URBAN HIGHWAY STORM DRAINAGE MODEL

Research, Development, and Technology

Turner-Fairbank Highway Research Center
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VOL. 3 INLET DESIGN PROGRAM

Final Report

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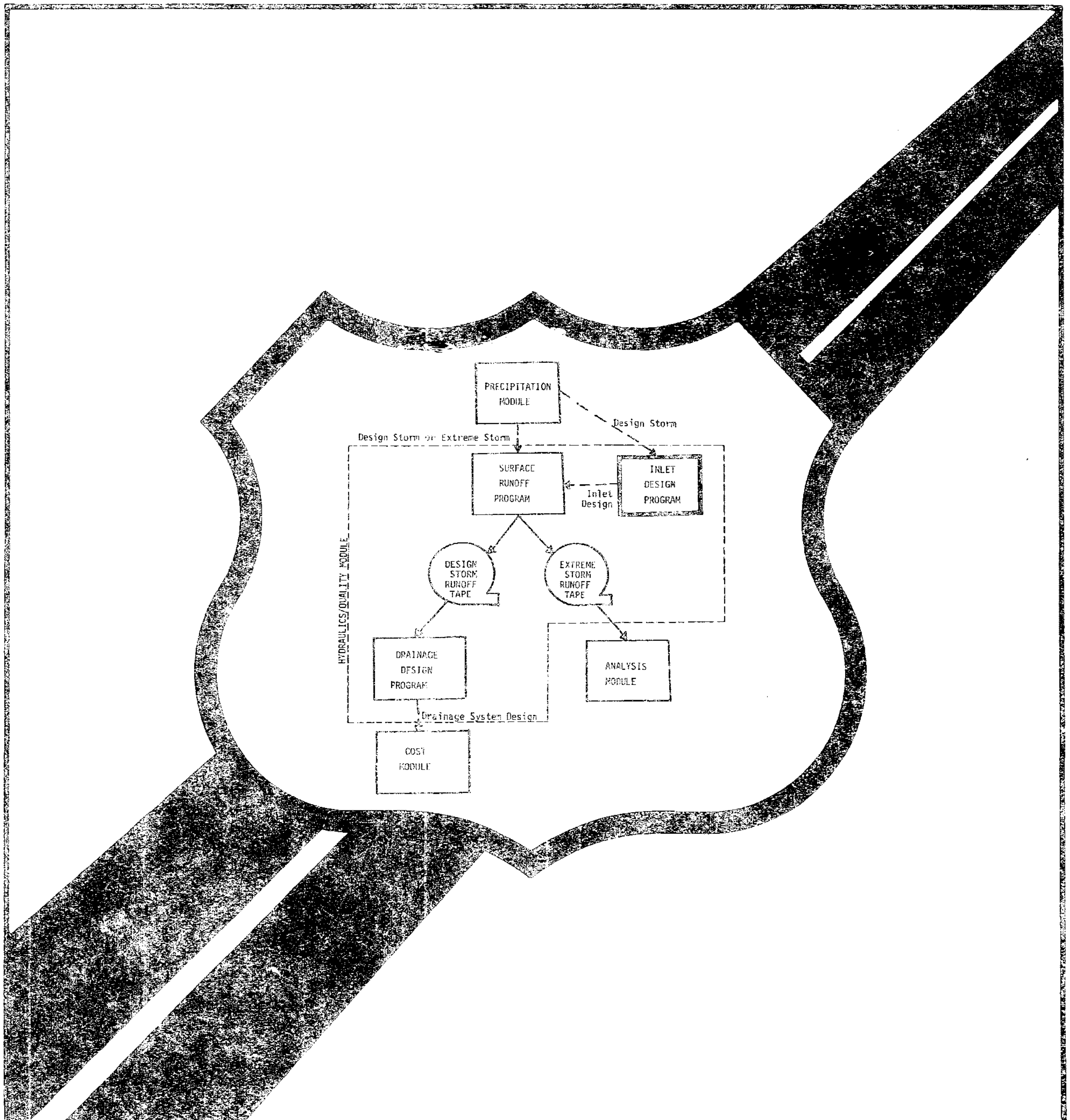

FOREWORD

This report documents the development and presents the user's manual for the Inlet Design Program of the Hydraulics/Quality Module of this computer model. From the local design storms, either derived from the Precipitation Module or from other sources, this program computes the surface runoff on the highway, then determines the locations of the inlets according to the specified criteria.

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

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

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

A package of six user-oriented computer programs has been developed and tested for the analysis and design of urban highway drainage systems and related 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 Inlet Design Program of the Hydraulics/Quality Module. User-specified design criteria are used by the program to determine the location of fixed-sized inlets in the surface runoff conveyance system.

This report is the third 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
4	83/044	Surface Runoff Program
5	83/045	Drainage Design Program
6	83/046	Analysis Module
7	83/047	Cost Estimation Module

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

To use this Inlet Design Program, the designer must first select the inlet to be used in his design. Normally, the State Highway Department has standard State inlets which have a particular design and certain sizes. The hydraulic efficiency of the selected inlet must be provided. The Program can store this information in equations or in curves in the format

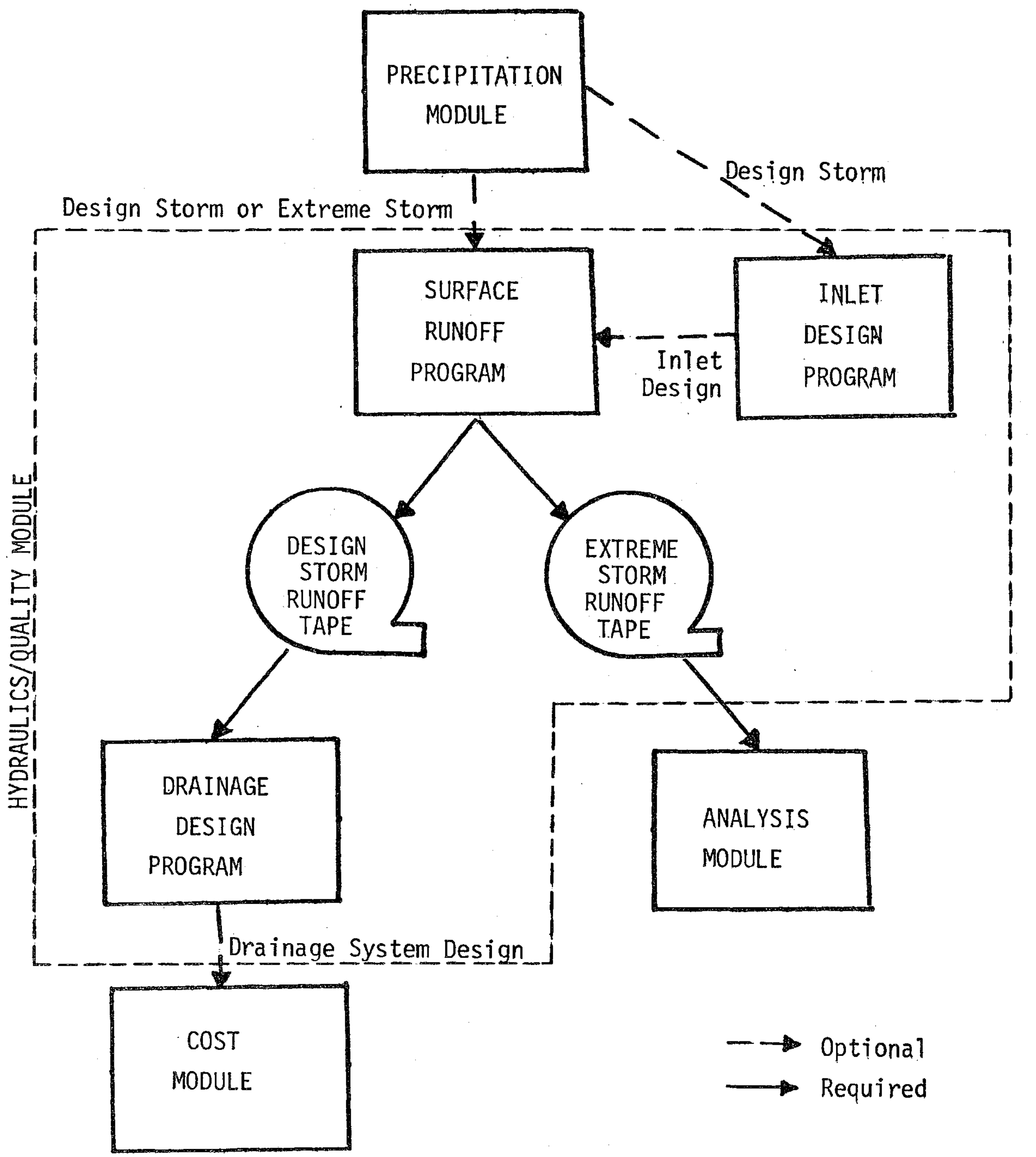

FIGURE I-1. Urban Highway Storm Drainage Model

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

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of block data. The Izzard's equations for computing the hydraulic efficiency of the curb-opening inlet with FHWA depression on continuous grades have been programmed and included in the Program. The designer must also specify the criteria for determining the location of the inlets.

From the design storms derived from the Precipitation Module, this Program will compute the surface runoff on the highway, then determine the locations of the inlet according to the specified criteria.

CHAPTER II
INTRODUCTION TO THE INLET DESIGN PROGRAM

The highway storm drainage system consists of a surface runoff conveyance system and a major drainage system. In order for the entire drainage system to operate efficiently, it is necessary that both systems be properly designed. If the surface runoff conveyance system is poorly designed, highway runoff will be concentrated and local flooding will occur at sites along the highway, causing excessive traffic delays and inconvenience regardless of the quality of design of the major drainage system.

The design of the surface runoff conveyance system includes the location of stormwater inlets to intercept surface runoff and transmit it efficiently to the subsurface drainage system. The Inlet Design Program (INLET) is a computer-based tool for performing the inlet location task.

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 or drainage channels. The runoff is routed to a series of inlets, as shown in Figure II-2, located to remove runoff so as to prevent flooding of the highway surface. The runoff so collected is then routed through the underground conduit system, generally to a nearby stream or other body of water.

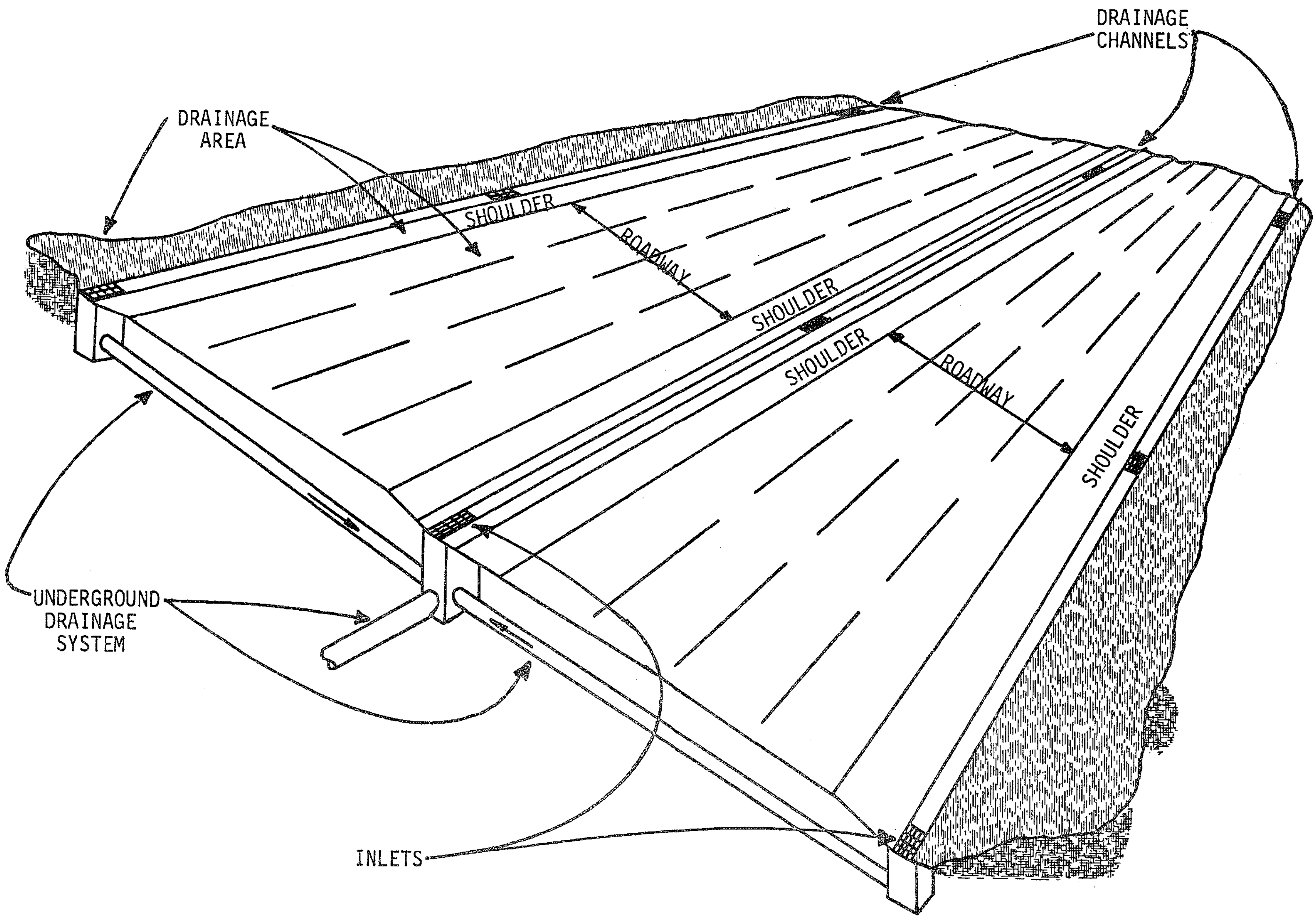


FIGURE II-1. Typical Urban Highway Drainage System

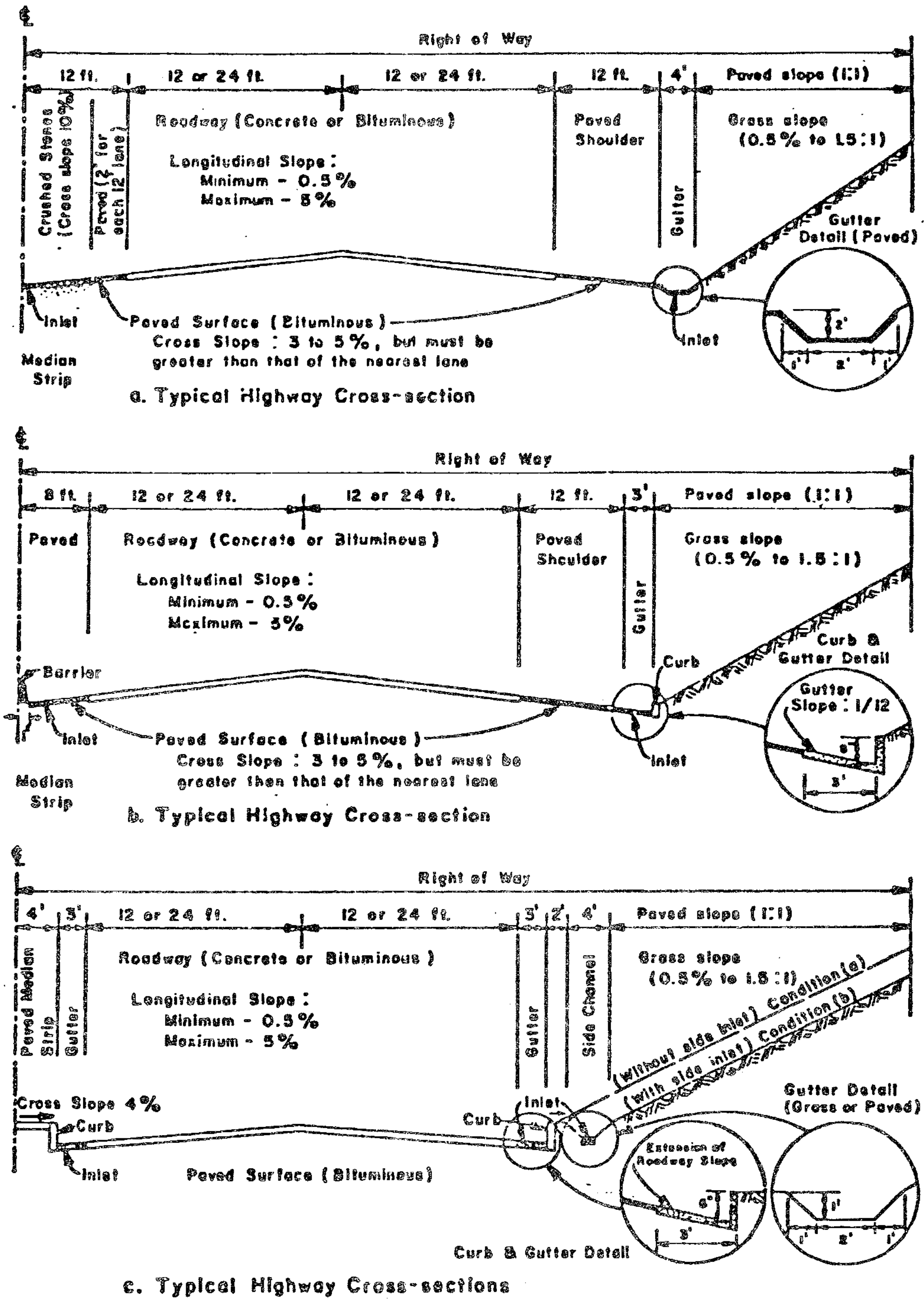


Figure II-2. Schematic Diagrams of Typical Urban Highway Cross-section

The purpose of Program INLET is to locate fixed-size inlets in the gutters or channels of the surface runoff conveyance system according to user-specified design criteria. Specifically, INLET will simulate time-varying surface runoff from a design storm and route the runoff through surface gutters and channels. The program will locate inlets in gutters such that the flow spread onto the highway surface is maintained within a user-specified maximum during the design storm. Similarly, the program can be used to locate inlets in channels such that a user-specified maximum depth is not exceeded during the design storm. If the user wishes to prespecify the location of selected inlets (e.g., at entrance and exit ramps), he may do so and the program will locate the remaining inlets.

In general, the engineer would typically follow the procedure outlined below in using this program as a computational tool during inlet design:

1. Select the type and size of inlet to be used on continuous grades, in sump conditions, and in special locations.
2. Provide the inlet efficiency equations or inlet efficiency curves of these selected inlets to be used in the hydraulic calculations.
3. Determine the special locations where events must be placed (such as entrance or exit ramps).
4. Compute the remaining inlet locations with the Inlet Design Program. To do this, the engineer must first divide the highway drainage area into a series of discrete gutter lengths, channel lengths, and watershed areas, the physical characteristics of which will be input to the program. The engineer must then select the appropriate design storm and run the program. (See Chapter IV for detailed instructions.)
5. Evaluate the inlet locations computed by the program along with the location of required inlets determined above.
6. Make the final determination of all inlet locations.

Design Criteria

This program is developed based upon the following design criteria:

1. For inlets on continuous grades -
   a. In curb and gutter sections, the maximum allowable width of gutter flow spread must be specified.
   b. In roadside channels, the maximum allowable depth must be specified.
   c. For economical reasons, inlets can be spaced so that each will intercept a minimum portion of the peak gutter flow. In this case, the carry-over factor, the intercepted portion of the peak gutter flow, must be specified.
2. For inlets at sump condition -
   a. In curb and gutter sections, the maximum allowable depth of ponding must be specified and the program will check to see if this depth is exceeded.
   b. In roadside channels, the maximum allowable depth must be specified and the program will check to see if this depth is exceeded.
3. Factors of safety - since it is possible for inlets to be completly plugged by road debris due to inadequate maintenance or some other unpredictable situations, a factor of safety is sometimes employed in spacing the inlets. This can be done through the arbitrary use of half of the actual length of the selected inlet in deriving the inlet capacity, or by attaching a specified reduction factor to the inlet capacity or the carry-over factor of the inlet.

Design Rainstorm

There are two sources for deriving the local storms for use in this program:

1. Output of the Precipitation Module; or
2. Storm specified by the user.

Inlet Efficiencies

The INLET can simulate the hydraulics of the following six basic inlet types:

- Curb Opening Inlet

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

The user may select only one inlet type for all the inlets on-grade in a single computer run. The inlet efficiencies can be programmed in one of the three forms: efficiency curves, efficiency curves in Block Data, and design equations.

A maximum of 24 efficiency curves can be programmed for one selected on-grade inlet. This covers the condition of four cross-slopes (1/64, 1/48, 1/24, and 1/16) and six longitudinal slopes (0.5, 1, 2, 4, 6, and 9%) of the gutter channel.

The procedure to set up the Block Data for the efficiency curves is not described in detail in this report. The user is referred to the Fortran reference manual for the mainframe computer he is using, if he is not familiar with the Block Data option.

For the design equations, only Izzard's equation (1) for the Federal Highway Administration's depressed curb-opening inlets on continuous grades are programmed in INLET.

For the sump-inlet, only the general form of an orifice equation is programmed in INLET. In reality, the sump inlet functions like a weir or an orifice or something in-between. The user must provide the appropriate information for the selected inlet.

Computation of Inlet Locations

There are three elements which will dictate the manner of computation:

1. The location of the first inlet on a continuous grade:
   a. may be prefixed by the user; or
   b. may be computed by the program, starting from top of grade.

2. The location of the last inlet on a continuous grade may be:

   a. pre-fixed by the user on the continuous grade; or

   b. pre-fixed by the user at the level point of the sag vertical curve (or at the sump).

3. Note that flow to the inlet in the sump condition comes from both sides of this level point. Special attention should be given to the transition section from control by width of gutter flow spread on continuous grade to control by depth of ponding at the level point.

Computation Criteria

Careful selection of the time step used in the computation is required to insure that the Inlet Design Program converges on a suitable solution. Non-convergent solutions are likely to occur if it is possible for a channel to completely empty or severely flood within one time step. The most critical parts of the drainage system in terms of convergence, therefore, are short channels.

Successful runs have been made with this program using time steps ranging from one to five minutes. If a first estimate in this range fails to produce a solution, however, a rough estimate of the time step can be made by computing:

$$\Delta t < \frac{L}{V} \qquad \text{(II-1)}$$

where Δt is the time step, L is the channel length and V is the velocity of flow, for any non- convergent channels in the solution. The user should attempt to use the largest time step possible, though, to hold down computer costs.

LIMITATIONS

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

- Inlets may be spaced in a single continuous series of gutter or channel sections, from the top of grade to the sump, with each program run;

- The program will locate inlets only at the downstream end of incremental gutter or channel sections (the incremental length being a constant specified by the user);
- The number of gutter or channel sections must be less than or equal to 200:
- 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 ten;
- The number of infiltration types must be less than or equal to four (not including impervious surfaces);
- The number of inlets located must be less than or equal to 50; and
- The number of prespecified inlets must be less than or equal to 20.

COMPUTATIONAL REQUIREMENTS

Program INLET was developed on a CDC 6600/6700 shared system at the Naval Ship Research and Development Center in Carderock, Maryland. The program requires approximately 61000_8 words of central memory. Execution of a single gutter system with 10 separate sections and 10 watersheds which spaced 17 inlets required approximately 45 seconds of central processing unit time.

CHAPTER III

TECHNICAL APPROACH

The location of inlets in the highway right-of-way is considered in the following general terms. The program operates on a single continuous length of gutter or channel extending from the top of grade to the sump. The gutter or channel is divided by the user into a series of sections, each section having constant geometric and hydraulic properties such as width, side slopes, longitudinal slope, and roughness. Similarly, the drainage area on either side of the gutter or channel is divided into a series of watersheds, each with constant properties such as slope, infiltration characteristics, and depression storage. (Each watershed may be further divided into up to three subareas; this process is described below).

The program operates by first calculating time-varying runoff based on watershed characteristics and the input design storm hyetograph. The runoff is then routed through the gutter or channel sections being simulated and relevant characteristics, such as flow spread and depth, calculated at each time step. The program checks the flow characteristics along the gutter or channel section at increments prespecified by the user. Inlets are then located to maintain flow for the storm duration within the spread or depth specified by the user. If the program cannot satisfy the flow depth or spread criterion because the size inlet selected does not have sufficient capacity or because the incremental length is too great to allow proper spacing of the inlets, then the program will print an error message and stop execution.

The remainder of this chapter presents a discussion of the technical approach used by the program to implement the algorithm described above. Specifically, topics discussed include the definition of computational elements used in the program and the calculation of surface runoff, channel routing, and flow interception by inlets.

COMPUTATIONAL ELEMENTS

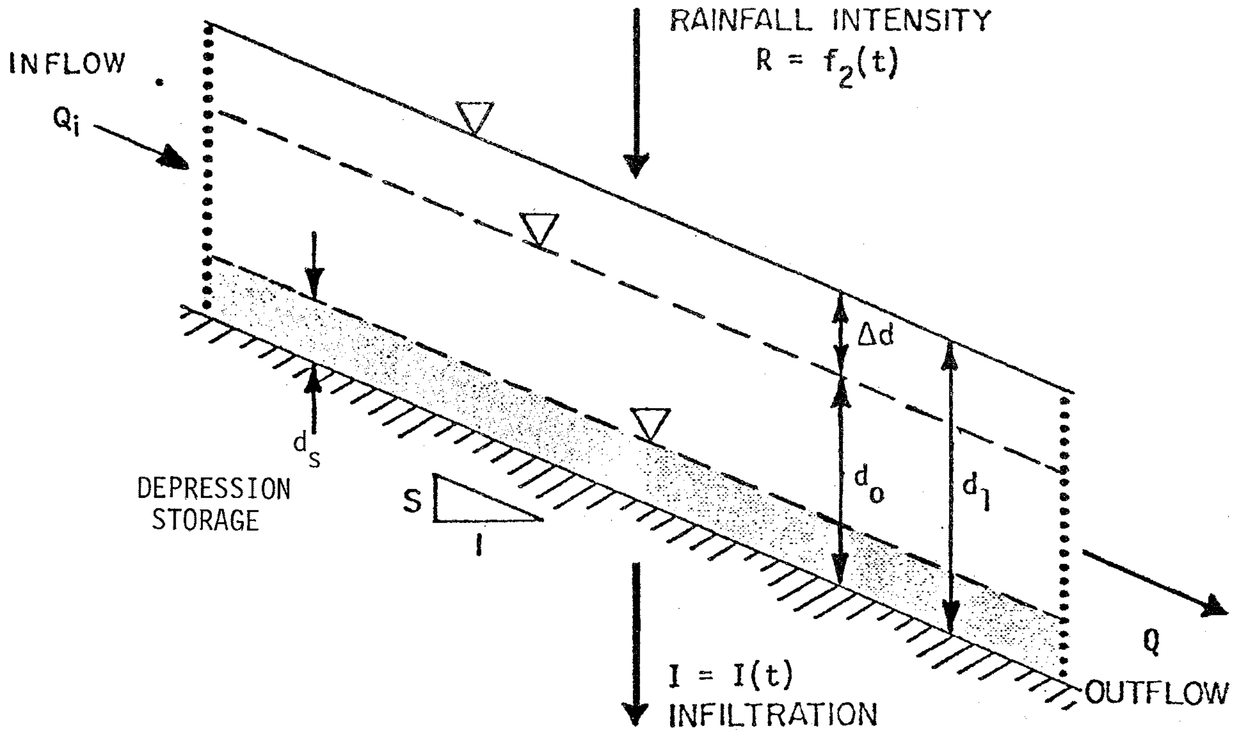
The gutters/channels and watersheds of the drainage area being simulated must be discretized into a series of computational elements by the user. The gutters or channels being simulated are divided into a series of sections having constant hydraulic and geometric characteristics, as mentioned above. Furthermore, the entire length of gutter or channel, L, is partitioned by the program into n segments of Δx length, where n is an integer and Δx is an incremental length selected by the user such that $L = n\Delta x$. The program checks every Δx along the gutter or channel for the need to locate an inlet.

The drainage area along either side of the gutter or channel must also be discretized into a series of watersheds of constant hydraulic and geometric characteristics. Each watershed must drain to a gutter; 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 Inlet Design 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.

The three-plane runoff computation sequence can be generalized for an arbitrary subarea as shown in Figure III-1. 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:



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

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

INFLOW: Q_i

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

FIGURE III-1. Basic Flow Computations for Typical Watershed Subarea

d_o = depth at time t;
d_1 = depth at time t + Δt; 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):

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

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 and thus modify the Horton approach.

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:

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

where

F = Newton's function

$$k = -\left(\frac{1.49}{n} S^{1/2} W\right) / A_s$$

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

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

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:

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

The subscripts refer to the n^{th} and $(n+1)^{th}$ iterations. Repeated application of this expression converges 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:

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

The corresponding value of Δd gives the final depth, d_1, and the outflow, Q, can then be calculated from equation III-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 ROUTING

The surface runoff calculated as described above is next routed through the gutters or channels of the highway right-of-way. Consider the typical trapezoidal channel shown in Figure III-2. (Note that a curb and gutter would just be a special case of the trapezoidal channel with the bottom width set equal to zero.) The outflow from each channel, Q, is determined beginning with the most upstream channel and working downstream, the outflow from each channel then serving as inflow to the next downstream channel if no inlet has been located at the end of the upstream channel. If an inlet has been located there, the appropriate carryover flow is calculated as described in the next section of this chapter.

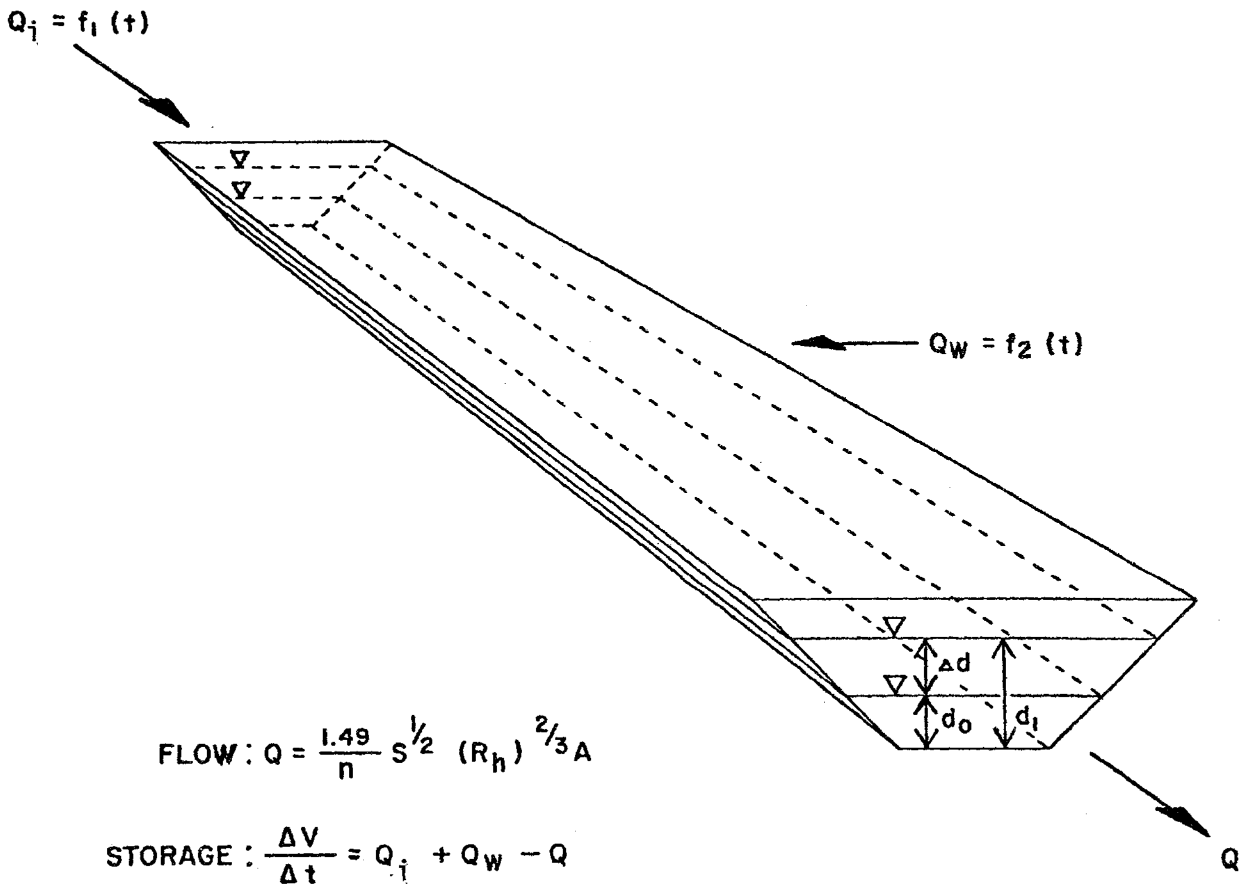


FIGURE III-2. Flow Calculations for Typical Channel

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 $t + \Delta t$;
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 plan 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 from channel 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_0 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_0 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:

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

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

INLET HYDRAULICS

The algorithm used to locate inlets in the gutters and channels of the highway right-of-way was described briefly above and will be discussed further in the next chapter. An integral part of the inlet spacing algorithm is the simulation of inlet hydraulics. Specifically, the program can calculate the flow intercepted by several different types of inlets as a function of the gutter/channel characteristics and the gutter/channel flow. The remainder of this section describes the technical approach used by the program to simulate inlet hydraulics.

The Inlet Design 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 (1) 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/channel flow can be input for a fixed-size inlet of any of the six types listed above.

The hydraulic performance of the sump inlet is approximated by an orifice equation approach, described below.

FHWA Depressed Curb Opening Inlets on Continuous Grades - Izzard Methodology

A methodology has been developed by Izzard (1) to determine the flow properties of the FHWA depressed curb opening inlet, as shown in Figure III-3. The methodology proceeds as follows.

Based upon the depth of flow in the gutter and the cross-sectional properties of the gutter, the flow spread T (ft) and the

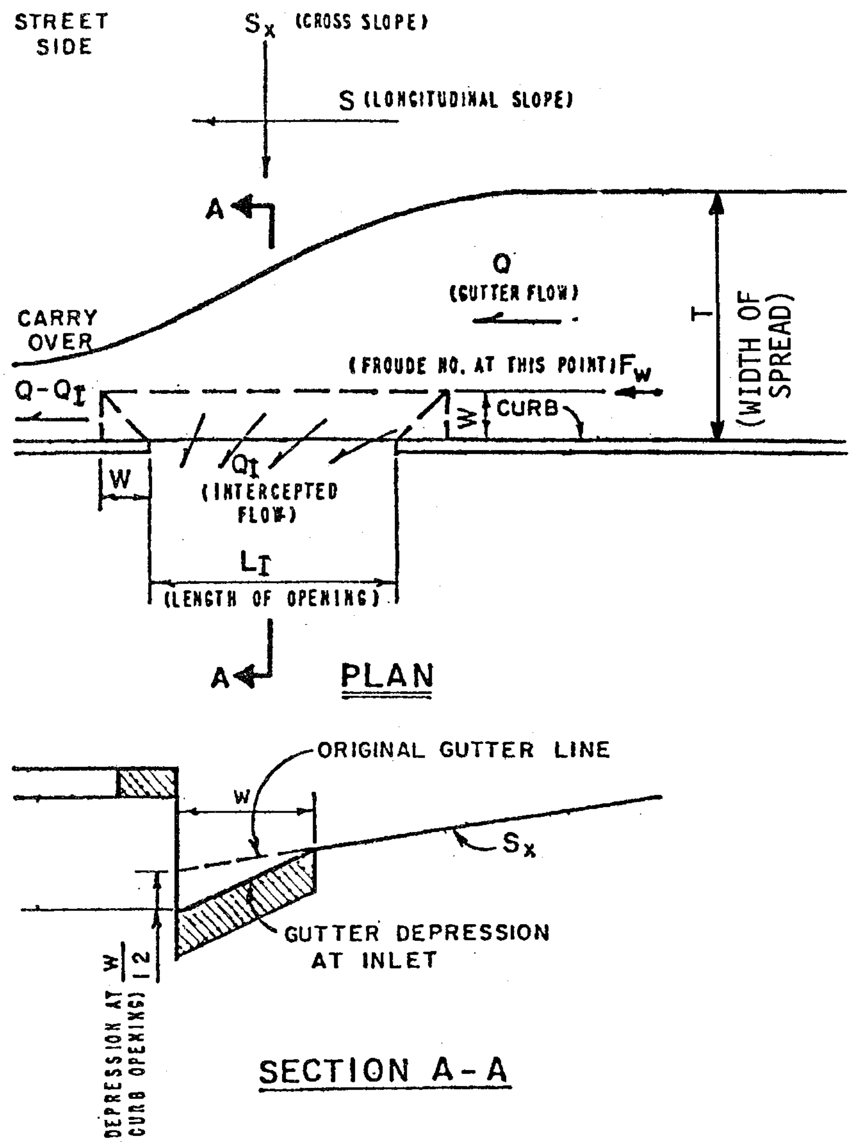


FIGURE III-3. FHWA Depressed Curb Opening Inlet flow Q (cfs) may be determined. The design engineer is required to specify the depression width W (ft). The depression depth is assumed to be equal to W/12 (feet). The following steps are then followed to compute the flow characteristics.

Step 1: Compute Froude Number:

$$F_w = \frac{0.262}{n} \{ (T - W)S_x\}^{1/6} S^{1/2} \qquad \text{(III-13)}$$

where

F_w = Froude Number at a distance W from the curb face
n = Mannings 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:

$$L_1 = 2.79\, W^{-1/6}\, S_x^{\,0.3} F_w T \qquad \text{(III-14)}$$

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

Step 3: Compute maximum inlet length for weir flow:

$$L_{max} = 3.67 W^{-1/6}\, S_x^{\,0.5} F_w T \qquad \text{(III-15)}$$

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

Step 4: Compute inlet length for complete interception:

$$L_{100} = 1.85 W^{1/6} F_w T \qquad \text{(III-16)}$$

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

Step 5: Compute flow intercepted and carryover flow:

$$Q_I = \left(\frac{L_I}{L_1}\right) Q \text{ when } L_I < L_{max} \qquad \text{(III-17)}$$

$$Q_I = \left(\frac{L_I}{L_{100}}\right)^{0.4} Q \text{ when } L_I \geq L \qquad \text{(III-18)}$$

$$Q_c = Q - Q_I \qquad \text{(III-19)}$$

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-4. (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 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 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

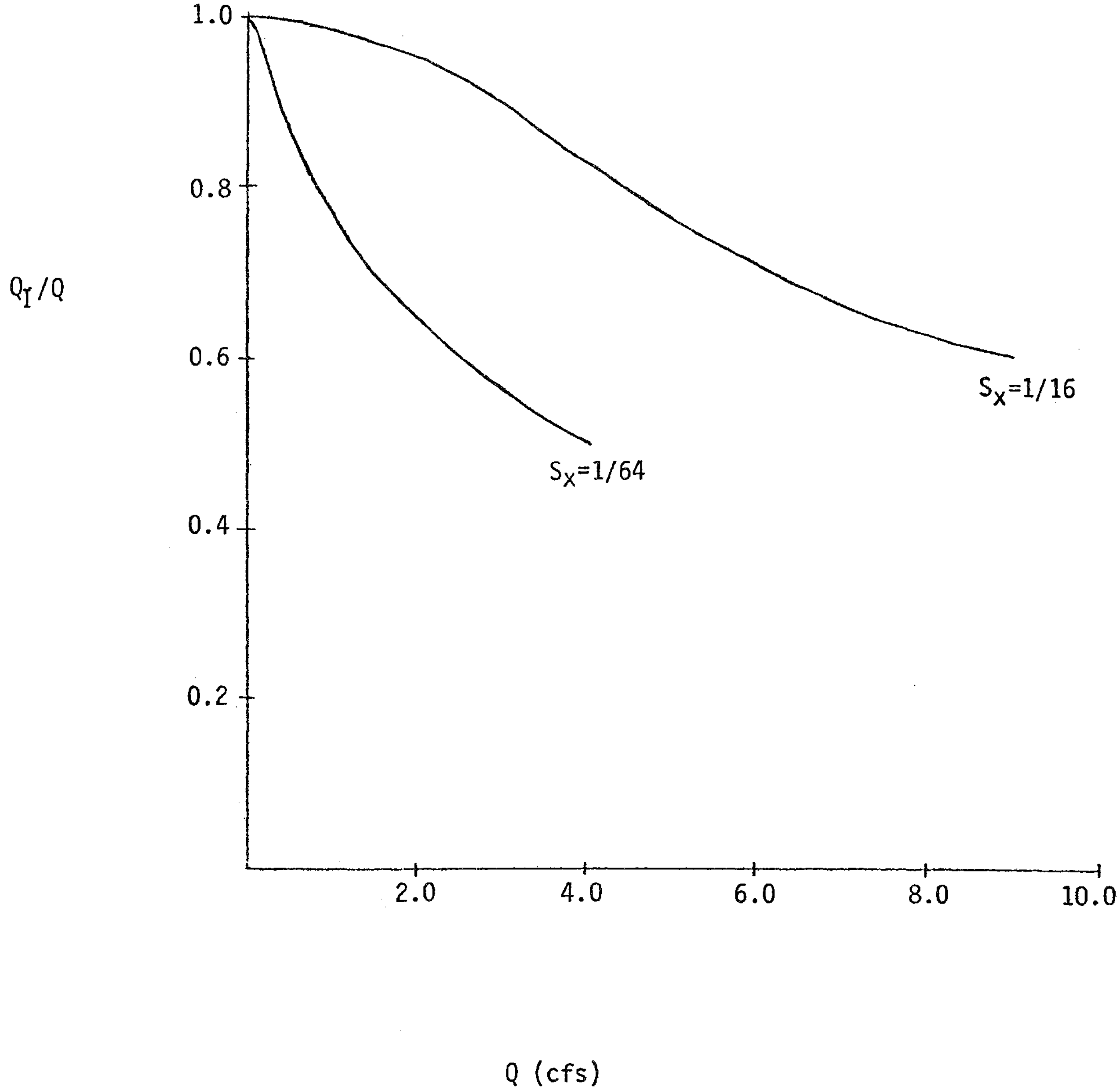


FIGURE III-4

INLET EFFICIENCY CURVES FOR 2' X 4'
PARALLEL BAR GRATE INLET WITH LONGITUDINAL
SLOPE = 0.02 (ℓ)

slopes must be input by the user. In the example curves of Figure III-4 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.

Sump Inlet

The hydraulic performance of the sump inlet is computed with an orifice equation approach. The program assumes that the sump has the following typical dimensions: 1) a maximum depth (curb height) of one foot; 2) a cross-slope of 1/24; and 3) a longitudinal slope of 0.2%. The following orifice equation is used to calculate flow interception by the inlet in the sump:

$$Q_I = CA(2gH)^{1/2} \qquad \text{(III-20)}$$

where

Q_I = flow intercepted by the inlet (cfs)

C = orifice discharge coefficient

g = acceleration due to gravity (=32.2 ft/sec^2)

H = depth at inlet (ft)

A = area of inlet opening (ft^2)

Note that the area of the inlet opening is calculated by multiplying an inlet length and an inlet width input by the user. This should be kept in mind if the user is specifying a grate inlet in the sump whose opening area is less than its total area, or if the user wishes to account for clogging.

The program first calculates the volume of flow into the sump at the given time step. This flow volume is added to any ponded water that may remain from the previous time step. If the resulting total volume of ponded water exceeds the maximum volume of the sump (i.e., the depth of ponding exceeds the curb height), then the excess volume is considered lost to flooding and the total volume of ponded water is set equal to the sump volume. A running total is kept of the excess flow volume.

The volume of ponded water is then used to calculate the depth of ponding at the inlet (H) and with equation III-20, the resulting flow into the inlet. The volume of ponded water is reduced by the volume that flows into the inlet during the time step. The program then proceeds to the next time step and repeats the above series of computations.

Upon completing the sump inlet calculations, a summary of the hydraulic conditions at the sump is printed. Included in this summary are: 1) the maximum spread of ponded water during the storm; 2) the maximum depth of ponded water; 3) the peak flow to the sump; and 4) the total volume of ponded water in excess of the sump volume.

CHAPTER IV

USER'S MANUAL

The Inlet Design Program requires as input a series of cards describing the drainage area to be simulated, the design hyetograph, and the relevant design criteria. The program output includes a rainfall-runoff continuity summary, the location of the required inlets, and the peak hydraulic conditions at each inlet during the design storm. This chapter gives the input requirements for the program, a detailed program description and an example problem.

INPUT REQUIREMENTS

The input data required by the Inlet Design Program and the formats in which the data must be supplied are presented in Table IV-1. Input data are divided into the following seven 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: Prespecified Inlet Data
- Card Group 6: Gutter/Channel Data
- Card Group 7: Watershed Data

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

Card Group One: Simulation Control Data

Card Group 1A of this card group consists of two title cards which can be used to describe the drainage project being designed.

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

Card Group	Format	Card Column	Description	Variable Name	Default Value
			SIMULATION CONTROL CARDS		
1A	20A4	1-80	Title Information (2 cards)	TITLE(40)	-
1B	17	1-7	Start Stationing (hundreds of feet or meters)	IS100	-
	I1	9	Start Stationing (tens of feet or meters)	IS10	-
	I1	10	Start Stationing (units feet or meters)	IS1	-
	I7	11-17	Final Stationing (hundreds of feet or meters)	IF100	-
	I1	19	Final Stationing (tens of feet or meters)	IF10	-
	I1	20	Final Stationing (units feet or meters)	IF1	-
	I5	21-25	Number of Time Steps	NSTEP	-
	F5.0	26-30	Time Step Length (minutes)	DELT	-
	I5	31-35	Number of Raingages	NRGAG	-
	I5	36-40	Units Option (IMET=0 - British units) (IMET=1 - Metric units)	IMET	0
1C	3I5	1-5	Upstream Gutter Flow Depth Scratch Disc File	NU	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
		6-10	Downstream Gutter Flow Depth Scratch Disc File	ND	-
		11-15	Watershed Flow Scratch Disc File	NTAPE	-
			RAINFALL CARDS		
2A	I5	1-5	Number of Rainfall Intervals	NHISTO	-
	F5.0	6-10	Duration of Rainfall Interval (minutes)	THISTO	-
2B		Repeat Card 2B for each raingage (J=1, NRGAG). Place up to 5 rainfall intensities per card.			
	5F10.0	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	-
		Repeat Card Group 3B for each infiltration type (K=1, INFIL, INFIL $\leq$ 4).			

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
3B	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)	-
			INLET CARDS		
4A			Inlet Type (ITYPC) 1 = Curb Opening Inlet 2 = Depressed Curb Opening Inlet 3 = Grate Inlet 4 = Depressed Grate Inlet 5 = Combination Inlet 6 = Depressed Combination Inlet		
	I10	1-10	Type of Inlet on Grade (1-6)	ITYPC	-
	F10.0	11-20	Incremental Routing Length (feet or meters)	DX	-
	F5.0	21-25	Minimum Capture Ratio for Inlets on Grade (ratio of flow intercepted to gutter/channel flow)	RIN	-
	F5.0	26-30	Routing Direction + 1 - Ascending Direction - 1 - Descending Direction	DIR	-
	I5	31-35	Incremental Routing Length Reduction Factor	MULT	1

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	I5	36-40	Type of Surface Conveyance System 1 - Gutters 2 - Channels	NPG	
			Inlet Design Option (INOMG) 0 - Supply Efficiency Curves as Input 1 - Supply Efficiency Curves in Block Data 2 - Use Design Equations in Program		
	I5	41-45	Inlet on Grade Design Option	INOMG	0
	F10.0	46-55	Inlet Capacity Reduction Factor	RD	1.0
	F10.0	56-65	Sump Inlet Grate Width (feet or meters)	SWIDTH	-
	F10.0	66-75	Sump Inlet Grate Length (feet or meters)	SLENG	-
	F5.0	76-80	Orifice Discharge Coefficient for Sump	SCOEFF	-
			If the surface conveyance system consists of channels (i.e., NPG = 2), omit the next two card groups and proceed to Card Group 4D.		
			If the user is supplying efficiency curves for inlets on grade (i.e., INOMG = 0), continue to Card Group 4B. Otherwise, omit this card group and proceed to Card Group 4C.		

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
4B			Efficiency Curves for Inlets on Grade in Gutters 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
		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)	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			Include Card Group 4C only if the depressed curb opening inlet is being used (i.e., ITYPC = 2) and the inlet design equations in the program are being used (i.e., INOMG = 2). Otherwise, omit this card group.		
4C	2F10.0	1-10	Apron Depression Width (feet or meters)	W	-
		11-20	Inlet Length (ft or m)	GLI	-
			Include Card Group 4D only if the surface conveyance system is channels (i.e., NPG = 2) and the user is supplying efficiency curves for inlets on grade (i.e., INOMG = 0).		
4D			Efficiency Curves for Inlets on Grade in Channels		
			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	QINLG(I,J,1)	1.0
		7-12	Depth (ft or m)	QINLG(I,J,2)	0.0
		13-18	Ratio of Flow Intercepted to Channel Flow	QINLG(I,J,3)	-
		19-24	Depth (ft or m)	QINLG(I,J,4)	-
		25-30	Ratio of Flow Intercepted to Channel Flow	QINLG(I,J,5)	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
		31-36	Depth (ft or m)	QINLG(I,J,6)	-
		37-42	Ratio of Flow Intercepted to Channel Flow	QINLG(I,J,7)	-
		43-48	Depth (ft or m)	QINLG(I,J,8)	-
		49-54	Ratio of Flow Intercepted to Channel Flow	QINLG(I,J,9)	-
		55-60	Depth (ft or m)	QINLG(I,J,10)	-
		61-66	Ratio of Flow Intercepted to Channel Flow	QINLG(I,J,11)	-
		67-72	Depth (ft or m)	QINLG(I,J,12)	-
			PRESPECIFIED INLET CARDS		
5A	I10	1-10	Number of Prespecified Inlets	NSPEC	0
		If NSPEC = 0, skip to Card Group 6			
5B		Repeat Card Group 5B NSPEC times.			
	I7	1-7	Station (hundreds of feet or meters at inlet)	NG100	-
	I1	9	Station (tens of feet or meters at inlet)	NG10	-
	I1	10	Station (units of feet or meters at inlet)	NG1	-
	F10.0	11-20	Inlet Length (feet or meters)	XSPEC(I)	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
			GUTTER/CHANNEL CARDS		
			Repeat Card Group 6 for up to 200 gutters/ channels, two cards for each gutter/channel.		
6A	I10	1-10	Name of Gutter/Channel (external number)	NAMEG(N)	-
	I7	11-17	Upstream Station (hundreds of feet or meters)	NG100	-
	I1	19	Upstream Station (tens of feet or meters)	NG10	-
	I1	20	Upstream Station (units of feet or meters)	NG1	-
	I7	21-27	Downstream Station (hundreds of feet or meters)	NP100	-
	I1	29	Downstream Station (tens of feet or meters)	NP10	-
	I1	30	Downstream Station (units of feet or meters)	NP1	-
	F10.0	31-40	Width of Gutter/Channel (feet or meters)	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)	-
	F10.0	61-70	Reciprocal Side Slope 2 (ft/ft or m/m)	GS2(N)	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	F10.0	71-80	Manning Roughness Coefficient	GN(N)	-
6B	I10	1-10	Number of DX Lengths in Gutter/ Channel	NG2	-
	F10.0	11-20	Design Flow Spread (ft or m) (only for gutter case)	SPMAX(N)	-
	F10.0	21-30	Design Depth (ft or m) (only for channel case)	DFULL(N)	-
			Terminate this card group with one blank card.		
			WATERSHED CARDS		
			Repeat Card Group 7A for each watershed, up to 200 watersheds.		
7A	I10	1-10	Name of Watershed (external)	NAMEW(N)	-
	I10	11-20	Gutter/Channel Drainage Side 1 or 2 (1 must be the highway side for gutters)	NGTO(N)	-
	I10	21-30	Raingage Number	JK	-
	F10.0	31-40	Watershed Area (acres or hectares)	AREA	-
	I10	41-50	Number of Watershed Subareas	NW3	-
	I7	51-57	Start Station (hundreds of feet or meters)	NW100	-
	I1	59	Start Station (tens of feet or meters)	NW10	-

TABLE IV-1

PROGRAM INLET INPUT DATA REQUIREMENTS

(Continued)

Card Group	Format	Card Column	Description	Variable Name	Default Value
	I1	60	Start Station (units of feet or meters)	NW1	-
	I10	61-70	Number of DX Lengths in Watershed Width	NW2	
			Repeat Card Group 7B NW3 times for each watershed, immediately after the corresponding 7A card.		
7B	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 Card Group 7 with one blank card		

Card Group 1B consists of a single card containing several simulation control variables. The first six variables give the highway stations at the beginning and end of the gutters or channels being simulated. The next two variables give the number of time steps, NSTEP, and the time step length in minutes, DELT. 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 on Card 1B describes an option of the program. The units to be used are selected with variable IMET; IMET set equal to zero selects British units, IMET equal to one selects metric units.

Card Group 1C is used to identify the unit numbers on the user's computer system corresponding to the three disc files required by the program.

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.

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 last 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 to be located, the characteristics of the inlets and related information.

Card Group 4A contains several variables that control the inlet location task. The first variable is used to select the inlet types - ITYPC for inlets on grade. Note that only one inlet type may be used for all the on-grade inlets in a single program run. The next variable, DX, is the incremental routing length; the program will check every

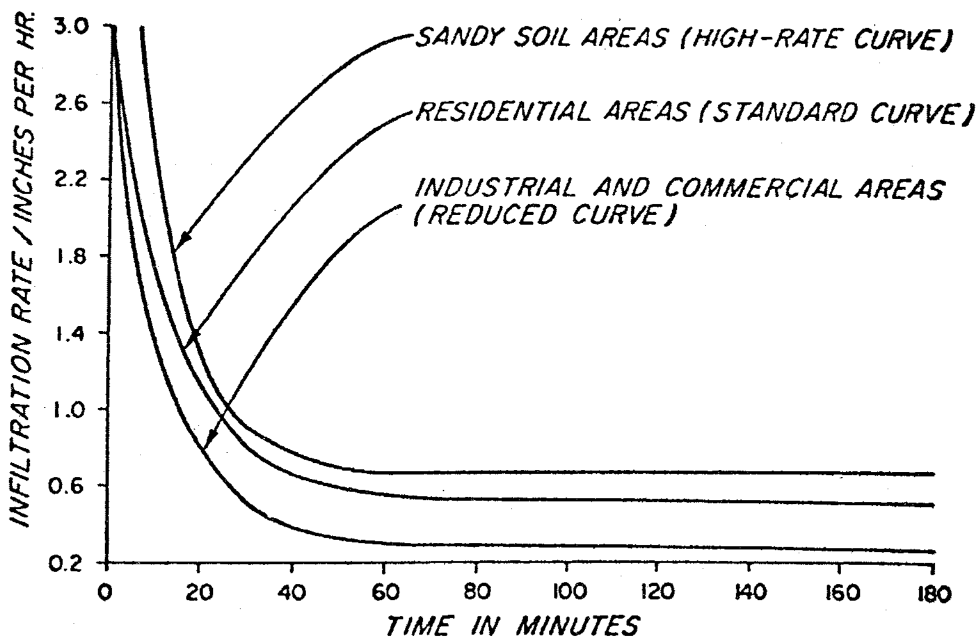


FIGURE IV-1. Example Infiltration Curves (3)

TABLE IV-2

TYPICAL VALUES FOR HORTON INFILTRATION FORMULA FOR GRASSED AREAS (4)

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.

DX feet (or meters) along the gutters or channels for the need to locate an inlet. Tests of the program have indicated that a DX on the order of 25 feet or 50 feet is suitable for most applications.

The user specifies the minimum capture ratio to be achieved by each inlet on grade with the next variable, RIN. RIN is defined as the ratio of the flow intercepted by the inlet to the total gutter/channel flow at the inlet. The next variable, DIR, specifies the gutter/channel flow routing direction in terms of highway stations. If the highway stations increase from the upstream end to the downstream end of the gutters/channels, then DIR should be set equal to +1; if the stations decrease from the upstream end to the downstream end, then DIR should be set equal to -1.

The incremental routing length reduction factor, MULT, allows the user to decrease the routing length DX if program runs show that the initial value of DX selected was too large to allow adequate inlet spacing. Card Groups Six and Seven, the gutter/channel cards and the watershed cards, use DX to define lengths; with MULT, the user can change the value of DX without having to change DX on all the gutter/channel cards and the watershed cards. The value of DX specified will be multiplied in the program by the inverse of MULT.

The next variable on Card Group 4A, NPG, specifies whether the surface conveyance system being simulated consists of gutters or channels. Three options for on-grade inlet capacity computation are available; the next variable, INOMG, is used to select one of these options. If the user supplies inlet efficiency curves as input, then INOMG should be set equal to zero. If inlet efficiency curves stored in Block Data of the program are to be used, then INOMG should be set equal to one. If inlet capacity equations in the program are used, then INOMG should be set equal to two. (Note that the only equations presently in the code are those for depressed curb opening inlets in gutters.)

The next variable on Card Group 4A is 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 $0 < RD \leq 1$.

The last three variables give the characteristics of the sump inlet. SWIDTH and SLENG are the width and length respectively of the sump inlet grate. SCOEFF is the orifice discharge coefficient for the inlet, as defined in equation III-20.

Card Group 4B is used to supply efficiency curves for on-grade inlets in gutters when this option has been selected. Use of the curves is explained in Chapter III and example curves are shown in Figure III-4. 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 consists of gutters, if the on-grade inlet selected 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, as defined in Figure III-3, and the inlet length.

Card Group 4D is used to supply efficiency curves for inlets in channels when this option has been selected. 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 Five: Prespecified Inlet Cards

The characteristics of prespecified inlets are defined with these cards. Card Group 5A is a single card on which the number of prespecified inlets NSPEC is given. If no inlets are to be prespecified, then NSPEC should be set equal to zero and Card Group 5B skipped.

Card Group 5B should be supplied for each inlet to be prespecified, one card for each inlet. The first three variables on the card give the highway station of the inlet. The last variable gives the inlet length.

Card Group Six: 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.

Card Group 6A is a single card with twelve 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 six variables define the upstream and downstream stations of the gutter or channel.

Hydrogeometric properties, including the cross-section of the gutter/channel in terms of a general trapezoidal cross-section, 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, then GWIDTH(N) equals zero. 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. The first slope, GS1(N), should be the slope on the highway side. The last variable is the Manning roughness coefficient of the gutter/channel.

Card Group 6B is used first to define the number of incremental lengths DX (as given in Card Group 4A) in the gutter/channel length. Note that the gutter/channel length must be an integral multiple of DX. The second variable on this card group SPMAX(N) is used only for gutters and defines the maximum allowable flow spread. The last variable, DFULL(N), is used only for channels and defines the maximum allowable flow depth. These last two variables should be selected in accordance with local design criteria.

Note that for each gutter or channel the 6B card must follow immediately after the corresponding 6A card.

Card Group Seven: 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 7A and 7B must be provided for each watershed.

Card Group 7A contains nine 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 which side of the appropriate gutter or channel the watershed drains to. The sides are identified as sides one and two, corresponding to the gutter/channel side slopes GS1 and GS2 specified in Card Group Six. In general, the highway surface should drain to side one of the gutter or 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 next three variables give the highway station at the upstream end of the watershed. The final variable on Card Group 7A is the number of incremental lengths DX (as specified on Card Group 4A) in the watershed width, parallel to the gutters or channels.

Card Group 7B is supplied once for each subarea; thus, there can be from one to three 7B cards following each 7A 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 (5). 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.

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

PROGRAM DESCRIPTION

General Structure

Program INLET is structured into eight computational units--Main Program INLET, Subroutine RHYDRO, Subroutine WSHED, Subroutine OUTPUT, Subroutine CARRY, BLOCK DATA, Subroutine GUTTER and Function DEPTH. The relationships among these units are illustrated in Figure IV-2. The main program INLET controls the computational sequence. The primary function of each subroutine is as follows:

- RHYDRO - Reads input data
- WSHED - Computes watershed flows
- OUTPUT - Prints location of required inlets
- CARRY - Computes inlet interception and carryover
- BLOCK DATA - Initializes data array
- GUTTER - Computes flow in each gutter/channel
- DEPTH - Computes gutter/channel depth corresponding to given flow

The main program and each of these subroutines is discussed in turn below, followed by a complete definition of all common block variables.

Main Program INLET

The following subroutines are called from the main program:

- GUTTER
- OUTPUT
- RHYDRO
- WSHED

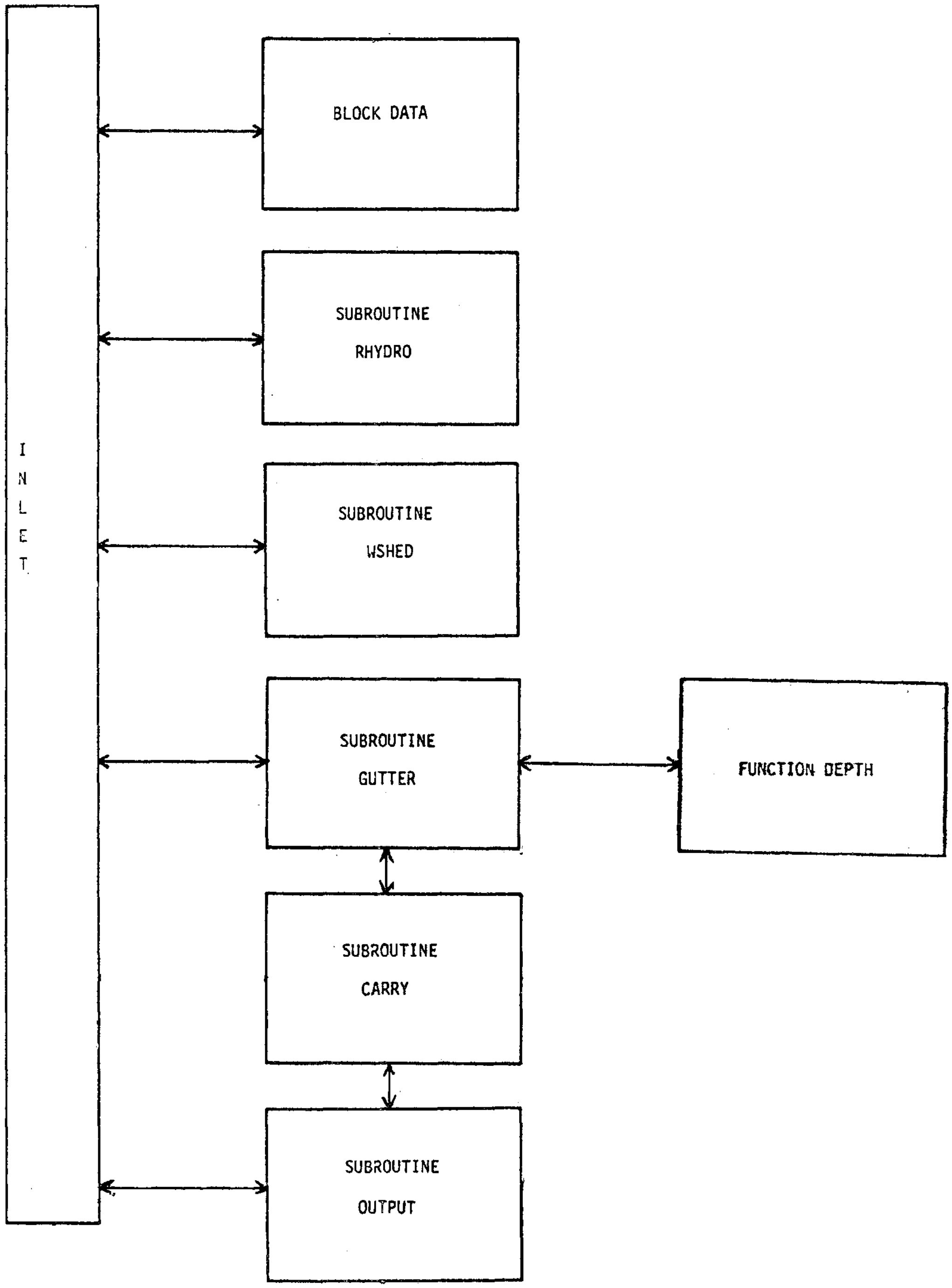


FIGURE IV-2. Computational Unit Relationships

The following common blocks are employed in the main program:

- BLANK COMMON
- TAPES
- INLET
- SYS
- LOC
- ROUT
- CONT
- LENGTH
- SUMP

The main program INLET is presented in flowchart form in Figure IV-3. Subroutine RHYDRO is called to read all input data. Subroutine WSHED is next called to compute all watershed flows for all time steps. These flows are saved as watershed file NTAPE.

Initialization of gutter/channel section parameters and of the simulation time are next performed. The simulation proceeds from upstream to downstream considering each gutter/channel section over all time increments. A file is employed to store the hydrograph at the end of gutter/channel section I. This hydrograph becomes the inflow hydrograph to gutter/channel section I + 1. After depth and flow are computed for each time step for gutter/channel section I + 1, the outflow hydrograph is written to a second file. Thus, for each gutter/channel section, one file, containing the inflow hydrograph, is read and a second file, for the outflow hydrograph, is written.

Subroutine GUTTER is called to compute the depth and flow in each gutter/channel section, based on the watershed flows to that section and the inflow from the upstream section. If an inlet has been located at the end of the upstream section, either by the user as a prespecified inlet or by the program during the simulation, then subroutine CARRY is called to compute the percentage of outflow intercepted by the inlet and the percentage of outflow carried over to the downstream section.

The inlet location algorithm proceeds as follows. The entire gutter/channel to be simulated is divided into n increments of Δx length, as specified by the user. For a given gutter/channel length, the appropriate design criteria are checked at each time step. For gutters, the flow spread

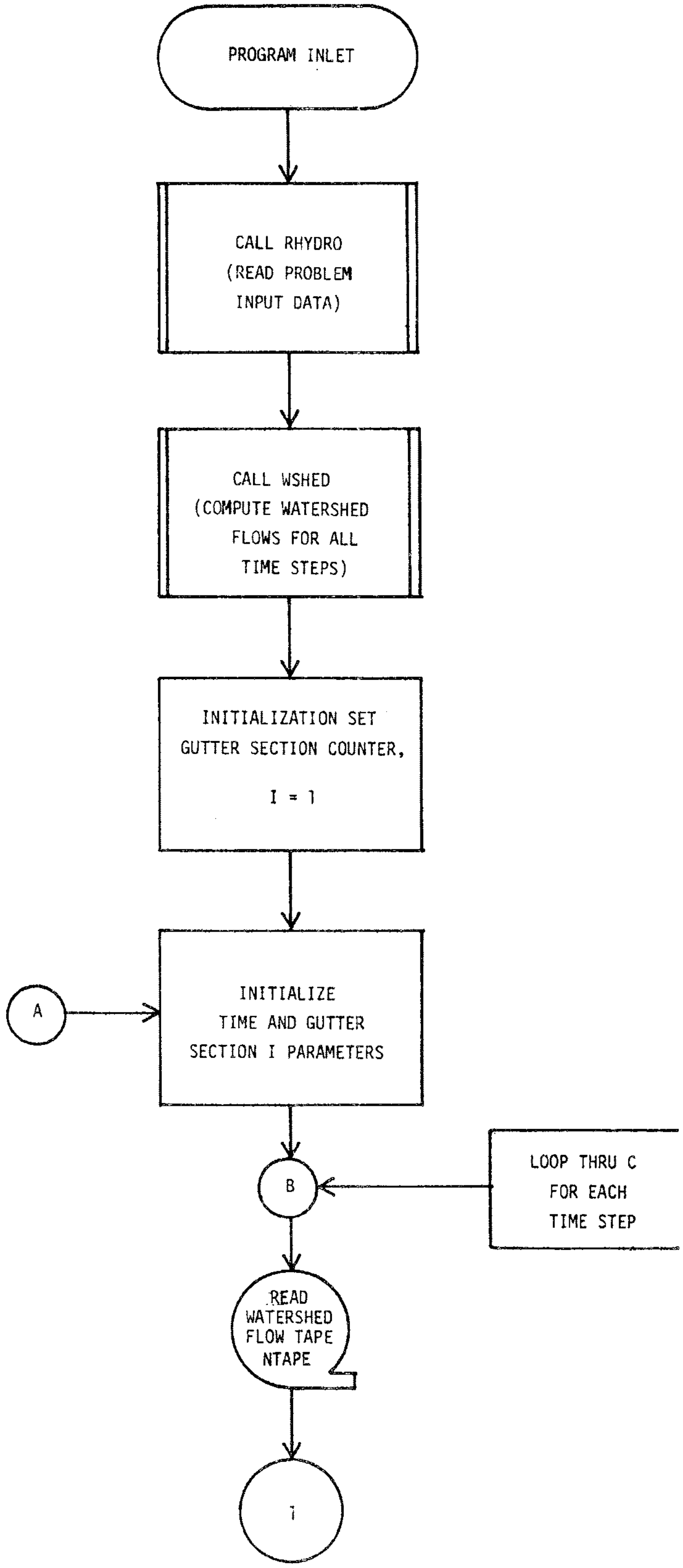


FIGURE IV-3. Flowchart For Main Program INLET

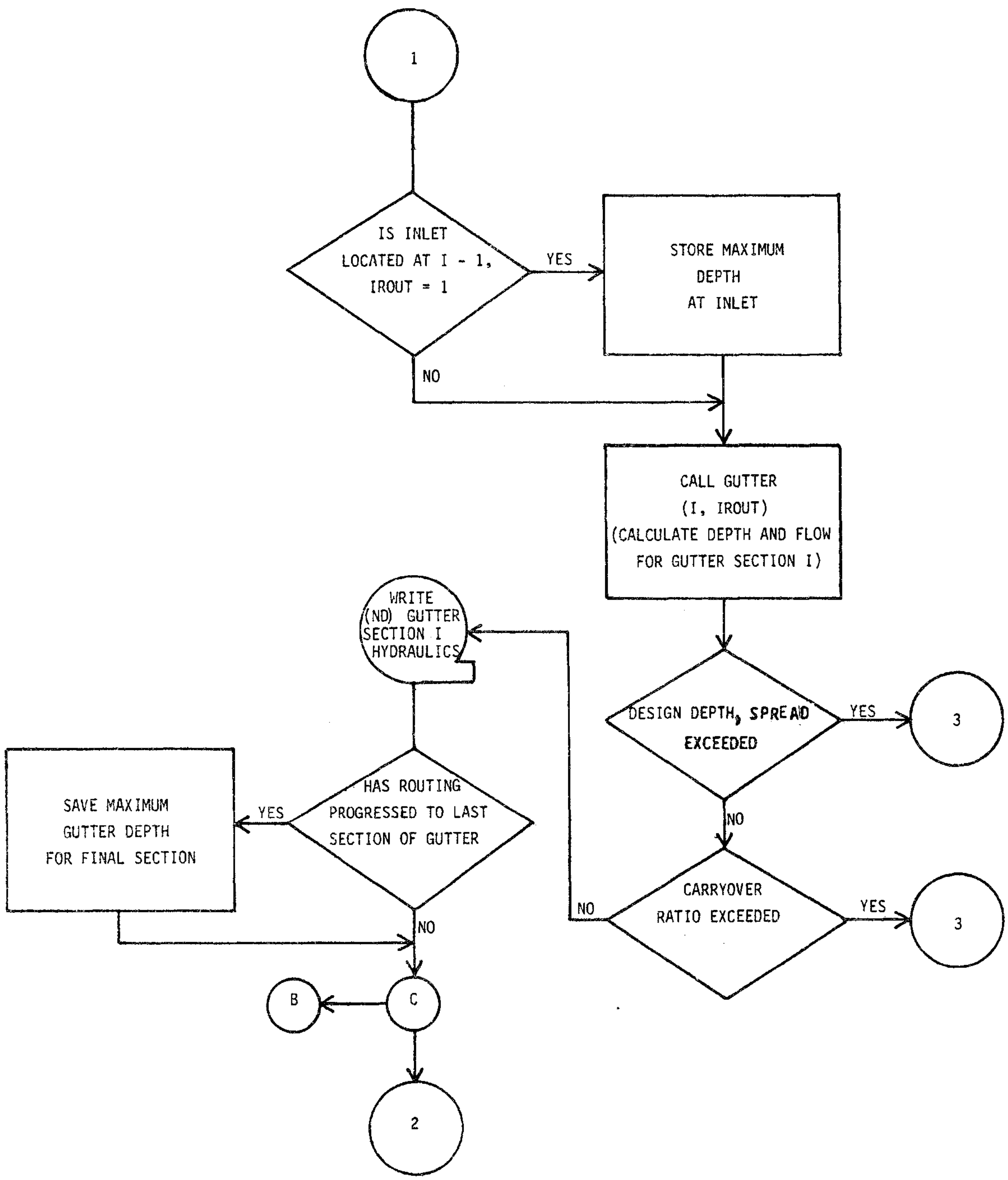


Figure IV-3 (Continued)

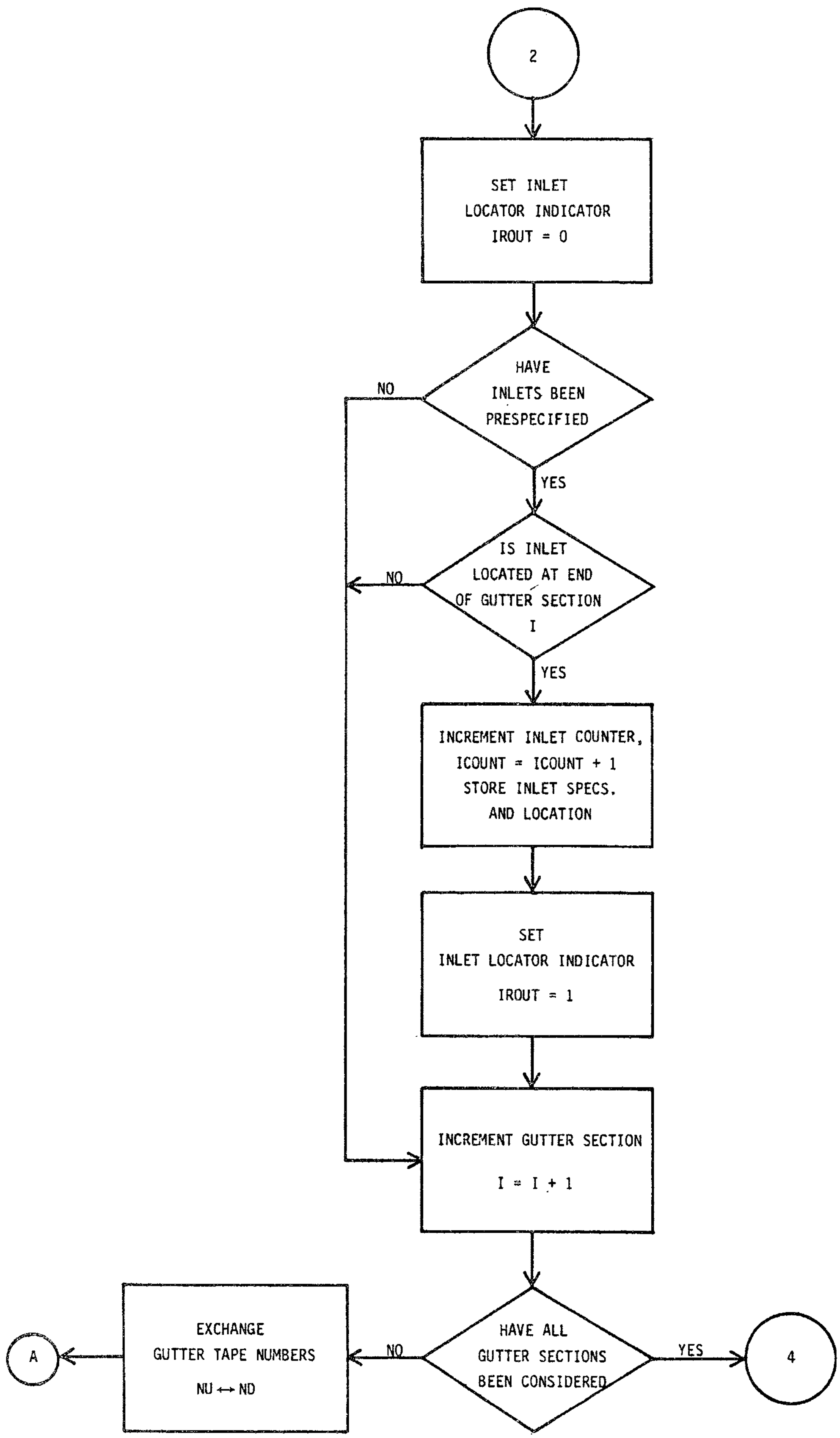


Figure IV-3 (Continued)

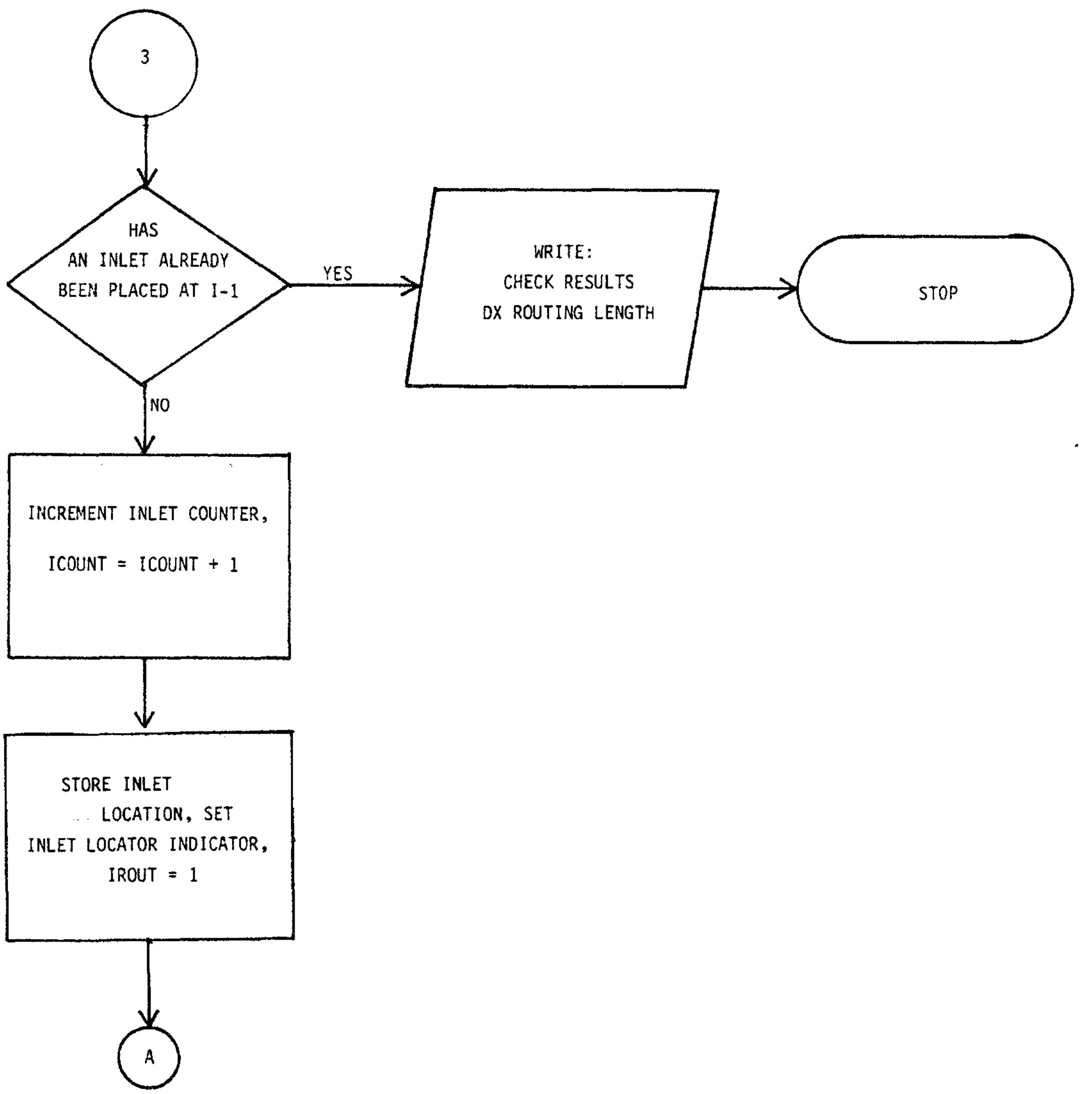


Figure IV-3 (Continued)

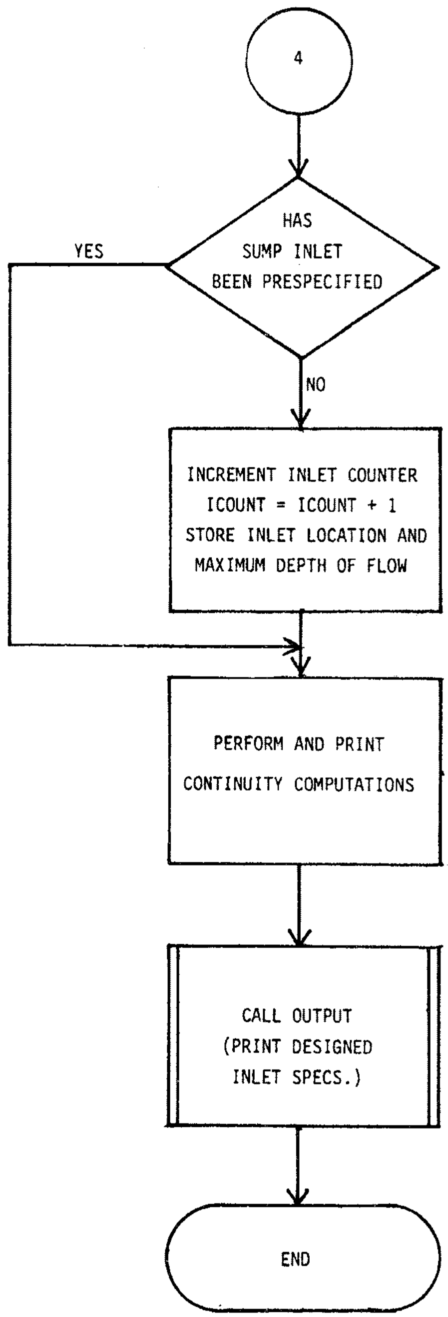


Figure IV-3 (Continued)

is compared with the maximum allowable flow spread; for channels, the flow depth is compared with the maximum allowable depth. If an inlet has been prespecified at the end of the upstream gutter/channel length, then the maximum allowable carryover ratio is also checked.

If neither of the design criteria is violated at any time step, then the program proceeds to the next gutter/channel length downstream. However, if one of the design criteria is violated, then the program places an inlet at the end of the upstream gutter/channel length. In the special case when an inlet has been prespecified by the user at that location, the program stops execution and prints an error message indicating that the incremental length must be decreased or an inlet with greater capacity specified.

After the program places an inlet at the end of the upstream gutter/channel length, the simulation resumes, now including the reduction in outflow from the upstream gutter/channel due to the presence of the inlet. The program continues to check the appropriate design criteria at each time step. If neither criterion is subsequently violated, the inlet placed by the program is adequate and the program proceeds to the next downstream gutter/channel length. However, if either criterion is violated later in the simulation, the program will again try to place an inlet at the end of the upstream gutter/channel length. When the program finds that it has already placed an inlet at that location, the program stops execution and prints an error message indicating that the incremental length must be decreased or an inlet with greater capacity specified.

After all gutter/channel sections have been considered, the program assumes it has reached the sump. A check is made to see if the sump inlet has been prespecified; if not, an inlet is placed in the sump.

Continuity calculations are next performed and then printed. Subroutine OUTPUT is then called to print the design inlet specifications and thereby complete the simulation.

All key variables not contained in common are presented in Table IV-4. The listing of the main program follows.

Subroutine RHYDRO

This routine is called from the main program INLET to read all input data. No subroutines are called from Subroutine RHYDRO; however, the following common blocks are employed:

- ROUT
- TAPES
- BLANK COMMON
- NEW
- INFL
- INLET
- SYS
- LENGTH
- CONT
- SUMP

The major data groups are read in the following sequence:

- Simulation Control Data
- Rainfall Intensity Data
- Infiltration Characteristics
- Inlet Routing Parameters and Sump Inlet Data
- Inlet on Grade Data
- Prespecified Inlet Data
- Gutter/channel Definition Data
- Watershed Data

The exact card format for each data group was presented earlier in this chapter. Error checking is included in this routine for the gutter/channel and watershed stationing. If errors are encountered, an appropriate message is printed to inform the engineer how to correct the problem and the

TABLE IV-4

KEY VARIABLES NOT IN COMMON FOR MAIN PROGRAM INLET

FORTRAN VARIABLE	DESCRIPTION	UNITS
DMAX	Maximum gutter depth at sump inlet	ft or m
IROUT	Current Inlet Locator Indicator Variable	--
ISAVE	Previous Inlet Locator Indicator Variable	--
GL	Previous inlet length	ft or m
SUMCHL	Sum of change in storage over all gutter sections	ft^3 or m^3
SUMST	Sum of change in storage over all watersheds	ft^3 or m^3
TOTIN	Total inflow volume	ft^3 or m^3
TOTOUT	Total outflow volume plus change in storage	ft^3 or m^3
ERROR	Error in continuity as a percentage of total inflow volume	--

```
      PROGRAM INLET(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE8,TAPE9,
     2 TAPE10)
      COMMON/ROUT/DIR,DST
      COMMON/SUMP/SVOL,FVOL,SHMAX,SSMAX,SLENG,SWIDTH,SCOEFF,SFLOW(100),
     2SQMAX
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/NEW/NAMEG(200),NGTO(200)
      COMMON/INLET/F,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/SYS/NINCR,NGUT(200),NWAT(200,2),NPG
      COMMON/LENGTH/GLI,GLIS,NSPEC,ISPEC,NLOC(20),XSPEC(20)
      COMMON/CONT/SUMR,SUMI,SUMQI,SUMUP,VOL1(200),VOL2(200)
      COMMON/LOC/ICOUNT,XLOCUS(200),DLOCUS(200),XGLI(200),FR(200)
C
C******** CALL INPUT SUBROUTINE
C
      CALL RHYDRO
C
C******** CALL WATERSHED FLOW SUBROUTINE
C
      CALL WSHED
      ICOUNT=0
      ISAVE=0
      I=1
      SVOL=0.
C
C******** INITIALIZATION FOR EACH ROUTING PROCESS
C
1     TIME=TZERO
      DELD(I)=0.
      QIN(I)=0.
      GDEPTH(I)=0.
      SFLOW(I)=0.
      GFLOW(I)=0.
      REWIND NTAPE
      REWIND NU
      REWIND ND
      DMAX=0.
C
C******** ROUTE FLOWS IN GUTTERS FOR EACH TIME STEP
C
      DO 430 IJ=1,NSTEP
      TIME=TIME+DELT
C
C**** READ WATERSHED HYDROGRAPHS (OVERLAND FLOW)
      READ(NTAPE)T,(WFLOW(K),K=1,NOW)
C
C**** ROUTE HYDROGRAPHS
      IF(I.GE.2) GO TO 6
```

```
18    IROUT=0
      GO TO 7
6     READ(NU)T,GDEPTH(I-1),DELD(I-1),GFLOW(I-1)
      IF(IROUT.EQ.0) GO TO 7
      IF(GDEPTH(I-1).GT.DLOCUS(ICOUNT)) DLOCUS(ICOUNT)=GDEPTH(I-1)
7     CALL GUTTER(I,IROUT,GL,IFLG,IC)
      IF(IFLG.GT.0) GO TO 431
      IF(IC.GT.0) GO TO 431
      WRITE(ND)TIME,GDEPTH(I),DELD(I),GFLOW(I)
      IF(I.NE.NINCR) GO TO 430
      IF(GDEPTH(I).GT.DMAX) DMAX=GDEPTH(I)
      SUMQI=SUMQI+GFLOW(I)*DELT
      SFLOW(IJ)=GFLOW(I)
430   CONTINUE
      IROUT=0
      IF(NSPEC.LE.0) GO TO 30
      IF(I.NE.NLOC(ISPEC)) GO TO 30
      ICOUNT=ICOUNT+1
      DLOCUS(ICOUNT)=0.
      IF(I.EQ.NINCR) DLOCUS(ICOUNT)=DMAX
      FR(ICOUNT)=0.
      XLOCUS(ICOUNT)=X1+DIR*FLOAT(I)*DX
      XGLI(ICOUNT)=XSPEC(ISPEC)
      GL=XSPEC(ISPED)
      ISAVE=I
      ISPEC=ISPEC+1
      IROUT=1
30    I=I+1
C
C******** IF ALL GUTTER SECTIONS HAVE BEEN CONSIDERED, COMPLETE RUN
C
      IF(FLOAT(I)*DX.GT.DST) GO TO 2
      NTEMP=NU
      NU=ND
      ND=NTEMP
      GO TO 1
C
C******** STORE INLET LOCATIONS
C
431   IF((I-ISAVE).GT.1) GO TO 432
      WRITE(N6,503) ISAVE
503   FORMAT(* *,25X,*ROUTING LENGTH OF DX SHOULD BE DECREASED OR LARGER
     2 INLET USED.*,/,25X,*LAST INLET LOCATED AT *,I4,* TIMES INCREMENTA
     3L ROUTING LENGTH.*,/,* ...... SIMULATION TERMINATED .....*)
      STOP
432   ICOUNT=ICOUNT+1
      XLOCUS(ICOUNT)=X1+DIR*FLOAT(I-1)*DX
C
C******** INLETS ON GRADE
C
      ISAVE=I-1
      XGLI(ICOUNT)=GLI
      FR(ICOUNT)=0.
      DLOCUS(ICOUNT)=0.
      IROUT=1
      GO TO 1
C
```

```
C******** SUMP INLET
C
2      IF(IROUT.EQ.1) GO TO 3
       ICOUNT=ICOUNT+1
       DLOCUS(ICOUNT)=DMAX
       XLOCUS(ICOUNT)=X1+DIR*FLOAT(I-1)*DX
       XGLI(ICOUNT)=GLIS
C
C******** CONTINUITY CHECK
C
3      SUMCHL=0.
       DO 300 I=1,NINCR
300    SUMCHL=SUMCHL+VOL2(I)-VOL1(I)
       SUMST=0.
       DO 310 J=1,NOW
       NCA=NC(J)
       DO 310 JJ=1,NCA
310    SUMST=SUMST+WDEPTH(J,JJ)*WAREA(J,JJ)
       TOTIN=SUMR+SUMUP
       TOTOUT=SUMI+SUMQI+SUMCHL+SUMST
       ERROR=(TOTIN-TOTOUT)/TOTIN*100.
       IF(IMET.EQ.0) GO TO 1400
C
C**** METRIC OUTPUT
       WRITE(N6,1350) SUMR,SUMUP,TOTIN,SUMI,SUMQI,SUMCHL,SUMST,TOTOUT,
      2ERROR
1350   FORMAT(*1*,T40,*RAINFALL ON WATERSHED (M3) *,E12.6,/,
      2 T40,*BOUNDARY FLOW VOLUME (M3) *,E12.6,/,
      3 T40,*----- TOTAL INPUT VOLUME (M3)  ------*,E12.6,///,
      4 T40,*INFILTRATION (M3) *,E12.6,/,
      5 T40,*INLET VOLUME (M3) *,E12.6,/,
      6 T40,*CHANNEL STORAGE (M3) *,E12.6,/,
      7 T40,*WATERSHED STORAGE (M3) *,E12.6,/,
      8 T40,*----- TOTAL OUTFLOW STORAGE (M3)  ------*,E12.6,////,
      9 T40,*      ERROR IN CONTINUITY, PERCENTAGE OF INFLOW    *,F10.5)
       GO TO 1500
C
C**** ENGLISH UNITS OUTPUT
1400   WRITE(N6,1430) SUMR,SUMUP,TOTIN,SUMI,SUMQI,SUMCHL,SUMST,TOTOUT,
      2 ERROR
1430   FORMAT(*1*,T40,*RAINFALL ON WATERSHED (FT3)*,E12.6,/,
      2 T40,*BOUNDARY FLOW VOLUME (FT3)*,E12.6,/,
      3 T40,*----- TOTAL INPUT VOLUME (FT3) ------*,E12.6,///,
      4 T40,*INFILTRATION (FT3)*,E12.6,/,
      5 T40,*INLET VOLUME (FT3)*,E12.6,/,
      6 T40,*CHANNEL STORAGE (FT3)*,E12.6,/,
      7 T40,*WATERSHED STORAGE (FT3)*,E12.6,/,
      8 T40,*----- TOTAL OUTFLOW STORAGE (FT3) ------*,E12.6,////,
      9 T40,*      ERROR IN CONTINUITY, PERCENTAGE OF INFLOW    *,F10.5)
C
C******** OUTPUT SUBROUTINE
C
1500   CALL OUTPUT
       STOP
       END
```

simulation is halted. The key variables not in common are as shown in Table IV-5 followed by the subroutine listing.

Subroutine WSHED

This subroutine is called from the main program INLET. No routines are called by Subroutine WSHED. The following common blocks are employed:

- BLANK COMMON
- INFL
- INLET
- CONT
- TAPES

The flowchart is presented in Figure IV-4. The subroutine consists of a nested set of DO loops of order three. The outer loop increments time. For each time step, the second loop increments over the watersheds. For each watershed, the rainfall intensity is determined for the current time step. The third and innermost loop considers each subarea within the given watershed. Up to three subareas may be specified for each watershed. These subareas are cascaded such that the outflow of an upstream subarea represents the inflow to its immediate downstream neighbor. The change in depth and outflow for each subarea is determined from water balance considerations using a Newton-Raphson iteration procedure. The outflow from the downstream-most subarea is written to a disc or tape file for each time step, to be subsequently routed through the gutters or channels of the runoff conveyance system.

The key variables not contained in common are presented in Table IV-6 followed by a listing of the subroutine.

TABLE IV-5

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE RHYDRO

Fortran Variable	Description	Units
AREA	Watershed area	ft^2 or m^2
DSTR	Previous Downstream Gutter Stationing	ft or m
DSTRW(2)	Previous Downstream Watershed Stationing Along Each Side of Gutter	ft or m
IF1	Initial Stationing For Simulation (units)	ft or m
IF1Ø	Initial Stationing For Simulation (tens)	ft or m
IF1ØØ	Initial Stationing For Simulation (hundreds)	ft or m
IS1	Final Stationing for Simulation (units)	ft or m
IS1Ø	Final Stationing For Simulation (tens)	ft or m
IS1ØØ	Final Stationing For Simulation (hundreds)	ft or m
NG1	Start Station for Given Gutter (units)	ft or m
NG1Ø	Start Station for Given Gutter (tens)	ft or m
NG1ØØ	Start Station for Given Gutter (hundreds)	ft or m
NG2	Number of DX Routing Lengths Contained in Gutter Length	-
NINCRW(2)	Incremental DX Routing Length Counter for Watersheds	-
NP1	Final Station for Gutter or Watershed (units)	ft or m
NP1Ø	Final Station for Gutter or Watershed (tens)	ft or m
NP1ØØ	Final Station for Gutter or Watershed (hundreds)	ft or m
NRANVL	Number of Rainfall Intervals	-
NW1	Start Station for Given Watershed (units)	ft or m
NW1Ø	Start Station for Given Watershed (tens)	ft or m
NW1ØØ	Start Station for Given Watershed (hundreds)	ft or m
NW2	Number of DX Routing Lengths Contained in Watershed Width	-
NW3	Number of Subareas for Given Watershed	-

TABLE IV-5
(cont.)

Fortran Variable	Description	Units
USTR	Current Upstream Gutter Stationing	ft or m
USTRW(2)	Current Upstream Watershed Stationing Along Each Side of Gutter	ft or m
W1	Upstream Watershed Station	ft or m
W2	Downstream Watershed Station	ft or m
W4	Subarea Manning's Roughness Coefficient	--

```
      SUBROUTINE RHYDRO
      COMMON/ROUT/DIR,DST
      COMMON/SUMP/SVOL,FVOL,SHMAX,SSMAX,SLENG,SWIDTH,SCOEFF,SFLOW(100),
     2SQMAX
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/NEW/NAMEG(200),NGTO(200)
      COMMON/INFL/INFIL,WTYPE(200,3),WLMAX(4),WLMIN(4),DECAY(4),DEPIN(4)
      COMMON/INLET/F,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/SYS/NINCR,NGUT(200),NWAT(200,2),NPG
      COMMON/LENGTH/GLI,GLIS,NSPEC,ISPEC,NLOC(20),XSPEC(20)
      COMMON/CONT/SUMR,SUMI,SUMQI,SUMUP,VOL1(200),VOL2(200)
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMS,QINLG(4,6,12),DINLG(4,6,12)
     2,DINLGC(6,12)
      DIMENSION NINCRW(2),USTRW(2),DSTRW(2)
C
C******** INITIALIZATION
C
      NW=200
      NG=200
      NRANVL=200
      SUMR=0.
      SUMI=0.
      SUMQI=0.
      SUMUP=0.
      DO 220 I=1,NW
      WFLOW(I)=0.0
      WWIDTH(I)=0.
      DO 220 J=1,3
      WDEPTH(I,J)=0.
  220 RAININ(I,J)=0.
      DO 240 I=1,NG
      VOL1(I)=0.
      VOL2(I)=0.
      NGUT(I)=0.
  240 GLEN(I)=0.
      DO 260 I=1,NG
      DO 260 J=1,2
  260 NWAT(I,J)=0
      DO 280 I=1,NRANVL
      DO 280 J=1,10
  280 RAIN(I,J)=0.
C
C******** READ SIMULATION CONTROL DATA
C
      N5=5
      N6=6
```

```
      READ(N5,1005) TITLE
 1005 FORMAT(20A4)
      TZERO=0.
      WRITE(N6,1010) TITLE
 1010 FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
     240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
     38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
     416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
     5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
     6*ANNANDALE,VIRGINIA*,//,1X,20A4,/,1X,20A4,//)
      READ(N5,1000)IS100,IS10,IS1,IF100,IF10,IF1,NSTEP,DELT,NRGAG,IMET
 1000 FORMAT(2(I7,1X,2I1),I5,F5.0,3I5)
      XSTRT=100.*FLOAT(IS100)+10.*FLOAT(IS10)+FLOAT(IS1)
      XFIN=100.*FLOAT(IF100)+10.*FLOAT(IF10)+FLOAT(IF1)
      READ(N5,4002) NU,ND,NTAPE
 4002 FORMAT(3I5)
      WRITE(N6,4010) IS100,IS10,IS1,IF100,IF10,IF1,N5,N6,NTAPE,DELT,NU,
     2 NSTEP,ND
 4010 FORMAT(* *,53(1H-),*SIMULATION CONTROL DATA*,52(1H-),//,40X,
     2*FROM STATION*,I6,***,2I1,* TO STATION*,I6,***,2I1,* INLET DESIGN*
     3///,35X,*READ UNIT *,I10,20X,*WATERSHED*,/,
     4 35X,*WRITE UNIT*,I10,20X,*FLOW TAPE*,I11,//,
     5 35X,*TIME STEP*,31X,*UPSTREAM*,/,
     6 35X,*LENGTH(MIN)*,F9.0,20X,*FLOW TAPE*,I11,//,
     7 35X,*NUMBER OF*,31X,*DOWNSTREAM*,/,
     8 35X,*TIME STEPS*,I10,20X,*FLOW TAPE*,I11,////)
      IF(IMET.EQ.0) GO TO 4700
      WRITE(N6,4650)
 4650 FORMAT(/,35X,*SI UNITS (METRIC SYSTEM) ARE USED*)
      GO TO 4800
 4700 WRITE(N6,4750)
 4750 FORMAT(/,35X,*BRITISH UNITS (FPS SYSTEM) ARE USED*)
 4800 CONTINUE
C
C********** RAINFALL DATA
C
      READ(N5,1020) NHISTO,THISTO
 1020 FORMAT(I5,F5.0)
      WRITE(N6,1041)
 1041 FORMAT(* *,//,56(1H-),*DESIGN RAINFALL*,57(1H-))
      WRITE(N6,1040) NRGAG,NHISTO,THISTO
 1040 FORMAT(* *,///,46X,*NUMBER OF RAINGAGES*,I3,//
     2,46X,*NUMBER OF*,/,46X,*INTERVALS*,I13,//,46X,*INTERVAL*,/,46X,
     3*DURATION(MIN)*,F8.0,////)
      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
      IF(MOD(N,3).EQ.1) WRITE(N6,1010) TITLE
      IF(IMET.EQ.0) GO TO 180
C
C**** METRIC OUTPUT
      WRITE(N6,150) N,(RAIN(I,N),I=1,NHISTO)
  150 FORMAT(* *,36X,*RAINGAGE*,I3,* RAINFALL INTENSITY (MM/HR) HISTORY:
     2*,//,(10F10.2))
```

```
C**** 1 M/S = 3600000 MM/HR
      DO 160 I=1,NHISTO
160   RAIN(I,N)=RAIN(I,N)/3600000.
      GO TO 230
C
C**** ENGLISH UNITS OUTPUT
180   WRITE(N6,1042) N,(RAIN(I,N),I=1,NHISTO)
1042  FORMAT(* *,36X,*RAINGAGE*,I3,* RAINFALL INTENSITY(IN/HR) HISTORY:*
     2,//,(10F10.2))
C
C**** 1 FPS = 43200 IN/HR
190   DO 2000 I=1,NHISTO
2000  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(N6,1010) TITLE
      IF(IMET.EQ.0) GO TO 606
C
C**** METRIC UNITS
      WRITE(N6,91203)
91203 FORMAT(* *,///,55(1H-),*INFILTRATION TYPES*,55(1H-),//,
     230X,*MAX RATE*,6X,*MIN RATE*,9X,*DECAY*,5X,*MAX DEPTH*,/,
     330X,* MM/HR  *,6X,*  MM/HR *,9X,* HR-1*,5X,*    MM    *,/)
      WRITE(N6,1202)
1202  FORMAT(* *,10X,*TYPE 0*,9X,*CORRESPONDS TO IMPERVIOUS SURFACE*)
      IF(INFIL.EQ.0) GO TO 636
      DO 623 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(* *,10X,*TYPE*,I2,4X,2(5X,F10.2),5X,F10.4,5X,F10.1)
C
C**** 1 MPS = 3600000 MM/HR
      DECAY(K)=DECAY(K)/3600.
      WLMAX(K)=WLMAX(K)/3600000.
      WLMIN(K)=WLMIN(K)/3600000.
623   DEPIN(K)=DEPIN(K)/1000.
      GO TO 636
C
C**** ENGLISH UNITS
606   WRITE(N6,91201)
91201 FORMAT(* *,///,55(1H-),*INFILTRATION TYPES*,55(1H-),//,
     230X,*MAX RATE*,6X,*MIN RATE*,9X,*DECAY*,5X,*MAX DEPTH*,/,
     330X,* IN/HR  *,6X,*  IN/HR *,9X,* HR-1*,5X,* INCHES *,/)
      WRITE(N6,1202)
      IF(INFIL.EQ.0) GO TO 636

      DO 620 K=1,INFIL
      READ(N5,622) WLMAX(K),WLMIN(K),DECAY(K),DEPIN(K)
      WRITE(N6,1201)  K,WLMAX(K),WLMIN(K),DECAY(K),DEPIN(K)
C
```

```
      C**** 1 FPS = 43200 IN/HR
            DECAY(K)=DECAY(K)/3600.
            WLMAX(K)=WLMAX(K)/43200.
            DEPIN(K)=DEPIN(K)/12.
      620   WLMIN(K)=WLMIN(K)/43200.
      C
      C******** READ SPECIFIED INLET ROUTING PARAMETERS
      C

        636 READ(N5,9115)ITYPC,DX,RIN,DIR,MULT,NPG,INOMG,RD,SWIDTH,SLENG,
           *SCOEFF
       9115 FORMAT(I10,F10.0,2F5.0,3I5,3F10.0,F5.0)
            IF(MULT.EQ.0) MULT=1
            DX=DX/FLOAT(MULT)
            F=1.-RIN
            WRITE(N6,1010) TITLE
            IF(IMET.EQ.0)GO TO 4500
            WRITE(N6,4502)DX,F
      4502  FORMAT(* *,52(1H-),*INLET DESIGN PARAMETERS*,53(1H-),//,
           1 11X,*INCREMENTAL LENGTH    *,F10.0,*  M.*,13X,*MAXIMUM CARRYOVER R
           2ATIO FOR INLETS ON GRADE*,F5.2,//)
            GO TO 4501
      4500  WRITE(N6,4000) DX,F
      4000  FORMAT(* *,52(1H-),*INLET DESIGN PARAMETERS*,53(1H-),//,
           1 11X,*INCREMENTAL LENGTH    *,F10.0,* FT.*,13X,*MAXIMUM CARRYOVER
           2RATIO FOR INLETS ON GRADE*,F5.2,//)
      4501  WRITE(N6,4503) RD
      4503  FORMAT(11X,*INLET CAPACITY REDUCTION FACTOR*,F8.2,//)
            IF(DIR.GT.0) WRITE(N6,7005)
      7005  FORMAT(* *,11X,*ROUTING IN THE DIRECTION OF ASCENDING STATION NUMB
           2ERING*,//)
            IF(DIR.LT.0) WRITE(N6,7010)
      7010  FORMAT(* *,11X,*ROUTING IN THE DIRECTION OF DESCENDING STATION NUM
           2BERING*,//)
      C
      C**** INLETS ON GRADE
            WRITE(N6,4005)
      4005  FORMAT(* *,11X,*FOR INLETS ON GRADE:*)
            GO TO (5000,5010,5020,5030,5040,5050,5060),ITYPC
      5000  WRITE(N6,5001)
      5001  FORMAT(***,T34,*UNDEPRESSED CURB OPENING INLETS SELECTED*)
            GO TO 6010
      5010  WRITE(N6,5002)
      5002  FORMAT(***,T34,*DEPRESSED CURB OPENING INLET SELECTED*)
            IF(INOMG.NE.2) GO TO 6010
            IF(NPG.GT.1) GO TO 6010
            READ(N5,1030) W,GLI
            A=W/12.
            IF(IMET.EQ.0) GO TO 710
            WRITE(N6,720) W,A,GLI
      720   FORMAT(1X,T34,*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.*,//)
            GO TO 4066
      710   WRITE(N6,5202) W,A,GLI
      5202  FORMAT(1X,T34,*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(***,T34,*UNDEPRESSED GRATE INLET SELECTED*)
       GO TO 6010
 5030  WRITE(N6,5031)
 5031  FORMAT(***,T34,*DEPRESSED GRATE INLET SELECTED*)
       GO TO 6010
 5040  WRITE(N6,5041)
 5041  FORMAT(***,T34,*UNDEPRESSED COMBINATION INLET SELECTED*)
       GO TO 6010
 5050  WRITE(N6,5051)
 5051  FORMAT(***,T34,*DEPRESSED COMBINATION INLET SELECTED*)
       GO TO 6010
 5060  WRITE(N6,5021)
 6010  IF(INOMG.EQ.0) WRITE(N6,6011)
       IF(INOMG.EQ.1) WRITE(N6,6012)
       IF(INOMG.EQ.2.AND.ITYPC.EQ.2.AND.NPG.LE.0) WRITE(N6,6013)
 6011  FORMAT(* *,T34,*INLET CAPACITY NOMOGRAPH INPUT BY USER*,//)
 6012  FORMAT(* *,T34,*INLET CAPACITY NOMOGRAPH FROM BLOCK DATA USED*,//)
 6013  FORMAT(* *,T34,*INLET CAPACITY EQUATION TO BE USED*,//)
       IF(INOMG.EQ.2) GO TO 4066
       IF(INOMG.EQ.1) GO TO 6021
C
C**** NOMOGRAPH INPUT ON CARDS
       IF(NPG.GT.1) GO TO 60221
       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**** NOMOGRAPH FROM BLOCK DATA
 6021  IF(NPG.GT.1) GO TO 60223
       DO 6030 I=1,4
       DO 6030 J=1,6
       DO 6030 K=1,12
 6030  QINLG(I,J,K)=DINLG(I,J,K)
C
C**** PRINT NOMOGRAPHS
 6022  DO 6040 I=1,4
       DO 6040 J=1,6
       IF(QINLG(I,J,1).NE.1.) QINLG(I,J,1)=1.
       IF(QINLG(I,J,2).NE.0.) QINLG(I,J,2)=0.
 6040  CONTINUE
       IF(IMET.EQ.0) GO TO 6024
C
C**** METRIC OUTPJT
       WRITE(N6,1111)
 1111  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
      240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
      38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
      416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
      5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
      6*ANNANDALE,VIRGINIA*,//,1X,
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```
          7*ON-GRADE INLET CAPACITY NOMOGRAPHS FOR INLETS IN GUTTERS*,
          8* (Q IN CMS) :*,/)
           GO TO 6026
      C
      C**** ENGLISH UNITS OUTPUT
      6024  WRITE(N6,1011)
      1011  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
          240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
          38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
          416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
          5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
          6*ANNANDALE,VIRGINIA*,//,1X,
          7*ON-GRADE INLET CAPACITY NOMOGRAPHS FOR INLETS IN GUTTERS*,
          8* (Q IN CFS) :*,/)
      6026  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
            GO TO 4066
      60221 DO 95105 J=1,6
      95105 READ(N5,5111)(QINLG(1,J,K),K=1,12)
            GO TO 60222
      60223 DO 96030 J=1,5
            DO 96030 K=1,12
      96030 QINLG(1,J,K)=DINLGC(J,K)
      60222 DO 6045 J=1,6
            IF(QINLG(1,J,1).NE.1.) QINLG(1,J,1)=1.
            IF(QINLG(1,J,2).NE.0.) QINLG(1,J,2)=0.
      6045  CONTINUE
            IF(IMET.EQ.0)GO TO 96024
            WRITE(N6,91111)
      91111 FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
          240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
          38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
          416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
          5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
          6*ANNANDALE,VIRGINIA*,//,1X,
          7*ON-GRADE INLET CAPACITY NOMOGRAPHS FOR INLETS IN CHANNELS*,
          8* (D IN METERS) :*,/)
           GO TO 96026
      96024 WRITE(N6,91011)
      91011 FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
          240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
          38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
          416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
          5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
          6*ANNANDALE,VIRGINIA*,//,1X,
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     7*ON-GRADE INLET CAPACITY NOMOGRAPHS FOR INLETS IN CHANNELS*,
     8* (D IN FEET) :*,/)
96026 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)((QINLG(1,J,K),K=K1,KK),J=1,6)
 4066 CONTINUE
C
 8066 WRITE(N6,1010) TITLE
 4321 FORMAT(* *,49(1H-),*SUMP INLET DESIGN PARAMETERS*,47(1H-),//////)
      WRITE(N6,4321)
      IF(IMET.NE.0) GO TO 1955
      WRITE(N6,1855) SWIDTH,SLENG,SCOEFF
 1855 FORMAT(1X,*SUMP INLET WIDTH=*,F6.2,* FT., LENGTH=*,
     2F6.2,* FT.*,//,1X,*SUMP INLET ORIFICE DISCHARGE COEFFICIENT = *,
     3F5.3,//)
      GO TO 1956
 1955 WRITE(N6,1957) SWIDTH,SLENG,SCOEFF
 1957 FORMAT(1X,*SUMP INLET WIDTH=*,F6.2,* M., LENGTH=*,
     2F6.2,* M.*,//,1X,*SUMP INLET ORIFICE DISCHARGE COEFF
     3ICIENT=*,F5.3,//)
 1956 CONTINUE
C
1965  X1=XSTRT
      DST=XFIN-XSTRT
      IF(DIR.LT.0) X1=XFIN
      READ(N5,1115) NSPEC
      IF(NSPEC.LE.0) GO TO 8000
      WRITE(N6,1010) TITLE
      IF(IMET.EQ.0) GO TO 8240
C
C**** METRIC OUTPUT
      WRITE(N6,8245)
8245  FORMAT(* *,45(1H-),*PRESPECIFIED INLET DESIGN PARAMETERS*,46(1H-),
     2///,46X,*LOCATION*,20X,*LENGTH(M.)*,/,46X,8(1H-),20X,10(1H-),/)
      GO TO 8445
C
C**** ENGLISH UNITS OUTPUT
8240  WRITE(N6,8345)
8345  FORMAT(* *,46(1H-),*PRESPECIFIED INLET DESIGN PARAMETERS*,46(1H-),
     2///,46X,*LOCATION*,20X,*LENGTH(FT)*,/,46X,8(1H-),20X,10(1H-),/)
8445  DO 8010 I=1,NSPEC
      READ(N5,1960) NG100,NG10,NG1,XSPEC(I)
1960  FORMAT(I7,1X,2I1,F10.0)
      XTEMP=100.*FLOAT(NG100)+10.*FLOAT(NG10)+FLOAT(NG1)
      NLOC(I)=(XTEMP-X1)*DIR/DX
8010  WRITE(N6,8006) NG100,NG10,NG1,XSPEC(I)
8006  FORMAT(47X,I4,*+*,2I1,20X,F7.1)
      ISPEC=1
8000  CONTINUE
C
C******** GUTTER DATA
C
      NINCR=0
```

```
          DSTR=XSTRT
          DO 480 N=1,NG
          READ(N5,1115)NAMEG(N),NG100,NG10,NG1,NP100,NP10,NP1,GWIDTH(N),
        2 GSLOPE(N),GS1(N),GS2(N),GN(N)
 1115     FORMAT(I10,2(I7,1X,2I1),5F10.0)
          IF(NAMEG(N).EQ.0)GO TO 500
          READ(N5,1116)NG2,SPMAX(N),DFULL(N)
 1116     FORMAT(I10,2F10.0)
          NG2=NG2*MULT
          IF(NAMEG(N).EQ.0) GO TO 500
          IF(MOD(N,30).NE.1) GO TO 94500
          WRITE(N6,1010) TITLE
          IF(IMET.EQ.0) GO TO 91140
C
C**** METRIC OUTPUT
          WRITE(N6,91150)
91150 FORMAT(1H0,56(1H-),*HIGHWAY SURFACE DRAINAGE GUTTERS*,40(1H-),///,
        23X,*GUTTER     GUTTER    STATION    STATION      WIDTH     LENGTH     SL
        3OPE    RECIPROCAL LEFT  RECIPROCAL RIGHT  MANNING N  DESIGN*,/,
        4 5X,*NO.       NAME        1          2           (M.)       (M.)       (M./
        5M.)  SIDE SLOPE(M./M.) SIDE SLOPE(M./M.) (M.)1/6*)
          IF(NPG.EQ.1) WRITE(N6,91151)
          IF(NPG.EQ.2) WRITE(N6,91152)
91151 FORMAT(***,T117,*SPREAD(M.)*)
91152 FORMAT(***,T117,*DEPTH(M.)*)
          GO TO 94500
C
C**** ENGLISH UNITS OUTPUT
91140 WRITE(N6,91120)
91120 FORMAT(1H0,56(1H-),*HIGHWAY SURFACE DRAINAGE GUTTERS*,40(1H-),///,
        23X,*GUTTER     GUTTER    STATION    STATION      WIDTH     LENGTH     SL
        3OPE    RECIPROCAL LEFT  RECIPROCAL RIGHT  MANNING N  DESIGN*,/,
        4 5X,*NO.       NAME        1          2           (FT)       (FT)       (FT/
        5FT)  SIDE SLOPE(FT/FT) SIDE SLOPE(FT/FT) (FT)1/6*)
          IF(NPG.EQ.1) WRITE(N6,91121)
          IF(NPG.EQ.2) WRITE(N6,91122)
91121 FORMAT(***,T117,*SPREAD(FT)*)
91122 FORMAT(***,T117,*DEPTH(FT)*)
94500 DO 1950 JKW=1,NG2
          NINCR=NINCR+1
 1950     NGUT(NINCR)=N
          GLEN(N)=DX*FLOAT(NG2)
          USTR=100.*FLOAT(NG100)+10.*FLOAT(NG10)+FLOAT(NG1)
          IF(NPG-2)6750,6700,6750
 6700     DIST=DFULL(N)
          GO TO 6770
 6750     DIST=SPMAX(N)
          DFULL(N)=(SPMAX(N)-GWIDTH(N))/(GS1(N)+GS2(N))
C
C**** PRINT GUTTER DATA
 6770     WRITE(N6,1120) N,NAMEG(N),NG100,NG10,NG1,NP100,NP10,NP1,GWIDTH(N),
        2 GLEN(N),GSLOPE(N),GS1(N),GS2(N),GN(N),DIST
 1120     FORMAT(2I9,2(I7,***,2I1),2F10.0,F10.3,2F15.3,5X,2F10.3)
          IF(USTR.EQ.DSTR) GO TO 1800
          WRITE(N6,850)
  850     FORMAT(* *,//,10X,40(1H*),/,10X,1H*,*   ERROR---CHECK GUTTER STATI
        2ONING  *,1H*,/,10X,40(1H*))
```

```
      STOP
1800  DSTR=USTR+GLEN(N)
      IF(IMET.EQ.0) GCON(N)=(1.486/GN(N))*SQRT(GSLOPE(N))
      IF(IMET.EQ.1) GCON(N)=(1.000/GN(N))*SQRT(GSLOPE(N))
480   CONTINUE
500   NOG=N-1
      WRITE(N6,1150) NOG
1150  FORMAT(*0TOTAL NUMBER OF GUTTERS/CHANNELS :*,I4)
C
C******** WATERSHED DATA
C
      TAREA=0.
      DO 2240 JKW=1,2
      DSTRW(JKW)=XSTRT
2240  NINCRW(JKW)=0
      DO 340 N=1,NW
      READ(N5,1060) NAMEW(N),NGTO(N),JK,AREA,NW3,NW100,NW10,NW1,NW2
1060  FORMAT(3I10,F10.0,I10,I7,1X,2I1,I10)
      NW2=NW2*MULT
      W1=100.*FLOAT(NW100)+10.*FLOAT(NW10)+FLOAT(NW1)
      W2=W1+NW2*DX
      NP100=W2/100.
      NP10=IFIX((W2-NP100*100.)/10.)
      NP1=IFIX(W2-NP100*100.-NP10*10.)
      IF(JK.EQ.0) JK=1
      IF(NAMEW(N).EQ.0) GO TO 360
C
C**** PRINT WATERSHED DATA
      IF(MOD(N,2).NE.1) GO TO 4505
      WRITE(N6,1010) TITLE
      WRITE(N6,9970)
9970  FORMAT(* *,46(1H-),*HIGHWAY SURFACE DRAINAGE INFORMATION*,46(1H-),
     2///)
4505  IF(IMET.EQ.0) GO TO 4510
C
C**** METRIC HEADING
      WRITE(N6,9974)
9974  FORMAT(* *,31X,*WATERSHED WATERSHED  STATION   STATION    GUTTER
     2RAINGAGE   AREA     NUMBER OF*,/,35X,*NO.*,7X,*NAME*,7X,*1
     3 2*,8X,*SIDE*,6X,*NO.*,4X,* (HA.)     SUBAREAS*,/)
      GO TO 1069
C
C**** ENGLISH UNITS HEADING
4510  WRITE(N6,9975)
9975  FORMAT(* *,31X,*WATERSHED WATERSHED  STATION   STATION    GUTTER
     2RAINGAGE   AREA     NUMBER OF*,/,35X,*NO.*,7X,*NAME*,7X,*1
     3 2*,8X,*SIDE*,6X,*NO.*,4X,*(ACRES)   SUBAREAS*,/)
1069  WRITE(N6,1070) N,NAMEW(N),NW100,NW10,NW1,NP100,NP10,NP1,NGTO(N),JK
     2,AREA,NW3
1070  FORMAT(* *,29X,2I10,2(I7,*+*,2I1),I7,I10,F10.2,5X,I5,///)
C
C**** TRANSFER DATA AND CONVERT UNITS
940   NHYET(N)=JK
      K=NGTO(N)
      DO 950 JKW=1,NW2
      NINCRW(K)=NINCRW(K)+1
      J=NINCRW(K)
```

```
950   NWAT(J,K)=N
      USTRW(K)=W1
      IF(USTRW(K).EQ.DSTRW(K)) GO TO 800
      WRITE(N6,851)
851   FORMAT(* *,//,10X,40(1H*),/,10X,1H*,* ERROR---CHECK WATERSHED STAT
     2IONING   *,1H*,/,10X,40(1H*))
      STOP
800   DSTRW(K)=W2
      WWIDTH(N)=W2-W1
      NC(N)=NW3
      IF(IMET.EQ.0) GO TO 9986
C
C**** METRIC HEADING
      WRITE(N6,9980)
9980  FORMAT(56X,*SUBAREA DEFINITION*,//,44X,*AREA*,3X,*INFILTRATION*,
     2 3X,*SLOPE*,3X,*STORAGE*,2X,*MANNING N*,/,43X,* (HA.) *,4X,*TYPE*,
     3 7X,*(M./M.)*,4X,*(MM)*,4X,*(M.)1/6*)
      GO TO 9988
C
C**** ENGLISH UNITS HEADING
9986  WRITE(N6,9976)
9976  FORMAT(56X,*SJBAREA DEFINITION*,//,44X,*AREA*,3X,*INFILTRATION*,
     2 3X,*SLOPE*,3X,*STORAGE*,2X,*MANNING N*,/,43X,*(ACRES)*,4X,*TYPE*,
     3 7X,*(FT/FT)*,4X,*(IN)*,4X,*(FT)1/6*)
9988  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,//)
      IF(IMET.EQ.0) WSTORE(N,K)=WSTORE(N,K)/12.
      IF(IMET.EQ.1) WSTORE(N,K)=WSTORE(N,K)/1000.
      TAREA=TAREA+WAREA(N,K)
C
C**** 10000 SQ. M. = 1 HECTARE
      IF(IMET.EQ.0) WAREA(N,K)=WAREA(N,K)*43560.
      IF(IMET.EQ.1) WAREA(N,K)=WAREA(N,K)*10000.
      IF(IMET.EQ.0) WCON(N,K)=-(1.486/W4)*SQRT(WSLOPE(N,K))*WWIDTH(N)/WA
     2REA(N,K)
      IF(IMET.EQ.1) WCON(N,K)=-(1.000/W4)*SQRT(WSLOPE(N,K))*WWIDTH(N)/WA
     2REA(N,K)
90170 CONTINUE
340   CONTINUE
360   NOW=N-1
      IF(IMET.EQ.0) GO TO 845
C
C**** METRIC OUTPUT
      WRITE(N6,847) NOW,TAREA
847   FORMAT(*OTOTAL NUMBER OF SUBCATCHMENTS,*,I4,/,
     2 *OTOTAL TRIBJTARY AREA   (HA.),*,F8.2)
      GO TO 855
C
C**** ENGLISH UNITS OUTPUT
845   WRITE(N6,1100) NOW,TAREA
1100  FORMAT(*OTOTAL NUMBER OF SUBCATCHMENTS,*,I4,/,
     2 *OTOTAL TRIBUTARY AREA (ACRES),*,F8.2)
```

```
 855    DO 9850 JKW=1,2
        IF(NINCRW(JKW).EQ.NINCR) GO TO 9850
        WRITE(N6,852)
 852    FORMAT(* *,//,10X,40(1H*),/,10X,1H*,*      ERROR----CHECK ALL STATI
       2ONING   *,1H,/,10X,40(1H*))
        STOP
9850    CONTINUE
        RETURN
        END
```

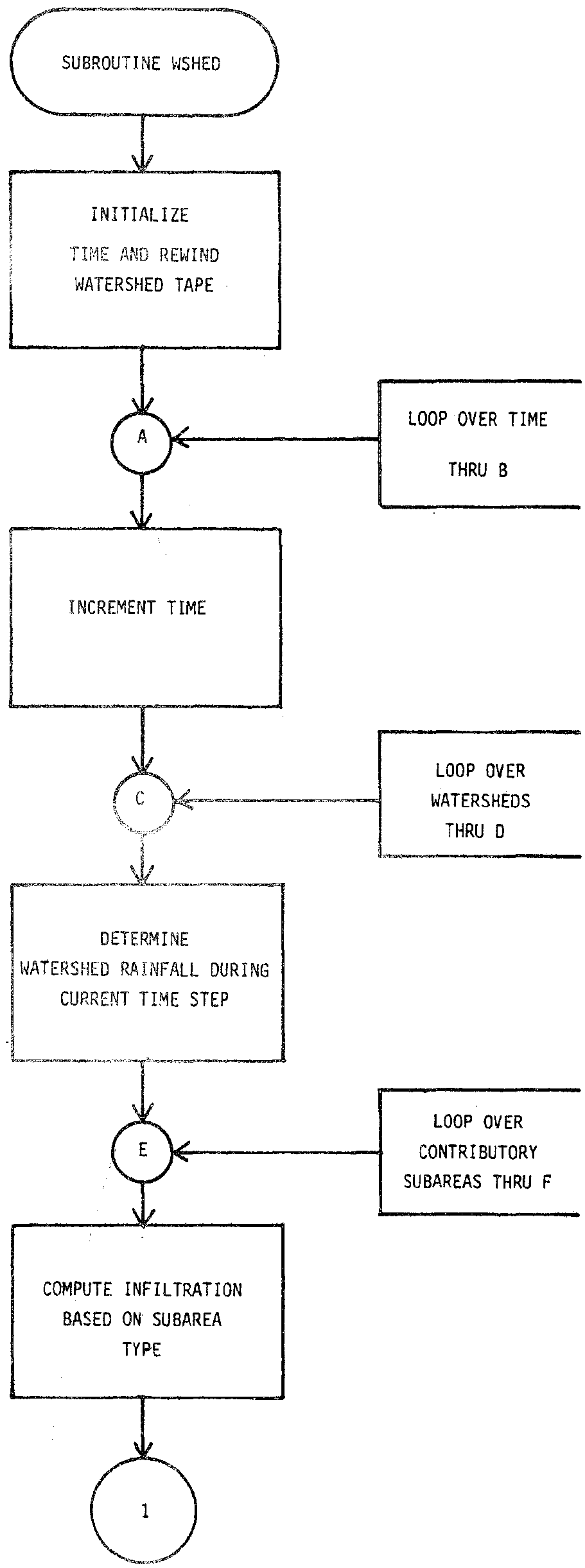

FIGURE IV-4. Flowchart for Subroutine WSHED

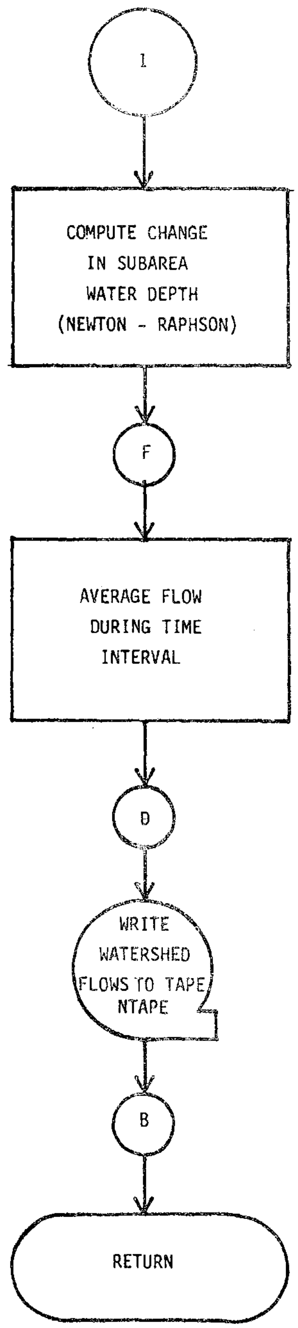

Figure IV-4 (Continued)

TABLE IV-6

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE WSHED

Fortran Variable	Description	Units
DCORR	Current Corrected Depth for Each Watershed Subarea	ft or m
DEL	Newton-Raphson Change in Depth for Each Watershed Area	ft or m
DELR	Previous Corrected Depth for Each Watershed Subarea	ft or m
DF	Derivative of Newton-Raphson F Function	-
DØ	Watershed Subarea Depth at Beginning of Time Step	ft or m
EXPON	Infiltration Function Exponent	-
F	Newton-Raphson F Function	ft or m
IND	Position in Rainfall Array for Current Time Step	-
JTYP	Watershed Subarea Infiltration Type	-
NGAG	Rainfall Gage Number for Watershed	-
WAR	Watershed Subarea Area	ft^2 or m^2
WFLO(200,3)	Watershed Subarea Outflow	cfs or cms
WFLOT	Watershed Subarea Inflow from Upstream Subarea Per Unit Area	cfs/ft^2 or cms/m^2

```
      SUBROUTINE WSHED
C
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/INFL/INFIL,WTYPE(200,3),WLMAX(4),WLMIN(4),DECAY(4),DEPIN(4)
      COMMON/INLET/G,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/CONT/SUMR,SUMI,SUMQI,SUMUP,VOL1(200),VOL2(200)
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      DIMENSION WFLO(200,3)
C
C******** BEGIN MAJOR LOOP FOR TIME
C
      TIME=TZERO
      REWIND NTAPE
      DO 330 II=1,NSTEP
      TIME=TIME+DELT
      TIME2=TIME-DELT2
C
C******** SELECT AVERAGE RAINFALL INTENSITY DURING TIME STEP
C
      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)
      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)
      GO TO 215
C
C**** COMPUTE AVERAGE INFILTRATION DURING TIME STEP
215   EXPON=DECAY(JTYP)*(TIME2-TZERO)
      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)
      220   IF((RI-RLOSS+WFLOT)*DELT+WDEPTH(J,K).LE.WSTORE(J,K)) GO TO 285
            DO 260 I=1,11
            DO=WDEPTH(J,K)-WSTORE(J,K)+0.5*DELR
            IF(DO.LT.0) DO=0.
            F=DELR-DELT*(WCON(J,K)*DO**1.6666667+(RI-RLOSS+WFLOT))
            DF=1.-DELT*(0.83333333*WCON(J,K)*DO**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 STEP
            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
      290   WDEPTH(J,K)=DCORR
      C
      C**** SUM INFILTRATION LOSS FOR CHECK ON MAXIMUM INFILTRATION
      310   RAININ(J,K)=RAININ(J,K)+RLOSS*12.*DELT
            SUMR=SUMR+RI*DELT*WAR
            SUMI=SUMI+RLOSS*DELT*WAR
      315   CONTINUE
            WFLOW(J)=WFLO(J,NCA)/WWIDTH(J)*DX
      320   CONTINUE
      C
      C******** WRITE WATERSHED TAPE FOR EACH TIME STEP FOR ALL WATERSHEDS
      C
            WRITE(NTAPE) TIME,(WFLOW(J),J=1,NOW)
      330   CONTINUE
            REWIND NTAPE
            RETURN
            END
```

Subroutine OUTPUT

This subroutine is called from main program INLET to print the characteristics of all inlets determined during the simulation. The following common blocks are utilized:

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

The flowchart for Subroutine OUTPUT is presented in Figure IV-5. For each inlet, the location along the gutter or channel in terms of highway stationing is printed. The following characteristics of the gutter or channel section at this location are also printed:

- Longitudinal slope
- Bottom width
- Side slopes

The peak hydraulic conditions at each inlet are output in the following manner:

- Flow spread
- Flow depth
- Flow
- Velocity

Key variables not in common are presented in Table IV-7 followed by the listing.

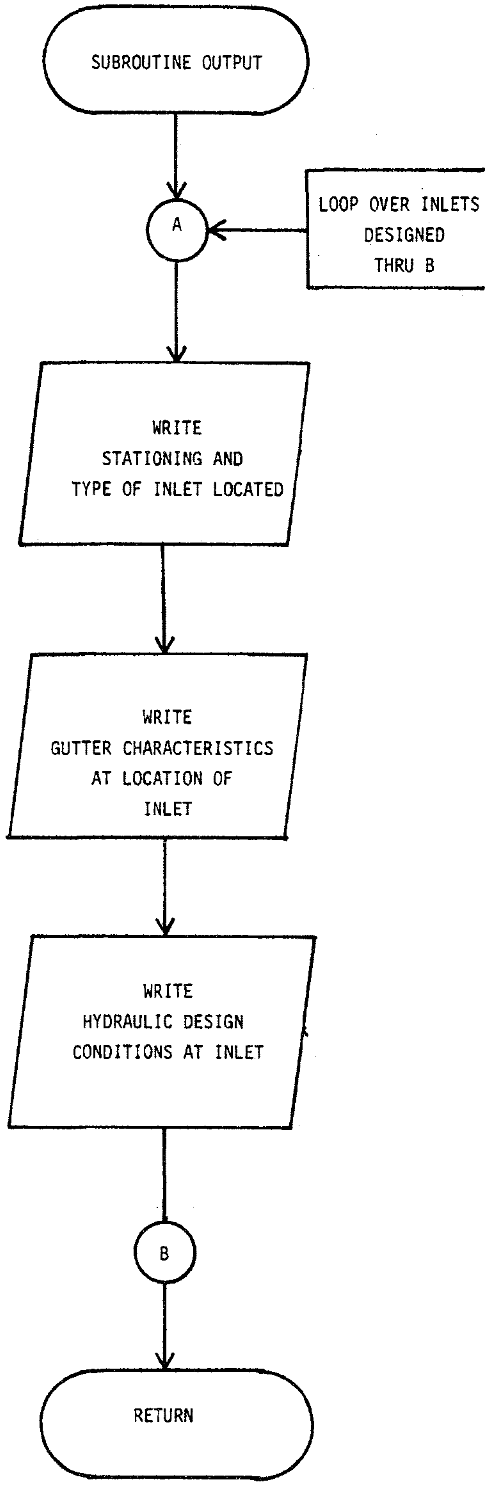

FIGURE IV-5. Flowchart for Subroutine OUTPUT

TABLE IV-7

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE OUTPUT

Fortran Variable	Description	Units
ALOCUS	Flow Area in Gutter at Inlet	ft^2 or m^2
I1	Inlet Station (Units)	ft or m
I1Ø	Inlet Station (tens)	ft or m
I1ØØ	Inlet Station (hundreds)	ft or m
QLOCUS	Flow in Gutter at Inlet	cfs or cms
VLOCUS	Velocity in Gutter at Inlet	fps or mps
WLOCUS	Flow Spread in Gutter at Inlet	ft or m
WP	Wetted Perimeter in Gutter at Inlet	ft or m

```
      SUBROUTINE OUTPUT
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON/SUMP/SVOL,FVOL,SHMAX,SSMAX,SLENG,SWIDTH,SCOEFF,SFLOW(100),
     2SQMAX
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      COMMON/INLET/F,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/SYS/NINCR,NGUT(200),NWAT(200,2),NPG
      COMMON/LOC/ICOUNT,XLOCUS(200),DLOCUS(200),XGLI(200),FR(200)
      COMMON/ROUT/DIR,DST
      COMMON/CONT/SUMR,SUMI,SUMQI,SUMUP,VOL1(200),VOL2(200)
      COMMON/LENGTH/GLI,GLIS,NSPEC,ISPEC,NLOC(20),XSPEC(20)
      DIMENSION ITYPE(6,7)
      DATA ITYPE/4HJNDE,4HPRES,4HSED ,4HCURB,4HOPEN,4HING ,
     2           4HDEPR,4HESSE,4HD CU,4HRB O,4HPENI,4HNG  ,
     3           4HUNDE,4HPRES,4HSED ,4HGRAT,4HE   ,4H    ,
     4           4HDEPR,4HESSE,4HD   ,4HCOMB,4HINAT,4HION ,
     5           4HUNDE,4HPRES,4HSED ,4HCOMB,4HINAT,4HION ,
     6     4HDEPR,4HESSE,4HD CO,4HMBIN,4HATIO,4HN   ,
     7   4HGRAT,4HE OP,4HENIN,4HG IN,4H CHA,4HNNEL/
      DO 200 I=1,ICOUNT
      WRITE(N6,1010) TITLE
 1010 FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
     240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
     38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
     416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
     5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
     6*ANNANDALE,VIRGINIA*,//,1X,20A4,/,1X,20A4,//)
      WRITE(N6,1012) I
 1012 FORMAT(* *,49(1H-),*INLET*,I3,* DESIGN SPECIFICATIONS*,49(1H-),//)
      I100=XLOCUS(I)/100.
      TEMP=XLOCUS(I)-I100*100.
      I10=TEMP/10.
      TEMP=TEMP-I10*10.
      I1=TEMP
      WRITE(N6,1013) I100,I10,I1
 1013 FORMAT(* *,T45,*INLET LOCATED AT STATION*,I6,*+*,2I1)
      JREF1=(XLOCUS(I)-X1)*DIR/DX
      JREF=JREF1
      IF(DIR.LT.0) JREF=NINCR-JREF1+1
      N=NGUT(JREF)
      WLOCUS=GWIDTH(N)+DLOCUS(I)*(GS1(N)+GS2(N))
      ALOCUS=0.5*(GS1(N)+GS2(N))*DLOCUS(I)**2+GWIDTH(N)*DLOCUS(I)
      WP=SQRT(GS1(N)**2+1.)+SQRT(GS2(N)**2+1.)
      WP=WP*DLOCUS(I)+GWIDTH(N)
      IF(WP.LE.0) WP=0.001
      QLOCUS=GCON(N)*(ALOCUS**1.6666667)/(WP**.6666667)
      IF(QLOCUS.LE.0) GO TO 1030
      VLOCUS=QLOCUS/ALOCUS
```

```
      GO TO 1040
1030  VLOCUS=0.
1040  IF(FLOAT(JREF1+1)*DX.GE.DST) GO TO 9000
      IF(IMET.EQ.0) GO TO 1115
C
C**** METRIC OUTPUT
      WRITE(N6,1113) (ITYPE(J,ITYPC),J=1,6),F,FR(I)
1113  FORMAT(*+*,T80,*------ ON GRADE ------*,/,T50,6A4,//,
     2 T50,*DESIGN CARRYOVER*,F4.2,1X,*OF PEAK FLOW*,//,
     4 T50,*MAXIMUM CARRYOVER RATIO*,F4.2,//)
      GO TO 120
C
C**** ENGLISH UNITS OUTPUT
1115  WRITE(N6,1015) (ITYPE(J,ITYPC),J=1,6),F,FR(I)
1015  FORMAT(*+*,T80,*------ ON GRADE ------*,/,T50,6A4,//,
     2 T50,*DESIGN CARRYOVER*,F4.2,1X,*OF PEAK FLOW*,//,
     4 T50,*MAXIMUM CARRYOVER RATIO*,F4.2,//)
120   IF(IMET.EQ.0) GO TO 1125
C
C**** METRIC OUTPUT
      WRITE(N6,1216) GSLOPE(N),GWIDTH(N),GS1(N),GS2(N)
1216  FORMAT(* *,T50,*GUTTER/CHANNEL CHARACTERISTICS AT INLET*,//,
     2 T45,*SLOPE*,T90,F10.4,/,
     3 T45,*WIDTH*,T90,F10.2,1X,*M.*,/,
     4 T45,*SIDE SLOPE 1 RECIPROCAL*,T90,F10.4,/,
     5 T45,*SIDE SLOPE 2 RECIPROCAL*,T90,F10.4,///)
      WRITE(N6,1217) WLOCUS,DLOCUS(I),QLOCUS,VLOCUS
1217  FORMAT(* *,T50,*PEAK HYDRAULIC CONDITIONS AT INLET*,//,
     2 T45,*FLOW SPREAD*,T90,F10.2,1X,*M.*,/,
     3 T45,*DEPTH*,T90,F10.2,1X,*M.*,/,
     4 T45,*FLOW*,T90,F10.2,1X,*CMS*,/,
     5 T45,*VELOCITY*,T90,F10.2,1X,*M/S*,///)
      GO TO 200
C
C**** ENGLISH UNITS OUTPUT
1125  WRITE(N6,1016) GSLOPE(N),GWIDTH(N),GS1(N),GS2(N)
1016  FORMAT(* *,T50,*GUTTER/CHANNEL CHARACTERISTICS AT INLET*,//,
     2 T45,*SLOPE*,T90,F10.4,/,
     3 T45,*WIDTH*,T90,F10.2,1X,*FT*,/,
     4 T45,*SIDE SLOPE 1 RECIPROCAL*,T90,F10.4,/,
     5 T45,*SIDE SLOPE 2 RECIPROCAL*,T90,F10.4,///)
      WRITE(N6,1017) WLOCUS,DLOCUS(I),QLOCUS,VLOCUS
1017  FORMAT(* *,T50,*PEAK HYDRAULIC CONDITIONS AT INLET*,//,
     2 T45,*FLOW SPREAD*,T90,F10.2,1X,*FT*,/,
     3 T45,*DEPTH*,T90,F10.2,1X,*FT*,/,
     4 T45,*FLOW*,T90,F10.2,1X,*CFS*,/,
     5 T45,*VELOCITY*,T90,F10.2,1X,*FPS*,///)
      GO TO 200
C
C**** SUMP
9000  IF(IMET.EQ.0) GO TO 9001
C
C**** METRIC OUTPUT
      WRITE(N6,1114) SWIDTH,SLENG
1114  FORMAT(*+*,T80,*------ IN SUMP ------*,///,
     2 T50,*THIS SUMP INLET INTERCEPTS ALL REMAINING FLOW*,//,
     3 T50,*DESIGN WIDTH *,F5.2,* M. AND DESIGN LENGTH*,F5.2,
```

```
      4 * M.*,//)
       GO TO 9002
C
C**** ENGLISH UNITS OUTPUT
9001  WRITE(N6,1014)SWIDTH,SLENG
1014  FORMAT(*+*,T80,*------ IN SUMP ------*,///,
     2 T50,*THIS SUMP INLET INTERCEPTS ALL REMAINING FLOW*,//,
     3 T50,*DESIGN WIDTH *,F5.2,* FT. AND DESIGN LENGTH*,F5.2,
     4 * FT.*,//)
9002  ISUMP=1
      JLOC1=(XLOCUS(I)-X1)*DIR/DX
      JLOC=JLOC1
      XGLI(I)=SLENG
      IF(DIR.GT.0) JLOC=NINCR-JLOC+1
      CALL CARRY(JLOC,ISUMP,XGLI(I),DLOCUS(I),QI,QC)
      IF(IMET.EQ.0) GO TO 1135
C
C**** METRIC OUTPUT
      WRITE(N6,1130)
1130  FORMAT(* *,T60,*SUMP CHARACTERISTICS*,//,
     2 T45,*SLOPE*,T90,*.002*,/,
     3 T45,*MAXIMUM DEPTH*,T90,*.305 M*,/,
     4 T45,*RECIPROCAL CROSS-SLOPE*,T90,*24.*,///)
      WRITE(N6,1131) SSMAX,SHMAX,SQMAX,FVOL
1131  FORMAT(* *,T50,*PEAK HYDRAULIC CONDITIONS AT SUMP*,//,
     2 T45,*SPREAD OF PONDED WATER*,T90,F10.2,1X,*M*,/,
     3 T45,*DEPTH OF PONDED WATER*,T90,F10.2,1X,*M*,/,
     4 T45,*FLOW TO SUMP*,T90,F10.2,1X,*CMS*,/,
     5 T45,*PONDED WATER IN EXCESS OF SUMP VOLUME*,T90,F10.2,1X,*CU. M.*
     6,///)
      GO TO 200
C
C**** ENGLISH UNITS OUTPUT
1135  WRITE(N6,1132)
1132  FORMAT(* *,T60,*SUMP CHARACTERISTICS*,//,
     2 T45,*SLOPE*,T90,*.002*,/,
     3 T45,*MAXIMUM DEPTH*,T90,*1.0 FT*,/,
     4 T45,*RECIPROCAL CROSS-SLOPE*,T90,*24.*,///)
      WRITE(N6,1133) SSMAX,SHMAX,SQMAX,FVOL
1133  FORMAT(* *,T50,*PEAK HYDRAULIC CONDITIONS AT SUMP*,//,
     2 T45,*SPREAD OF PONDED WATER*,T90,F10.2,1X,*FT*,/,
     3 T45,*DEPTH OF PONDED WATER*,T90,F10.2,1X,*FT*,/,
     4 T45,*FLOW TO SUMP*,T90,F10.2,1X,*CFS*,/,
     5 T45,*PONDED WATER IN EXCESS OF SUMP VOLUME*,T90,F10.2,1X,*CU. FT.
     6*,///)
200   CONTINUE
      WRITE(N6,1018)
1018  FORMAT(* *,128(1H-))
      WRITE(N6,1019)
1019  FORMAT(* *,52X,*INLET SPACING ALGORITHM COMPLETED*)
      WRITE(N6,1018)
      RETURN
      END
```

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
- SUMP

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 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-8, followed by a listing of this subroutine.

Block Data

This subroutine is used to initialize several variables used elsewhere in the program. The values of gutter/channel slopes and highway surface cross-slopes corresponding to the input inlet efficiency curves are set here. Also, two arrays for storing inlet efficiency curves in the program code can be initialized here by the user. Two sets of example

TABLE IV-8

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
IXTRP	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(JLOC,ISUMP,GLI,DQ,QI,QC)
      COMMON/ROUT/DIR,DST
      COMMON/SUMP/SVOL,FVOL,SHMAX,SSMAX,SLENG,SWIDTH,SCOEFF,SFLOW(100),
     2SQMAX
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/INLET/F,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/SYS/NINCR,NGUT(200),NWAT(200,2),NPG
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMS,QINLG(4,6,12),DINLG(4,6,12)
     2,DINLGC(6,12)
      COMMON/LOC/ICOUNT,XLOCUS(200),DLOCUS(200),XGLI(200),FR(200)
C
C******** TEST FOR ZERO DEPTH
C
      Q=0.
      IF(DQ.LT.1.E-5) GO TO 6009
C
C******** DETERMINE GUTTER HYDRAULIC CONDITIONS BASED ON GUTTER DEPTH
C
      N=NGUT(JLOC)
      WLOCUS=GWIDTH(N)+DQ*(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=WP*DQ+GWIDTH(N)
      Q=GCON(N)*(ALOCUS**1.6666667)/(WP**.6666667)
C
C******** IF SUMP INLET, GO TO SUMP INLET PORTION OF SUBROUTINE
C
      IF(ISUMP.GT.0) GO TO 9000
C
C******** IF INLET ON GRADE, CONTINUE AND GO TO APPROPRIATE INLET
C******** CAPACITY COMPUTATION.  (SUBROUTINE IS STRUCTURED FOR
C******** SUBSEQUENT ADDITIONS/MODIFICATIONS TO ON-GRADE INLET
C******** CAPACITY COMPUTATIONS.)
C
      IF(INOMG.NE.2) GO TO 500
      GO TO (10,20,30,40,50,60,70),ITYPC
C
C******* EQUATION FOR UNDEPRESSED CURB OPENINGS
C
10    CONTINUE
1010  FORMAT(*1*,64(2H--)/* *,*FEDERAL HIGHWAY ADMINISTRATION*,14X,
     240H****  URBAN HIGHWAY DRAINAGE MODEL  ****,
     38X,*WATER RESOURCES DIVISION*/* *,*DEPARTMENT OF TRANSPORTATION*,
     416X,4H****,32X,4H****,8X,*CAMP DRESSER & MCKEE*/* *,*WASHINGTON*,
     5* D.C.*,29X,4H****,5X,* INLET DESIGN PROGRAM *,5X,4H****,8X,
     6*ANNANDALE,VIRGINIA*,//,1X,20A4,/,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  (I
     2NOMG=0).*,/,45X,* 2) SUPPLY AN INLET CAPACITY NOMOGRAPH IN THE BLO
     3CK DATA*,/,48X,* SECTION OF THE PROGRAM (INOMG=1).*,/,45X,* 3) PRO
     4GRAM AN INLET CAPACITY EQUATION IN SUBROUTINE CARRY (INOMG=2).*)
      WRITE(N6,6019)
6019  FORMAT(*0*,45X,75(*-*),/,70X,*PROGRAM TERMINATED*,/,45X,75(*-*))
      STOP
C
C******** IZZARD DESIGN EQUATIONS FOR DEPRESSED CURB OPENINGS
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,*G
     2S1 = 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 6009
      FW=.262*SQRT(3SLOPE(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
C
C******** EQUATION FOR UNDEPRESSED GRATE OPENING INLETS
C
30    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)
      WRITE(N6,6019)
      STOP
C
C******** EQUATION FOR DEPRESSED GRATE OPENING INLETS
C
40    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)
      WRITE(N6,6019)
      STOP
C
C******** EQUATION FOR UNDEPRESSED COMBINATION INLETS
```

```
      C
      50    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)
            WRITE(N6,6019)
            STOP
      C
      C******** EQUATION FOR DEPRESSED COMBINATION INLETS
      C
      60    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)
            WRITE(N6,6019)
            STOP
      C
      C******* EQUATION FOR UNDEPRESSED GRATE OPENINGS IN TRAPEZOIDAL
      C******* OPEN CHANNELS
      C
      70    WRITE(N6,75)
      75    FORMAT(*0*,////,40X,* AN INLET CAPACITY EQUATION FOR UNDEPRESSED G
           2RATE OPENINGS*,/,40X,* IN TRAPEZOIDAL OPEN CHANNELS HAS NOT YET BE
           3EN*,/,40X,* PROGRAMMED. THE USER MAY :*)
            WRITE(N6,18)
            WRITE(N6,6019)
            STOP
      C
      C******** ON-GRADE INLET CAPACITY TO BE COMPUTED FROM USER-SUPPLIED
      C******** NOMOGRAPH
      C
      C**** SELECT NOMOGRAPH BY CROSS-SLOPE AND GUTTER SLOPE
      500   IF(GS1(N).NE.0) GO TO 501
            WRITE(N6,21)
            STOP
      501   SX=1./GS1(N)
            C=Q
            IF(NPG.GT.1) GO TO 512
      C
      C**** CROSS-SLOPE
            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=DQ
      C
      C**** GUTTER 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
      IXTRP=0
      DO 600 K=1,6
      KK=K*2
      IF(C.EQ.QINLG(I,J,KK)) QI=(QINLG(I,J,KK-1))*Q*RD
      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
      QI=QINLG(I,J,KK-1)*Q*RD
      IF(QINLG(I,J,KK-1).GT..30)QI=QI-.1*Q*RD
  700 QC=Q-QI
      RETURN
C
 9000 CONTINUE
C
C******** CALCULATE SUMP FLOW WITH ORIFICE EQUATION
C
      SAREA=SLENG*SWIDTH
      SVOL=0.
      SQMAX=0.
      FVOL=0.
      VOL=0.
      SHMAX=0.
      SSMAX=0.
      DO 9050 I=1,NSTEP
      Q=SFLOW(I)
      IF(Q.GT.SQMAX) SQMAX=Q
      VOL = Q*DELT+SVOL
      IF(IMET.EQ.0) GO TO 9015
      IF(VOL.GT.85.) FVOL=FVOL+(VOL-85.)
      IF(VOL.GT.85.) VOL=85.
      GO TO 9020
 9015 IF(VOL.GT.3000.) FVOL = FVOL + (VOL-3000.)
      IF(VOL.GT.3000.) VOL = 3000.
 9020 HEAD = ((VOL)*(.002)/6.)**.3333
```

```
      GHEAD = 2.*32.2*HEAD
      IF(IMET.GT.0) GHEAD = (9.806) * HEAD *2.0
      QI = (SCOEFF) * (SAREA) * (SGRT(GHEAD))
      QNET = Q - QI
      IF(QNET.LT.0.) QNET = 0.
      SVOL = (QNET) * DELT
      IF(HEAD.GT.SHMAX) SHMAX = HEAD
      SSPRED = (24.) * HEAD
      IF(SSPRED.GT.SSMAX) SSMAX = SSPRED
 9050 QC=0.
      RETURN
C
 6009 QI=0.
      QC=0.
      RETURN
      END
```

curves are provided here - DINLG contains curves for a 2' by 4' parallel bar grate inlet on grade in a gutter (2) and DINLGC contains curves for the same inlet in a channel.

A listing of Block Data follows.

Subroutine GUTTER

This subroutine is called from the main program INLET. Subroutine CARRY is called from GUTTER to compute the carryover of the upstream inlet. Function DEPTH is called to compute upstream gutter/channel flow depth corresponding to the average upstream gutter/channel flow. The following common blocks are utilized by GUTTER:

- BLANK COMMON
- INLET
- LENGTH
- SYS
- CONT
- LOC
- ROUT
- SUMP

The computational sequence is presented in flowchart form in Figure IV-6.

Subroutine GUTTER is called each time step from the main program to compute the gutter/channel depth and flow characteristics for the given section I of the system under consideration. Input flows are contributed from adjacent watershed subareas. (A check is made to determine if the given section is the first; if this is the case and the inflow hydrograph option has been selected, the appropriate inflow is input to the initial section). For all sections other than the initial section, a check is made to see if an inlet has been located at the top of the gutter/channel section. If this is not the case, the outflow from section I-1 is added to the inflow of section I. If an inlet is located at the beginning of section I, Function DEPTH is called to compute the depth in Section I-1 corresponding to the average flow over the time step. Subroutine CARRY

```
      BLOCK DATA
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMS,QINLG(4,6,12),DINLG(4,6,12)
     2,DINLGC(6,12)
      DATA ISLOP/64,48,24,16/
      DATA SLOP/.005,.01,.02,.04,.06,.09/
      DATA CSLOP/0.015625,0.020833,0.041667,0.062500/
      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 DINLGC/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
```

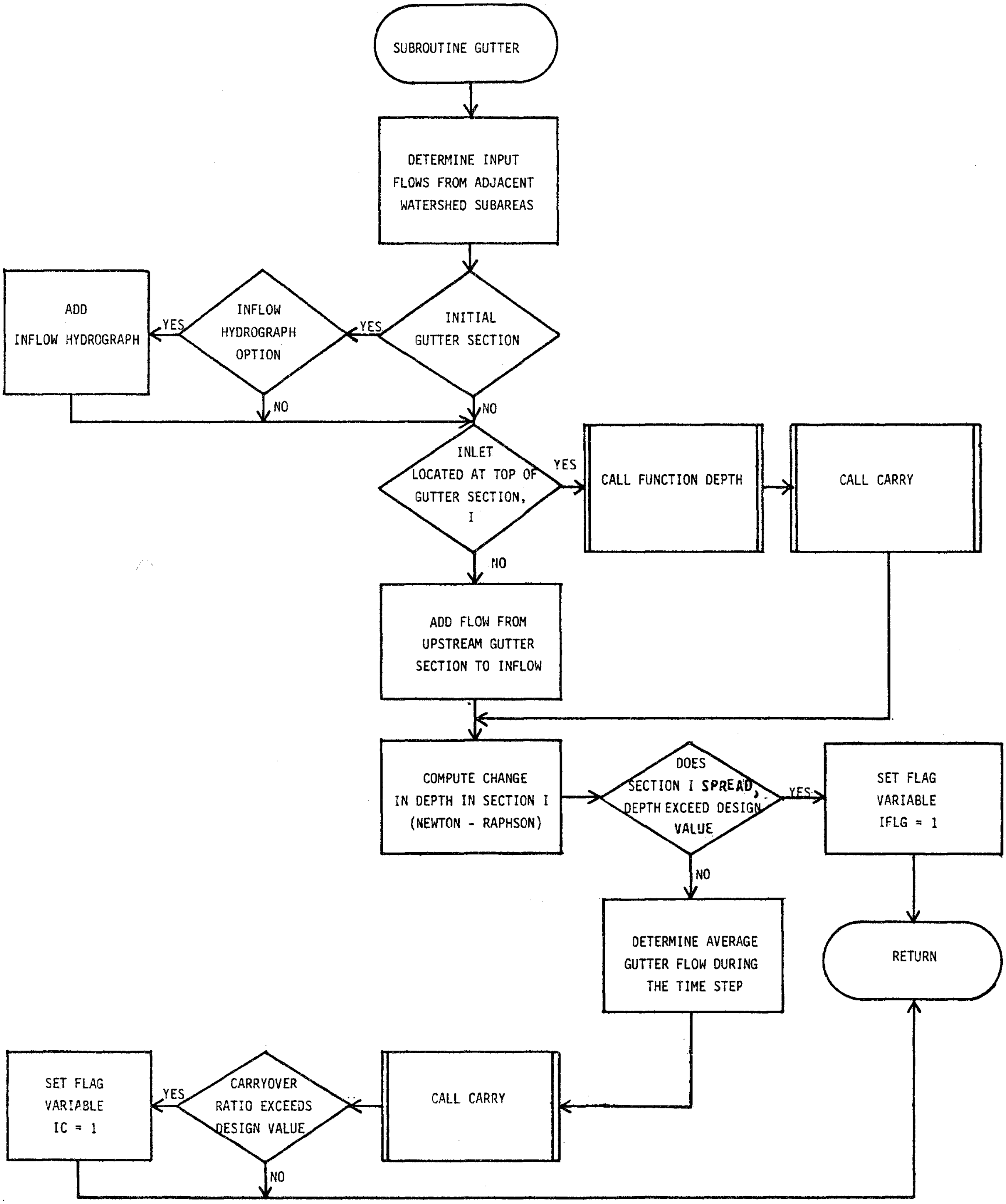

FIGURE IV-6. Flowchart for Subroutine GUTTER is then called with the previous calculated depth to compute the carryover flow which is added to the inflow for section I. The change in depth of the given section is computed using a Newton-Raphson technique. If any of the relevant design criteria are violated, the condition is flagged by an indicator variable and it is necessary to locate an inlet at the beginning of gutter/channel section I.

Key variables not in common are presented in Table IV-9 followed by a listing of the subroutine.

Function DEPTH

This routine is called from Subroutine GUTTER. It calls no other routines and employs no common blocks. The order of computations is shown in Figure IV-7. Function DEPTH computes the depth of flow in the given gutter/channel section corresponding to a given flow. The flow is known to occur for some depth lying between the depth at the beginning of the time step and the depth at the end of the time step. An interval halving procedure is used to estimate the unknown depth. Key variables are presented in Table IV-10 followed by the listing.

Variables in Common

Program INLET employs 12 separate common blocks as listed below:

- BLANK COMMON
- INLET
- TAPES
- NEW
- INFL
- ROUT
- LOC
- SYS
- CONT
- LENGTH
- SLOPES
- NOMOG

TABLE IV-9

KEY VARIABLES NOT IN COMMON FOR SUBROUTINE GUTTER

Fortran Variable	Description	Units
AXØ	Flow Area in the Gutter Section at Start of Time Step	ft^2 or m^2
AX1	Flow Area in the Gutter Section at End of Time Step	ft^2 or m^2
DAX1	Derivative of Flow Area with Respect to Change in Depth	ft or m
DDELV	Derivative of Flow Volume with Respect to Change in Depth	ft^2 or m^2
DEL	Change in Depth	ft or m
DELV	Volume in the Gutter Section as a Function of Change in Depth	ft^3 or m^3
DF	Derivative of Newton-Raphson F Function	ft^2 or m^2
DFLOW1	Derivative of Flow at End of Time Step With Respect to Change in Depth	cfs/ft or cms/m
DWP1	Derivative of Wetted Perimeter with Respect to Change in Depth	-
DØ	Depth at Beginning of the Time Step	ft or m
D1	Depth at End of the Time Step	ft or m
F	Newton-Raphson F Function	ft^3 or m^3
FL	Carryover Ratio	-
FLOW	Average Flow over the Time Step	ft^3 or m^3
FLOWØ	Flow at Depth at Beginning of the Time Step	ft^3 or m^3
FLOW1	Flow at Depth at End of the Time Step	ft^3 or m^3
GL	Length of Upstream Inlet	ft or m
IFLG	Flag Set When Gutter Depth Exceeds Design Depth	-
Q	Total Flow at Upstream Inlet	cfs or cms
QC	Carryover from Upstream Inlet	cfs or cms
QI	Interception at Upstream Inlet	cfs or cms

TABLE IV-9
(cont.)

Fortran Variable	Description	Units
RAD1	Hydraulic Radius at End of Time Step	ft or m
VOLØ	Volume at the Beginning of the Time Step	ft^3 or m^3
WPØ	Wetted Perimeter at Start of Time Step	ft or m
WP1	Wetted Perimeter at End of Time Step	ft or m
IROUT	Inlet Locator Indicator	-
IC	Flag Set When Carryover Rato for Inlets Exceeds Design Value	-
J	Gutter Section Number	-

```
      SUBROUTINE GUTTER(J,IROUT,GL,IFLG,IC)
      COMMON/ROUT/DIR,DST
      COMMON/SUMP/SVOL,FVOL,SHMAX,SSMAX,SLENG,SWIDTH,SCOEFF,SFLOW(100),
     2SQMAX
      COMMON/TAPES/NTAPE,NU,ND,N5,N6
      COMMON NW,NG,HISTOG,TRAIN,DELT,DELT2,NOW,NOG,NSTEP,TAREA,
     2 TIME,TIME2,RI,RLOSS,TZERO,IMET
      COMMON WFLOW(200),WWIDTH(200),WSLOPE(200,3),WN(200),
     2 WSTORE(200,3),WDEPTH(200,3),WAREA(200,3),WCON(200,3),NAMEW(200)
      COMMON GFLOW(200),GWIDTH(200),GLEN(200),GSLOPE(200),GS1(200),
     2 GS2(200),GN(200),GDEPTH(200),GCON(200),DFULL(200),
     3 SUMWQ(200),RAININ(200,3),TITLE(40),NC(200),SPMAX(200)
      COMMON RAIN(200,10),NHYET(200),NRGAG,NHISTO,THISTO
      COMMON DELD(200),QIN(200)
      COMMON/INLET/G,ITYPC,ITYPS,DX,XSTRT,XFIN,W,A,X1,RD
      COMMON/SYS/NINCR,NGUT(200),NWAT(200,2),NPG
      COMMON/LENGTH/GLI,GLIS,NSPEC,ISPEC,NLOC(20),XSPEC(20)
      COMMON/CONT/SUMR,SUMI,SUMQI,SUMUP,VOL1(200),VOL2(200)
      COMMON/SLOPES/ISLOP(4),SLOP(6),CSLOP(4)
      COMMON/NOMOG/INOMG,INOMS,QINLG(4,6,12),DINLG(4,6,12)
     2,DINLGC(6,12)
      COMMON/LOC/ICOUNT,XLOCUS(200),DLOCUS(200),XGLI(200),FR(200)
      N=NGUT(J)
      IF(DIR.LT.0) N=NGUT(NINCR-J+1)
C
C******** INPUTS FROM ADJACENT WATERSHED AREAS
C
      SUMWQ(J)=0.
      DO 220 JK=1,2
      NX=NWAT(J,JK)
      IF(DIR.LT.0) NX=NWAT(NINCR-J+1,JK)
  220 SUMWQ(J)=SUMWQ(J)+WFLOW(NX)
      QIN(J)=SUMWQ(J)
      IF(J.NE.1) GO TO 610
      IHYD=0
      IF(IHYD) 603,603,611
  611 QC=GFLOW(NINCR+1)
      GO TO 612
  610 IF(IROUT-1) 601,600,600
C
C******** CARRYOVER FROM UPSTREAM INLET
C
  600 ISUMP=0
      DQ=DEPTH(DELD(J-1),GDEPTH(J-1),GFLOW(J-1),GCON(N),GWIDTH(N),GS1(N)
     2,GS2(N))
      JLOC=J-1
      CALL CARRY(JLOC,ISUMP,GLI,DQ,QI,QC)
      SUMQI=SUMQI+QI*DELT
      Q=QI+QC
      IF(GFLOW(J-1).LT.1.E-4) GO TO 1250
      IF(ABS((Q-GFLOW(J-1))/GFLOW(J-1)).GT..001) WRITE(N6,1240)J,TIME,
     2 GDEPTH(J-1),GFLOW(J-1),DQ,Q
 1240 FORMAT(* DEPTH AT INLET NOT CONVERGED*,/,5X,I5,5F15.4)
 1250 FC=0.
      IF(Q.GT.0) FC=QC/Q
      IF(FC.GT.FR(ICOUNT)) FR(ICOUNT)=FC
```

```
612   QIN(J)=QIN(J)+QC
      GO TO 603
C
C******** FLOW FROM UPSTREAM INCREMENTAL GUTTER SECTION
C
601   QIN(J)=QIN(J)+GFLOW(J-1)
603   D0=GDEPTH(J)
      IC=0
      IFLG=0
      IF(QIN(J).NE.0) GO TO 290
      IF(GDEPTH(J).EQ.0) GO TO 391
290   FLOW1=0.
      DELD(J)=0.
C
C******** COMPUTE CHANGE IN DEPTH (NEWTON-RAPHSON)
C
      DO 360 I=1,30
      FLOW10=FLOW1
C
C**** ESTIMATED FINAL DEPTH
      D1=GDEPTH(J)+DELD(J)
      IF(D1.GT.0) GO TO 307
      D1=0.
      DELD(J)=-GDEPTH(J)
C
C**** VOLUME (TRAPEZOIDAL CROSS-SECTION)
307   DELV=DX*DELD(J)*((GS1(N)+GS2(N))*(D0+.5*DELD(J))+GWIDTH(N))
      DDELV=DX*((GS1(N)+GS2(N))*D1+GWIDTH(N))
C
C**** CROSS-SECTIONAL AREA (TRAPEZOIDAL CROSS-SECTION)
      AX0=0.5*(GS1(N)+GS2(N))*D0**2+GWIDTH(N)*D0
      AX1=0.5*(GS1(N)+GS2(N))*D1**2+GWIDTH(N)*D1
      DAX1=(GS1(N)+GS2(N))*D1+GWIDTH(N)
C
C**** WETTED PERIMETER (TRAPEZOIDAL CROSS-SECTION)
      DWP1=SQRT(GS1(N)**2+1.)+SQRT(GS2(N)**2+1.)
      WP0=DWP1*D0+GWIDTH(N)
      WP1=DWP1*D1+GWIDTH(N)
C
C**** HYDRAULIC RADIUS
      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(N)*(AX0**1.6666667)/(WP0**0.6666667)
      FLOW1=GCON(N)*(AX1**1.6666667)/(WP1**0.6666667)
      FLOW=0.5*(FLOW0+FLOW1)
      DFLOW1=0.5*GCON(N)*(1.6666667*(RAD1**0.6666667)*DAX1
     2 -0.6666667*(RAD1**1.6666667)*DWP1)
C
C**** NEWTON-RAPHSON CORRECTION
      F=DELV+DELT*(FLOW-QIN(J))
      DF=DDELV+DELT*DFLOW1
      IF(DF.GT.0) GO TO 320
```

```
      C
      C**** ZERO SLOPE
            DEL=0.01
            GO TO 340
      C
      C**** NON-ZERO SLOPE
      320   DEL=DELD(J)-F/DF
      C
      C**** CONVERGENCE CHECK (INDIVIDUAL GUTTER)
      340   IF(I.EQ.1) GO TO 360
            IF(J.EQ.1) GO TO 355
            IF(GDEPTH(J)+DEL.LT.DFULL(N))GO TO 355
            IF(IFLG.EQ.1) GO TO 390
            DEL=DFULL(N)-GDEPTH(J)
            IFLG=1
            GO TO 360
      355   IFLG=0
            IF(FLOW10.GT..001) GO TO 363
            IF(ABS(FLOW1-FLOW10).LT..001) GO TO 380
            GO TO 360
      363   CONTINUE
            IF(ABS(FLOW1-FLOW10).LT..001*FLOW1) GO TO 380
      360   DELD(J)=DEL
      C
      C******** NON-CONVERGENT SOLUTION
      C******** CHECK IF OUTFLOW EXCEEDS AVAILABLE WATER
      C
            VOL0=AX0*DX
            IF((FLOW0*.5*DELT).GT.(VOL0+QIN(J)*DELT)) GO TO 366
            WRITE(6,1000) TIME,J,GDEPTH(J),DELD(J)
      1000  FORMAT(*  CHECK RESULTS. NOT CONVERGED IN GUTTER *,
           2 F8.0,I6,2E12.5)
            FLOW=QIN(J)
            DELD(J)=.01*DFULL(N)-GDEPTH(J)
            GO TO 380
      366   WRITE(N6,1001) J,TIME
      1001  FORMAT(*    OUTFLOW EXCEEDS AVAILABLE WATER IN GUTTER  *,I4,
           2 * AT TIME   *,F8.0)
            FLOW=QIN(J)+VOL0/DELT
            DELD(J)=-GDEPTH(J)
            AX1=0.
      C
      C******** NEW DEPTH AT END OF TIME INTERVAL
      C
      380   GDEPTH(J)=GDEPTH(J)+DELD(J)
      C
      C******** AVERAGE FLOW DURING TIME INTERVAL
      C
            IF(FLOW.LT.1.E-10) FLOW=0.0
            GFLOW(J)=FLOW
            GO TO 410
      391   GFLOW(J)=QIN(J)
            AX0=0.
      410   CONTINUE
            DQ=DEPTH(DELD(J),GDEPTH(J),GFLOW(J),GCON(N),GWIDTH(N),GS1(N),
           2GS2(N))
            GLP=GLI
```

```
          ISUMP=0
          CALL CARRY(J,ISUMP,GLP,DQ,QI,QC)
          FC=1.
          IF((QI+QC).GT.0) FC=QI/(QI+QC)
          IF(FC.LT.(1.-G)) IC=1
          IF(IC.EQ.1) GO TO 390
    395   IF(TIME.GT.(TZERO+DELT)) GO TO 1230
          VOL1(J)=AX0*DX
   1230   VOL2(J)=AX1*DX
    390   RETURN
          END
```

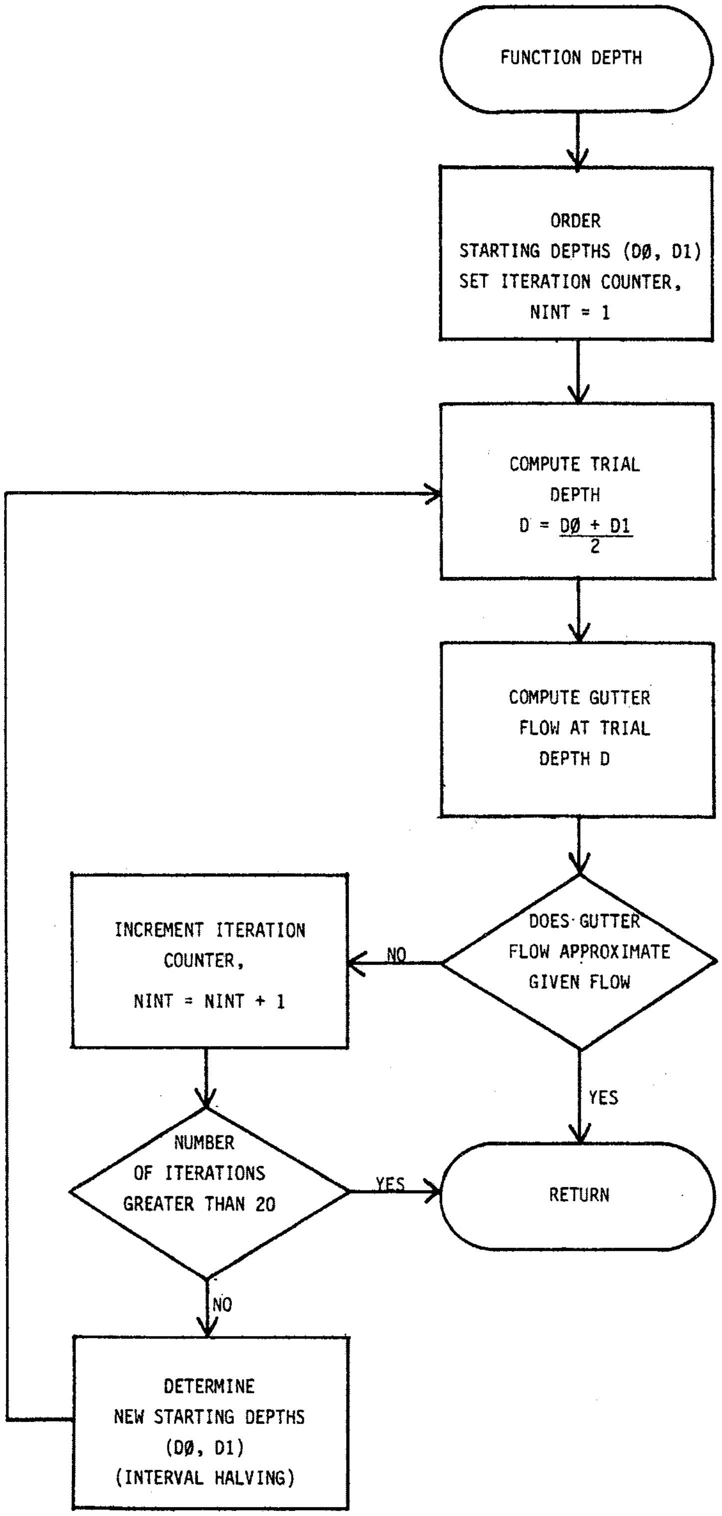

FIGURE IV-7. Flowchart for Function DEPTH

TABLE IV-10

KEY VARIABLES NOT IN COMMON FOR FUNCTION DEPTH

Fortran Variable	Description	Units
A	Flow Area at Trial Depth	ft^2 or m^2
D	Trial Depth	ft or m
DEPTH	Final Depth Estimate	ft or m
DØ	Starting Depth 1	ft or m
D1	Starting Depth 2	ft or m
K	Gutter/Channel Flow Constant	$cfs/ft^{8/3}$ or $cms/m^{8/3}$
NINT	Iteration Counter	-
Q	Flow at Trial Depth	cfs or cms
QF	Given Flow	cfs or cms
S1	Gutter/Channel Side Slope 1	ft/ft or m/m
S2	Gutter/Channel Side Slope 2	ft/ft or m/m
TØ	Initial Starting Depth 1	ft or m
T1	Initial Starting Depth 2	ft or m
W	Gutter/Channel Width	ft or m
WP	Wetted Perimeter at Trial Depth	ft or m

```
      FUNCTION DEPTH(T0,T1,QF,K,W,S1,S2)
      REAL K
      TT=T1-T0
      D0=AMIN1(TT,T1)
      D1=AMAX1(TT,T1)
      NINT=1
    1 D=(D0+D1)/2.
      IF(D.LT.1.E-4) GO TO 2
      WP=SQRT(S1**2+1.)+SQRT(S2**2+1.)
      WP=WP*D+W
      A=D*(.5*D*(S1+S2)+W)
      Q=K*(A**1.6666667)/(WP**0.6666667)
      IF(ABS(QF-Q).LT.1.0E-5) GO TO 2
      NINT=NINT+1
      IF(NINT.GT.20) GO TO 2
      IF(QF-Q) 4,3,3
    3 D0=D
      GO TO 1
    4 D1=D
      GO TO 1
    2 DEPTH=D
      RETURN
      END
```

The variables contained in each block are presented in Tables IV-11 through IV-23.

TABLE IV-11

BLANK COMMON

Fortran Variable	Description	Units	Input Data
NW	Dimension for Number of Watersheds	-	No
NG	Dimension for Number of Gutters or Channels	-	No
HISTOG	Rainfall Interval	seconds	No
TRAIN	End Time of Rainfall	seconds	No
DELT	Time Step Length	minutes	Yes
DELT1	Half Time Step Length	seconds	No
NOW	Number of Watersheds	-	No
NOG	Number of Gutters or Channels	-	No
NSTEP	Number of Time Steps Simulated	-	Yes
TAREA	Total Watershed Area	acres or hectares	No
TIME	Current Simulation Time at End of Time Step	seconds	No
TIME2	Current Simulation Time at Middle of Time Step	seconds	No
RI	Rainfall Rate	ft/sec or m/sec	No
RLOSS	Rainfall Loss Due to Infiltration and Depression Storage	ft/sec or m/sec	No
TZERO	Initial Simulation Time	seconds	No
IMET	Flag for Metric Units Option	-	Yes
WFLOW(200)	Watershed Subarea Flows Contributory to Gutter/Channel	cfs or cms	No
WWIDTH(200)	Watershed Width	ft or m	No
WSLOPE(200,3)	Watershed Subarea Slopes	ft/ft or m/m	Yes
WN(200)	Gutter Depth Storage Array	ft or m	No
WSTORE(200,3)	Watershed Subarea Depression Storage Depth	in or mm	Yes
WDEPTH(200,3)	Watershed Subarea Depth	ft or m	No
WAREA(200,3)	Watershed Subarea Area Fraction	-	Yes

TABLE IV-11

(Cont.)

Fortran Variable	Description	Units	Input Data
WCON(200,3)	Watershed Subarea Coefficients	$sec^{-1}\ ft^{-2/3}$ or $sec^{-1}m^{-2/3}$	No
NAMEW(200)	Watershed Name	-	Yes
GFLOW(200)	Gutter/Channel Section Flow	cfs or cms	No
GWIDTH(200)	Gutter/Channel Width	ft or m	Yes
GLEN(200)	Gutter/Channel Length	ft or m	No
GSLOPE(200)	Gutter/Channel Slope	ft/ft or m/m	Yes
GS1(200)	Gutter/Channel Side Slope 1	ft/ft or m/m	Yes
GS2(200)	Gutter/Channel Side Slope 2	ft/ft or m/m	Yes
GN(200)	Gutter/Channel Roughness Factor	$ft^{8/3}$/cfs or $m^{8/3}$/cms	Yes
GDEPTH(200)	Gutter/Channel Section Depth	ft or m	No
GCON(200)	Gutter/Channel Coefficient	cfs/$ft^{8/3}$ or cms/$m^{8/3}$	No
DFULL(200)	Channel Design Depth	ft or m	Yes
SUMWQ(200)	Watershed Inflow to Gutter/Channel	cfs or mps	No
RAININ(200,3)	Infiltration for Each Subarea of Each Watershed	ft or m	No
TITLE(40)	Simulation Title	-	Yes
NC(200)	Number of Subareas for Each Watershed	-	No
SPMAX(200)	Gutter Design Spread	ft or m	Yes
RAIN(200,10)	Rainfall Intensity Histories for Each Raingage	in/hr or mm/hr	Yes
NHYET(200)	Raingage Number for Each Watershed	-	No
NRGAG	Number of Raingages	-	Yes
NHISTO	Number of Rainfall Intervals	-	Yes
THISTO	Rainfall Interval Duration	minutes	Yes
DELD(200)	Gutter/Channel Depth Increment	ft or m	No
QIN(200)	Gutter/Channel Inflow	cfs or mps	No

TABLE IV-12

COMMON BLOCK INLET

Fortran Variable	Description	Units	Input Data
G,F	Capture Ratio for Inlets on Grade	-	Yes
ITYPC	Inlet Type on Grade	-	Yes
ITYPS	Inlet Type in Sump	-	Yes
DX	Routing Increment	ft or m	Yes
XSTRT	Starting Coordinate for Stationing	ft or m	No
XFIN	Ending Coordinate for Stationing	ft or m	No
W	Grate Width for Inlets on Grade	ft or m	Yes
A	Depression Depth for Inlets on Grade	ft or m	No
X1	Starting Coordinate for Routing	ft or m	No
RD	Inlet Capacity Reduction Factor	-	Yes

TABLE IV-13

COMMON BLOCK TAPES

Fortran Variable	Description	Units	Input Data
NTAPE	Watershed Flow Tape Number	-	Yes
NU	Upstream Gutter Depth Scratch Tape Number	-	Yes
ND	Downstream Gutter Depth Scratch Tape Number	-	Yes
N5	Input File Unit Number	-	Yes
N6	Output File Unit Number	-	Yes

TABLE IV-14

COMMON BLOCK NEW

Fortran Variable	Description	Units	Input Data
NAMEG(200	Name of Gutter/Channel	-	Yes
NGTO(200)	Gutter/Channel Side Number for Watershed Drainage	-	Yes

TABLE IV-15

COMMON BLOCK INFL

Fortran Variable	Description	Units	Input Data
INFIL	Number of Infiltration Types	-	Yes
WTYPE(200,3)	Infiltration Type for Watershed Subareas	-	Yes
WLMAX(4)	Maximum Infiltration Rate	in/hr or mm/hr	Yes
WLMIN(4)	Minimum Infiltration Rate	in/hr or mm/hr	Yes
DECAY(4)	Infiltration Decay Rate	sec^{-1}	Yes
DEPIN(4)	Maximum Infiltration Depth	in or mm	Yes

TABLE IV-16

COMMON BLOCK ROUT

Fortran Variable	Description	Units	Input Data
DIR	Routing Direction	-	Yes
DST	Routing Length	ft or m	No

TABLE IV-17

COMMON BLOCK LOC

Fortran Variable	Description	Units	Input Data
ICOUNT	Number of Inlets Spaced	-	No
XLOCUS(6)	Gutter/Channel Stationing at Inlet	ft or m	No
DLOCUS(6)	Gutter/Channel Depth at Inlet	ft or m	No
XGLI(6)	Inlet Length	ft or m	No
FR(6)	Carryover Ratio	-	No

TABLE IV-18

COMMON BLOCK SYS

Fortran Variable	Description	Units	Input Data
NINCR	Number of ΔX Increments for Routing	-	No
NGUT(200)	Gutter/Channel Connectivity for ΔX Increments	-	No
NWAT(200,2)	Watershed Connectivity for ΔX Increments	-	No
NPG	Gutter vs. Channel Option	-	Yes

TABLE IV-19

COMMON BLOCK CONT

Fortran Variable	Description	Units	Input Data
SUMR	Rainfall Volume	ft^3 or m^3	No
SUMI	Infiltration Volume	ft^3 or m^3	No
SUMQI	Inlet Volume	ft^3 or m^3	No
SUMUP	Inflow Hydrograph Volume	ft^3 or m^3	No
VOL1(200)	Initial Volume in Gutter/Channel Section	ft^3 or m^3	No
VOL2(200)	Final Volume in Gutter/Channel Section	ft^3 or m^3	No

TABLE IV-20

COMMON BLOCK LENGTH

Fortran Variable	Description	Units	Input Data
GLI	Inlet Length on Grade	ft or m	Yes
GLIS	Inlet Length in Sump	ft or m	Yes
NSPEC	Number of Prespecified Inlets	-	Yes
ISPEC	Number of Next Prespecified Inlets	-	No
NLOC(20)	Location of Prespecified Inlets	-	No
XSPEC(20)	Length of Prespecified Inlets	ft or m	Yes

TABLE IV-21

COMMON BLOCK SLOPES

Fortran Variable	Description	Units	Input Data
ISLOP(4)	Reciprocal Cross-Slopes Corresponding to Inlet Efficiency Curves	-	No
SLOP(4)	Longitudinal Slopes Corresponding to Inlet Efficiency Curves	-	No
CSLOP(4)	Cross-Slopes Corresponding to Inlet Efficiency Curves	-	No

TABLE IV-22

COMMON BLOCK NOMOG

Fortran Variable	Description	Units	Input Data
INOMG	Inlet on Grade Capacity Computation Option	-	Yes
INOMS*	Inlet In Sump Capacity Computation Option	-	Yes
QINLG(4,6,12)	Inlet Efficiency Curves for Inlet on Grade	-	Yes
DINLG(4,6,12)	Inlet Efficiency Curves for Inlet on Grade in Gutter (Block Data)	-	No
DINLGC(6,12)	Inlet Efficiency Curves for Inlet on Grade in Channel (Block Data)	-	No

*Variable not presently used.

TABLE IV-23

COMMON BLOCK SUMP

Fortran Variable	Description	Units	Input Data
SVOL	Volume of ponded water in sump	ft^3 or m^3	No
FVOL	Volume of ponded water in excess of sump volume	ft^3 or m^3	No
SHMAX	Depth of ponded water in sump	ft or m	No
SSMAX	Spread of ponded water at sump	ft or m	No
SWIDTH	Width of sump inlet grate	ft or m	Yes
SLENG	Length of sump inlet grate	ft or m	Yes
SCOEFF	Orifice Discharge Coefficient for sump	-	Yes
SFLOW(100)	Flow into sump	cfs or cms	No
SQMAX	Maximum flow into sump	cfs or cms	No

EXAMPLE PROBLEM

The remainder of this chapter presents the input and output from an example problem. The simulated area includes approximately 2200 feet of highway and two acres of contributory drainage area. In this problem, the program locates nine grate inlets, using the two-year storm as the design event.

The input card deck for this problem is reproduced as Exhibit IV-1; the output is given as Exhibit IV-2.

```
1  EXAMPLE PROBLEM
   VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM
     867 25    889 50    6  5.0    1     0
      8    9    10
2   16   1.
       1.92       2.23       2.63       3.15       3.84
       4.82       6.23       5.89       4.90       4.14
       3.55       3.09       2.71       2.40       2.14
       1.92
3         1
        7.0        0.4        2.0        3.0
4         4        25.  1.0   -1.    1     1     0       1.0        1.5        1.5  .67
    1.0    0.0  .97   0.5    .86   1.0   .97   2.0   .84   4.0   .67   8.0
    1.0    0.   1.00  0.5    .86   1.0   .66   2.0   .58   4.0   .42   8.0
    1.0    0.   1.00  0.5    .86   1.0   .69   2.0   .59   4.0   .42   8.0
    1.0    0.   1.00  0.5    .93   1.0   .70   2.0   .62   4.0   .49   8.0
    1.0    0.   1.00  0.5    .96   1.0   .77   2.0   .64   4.0   .56   8.0
    1.0    0.   1.00  0.5    1.0   1.0   .86   2.0   .65   4.0   .56   8.0
    1.0    0.    .99  0.5    .82   1.0   .75   2.0   .53   4.0   .48   8.0
    1.0    0.    .99  0.5    .86   1.0   .78   2.0   .63   4.0   .48   8.0
    1.0    0.    1.0  0.5    .89   1.0   .80   2.0   .65   4.0   .48   8.0
    1.0    0.    1.0  0.5    .94   1.0   .83   2.0   .66   4.0   .48   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .84   2.0   .70   4.0   .53   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .87   2.0   .84   4.0   .53   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .95   2.0   .78   4.0   .67   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .97   2.0   .84   4.0   .67   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .98   2.0   .88   4.0   .70   8.0
    1.0    0.    1.0  0.5    1.0   1.0   .99   2.0   .90   4.0   .77   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .95   4.0   .83   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .97   4.0   .89   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .82   4.0   .64   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .93   4.0   .79   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .96   4.0   .88   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .99   4.0   .91   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   .99   4.0   .94   8.0
    1.0    0.    1.0  0.5    1.0   1.0   1.0   2.0   1.0   4.0   .94   8.0
5         0
```

EXHIBIT IV-1. Example Problem Data

6	1222	867 25	870 00	0.0	.006	19.2	.57735	.013
	11	12.0						
	1228	870 00	872 50	0.0	.009	19.2	.57735	.013
	10	12.0						
	1234	872 50	876 50	0.0	.009	19.2	.57735	.013
	16	12.0						
	1242	876 50	882 25	0.0	.009	19.2	.57735	.013
	23	12.0						
	1314	882 25	884 50	0.0	.008	19.2	.57735	.013
	9	12.0						
	1810	884 50	887 00	0.0	.007	19.2	.57735	.013
	10	12.0						
	1820	887 00	889 50	0.0	.004	19.2	.57735	.013
	10	12.0						
7	2999	1	1	1.6345	2	867 25	89	
	.67	0	.0208	.050	.013			
	.33	0	.0521	.075	.013			
	2998	2	1	.03	1	867 25	89	
	1.	9	1.73	.075	.013			

Exhibit IV-1 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

----------------------------------------------SIMULATION CONTROL DATA---------------------------------------------

                                   FROM STATION   867+25 TO STATION   889+50 INLET DESIGN

                               READ UNIT          5                   WATERSHED
                               WRITE UNIT         6                   FLOW TAPE          10

                               TIME STEP                              UPSTREAM
                               LENGTH(MIN)       5.                   FLOW TAPE           8

                               NUMBER OF                              DOWNSTREAM
                               TIME STEPS         6                   FLOW TAPE           9


                               BRITISH UNITS (FPS SYSTEM) ARE USED


-----------------------------------------------DESIGN RAINFALL---------------------------------------------------

                                         NUMBER OF RAINGAGES  1

                                         NUMBER OF
                                         INTERVALS           16

                                         INTERVAL
                                         DURATION(MIN)       1.
```

EXHIBIT IV-2. Example Problem Output

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

                                 RAINGAGE  1 RAINFALL INTENSITY(IN/HR) HISTORY:

     1.92      2.23      2.63      3.15      3.84      4.82      6.23      5.89      4.90      4.14
     3.55      3.09      2.71      2.40      2.14      1.92
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM



--------------------------------------------------INFILTRATION TYPES----------------------------------------------------

                              MAX RATE      MIN RATE        DECAY     MAX DEPTH
                               IN/HR         IN/HR          HR-1       INCHES

         TYPE 0         CORRESPONDS TO IMPERVIOUS SURFACE
         TYPE 1                7.00           .40         2.0000            3.0
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

--------------------------------------------------INLET DESIGN PARAMETERS-----------------------------------------------------

         INCREMENTAL LENGTH          25. FT.            MAXIMUM CARRYOVER  RATIO FOR INLETS ON GRADE 0.00


         INLET CAPACITY REDUCTION FACTOR    1.00


          ROUTING IN THE DIRECTION OF DESCENDING STATION NUMBERING


          FOR INLETS ON GRADE: DEPRESSED GRATE INLET SELECTED
                               INLET CAPACITY NOMOGRAPH INPUT BY USER
```

Exhibit IV-2 (Continued)

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

ON-GRADE INLET CAPACITY NOMOGRAPHS 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
.97	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5
.86	1.0	.86	1.0	.86	1.0	.93	1.0	.96	1.0	1.00	1.0
.97	2.0	.66	2.0	.69	2.0	.70	2.0	.77	2.0	.86	2.0
.84	4.0	.58	4.0	.59	4.0	.62	4.0	.64	4.0	.65	4.0
.67	8.0	.42	8.0	.42	8.0	.49	8.0	.56	8.0	.56	8.0

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
.99	.5	.99	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5
.82	1.0	.86	1.0	.89	1.0	.94	1.0	1.00	1.0	1.00	1.0
.75	2.0	.78	2.0	.80	2.0	.83	2.0	.84	2.0	.87	2.0
.53	4.0	.63	4.0	.65	4.0	.66	4.0	.70	4.0	.84	4.0
.48	8.0	.48	8.0	.48	8.0	.48	8.0	.53	8.0	.53	8.0

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	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5
1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
.95	2.0	.97	2.0	.98	2.0	.99	2.0	1.00	2.0	1.00	2.0
.78	4.0	.84	4.0	.88	4.0	.90	4.0	.95	4.0	.97	4.0
.67	8.0	.67	8.0	.70	8.0	.77	8.0	.83	8.0	.89	8.0

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	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5	1.00	.5
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
.82	4.0	.93	4.0	.96	4.0	.99	4.0	.99	4.0	1.00	4.0
.64	8.0	.79	8.0	.88	8.0	.91	8.0	.94	8.0	.94	8.0

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-------------------------------------------------SUMP INLET DESIGN PARAMETERS-------------------------------------------------


SUMP INLET WIDTH=  1.50 FT., LENGTH=  1.50 FT.

SUMP INLET ORIFICE DISCHARGE COEFFICIENT =  .670
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Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM
```

HIGHWAY SURFACE DRAINAGE GUTTERS

GUTTER NO.	GUTTER NAME	STATION 1	STATION 2	WIDTH (FT)	LENGTH (FT)	SLOPE (FT/FT)	RECIPROCAL LEFT SIDE SLOPE(FT/FT)	RECIPROCAL RIGHT SIDE SLOPE(FT/FT)	MANNING N (FT)1/6	DESIGN SPREAD(FT)
1	1222	867+25	870+00	0.	275.	.006	19.200	.577	.013	12.000
2	1228	870+00	872+50	0.	250.	.009	19.200	.577	.013	12.000
3	1234	872+50	876+50	0.	400.	.009	19.200	.577	.013	12.000
4	1242	876+50	882+25	0.	575.	.009	19.200	.577	.013	12.000
5	1314	882+25	884+50	0.	225.	.008	19.200	.577	.013	12.000
6	1810	884+50	887+00	0.	250.	.007	19.200	.577	.013	12.000
7	1820	887+00	889+50	0.	250.	.004	19.200	.577	.013	12.000

TOTAL NUMBER OF GUTTERS/CHANNELS : 7

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

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


                           WATERSHED WATERSHED  STATION   STATION    GUTTER  RAINGAGE   AREA     NUMBER OF
                              NO.       NAME       1         2        SIDE      NO.    (ACRES)   SUBAREAS

                               1        2999    867+25    889+50       1         1     1.63          2


                                                     SUBAREA DEFINITION

                                      AREA   INFILTRATION   SLOPE   STORAGE  MANNING N
                                     (ACRES)     TYPE      (FT/FT)    (IN)    (FT)1/6
                                       1.10          0       .02       .05       .01


                                        .54          0       .05       .08       .01

                           WATERSHED WATERSHED  STATION   STATION    GUTTER  RAINGAGE   AREA     NUMBER OF
                              NO.       NAME       1         2        SIDE      NO.    (ACRES)   SUBAREAS

                               2        2998    867+25    889+50       2         1      .03          1


                                                     SUBAREA DEFINITION

                                      AREA   INFILTRATION   SLOPE   STORAGE  MANNING N
                                     (ACRES)     TYPE      (FT/FT)    (IN)    (FT)1/6
                                        .03          0      1.73       .08       .01


TOTAL NUMBER OF SUBCATCHMENTS,    2

TOTAL TRIBUTARY AREA (ACRES),     1.66
   OUTFLOW EXCEEDS AVAILABLE WATER IN GUTTER     1 AT TIME       900.
   OUTFLOW EXCEEDS AVAILABLE WATER IN GUTTER     3 AT TIME       900.
DEPTH AT INLET NOT CONVERGED
        9       300.0000          .0100          .0001          .0075          .0001
DEPTH AT INLET NOT CONVERGED
        9       600.0000          .2701          .6730          .2083          .8243
DEPTH AT INLET NOT CONVERGED
        9       900.0000          .1284          .7654          .2186          .9374
   OUTFLOW EXCEEDS AVAILABLE WATER IN GUTTER     9 AT TIME       900.
DEPTH AT INLET NOT CONVERGED
        9      1200.0000         0.0000          .0925          .0990          .1133
```

Exhibit IV-2 (Continued)

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RAINFALL ON WATERSHED (FT3) .565443E+04
BOUNDARY FLOW VOLUME (FT3)0.
----- TOTAL INPUT VOLUME (FT3) ----- .565443E+04

INFILTRATION (FT3)0.
INLET VOLUME (FT3) .534945E+04
CHANNEL STORAGE (FT3) .237083E+01
WATERSHED STORAGE (FT3) .282542E+03
----- TOTAL CUTFLOW STORAGE (FT3) ----- .563436E+04

      ERROR IN CONTINUITY, PERCENTAGE OF INFLOW        .35498
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Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-----------------------------------------------INLET  1 DESIGN SPECIFICATIONS-----------------------------------------------

                                           INLET LOCATED AT STATION   887+50  ----- ON GRADE -----
                                                DEPRESSED   COMBINATION

                                                DESIGN CARRYOVER0.00 OF PEAK FLOW

                                                MAXIMUM CARRYOVER RATIO0.00

                                                GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                           SLOPE                                                 .0040
                                           WIDTH                                                  0.00 FT
                                           SIDE SLOPE 1 RECIPROCAL                             19.2000
                                           SIDE SLOPE 2 RECIPROCAL                               .5774


                                                PEAK HYDRAULIC CONDITIONS AT INLET

                                           FLOW SPREAD                                            5.34 FT
                                           DEPTH                                                   .27 FT
                                           FLOW                                                   1.35 CFS
                                           VELOCITY                                               1.87 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-----------------------------------------------INLET  2 DESIGN SPECIFICATIONS-----------------------------------------------

                                        INLET LOCATED AT STATION   885+25  ----- ON GRADE -----
                                             DEPRESSED   COMBINATION

                                             DESIGN CARRYOVER0.00 OF PEAK FLOW

                                             MAXIMUM CARRYOVER RATIO0.00

                                             GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                        SLOPE                                              .0070
                                        WIDTH                                               0.00 FT
                                        SIDE SLOPE 1 RECIPROCAL                          19.2000
                                        SIDE SLOPE 2 RECIPROCAL                            .5774


                                             PEAK HYDRAULIC CONDITIONS AT INLET

                                        FLOW SPREAD                                         5.10 FT
                                        DEPTH                                                .26 FT
                                        FLOW                                                1.58 CFS
                                        VELOCITY                                            2.39 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-----------------------------------------------INLET  3 DESIGN SPECIFICATIONS-----------------------------------------------

                                          INLET LOCATED AT STATION   883+00  ----- ON GRADE -----
                                               DEPRESSED   COMBINATION

                                               DESIGN CARRYOVER0.00 OF PEAK FLOW

                                               MAXIMUM CARRYOVER RATIO0.00

                                               GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                          SLOPE                                              .0080
                                          WIDTH                                               0.00 FT
                                          SIDE SLOPE 1 RECIPROCAL                          19.2000
                                          SIDE SLOPF 2 RECIPROCAL                            .5774


                                               PEAK HYDRAULIC CONDITIONS AT INLET

                                          FLOW SPREAD                                         5.02 FT
                                          DEPTH                                                .25 FT
                                          FLOW                                                1.61 CFS
                                          VELOCITY                                            2.53 FPS
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Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

------------------------------------------------INLET  4 DESIGN SPECIFICATIONS------------------------------------------------

                                         INLET LOCATED AT STATION   880+50  ----- ON GRADE -----
                                              DEPRESSED   COMBINATION

                                              DESIGN CARRYOVER0.00 OF PEAK FLOW

                                              MAXIMUM CARRYOVER RATIO0.00

                                              GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                         SLOPE                                             .0090
                                         WIDTH                                              0.00 FT
                                         SIDE SLOPE 1 RECIPROCA'                         19.2000
                                         SIDE SLOPE 2 RECIPROCAL                           .5774


                                              PEAK HYDRAULIC CONDITIONS AT INLET

                                         FLOW SPREAD                                        5.09 FT
                                         DEPTH                                               .26 FT
                                         FLOW                                               1.77 CFS
                                         VELOCITY                                           2.71 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

------------------------------------------------INLET  5 DESIGN SPECIFICATIONS------------------------------------------------------

                                           INLET LOCATED AT STATION   878+00  ----- ON GRADE -----
                                                DEPRESSED   COMBINATION

                                                DESIGN CARRYOVER0.00 OF PEAK FLOW

                                                MAXIMUM CARRYOVER RATIO0.00


                                                GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                           SLOPE                                              .0090
                                           WIDTH                                               0.00 FT
                                           SIDE SLOPE 1 RECIPROCAL                          19.2000
                                           SIDE SLOPE 2 RECIPROCAL                            .5774


                                                PEAK HYDRAULIC CONDITIONS AT INLET

                                           FLOW SPREAD                                         5.09 FT
                                           DEPTH                                                .26 FT
                                           FLOW                                                1.78 CFS
                                           VELOCITY                                            2.71 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT C066-000-101, GRATE INLET WITH 2 YEAR STORM

--------------------------------------------------INLET  6 DESIGN SPECIFICATIONS--------------------------------------------------

                                            INLET LOCATED AT STATION   875+50  ----- ON GRADE -----
                                                 DEPRESSED   COMBINATION

                                                 DESIGN CARRYOVER0.00 OF PEAK FLOW

                                                 MAXIMUM CARRYOVER RATIO0.00

                                                 GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                            SLOPE                                                   .0090
                                            WIDTH                                                   0.00 FT
                                            SIDE SLOPE 1 RECIPROCAL                               19.2000
                                            SIDE SLOPE 2 RECIPROCAL                                 .5774

                                                 PEAK HYDRAULIC CONDITIONS AT INLET

                                            FLOW SPREAD                                             5.09 FT
                                            DEPTH                                                    .26 FT
                                            FLOW                                                    1.78 CFS
                                            VELOCITY                                                2.71 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

--------------------  ------------------------INLET  7 DESIGN SPECIFICATIONS-----------------------------------------------

                                          INLET LOCATED AT STATION   872+75  ----- ON GRADE -----
                                               DEPRESSED   COMBINATION

                                               DESIGN CARRYOVER0.00 OF PEAK FLOW

                                               MAXIMUM CARRYOVER RATIO0.00

                                               GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                          SLOPE                                             .0090
                                          WIDTH                                              0.00 FT
                                          SIDE SLOPE 1 RECIPROCAL                         19.2000
                                          SIDE SLOPE 2 RECIPROCAL                           .5774


                                               PEAK HYDRAULIC CONDITIONS AT INLET

                                          FLOW SPREAD                                        5.23 FT
                                          DEPTH                                               .26 FT
                                          FLOW                                               1.91 CFS
                                          VELOCITY                                           2.76 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-----------------------------------------------INLET  8 DESIGN SPECIFICATIONS-----------------------------------------------

                                          INLET LOCATED AT STATION   870+00  ----- ON GRADE -----
                                               DEPRESSED   COMBINATION

                                               DESIGN CARRYOVER0.00 OF PEAK FLOW

                                               MAXIMUM CARRYOVER RATIO .01

                                               GUTTER/CHANNEL CHARACTERISTICS AT INLET

                                          SLOPE                                            .0090
                                          WIDTH                                             0.00 FT
                                          SIDE SLOPE 1 RECIPROCAL                        19.2000
                                          SIDE SLOPE 2 RECIPROCAL                          .5774


                                               PEAK HYDRAULIC CONDITIONS AT INLET

                                          FLOW SPREAD                                       5.23 FT
                                          DEPTH                                              .26 FT
                                          FLOW                                              1.91 CFS
                                          VELOCITY                                          2.76 FPS
```

Exhibit IV-2 (Continued)

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

 EXAMPLE PROBLEM
 VIRGINIA INTERSTATE 66 PROJECT 0066-000-101, GRATE INLET WITH 2 YEAR STORM

-----------------------------------------------INLET  9 DESIGN SPECIFICATIONS-----------------------------------------------

                                         INLET LOCATED AT STATION   867+25  ----- IN SUMP -----

                                              THIS SUMP INLET INTERCEPTS ALL REMAINING FLOW

                                              DESIGN WIDTH  1.50 FT. AND DESIGN LENGTH 1.50 FT.

                                                        SUMP CHARACTERISTICS

                                         SLOPE                                        .002
                                         MAXIMUM DEPTH                                1.0 FT
                                         RECIPROCAL CROSS-SLOPE                       24.


                                              PEAK HYDRAULIC CONDITIONS AT SUMP

                                         SPREAD OF PONDED WATER                            11.26 FT
                                         DEPTH OF PONDED WATER                               .47 FT
                                         FLOW TO SUMP                                       1.03 CFS
                                         PONDED WATER IN EXCESS OF SUMP VOLUME              0.00 CU. FT.


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                                                   INLET SPACING ALGORITHM COMPLETED
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Exhibit IV-2 (Continued)

CHAPTER IV

REFERENCES

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4. Golding, B., "HNV-Santa Barbara Urban Hydrograph Method," Proceedings of the Storm Water Management Model Users Group Meeting, June 19-20, 1980, U.S. Environmental Protection Agency (to be published).

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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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HRD-10/12-83(300)