QIW=WFLO(J,K-1)
      VDOT=QIW-QT+DORG*WAREA(J,K)
      V=(WDEPTH(J,K)-WSTORE(J,K))*WAREA(J,K)
      TEMP=1./(VDOT+ALFA*V+QT)
C
C******** COMPUTE FINAL CONCENTRATION AND UPDATE TIME PARAMETERS
C
      DO 270 L=1,5
      BETA=ALFA*W(J,K,L)+WDOT(J,K,L)
      W(J,K,L)=TEMP*(FLUX(L)+V*BETA)
270   WDOT(J,K,L)=ALFA*W(J,K,L)-BETA
      RETURN
      END
```

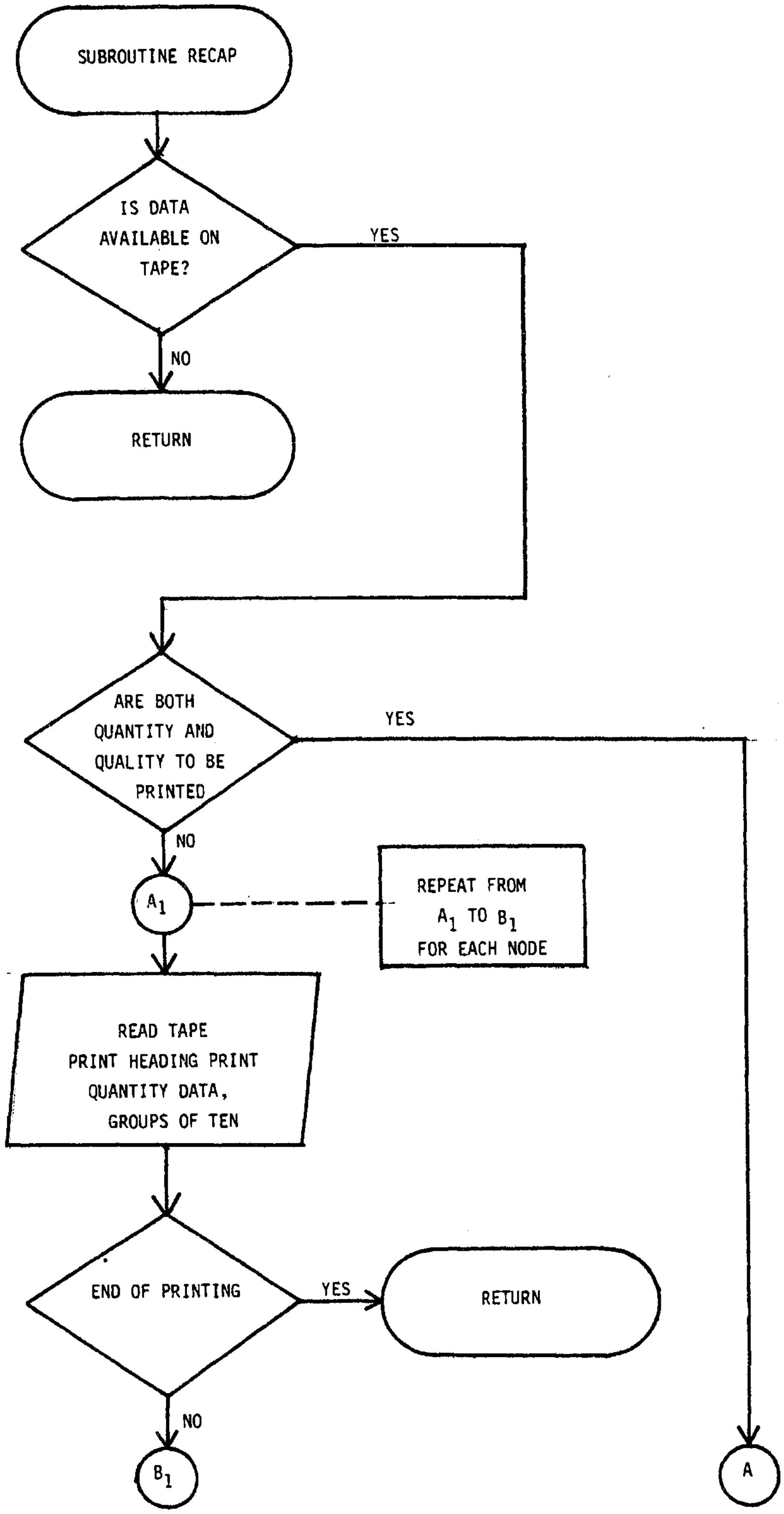


FIGURE IV-11. Flowchart of Subroutine RECAP

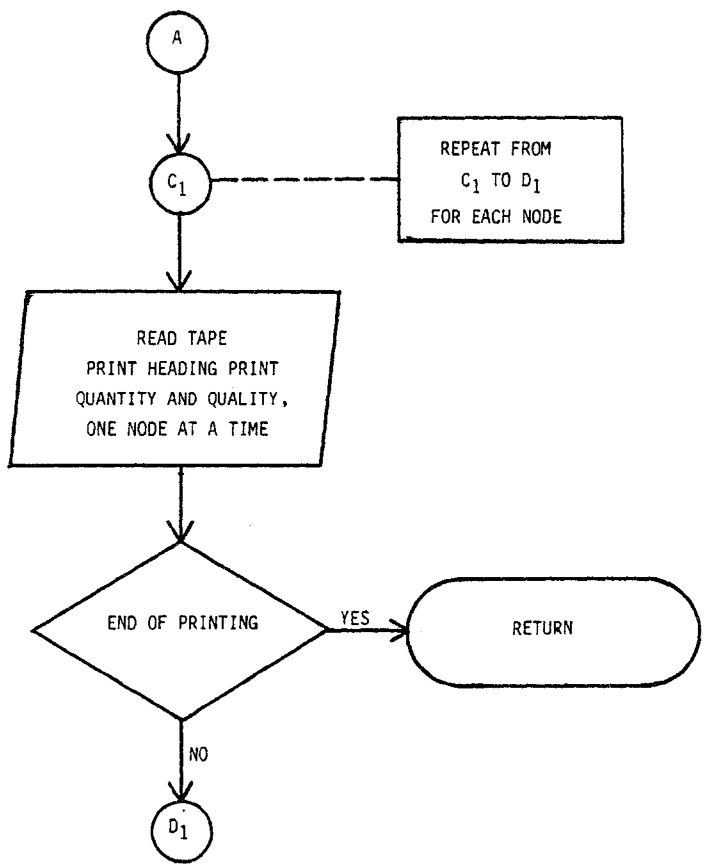


Figure IV-11
(Continued)

```
      SUBROUTINE RECAP
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON/ARLK/ NGS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2             C(150,5),CDOT(150,5),PSHED(200,3),PCFF(200,13 ),
     3             SSFACT(5,2),OFACT(5,13)
      COMMON NW,NG,VIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON FLOW(150),QUAL(150,24),IPRNT(150),TITLE(40),
     2NHR(150),TMIN(150),OUT(150,13 ),FLOWOT(150)
C
C******** READ TAPE HEADERS
C
      IF(JOUT(2).LT.1) RETURN
      NT1=JOUT(2)
      REWIND NT1
      READ (NT1) TITLE
      READ (NT1) NSTEP,NPTS,NQS,DELT,TZERO,TAREA
      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-S
     4S   COLI     CL*,*        NH3   NO2+NO3  ORG-N  TOT-PHOS   PO4     GRE
     5ASE  H-METALS*,/,15X,*CMS    CFS*)
      NRD=NREAD
      DO 90 K=1,NREAD
      READ (NT1) NTIMEH,TIMEM,(FLOW(N),N=1,NPTS)
      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 1000/100 ML
            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  N (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(IMET.EQ.0) GO TO 176
            DO 175 N=1,NPTS
      175   FLOW(N)=FLOW(N)*0.02832
      176   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
```

In addition to reading and printing input data, RHYDRO orders gutters and channels from upstream to downstream, creates dummy channels at inlets, prints gutter/channel connections and inlets, and sets up output tapes.

The following common blocks are employed in this subroutine:

- INLET
- BLANK COMMON
- TAPES
- ABLK
- INFIL
- NEW
- MISC
- REMOVE
- SLOPES

The flowchart for this subroutine is illustrated in Figure IV-12. Key variables not included in common are presented in Table IV-9 followed by the subroutine listing.

Subroutine WSHED

WSHED computes the depth and flow of water for each watershed subarea. A Newton-Raphson solution technique is used to solve for the depth and outflow from each subarea based on continuity and uniform flow equations. Subroutine QSHED2 is called to compute the corresponding pollutographs for each watershed subarea.

The following common blocks are employed:

- BLANK COMMON
- INFIL
- POLUT

The computational sequence is shown in the flowchart of Figure IV-13. Key variables not included in common are itemized in Table IV-10.

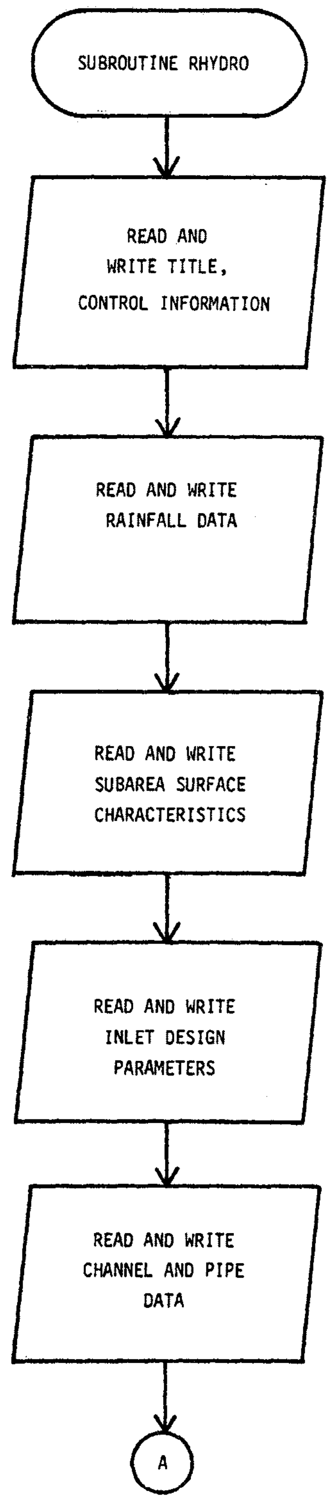


FIGURE IV-12. Flowchart of Subroutine RHYDRO

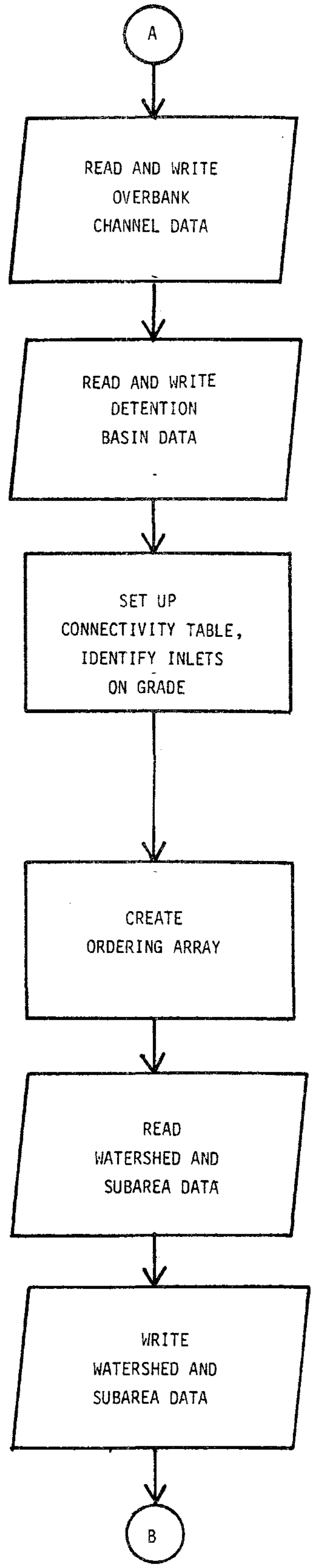


Figure IV-12
(Continued)

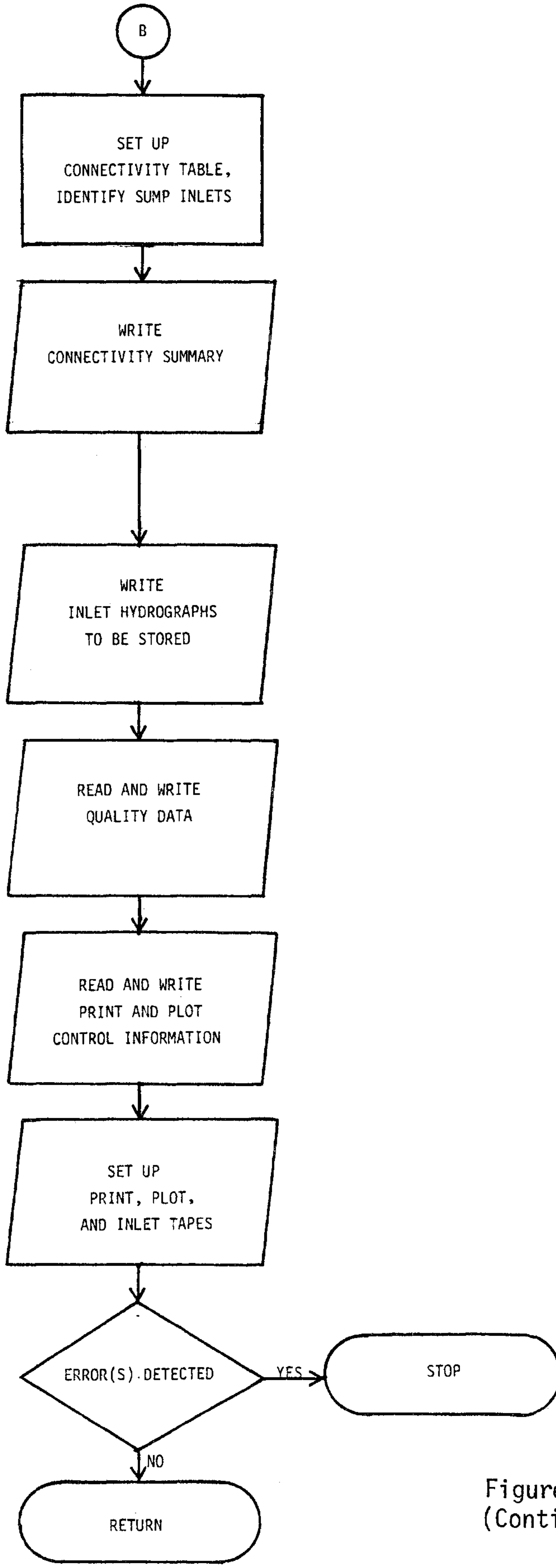


Figure IV-12
(Continued)

TABLE IV-9

KEY VARIABLES NOT CONTAINED IN COMMON FOR SUBROUTINE RHYDRO

Fortran Variable	Description	Units
AREA	Watershed area	ac or ha
BASIN	Basin number	-
GA	Full flow area of the channel	ft^2 or m^2
GMAN	Average Manning coefficient for normal and overbank channel	$ft^{1/6}$ or $m^{1/6}$
GP	Full flow wetted perimeter of the channel	ft or m
GQ	Full channel flow	cfs or cms
GR	Full channel hydraulic radius	ft or m
G1	Detention basin or Overbank channel width	ft or m
G2	Detention basin area	ac or ha
G3	Detention basin slope	-
G4	Detention basin or Overbank channel side slope 1	-
G5	Detention basin or Overbank channel side slope 2	-
G6	Overbank channel Manning's n	$ft^{1/6}$ or $m^{1/6}$
G7	Overbank channel maximum depth	ft or m
G8	Detention basin volume at outfall	acre-ft or m^3
G9	Detention basin initial depth	ft or m
IDENT	Overbank channel number	-
IG	Detention basin raingage	-
INFIL	Number of infiltration types	-
INLETS	Number of inlets	-
NBASIN	Basin number	-
NCHAN	Number of channels	-
NDIM	Dimension limit	-

TABLE IV-9
(continued)

Fortran Variable	Description	Units
NERROR	Number of input errors	-
NGSAVE	Number of inlet	-
NHR	Number of hours	-
NHRR	Temporary variable	-
NINLET	Number of inlets on grade	-
NLAKE	Number of detention basins	-
NMN	Number of minutes	-
NMNN	Temporary variable	-
NOGG	Number of channels and inlets on grade	-
NOGS	Number of channels and inlets on grade	-
NOVR	Number of overbank channels	-
NP	Type channel	-
NSTP	Number of time steps simulated	-
NTRY	Temporary internal channel number	-
NW3	Number of subareas in the given watershed	-
N5	Read unit number	-
N6	Write unit number	-
OVRGQ	Overbank channel maximum flow	cfs or cms
OVRGV	Overbank channel maximum velocity	ft/sec or m/sec
W4	Subarea Manning's roughness factor	$ft^{1/6}$ or $m^{1/6}$

```
      SUBROUTINE RHYDRO (BASIN)
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),QIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/INFIL/RAININ(200,3),DEPIN( 5 ),TIMEW(200),WTYPE(200,3),
     2NC(200)
      COMMON/INLET/ITYPG,ITYPC,      W,A,CW,CORF,WS,AS,GLI,GLIC,GLIS,RD
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMC,      QINLG(4,6,12),
     2DINLG(12,6,4),                QINLC(6,12),DINLC(12,6)
      COMMON/ABLK/ NOS,CLFREQ,DRYDAY,REFF,NQO,PLAND(200,3),
     2              C(150,5),CDOT(150,5),PSHED(200,3),POFF(200,13 ),
     3              SSFACT(5,2),QFACT(5,13)
      COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
     1            GDEPT(3),QI(3),VOL1(150),VOL2(150),XFLOW(150),
     2            NGSTO(200),NQSUR(150),QINLET(150),PINLET(150,13),
     3            ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
     4            OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
     5            OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
      COMMON/MISC/XSLOPE(150),MGTO(200),
     2ISTA1A(150),ISTA1B(150),ISTA2A(150),ISTA2B(150),
     3ELEVA1(150),ELEVA2(150),NOGUTTR,DSG,DSC
      COMMON/REMOVE/DET
      DIMENSION OVRGV(3),OVRGQ(3),TY(30),PE(30)
      INTEGER BASIN
      DATA W,EIR, OJ,TLET/4H  WE,4HIR  ,4H OUT,4HLET /
C
C******** GENERAL INFORMATION
C
      NERROR=0
      READ(N5,40) TITLE
40    FORMAT(20A4)
      READ(N5,50) BASIN,NSTEP,NHR,NMN,DELT,NRGAG,IMET
50    FORMAT (2I5,I3,I2,F5.1,2I5)
      TZERO=3600.*FLOAT(NHR)+60.*FLOAT(NMN)
      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,40H****
     4              ****,8X,*CAMP DRESSER AND MCKEE               */* *
     5,*WASHINGTON, D.C.*,28X,4H****,4X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE,VIRGINIA    *)
      WRITE(N6,4000) TITLE
4000  FORMAT(///* *,24X,20A4/* *,24X,20A4)
      WRITE(N6,40001)
40001 FORMAT(////,* *,46(1H-),* GENERAL INPUT / OUTPUT INFORMATION *,
```

```
     246(1H-))
      WRITE(N6,40002) N5,N6,BASIN,NSTEP,DELT,NRGAG
40002 FORMAT(///////////////* *,50X,*CARD READER UNIT NO. (N5)=*,I2/*0*,5
     22X,*PRINTER UNIT NO. (N6)=*,I2/*0*,52X,*BASIN NUMBER (BASIN)=*,I5/
     3*0*,47X,*NUMBER OF TIME STEPS (NSTEP)=*,I4/*0*,39X,*INTEGRATION TI
     4ME INTERVAL IN MINUTES (DELT)=*,F6.2/*0*,49X,
     5*NO. OF RAIN GAGES  (NRGAG)=*,I3)
      IF(IMET.EQ.0) WRITE(N6,65)
65    FORMAT(*0*,47X,*BRITISH UNITS USED. (IMET=0)*)
      IF(IMET.EQ.1) WRITE(N6,66)
66    FORMAT(*0*,47X,*METRIC UNITS USED. (IMET=1)*)
C
C******** RAINFALL INTENSITY HISTOGRAM
C
      READ(N5,1020) NHISTO,THISTO
1020  FORMAT(I5,F5.0)
      TRAIN=FLOAT(NHISTO)*THISTO*60.+TZERO
      DO 230 N=1,NRGAG
      READ(N5,1030) (RAIN(I,N),I=1,NHISTO)
1030  FORMAT(5F10.0)
C
C**** PRINT RAINFALL HISTORY
      NHRR=NHR
      NMNN=NMN
      DO 4005 I=1,NHISTO
      IF(I.EQ.1.OR.(I/38*38).EQ.I) GO TO 4006
      GO TO 4009
4006  WRITE(N6,2999)
      WRITE(N6,4007) N
4007  FORMAT(///* *,43X,*RAINFALL HYETOGRAPH FOR RAIN GAGE NO. *,I3/* *,
     243X,42(*=*))
      IF(IMET.EQ.0) GO TO 4028
C
C**** METRIC OUTPUT
      WRITE(N6,4029)
4029  FORMAT(//* *,48X,*TIME*,15X,*RAINFALL INTENSITY*/* *,43X,*HOUR   M
     2INUTES*,13X,*    (MM./HR)*/* *,43X,4H----,3X,7H-------,10X,18(*-*)/
     3)
      GO TO 4009
C
C**** BRITISH UNITS OUTPUT
4028  WRITE(N6,4008)
4008  FORMAT(//* *,48X,*TIME*,15X,*RAINFALL INTENSITY*/* *,43X,*HOUR   M
     2INUTES*,13X,*(INCHES/HOUR)*/* *,43X,4H----,3X,7H-------,10X,18(*-*
     3)/)
4009  WRITE(N6,4010) NHRR,NMNN,RAIN(I,N)
4010  FORMAT(* *,43X,I3,6X,I3,16X,F8.2)
      NMNN=NMNN+THISTO
4012  IF(NMNN.GE.60) GO TO 4011
      GO TO 4005
4011  NMNN=NMNN-60
      NHRR=NHRR+1
      GO TO 4012
4005  CONTINUE
      IF(IMET.EQ.0) GO TO 4350
C
C**** CONVERT MM/HR TO FPS
```

```
      DO 221 I=1,NHISTO
221   RAIN(I,N)=RAIN(I,N)/(43200.*25.4)
      GO TO 230
C
C**** CONVERT IN/HR TO FPS
4350  DO 220 I=1,NHISTO
220   RAIN(I,N)=RAIN(I,N)/43200.
230   CONTINUE
      HISTOG=THISTO*60.
      DELT=DELT*60.
      DELT2=DELT/2.
C
C******** READ INFILTRATION CHARACTERISTICS
C
      READ(N5,1115) INFIL
      WRITE(N6,2999)
      WRITE(N6,4000) TITLE
      IF(IMET.EQ.0) GO TO 92201
C
C**** METRIC OUTPUT
      WRITE(N6,91202)
91202 FORMAT(* *,//,48(1H-),*SUBAREA SURFACE CHARACTERISTICS*,48(1H-),//
     2/,55X,*INFILTRATION  DATA*,//,30X,*SURFACE*,8X,*MAX RATE*,8X,*MIN
     3RATE*,8X,*DECAY*,8X,*MAX DEPTH*,/,31X,*TYPE*,11X,*MM/HR*,11X,*MM/H
     4R*,10X,* HR-1*,9X,*MM.  *,/,30X,7(1H-),8X,8(1H-),8X,8(1H-),8X,5(1
     5H-),8X,9(1H-),//,33X,*0*,11X,*IMPERVIOUS SURFACE*)
      GO TO 92202
92201 WRITE(N6,91201)
91201 FORMAT(* *,//,48(1H-),*SUBAREA SURFACE CHARACTERISTICS*,48(1H-),
     2  ///,55X,*INFILTRATION  DATA*,//,
     3 30X,*SURFACE*,8X,*MAX RATE*,8X,*MIN RATE*,8X,*DECAY*,8X,
     4  *MAX DEPTH*,/,31X,*TYPE*,11X,*IN/HR*,11X,*IN/HR*,10X,
     5  * HR-1*,9X,*INCHES*,/,30X,7(1H-),8X,8(1H-),8X,8(1H-),8X,
     6  5(1H-),8X,9(1H-),//,33X,*0*,11X,*IMPERVIOUS SURFACE*)
92202 DO 620 K=1,INFIL
      READ(N5,622) WLMAX(K),WLMIN(K),DECAY(K),DEPIN(K)
622   FORMAT(4F10.0)
      WRITE(N6,1201)  K,WLMAX(K),WLMIN(K),DECAY(K),DEPIN(K)
1201  FORMAT(* *,31X,I2,12X,F5.2,11X,F5.2,5X,F10.4,10X,F5.1)
      DECAY(K)=DECAY(K)/3600.
      IF(IMET.EQ.0) GO TO 92203
C
C**** CONVERT MM/HR TO FPS
      WLMAX(K)=WLMAX(K)/(43200.*25.4)
      WLMIN(K)=WLMIN(K)/(43200.*25.4)
      GO TO 620
92203 WLMAX(K)=WLMAX(K)/43200.
      WLMIN(K)=WLMIN(K)/43200.
620   CONTINUE
      IF(NGS.LE.0) GO TO 9114
      IF(IMET.EQ.0) GO TO 92205
C
C**** METRIC OUTPUT
      WRITE(N6,92204)
92204 FORMAT(* *,/////,58X,*QUALITY DATA*,//,16X,*MAXIMUM*,/,15X,*SUSPEN
     2DED*,47X,*POLLUTANT RATIO TO SUSPENDED SOLIDS*,/,
     3 17X,*SOLIDS*,9X,*RATE*,45X,*(MG/GM OF SS)*,/,
```

```
         4 3X,*SURFACE*,4X,*ACCUMULATION*,4X,*CONSTANT*,32X,*EXCEPT FECAL CO
         5LIFORM (NO./10GM SS)*,/,4X,*TYPE*,7X,*(LBS/ACRE)*,6X,*(DAYS)*,10X,
         6*DO*,3X,*BOD*,3X,*TSS*,3X,*F COLI*,3X,*CL*,3X, *NH3*,3X,*NO2*,3X,
         7*NO3*,3X,*ORG N*,3X,*TOT P*,2X,*D-OPO4*,3X,*O+G*,3X,*PB*,
         8  /,3X,7(1H-),4X,12(1H-),4X,8(1H-),9X,81(1H-),/)
          GO TO 92206
92205 WRITE(N6,2510)
2510  FORMAT(* *,/////58X,*QUALITY DATA*//16X,*MAXIMUM*,/,15X,*SUSPENDED
     2*,47X,*POLLUTANT RATIO TO SUSPENDED SOLIDS*,/,
     3 17X,*SOLIDS*, 9X,*RATE*,45X,*(MG/GM OF SS)*,/,
     4 3X,*SURFACE*,4X,*ACCUMULATION*,4X,*CONSTANT*,32X,*EXCEPT FECAL CO
     5LIFORM (NO./10GM SS)*,/,4X,*TYPE*,7X,*(LBS/ACRE)*,6X,*(DAYS)*,10X,
     6*DO*,3X,*BOD*,3X,*TSS*,3X,*F COLI*,3X,*CL*,3X,*NH3*,3X,*NO2*,3X,
     7*NO3*,3X,*ORG N*,3X,*TOT P*,3X,*D-PO4*,3X,*O+G*,3X,*PB*,
     8  /,3X,7(1H-),4X,12(1H-),4X,8(1H-),9X,81(1H-),/)
92206 DO 2530 J=1,5
      JJ=J-1
      WRITE(N6,2520)JJ,SSFACT(J,1),SSFACT(J,2),(QFACT(J,K),K=1,13)
C
C**** CONVERT KG/HA TO LB/ACRE
2530  IF(IMET.EQ.1) SSFACT(J,1)=SSFACT(J,1)/1.122
2520  FORMAT(* *,I6,9X,F5.1,10X,F4.1,10X,F4.1,1X,F5.1,1X,F5.0,3X,F6.0,1X
     2,F4.1,2X,F4.1,2X,F4.1,2X,F4.1,3X,F4.1,4X,F4.1,4X,F4.1,4X,F4.1,1X,F
     34.1)
C
C******** READ SPECIFIED INLET ROUTING PARAMETERS
C
9114  READ(N5,9115) ITYPG,ITYPC,      INOMG,INOMC
9115  FORMAT(4I10)
C
C**** INLETS ON GRADE IN GUTTERS
      WRITE(N6,2999)
      WRITE(N6,4105)
4105  FORMAT(////,30X,*FOR INLETS ON GRADE IN GUTTERS:*)
      GO TO (5000,5010,5020,5030,5040,5050),ITYPG
5000  WRITE(N6,5001)
5001  FORMAT(***,T65,*CURB OPENING INLETS SELECTED*)
      GO TO 6010
5010  WRITE(N6,5002)
5002  FORMAT(***,T65,*DEPRESSED CURB OPENING INLETS SELECTED*)
      IF(INOMG.NE.2) GO TO 6010
      READ(N5,1030) W,GLI
      A=W/12.
      IF(IMET.EQ.0) GO TO 92207
C
C**** METRIC OUTPUT
      WRITE(N6,92208) W,A,GLI
92208 FORMAT(1X,T65,*IZZARD FLOW EQUATIONS*,//,30X,*DEPRESSION WIDTH*,F1
     20.2,1X,*M.*,/,30X,*DEPRESSION DEPTH*,F10.2,1X,*M.*,/,
     330X,*INLET LENGTH *,F10.2,1X,*M.*,//)
      W=W*3.281
      A=A*3.281
      GO TO 4066
C
C**** BRITISH UNITS
92207 WRITE(N6,5202) W,A,GLI
5202  FORMAT(1X,T65,*IZZARD FLOW EQUATIONS*,//,30X,*DEPRESSION WIDTH*,F1
```

```
          20.2,1X,*FT*,/,30X,*DEPRESSION DEPTH*,F10.2,1X,*FT*,/,
          330X,*INLET LENGTH *,F10.2,1X,*FT*,//)
           GO TO 4066
     5020  WRITE(N6,5021)
     5021  FORMAT(*+*,T65,*GRATE INLETS SELECTED*)
           GO TO 6010
     5030  WRITE(N6,5031)
     5031  FORMAT(*+*,T65,*DEPRESSED GRATE INLETS SELECTED*)
           GO TO 6010
     5040  WRITE(N6,5041)
     5041  FORMAT(*+*,T65,*COMBINATION INLETS SELECTED*)
           GO TO 6010
     5050  WRITE(N6,5051)
     5051  FORMAT(*+*,T65,*DEPRESSED COMBINATION INLETS SELECTED*)
     6010  IF(INOMG.EQ.0) WRITE(N6,6011)
           IF(INOMG.EQ.1) WRITE(N6,6012)
           IF(INOMG.EQ.2.AND.ITYPG.NE.2) WRITE(N6,6013)
     6011  FORMAT(* *,T65,*INLET CAPACITY CURVES INPUT BY USER*,//)
     6012  FORMAT(* *,T65,*INLET CAPACITY CURVES FROM BLOCK DATA USED*,//)
     6013  FORMAT(* *,T65,*INLET CAPACITY EQUATION TO BE USED*,//)
     C
     C**** INLETS ON GRADE IN CHANNELS
           WRITE(N6,4106)
     4106  FORMAT(* *,30X,*FOR INLETS ON GRADE IN CHANNELS:*)
           GO TO (5500,5510,5520,5530,5540,5550),ITYPC
     5500  WRITE(N6,5001)
           GO TO 6060
     5510  WRITE(N6,5002)
           GO TO 6060
     5520  WRITE(N6,5021)
           GO TO 6060
     5530  WRITE(N6,5031)
           GO TO 6060
     5540  WRITE(N6,5041)
           GO TO 6060
     5550  WRITE(N6,5051)
     6060  IF(INOMC.EQ.0) WRITE(N6,6011)
           IF(INOMC.EQ.1) WRITE(N6,6012)
           IF(INOMC.EQ.2) WRITE(N6,6013)
     C
           IF(INOMG.EQ.2) GO TO 4066
           IF(INOMG.EQ.1) GO TO 6021
     C
     C**** CURVES FOR INLETS IN GUTTERS INPUT ON CARDS
           DO 5105 I=1,4
           DO 5100 J=1,6
           READ(N5,5111) (QINLG(I,J,K),K=1,12)
     5111  FORMAT(12F6.2)
     5100  CONTINUE
     5105  CONTINUE
           GO TO 6022
     C
     C**** CURVES FOR INLETS IN GUTTERS FROM BLOCK DATA
     6021  DO 6030 I=1,4
           DO 6030 J=1,6
           DO 6030 K=1,12
     6030  QINLG(I,J,K)=DINLG(K,J,I)
```

```
C
C**** PRINT CURVES
6022  IF(IMET.EQ.0) GO TO 1112
C
C**** METRIC OUTPUT
      WRITE(N6,1111)
1111  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,40H****
     4                    ****,8X,*CAMP DRESSER AND MCKEE             */* *
     5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE, VIRGINIA  *//,1X,*CAPACITY CURVES FOR INLETS IN
     7GUTTERS (Q IN CMS) :*/)
      GO TO 1113
C
C**** BRITISH UNITS OUTPUT
1112  WRITE(N6,1011)
1011  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,40H****
     4                    ****,8X,*CAMP DRESSER AND MCKEE             */* *
     5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE, VIRGINIA  *//,1X,*CAPACITY CURVES FOR INLETS IN
     7GUTTERS (Q IN CFS) :*/)
1113  DO 5110 I=1,4
      WRITE(N6,5005) ISLOP(I)
5005  FORMAT(*0*,1X,25(2H--),*CROSS-SLOPE: 1/*,I2,25(2H--))
      WRITE(N6,5120) (SLOP(J),J=1,6)
5120  FORMAT(* *,1X,6(*S = *,F5.3,11X)/,2X,6(10(1H-),10X)/)
      WRITE(N6,5125)
5125  FORMAT(1X,6(* QI/Q*,5X,*Q*,9X))
      DO 5135 NLINE=1,6
      KK=NLINE*2
      K1=KK-1
      WRITE(N6,5130) ((QINLG(I,J,K),K=K1,KK),J=1,6)
5130  FORMAT(1X,6(F4.2,3X,F5.1,8X))
5135  CONTINUE
5110  CONTINUE
      IF(IMET.EQ.0) GO TO 4066
C
C**** CONVERT CMS TO CFS
      DO 4166 I=1,4
      DO 4166 J=1,6
      DO 4166 K=2,12,2
4166  QINLG(I,J,K)=QINLG(I,J,K)*35.3
4066  CONTINUE
C
      IF(INOMC.EQ.2) GO TO 7066
      IF(INOMC.EQ.1) GO TO 9021
C
C**** CURVES FOR INLETS IN CHANNELS INPUT ON CARDS
      DO 9105 J=1,6
9105  READ(N5,5111) (QINLC(J,K),K=1,12)
      GO TO 9022
C
C**** CURVES FOR INLETS IN CHANNELS FROM BLOCK DATA
9021  DO 9030 J=1,6
```

```
      DO 9030 K=1,12
9030  GINLC(J,K)=DINLC(K,J)
C
C**** PRINT CURVES
9022  IF(IMET.EQ.0) GO TO 9112
C
C**** METRIC OUTPUT
      WRITE(N6,9111)
9111  FORMAT(*1*,54(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,40H****
     4                         ****,8X,*CAMP DRESSER AND MCKEE              */* *
     5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE, VIRGINIA  *//,1X,*CAPACITY CURVES FOR INLETS IN
     7CHANNELS (D IN METERS) :*/)
      GO TO 9113
C
C**** BRITISH UNITS
9112  WRITE(N6,9011)
9011  FORMAT(*1*,54(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL  ****,8X,*WATER RESOURCES DIVISIO
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,40H****
     4                         ****,8X,*CAMP DRESSER AND MCKEE              */* *
     5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE, VIRGINIA  *//,1X,*CAPACITY CURVES FOR INLETS IN
     7CHANNELS (D IN FEET) :*/)
9113  WRITE(N6,5120) (SLOP(J),J=1,6)
      WRITE(N6,95125)
95125 FORMAT(1X,6(* QI/Q*,5X,*D*,9X))
      DO 95135 NLINE=1,6
      KK=NLINE*2
      K1=KK-1
95135 WRITE(N6,5130) ((GINLC(J,K),K=K1,KK),J=1,6)
      IF(IMET.EQ.0) GO TO 7066
C
C**** CONVERT CMS TO CFS
      DO 7166 J=1,6
      DO 7166 K=2,12,2
7166  GINLC(J,K)=QINLC(J,K)*35.3
7066  CONTINUE
C
C**** INLET SIZE - GUTTERS, CHANNELS AND SUMPS
8066  READ(N5,1030) RD
      IF(RD.EQ.0.) RD=1.
      IF(INOMC.NE.2) GO TO 3320
      IF(IMET.EQ.0) GO TO 1952
C
C**** METRIC OUTPUT
      WRITE(N6,1951) RD
1951  FORMAT(///,20X,*INLET CAPACITY REDUCTION FACTOR*,F10.2,/)
      GO TO 3021
C
C**** BRITISH UNITS
1952  WRITE(N6,1955) RD
1955  FORMAT(///,20X,*INLET CAPACITY REDUCTION FACTOR*,F10.2,/)
      GO TO 3021
3320  WRITE(N6,2999)
```

```
      IF(IMET.EQ.0) WRITE(N6,1955) RD
      IF(IMET.EQ.1) WRITE(N6,1951) RD
C
C******** GUTTER/CHANNEL DATA
C
3021  NOGUTTR=0
      ICHK=1
      DO 480 N=1,NG
4021  READ(N5,1115) NAMEG(N),ISTA1A(N),ISTA1B(N),ISTA2A(N),ISTA2B(N),
     2GWIDTH(N),GSLOPE(N),GS1(N),GS2(N),GN(N)
1115  FORMAT(I10,2(I7,1X,I2),5F10.0)
      READ(N5,1116) NGTO(N),NGSTO(N),NFG(N),DFULL(N),SPMAX(N)
1116  FORMAT(10X,3I10,2F10.0)
C
C**** CALCULATE GUTTER/CHANNEL LENGTH
      GLEN(N)=ABS((ISTA2A(N)-ISTA1A(N))*100.0+(ISTA2B(N)-ISTA1B(N)))
      IF((N/39*39).EQ.N) GO TO 4020
      IF(NAMEG(N).EQ.0) GO TO 4020
4042  IF(NGTO(N).GT.0.OR.NGSTO(N).GT.0) GO TO 5012
      NERROR=NERROR+1
      WRITE(N6,5011) NAMEG(N)
5011  FORMAT(*0*,*--- ERROR --- CHANNEL*,I5,* DOES NOT DRAIN TO INLET OR
     2 A DOWNSTREAM GUTTER*)
5012  IF(GN(N).EQ.0.0) GN(N)=0.014
C
C**** PRINT GUTTER/CHANNEL DATA
      IF(N.EQ.1.OR.(N/39*39).EQ.N) GO TO 4016
      GO TO 4017
4016  WRITE(N6,2999)
      WRITE(N6,4018)
4018  FORMAT(///* *,41X,*INPUT DATA FOR SURFACE RUNOFF GUTTERS/CHANNELS*
     2/* *,41X,46(*=*)//)
      IF(IMET.EQ.1) GO TO 4118
C
C**** BRITISH UNITS
      WRITE(N6,4115)
4115  FORMAT(* *,4X,*GUTTER/*,7X,*CONNECTED TO*/* *,4X,*CHANNEL*,6X,*GUT
     2TER/CHANNEL*,8X,*INLET*,12X,*STATIONS*,11X,*LENGTH*,8X,*MANNINGS*,
     39X,*SLOPE*/* *,4X,*NUMBER*,11X,*NUMBER*,13X,*NO.*,11X,*1*,9X,*2*,1
     41X,*(FT)*,12X,*N*,12X,*(FT/FT)*/* *,4X,6(*-*),8X,12(*-*),9X,5(*-*)
     5,7X,16(*-*),8X,6(*-*),8X,8(*-*),8X,7(*-*)/)
      GO TO 4017
C
C**** METRIC OUTPUT
4118  WRITE(N6,4019)
4019  FORMAT(* *,4X,*GUTTER/*,7X,*CONNECTED TO*/* *,4X,*CHANNEL*,6X,*GUT
     2TER/CHANNEL*,8X,*INLET*,12X,*STATIONS*,11X,*LENGTH*,8X,*MANNINGS*,
     39X,*SLOPE*/* *,4X,*NUMBER*,11X,*NUMBER*,13X,*NO.*,11X,*1*,9X,*2*,1
     41X,*(M.)*,12X,*N*,12X,*(M./M.)*/* *,4X,6(*-*),8X,12(*-*),9X,5(*-*)
     5,7X,16(*-*),8X,6(*-*),8X,8(*-*),8X,7(*-*)/)
4017  WRITE(N6,4025) NAMEG(N),NGTO(N),NGSTO(N),ISTA1A(N),ISTA1B(N),ISTA2
     2A(N),ISTA2B(N),GLEN(N),GN(N),GSLOPE(N)
4025  FORMAT(* *,5X,I4,13X,I4,11X,I6,8X,I4,*+*,I2,2X,I4,*+*,I2,8X,F6.1,
     29X,F6.4,9X,F7.3)
      MGTO(N)=NGTO(N)
      GO TO 480
4020  MN=N-1
```

```
      WRITE(N6,2999)
      WRITE(N6,4031)
4031  FORMAT(///* *,36X,*INPUT DATA FOR SURFACE RUNOFF GUTTERS/CHANNELS
     2(CONTINUED)*/* *,36X,58(*=*)//)
      IF(IMET.EQ.0) GO TO 4135
C
C**** METRIC OUTPUT
      WRITE(N6,4133)
4133  FORMAT(* *,7X,*GUTTER/*,11X,*TRAPEZOIDAL CHANNEL*,12X,*MAXIMUM*,11
     2X,*DESIGN*/* *,7X,*CHANNEL*,7X,*RECIP. SIDE SLOPE*,4X,*WIDTH*,10X,
     3*DEPTH*,12X,*SPREAD*,6X,*V FULL*,8X,*Q FULL*/* *,7X,*NUMBER*,12X,*
     41*,8X,*2*,8X,*(M.)*,11X,*(M.)*,13X,*(M.)*, 7X,*(M/S)*,9X,*(CMS)*/*
     5 *,7X,6(*-*),8X,17(*-*),3X,7(*-*),8X,7(*-*),10X,7(*-*),5X,7(*-*),7
     6X,7(*-*)/)
      GO TO 4137
C
C**** BRITISH UNITS
4135  WRITE(N6,4032)
4032  FORMAT(* *,7X,*GUTTER/*,11X,*TRAPEZOIDAL CHANNEL*,12X,*MAXIMUM*,11
     2X,*DESIGN*/* *,7X,*CHANNEL*,7X,*RECIP. SIDE SLOPE*,4X,*WIDTH*,10X,
     3*DEPTH*,12X,*SPREAD*,6X,*V FULL*,8X,*Q FULL*/* *,7X,*NUMBER*,12X,*
     41*,8X,*2*,8X,*(FT)*,11X,*(FT)*,13X,*(FT)*, 7X,*(FPS)*,9X,*(CFS)*/*
     5 *,7X,6(*-*),8X,17(*-*),3X,7(*-*),8X,7(*-*),10X,7(*-*),5X,7(*-*),7
     6X,7(*-*)/)
4137  DO 4040 NN=ICHK,MN
C
C******** COMPUTE V FULL AND Q FULL
      IF(NPG(NN).EQ.3) GO TO 4138
      IF(NPG(NN).EQ.1) DFULL(NN)=(SPMAX(NN)-GWIDTH(NN))/(GS1(NN)+GS2(NN)
     2)
      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)
      GO TO 4139
4138  DFULL(NN)=GWIDTH(NN)
      GA=0.7854*DFULL(NN)**2.
      GP=3.1416*DFULL(NN)
4139  GR=GA/GP
      IF(IMET.EQ.0) GV=1.486/GN(NN)*SQRT(GSLOPE(NN))*GR**0.666667
      IF(IMET.EQ.1) GV=1.000/GN(NN)*SQRT(GSLOPE(NN))*GR**0.666667
      GQ=GA*GV
      IF(NPG(NN).NE.3) GO TO 4036
C
C**** CIRCULAR PIPE
      WRITE(N6,4033) NAMEG(NN),GWIDTH(NN),DFULL(NN),GV,GQ
4033  FORMAT(* *,8X,I4,10X,*-*,8X,*-*,6X,F7.3,8X,F7.3,10X,*-*,11X,F6.3,8
     2X,F6.3)
      GO TO 4038
C
C**** TRAP. SECTIONS
4036  WRITE(N6,4037) NAMEG(NN),GS1(NN),GS2(NN),GWIDTH(NN),DFULL(NN),SPMA
     2X(NN),GV,GQ
4037  FORMAT(* *,8X,I4,9X,F7.3,2X,F7.3,4X,F7.3,8X,F7.3,10X,F6.3,7X,F6.3,
     27X,F7.3)
4038  GCON(NN)=(1.486/GN(NN))*SQRT(GSLOPE(NN))
4040  CONTINUE
      IF(NAMEG(N).EQ.0) GO TO 4015
```

```
      ICHK=N
      GO TO 4042
480   CONTINUE
4015  NOGUTTR=N-1
      WRITE(N6,1151) NOGUTTR
1151  FORMAT(//* *,45X,*TOTAL NUMBER OF GUTTERS/CHANNELS=*,I4)
      NOG=NOGUTTR
C
C******** READ IN OVERBANK CHANNEL DATA
C
      DO 430 JUP=1,50
      READ(N5,320) NBASIN,IDENT,G1,G4,G5,G6,G7
320   FORMAT(2I10,5F10.0)
      IF(IDENT.EQ.0) GO TO 440
      IF(NBASIN.EQ.BASIN) GO TO 9340
      WRITE(N6,330) NBASIN,IDENT
330   FORMAT(*0*,*--- ERROR --- CHANNEL*,I2,I5,* IS NOT IN THIS BASIN*)
      NERROR=NERROR+1
C
C**** SET UP ARRAY JOVER
9340  DO 350 J=1,NOG
      IF(NPG(J).NE.4) GO TO 350
      IF(NAMEG(J).NE.IDENT) GO TO 350
      JOVER(J)=JUP
      GO TO 370
350   CONTINUE
      WRITE(N6,9360) IDENT
9360  FORMAT(* ---- ERROR ---- OVERBANK CHANNEL*,I6,* HAS NO BASE CHANNE
     2L*)
      NERROR=NERROR+1
C
C******** COMPUTE V FULL AND G FULL
C
370   GA=DFULL(J)*(GWIDTH(J)+0.5*DFULL(J)*(GS1(J)+GS2(J)))+G7*(G1+0.5*G7
     2*(G4+G5))
      TWIDTH(J)=GWIDTH(J)+(GS1(J)+GS2(J))*DFULL(J)
      GP1=GWIDTH(J)+DFULL(J)*(SQRT(1.0+GS1(J)**2)+SQRT(1.0+GS2(J)**2))
      GP2=G1+G7*(SQRT(1.0+G4**2)+SQRT(1.0+G5**2))-TWIDTH(J)
      GMAN=(GN(J)*GP1+G6*GP2)/(GP1+GP2)
      GR=GA/(GP1+GP2)
      IF(IMET.EQ.0) GV=1.486/GN(NN)*SQRT(GSLOPE(NN))*GR**0.6666667
      IF(IMET.EQ.1) GV=1.000/GN(NN)*SQRT(GSLOPE(NN))*GR**0.6666667
      GQ=GA*GV
C
C******** SUMMARIZE OVERBANK CHANNEL DATA
C
      IF(JUP.NE.1) GO TO 390
      IF(IMET.EQ.0) GO TO 377
C
C**** METRIC OUTPUT
      WRITE(N6,375) BASIN
375   FORMAT(*1*,//,*0*,*SUMMARY OF OVERBANK CHANNEL DATA FOR BASIN NO.*
     2,I2,//4X,*INT   CHAN   WIDTH    SIDE SLOPES   MANNING   DEPTH*,*
     3  V FULL   Q FULL*/4X,*NUM    NUM    (M.)   LEFT  RIGHT      N
     4    (M.)      (M/S)     (CMS)*/)
      GO TO 390
C
```

```
C**** BRITISH UNITS
377   WRITE(N6,380) BASIN
380   FORMAT(*1*,//,*0*,*SUMMARY OF OVERBANK CHANNEL DATA FOR BASIN NO.*
     2,I2,//4X,*INT    CHAN    WIDTH     SIDE SLOPES    MANNING    DEPTH*,*
     3  V FULL    Q FULL*/4X,*NUM     NUM     (FT)    LEFT  RIGHT       N
     4     (FT)      (FPS)     (CFS)*/)
390   WRITE(N6,400) JUP,IDENT,G1,G4,G5,G6,G7,GV,GQ
400   FORMAT(3X,I3,I8,F8.2,2F7.1,F9.3,F9.2,2F10.2)
C
C**** TRANSFER OVERBANK CHANNEL DATA
      OVRWTH(JUP)=G1
      IF(OVRWTH(JUP).GT.TWIDTH(J)) GO TO 420
      WRITE(N6,410) IDENT
410   FORMAT(* ---- ERROR ---- OVERBANK CHANNEL*,I6,* HAS A BASE WIDTH L
     2ESS THAN ITS BASE CHANNEL TOP WIDTH*)
      NERROR=NERROR+1
420   OVRGS1(JUP)=G4
      OVRGS2(JUP)=G5
      OVRGN(JUP)=G6
      OVRDFL(JUP)=G7
      OVRCON(JUP)=(1.486/OVRGN(JUP))*SQRT(GSLOPE(J))
      OVRDEP(JUP)=0.
      OVRGV(JUP)=GV
      OVRGQ(JUP)=GQ
      IF(IMET.EQ.0) GO TO 430
      OVRDFL(JUP)=OVRDFL(JUP)*3.281
      OVRGV(JUP)=OVRGV(JUP)*3.281
      OVRGQ(JUP)=OVRGQ(JUP)*35.3
430   CONTINUE
440   NOVR=JUP-1
      NOG=NOG+NOVR
      WRITE(N6,670) NOVR
670   FORMAT(*0*,45X,*NUMBER OF OVERBANK CHANNELS*,I4)
      IF(IMET.EQ.0) GO TO 445
      DO 443 N=1,NG
      IF(NAMEG(N).EQ.0) GO TO 445
      ISTA1A(N)=ISTA1A(N)*3.281
      ISTA1B(N)=ISTA1B(N)*3.281
      ISTA2A(N)=ISTA2A(N)*3.281
      ISTA2B(N)=ISTA2B(N)*3.281
      GWIDTH(N)=GWIDTH(N)*3.281
      DFULL(N)=DFULL(N)*3.281
443   SPMAX(N)=SPMAX(N)*3.281
C
C******** READ SURFACE STORAGE DATA
C
445   NLAKE=0
      NOG1=NOG+1
      DO 530 N=NOG1,NG
      READ(N5,450) NBASIN,NAMEG(N),NGTO(N),NGSTO(N),NP,IG,
     2 G1,G2,G3,G4,G5,G6,G7,G8,G9
450   FORMAT(6I5/10F8.0)
      IF(NAMEG(N).EQ.0) GO TO 540
      IF(NBASIN.EQ.BASIN) GO TO 470
      WRITE(N6,460) NBASIN,NAMEG(N)
460   FQRMAT(*0*,*---- ERROR ---- CHANNEL*,I2,I5,* IS NOT IN THIS BASIN*
     2)
```

```
      NERROR=NERROR+1
470   NLAKE=NLKAKE+1
C
C**** TRANSFER SURFACE STORAGE DATA
      NPG(N)=NP
      LKHYET(N)=IG
      GWIDTH(N)=G1
      IF(GWIDTH(N).LE.0) GWIDTH(N)=0.001
C
C**** CONVERT ACRES OR HECTARES TO SQ. FT.
      IF(IMET.EQ.0) AREALK(N)=G2*43560.
      IF(IMET.EQ.1) AREALK(N)=G2*107600.
      GSLOPE(N)=G3
      GS1(N)=G4
      GS2(N)=G5
      GN(N)=G6
      GLEN(N)=G7
C
C**** CONVERT ACRE-FT OR CU. METERS TO CU. FT.
      IF(IMET.EQ.0) VOLMLK(N)=G8*43560.
      IF(IMET.EQ.1) VOLMLK(N)=G8*35.3
      GDEPTH(N)=G9
      GCON(N)=(1.486/GN(N))*SQRT(GSLOPE(N))
C
C**** SUMMARIZE STORAGE DATA
      IF(N.NE.NOG1) GO TO 510
      IF(IMET.EQ.0) GO TO 490
      WRITE(N6,478) BASIN
478   FORMAT(*0*,//,*0*,*SUMMARY OF DETENTION BASIN NO.*,I2,//,*   CHAN
     2 INLET   CHAN     BASIN      OUTLET      WIDTH   LENGTH       SLOPE*,
     37X,*SIDE SLOPES*,4X,*DISCHARGE  INT. DEPTH  VOLUME HYET*/,4X,*NUM
     4  NUM    CONN    AREA (HA)  CONTROL      (M.)      (M.)        (M./M.)
     5  LEFT        RIGHT     COEFF         (M.)      (CU. M.)*)
      GO TO 510
490   WRITE(N6,500) BASIN
500   FORMAT(*0*,//,*0*,*SUMMARY OF DETENTION BASIN NO.*,I2,//,*   CHAN
     2 INLET   CHAN     BASIN      OUTLET      WIDTH   LENGTH       SLOPE*,
     37X,*SIDE SLOPES*,4X,*DISCHARGE  INT. DEPTH  VOLUME HYET*/,4X,*NUM
     4  NUM    CONV    AREA (AC)  CONTROL      (FT)      (FT)       (FT/MI)
     5  LEFT        RIGHT     COEFF         (FT)      (AC-FT)*)
510   NN=N-NOG1+1
      TY(NN)=W
      PE(NN)=EIR
      IF(NPG(N).EQ.6) TY(NN)=OU
      IF(NPG(N).EQ.6) PE(NN)=TLET
      WRITE(N6,520) NAMEG(N),NGTO(N),NGSTO(N),G2,TY(NN),PE(NN),GWIDTH(N)
     2,GLEN(N),G3,GS1(N),GS2(N),GN(N),GDEPTH(N),G8,LKHYET(N)
520   FORMAT(3I7,F10.1,2X,2A4,3F10.1,2F10.2,2F10.3,2X,F10.2,I4)
      IF(IMET.EQ.0) GO TO 521
      GLEN(N)=GLEN(N)*3.281
      GWIDTH(N)=GWIDTH(N)*3.281
521   IF(NP.EQ.6) GCON(N)=GN(N)*GWIDTH(N)
530   CONTINUE
540   CONTINUE
      WRITE(N6,550) NLAKE
550   FORMAT(*0*,45X,*TOTAL NUMBER OF DETENTION BASINS *,I3)
      NOG=NOG+NLAKE
```

```
      C
      C******** SET UP GUTTER/INLET CONNECTIONS
      C
            INLETS=0
            NCHAN=NOG
            DO 640 N=1,NOG
            IF(NGSTO(N).EQ.0) GO TO 640
            IF(NGTO(N).EQ.0) GO TO 640
            IF(INLETS.LE.0) GO TO 638
            N1=NOG+1
            N2=NOG+INLETS
            DO 635 NN=N1,N2
            IF(NGSTO(N).EQ.NAMEG(NN)) GO TO 630
      635   CONTINUE
      638   INLETS=INLETS+1
            NCHAN=NCHAN+1
            NAMEG(NCHAN)=NGSTO(N)
            NGTO(NCHAN)=NGTO(N)
            NGTOI(INLETS)=NCHAN
            NPG(NCHAN)=9
      630   NGTO(N)=NGSTO(N)
      640   CONTINUE
      C
      C******** SET UP GUTTER CONNECTIVITY TABLES
      C
            NCHAN=NOG+INLETS
            DO 750 N=1,NCHAN
            NN=NOG+INLETS
            DO 720 NGOTO=1,NN
            IF(NGTO(N).EQ.NAMEG(NGOTO)) GO TO 730
      720   CONTINUE
      C
      C**** CREATE DUMMY GUTTERS AS NEEDED
            INLETS=INLETS+1
            NGOTO=NOG+INLETS
            IF(NGOTO.GT.NG) GO TO 760
            NAMEG(NGOTO)=NGSTO(N)
            NGTO(N)=NGSTO(N)
            NPG(NGOTO)=10
            NGTOI(INLETS)=NGOTO
      730   CONTINUE
            DO 740 J=1,NIV
            IF(NGTOG(NGOTO,J).GT.0) GO TO 740
            NGTOG(NGOTO,J)=N
            GO TO 750
      740   CONTINUE
      750   CONTINUE
            GO TO 780
      C
      C**** ERROR IN DATA
      760   WRITE(N6,770) NGOTO,NG
      770   FORMAT(* ---- ERROR ---- THE ASSIGNED CHANNEL NUMBERS*,I5,* WHICH
           2INCLUDES DUMMIES EXCEEDS THE COMMON STORAGE BLOCK*,I5)
            NERROR=NERROR+1
      780   CONTINUE
            NOGS=NOG+INLETS
            DO 800 N=1,NCHAN
```

```
      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,NCHAN
      NGUT(KOUNT)=NTRY
      NTRY=NGTO(NTRY)
      NDUM=NTRY
830   NGSAVE=0
      DO 860 J=1,10
      IF(NGTOG(NTRY,J).EQ.0) GO TO 870
      DO 840 JJ=1,KOUNT
      IF(NGTOG(NTRY,J).EQ.NGUT(JJ)) GO TO 860
840   CONTINUE
      NGSAVE=NGTOG(NTRY,J)
      IF(NGSAVE.NE.NDUM) GO TO 860
      WRITE(N6,850) NAMEG(NGSAVE)
850   FORMAT(1H ,* ---- ERROR ----  CHANNEL *,I6,*LOOPS BACK ON ITSELF*)
      STOP
860   CONTINUE
870   CONTINUE
      IF(NGSAVE.EQ.0) GO TO 880
      NTRY=NGSAVE
      GO TO 830
880   IF(NTRY.LE.NCHAN) GO TO 920
      K=NCHAN+NINLET
      NGUT(K)=NTRY
      NINLET=NINLET+1
      IF(K.NE.NOGS) GO TO 890
      GO TO 930
890   CONTINUE
      DO 910 L=1,NCHAN
      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******** WATERSHED DATA
C
      TAREA=0.
      DO 340 N=1,NW
      READ(N5,1060) NAMEW(N),NGTO(N),JK,AREA,NW3,WWIDTH(N)
1060  FORMAT(3I10,F10.0,I10,F10.0)
      IF(JK.EQ.0) JK=1
```

```
      IF(NAMEW(N).EQ.0) GO TO 360
C
C**** TRANSFER DATA AND CONVERT UNITS
      NHYET(N)=JK
      DO 6330 KK=1,NOGUTTR
      IF(NAMEG(KK).NE.NGTO(N)) GO TO 6330
      WWIDTH(N)=GLEN(KK)
      GO TO 6035
6330  CONTINUE
      WRITE(N6,6040) NAMEW(N),NGTO(N)
6040  FORMAT(*0*,*---- WARNING --- WATERSHED*,I5,* DOES NOT DRAIN TO A SU
     2RFACE CONDUIT BUT TO DRAINAGE CONDUIT*,I5)
6035  NC(N)=NW3
C
C**** PRINT WATERSHED DATA
      IF(MOD(N,2).NE.1) GO TO 4505
      WRITE(N6,2999)
      WRITE(N6,4000) TITLE
      WRITE(N6,9970)
9970  FORMAT(* *,//46(1H-),*HIGHWAY SURFACE DRAINAGE INFORMATION*,46(1H-
     2),/)
4505  IF(IMET.EQ.0) GO TO 4507
C
C**** METRIC OUTPUT
      WRITE(N6,4506)
4506  FORMAT(* *,//,29X,* WATERSHED   WATERSHED     WATERSHED       DRAI
     2N  RAINGAGE   AREA    NUMBER OF*,/,33X,*NO.*,9X,*NAME*, 9X,*WIDTH
     3*,8X,*GUTTER*,3X,*NO.*,5X,*  (HA)   SUBAREAS*,/)
      GO TO 4508
C
C**** BRITISH UNITS
4507  WRITE(N6,9975)
9975  FORMAT(* *,//,29X,* WATERSHED   WATERSHED     WATERSHED       DRAI
     2N  RAINGAGE   AREA    NUMBER OF*/,33X,*NO.*,9X,*NAME*, 9X,*WIDTH *
     3,8X,*GUTTER*,3X,*NO.*,5X,*(ACRES)  SUBAREAS*,/)
4508  WRITE(N6,1070) N,NAMEW(N),WWIDTH(N),NGTO(N),JK,AREA,NW3
1070  FORMAT(* *,26X,I10,3X,I10,5X,F10.2,4X,I8,I7,2X,F10.2,4X,I5,///)
      IF(IMET.EQ.0) GO TO 9988
C
C**** METRIC OUTPUT
      WRITE(N6,9986)
9986  FORMAT(56X,*SUBAREA DEFINITION*,//,44X,*AREA*,8X,*SURFACE*,
     2 3X,*SLOPE*,3X,*STORAGE*,2X,*MANNING N*,/,43X,*  (HA) *,7X,*TYPE*,
     3 4X,*(M./M.)*,3X,*(MM)*,5X,*(M.)1/6*)
      GO TO 9989
C
C**** BRITISH UNITS
9988  WRITE(N6,9976)
9976  FORMAT(56X,*SUBAREA DEFINITION*,//,44X,*AREA*,8X,*SURFACE*,
     2 3X,*SLOPE*,3X,*STORAGE*,2X,*MANNING N*,/,43X,*(ACRES)*,7X,*TYPE*,
     3 4X,*(FT/FT)*,3X,*(IN)*,5X,*(FT)1/6*)
9989  DO 90170 K=1,NW3
      READ(N5,90171) WAREA(N,K),WTYPE(N,K),WSLOPE(N,K),WSTORE(N,K),W4
90171 FORMAT(5F10.0)
      WAREA(N,K)=WAREA(N,K)*AREA
      JK=WTYPE(N,K)
      WRITE(N6,90172) WAREA(N,K),JK,WSLOPE(N,K),WSTORE(N,K),W4
```

```
90172 FORMAT(* *,39X,F10.2,I10,3F10.2,/)
      TAREA=TAREA+WAREA(N,K)
      IF(IMET.EQ.0) GO TO 90174
C
C**** CONVERT METRIC TO BRITISH UNITS
      WSTORE(N,K)=WSTORE(N,K)/(25.4*12.)
      WAREA(N,K)=WAREA(N,K)*2.471*43560.
      WWIDTH(N)=WWIDTH(N)*3.281
      GO TO 90170
C
C**** CONVERT FOR INTERNAL USE
90174 WSTORE(N,K)=WSTORE(N,K)/12.
      WAREA(N,K)=WAREA(N,K)*43560.
90170 WCON(N,K)=-(1.486/W4)*SQRT(WSLOPE(N,K))*WWIDTH(N)/WAREA(N,K)
340   CONTINUE
360   NOW=N-1
      WRITE(N6,1100) NOW,TAREA
1100  FORMAT(*0*,*TOTAL NUMBER OF SUBCATCHMENTS *,I4/
     2 *0*,*TOTAL TRIBUTARY AREA (ACRES) *,F8.2)
C
C**** SET UP CONNECTIVITY TABLES
      DO 1120 N=1,NOW
      NN=NOG+INLETS
      DO 1090 NGOTO=1,NN
      IF(NGTO(N).EQ.NAMEG(NGOTO)) GO TO 91100
1090  CONTINUE
C
C**** IDENTIFY ADDITIONAL INLETS
      INLETS=INLETS+1
      NGOTO=NOG+INLETS
      IF(NGOTO.GT.NG) GO TO 760
      NAMEG(NGOTO)=NGTO(N)
      NPG(NGOTO)=10
      NGTOI(INLETS)=NGOTO
91100 CONTINUE
C
C**** GUTTER CONNECTION
      DO 1110 J=1,NIN
      IF(NWTOG(NGOTO,J).GT.0) GO TO 1110
      NWTOG(NGOTO,J)=N
      GO TO 1120
1110  CONTINUE
1120  CONTINUE
C
C********* PRINT CONNECTIVITY SUMMARY
C
      WRITE(N6,1220)
1220  FORMAT(*1*,*ARRANGEMENT OF SUBCATCHMENTS AND CHANNELS*//*      CHA
     2NNEL*,4X,*TRIBUTARY CHANNEL*,45X,*TRIBUTARY SUBAREA*,/17X,*OR MAIN
     3 CHANNEL*)
      DO 1350 NN=1,NCHAN
      J=NGUT(NN)
      DO 1240 N=1,NIN
      IF(NGTOG(J,N)) 1230,1250,1230
1230  INUM=NGTOG(J,N)
      NGTO(N)=NAMEG(INUM)
1240  CONTINUE
```

```
      GO TO 1270
1250  N=N-1
      IF(N) 1260,1260,1270
1260  WRITE(N6,1280) NAMEG(J)
      GO TO 1290
1270  WRITE(N6,1280) NAMEG(J),(NGTO(K),K=1,N)
1280  FORMAT(/I10,5X,10I5)
1290  DO 1310 N=1,NIN
      IF(NWTOG(J,N)) 1300,1320,1300
1300  INUM=NWTOG(J,N)
      NGTO(N)=NAMEW(INUM)
1310  CONTINUE
1320  N=N-1
      IF(N) 1350,1350,1330
1330  WRITE(N6,1340) (NGTO(K),K=1,N)
1340  FORMAT(1H+,74X,10I5)
1350  CONTINUE
      WRITE(N6,1360)
1360  FORMAT(*0*,*      INLET*,6X,*TRIBUTARY CHANNELS             *,25X,*T
     2RIBUTARY SUBAREAS*)
      DO 1420 I=1,INLETS
      N=NGTOI(I)
      JG=0
      JW=10
      DO 1400 J=1,NIN
      IF(NGTOG(N,J)) 1370,1380,1370
1370  JG=JG+1
      INUM=NGTOG(N,J)
      NGTO(JG)=NAMEG(INUM)
1380  IF(NWTOG(N,J)) 1390,1400,1390
1390  JW=JW+1
      INUM=NWTOG(N,J)
      NGTO(JW)=NAMEW(INUM)
1400  CONTINUE
      WRITE(N6,1280) NAMEG(N)
      IF(JG.GT.0) WRITE(N6,1410) (NGTO(J),J=1,JG)
1410  FORMAT(1H+,15X,10I5)
      IF(JW.GT.10) WRITE(N6,1340) (NGTO(J),J=11,JW)
1420  CONTINUE
C
C******** READ INFORMATION TO CONTROL INLETS SAVED AND PRINTED
C
      NSAVE=INLETS
      DO 1540 J=1,INLETS
      N=NGTOI(J)
      ISAVE(J)=NAMEG(N)
1540  CONTINUE
      WRITE(N6,1550) INLETS,(ISAVE(K),K=1,INLETS)
1550  FORMAT(*0*,*HYDROGRAPHS WILL BE STORED FOR THE FOLLOWING*,I5,* INL
     2ETS*/(8I10))
C
C******** READ AND WRITE QUALITY INPUTS
C
      READ(N5,1560) NQS,DRYDAY,CLFREQ,REFF,DET
1560  FORMAT(I10,4F10.0)
      IF(NQS.GT.0) GO TO 1600
      WRITE(N6,1590)
```

```
 1590 FORMAT(///10X,*.....QUALITY SIMULATION NOT INCLUDED IN THIS RUN...
     2..*)
      GO TO 1670
 1600 WRITE(N6,1660) NQS,DRYDAY,CLFREQ,REFF
 1660 FORMAT(1H1,9X,*.....CONSERVATIVE QUALITY CHANNEL ROUTING INCLUDED
     2IN THIS RUN.....*//10X,*INPUT PARAMETERS AS FOLLOWS*//10X,*NUMBER
     3OF CONSTITUENTS*,I8,/10X,*NUMBER OF DRY DAYS*,F12.1,
     4/10X,*MAINTENANCE PERIOD IN DAYS*,F12.1,
     5/10X,*FRACTIONAL MAINTENANCE EFFICIENCY*,F12.1)
      WRITE(N6,1661) DET
 1661 FORMAT(* *,9X,*DETENTION TIME(HRS) FOR 50 PERCENT SUSPENDED SOLIDS
     2 REMOVAL*,F5.1)
 1670 CONTINUE
      READ(N5,1680) NPRNT,INTERV
 1680 FORMAT(2I5)
      IF(NPRNT.LT.1) GO TO 1710
      READ(N5,1690) (IPRNT(K),K=1,NPRNT)
 1690 FORMAT(16I5)
      WRITE(N6,1700) (IPRNT(K),K=1,NPRNT)
 1700 FORMAT(*0*,*HYDROGRAPHS AND POLLUTOGRAPHS WILL BE LISTED FOR THE F
     2OLLOWING CHANNELS OR INLETS*,//,* LOCATION *,10I10,(/,10X,10I10))
 1710 CONTINUE
      READ(N5,1680) NPLOT
      IF(NPLOT.EQ.0) GO TO 1750
      READ(N5,1690) (IPLOT(K),K=1,NPLOT)
      READ(N5,1720) (ICODE(K),K=1,13)
      WRITE(N6,1730) (IPLOT(K),K=1,NPLOT)
      WRITE(N6,1740) (ICODE(K),K=1,13)
 1720 FORMAT(25I1)
 1730 FORMAT(*0*,*HYDROGRAPHS AND POLLUTOGRAPHS WILL BE PLOTTED FOR THE
     2FOLLOWING CHANNELS OR INLETS*//* LOCATION *,10I10/(10X,10I10))
 1740 FORMAT(*0*,*PLOT CODES ARE*,/1X,25I2)
 1750 CONTINUE
C
C******** SET UP OUTPUT FILES
C
      NSTP=NSTEP+1
      NQT=NQS
      IF(NQT.EQ.0) NQT=1
      DO 1920 J=1,3
      IF(JOUT(J).LT.1) GO TO 1920
      NTX=JOUT(J)
      REWIND NTX
      WRITE (NTX) TITLE
      IF(J-2) 1820,1840,1880
 1820 WRITE(NTX) NSTP,INLETS,NQS,DELT,TZERO,TAREA
      WRITE(NTX) (ISAVE(K),K=1,INLETS)
      DO 1830 K=1,INLETS
      JJ=NGTOI(K)
 1830 OUTFLW(K)=GFLOW(JJ)
      IF(NQS.LE.0) GO TO 2500
      WRITE(NTX) ((QFACT(L,M),L=1,5),M=1,13)
      WRITE(NTX) TZERO,(OUTFLW(K),K=1,INLETS),((POFF(K,N),N=1,5),K=1,INL
     2ETS)
      GO TO 1920
 2500 WRITE(NTX) TZERO,(OUTFLW(K),K=1,INLETS)
      GO TO 1920
```

```
1840  WRITE(NTX) NSTP,NPRNT,NGS,DELT,TZERO,TAREA,INTERV
      WRITE(NTX) (IPRNT(K),K=1,NPRNT)
C
C**** FIND INITIAL FLOWS
      NOGG=NOG+NSAVE
      DO 1870 JK=1,NPRNT
      DO 1850 JJ=1,NOGG
      IF(NAMEG(JJ).EQ.IPRNT(JK)) GO TO 1860
1850  CONTINUE
1860  OUTFLW(JK)=GFLOW(JJ)
1870  CONTINUE
      XMIN=NMN
      WRITE(NTX) NHR,XMIN,(OUTFLW(K),K=1,NPRNT)
      IF(NGS.GT.0) WRITE(NTX) NHR,XMIN,((POFF(K,N),N=1,NQT),K=1,NPRNT)
      GO TO 1920
1880  WRITE(NTX) NSTP,NPLOT,NGS,DELT,TZERO,TAREA
      WRITE(NTX) (IPLOT(K),K=1,NPLOT)
C
C**** FIND INITIAL FLOWS
      NOGG=NOG+NSAVE
      DO 1910 JK=1,NPLOT
      DO 1890 JJ=1,NOGG
      IF(NAMEG(JJ).EQ.IPLOT(JK)) GO TO 1900
1890  CONTINUE
1900  OUTFLW(JK)=GFLOW(JJ)
1910  CONTINUE
      WRITE(NTX) TZERO,(OUTFLW(K),K=1,NPLOT),((POFF(K,N),N=1,NQT),K=1,NP
     2LOT)
1920  CONTINUE
C
C**** CONVERT IPRNT TO INTERNAL NUMBERS
      IF(NPRNT.EQ.0) GO TO 1980
      DO 1970 N=1,NPRNT
      NN=NOG+INLETS
      DO 1940 J=1,NN
      IF(IPRNT(N).EQ.NAMEG(J)) GO TO 1960
1940  CONTINUE
      WRITE(N6,1950) IPRNT(N),N,NAMEG(J),J
1950  FORMAT(*  ERROR - - CANNOT MATCH IPRNT(N)*,I5,* FOR N=*,I5,* AND N
     2AMEG(J)*,I5,* FOR J=*,I5)
      STOP
1960  IPRNT(N)=J
1970  CONTINUE
1980  CONTINUE
      IF(NPLOT.EQ.0) GO TO 2030
      NN=NOG+INLETS
      DO 2020 N=1,NPLOT
      DO 1990 J=1,NN
      IF(IPLOT(N).EQ.NAMEG(J)) GO TO 2010
1990  CONTINUE
      WRITE(N6,2000) IPLOT(N)
2000  FORMAT(* ---- ERROR ---- CANNOT MATCH PLOT REQUEST*,I5,* WITH CHAN
     2NEL*)
      NERROR=NERROR+1
2010  IPLOT(N)=J
2020  CONTINUE
2030  CONTINUE
```

```
      IF(NERROR.EQ.0) GO TO 2050
      WRITE(N6,2040) NERROR
 2040 FORMAT(*0*,*EXECUTION TERMINATED IN RHYDRO DUE TO*,I3,* ERRORS IN*
     2,* INPUT DATA*)
      STOP
 2050 CONTINUE
      RETURN
      END
```

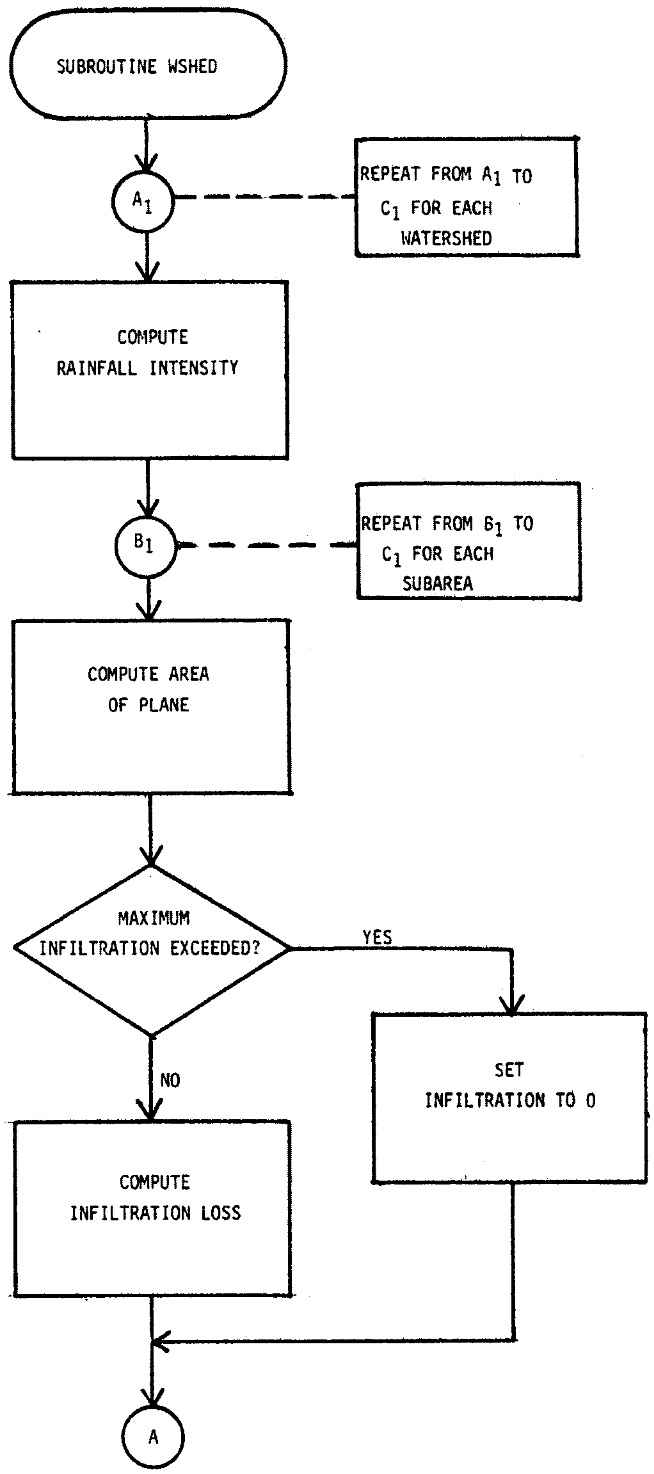


FIGURE IV-13. Flowchart of Subroutine WSHED

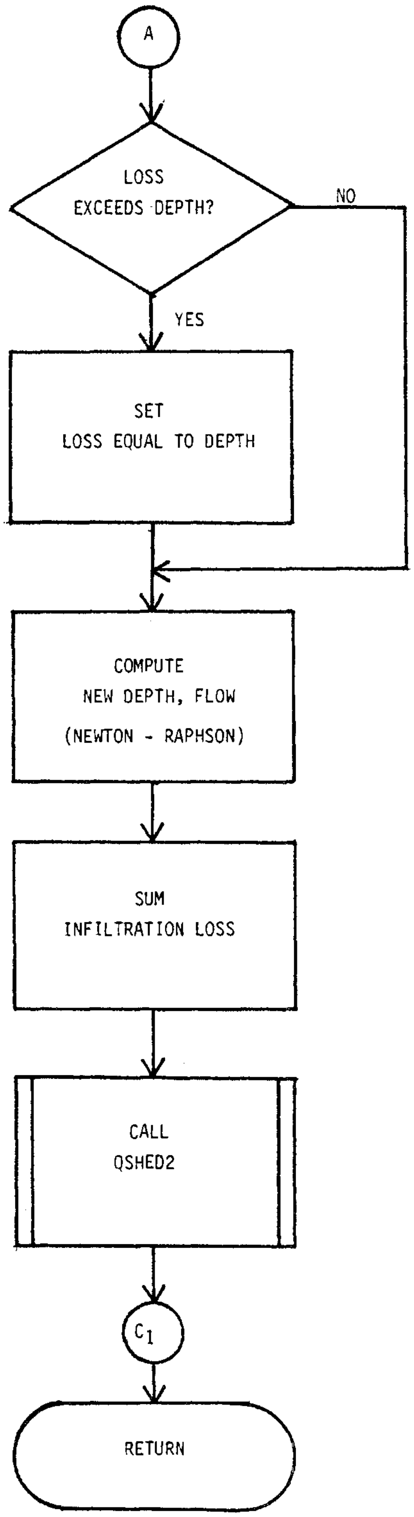


Figure IV-13
(Continued)

TABLE IV-10

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE WSHED

Fortran Variable	Description	Units
NQS	Quality option indicator	-
DORG	Rainfall minus infiltration	ft

```
      SUBROUTINE WSHED(NQS)
C
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTOPE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),QIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
     2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
      COMMON/INFIL/RAININ(200,3),DEPIN( 5 ),TIMEW(200),WTYPE(200,3),
     2NC(200)
      COMMON/POLUT/WFLO(200,3),WDOT(200,3,5),W(200,3,5)
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
C
C******** SELECT AVERAGE RAINFALL DURING TIME INTERVAL
C
      TIME2=TIME-DELT2
      IND=1.+(TIME2-TZERO)/HISTOG
C
C******** BEGIN MAJOR LOOP FOR WSHED
C
      DO 320 J=1,NOW
      RI=0.
      NGAG=NHYET(J)
      IF(TIME2.LE.TRAIN) RI=RAIN(IND,NGAG)
      IF(RI.LE.0) GO TO 70
      IF(TIMEW(J).GT.0.)GO TO 60
      TIMEW(J)=0.5*DELT
      GO TO 70
60    TIMEW(J)=TIMEW(J)+DELT
70    DELR=0.
      NCA=NC(J)
      DO 315 K=1,NCA
      WFLO(J,K)=0.
      WFLOT=0.
      WAR=WAREA(J,K)
      IF(K.GT.1) WFLOT=WFLO(J,K-1)/WAR
      JTYP=WTYPE(J,K)
      IF(JTYP) 201,201,205
201   RLOSS=0.
      GO TO 220
205   IF(RAININ(J,K).LT.DEPIN(JTYP)) GO TO 206
      RLOSS=0.0
      GO TO 220
206   RLOSS=WLMIN(JTYP)
C
C******** COMPUTE AVERAGE INFILTRATION DURING TIME INTERVAL
C
      EXPON=DECAY(JTYP)*TIMEW(J)
      IF(EXPON.LE.60) RLOSS=RLOSS+(WLMAX(JTYP)-WLMIN(JTYP))
     2/EXP(EXPON)
```

```
      IF((RI-RLOSS+WFLOT)*DELT+WDEPTH(J,K).GT.0.) GO TO 220
C
C**** INFILTRATION LOSS EXCEEDS AVAILABLE WATER
      RLOSS=RI+WFLOT+WDEPTH(J,K)/DELT
      WDEPTH(J,K)=0.
      WFLO(J,K)=0.
      GO TO 310
C
C******** COMPUTE CHANGE IN DEPTH (NEWTON-RAPHSON)
C
220   IF((RI-RLOSS+WFLOT)*DELT+WDEPTH(J,K).LE.WSTORE(J,K)) GO TO 285
      DO 260 I=1,11
      D0=WDEPTH(J,K)-WSTORE(J,K)+0.5*DELR
      IF(D0.LT.0.) D0=0.
      F=DELR-DELT*(WCON(J,K)*D0**1.6666667+(RI-RLOSS+WFLOT))
      DF=1.-DELT*(0.83333333*WCON(J,K)*D0**0.6666667)
      DEL=DELR-F/DF
      IF(I.EQ.1) GO TO 240
      IF((ABS(DEL-DELR)).LT.(ABS(0.01*DELR))) GO TO 280
240   DELR=DEL
260   CONTINUE
      IF(DELR.LT..0001*WDEPTH(J,K)) GO TO 280
      WRITE(N6,1000) TIME,J,WDEPTH(J,K),DELR
1000  FORMAT(* CHECK RESULTS. NO CONVERGENCE IN WSHED *,F8.0,I6
     2,2E12.5)
280   DCORR=WDEPTH(J,K)+DEL
      DELR=0.
C
C******** AVERAGE FLOW DURING TIME INTERVAL
C
      WFLO(J,K)=(WFLOT+RI-RLOSS)*WAR-(DCORR-WDEPTH(J,K))*WAR/DELT
      IF(WFLO(J,K).GT.0.) GO TO 290
285   WFLO(J,K)=0.
      DCORR=WDEPTH(J,K)+(RI-RLOSS+WFLOT)*DELT
C
C******** TRANSFER DEPTH FOR NEXT TIME INTERVAL
C
290   WDEPTH(J,K)=DCORR
C
C******** SUM TO CHECK CONTINUITY AND LIMIT OF INFILTRATION
C
310   RAININ(J,K)=RAININ(J,K)+RLOSS*12.*DELT
      DORG=AMAX1(0.,RI-RLOSS)
      SUMR=SUMR+RI*DELT*WAR
      SUMI=SUMI+RLOSS*DELT*WAR
      IF(NQS.GT.0) CALL QSHED2(J,K,DORG)
315   CONTINUE
      WFLOW(J)=WFLO(J,NCA)
320   CONTINUE
      RETURN
      END
```

Subroutine SUMSAT

This routine summarizes the simulation results. For surface channels and gutters, full flow, velocity, depth, and flow spread are printed. The simulation results are presented for each channel and gutter in terms of maximum computed flow, velocity, and depth and their time of occurrence. The computational sequence is presented in flowchart form in Figure IV-14. Key variables not contained in the following common blocks employed in the routine are presented in Table IV-11:

- BLANK COMMON
- MAX
- NEW
- MISC

The computer listing follows.

Subroutine CARRY

This subroutine is called from Subroutine GUTTER to compute the carryover for the inlet immediately upstream of the gutter or channel section considered. Subroutine CARRY employs the following common blocks:

- BLANK COMMON
- SYS
- LOC
- INLET
- ROUT
- COEFI

For zero gutter/channel depth, the carryover flow is set to zero. For nonzero gutter/channel depth, the hydraulic conditions at the inlet are calculated based on the depth. For inlets on grade, the appropriate design equations based on inlet type, efficiency curves supplied as input, or efficiency curves from Block Data are used to determine the carryover. When efficiency curves supplied as input are used, the subroutine will select and use the appropriate curve based on longitudinal slope and cross-slope

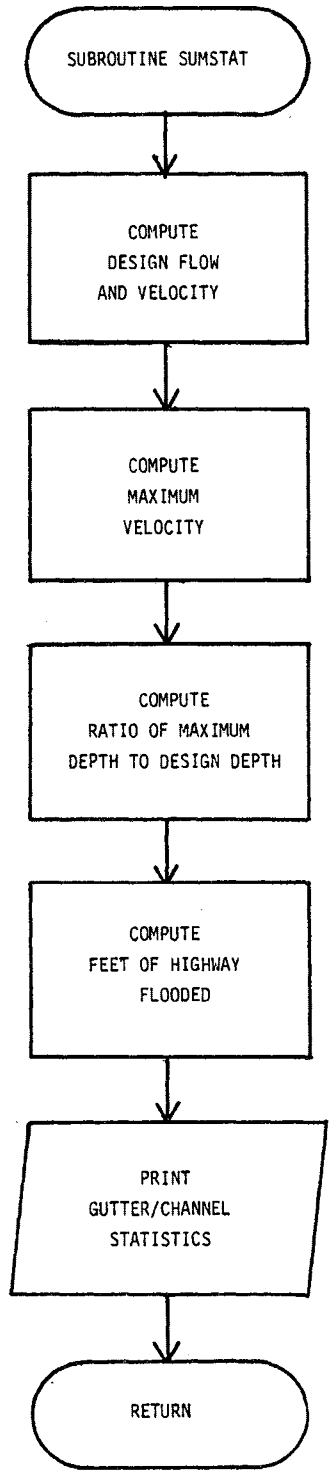


FIGURE IV-14. Flowchart of Subroutine SUMSTAT

TABLE IV-11

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE SUMSTAT

Fortran Variable	Description	Units
DR	Ratio of maximum computed depth to design depth	-
R	Fraction of maximum depth at design flow spread	-
FHF	Feet of highway flooded	ft
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
DSF	Maximum computed flow spread	ft

```
          SUBROUTINE SUMSTAT
          COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
         1 TIME,TIME2,RI,RLOSS,TZERC,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
          COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
         2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
         3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
          COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
         2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMGW(150),
         3NGUT(200),PCTZER,NPG(150),SPMAX(150)
          COMMON DELD(150),GIN(150),GSUR(150)
          COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
          COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
          COMMON IPRNT(150),ISAVE(150),NPRNT,NSAVE,OUTFLW(150),INTERV,
         2INTCNT,TITLE(40),IPLOT(150),ICODE(150),NPLOT
          COMMON/TAPES/JIN(1),JOUT(3),N5,N6
          COMMON/NEW/NAMEG(150),NGTO(200),BASFLO(3),DVDT(3),ABAR(3),
         1            GDEPT(3),GI(3),VOL1(150),VOL2(150),XFLOW(150),
         2            NGSTO(200),NGSUR(150),QINLET(150),PINLET(150,13),
         3            ISAVE2(150),INLET2,AREALK(3),VOLMLK(3),LKHYET(3),
         4            OVRDEP(3),OVRWTH(3),OVRGS1(3),OVRGS2(3),OVRGN(3),
         5            OVRDFL(3),OVRCON(3),JOVER(3),TWIDTH(13),SUMRL,SUMGWI
          REAL MAXFLW,MAXDEP
          COMMON/MAX/MAXFLW(150),MAXHR(150),MAXMIN(150),MAXDEP(150),
         2SURLEN(150)
          COMMON/MISC/XSLOPE(150),MGTO(200),
         2ISTA1A(150),ISTA1B(150),ISTA2A(150),ISTA2B(150),
         3ELEVA1(150),ELEVA2(150),NOGUTTR,DSG,DSC
C
C******** COMPUTE SUMMARY STATISTICS FOR ABOVE-GROUND CHANNELS
C
          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,40H****
         4                    ****,8X,*CAMP DRESSER AND MCKEE             */* *
         5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
         6**,8X,*ANNANDALE, VIRGINIA  *)
          WRITE(N6,300)
 300      FORMAT(///* *,38X,*SUMMARY STATISTICS FOR ABOVE-GROUND GUTTERS/CHA
         2NNELS*/* *,38X,52(*=*)//)
          IF(IMET.EQ.0) GO TO 302
C
C**** METRIC HEADING
          WRITE(N6,301)
 301      FORMAT(* *,52X,*DESIGN*,4X,4(3X,*MAXIMUM*),4X,*TIME*/* *,2X,*GUTTE
         2R/*,5X,*DESIGN*,2(7X,*DESIGN*),7X,*FLOW*,5X,4(2X,*COMPUTED*),5X,*O
         3F*/* *,2X,*CHANNEL*,6X,*FLOW*,7X,*VELOCITY*,7X,*DEPTH*,6X,*SPREAD*
         4,8X,*FLOW*,4X,*VELOCITY*,4X,*DEPTH*,4X,*SPREAD*,2X,*OCCURENCE*,7X,
         5        /* *,2X,*NUMBER*,7X,*(CMS)*,8X,*(M/S)*,2(8X,*(M.)*),9X,*(C
         6MS)*,4X,*(M/S)*,5X,*(M.)*,6X,*(M.)*,3X,*HR.  MIN.*/* *,2X,6(*-*),6
         7X,6(*-*),6X,8(*-*),2(6X,6(*-*)),6X,48(*-*)/)
          GO TO 201
C
C**** BRITISH UNITS HEADING
```

```
302   WRITE(N6,303)
303   FORMAT(* *,52X,*DESIGN*,4X,4(3X,*MAXIMUM*),4X,*TIME*/* *,2X,*GUTTE
     2R/*,5X,*DESIGN*,2(7X,*DESIGN*),7X,*FLOW*,5X,4(2X,*COMPUTED*),5X,*O
     3F*/* *,2X,*CHANNEL*,6X,*FLOW*,7X,*VELOCITY*,7X,*DEPTH*,6X,*SPREAD*
     4,8X,*FLOW*,4X,*VELOCITY*,4X,*DEPTH*,4X,*SPREAD*,2X,*OCCURENCE*,7X,
     5          /* *,2X,*NUMBER*,7X,*(CFS)*,8X,*(FPS)*,2(8X,*(FT)*),9X,*(
     6CFS)*,5X,*(FPS)*,5X,*(FT)*,6X,*(FT)*,3X,*HR.  MIN.*/* *,2X,6(*-*),
     76X,6(*-*),6X,8(*-*),2(6X,6(*-*)),6X,48(*-*)/)
C
C**** DESIGN FLOW AND VELOCITY
201   IF(NPG(I).EQ.3) GO TO 250
      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(NN)**2))
      GO TO 260
250   GA=0.7854*DFULL(I)**2.
      GP=3.1416*DFULL(I)
260   GR=GA/GP
      GV=1.486/GN(I)*SQRT(GSLOPE(I))*GR**0.6666667
      GQ=GA*GV
C
C**** COMPUTE MAXIMUM FLOW FOR RUN
      IF(NPG(I).EQ.3) GO TO 270
      GAA=MAXDEP(I)*(GWIDTH(I)+C.5*MAXDEP(I)*(GS1(I)+GS2(I)))
      GO TO 280
270   GAA=(GWIDTH(I)**2/4.)*(MAXDEP(I)-0.5*SIN(2.*MAXDEP(I)))
280   GVV=MAXFLW(I)/GAA
C
C**** PRINT GUTTER/CHANNEL STATISTICS
      FSP=GWIDTH(I)+MAXDEP(I)*(GS1(I)+GS2(I))
      IF(IMET.EQ.0) GO TO 400
C
C**** METRIC OUTPUT
      GQ=GQ/35.3
      GV=GV/3.281
      MAXFLW(I)=MAXFLW(I)/35.3
      GVV=GVV/3.281
      SPMAX(I)=SPMAX(I)/3.281
      FSP=FSP/3.281
      DFULL(I)=DFULL(I)/3.281
      MAXDEP(I)=MAXDEP(I)/3.281
400   IF(NPG(I).EQ.1) GO TO 420
      WRITE(6,410) NAMEG(I),GQ,GV,DFULL(I),MAXFLW(I),GVV,MAXDEP(I),MAXH
     2R(I),MAXMIN(I)
410   FORMAT(* *,3X,I4,7X,F6.2,7X,F6.2,8X,F4.2,9X,*-*,9X,F6.2,4X,F6.2,5X
     2,F4.2,7X,*-*,4X,I3,3X,I2)
      GO TO 100
420   WRITE(N6,430) NAMEG(I),GQ,GV,DFULL(I),SPMAX(I),MAXFLW(I),GVV,
     2MAXDEP(I),FSP,MAXHR(I),MAXMIN(I)
430   FORMAT(* *,3X,I4,7X,F6.2,7X,F6.2,8X,F4.2,7X,F4.1,8X,F6.2,4X,F6.2,
     25X,F4.2,5X,F4.1,3X,I3,3X,I2)
100   CONTINUE
      RETURN
      END
```

in the case of gutters and on longitudinal slope in the case of channels. The user may also elect the option whereby efficiency curves are built into the program in Block Data. In that case, the appropriate curve is selected from Block Data.

Key variables not in common are shown in Table IV-12, followed by a listing of this subroutine.

Variables in Common

Program SRO employes 15 separate common blocks as listed below:

- LAB
- ABLK
- CON
- BLANK COMMON
- NEW
- POLUT
- INFIL
- REMOVE
- TEST
- TAPES
- MAX
- INLET
- MISC
- SLOPES
- NOMOG

The variables contained in each block are presented in Tables IV-13 through IV-27, respectively.

TABLE IV-12

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE CARRY

Fortran Variable	Description	Units
ALOCUS	Gutter Flow Area	ft^2 or m^2
C	Flow for Inlets in Gutters	cfs or cms
	Flow Depth for Inlets in Channels	ft or m
DDES	Gutter Flow Depth for Sump Inlet	ft or m
DQ	Gutter Flow Depth for Inlets on Grade	ft or m
FW	Izzard Froude No. for Depressed Curb Inlets	-
GLMAX	Izzard Depressed Curb Opening Maximum Length for Weir Phase	ft or m
GL1	Izzard Depressed Curb Opening Length One	ft or m
GL1ØØ	Izzard Depressed Curb Opening Length for 100% Interception	ft or m
IZTRP	Flag for Extrapolation Beyond Last Point on Inlet Efficiency Curve	-
QC	Carryover	cfs or cms
QI	Intercepted Flow	cfs or cms
Q	Gutter Flow to Inlet	cfs or cms
SX	Gutter Cross Slope at Inlet (Side Slope 1)	ft/ft or m/m
VLOCUS	Gutter Flow Velocity at Inlet	fps or mps
WLOCUS	Gutter Flow Spread at Inlet	ft or m
WP	Wetted Perimeter of Gutter Flow at Inlet	ft or m

```
      SUBROUTINE CARRY(DG,ISUMP,N,GI,GC)
      COMMON NW,NG,NIN,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     1 TIME,TIME2,RI,RLOSS,TZEPC,SUMR,SUMI,SUMOFF,SUMST,NING,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WSTORE(200,3),
     2WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200),WLMAX( 5 ),
     3WLMIN( 5 ),DECAY( 5 ),PCIMP(200)
      COMMON GFLOW(150),GWIDTH(150),GLEN(150),GSLOPE(150),GS1(150),
     2GS2(150),GN(150),GDEPTH(150),GCON(150),DFULL(150),SUMQW(150),
     3NGUT(200),PCTZER,NPG(150),SPMAX(150)
      COMMON DELD(150),GIN(150),QSUR(150)
      COMMON NWTOG(200,10),NGTOG(200,10),NWTOI(10 ),NGTOI(200)
      COMMON RAIN(100,13),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON/INLET/ITYPG,ITYPC,       W,A,CW,CORF,WS,AS,GLI,GLIC,GLIS,RD
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMC,       QINLG(4,6,12),
     2DINLG(12,6,4),                QINLC(6,12),DINLC(12,6)
      COMMON/TAPES/JIN(1),JOUT(3),N5,N6
C
C******** TEST FOR ZERO DEPTH
C
      Q=0.
      IF(DG.LT.1.E-5) GO TO 6009
C
C******** DETERMINE GUTTER HYDRAULIC CONDITIONS BASED ON GUTTER DEPTH
C
      WLOCUS=GWIDTH(N)+DG*(GS1(N)+GS2(N))
      ALOCUS=0.5*(GS1(N)+GS2(N))*DQ**2+GWIDTH(N)*DQ
      WP=SQRT(1.+GS1(N)**2)+SQRT(1.+GS2(N)**2)
      WP=WF*DQ+GWIDTH(N)
      Q=GCON(N)*(ALOCUS**1.6666667)/(WP**.6666667)
      VLOCUS=Q/ALOCUS
C
C******** IF SUMP INLET, GO TO SUMP INLET PORTION OF SUBROUTINE
C
      IF(ISUMP.GT.0) GO TO 9000
C
C******** DETERMINE IF INLET IS IN GUTTER OR CHANNEL
C
      IF(NPG(N).EQ.1) GO TO 5
C
C**** INLETS IN CHANNELS
      IF(INOMC.NE.2) GO TO 500
      GO TO (10,28,30,40,50,60),ITYPC
C
C**** INLETS IN GUTTERS
5     IF(INOMG.NE.2) GO TO 500
      GO TO (10,20,30,40,50,60),ITYPG
C
C******* EQUATION FOR UNDEPRESSED CURB OPENINGS
C
10    WRITE(N6,1010) TITLE
1010  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,40H**
     2**  URBAN HIGHWAY DRAINAGE MODEL   ****,8X,*WATER RESOURCES DIVISIC
     3N */* *,*DEPARTMENT OF TRANSPORTATION*,16X,40H****
     4                  ****,8X,*CAMP DRESSER AND MCKEE               */* *
     5,*WASHINGTON, D.C.*,28X,4H****,6X,*SURFACE RUNOFF PROGRAM*,6X,4H**
     6**,8X,*ANNANDALE,VIRGINIA    *//1X,20A4/)
```

```
      WRITE(N6,15)
15    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR UNDEPRESSED C
     2URB OPENING INLETS *,/,40X,* HAS NOT YET BEEN PROGRAMMED.  THE USE
     3R MAY :*)
      WRITE(N6,18)
18    FORMAT(*0*,45X,* 1) SUPPLY AN INLET CAPACITY NOMOGRAPH AS INPUT
     2          *,/,45X,* 2) SUPPLY AN INLET CAPACITY NOMOGRAPH IN THE BLO
     3CK DATA*,/,40X,* SECTION OF THE PROGRAM           *,/,45X,* 3) PRO
     4GRAM AN INLET CAPACITY EQUATION IN SUBROUTINE CARRY          *)
      STOP
C
C******** IZZARD DESIGN EQUATIONS FOR DEPRESSED CURB OPENINGS IN GUTTERS
C******** H=0.5 FT AND A=W/12 FT
C
20    IF(GS1(N).NE.0) GO TO 22
      WRITE(N6,21)
21    FORMAT(*0*,////,40X,* ... ERROR IN SUBROUTINE CARRY ... *,/,40X,
     2*GS1=0 (I.E., VERTICAL) BUT SHOULD BE EQUAL TO RECIPROCAL CROWN SL
     3OPE*,/,40X,*OF HIGHWAY. CHECK INPUT GUTTER CHARACTERISTICS.*)
      STOP
22    SX=1./GS1(N)
      IF(WLOCUS.LE.W) GO TO 6109
      FW=.262*SQRT(GSLOPE(N))/GN(N)*((WLOCUS-W)*SX)**.16666667
      GL1=2.79*FW*WLOCUS/W**.16666667*SX**.294
      GLMAX=3.67*FW*WLOCUS/W**.16666667*SX**.5
      GL100=1.85*FW*WLOCUS/W**.16666667
      IF(GLI.GE.GLMAX) GO TO 25
      QI=Q*(GLI/GL1)
26    QI=AMIN1(QI,Q)
      QC=Q-QI
      RETURN
25    QI=Q*(GLI/GL100)**0.4
      GO TO 26
28    WRITE(N6,29)
29    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR DEPRESED CURB
     2 OPENING INLETS IN CHANNELS*,/,40X,* HAS NOT YET BEEN PROGRAMMED.
     3THE USEP MAY:*)
      WRITE(N6,18)
C
C******** EQUATION FOR UNDEPRESSED GRATE OPENING INLETS
C
30    WRITE(N6,1010) TITLE
      WRITE(N6,35)
35    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR UNDEPRESSED G
     2RATE OPENING INLETS*,/,40X,* HAS NOT YET BEEN PROGRAMMED. THE USER
     3 MAY :*)
      WRITE(N6,18)
      STOP
C
C******** EQUATION FOR DEPRESSED GRATE OPENING INLETS
C
40    WRITE(N6,1010) TITLE
      WRITE(N6,45)
45    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR DEPRESSED GRA
     2TE OPENING INLETS*,/,40X,* HAS NOT YET BEEN PROGRAMMED. THE USER M
     3AY :*)
      WRITE(N6,18)
```

```
      STOP
C
C******** EQUATION FOR UNDEPRESSED COMBINATION INLETS
C
50    WRITE(N6,1010) TITLE
      WRITE(N6,55)
55    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR UNDEPRESSED C
     2OMBINATION INLETS*,/,40X,* HAS NOT YET BEEN PROGRAMMED. THE USER M
     3AY :*)
      WRITE(N6,18)
      STOP
C
C******** EQUATION FOR DEPRESSED COMBINATION INLETS
C
60    WRITE(N6,1010) TITLE
      WRITE(N6,65)
65    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR DEPRESSED COM
     2BINATION INLETS*,/,40X,* HAS NOT YET BEEN PROGRAMMED. THE USER MAY
     3 :*)
      WRITE(N6,18)
      STOP
C
C******** ON-GRADE INLET CAPACITY TO BE COMPUTED FROM USER-SUPPLIED
C******** NOMOGRAPH
C
500   IF(NPG(N).GT.1) GO TO 512
C
C**** SELECT NOMOGRAPH BY CROSS-SLOPE AND GUTTER/CHANNEL SLOPE
      IF(GS1(N).NE.0) GO TO 501
      WRITE(N6,21)
      STOP
501   SX=1/GS1(N)
      C=Q
5000  DO 505 I=1,4
505   CSLOP(I)=1./FLOAT(ISLOP(I))
C
C**** CROSS-SLOPE (GUTTERS ONLY)
      CMID=CSLOP(1)+((CSLOP(2)-CSLOP(1))/2.)
      IF(SX.LT.CMID) I=1
      DO 510 II=2,3
      CMID1=CSLOP(II-1)+((CSLOP(II)-CSLOP(II-1))/2.)
      CMID2=CSLOP(II)+((CSLOP(II+1)-CSLOP(II))/2.)
      IF(SX.GE.CMID1.AND.SX.LT.CMID2) I=II
510   CONTINUE
      CMID=CSLOP(3)+((CSLOP(4)-CSLOP(3))/2.)
      IF(SX.GE.CMID) I=4
      GO TO 511
512   I=1
      C=DG
C
C**** GUTTER/CHANNEL SLOPE
511   CMID=SLOP(1)+((SLOP(2)-SLOP(1))/2.)
      IF(GSLOPE(N).LT.CMID) J=1
      DO 515 JJ=2,5
      CMID1=SLOP(JJ-1)+((SLOP(JJ)-SLOP(JJ-1))/2.)
      CMID2=SLOP(JJ)+((SLOP(JJ+1)-SLOP(JJ))/2.)
      IF(GSLOPE(N).GE.CMID1.AND.GSLOPE(N).LT.CMID2) J=JJ
```

```
  515 CONTINUE
      CMID=SLOP(5)+((SLOP(6)-SLOP(5))/2.)
      IF(GSLOPE(N).GE.CMID) J=6
C
C**** INTERPOLATE IF NECESSARY, GUTTER CURVES
      IXTRP=0
      IF(NFG(N).GT.1) GO TO 650
      DO 600 K=1,6
      KK=K*2
      IF(C.EQ.QINLG(I,J,KK)) QI=(QINLG(I,J,KK-1))*Q
      IF(C.EQ.QINLG(I,J,KK)) GO TO 610
      IF(K.EQ.6) GO TO 590
      IF(C.GT.QINLG(I,J,KK).AND.C.LT.QINLG(I,J,KK+2)) GO TO 550
      GO TO 600
  550 Q1=QINLG(I,J,KK)
      Q2=QINLG(I,J,KK+2)
      QI1=QINLG(I,J,KK-1)
      QI2=QINLG(I,J,KK+1)
      QI=((QI2-QI1)*((C-Q1)/(Q2-Q1))+QI1)*Q*RD
      GO TO 610
  590 IXTRP=1
  600 CONTINUE
  610 CONTINUE
C
C**** EXTRAPOLATE IF NECESSARY
      IF(IXTRP.EQ.0) GO TO 700
      IF(QINLG(I,J,11).LE.0.30) QI=QINLG(I,J,11)*Q*RD
      IF(QINLG(I,J,11).GT.0.30) QI=(QINLG(I,J,11)-0.1)*Q*RD
  700 GC=Q-QI
      RETURN
C
C**** INTERPOLATE IF NECESSARY, CHANNEL CURVES
  650 DO 680 K=1,6
      KK=K*2
      IF(C.EQ.QINLC(J,KK)) QI=(QINLC(J,KK-1))*Q
      IF(C.EQ.QINLC(J,KK)) GO TO 690
      IF(K.EQ.6) GO TO 670
      IF(C.GT.QINLC(J,KK).AND.C.LT.QINLC(J,KK+2)) GO TO 660
      GO TO 680
  660 Q1=QINLC(J,KK)
      Q2=QINLC(J,KK+2)
      QI1=QINLC(J,KK-1)
      QI2=QINLC(J,KK+1)
      QI=((QI2-QI1)*((C-Q1)/(Q2-Q1))+QI1)*Q*RD
      GO TO 690
  670 IXTRP=1
  680 CONTINUE
  690 CONTINUE
C
C**** EXTRAPOLATE IF NECESSARY
      IF(IXTRP.EQ.0) GO TO 695
      QI=(QINLC(J,KK-1))*Q*RD
      IF(QINLC(J,KK-1).GT..30) QI=QI-0.1*Q*RD
```

```
      695  QC=Q-QI
           RETURN
     9000  CONTINUE
     6009  QI=Q

           QC=0.
           RETURN
           END
```

TABLE IV-13

COMMON BLOCK LAB

Fortran Variable	Description	Units
HORIZ	Curve label for x-axis	None
IT	Internal control variable subroutine HCURVE (PPLOT)	None
TITLE	Title printed out with graphs	None
VERT	Curve label for y-axis (British units)	None
XLAB	Numerical scale labels for x-axis	None
YLAB	Numerical scale labels for y-axis	None
VERTM	Curve label for y-axis (metric units)	None

TABLE IV-14

COMMON BLOCK ABLK

Fortran Variable	Description	Units
C	Concentration of conservative constituent in channel	g/l
CDOT	Internal variable, time derivative of concentration	g/l/sec
CLFREQ	Interval between maintenance	days
DRYDAY	Number of dry days prior to storm	days
NQS	Number of quality constituents	None
POFF	Rate of mass runoff, later concentration	g/sec,mg/l
PSHED	Mass of suspended solids on watershed subarea	grams
QFACT	mg constituent per g of suspended solids	mg/gram
REFF	Fraction of suspended solids removed by maintenance	None
SSFACT	Suspended solids ultimate load (half saturation constants)	lbs/days

TABLE IV-15

COMMON BLOCK CON

Fortran Variable	Description	Units
ICTTL	Constituent title array	None

TABLE IV-16

BLANK COMMON

Variable Name	Description	Unit
DECAY	Exponential decay rate for infiltration	1/sec
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
DUMMY[2]	Dummy variable	none
FLOW[3]	Hydrograph flow value	cfs
FLOWOT[3]	Temporary variable for printing flow	cfs
GCON	Manning's equation less hydraulic radius	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
HGRAPH[1]	Magnitude of variable to be printed in vertical coordinate of the curve	None
HISTOG	Time interval between hyetograph input values	sec
HTIME[1]	Time interval to be printed in the horizontal coordinate of the curve	none
IPLOT	External numbers of channels and inlets to be plotted	none
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
IMET	Units option flag	none

TABLE IV-16
(cont.)

Variable Name	Description	Unit
ISAVE	External numbers of inlets for which hydrographs will be saved	none
NAMEW	External number of watershed	none
ICODE	Plot control integer, zero means no plot, one means plot	none
NG	Maximum number of channels	none
NGTOC	Channel connections	none
NGTOI	Sump inlet connections	none
NGUT	Array ordering channels from upstream to downstream	none
NHISTO	Number of rainfall time intervals	none
NHR[3]	Hour for hydrograph output	hr
NHYET	Internal number of hyetograph applied to subarea	none
NIN	Maximum number of channels draining to channel, and watersheds draining to channel	none
NING	Maximum number of channels draining to sump inlets	none
NLOC[4]	Node number of hydrograph point	none
NOG	Total number of channels	none
NOW	Total number of watersheds	none
NPG	Control switch for type of channel	none
NPLOT	Number of inlets and channels to be plotted	none
NPRNT	Number of inlets and channels to be printed	none
NPT[4]	Number of points to be plotted	none
NRGAG	Number of hyetographs	none
NSAVE	Number of inlets	none
NSTEP	Number of time steps in simulation	none
NW	Maximum number of watersheds	none

TABLE IV-16
(cont.)

Variable Name	Description	Unit
NWTOG	Channel connection	none
NWTOI	Sump inlet connection	none
OUT[3]	Temporary variable for printing concentration	mg/l
OUTFLW	Flow out of the channel	cfs
QUAL[3]	Concentration of quality constituents	mg/l
QIN	Inflow to channel	cfs
QSUR	Surcharge volume	ft^3
RAIN	Rainfall rates	in/hr & ft/sec
RI	Rainfall rate for the time step	ft/sec
RLOSS	Infiltration loss	ft/sec
SUMI	Total infiltration into ground	ft^3
SUMOFF	Total channel flow @ inlets	ft^3
SUMQW	Total flow for each watershed	ft^3
SUMR	Total rainfall	ft^3
SUMST	Total watershed storage	ft^3
TAREA	Total area of watershed	acres
THISTO	Duration of rainfall time intervals	min
TIME	Current time	sec
TIME2	Current time minus half step	sec
TITLE[2]	Description of problem	none
TMIN[3]	Minutes for hydrograph output	min
TRAIN	Time when rainfall ends	min,sec
TZERO	Starting time of simulation	sec
WAREA	Area of subarea	acres, sq.ft
WCON	Modified Manning's coefficients	none
WDEPTH	Depth of flow on subarea	ft

TABLE IV-16
(cont.)

Variable Name	Description	Unit
WFLOW	Flow off watershed	cfs
WLMAX	Maximum infiltration rate	in/hr
WLMIN	Minimum infiltration rate	in/hr
WSLOPE	Average slope of subarea	ft/ft
WSTORE	Depression storage on surface of subarea	ft
WWIDTH	Average width of watershed	ft
X[4]	X coordinate array for plots	
Y[4]	Y coordinate array for plots	
YS[4]	Data file information for plots	
YT[4]	Data file information for plots	

[1]Used only in HCURVE and HYDRO

[2]Used only in HCURVE

[3]Used only in RECAP

[4]Used only in GRAPH

TABLE IV-17

COMMON BLOCK NEW

Fortran Variable	Description	Units
AREALK	Surface area of detention basin	ft^2
INLET2	Number of inputs read from tape	none
ISAVE2	External numbers of input channels read from tape	none
JOVER	Internal number of overbank channel	none
LKHYET	Internal raingage number for detention basin	none
NAMEG	External number of channel	none
NGSTO	External number of inlet	none
NGSUR	Internal number of channel receiving overflows	none
NGTO	External number of channel to which subarea drains	none
OVRCON	Manning's equation for overbank channel, less hydraulic radius	none
OVRDEP	Depth of flow in overbank channel	feet
OVRDFL	Full depth of overbank channel	feet
OVRGN	Manning's n of overbank channel	none
OVRGS1	Left-hand side slope of overbank channel	none
OVRGS2	Right-hand side slope of overbank channel	none
OVRWTH	Bottom width of overbank channel	feet
PINLET	Input loadagraph	cfs x g/l
QI	Flow off watersheds into channel during time step	cfs
QINLET	Input hydrograph	cfs
SUMRL	Sum of volume of rain on detention basin	ft^3
TWIDTH	Top width of base channel	feet
VOLMLK	Volume of detention basin	ft^3
VOL1	Volume of water in channel at start of simulation	ft^3

TABLE IV-17
(cont.)

Fortran Variable	Description	Units
VOL2	Volume of water in channel at end of simulation	ft^3
XFLOW	Intercepted flow for inlets on grade	cfs

TABLE IV-18

COMMON BLOCK POLUT

Fortran Variable	Description	Units
WFLO	Watershed subarea outflow	cfs
WDOT	Derivative of watershed subarea concentration with respect to time	gm/l/sec
W	Watershed subarea concentration	gm/l

TABLE IV-19

COMMON BLOCK INFIL

Fortran Variable	Description	Units
DEPIN	Maximum allowable infiltration	inches
RAININ	Summation of infiltration	inches
TIMEW	Time for infiltration rate decay	sec
WTYPE	Watershed subarea surface type	none
NC	Number of subareas in each watershed	none

TABLE IV-20

COMMON BLOCK REMOVE

Fortran Variable	Description	Units
DET	Detention time for 50% suspended solids removal	hrs

TABLE IV-21

COMMON BLOCK TEST

Fortran Variable	Description	Units
SUMTI	Watershed load to drainage system	Kg

TABLE IV-22

COMMON BLOCK TAPES

Fortran Variable	Description	Units
JIN	Input tape number array	None
JOUT	Output tape number array	None
N5	Input device number	None
N6	Output device number	None

TABLE IV-23

COMMON BLOCK MAX

Fortran Variable	Description	Units
MAXFLW	Maximum computed flow	cfs
MAXHR	Time of maximum computed depth	hrs
MAXMIN	Time of maximum computed depth	min
MAXDEP	Maximum computed depth	ft
SURLEN	Length of surcharge	hr

TABLE IV-24

COMMON BLOCK INLET

Fortran Variable	Description	Units
ITYPG	Inlet type in gutters	None
ITYPC	Inlet type in channels	None
ITYPS	Inlet type in sump	None
W	Grate width for inlets on grade	ft
A	Depression depth for inlets on grade	ft
CW	Weir coefficient	$ft^{1/2}/sec$
CORF	Orifice coefficient	None
WS	Grate width for inlets in sump	ft
AS	Depression depth for inlets in sump	ft
GLI	Inlet length in gutters	ft
GLIS	Inlet length in sump	ft
GLIC	Inlet length in channels	ft
RD	Inlet capacity reduction factor	None

TABLE IV-25

COMMON BLOCK MISC

Fortran Variable	Description	Units
ISTA1A	Station number 1 (hundreds)	ft
ISTA1B	Station number 1 (units)	ft
ISTA2A	Station number 2 (hundreds)	ft
ISTA2B	Station number 2 (units)	ft
ELEVA1	Elevation at station 1	ft
ELEVA2	Elevation at station 2	ft
NOGUTTR	Number of channels/gutters	None

TABLE IV-26

COMMON BLOCK SLOPES

Fortran Variable	Description	Units
ISLOP	Reciprocal of highway cross-slope	None
SLOP	Gutter/channel longitudinal slope	None
CSLOP	Highway cross-slope	None

TABLE IV-27

COMMON BLOCK NOMOG

Fortran Variable	Description	Units
INOMG	Gutter inlet simulation option	None
INOMC	Channel inlet simulation option	None
INOMS	Sump inlet simulation option	None
QINLG	Gutter inlet efficiency curves	--
QINLS	Sump inlet efficiency curves	--
DINLG	Gutter inlet efficiency curves in Block Data	--
DINLS	Sump inlet efficiency curves in Block Data	--
QINLC	Channel inlet efficiency curves	--
DINLC	Channel inlet efficiency curves in Block Data	--

EXAMPLE PROBLEM

The remainder of this chapter presents the input and output from an example problem. The simulated area includes approximately 2500 feet of highway and 8.5 acres of contributory drainage area.

A schematic diagram of the example problem's prototype is shown in Figure IV-15. The input data for the problem is given as Exhibit IV-1; output from the example problem follows as Exhibit IV-2.

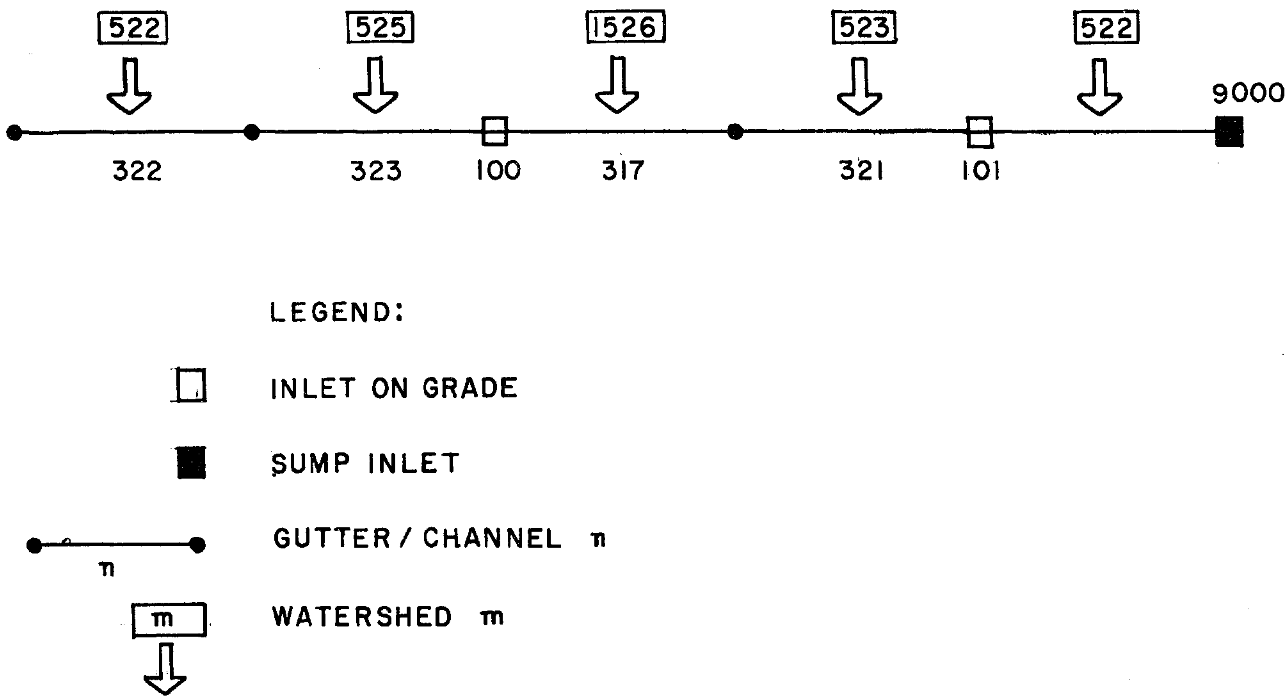


FIGURE IV-15. Program SRO
Test Problem

1

```
  0  10  11   0
FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM
   1  200 2345   1.    1
```

2

```
  24   5.
       0.43       0.47       0.53       0.50       0.76
       1.02       1.63       5.50       3.26       2.13
       1.43       1.05       0.85       0.77       0.74
       0.55       0.57       0.55       0.51       0.49
       0.46       0.44       0.42       0.41
```

3

```
          4
         5.0       0.70       4.32      10.0
         3.5       0.65       4.32      10.0
         2.9       0.55       4.32      12.0
         3.2       0.60       4.32      10.0
```

4

```
          4          4          0          0
  1.   0.   1.   1.   1.   2.   1.    4.   .86   6.   .56   10.
  1.   0.   1.   1.   1.   2.   1.    4.   .83   6.   .55   10.
  1.   0.   1.   1.   1.   2.   1.    4.   .78   6.   .51   10.
  1.   0.   1.   1.   1.   2.   1.    4.   .73   6.   .48   10.
  1.   0.   1.   1.   1.   2.   .94   4.   .71   6.   .47   10.
  1.   0.   1.   1.   1.   2.   .89   4.   .68   6.   .40   10.
  1.   0.   1.   1.   1.   2.   1.0   4.   .88   6.   .62   10.
  1.   0.   1.   1.   1.   2.   1.0   4.   .86   6.   .57   10.
  1.   0.   1.   1.   1.   2.   1.0   4.   .79   6.   .53   10.
  1.   0.   1.   1.   1.   2.   1.0   4.   .76   6.   .50   10.
  1.   0.   1.   1.   1.   2.   .94   4.   .71   6.   .48   10.
  1.   0.   1.   1.   1.   2.   .91   4.   .68   6.   .42   10.
  1.   0.   1.   1.   1.   2.   1.0   4.   .93   6.   .63   10.
```

EXHIBIT IV.- 1. Example Problem Data

4

1.	0.	1.	1.	1.	2.	1.0	4.	.90	6.	.59	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.86	6.	.56	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.79	6.	.52	10.
1.	0.	1.	1.	1.	2.	.97	4.	.76	6.	.50	10.
1.	0.	1.	1.	1.	2.	.94	4.	.73	6.	.47	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.96	6.	.65	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.95	6.	.63	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.89	6.	.57	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.83	6.	.54	10.
1.	0.	1.	1.	1.	2.	1.0	4.	.78	6.	.53	10.
1.	0.	1.	1.	1.	2.	.94	4.	.75	6.	.52	10.
1.	0.	1.	.40	1.	.48	1.0	.66	1.	.76	.86	.88
1.	0.	1.	.35	1.	.41	1.0	.55	.92	.65	.78	.73
1.	0.	1.	.29	1.	.35	1.0	.48	.85	.55	.71	.61
1.	0.	1.	.25	1.	.30	.96	.40	.76	.46	.66	.52
1.	0.	1.	.23	1.	.27	.93	.37	.74	.42	.63	.48
1.	0.	1.	.20	1.	.25	.89	.33	.70	.38	.60	.43

1.0

5

322	100 00	101 78	0.0	0.024	48.0	0.0
	323	0	1		14.4	
323	101 78	106 67	0.0	0.016	48.0	0.0
	317	100	1		15.4	
317	106 67	113 03	0.0	0.021	48.0	0.0
	321	0	1		15.4	
321	113 03	119 04	0.0	0.016	48.0	0.0
	320	101	1		14.4	
320	119 04	125 12	0.0	0.016	48.0	0.0
	0	9000	1		14.4	

6

EXHIBIT IV-1 (Continued)

7										
8		524		322		1		0.10	1	178.
		1.0		3.		.08		0.16	0.16	
		525		323		1		0.50	1	489.
		1.0		3.		.03		0.15	0.16	
		523		321		1		1.70	1	601.
		1.0		1.		.02		0.10	0.10	
		1526		317		1		2.70	1	636.
		1.0		2.		.07		0.46	0.37	
		522		320		1		3.40	1	608.
		1.0		4.		.02		0.19	0.18	
9		13		10.		30.		0.5		
10	8	1								
	322	323	317	321	320	100	101	9000		
	0									

EXHIBIT IV-1. (Continued)

```
--------------------------------------------------------------------------------------------------------------------------------
FEDERAL HIGHWAY ADMINISTRATION          **** URBAN HIGHWAY DRAINAGE PROGRAM ****        WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION            ****                                ****        CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                        ****     SURFACE RUNOFF PROGRAM     ****        ANNANDALE, VIRGINA

  ENTRY MADE TO SURFACE RUNOFF PROGRAM


                         TAPE ASSIGNMENTS

         INFLOW TAPE                                        C
         INLET TAPE                                        10
         PRINT TAPE                                        11
         PLOT TAPE                                          0
```

EXHIBIT IV-2. Example Problem Output

```
------------------------------------------------------------------------------------------------------------------------------------
FEDERAL HIGHWAY ADMINISTRATION          ****  URBAN HIGHWAY DRAINAGE MODEL  ****        WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION            ****                                ****        CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                        ****     SURFACE RUNOFF PROGRAM     ****        ANNANDALE,VIRGINIA


                FEDERAL HIGHWAY ADMINISTRATION
                SURFACE RUNOFF TEST PROBLEM


---------------------------------------------- GENERAL INPUT / OUTPUT INFORMATION ----------------------------------------------



                              CARD READER UNIT NO. (N5)= 5

                                PRINTER UNIT NO. (N6)= 6

                                BASIN NUMBER (BASIN)=     1

                           NUMBER OF TIME STEPS (NSTEP)= 200

                 INTEGRATION TIME INTERVAL IN MINUTES (DELT)=  1.00

                              NO. OF RAIN GAGES  (NRGAG)=  1

                           BRITISH UNITS USED. (IMET=0)
```

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION	**** URBAN HIGHWAY DRAINAGE MODEL ****	WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION	**** ****	CAMP DRESSER AND MCKEE
WASHINGTON, D.C.	**** SURFACE RUNOFF PROGRAM ****	ANNANDALE,VIRGINIA

RAINFALL HYETOGRAPH FOR RAIN GAGE NO. 1

TIME HOUR	TIME MINUTES	RAINFALL INTENSITY (INCHES/HOUR)
23	45	.43
23	50	.47
23	55	.53
24	0	.60
24	5	.76
24	10	1.02
24	15	1.63
24	20	5.50
24	25	3.26
24	30	2.13
24	35	1.43
24	40	1.05
24	45	.85
24	50	.77
24	55	.74
25	0	.65
25	5	.57
25	10	.55
25	15	.51
25	20	.49
25	25	.46
25	30	.44
25	35	.42
25	40	.41

Exhibit IV-2
(Continued)

```
FEDERAL HIGHWAY ADMINISTRATION       ****  URBAN HIGHWAY DRAINAGE MODEL  ****    WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION         ****                                ****    CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                     ****     SURFACE RUNOFF PROGRAM     ****    ANNANDALE,VIRGINIA
```

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUBAREA SURFACE CHARACTERISTICS

INFILTRATION DATA

SURFACE TYPE	MAX RATE IN/HR	MIN RATE IN/HR	DECAY HR-1	MAX DEPTH INCHES
0	IMPERVIOUS SURFACE			
1	5.00	.70	4.3200	10.0
2	3.50	.65	4.3200	10.0
3	2.90	.55	4.3200	12.0
4	3.20	.60	4.3200	10.0

FOR INLETS ON GRADE IN GUTTERS: DEPRESSED GRATE INLETS SELECTED
INLET CAPACITY CURVES INPUT BY USER

FOR INLETS ON GRADE IN CHANNELS: DEPRESSED GRATE INLETS SELECTED
INLET CAPACITY CURVES INPUT BY USER

Exhibit IV-2
(Continued)

CAPACITY CURVES FOR INLETS IN GUTTERS (Q IN CFS) :

CROSS-SLOPE: 1/64

S = .005		S = .010		S = .020		S = .040		S = .060		S = .090	
QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q
1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	.94	4.0	.89	4.0
.86	6.0	.83	6.0	.78	6.0	.73	6.0	.71	6.0	.68	6.0
.56	10.0	.55	10.0	.51	10.0	.48	10.0	.47	10.0	.40	10.0

CROSS-SLOPE: 1/48

S = .005		S = .010		S = .020		S = .040		S = .060		S = .090	
QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q
1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	.94	4.0	.91	4.0
.88	6.0	.86	6.0	.79	6.0	.76	6.0	.71	6.0	.68	6.0
.62	10.0	.57	10.0	.53	10.0	.50	10.0	.48	10.0	.42	10.0

CROSS-SLOPE: 1/24

S = .005		S = .010		S = .020		S = .040		S = .060		S = .090	
QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q
1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	.97	4.0	.94	4.0
.93	6.0	.90	6.0	.86	6.0	.79	6.0	.76	6.0	.73	6.0
.63	10.0	.59	10.0	.56	10.0	.52	10.0	.50	10.0	.47	10.0

CROSS-SLOPE: 1/16

S = .005		S = .010		S = .020		S = .040		S = .060		S = .090	
QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q	QI/Q	Q
1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	.94	4.0
.96	6.0	.95	6.0	.89	6.0	.83	6.0	.78	6.0	.75	6.0
.65	10.0	.63	10.0	.57	10.0	.54	10.0	.53	10.0	.52	10.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION **** URBAN HIGHWAY DRAINAGE MODEL **** WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION **** **** CAMP DRESSER AND MCKEE
WASHINGTON, D.C. **** SURFACE RUNOFF PROGRAM **** ANNANDALE, VIRGINIA

CAPACITY CURVES FOR INLETS IN CHANNELS (D IN FEET) :

S = .005		S = .010		S = .020		S = .040		S = .060		S = .090	
QI/Q	D	QI/Q	D	QI/Q	D	QI/Q	D	QI/Q	D	QI/Q	D
1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
1.00	.4	1.00	.4	1.00	.3	1.00	.3	1.00	.2	1.00	.2
1.00	.5	1.00	.4	1.00	.4	1.00	.3	1.00	.3	1.00	.3
1.00	.7	1.00	.6	1.00	.5	.96	.4	.93	.4	.89	.3
1.00	.8	.92	.7	.85	.6	.76	.5	.74	.4	.70	.4
.86	.9	.78	.7	.71	.6	.66	.5	.63	.5	.60	.4

INLET CAPACITY REDUCTION FACTOR 1.00

Exhibit IV-2
(Continued)

INPUT DATA FOR SURFACE RUNOFF GUTTERS/CHANNELS

GUTTER/ CHANNEL NUMBER	CONNECTED TO GUTTER/CHANNEL NUMBER	INLET NO.	STATIONS 1	STATIONS 2	LENGTH (FT)	MANNINGS N	SLOPE (FT/FT)
322	323	0	100+ 0	101+78	178.0	.0140	.024
323	317	100	101+78	106+67	489.0	.0140	.016
317	321	0	106+67	113+ 3	636.0	.0140	.021
321	320	101	113+ 3	119+ 4	601.0	.0140	.016
320	0	9000	119+ 4	125+12	608.0	.0140	.016

GUTTER/ CHANNEL NUMBER	TRAPEZOIDAL CHANNEL RECIP. SIDE SLOPE 1	TRAPEZOIDAL CHANNEL RECIP. SIDE SLOPE 2	TRAPEZOIDAL CHANNEL WIDTH (FT)	MAXIMUM DEPTH (FT)	DESIGN SPREAD (FT)	V FULL (FPS)	Q FULL (CFS)
322	48.000	0.003	0.000	.300	14.400	4.578	9.889
323	48.000	0.003	0.000	.321	15.400	3.909	9.657
317	48.000	0.003	0.000	.321	15.400	4.479	11.064
321	48.000	0.000	0.000	.300	14.400	3.738	8.074
320	48.000	0.000	0.000	.300	14.400	3.738	8.074

TOTAL NUMBER OF GUTTERS/CHANNELS= 5

NUMBER OF OVERBANK CHANNELS 0

TOTAL NUMBER OF DETENTION BASINS 0

Exhibit IV-2
(Continued)

```
FEDERAL HIGHWAY ADMINISTRATION          ****  URBAN HIGHWAY DRAINAGE MODEL  ****     WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION            ****                                ****     CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                        ****    SURFACE RUNOFF PROGRAM      ****     ANNANDALE,VIRGINIA
```

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

HIGHWAY SURFACE DRAINAGE INFORMATION

WATERSHED NO.	WATERSHED NAME	WATERSHED WIDTH	DRAIN GUTTER	RAINGAGE NO.	AREA (ACRES)	NUMBER OF SUBAREAS
1	524	178.00	322	1	.10	1

SUBAREA DEFINITION

AREA (ACRES)	SURFACE TYPE	SLOPE (FT/FT)	STORAGE (IN)	MANNING N (FT)1/6
.10	3	.08	.16	.16

WATERSHED NO.	WATERSHED NAME	WATERSHED WIDTH	DRAIN GUTTER	RAINGAGE NO.	AREA (ACRES)	NUMBER OF SUBAREAS
2	525	489.00	323	1	.60	1

SUBAREA DEFINITION

AREA (ACRES)	SURFACE TYPE	SLOPE (FT/FT)	STORAGE (IN)	MANNING N (FT)1/6
.60	3	.03	.16	.16

Exhibit IV-2
(Continued)

```
FEDERAL HIGHWAY ADMINISTRATION        **** URBAN HIGHWAY DRAINAGE MODEL ****      WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION          ****                              ****      CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                      ****   SURFACE RUNOFF PROGRAM     ****      ANNANDALE,VIRGINIA
```

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

HIGHWAY SURFACE DRAINAGE INFORMATION

WATERSHED NO.	WATERSHED NAME	WATERSHED WIDTH	DRAIN GUTTER	RAINGAGE NO.	AREA (ACRES)	NUMBER OF SUBAREAS
3	523	601.00	321	1	1.70	1

SUBAREA DEFINITION

AREA (ACRES)	SURFACE TYPE	SLOPE (FT/FT)	STORAGE (IN)	MANNING N (FT)1/6
1.70	1	.02	.10	.10

WATERSHED NO.	WATERSHED NAME	WATERSHED WIDTH	DRAIN GUTTER	RAINGAGE NO.	AREA (ACRES)	NUMBER OF SUBAREAS
4	1526	636.00	317	1	2.70	1

SUBAREA DEFINITION

AREA (ACRES)	SURFACE TYPE	SLOPE (FT/FT)	STORAGE (IN)	MANNING N (FT)1/6
2.70	2	.07	.46	.20

Exhibit IV-2
(Continued)

```
-----------------------------------------------------------------------------------------------------------------------
FEDERAL HIGHWAY ADMINISTRATION        ****  URBAN HIGHWAY DRAINAGE MODEL  ****     WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION          ****                                ****     CAMP DRESSER AND MCKEE
WASHINGTON, D.C.                      ****    SURFACE RUNOFF PROGRAM      ****     ANNANDALE,VIRGINIA

                    FEDERAL HIGHWAY ADMINISTRATION
                    SURFACE RUNOFF TEST PROBLEM

-----------------------------------------HIGHWAY SURFACE DRAINAGE INFORMATION-----------------------------------------

                        WATERSHED   WATERSHED     WATERSHED      DRAIN  RAINGAGE   AREA    NUMBER OF
                           NO.        NAME          WIDTH        GUTTER   NO.     (ACRES)  SUBAREAS

                            5          522         608.00         320      1        3.40        1

                                                 SUBAREA DEFINITION

                                      AREA       SURFACE   SLOPE   STORAGE  MANNING N
                                     (ACRES)      TYPE    (FT/FT)   (IN)     (FT)1/6
                                       3.40        4        .02      .19      .18

TOTAL NUMBER OF SUBCATCHMENTS    5

TOTAL TRIBUTARY AREA (ACRES)     8.50
```

Exhibit IV-2
(Continued)

ARRANGEMENT OF SUBCATCHMENTS AND CHANNELS

CHANNEL	TRIBUTARY CHANNEL OR MAIN CHANNEL	TRIBUTARY SUBAREA
322		524
323	322	525
100	323	
317	100	1526
321	317	523
101	321	
320	101	522

INLET	TRIBUTARY CHANNELS	TRIBUTARY SUBAREAS
100	323	
101	321	
9000	320	

HYDROGRAPHS WILL BE STORED FOR THE FOLLOWING 3 INLETS
100 101 9000

Exhibit IV-2
(Continued)

```
.....CONSERVATIVE QUALITY CHANNEL ROUTING INCLUDED IN THIS RUN.....

INPUT PARAMETERS AS FOLLOWS

NUMBER OF CONSTITUENTS        13
NUMBER OF DRY DAYS          10.0
MAINTENANCE PERIOD IN DAYS          30.0
FRACTIONAL MAINTENANCE EFFICIENCY          .5
DETENTION TIME(HRS) FOR 50 PERCENT SUSPENDED SOLIDS REMOVAL  0.0

HYDROGRAPHS AND POLLUTOGRAPHS WILL BE LISTED FOR THE FOLLOWING CHANNELS OR INLETS

LOCATION       322      323      317      321      320      100      101      9000


RAINFALL ON WATERSHED (FT3) .660040E+05
RAINFALL ON STORAGE (FT3)0.
INFLOW VOLUME (FT3)0.
----- TOTAL INPUT VOLUME (FT3) ----- .660040E+05

INFILTRATION (FT3) .492665E+05
INLET VOLUME (FT3) .167363E+05
WATERSHED STORAGE (FT3)0.
SURCHARGE STORAGE (FT3)0.
CHANNEL STORAGE (FT3) .228920E+01
RETENTION STORAGE (FT3)0.
----- TOTAL OUTFLOW STORAGE (FT3) ----- .660050E+05

            ERROR IN CONTINUITY, PERCENTAGE OF INFLOW      -.00161
```

Exhibit IV-2
(Continued)

TOTAL SUSPENDED SOLIDS WASHOFF BY SUBAREA TYPE, IN KILOGRAMS

WATERSHED 524
SUBAREA 1 TYPE 4
ORIGINAL AMOUNT 2.920
AMOUNT REMAINING .5748
AMOUNT WASHED OFF 2.345

SUBAREA TOTAL 2.345

WATERSHED 525
SUBAREA 1 TYPE 4
ORIGINAL AMOUNT 17.52
AMOUNT REMAINING 3.615
AMOUNT WASHED OFF 13.91

SUBAREA TOTAL 13.91

WATERSHED 523
SUBAREA 1 TYPE 2
ORIGINAL AMOUNT 28.75
AMOUNT REMAINING 8.058
AMOUNT WASHED OFF 20.70

SUBAREA TOTAL 20.70

WATERSHED 1526
SUBAREA 1 TYPE 3
ORIGINAL AMOUNT 57.92
AMOUNT REMAINING 30.17
AMOUNT WASHED OFF 27.75

SUBAREA TOTAL 27.75

Exhibit IV-2
(Continued)

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TOTAL SUSPENDED SOLIDS WASHOFF BY SUBAREA TYPE, IN KILOGRAMS

                   WATERSHED  522
              SUBAREA 1 TYPE 5
        ORIGINAL AMOUNT  120.8
        AMOUNT REMAINING  38.51
        AMOUNT WASHED OFF  82.24

SUBAREA TOTAL 82.24


TOTAL HIGHWAY LOAD 146.9


TOTAL INLET LOAD 103.9


PERCENT LOAD REDUCTION BY SURFACE STORAGE 29.27


TOTAL WATERSHED INPUT LOAD 105.9

         INLET LOAD IN KG EXCEPT FOR FECAL COLIFORM
         EXPRESSED AS NO. ORGANISMS


                   DO          0.
                   BOD          .45E+01
                   TSS          .10E+03
                   FCOL         .34E+08
                   CL          0.
                   NH3          .17E+00
                   NO2         0.
                   NO3          .58E+00
                   ORGN         .43E+00
                   TOTP         .18E+00
                   OPO4         .45E-01
                   O+G          .11E+01
                   PB           .15E+00
```

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION **** URBAN HIGHWAY DRAINAGE MODEL **** WATER RESOURCES DIVISION
DEPARTMENT OF TRANSPORTATION **** **** CAMP DRESSER AND MCKEE
WASHINGTON, D.C. **** SURFACE RUNOFF PROGRAM **** ANNANDALE, VIRGINIA

SUMMARY STATISTICS FOR ABOVE-GROUND GUTTERS/CHANNELS

GUTTER/ CHANNEL NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	DESIGN DEPTH (FT)	DESIGN FLOW SPREAD (FT)	MAXIMUM COMPUTED FLOW (CFS)	MAXIMUM COMPUTED VELOCITY (FPS)	MAXIMUM COMPUTED DEPTH (FT)	MAXIMUM COMPUTED SPREAD (FT)	TIME OF OCCURENCE HR.	MIN.
322	9.89	4.58	.30	14.4	.34	2.00	.08	4.0	24	27
323	9.66	3.91	.32	15.4	1.61	2.50	.16	7.9	24	32
317	11.06	4.48	.32	15.4	1.86	2.87	.16	7.9	24	42
321	8.07	3.74	.30	14.4	3.75	3.09	.22	10.8	24	40
320	8.07	3.74	.30	14.4	3.13	2.95	.21	10.1	24	40

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 322

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.007	.24	8.0	7.0	155.2	5.7	0.0	.1	1.0	.6	.3	.1	1.2	.2
24 30.00	.008	.29	8.0	15.1	336.0	12.4	0.0	.3	2.2	1.4	.6	.2	2.7	.5
24 35.00	.005	.18	8.0	14.2	315.6	11.7	0.0	.3	2.0	1.3	.5	.1	2.5	.4
24 40.00	.003	.11	8.0	12.3	273.7	10.1	0.0	.2	1.8	1.1	.5	.1	2.2	.4
24 45.00	.002	.07	8.0	11.0	245.3	9.1	0.0	.2	1.6	1.0	.4	.1	2.0	.3
24 50.00	.001	.04	8.0	10.3	227.9	8.4	0.0	.2	1.5	.9	.4	.1	1.8	.3
24 55.00	.001	.03	8.0	9.6	212.6	7.9	0.0	.2	1.4	.9	.4	.1	1.7	.3
25 0.00	.001	.02	8.0	8.7	194.2	7.2	0.0	.2	1.2	.8	.3	.1	1.6	.3
25 5.00	.000	.02	8.0	8.3	185.4	6.9	0.0	.1	1.2	.8	.3	.1	1.5	.3
25 10.00	.000	.01	8.0	8.3	184.7	6.8	0.0	.1	1.2	.8	.3	.1	1.5	.3
25 15.00	.000	.01	8.0	6.5	145.0	5.4	0.0	.1	.9	.6	.2	.1	1.2	.2
25 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 10.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 15.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 323

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.009	.31	8.0	2.9	63.9	2.4	0.0	.1	.4	.3	.1	.0	.5	.1
24 30.00	.042	1.50	8.0	9.1	201.6	7.5	0.0	.2	1.3	.8	.3	.1	1.6	.3
24 35.00	.042	1.47	8.0	12.2	270.0	10.0	0.0	.2	1.7	1.1	.5	.1	2.2	.4
24 40.00	.030	1.07	8.0	13.4	297.8	11.0	0.0	.2	1.9	1.2	.5	.1	2.4	.4
24 45.00	.021	.73	8.0	13.9	308.4	11.4	0.0	.2	2.0	1.3	.5	.1	2.5	.4
24 50.00	.014	.49	8.0	14.1	312.9	11.6	0.0	.3	2.0	1.3	.5	.1	2.5	.4
24 55.00	.010	.35	8.0	14.1	313.7	11.6	0.0	.3	2.0	1.3	.5	.1	2.5	.4
25 0.00	.007	.26	8.0	13.9	308.9	11.4	0.0	.2	2.0	1.3	.5	.1	2.5	.4
25 5.00	.006	.20	8.0	13.6	303.0	11.2	0.0	.2	1.9	1.2	.5	.1	2.4	.4
25 10.00	.004	.14	8.0	13.7	304.8	11.3	0.0	.2	2.0	1.2	.5	.1	2.4	.4
25 15.00	.003	.10	8.0	14.1	312.8	11.6	0.0	.3	2.0	1.3	.5	.1	2.5	.4
25 20.00	.002	.07	8.0	14.3	317.1	11.7	0.0	.3	2.0	1.3	.5	.1	2.5	.4
25 25.00	.001	.05	8.0	14.4	320.7	11.9	0.0	.3	2.1	1.3	.5	.2	2.6	.4
25 30.00	.001	.03	8.0	14.6	324.1	12.0	0.0	.3	2.1	1.3	.6	.2	2.6	.5
25 35.00	.000	.02	8.0	13.8	307.5	11.4	0.0	.2	2.0	1.3	.5	.1	2.5	.4
25 40.00	.000	.01	8.0	13.7	304.8	11.3	0.0	.2	2.0	1.2	.5	.1	2.4	.4
25 45.00	.000	.01	8.0	13.6	303.2	11.2	0.0	.2	1.9	1.2	.5	.1	2.4	.4
25 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 10.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 15.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 317

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 30.00	.006	.22	8.0	.4	8.9	.3	0.0	.0	.1	.0	.0	.0	.1	.0
24 35.00	.035	1.25	8.0	2.2	49.2	1.8	0.0	.0	.3	.2	.1	.0	.4	.1
24 40.00	.052	1.83	8.0	4.4	97.9	3.6	0.0	.1	.6	.4	.2	.0	.8	.1
24 45.00	.050	1.78	8.0	6.6	146.8	5.4	0.0	.1	.9	.6	.2	.1	1.2	.2
24 50.00	.042	1.49	8.0	8.7	192.5	7.1	0.0	.2	1.2	.8	.3	.1	1.5	.3
24 55.00	.034	1.20	8.0	10.5	233.9	8.7	0.0	.2	1.5	1.0	.4	.1	1.9	.3
25 0.00	.027	.95	8.0	12.1	269.8	10.0	0.0	.2	1.7	1.1	.5	.1	2.2	.4
25 5.00	.021	.75	8.0	13.6	303.1	11.2	0.0	.2	1.9	1.2	.5	.1	2.4	.4
25 10.00	.016	.57	8.0	15.1	335.0	12.4	0.0	.3	2.1	1.4	.6	.2	2.7	.5
25 15.00	.012	.42	8.0	16.2	360.9	13.4	0.0	.3	2.3	1.5	.6	.2	2.9	.5
25 20.00	.008	.30	8.0	17.0	377.6	14.0	0.0	.3	2.4	1.5	.6	.2	3.0	.5
25 25.00	.006	.20	8.0	17.4	386.9	14.3	0.0	.3	2.5	1.6	.7	.2	3.1	.5
25 30.00	.003	.12	8.0	17.6	391.7	14.5	0.0	.3	2.5	1.6	.7	.2	3.1	.5
25 35.00	.002	.06	8.0	17.7	393.4	14.6	0.0	.3	2.5	1.6	.7	.2	3.1	.6
25 40.00	.001	.03	8.0	17.6	391.3	14.5	0.0	.3	2.5	1.6	.7	.2	3.1	.5
25 45.00	.000	.02	8.0	17.6	391.3	14.5	0.0	.3	2.5	1.6	.7	.2	3.1	.5
25 50.00	.000	.01	8.0	17.6	391.3	14.5	0.0	.3	2.5	1.6	.7	.2	3.1	.5
25 55.00	.000	.01	8.0	17.6	391.3	14.5	0.0	.3	2.5	1.6	.7	.2	3.1	.5
26 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 10.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 15.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 321

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.014	.48	8.0	.6	17.7	.2	0.0	.0	.0	.1	.0	.0	.4	.0
24 30.00	.069	2.44	8.0	2.5	72.6	.6	0.0	.1	.1	.3	.1	.0	1.8	.1
24 35.00	.097	3.42	8.0	3.8	110.7	1.2	0.0	.1	.2	.5	.2	.0	2.6	.2
24 40.00	.106	3.75	8.0	4.8	130.6	2.0	0.0	.1	.4	.6	.2	.0	2.8	.2
24 45.00	.097	3.41	8.0	5.8	152.2	3.0	0.0	.1	.5	.6	.3	.1	2.8	.2
24 50.00	.079	2.78	8.0	7.1	178.3	4.2	0.0	.1	.7	.7	.3	.1	2.9	.3
24 55.00	.061	2.16	8.0	8.4	206.7	5.3	0.0	.2	.9	.9	.4	.1	3.1	.3
25 0.00	.047	1.67	8.0	9.7	235.2	6.4	0.0	.2	1.1	1.0	.4	.1	3.3	.4
25 5.00	.036	1.29	8.0	10.9	261.7	7.5	0.0	.2	1.3	1.1	.5	.1	3.4	.4
25 10.00	.027	.97	8.0	12.1	285.7	8.5	0.0	.2	1.5	1.2	.5	.1	3.5	.4
25 15.00	.020	.70	8.0	13.1	306.7	9.6	0.0	.2	1.7	1.3	.5	.1	3.5	.5
25 20.00	.014	.49	8.0	14.1	323.8	10.7	0.0	.3	1.9	1.3	.6	.1	3.4	.5
25 25.00	.009	.33	8.0	14.8	336.2	11.6	0.0	.3	2.0	1.4	.6	.2	3.2	.5
25 30.00	.006	.22	8.0	15.2	343.1	12.2	0.0	.3	2.1	1.4	.6	.2	3.0	.5
25 35.00	.004	.15	8.0	15.4	344.6	12.4	0.0	.3	2.1	1.4	.6	.2	3.0	.5
25 40.00	.003	.09	8.0	15.4	343.6	12.5	0.0	.3	2.2	1.4	.6	.2	2.9	.5
25 45.00	.002	.06	8.0	15.4	344.0	12.5	0.0	.3	2.2	1.4	.6	.2	2.9	.5
25 50.00	.001	.04	8.0	15.5	345.2	12.6	0.0	.3	2.2	1.4	.6	.2	2.9	.5
25 55.00	.001	.02	8.0	15.5	346.7	12.7	0.0	.3	2.2	1.4	.6	.2	2.9	.5
26 0.00	.000	.02	8.0	15.1	335.8	12.3	0.0	.3	2.1	1.4	.6	.2	2.8	.5
26 5.00	.000	.01	8.0	13.5	301.5	11.0	0.0	.2	1.9	1.2	.5	.1	2.5	.4
26 10.00	.000	.01	8.0	12.3	273.7	10.0	0.0	.2	1.7	1.1	.5	.1	2.3	.4
26 15.00	.000	.01	8.0	11.2	250.7	9.2	0.0	.2	1.6	1.0	.4	.1	2.1	.4
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 320

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL.	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.004	.14	8.0	.2	4.7	.2	0.0	.0	.0	.0	.0	.0	.0	.0
24 30.00	.043	1.53	8.0	2.0	45.0	1.7	0.0	.1	.3	.2	.1	.0	.4	.1
24 35.00	.079	2.79	8.0	4.4	98.7	3.7	0.0	.2	.6	.4	.2	.0	.8	.1
24 40.00	.089	3.13	8.0	7.0	155.0	5.7	0.0	.4	1.0	.6	.3	.1	1.2	.2
24 45.00	.083	2.92	8.0	9.3	207.5	7.7	0.0	.5	1.3	.9	.4	.1	1.7	.3
24 50.00	.072	2.54	8.0	11.4	254.2	9.4	0.0	.6	1.6	1.0	.4	.1	2.0	.4
24 55.00	.061	2.15	8.0	13.3	294.8	10.9	0.0	.7	1.9	1.2	.5	.1	2.4	.4
25 0.00	.052	1.83	8.0	14.8	328.8	12.2	0.0	.8	2.1	1.3	.6	.2	2.6	.5
25 5.00	.044	1.54	8.0	16.1	358.8	13.3	0.0	.9	2.3	1.5	.6	.2	2.9	.5
25 10.00	.036	1.28	8.0	17.4	387.7	14.3	0.0	.9	2.5	1.6	.7	.2	3.1	.5
25 15.00	.030	1.05	8.0	18.7	415.1	15.4	0.0	1.0	2.7	1.7	.7	.2	3.3	.6
25 20.00	.024	.86	8.0	19.8	439.8	16.3	0.0	1.1	2.8	1.8	.7	.2	3.5	.6
25 25.00	.020	.70	8.0	20.8	461.6	17.1	0.0	1.1	3.0	1.9	.8	.2	3.7	.6
25 30.00	.016	.55	8.0	21.6	480.0	17.8	0.0	1.2	3.1	2.0	.8	.2	3.8	.7
25 35.00	.012	.43	8.0	22.2	493.0	18.2	0.0	1.2	3.2	2.0	.8	.2	3.9	.7
25 40.00	.009	.33	8.0	22.6	501.3	18.5	0.0	1.2	3.2	2.1	.9	.2	4.0	.7
25 45.00	.007	.24	8.0	22.8	506.4	18.7	0.0	1.2	3.2	2.1	.9	.2	4.1	.7
25 50.00	.004	.15	8.0	22.9	508.6	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
25 55.00	.002	.07	8.0	22.9	508.9	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
26 0.00	.001	.03	8.0	22.9	508.9	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
26 5.00	.001	.02	8.0	22.9	508.9	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
26 10.00	.000	.01	8.0	22.9	508.9	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
26 15.00	.000	.01	8.0	22.9	508.9	18.8	0.0	1.2	3.3	2.1	.9	.2	4.1	.7
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 100

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.012	.44	8.0	7.7	170.0	6.3	0.0	.1	1.1	.7	.3	.1	1.4	.2
24 30.00	.044	1.56	8.0	10.0	222.7	8.2	0.0	.2	1.4	.9	.4	.1	1.8	.3
24 35.00	.041	1.44	8.0	11.7	259.2	9.6	0.0	.2	1.7	1.1	.4	.1	2.1	.4
24 40.00	.029	1.03	8.0	12.5	277.0	10.2	0.0	.2	1.8	1.1	.5	.1	2.2	.4
24 45.00	.020	.70	8.0	12.8	285.1	10.5	0.0	.2	1.8	1.2	.5	.1	2.3	.4
24 50.00	.013	.48	8.0	13.0	290.0	10.7	0.0	.2	1.9	1.2	.5	.1	2.3	.4
24 55.00	.009	.34	8.0	13.2	293.3	10.9	0.0	.2	1.9	1.2	.5	.1	2.3	.4
25 0.00	.007	.25	8.0	13.2	292.5	10.8	0.0	.2	1.9	1.2	.5	.1	2.3	.4
25 5.00	.005	.19	8.0	12.9	286.7	10.6	0.0	.2	1.8	1.2	.5	.1	2.3	.4
25 10.00	.004	.14	8.0	12.9	285.8	10.6	0.0	.2	1.8	1.2	.5	.1	2.3	.4
25 15.00	.003	.10	8.0	13.1	292.2	10.8	0.0	.2	1.9	1.2	.5	.1	2.3	.4
25 20.00	.002	.07	8.0	13.2	294.0	10.9	0.0	.2	1.9	1.2	.5	.1	2.4	.4
25 25.00	.001	.05	8.0	13.2	294.4	10.9	0.0	.2	1.9	1.2	.5	.1	2.4	.4
25 30.00	.001	.03	8.0	13.2	292.7	10.8	0.0	.2	1.9	1.2	.5	.1	2.3	.4
25 35.00	.000	.02	8.0	12.3	272.4	10.1	0.0	.2	1.7	1.1	.5	.1	2.2	.4
25 40.00	.000	.01	8.0	12.3	272.3	10.1	0.0	.2	1.7	1.1	.5	.1	2.2	.4
25 45.00	.000	.01	8.0	12.4	274.6	10.2	0.0	.2	1.8	1.1	.5	.1	2.2	.4
25 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 10.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 15.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 101

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.019	.67	8.0	1.5	44.2	.4	0.0	.0	.1	.2	.1	.0	1.1	.1
24 30.00	.074	2.60	8.0	2.9	83.8	.7	0.0	.1	.1	.4	.2	.0	2.1	.2
24 35.00	.099	3.50	8.0	4.0	115.6	1.2	0.0	.1	.2	.5	.2	.0	2.8	.2
24 40.00	.106	3.74	8.0	4.8	130.8	2.0	0.0	.1	.4	.6	.2	.0	2.8	.2
24 45.00	.095	3.36	8.0	5.7	147.6	2.9	0.0	.1	.5	.6	.3	.0	2.7	.2
24 50.00	.077	2.71	8.0	6.8	170.2	4.0	0.0	.1	.7	.7	.3	.1	2.8	.3
24 55.00	.060	2.10	8.0	8.0	196.3	5.0	0.0	.2	.9	.8	.3	.1	2.9	.3
25 0.00	.046	1.63	8.0	9.2	223.5	6.1	0.0	.2	1.1	.9	.4	.1	3.1	.3
25 5.00	.036	1.25	8.0	10.4	248.2	7.1	0.0	.2	1.2	1.0	.4	.1	3.2	.4
25 10.00	.027	.94	8.0	11.4	269.0	8.0	0.0	.2	1.4	1.1	.5	.1	3.3	.4
25 15.00	.019	.68	8.0	12.3	286.8	9.0	0.0	.2	1.6	1.2	.5	.1	3.3	.4
25 20.00	.013	.47	8.0	13.1	300.7	9.9	0.0	.2	1.7	1.2	.5	.1	3.1	.4
25 25.00	.009	.32	8.0	13.7	310.4	10.7	0.0	.2	1.9	1.3	.5	.1	2.9	.4
25 30.00	.006	.21	8.0	14.1	316.5	11.2	0.0	.3	1.9	1.3	.5	.1	2.8	.4
25 35.00	.004	.14	8.0	14.1	315.3	11.4	0.0	.3	2.0	1.3	.5	.1	2.7	.4
25 40.00	.002	.09	8.0	13.9	311.9	11.3	0.0	.2	2.0	1.3	.5	.1	2.6	.4
25 45.00	.002	.05	8.0	14.0	313.1	11.4	0.0	.3	2.0	1.3	.5	.1	2.6	.4
25 50.00	.001	.03	8.0	14.2	316.1	11.5	0.0	.3	2.0	1.3	.5	.1	2.6	.4
25 55.00	.001	.02	8.0	14.3	319.6	11.7	0.0	.3	2.0	1.3	.5	.1	2.6	.4
26 0.00	.000	.02	8.0	14.0	311.6	11.4	0.0	.2	2.0	1.3	.5	.1	2.6	.4
26 5.00	.000	.01	8.0	12.6	281.3	10.3	0.0	.2	1.8	1.2	.5	.1	2.3	.4
26 10.00	.000	.01	8.0	11.5	256.7	9.4	0.0	.2	1.6	1.1	.4	.1	2.1	.4
26 15.00	.000	.01	8.0	10.6	236.1	8.6	0.0	.2	1.5	1.0	.4	.1	1.9	.3
26 20.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Exhibit IV-2
(Continued)

FEDERAL HIGHWAY ADMINISTRATION
SURFACE RUNOFF TEST PROBLEM

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 9000

QUALITY IN (MG/L) EXCEPT COLIFORMS IN (1000/100ML)

TIME	FLOW CMS	FLOW CFS	DO	BOD	TOT-SS	COLI	CL	NH3	NO2+NO3	ORG-N	TOT-PHOS	PO4	GREASE	H-METALS
23 45.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 50.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 55.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 0.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 5.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 15.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 20.00	0.000	0.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 25.00	.001	.04	8.0	.8	16.8	.6	0.0	.0	.1	.1	.0	.0	.1	.0
24 30.00	.034	1.20	8.0	2.6	57.7	2.1	0.0	.1	.4	.2	.1	.0	.5	.1
24 35.00	.074	2.61	8.0	4.7	105.4	3.9	0.0	.3	.7	.4	.2	.0	.8	.1
24 40.00	.088	3.12	8.0	7.0	155.5	5.8	0.0	.4	1.0	.6	.3	.1	1.2	.2
24 45.00	.085	2.99	8.0	9.1	203.1	7.5	0.0	.5	1.3	.8	.3	.1	1.6	.3
24 50.00	.074	2.62	8.0	11.1	246.4	9.1	0.0	.6	1.6	1.0	.4	.1	2.0	.3
24 55.00	.063	2.23	8.0	12.8	285.0	10.5	0.0	.7	1.8	1.2	.5	.1	2.3	.4
25 0.00	.053	1.89	8.0	14.3	318.3	11.8	0.0	.8	2.0	1.3	.5	.1	2.5	.4
25 5.00	.045	1.60	8.0	15.6	346.6	12.8	0.0	.8	2.2	1.4	.6	.2	2.8	.5
25 10.00	.038	1.33	8.0	16.8	373.1	13.8	0.0	.9	2.4	1.5	.6	.2	3.0	.5
25 15.00	.031	1.10	8.0	18.0	399.1	14.8	0.0	1.0	2.6	1.6	.7	.2	3.2	.6
25 20.00	.025	.90	8.0	19.0	421.9	15.6	0.0	1.0	2.7	1.7	.7	.2	3.4	.6
25 25.00	.021	.73	8.0	19.9	442.1	16.4	0.0	1.1	2.8	1.8	.8	.2	3.5	.6
25 30.00	.016	.58	8.0	20.6	458.0	16.9	0.0	1.1	2.9	1.9	.8	.2	3.7	.6
25 35.00	.013	.46	8.0	21.1	468.4	17.3	0.0	1.1	3.0	1.9	.8	.2	3.7	.7
25 40.00	.010	.35	8.0	21.3	473.5	17.5	0.0	1.1	3.0	1.9	.8	.2	3.8	.7
25 45.00	.007	.26	8.0	21.4	474.8	17.6	0.0	1.1	3.0	1.9	.8	.2	3.8	.7
25 50.00	.005	.17	8.0	20.1	445.7	16.5	0.0	1.1	2.9	1.8	.8	.2	3.6	.6
25 55.00	.002	.08	8.0	19.7	437.1	16.2	0.0	1.0	2.8	1.8	.7	.2	3.5	.6
26 0.00	.001	.04	8.0	20.2	447.9	16.6	0.0	1.1	2.9	1.8	.8	.2	3.6	.6
26 5.00	.001	.02	8.0	20.5	455.8	16.9	0.0	1.1	2.9	1.9	.8	.2	3.6	.6
26 10.00	.000	.01	8.0	20.8	462.0	17.1	0.0	1.1	3.0	1.9	.8	.2	3.7	.6
26 15.00	.000	.01	8.0	21.0	466.8	17.3	0.0	1.1	3.0	1.9	.8	.2	3.7	.7
26 20.00	.000	.01	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 25.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 30.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 35.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 40.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 45.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 50.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 55.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 0.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 5.00	.000	.00	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SURFACE RUNOFF PROGRAM ENDED NORMALLY

Exhibit IV-2
(Continued)

CHAPTER V

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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.

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