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DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL--VERSION II

By William M. Alley and Peter E. Smith

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CONTENTS

FIGURES

TABLES

METRIC (SI) CONVERSION FACTORS

Multiply inch-pound unit	By	To obtain metric unit
inch	25.4	millimeter
inch per hour	25.4	millimeter per hour
foot (ft)	0.3048	meter
foot per second (ft/s)	.3048	meter per second
square foot (ft^2)	.0929	square meter
acre	.4047	hectare
square mile	2.590	square kilometer
cubic foot per second (ft^3/s)	.02832	cubic meter per second

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ABSTRACT

A computer program of a watershed model for routing storm runoff through a branched system of pipes and (or) natural channels using rainfall as input is described. The model provides detailed simulation of storm-runoff periods selected by the user and a daily soil-moisture accounting between storms. A drainage basin is represented as a set of overland-flow, channel, and reservoir segments which jointly describe the drainage features of the basin. Kinematic wave theory is used for routing flows over contributing overland-flow areas and through the channel network. A set of model segments can be arranged into a network that will represent many complex drainage basins. The model is intended primarily for application to urban watersheds, but may have limited applications to rural watersheds.

INTRODUCTION

The U.S. Geological Survey (USGS) has been developing simulation models of rainfall-runoff processes since the late 1960's. Dawdy, Lichty, and Bergmann (1972) reported on the first simulation model from this research; a lumped parameter rainfall-runoff model for small rural watersheds. Subsequent work by Dawdy, Schaake, and Alley (1978) produced a Distributed Routing Rainfall-Runoff Model (DR_3M). This model was largely the product of incorporating the routing component from a version of the Massachusetts Institute of Technology catchment model (Leclerc and Schaake, 1973) into the original USGS model.

The purpose of this user's manual is to document the current version of DR_3M and to update guidelines for use of the model. Major changes to DR_3M since 1978 include:

1. The user can select from three solution techniques for kinematic wave routing in channels and overland-flow segments. These include the original explicit finite difference formulation, an implicit finite difference formulation, and the method of characteristics. A means of avoiding kinematic shock problems in the method of characteristics formulation has been developed.

2. The model can be used to create segment flow files for later use by DR_3M-QUAL (Alley and Smith, report in preparation).

3. The model uses disk space for temporary storage of measured storm rainfall and runoff data. This reduces the core storage requirements of the model for long-term simulation.

4. Many changes have been made to the basic output structure of the model and numerous error messages have been incorporated into the code.

5. Effective impervious area can be included in the parameter optimization algorithm.

6. The minimum time interval for rainfall data input to the model has been reduced from 5 minutes to 1 minute.

DR3M operates on two time intervals. The model provides detailed simulation of storm runoff during days for which short-time interval rainfall data are input to the program. These days are referred to as "unit days", and it is only during unit days that flow routing is performed. Between unit days the model uses daily precipitation and daily evaporation data to provide a continuous daily accounting of soil moisture. Thus, the advantages of continuous simulation are combined with those of an event type model.

During simulation of a period of storm runoff, the generation of rainfall excess and flow routing are treated independently. The time series of rainfall excess is determined first and then, in a second step, it is routed to the watershed outlet.

ACKNOWLEDGEMENTS

The current version of DR3M is the product of over a decade of model development both within and outside the U.S. Geological Survey. Numerous individuals have contributed to its development. In particular, outstanding contributions have been made by David R. Dawdy, John C. Schaake, Jr., and Robert W. Lichty.

RAINFALL-EXCESS COMPONENTS

The rainfall-excess components include soil-moisture accounting, pervious-area rainfall excess, impervious-area rainfall excess, and parameter optimization. A substantial part of the rainfall-excess components has been adopted from the model developed by Dawdy, Lichty, and Bergmann (1972).

Soil Moisture Accounting

The soil-moisture-accounting component determines the effect of antecedent conditions on infiltration. Soil moisture is modeled as a dual storage system, one representing the antecedent base-moisture storage (BMS)[1/] and the other representing the upper-zone storage caused by infiltration into a saturated moisture storage (SMS).

During unit days, moisture is added to SMS based on the Green-Ampt infiltration equation (Green and Ampt, 1911). Between unit days, a specified proportion of daily rainfall is added to SMS.

1/ Definitions of selected model variables can be found in Attachment F.

Evapotranspiration takes place from SMS when available, otherwise from BMS, with the rate determined from pan evaporation multiplied by a pan coefficient. Moisture in SMS drains into BMS during periods of no rainfall at a rate based on the effective hydraulic conductivity. (Note: This is equivalent to setting DRN equal to 1.0 in the 1978 version of DR_3M.) Storage in BMS has a maximum value (BMSN) equivalent to the field-capacity moisture storage of the active soil zone. Zero storage in BMS is assumed to correspond to wilting point conditions in the active soil zone. When storage in BMS exceeds BMSN, the excess is spilled to deeper storage. These spills could be the basis for routing subsurface flow components. However, this option is not included in the present version of the model.

Pervious-Area Rainfall Excess

Point-potential infiltration (FR) is computed by a variation of the Green-Ampt equation (Green and Ampt, 1911):

$$FR = KSAT\ (1 + PS/SMS) \tag{1}$$

where KSAT is the hydraulic conductivity of the transmission zone and PS is defined as:

$$PS = P\ (m - m_o) \tag{2}$$

where P is average suction head across the wetting front (capillary drive), m is the moisture content of the soil after wetting, and m_o is the antecedent soil-moisture content. The Green-Ampt infiltration equation is derived by direct application of Darcy's Law under the following assumptions:

1. A distinct piston wetting front exists.

2. The suction head at the wetting front is constant regardless of time and position.

3. Behind the wetting front, the soil is uniformly wet and of constant conductivity (KSAT).

In a soil column, the capillary potential at the wetting front is not a constant, but varies according to the soil-moisture condition. Therefore, the model determines the effective value of PS as varying linearly between a value at plant wilting and a value at field capacity:

$$PS = PSP\ [RGF - (RGF - 1)\ \frac{BMS}{BMSN}\ ] \tag{3}$$

where PSP is the effective value of PS at field capacity and RGF is the ratio of PS at wilting point to that at field capacity. This relationship is shown in figure 1.

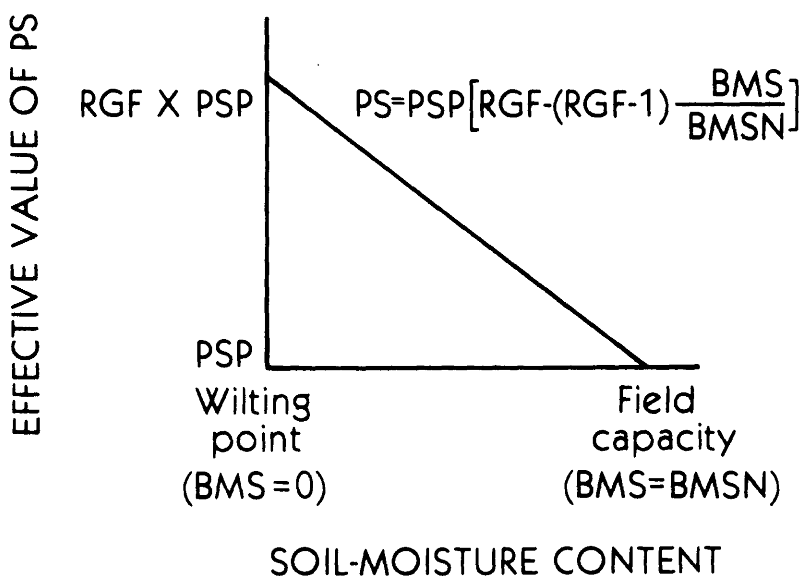


Figure 1.--The relation which determines the effective value of soil-moisture potential (PS) for use in the infiltration equation.

Point-potential infiltration (FR) computed by equation 1 is converted to effective infiltration over the basin using a scheme first presented by Crawford and Linsley (1966). Letting SR represent the supply rate of rainfall for infiltraton, and QR represent the rate of generation of rainfall excess, the equations are:

$$QR = \frac{SR^2}{2FR} \text{ ; if } SR \leq FR \tag{4a}$$

$$QR = SR - \frac{FR}{2} \text{ ; if } SR > FR \tag{4b}$$

A schematic of these relations is shown in figure 2. The rainfall excess rate, QR, is represented by the area in figure 2 between the dashed SR line and the linear infiltration capacity curve. Equation 4 is a relationship which eliminates a single-valued threshold for infiltration.

Impervious-Area Rainfall Excess

Two types of impervious surfaces are considered by the model. The first type, effective impervious surfaces, are those impervious areas that are directly connected to the channel drainage system. Roofs that drain onto driveways, streets, and paved parking lots that drain onto streets are examples of effective impervious surfaces. The second type, noneffective impervious surfaces, are those impervious areas that drain to pervious areas. An example of a noneffective impervious area is a roof that drains onto a lawn.

The only abstraction from rainfall on effective impervious area is impervious retention. One-third of the rain falling on the effective impervious area is stored as impervious retention until the impervious-retention-storage capacity is attained.

Rain falling on noneffective impervious areas is assumed to run off onto the surrounding pervious area. The model assumes that this occurs instantaneously and that the volume of runoff is uniformly distributed over the pervious area. This volume, expressed as inches over the pervious area, is added to the rain falling on the pervious areas prior to computation of pervious-area rainfall excess. This computation is performed in the model by multiplying rainfall on pervious areas by the model parameter RAT:

$$RAT = \frac{DA2 + DA3}{DA3} \tag{5}$$

where DA2 is the area of the basin covered by noneffective impervious surfaces and DA3 is the area of the basin covered by pervious surfaces.

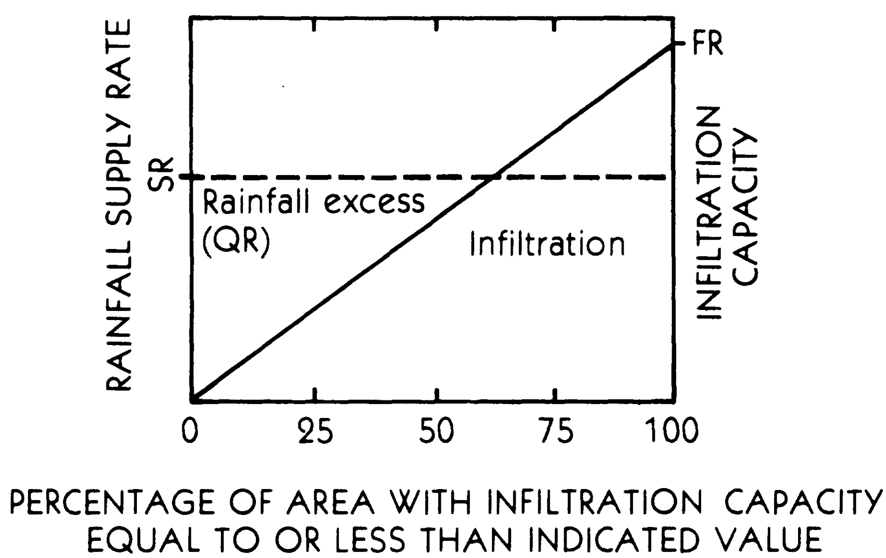


Figure 2.--The relation which determines rainfall excess (QR) as a function of maximum-infiltration capacity (FR) and supply rate of rainfall (SR).

Parameter Optimization

An optimization procedure (Rosenbrock, 1960) is included in the model to aid in calibrating several of the soil-moisture-accounting and rainfall-excess parameters. During an optimization run, storm-runoff volumes for a series of storms having measured rainfall and runoff data are simulated by the model. An objective function which is the sum of the squared deviations of the logarithms of simulated and measured storm-runoff volumes is computed:

$$U = \sum_{i=1}^{N} [\ln(S_i) - \ln(M_i)]^2 \tag{6}$$

where U is the value of the objective function, N is the number of storms included in the objective function, S_i is the i^{th} simulated runoff volume, and M_i is the i^{th} measured runoff volume. One of the parameter magnitudes is then revised and a second simulation made. If the result is an improvement, the revised set is accepted; if not, the previous best set of parameter values is retained. This procedure is repeated for a user-specified number of iterations.

Rosenbrock's method of optimization proceeds by stages. During the first stage, each parameter represents one axis in an orthogonal set of search directions. Adjustments are made in these search directions until end-of-stage criteria are satisfied. At the end of each stage, a new set of orthogonal directions is computed, based on the experience of parameter movement during the preceeding stage. The major feature of this procedure is that, after the first stage, one axis is aligned in a direction reflecting the net parameter movement experienced during the previous stage.

To start the fitting process, the model is assigned an initial set of parameter values and upper and lower bounds for each parameter. The model is run and the objective function is calculated and stored in the computer memory bank as a reference value. A step of user-specified length is then attempted in the first-search direction. If the resulting value of the objective function is less than or equal to the reference value, the trial is registered as a success, and the appropriate step size, e, for each parameter is multiplied by 3. If a failure results, the step is not allowed and e is multiplied by -1/2. An attempt is then made in the next search direction, and the process continues until the end-of-stage criteria are met. At this point, a new orthogonal search pattern is detemined, and another stage of optimization undertaken. The objective function value and associated parameter values are printed for each successful trial.

ROUTING COMPONENTS

DR3M approximates the complex topography and geometry of a watershed as a set of segments which jointly describe the drainage features of the basin. The purpose of this approach is to reduce the rainfall-excess routing problem to the hydraulic problem of unsteady flow over uniform planes and channels. There are four types of segments:

1. overland-flow segments

2. channel segments

3. reservoir segments

4. nodal segments

Overland-flow segments receive uniformly distributed lateral inflow from rainfall excess. They represent a rectangular plane of a given length, slope, roughness, and percent imperviousness.

Channel segments are used to represent natural or manmade conveyances such as gutters or storm-sewer pipes. Channel segments may receive upstream inflow from as many as three other segments, including combinations of other channel segments, reservoir segments, and nodal segments. They also can receive lateral inflow from overland-flow segments.

Reservoir segments can be used to describe an on-channel detention reservoir. Alternately, they can be used to simulate storage of water behind culverts for which outflows are uniquely described as a single-valued function of storage behind the culvert.

Nodal segments are used when more than three segments contribute inflow to the upstream end of a channel or reservoir segment or as input points where the user may specify an input hydrograph or constant discharge for each storm.

There is wide flexibility to the approach one can take in dividing a basin into segments for runoff computations. Guidelines for basin segmentation are presented in a later section of this user's manual.

Channel and Overland-Flow Segments

A schematic illustrating the relationships between channel and overland-flow segments is shown in figure 3. Kinematic wave theory is applied for both overland-flow and channel routing.

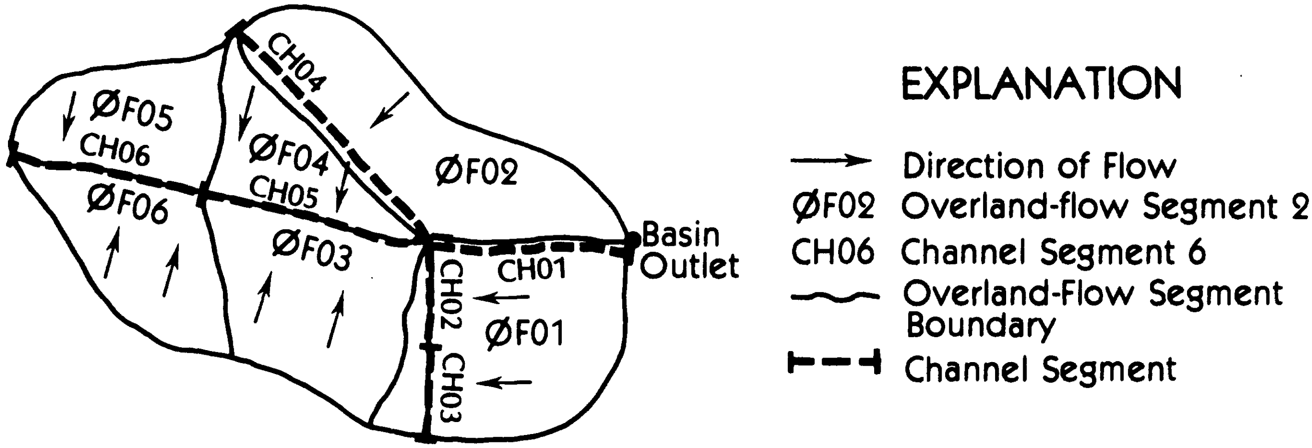
The Kinematic Wave Equations

Unsteady free-surface flow is governed by the equations of continuity and momentum, commonly referred to as the Saint-Venant or shallow-water equations. The continuity equation results from an expression of the principle of conservation of mass and may be written as

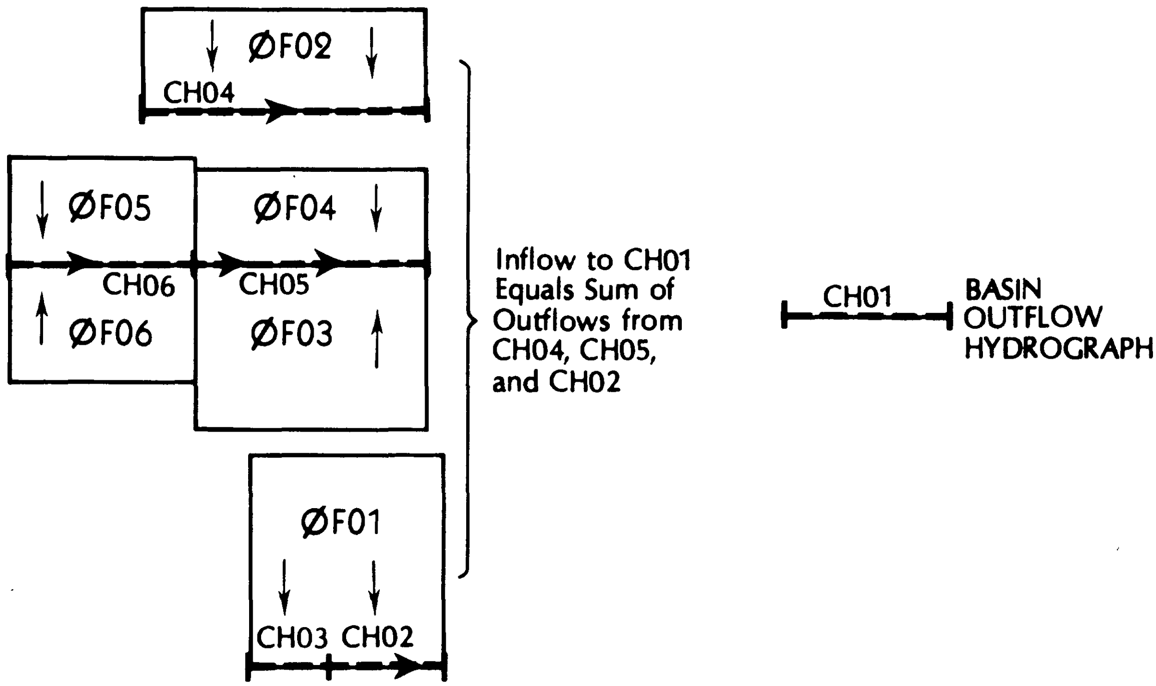
$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \tag{7}$$

in which Q is discharge, A is the flow cross-sectional area, q is the lateral inflow per unit length, and x and t are space and time coordinates. The momentum equation is an expression of Newton's second law of motion and for a prismatic channel may be written as

$$S_f = S_o - \left(\frac{\partial Y}{\partial x} + \frac{1}{g}\frac{\partial V}{\partial t} + \frac{V}{g}\frac{\partial V}{\partial x}\right) \tag{8}$$



(a) PLAN VIEW OF DRAINAGE BASIN



(b) SCHEMATIC REPRESENTATIONS OF MODEL SEGMENTS

Segment	Inflow to Segment	
	Lateral Inflow	Upstream Inflow
ØF01	Rainfall Excess	—
ØF02	" "	—
ØF03	" "	—
ØF04	" "	—
ØF05	" "	—
CH01	—	CH02, CH04, CH05
CH02	ØF01	CH03
CH03	ØF01	—
CH04	ØF02	—
CH05	ØF03, ØF04	CH06
CH06	ØF05, ØF06	—

(c) SEGMENT INTERRELATIONSHIPS

Figure 3.--Discretization of watershed into overland-flow and channel segment

in which Y is the depth of flow, V is the mean velocity, g is the acceleration due to gravity, and S_o and S_f are the bed slope and friction slope, respectively.

Both overland and channel flow are governed by the equations of continuity and momentum, and mathematically can be treated similarly. Overland flow is viewed as wide, shallow-channel flow, and analyzed on a unit foot basis with lateral inflow coming from rainfall excess.

Although the Saint-Venant equations can theoretically be applied to the problem of routing surface runoff, they are rarely used in watershed models. Using the complete form of the equations to route runoff from a complex configuration of channels and planes places too high a demand on computer resources. In watershed models there are also few situations where the required boundary conditions are available for solution of the equations. For these reasons, DR3M makes use of the kinematic wave approximation of the momentum equation to achieve simpler and faster solutions.

The underlying assumption of the kinematic wave approximation is that the water surface slope and acceleration terms of equation 8 are negligible in comparison with those of the bed slope and friction. This reduces the momentum equation to the form

$$S_f \approx S_o \tag{9}$$

where all partial derivatives of equation 8 are neglected. By defining the friction slope with an appropriate flow resistance relationship (such as the Manning formula for turbulent flow), equation 9 can be represented by a general power relationship of the form

$$Q = \alpha A^m \tag{10}$$

where α and m are constants that are determined from the geometry, slope, and roughness of an overland flow plane or channel.

Equations 7 and 10 are the form of the kinematic wave equations solved in the model. Because of the assumptions used in their derivation, they have properties that are different from those of the more complete St. Venant equations. It has been shown (Henderson, 1966), that the terms eliminated from the momentum equation in the kinematic model are responsible for introducing wave dispersion into solutions of the St. Venant equations. By neglecting these terms, the kinematic equations do not describe wave dispersion. The effect of this is most obvious in a hydrograph routed with no lateral inflow, where the presence of dispersion would result in attenuation of the wave. For this case, the kinematic equations do not describe attenuation. They describe only translation of the hydrograph and a deforming of the hydrograph shape that appears as a steepening of the rising limb and a flattening of the falling limb. The hydrograph does not lengthen (disperse) as it moves downstream. A note of explanation is necessary, however. These properties are those exhibited by analytical solutions of the kinematic equations. Numerical solutions of the equations may well exhibit numerical dispersion, due to unavoidable truncation errors. This dispersion is not present in the equations themselves, but is created when a numerical solution fails to converge to the true solution of the equations.

Several investigators have made use of the numerical dispersion in numerical solutions of the kinematic equations by controlling it to approximate physical dispersion. The control of dispersion is done by the "weighting" of derivatives in a finite difference method. This approach is available as an option in DR3M.

DR3M has three methods available for solution of equations 7 and 10: a method of characteristics and implicit and explicit finite-difference methods. The user has the option to select a particular solution method for each model segment. In the following sections the methods are described, and in a subsequent section some suggestions are given on selecting a solution method.

Method of Characteristics

Combining equations 10 and 7 yields the following:

$$\frac{\partial A}{\partial t} + \alpha m A^{m-1} \frac{\partial A}{\partial x} = q \tag{11}$$

This hyperbolic partial differential equation, sometimes called the kinematic wave equation, can be solved by the method of characteristics. The solution provides values of A that can be converted to discharge using equation 10.

Equation 11 can be represented by the following characteristic equations (Eagleson, 1970):

$$\frac{dx}{dt} = \alpha m A^{m-1} \tag{12}$$

$$\frac{dA}{dt} = q \tag{13}$$

Integration of equations 12 and 13 can be done explicitly if the lateral inflow, q, is assumed to be uniform in time and space. Since, for a model segment in DR3M, q is constant in space and piecewise constant in time, this assumption can be met by integrating over time steps where q remains constant. The result after integrating between two points on a characteristic path, (x,t) and (x+Δx,t+Δt), has been given by Harley and others (1970), and can be expressed as:

$$\Delta x = \frac{\alpha}{q}\left[(q\Delta t + A(x,t))^m - A(x,t)^m\right] \tag{14}$$

$$A(x+\Delta x,t+\Delta t) = A(x,t) + q\Delta t \tag{15}$$

for $q \neq 0$, and

$$\Delta x = \alpha m A(x,t)^{m-1} \Delta t \tag{16}$$

$$A(x+\Delta x,t+\Delta t) = A(x,t) \tag{17}$$

for $q = 0$.

Equations 14 to 17 are those used in the model. Equations 14 and 16 are used to follow characteristic paths in the x-t plane. The flow area is determined at points along the characteristic paths by equations 15 and 17.

The method of characteristics gives an essentially analytical solution to the kinematic wave equation. It deviates from a truly analytical solution only because interpolations are necessary to compute segment outflows at each time step. The advantage of an analytical solution is that it satisfies exactly the governing differential equation. It is free from problems with numerical error and stability that are present in numerical solutions by finite difference or finite element methods.

Despite its inherent attractiveness, the method of characteristics has not been widely used in watershed models because it suffers from the computational problem of kinematic shock. Kinematic shock is a term used to describe shock waves in kinematic flow that form at the intersections of characteristics in the x-t plane. Where two characteristics meet, two flow areas are defined that describe a vertical wave resembling a hydraulic bore. These shock waves result from the kinematic assumptions and accordingly have no physical significance. They must, however, be dealt with properly in the solution procedure.

In DR_3M kinematic shocks will only form in channel segments with upstream inflow. When conditions are favorable for shock formation, no attempt is made to identify the origin or path of the shock wave. If characteristics are far enough apart (because of the size of the time step) to prevent intersections before reaching the downstream boundary, then nothing is done. If two characteristics do cross, the two flow areas defined, one on each characteristic, are averaged at the end of the time step during which the crossing occurred. One new characteristic is traced forward from the averaged point, and the two that crossed are dropped out. The effect in either case is a smoothed appearance in the outflow hydrograph in the vicinity of the shock.

Finite-Difference Methods

A second option is available in DR_3M for solving equations 7 and 10 by an implicit finite-difference method. The method is a four-point formulation that requires an iterative procedure to solve for the unknown flow area. The explicit finite-difference method that was contained in the 1978 release of the model is used to obtain the initial estimate of the unknown flow area for the implicit method. The user has the option of using the explicit method by itself with no iterations, if it is desirable to save computer time and if the accuracy is acceptable. This provides the third flow routing option in the model.

Unlike the method of characteristics, applying the finite-difference methods requires that each model segment be subdivided into distance intervals. A distance interval, Δx, and a time interval (time step), Δt, form the computational box for the finite-difference methods. The value of Δx varies from segment to segment, but the value of Δt is constant for all segments.

Four points of a computational box are represented in figure 4. The purpose of a finite-difference method is to solve for A and Q at point d, given values of A and Q at points a, b, and c.

In the implicit method the continuity equation is represented by a finite-difference equation using quantities at all four corners of the box and a weighting factor for the space derivative. The equation can be written as

$$\frac{W(Q_d-Q_c) + (1-W)(Q_b-Q_a)}{\Delta x} + \frac{(A_d-A_b) + (A_c-A_a)}{2\Delta t} = q \tag{18}$$

where W is the weighting factor that is assigned by the user to a value between 0.5 and 1.0.

Equation 18 has two unknowns, Q_d and A_d, but they are related by equation 10. By substituting $Q_d = \alpha A_d^m$ into equation 18, the resulting equation is nonlinear with one unknown, A_d, and can be rearranged into the following form

$$C_0 A_d^m + C_1 A_d + C_2 = 0$$

where

$$C_0 = \alpha$$

$$C_1 = \Delta x/2W\Delta t$$

$$C_2 = C_1[(A_c - A_a) - A_b] + \frac{1-W}{W}(Q_b - Q_a) - Q_c - \frac{q\Delta x}{W}$$

The solution of the above nonlinear equation for A_d is obtained by an iterative procedure using Newton's second order method for finding the roots of an equation. The procedure converges rapidly to a correct solution if a good first estimate is made for the unknown area. To speed convergence, DR_3M obtains the first estimate using a modification of the explicit method presented by Leclerc and Schaake (1973).

The explicit method requires the use of two finite-difference equations. The selection of the appropriate equation to use within each computational box depends on a stability parameter, Θ, defined by:

$$\Theta = \frac{\alpha}{q\Delta x}\left[(q\Delta t + A_a)^m - A_a^m\right]$$

for $q \neq 0$, and

$$\Theta = \alpha m A_a^{m-1}\frac{\Delta t}{\Delta x} = m\frac{Q_a}{A_a}\frac{\Delta t}{\Delta x}$$

for $q = 0$. The stability parameter is an expression for the path of the characteristic curve originating from point a; it is obtained from equation 14 or 16 and defines whether the characteristic passes above or below the diagonal connecting points a and d in the computational box.

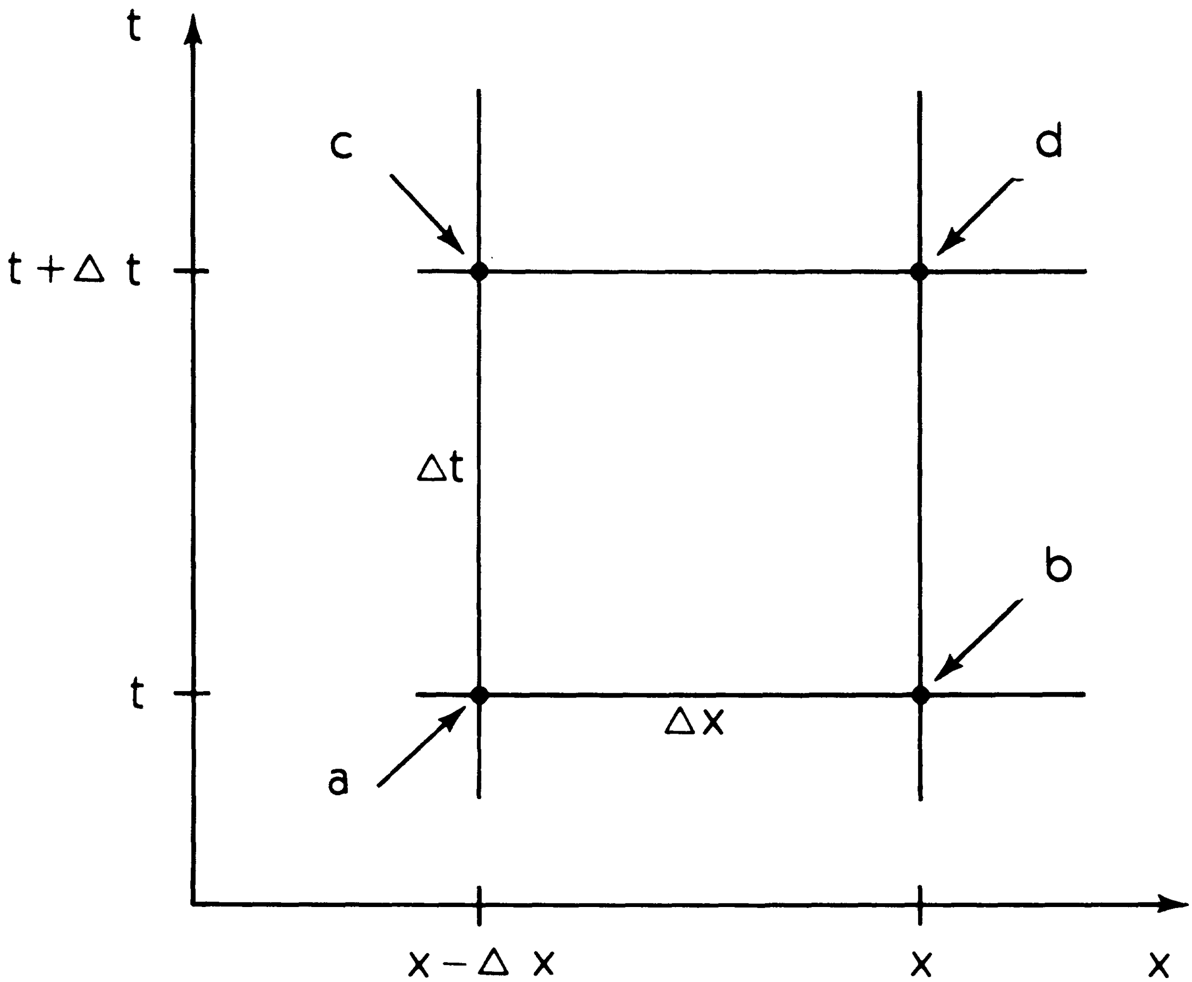


Figure 4.--Computational box for finite-difference methods.

If Θ is greater than or equal to unity, finite differences are written using grid points a, c, and d. The continuity equation is represented as

$$\frac{A_c - A_a}{\Delta t} + \frac{Q_d - Q_c}{\Delta x} = q$$

and can be solved for Q_d

$$Q_d = Q_c + q\Delta x - \frac{\Delta x}{\Delta t}(A_c - A_a) \tag{19}$$

Once Q_d is known, A_d can be determined by

$$A_d = (Q_d/\alpha)^{1/m} \tag{20}$$

If Θ is less than unity, finite differences are written using grid points a, b, and d. The continuity equation is represented as

$$\frac{A_d - A_b}{\Delta t} + \frac{Q_b - Q_a}{\Delta x} = q$$

and can be solved for A_d

$$A_d = A_b + q\Delta t + \frac{\Delta t}{\Delta x}(Q_a - Q_b)$$

Q_d is determined by

$$Q_d = \alpha A_d^m \tag{22}$$

Reservoir Segments

Provision is made in the model for reservoir routing based on the continuity equation. Either of two routing methods can be used. One method is linear-storage routing:

$$S = KO \tag{23}$$

where S is the reservoir storage, O is outflow from the reservoir, and K is a constant.

Alternately, the modified-Puls routing method (Soil Conservation Service, 1972) can be used:

$$\frac{2S_2}{\Delta t} + O_2 = I_1 + I_2 + \frac{2S_1}{\Delta t} - O_1 \tag{24}$$

where I is the inflow to the reservoir and the subscripts 1 and 2 refer to the beginning and end of the time interval (Δt), respectively. The modified-Puls method utilizes a table of storage and outflow values as supplied by the model user. From these values the model constructs a table of $(\frac{2S}{\Delta t} + O)$ versus outflow (O). Entering this table with the value of the right-hand side of equation 24, outflow (O_2) at the end of a routing period (Δt) is determined.

An assumption of the above procedure is that the water surface in the reservoir is level and responds instantaneously to inflows. All reservoirs are assumed to be empty or at the permanent pool capacity at the start of a storm unless the storm immediately follows a previous storm. Direct rainfall on the storage surface, evaporation, bank storage, and leakage are not accounted for by the model.

Reservoir segments can be used to simulate detention reservoirs and ponding behind culverts of limited capacity and for which outflows are uniquely described as a single-valued function of storage.

Nodal Segments

Three types of nodal segments are used by the model. The first type is a junction segment. Junction segments are used when more than three segments contribute inflow to the upstream end of a segment. A second type of nodal segment is an input-hydrograph point where the user may specify an input hydrograph for each storm. Only one input hydrograph point in the basin is permitted. A third type of nodal segment is an input discharge point where the user may specify a constant discharge for each storm to be added to the flow. Nodal segments (all three types) do not have a routing component; therefore, the output from the segment is equivalent to the sum of the inputs.

DETERMINATION OF MODEL PARAMETERS

Model parameters used by DR_3M include the total drainage area of the watershed, the soil-moisture-accounting and infiltration parameters, and the segment characteristics. Guidelines for determining these parameters are described in the following sections. The approaches described are not meant to provide hard and fast rules, but rather to serve as a guide. Different study objectives and constraints will require deviations from this guide.

Drainage Area

Determination of the drainage area of an urban watershed may appear trivial--simply outline the basin boundary on a topographic map and determine the drainage area with a planimeter. However, considerable errors might result from using such a technique. Major complications include the effects of street and storm-sewer systems, irrigation ditches, and the resolution capability of maps. The recommended approach to determining drainage area is to use topographic maps, available storm-sewer maps and appropriate field verification. Field verification during rainfall or snowmelt is sometimes necessary to resolve questions about the location of drainage divides. Some field verification may also be necessary to assure that storm-sewer maps and other information obtained for the basin are "as built."

Soil-Moisture-Accounting and Infiltration

The six soil-moisture-accounting and infiltration parameters are listed in table 1. For many small basin applications a single set of these parameters may be sufficient to represent the pervious part of the basin. However, two different soil types can be handled by the model with separate soil-moisture accounting and infiltration parameters for each soil type.

As earlier described, DR_3M includes an optimization procedure which can be used to fit the values of the soil-moisture-accounting and infiltration parameters. The Rosenbrock technique is most effective if the value of the objective function is sensitive to changes in the values of the model parameters, if parameter interactions are small, and if initial estimates of model parameters are within reasonable constraints.

DR_3M has several options with respect to the Rosenbrock optimization. One of these is that the user can select any subset of the total set of storms to be included in the objective function. For example, outliers can be removed from the objective function. Since the optimization procedure develops a nonlinear least-squares solution, outliers can significantly affect the values of the fitted parameters. The user also can restrict storms included in the objective function to those with significant pervious-area contributions to storm runoff. In fact, if runoff volumes are predominantly a result of impervious-area runoff, little can be gained by optimizing the soil-moisture-accounting and infiltration parameters.

A second option in the model is to select which of the soil-moisture-accounting and infiltration parameters are to be fitted using the Rosenbrock algorithm. Although as many as 12 soil-moisture accounting and infiltration parameters (six for each of two soil types) can be included in the optimization, this is not a recommended procedure. Generally, only parameters for one soil type should be optimized. Usually, only three or four of the soil-moisture-accounting and infiltration parameters need be fitted.

The model parameters EVC and RR are highly interactive. Fairly reliable estimates of these two parameters usually can be made and they can often be left out of the optimization. The parameters PSP and KSAT are also very interactive. Only one of the two should be included in the optimization. However, several optimization runs might be made with different estimates of the parameter left out of the optimization.

It is impossible to give precise estimates of soil-moisture-accounting and infiltration parameters that will apply to all soils encountered. Some general guidelines are presented in the following paragraphs. All estimates presented should be used with caution and may require revision for local conditions.

PSP

Values for PSP for most soils will lie within the range of 0.5 to 8.0 inches. Model estimates of infiltration are sensitive to this parameter. Generally, PSP will be larger for soils that are less permeable.

Table 1.--Parameters for soil-moisture accounting and infiltration

Soil-Moisture Accounting

Parameters:

EVC--A pan coefficient for converting measured pan evaporation to potential evapotranspiration

RR--The proportion of daily rainfall that infiltrates into the soil for the period of simulation excluding unit days

BMSN--Available soil water at field capacity, in inches

Infiltration

Parameters:

KSAT--The effective saturated value of hydraulic conductivity, in inches per hour

RGF--Ratio of suction at the wetting front for soil moisture at wilting point to that at field capacity

PSP--Suction at wetting front for soil moisture at field capacity, in inches

KSAT

Values of KSAT for soil types generally encountered will be on the order of a few tenths of an inch per hour. The U.S. Soil Conservation Service has classified most soils into Hydrologic Soil Groups A, B, C, and D. Typical values of KSAT in inches per hour for each of these four groups are: 0.5 to 1.2 for soil group A, 0.2 to 0.5 for soil group B, 0.1 to 0.3 for soil group C, and 0.05 to 0.2 for soil group D.

RGF

The relationship of RGF to soil properties is not well established. Values of RGF typically range from 5 to 20, with 10 being a reasonable initial estimate. As the value of RGF increases, the sensitivity of the model's infiltration estimates to antecedent soil moisture conditions also increases.

BMSN

Values for BMSN will generally range between 2.0 and 6.0 inches, depending on the development of the soil to the depth of the root zone.

EVC

EVC may be estimated as 0.7, if it is an adjustment of pan evaporation to potential evapotranspiration based on a nearby, reliable pan. EVC may differ from 0.7, if the pan evaporation data are collected from far outside the basin or from an unreliable pan. In that case, EVC may include an adjustment to make the pan evaporation data representative for the basin.

RR

RR is an estimate of the proportion of daily rainfall which infiltrates into pervious surfaces for the period of simulation excluding unit days. Typical values for RR range from 0.7 to 0.95.

Overland-Flow Segments

Characteristics required for each overland-flow segment include percent impervious area, length of overland flow, overland-flow slope, and a roughness coefficient.

Percent Impervious Area

Simulated runoff volumes and peak flows from urban areas are usually very sensitive to the percent impervious area. Several approaches have been used to determine effective impervious area.

One approach is to relate effective impervious area to the minimum ratio of runoff/rainfall measured for small storms. The rationale for this approach is that for basins with highly permeable soils, runoff from small storms comes almost entirely from the effective impervious area in the watershed. Limitations of this approach are the large scatter often observed in runoff/rainfall plots, the requirement for rainfall-runoff data from the watershed, the methodology may not apply to basins with soils of moderate to low permeability, and the sensitivity of the method to errors in rainfall and flow measurements.

An alternate approach used in Denver rainfall-runoff studies (Alley and Veenhuis, 1979) was as follows. The lengths and widths of all streets in each overland-flow segment were measured from aerial photos and the total area of streets for each overland-flow segment was determined. All roofs, parking lots, and other impervious areas which could not be identified as either effective or noneffective were then field inspected and all of these areas which were effectively impervious were colored in red on the aerial photo. If only part of a roof or other impervious area was effective, then only that part was colored. The areas of several representative roofs in each overland-flow segment were then measured from the aerial photographs and the average of these areas multiplied by the number of effective impervious roofs for each overland-flow segment. A similar approach was used for driveways. Finally, the area of remaining effective impervious areas, such as parking lots, was planimetered. The combined field and office work required for this approach was approximately 4-person days per square mile of basin for a highly-developed watershed.

Other approaches might include a random sampling of roofs or a grid overlay approach. Important requirements appear to be a large-scale aerial photo to delineate impervious areas and some field inspection to differentiate effective and noneffective impervious areas.

Any approach used to determine effective impervious area is inherently subjective. For example, it is often difficult to determine which part of a house roof is effective impervious area, particularly for houses with a downspout close, but not connected, to a driveway. Streets without curb and gutter can also present a problem. For this reason, effective impervious area can be included in the Rosenbrock optimization through use of the model parameter EAC. EAC is a factor by which the initial value of effective impervious area is multiplied. The starting value of EAC should be 1.0. The model assumes that any adjustment to effective impervious area using EAC is offset by an adjustment in the noneffective impervious area in order to maintain the total drainage area at its initial value. If EAC exceeds 1.0 and insufficient noneffective impervious area exists to compensate for the increased effective impervious area, then an appropriate amount of pervious area is converted to effective impervious area to maintain a constant total drainage area. During optimization, the value of EAC should not exceed the ratio of the total drainage area to the initial estimate of the effective impervious area.

If pervious-area runoff is a significant part of the total runoff then simulated runoff volumes will be sensitive to estimates of both EAC and the infiltration parameters. It may be difficult to separate the effects of these parameters. For this reason it is recommended to optimize EAC using small storms for which runoff is largely from the effective impervious area of the watershed and to calibrate the infiltration parameters using the larger storms.

Length of Overland Flow

For the simple case of a single "homogeneous" overland-flow segment draining into a single channel segment, the length of overland flow (L_o) in ft, can be computed as:

$$L_o = \frac{A_o}{L_c} \tag{25}$$

where A_o is the area in ft^2 of the overland-flow segment and L_c the length in ft of the channel into which it contributes lateral inflow. The area of each overland-flow segment is not an input requirement of the model. DR3M computes a basin drainage area based on the length of channels and their adjacent overland-flow lengths. For this reason, the same overland-flow segment can be used at different places throughout the watershed. The model routes the flow through a given overland-flow segment only once and uses the outflow in ft^3/s per ft of channel length as lateral inflow to all appropriate channel segments. For multiple use of an overland-flow segment, A_o in equation 25 would be the total area of the sub-basins comprised by the overland-flow segment and L_c in equation 25 would be:

$$L_c = \sum_{i=1}^{n} (L_i \cdot N_i) \tag{26}$$

where n is the number of channels having lateral inflow from the overland-flow segment of interest, L_i is the length of channel segment i having lateral inflow from the overland-flow segment, and N_i is the number of sides (1 or 2) of channel segment i that the overland-flow segment drains to. A detailed example of the multiple use of overland-flow segments is given in Attachment E.

Only one roughness coefficient can be specified for an overland-flow segment, yet pervious and impervious surfaces can have very different roughness coefficients. This factor can be taken into account by replacing a single overland-flow segment with two overland-flow segments one representing pervious-area runoff and the other representing impervious-area runoff. An example of how to establish pervious and impervious segments is included in Attachment E.

Often the pervious areas of a segment will be lawns where the distance of flow over pervious areas is short before the runoff contributes to a street or gutter. Therefore, a single roughness coefficient representative of the impervious surfaces may be sufficient in many instances. If segment flow files generated by DR_3M are to be used by DR_3M-QUAL for distributed runoff-quality simulation and the pervious area of a given segment is considered a significant source of water-quality constituent loads, then the overland-flow segment should be divided into pervious and impervious segments.

Overland-Flow Slope

A large-scale, small contour interval, topographic map can be very useful for determining overland-flow slopes. However, if not available, the expense of contracting services for such a map generally is not warranted. Overland-flow slopes can be estimated from U.S. Geological Survey 7 1/2-minute topographic maps. One method would be to determine a weighted average slope from representative cross sections of the overland-flow segment using the following equation:

$$\text{Slope} = \frac{\sum_{i=1}^{n} S_i . L_i}{\sum_{i=1}^{n} L_i} \tag{27}$$

where

S_i = the slope of the ith cross section,

L_i = the length of the ith cross-sectional line, and

n = the number of sampling lines.

An alternate would be to use the following equation described by Wisler and Brater (1959):

$$\text{Slope} = \frac{DC_L}{A} \tag{28}$$

where

D = contour interval, in ft,

C_L = total length of contours for segment, in ft, and

A = area of segment, in ft^2.

Roughness Coefficient

For each overland-flow segment a roughness coefficient must be input to the model. The model uses the roughness coefficient and overland-flow slope to determine the routing parameters, α and m, in equation 10. Because overland flows can be either laminar or turbulent, it is necessary to develop separate expressions for α and m for the two types of flow.

The classification of flow as laminar or turbulent is based on the flow Reynolds number (N_r), which for channel and overland flow can be expressed as

$$N_r = \frac{VR}{\nu}$$

in which V is the velocity of flow in ft/s; R is the hydraulic radius in ft, defined as flow area divided by wetted perimeter; and ν is the kinematic viscosity of water in ft^2/s. For overland flows, where the flow rate is expressed on a unit foot basis (q in ft^3/s per ft), a more convenient expression for the Reynolds number is

$$N_r = \frac{q}{\nu} \tag{29}$$

It is often assumed that the transitional range of N_r occurs between 500 and 2,000; the flow is laminar for N_r below 500 and turbulent for N_r above 2,000. These numbers are only approximate and must be used with caution.

DR3M requires the user to specify each overland-flow segment as either laminar or turbulent. The type of flow specified is assumed to occur throughout all runoff events. This assumption may be incorrect at times. Flow over natural land surfaces often begins as laminar at shallow depths and becomes turbulent as depth increases. For these situations the dominant flow type should be assigned to the segment.

The flow type for a segment can best be estimated by examining the range of Reynolds numbers during runoff. Equation 29 can be used to compute Reynolds number. The required values for runoff, q, can be determined from a preliminary model run where the flow type for each overland-flow segment is assigned arbitrarily. In general, unless laminar flow is known to exist, flow in the segment may be assumed turbulent.

Laminar Flow

In determining α and m for laminar overland flow the Darcy-Weisbach formula is used. The formula, as originally developed primarily for flow in pipes is

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

where h_f is the friction loss in ft for flow in the pipe, f is the friction factor, L is the length of the pipe in ft, D is the diameter of the pipe in ft, V is the velocity of flow in ft/s, and g is the acceleration due to gravity in ft/s^2.

Since D = 4R and the friction slope $S_f = h_f/L$, the above equation can be rewritten as

$$S_f = \frac{h_f}{L} = \frac{f\,V^2}{8gR} \tag{30}$$

This form of the formula may be applied to overland (or channel) flow.

For laminar flow over a smooth surface the theoretical relationship between the friction factor and the Reynolds number is given by

$$f = \frac{24}{N_r}$$

For laminar flow over rough surfaces a similar expression has been verified by experiment:

$$f = \frac{K}{N_r} \tag{31}$$

where K is a constant that is greater than or equal to 24.

Substitution of equation 31 into equation 30 gives

$$S_f = \frac{K\ V^2}{N_r\ 8gR}$$

which after letting $N_r = q/\nu$, $R = A$, and $V = q/A$ can be solved for q to give

$$q = \frac{8gS_f\ A^3}{K\nu} \tag{32}$$

From equation 32 the expressions for α and m can be written directly after setting $S_f = S_o$

$$\alpha = \frac{8gS_o}{K\nu} \tag{33}$$

$$m = 3.0 \tag{34}$$

Equations 33 and 34 are contained in DR_3M. They are used to define α and m for each laminar overland-flow segment. The values for kinematic viscosity, ν, and gravity, g, are set in the model to 0.0000141 ft^2/s (water at 50°F) and 32.2 ft/s^2, respectively. The values for overland-flow slope, S_o, and the roughness coefficient, K, must be supplied by the user.

The three most significant variables upon which the value of K depend are the surface roughness, the rainfall intensity, and the surface slope. There is a lack of quantitative evidence defining the effect of slope on K, and for this reason it is usually neglected. Chen (1976) has investigated the relationship between the two using laboratory data, and suggests the effect of slope on K is small for smooth surfaces, but can become large for grass surfaces where the roughness is very high. He found K increased with slope in most cases.

If slope is neglected, K can be expressed by a formula of the form

$$K = K_o + aI^b \tag{35}$$

where K_o is the parameter without the effect of rainfall; I is the rainfall intensity in inches per hour; and a and b are empirical coefficients. Equation 35 is not contained in the model, but is very useful for estimating K.

Values for the empirical rainfall coefficients, a and b, have been experimentally determined by several investigators. Fawkes (1972) gave the values $a = 10.0$ and $b = 1.0$, which should be adequate for modeling purposes. These values apply only to laminar flows. Rainfall intensity has a negligible effect on K for turbulent flows.

Values for the parameter K_0 suggested by Woolhiser (1975) for various surfaces are given in table 2 under the heading laminar flow. These numbers are very approximate and should be considered as such.

Table 2.--Resistance parameters for overland flow.
(After Woolhiser, 1975)

Surface	Laminar flow K_0	Turbulent flow Manning's n
Concrete or asphalt	24 - 108	0.01 - 0.013
Bare sand	30 - 120	.01 - .016
Graveled surface	90 - 400	.012 - .03
Bare clay-loam soil (eroded)	100 - 500	.012 - .033
Sparse vegetation	1,000 - 4,000	.053 - .13
Short grass prairie	3,000 - 10,000	.10 - .20
Bluegrass sod	7,000 - 40,000	.17 - .48

Turbulent Flow

For turbulent overland flow the Manning formula is used in determining α and m. The Manning formula is

$$Q = \frac{1.49}{n} A R^{2/3} S_f^{1/2} \tag{36}$$

where n is the Manning's roughness coefficient and all other variables are as previously defined. By substituting $S_f = S_o$ and $R = A$, the flow per unit foot over a plane can be given by

$$q = \frac{1.49\ S_o^{1/2}}{n} A^{5/3}$$

From this expression α and m can be written directly as

$$\alpha = \frac{1.49\ S_o^{1/2}}{n} \tag{37}$$

$$m = 1.67 \tag{38}$$

Equations 37 and 38 are the expressions in the model used to define α and m for turbulent flow, and are analogous to equations 33 and 34 for laminar flow. In a manner similar to estimating the laminar flow K, it is necessary to estimate the Manning's n. Table 2 provides guidance for selecting values for Manning's n. These values are typically higher than those used for open-channel flows; this, however, should be expected. The very shallow flows that occur on land surfaces have depths that are usually on the same order of magnitude as the surface roughness height and, as a consequence, resistance to flow is very high.

Channel Segments

Segment characteristics required for each channel segment include the kinematic wave parameters (α and m), channel length, and channel slope.

Channel Length

Channel length is a relatively easy parameter to measure from topographic maps, storm-sewer maps, or aerial photos. Lengths of storm sewers are often marked on storm-sewer maps.

Channel Slope

Channel slope is often measured as the difference in elevation at points 10 percent and 85 percent of the distance along the channel, measured from the downstream end of the channel, divided by the distance between the two points. Slopes of storm sewers are often marked on storm-sewer maps.

Kinematic Wave Parameters (α and m)

In the section on roughness coefficients, expressions for the routing parameters, α and m, were developed for overland flows. Similar expressions are used for channel flows.

For a channel of arbitrary cross-section, it is possible to write general expressions for α and m using the Manning formula (equation 36). These are:

$$\alpha = \frac{1.49 \quad S_0^{1/2}}{a_1^{2/3} \quad n} \tag{39}$$

$$m = (5-2b_1)/3 \tag{40}$$

Equations 39 and 40 are obtained by first replacing the hydraulic radius in the Manning formula by the definition

$$R = \frac{A}{P}$$

where P is wetted perimeter. The wetted perimeter is then replaced by a power function of flow area

$$P = a_1 A^{b_1} \tag{41}$$

where a_1 and b_1 are constants. Letting $S_f = S_0$, the resulting expression of the Manning formula can be arranged into the form of equation 10 and α and m identified.

Equations 39 and 40 are very useful for computing α and m when these are to be specified explicitly for a channel segment (see ITYPE=4 on card group 16). Before equations 39 and 40 can be used, cross-section geometry will be required to determine a_1 and b_1 in equation 41.

Because many of the channels in an urban environment are of circular or triangular cross-section, special formulas for α and m are included in DR_3M for these shapes.

Circular Channel

For a circular channel (pipe segment) a convenient way to express equation 10 is to assume the relationship is linear. The result is

$$Q = \alpha A \tag{42}$$

where the exponent m has been set equal to one. Equation 42 defines a channel where the average velocity remains constant for any discharge. The approximation made by this assumption is shown graphically in figure 5. For most practical situations this approximation is satisfactory.

The expression for α is determined by setting equation 42 equal to the Manning formula at full-pipe flow. This gives

$$\frac{1.49}{n} A_f R_f^{2/3} S_0^{1/2} = \alpha A_f$$

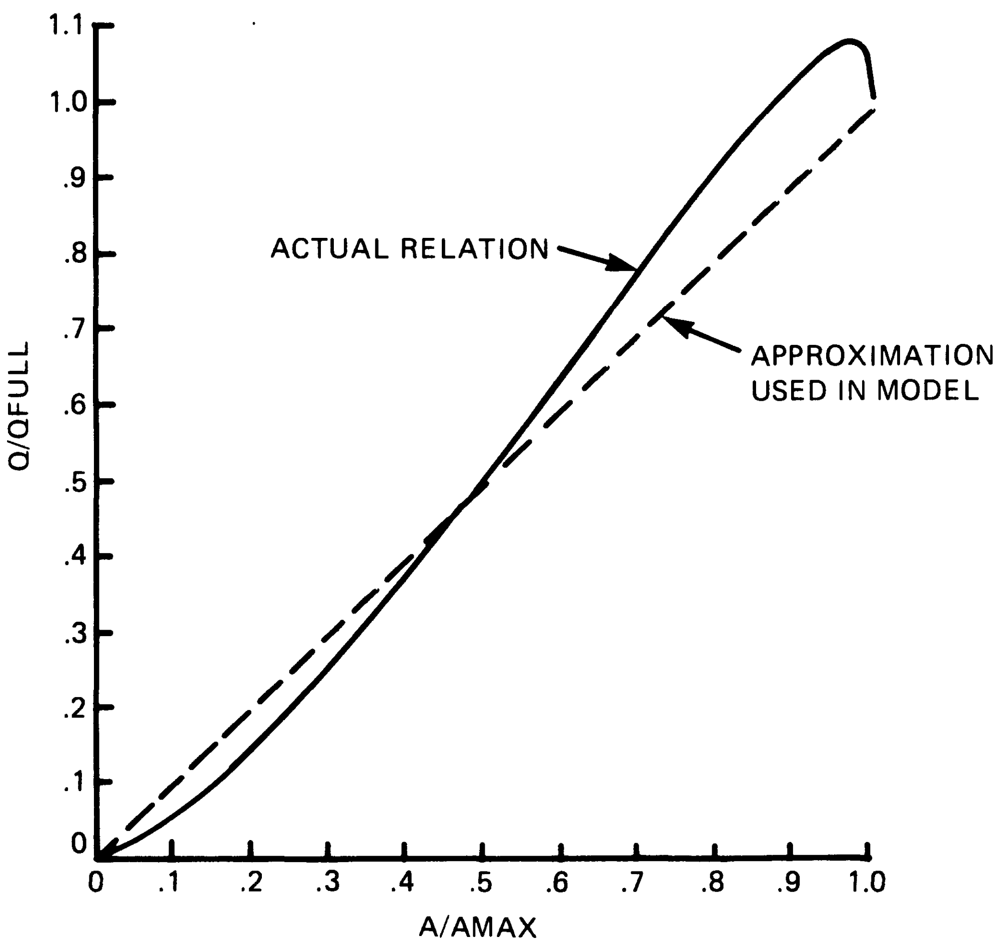


Figure 5.--Relation between Q/QFULL and A/AMAX for circular pipes.

where the subscript f stands for full-pipe flow. Solving for α yields

$$\alpha = \frac{1.49\ R_f^{2/3}\ S_o^{1/2}}{n}$$

Substituting $R_f = D/4$, where D equals the pipe diameter, gives the final form of the expression for α

$$\alpha = \frac{1.49}{n}\left(\frac{D}{4}\right)^{2/3}\ S_o^{1/2} \tag{43}$$

To determine α, the pipe slope, diameter, and roughness coefficient need to be input to the model.

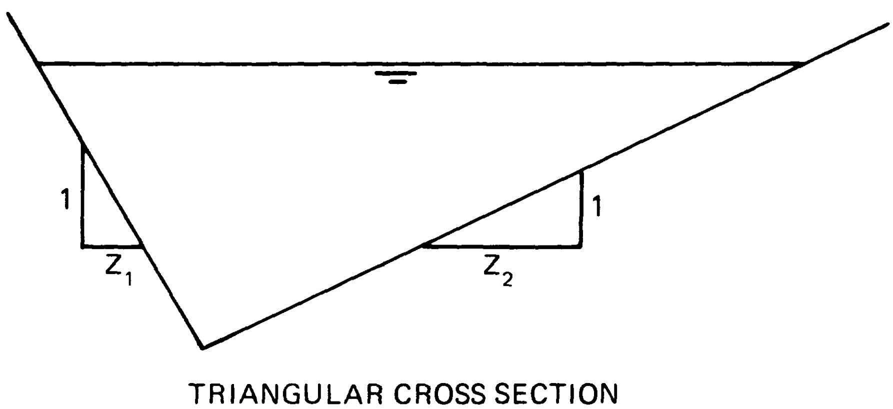
The capacity of circular-pipe segments is limited to nonpressurized-flow capacity. If that capacity is exceeded during a storm, provision is made to store the water arriving at the upstream end of the segment in excess of the segment capacity. The volume stored increases without upper limit as long as the upstream inflow exceeds segment capacity. After the upstream inflow drops below segment capacity, the volume stored is released to the segment. The upstream inflow to the segment remains at the maximum capacity until the water stored at the upper end of that segment has been released. A warning is given by the model that surcharging is occurring, whenever this problem arises. The user should be aware that, when the warning occurs, the model may not be giving correct results. In the real world, a sewer may flow under pressure, thus having more capacity than predicted by full pipe flow calculations. It is also possible that shortly after a sewer is flowing full, additional inflow to the sewer may be transferred to streets parallel to the sewer system rather than being stored behind the sewer as the model assumes. The user must always establish that there is a physical place to store water whenever surcharging occurs. A modified-Puls reservoir segment, described in the next section, can be used to simulate culverts which detain water due to limited capacity and for which outflows are uniquely described as a single-valued function of storage behind the culvert. More complex situations may call for revision of the model.

Triangular Channel

For a triangular channel, the following expression can be used to replace the hydraulic radius in the Manning formula.

$$R = \frac{(1/2)^{1/2}\ (z_1 + z_2)^{1/2}}{(z_1^2 + 1)^{1/2} + (z_2^2 + 1)^{1/2}}\ A^{1/2}$$

where z_1 and z_2 are the ratios of horizontal to vertical change in side slope (fig. 6). The resultant expressions for α and m are



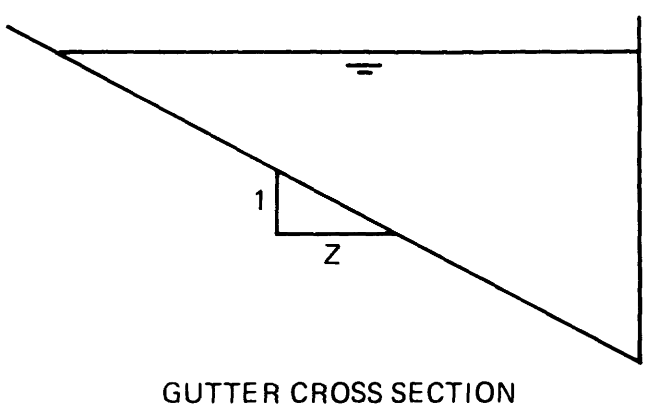


Figure 6.--Definition of z_1 and z_2 for triangular and gutter cross sections.

$$\alpha = \frac{1.18\ S_o^{1/2}}{n} \left(\frac{(z_1 + z_2)^{1/2}}{(z_1^2 + 1)^{1/2} + (z_2^2 + 1)^{1/2}} \right)^{2/3} \tag{44}$$

$$m = 1.33 \tag{45}$$

A triangular cross-section is useful to approximate the shape of drainage swales. To determine α, the channel side slopes, bed slope, and roughness coefficient need to be input to the model.

For the special case of gutter flow, z_2 in equation 44 can be set equal to zero and the following expression for α is obtained.

$$\alpha = \frac{1.18\ S_o^{1/2}}{n} \left(\frac{z_1^{1/2}}{1 + (z_1^2 + 1)^{1/2}} \right)^{2/3} \tag{46}$$

Overbank Flow

The preceding discussion has assumed that the values of α and m are constant for all discharges. In the case of discharge exceeding the main channel capacity and flowing as overbank flow, this is not usually a valid assumption. For this reason an option exists in the model to specify two sets of α and m; one for discharges smaller than the main channel capacity and one for discharges greater than the main channel capacity. The discharge at channel capacity is referred to as the "breakpoint" discharge. This option is only available for the finite-difference routing methods and for channels in which α and m are explicitly input to the model.

Parameter Adjustment

Calibration of the model parameters that affect simulated runoff volumes was discussed in an earlier section of this manual. Because runoff volumes are inexpensive to simulate, a modified-Rosenbrock direct-search technique has been incorporated into the model. This technique requires multiple simulations of the model in order to identify best-fit parameter values.

Generally, the runoff routing part of the model is considerably more expensive than the rainfall excess part. It would be expensive to adjust the routing parameters using an automatic method such as the Rosenbrock scheme. For this reason the routing part of DR3M is calibrated manually. Because the routing parameters are largely lumped together in α and m, it is recommended that adjustments in these parameters form the basis of the routing calibration. The parameter, α, contains the effects of roughness, bed slope, and cross-sectional geometry; whereas, the parameter, m, is a function of cross-sectional geometry. Of the two parameters, it is recommended that adjustments in α be used to calibrate the model. For this reason all values of α in the model are multiplied by the parameter ALPADJ. If ALPADJ is greater than 1.0, then water will be routed through each segment at a faster rate. On the other hand, if ALPADJ is less than 1.0, then water will be routed through each segment at a slower rate. Thus, watershed response time will be quicker and peak flows should be greater for larger values of ALPADJ. It should be noted that because of combinatorial effects of flows from different segments, it is possible for peak flows to decrease for some storms as ALPADJ is increased.

Thus, the calibration approach is to set ALPADJ to 1.0 initially and to adjust its value as necessary to reproduce similar timing and peaks of simulated and measured hydrographs. It is generally recommended that values of ALPADJ be greater than 0.7 and less than 1.5. These limits correspond to a 25 percent error in both slope and roughness coefficients.

Generally during calibration, a model user will focus attention on the accuracy of simulation of individual runoff periods. However, the user should also be sure that the slope of a regression of simulated versus measured peak flows (as well as runoff volumes) is close to 1.0. Experience with DR3M has indicated that a best-fit line through a plot of simulated (vertical axis) versus measured (horizontal axis) runoff peaks is more likely to have a slope greater than 1.0 than less than 1.0. This may be due in part to bias in the measured rainfall but can also be the result of the model not accounting for storm sewers flowing full, overbank flow, storage behind culverts, and (or) the nonattenuation characteristics of the kinematic wave equation. With the exception of storm sewers flowing full, these problems can often be resolved. In order to account for overbank flow, a channel segment can have two sets of α and m, one for the in-channel flow and one for overbank-flow conditions. This has been described in the previous section. In order to account for storage behind culverts, a modified-Puls relationship can often be developed for the culvert and input to the model. Finally, the nonattenuation characteristics of the kinematic wave equation can be accounted for by use of the implicit-finite difference scheme and appropriate choice of the weighting factor.

Selecting a Kinematic Routing Solution Method

Each of the three kinematic routing solution methods in DR3M is useful for different purposes. Providing the option to select any of the three is an attempt to make a routing component that is suitable for a range of applications. In some cases, the selection of a particular method may be based on personal preference.

The method of characteristics gives an essentially analytical solution to the kinematic wave equations. It does not suffer from problems with numerical dispersion that are present in finite difference methods. It is best suited for those situations where the assumptions of the kinematic approximation are valid. Namely, when there is no significant wave dispersion or attenuation. This will often be the case for small watersheds where routing lengths are short. It is very difficult to define what is a "small watershed" for routing purposes, but it is probably on the order of, at most, several square miles or less. A disadvantage of the method of characteristics is that one cannot vary α and m parameters for overbank-flow conditions.

The implicit finite difference method is presented for use when it is necessary to account for wave dispersion in routing. This may be the case when modeling larger watersheds (greater than several square miles). Wave dispersion, or what might also be called wave damping, is introduced numerically into the method by use of the weighting factor, W, applied to the space derivative in the finite difference equation. Theoretically, this weighting factor can take on a value between 0 and 1. However, for values of W less than or equal to 0.5 the finite difference method can be unstable, so in DR_3M the value of W (card group 15) must be defined greater than 0.5 and less than or equal to 1. The amount of damping increases as W increases from 0.5 to 1; a value of W close to 0.5 corresponds very closely to analytic kinematic routing A value of W equal to 1 usually overdamps a wave greater than is physically correct. Some limited numerical testing was performed to determine the best value for W that would cause the solution of the kinematic equations to match an accurate solution for the St. Venant equations. The results showed W equal to 0.9, and this value is recommended for use with DR_3M. An implicit finite difference method, very similar to the method in DR_3M, was presented by Rovey and others, (1977). They also found that a weighting factor of 0.9 was best when they simulated hydrographs in a circular pipe. In some cases it may be justifiable to use the weighting factor as a tool for calibration. If observed peak discharges are either overpredicted or underpredicted, the weighting factor can be adjusted to bring computed peaks into closer agreement with the observed data.

The explicit finite difference method is used in the model as a means of obtaining the first guess at the unknown flow area in the iteration scheme of the implicit method. The option, however, is available to use the method by itself without iteration, if that is desired. Computer time for the explicit method will always be less than for the implicit method, when the two methods are compared with the same routing time step. Therefore, the explicit method may be useful to save computer costs on large routing runs. The user is cautioned, however, that solutions with the explicit method can contain large amounts of numerical dispersion that cannot be conveniently controlled by any model parameter such as W in the implicit method. As a result, the explicit method may require a small time step to achieve desirable accuracy.

Selecting Δt and Δx

The use of either of the finite-difference methods requires careful selection of Δx and Δt to achieve accuracy. The selection is more important for the explicit method. Error is minimized if Δx and Δt are selected so that the characteristic passing through point a also passes through point d (fig. 4). For other selections of Δx and Δt, numerical errors will be introduced into the computations. Experience has indicated that peak discharges can be as much as 30 percent low if Δx and Δt are grossly in error.

One approach to selecting Δx and Δt is to choose Δt first and then set Δx for each segment to keep errors small. Two factors are important to consider in selecting Δt. One is the temporal variability of rainfall input to the model. It is advisable to choose a relatively small Δt if rainfall intensities are highly variable in time, and a larger Δt if rainfall intensities remain nearly constant in time. The other is response time of model segments used to describe the catchment. For an individual segment, response time is a function of slope, roughness, and flow length. Generally, the overland-flow planes that respond most quickly will bear most on the selection of Δt. The ruling consideration is that Δt be small enough to acceptably define the outflow hydrograph from any model segment. Of course, acceptable definition of the hydrograph from one particular model segment may not require great detail if the hydrograph at the watershed outlet is all that is of interest.

After a value for Δt is selected, Δx must be chosen for each model segment. The proper ratio of Δx to Δt can be expressed from the equation for a characteristic path (equation 12).

$$\frac{\Delta x}{\Delta t} = \alpha m A^{m-1} \tag{47}$$

In the special linear case (pipe segment) where m = 1, the above equation reduces to $\Delta x/\Delta t = \alpha$, and it is thus easy to compute Δx. In the general nonlinear case, $m \neq 1$, it is not so simple. Since flow area, A, is a function of both x and t, it is not possible to satisfy equation 47 at all times. It is therefore certain that some numerical error will be present. To minimize the error, it is recommended to use an average flow area expected in the segment.

A procedure for doing this can be illustrated by an example. Assume a segment is 620 ft long, α and m are equal to 3.0 and 1.67 respectively, and that Δt is 0.5 min (30 seconds). An average discharge ($\bar{Q}$) over the hydrograph has been estimated as 6 ft^3/s. For this discharge the corresponding flow area ($\bar{A}$) can be computed from equation 10. The result is

$$\bar{A} = \left(\frac{\bar{Q}}{\alpha}\right)^{1/m} = \left(\frac{6}{3}\right)^{1/1.67} = 1.5 \text{ ft}^2$$

Using this average flow area, equation 47 can be solved for Δx giving

$$\Delta x = \alpha m A^{m-1} \Delta t = (3)(1.67)(1.5)^{.67}(30) = 197 \text{ ft, use 200 ft.}$$

The value for Δx is not an input parameter to DR_3M. Instead, the model requires a parameter NDX that defines the number of Δx's into which a segment is divided. For this example

$$NDX = \frac{620}{200} = 3.2, \text{ use } 3$$

The one problem with computing NDX in the above manner is that before a model run the hydrograph is unknown. The average flow discharge or flow area can therefore only be estimated. This is not a serious problem, however, because it is possible to assign NDX a reasonable value for a first model run, and then refine the estimate after obtaining the hydrograph from the model output.

For an overland-flow segment, NDX is determined in the same manner as for a channel segment. Because routing is on a per unit width basis, the flow area for an overland-flow segment is really equal to flow depth. It is sometimes very difficult to estimate an average flow depth for overland flow. If this is the case, it is again possible to use the model to output the hydrograph of discharge per unit foot from any overland-flow segment, and from this hydrograph, estimate an average flow depth.

SEGMENTATION

Consider the segmentation of an urban drainage basin into a set of model segments; the following steps might be followed:

1. Obtain available information on the basin including storm-sewer maps, topographic maps, and land-use maps. Obtain 1-inch equals 100- to 1,000-ft aerial photography. Aerial photographs of this scale should be available either from local governments or from a local engineering firm. If no aerial photographs are available, then a contract for obtaining them might be considered. These services can usually be obtained at $300 to $2,000 per basin, depending on the number of basins flown, the size of the basins, and the scale of the photographs, among other factors. Mylar prints should be obtained so that work copies can be made of each photo.

2. Assuming aerial photographs are obtained, mark the location of the drainage network and inlets on a set of the work photos. This will require some field verification to assure that storm-sewer maps and other information obtained for the basin are "as built."

3. Mark overland- and street-flow directions on the aerial photographs, particularly at street intersections. This step will require some field inspection of the basin. Many times, flow directions on streets will be difficult to determine. Use of hand levels or field verification during periods of rainfall or snowmelt might be necessary to resolve questions about flow directions.

4. Using the marked-up photos, the basin can then be segmented. There are no exact rules on how to proceed; however, some general rules-of-thumb for basin segmentation are as follows:

A. It is often easiest to begin segmentation by starting at the downstream end of a basin.

B. Channel segmentation and overland-flow segmentation are generally done at the same time as the two are highly interrelated.

C. The more highly developed part of the basin generally will require a more detailed breakdown into segments because of additional complexity of the drainage and the greater contribution to watershed runoff per unit of land area.

D. This model, as do most urban-runoff models, assumes all overland-flow segments are rectangular. Therefore, attempts should be made to create overland-flow segments which approach this shape.

E. Attempts should be made to obtain segments of fairly uniform characteristics throughout the segment.

F. Channel intersections exert a controlling influence on overland-flow segmentation because each overland-flow segment must drain to a channel segment.

G. Segmentation into the fewest number of segments that will preserve the essential basin hydrologic-response characteristics is desired. Finding a suitable simplified segmentation is important for derivation of runoff frequency curves which can be expensive to simulate. If output from DR_3M is used as input to DR_3M-QUAL, then a simplified segmentation is particularly important. One approach might be to perform various levels of segmentation and to determine the sensitivity of the model to these different levels. Repeated use of the same overland-flow segment can be particularly valuable. Leclerc and Schaake (1973) have demonstrated that when a detailed segmentation is simplified, the changes most likely to be observed are a faster response of the rising limb and recession limb of the simulated hydrograph. Experience with the model has shown that the "optimum" number of segments may depend more on basin complexity and subbasin hydrograph interest than basin size.

H. Break points between channel segments should occur at channel intersections (for example, the intersection of CH01, CH02, and CH04, and CH05 in figure 3), at points of considerable change in channel characeristics, at points where sewer surcharge or culvert surcharging may restrict the flow, and at points of interest for subbasin hydrographs. Typically, it is not necessary to include short reaches of pipe segment to represent culverts under roadways. However, if a culvert detains much water during major periods of storm runoff, it may be necessary to use a reservoir segment to approximate this.

MODEL APPLICATIONS

DR_3M can be used for a wide variety of applications. A set of model segments can be arranged easily into a network that will represent simple or complex drainage basins.

DR_3M can be applied to drainage basins ranging from tens of acres to several square miles. However, it is not generally recommended for use on drainage basins over 10 square miles, unless sufficient rainfall data are available to adequately define its spatial variation. The model does not have a subsurface flow component. Thus, for larger watersheds, subsurface flow or upstream inflow to the watershed may have to be input to the model through use of an input-hydrograph or input-discharge point. The model is intended primarily for application to urban or urbanizing watersheds. However, it may have limited use for rural applications where subsurface flow and interflow contributions to runoff are either negligible or can be estimated and input to the model. The capability to use the same overland-flow segment repeatedly throughout the watershed can be used to define short distances of overland flow representative of many rural watersheds without use of an overwhelming number of segments.

The model can be calibrated and verified using data collected over a short period of time. Long-term historical records of rainfall can then be input to the model to extend the records of storm-runoff. Rainfall and runoff data collected by the U.S. Geological Survey can be retrieved from WATSTORE (National Water Data Storage and Retrieval System) in the format required by the model (Carrigan and others, 1977). Long-term records of rainfall data at short-time intervals (usually 5 or 10 minutes) can be obtained from the National Weather Service for many cities in the U.S. The data are for anywhere from 3 to over 10 "major" storms per year for a period of record often exceeding 50 years. Much of these data are stored in the U.S. Geological Survey WATSTORE computer files and can be retrieved in the format required by the model. Records of daily precipitation and daily evaporation for the period of record spanned by the short time interval data can also be retrieved from WATSTORE for most of these stations. Long-term records stored on WATSTORE are listed by Carrigan and others (1977).

The model can be used for urban-basin planning purposes by its determination of the hydrologic effects of different development configurations. Certain assumptions would have to be made to determine the changes required in model parameters to represent various types of development. To facilitate such applications, as well as to facilitate application of the model to ungaged watersheds, whenever possible, a physical interpretation has been placed upon parameters used in the model. Examples of the above application of the model might include assessing the effects of increased impervious cover, detention ponds, or culverts on runoff volumes and peak flows.

The separation of rainfall excess computations and flow routing in the model results in several advantages. The first of these advantages is that the soil-moisture accounting and infiltration parameters as well as the effective impervious area can be calibrated through repeated application of the Rosenbrock algorithm without having the expense of routing at each iteration. Secondly, a long-term sequence of runoff volumes can be inexpensively simulated. This information could be useful for purposes such as design of detention storage facilities (Raasch, 1979) or for determination of runoff volumes for pollutant load computations.

The model can be used as a tool for storm-water quality investigations in several additional ways. For example, concentrations of water-quality constituents in storm runoff have been related to instantaneous discharges through regression equations by several investigators (Colston, 1974; Alley and Ellis, 1978). DR$_3$M could be used to simulate instantaneous discharges from a drainage basin. The simulated discharges could then be used with regression equations of instantaneous concentrations versus discharge (and other appropriate independent variables) to estimate storm-runoff loads. For example, Alley and Ellis (1978) used regression equations and a similar model, the Storm Water Managment Model (Huber and others, 1975) to determine annual loads of arsenic, copper, lead, and zinc from a residential basin near Denver, Colorado. Additionally, output from DR$_3$M can be used as input to DR$_3$M-QUAL (Alley and Smith, report in preparation).

The assumptions behind the kinematic wave equations for channel and overland-flow routing should be recognized by any potential user of the model. The kinematic wave solution is based on the assumption that disturbances are allowed to propagate only in the downstream direction. Therefore, the model does not account for backwater effects or flow reversal. In addition, the capacity of circular-pipe segments is limited to nonpressurized-flow capacity. In addition to the assumptions behind the kinematic wave routing, other major assumptions are listed below.

- rainfall excess is assumed to be uniformly distributed over an overland-flow segment
- pervious and impervious parts of a segment are assumed uniformly distributed over the segment
- the complex uneven topography of the natural catchment can be approximated by planes
- rainfall excess does not infiltrate as it moves overland (once rainfall excess is computed, it must end up in a channel)
- when rainfall ceases, infiltration ceases
- lateral inflows to channels are assumed uniformly distributed (in an urban environment lateral inflows may enter through a gutter rather than uniformly)
- changes in flow from laminar to turbulent or vice versa will not occur
- rainfall on noneffective impervious areas is assumed to be instantaneously and uniformly distributed over the pervious area of the watershed.

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ATTACHMENT A

DATA INPUT SPECIFICATIONS

Data input specifications for this program are listed below. All listing of numeric data is right justified. All listing of alphabetic data is left justified. The letter "Oh" is written Ø to contrast with the number zero--written 0.

Experience with the program has indicated that great care must be exercised in preparing the input data deck. Model users should refer to the section on program debugging and interpretation (Attachment B) and the sample runs shown in Attachment H for additional assistance. Computer requirements for running the program are described in Attachment C. Changes required to convert a data deck that used the 1978 version of the model to a deck that will work on the current version are shown in Attachment D.

Input item	Program variable	Format	Card columns

Card Group 1

Model options (1 card)

Option to list data. If ØPTIØN=LIST, all input rainfall, runoff, and evaporation data are listed in output from program.	ØPTIØN	A4	1-4
If measured unit discharge data are not input to program, set ØPT=1. Otherwise, leave blank.	ØPT	I1	5
If daily rainfall are to be modified for irrigation, (see card group 2) set NØPT=1. Otherwise, leave blank.	NØPT1	I1	6
If segment outflows are to be stored semipermanently on disk for later use by DR_3M-QUAL, set JPERM=1. Otherwise, leave blank.	JPERM	I2	8

If JPERM is set to 1, make sure JRECDS on FT25 card is large enough. See section of Attachment C entitled "Semipermanent storage of segment discharge data."

The simulated hydrograph at the outlet from the watershed for each routed storm can be written to a file specified by JPUN. Otherwise, leave blank. See Attachment C for guidance in determining JPUN.	JPUN	I2	21-22

Input item	Program variable	Format	Card columns
Card Group 2			
Irrigation rates (1 card)			
(Include card group 2 only if NØPT=1.)			
Irrigation rate (inches/ week) for			
January	IRR(1)	F5.3	1-5
February	IRR(2)	F5.3	6-10
March	IRR(3)	F5.3	11-15
April	IRR(4)	F5.3	16-20
May	IRR(5)	F5.3	21-25
June	IRR(6)	F5.3	26-30
July	IRR(7)	F5.3	31-35
August	IRR(8)	F5.3	36-40
September	IRR(9)	F5.3	41-45
October	IRR(10)	F5.3	46-50
November	IRR(11)	F5.3	51-55
December	IRR(12)	F5.3	56-60

Card group 2 is used to account for irrigation (for example, lawn watering) in the daily water balance. If a daily rainfall is less than the daily irrigation rate, the daily rainfall is reset equal to the irrigation rate.

Input item	Program variable	Format	Card columns
Card Group 3			
Discharge station (1 card)			
Discharge station number	STAD	I8	1-8
Name of discharge station	TITLD	50A1	9-58
Drainage area of basin (square miles)	DA	F6.2	59-64
Card Group 4			
Daily rainfall station (1 card)			
Daily rainfall station number	STAP	I8	1-8
Name of daily rainfall station	TITLP	50A1	9-58

Input item	Program variable	Format	Card columns
	Card Group 5		
	Daily evaporation station (1 card)		
Daily evaporation station number	STAE	I8	1-8
Name of daily evaporation station	TITLE	50A1	9-58
	Card Group 6		
	Period of record (1 card)		
Beginning year,	BYR	I3	21-23
month, and	BMØ	I3	24-26
day of record	BDY	I3	27-29
Ending year,	EYR	I3	33-35
month, and	EMØ	I3	36-38
day of record	EDY	I3	39-41

SMS and BMS are set equal to zero at the start of simulation. Therefore, the beginning day of record should be 1 to 2 months prior to the first unit day. The ending day of record should be at least 1 day after the last unit day. The beginning and ending years should be from the same century. Thus, simulation of 1886 to 1902 would require at least 2 separate runs. The model will not handle the years 1800 or 1900.

Input item	Program variable	Format	Card columns
	Card Group 7		
	Unit rainfall station (1 card for each rain gage)		
Unit rainfall station number	STAUP	I8	1-8
Name of unit rainfall station	TITLUP	50A1	9-58
Time interval for unit data	PTIME	F6.0	59-64

PTIME is restricted to one of the following values (in minutes): 1, 2, 3, 4, 5, 10, 15, 30, 45, or 60.

If more than one rain gage is used, a Card 7 must be placed in front of the data for each rain gage.

The following types of cards (card groups 8-11) contain input data of unit rainfall, unit discharge, daily rainfall, and daily evaporation. The cards must be arranged in chronologic sequence for each data type, in the order listed below. If more than one rain gage is used, all data for one

Input item	Program variable	Format	Card columns

rain gage must be read in chronologic order before the data for another rain gage are input. The number of cards depends upon the number of days of record and the number of storm events. In column 80 of each data card, the type of data will be identified by the CØDE number as follows:

Type of data	Program variable	CØDE
Unit rainfall	UP	1
Unit discharge	UD	2
Daily rainfall	DP	3
Daily evaporation	DE	4

The number of cards required to list a complete day of unit rainfall (UP) or unit discharge (UD) is 120/PTIME. The card format for listing UP and UD provides 12 fields for these data. Each set of 12 units of data is numbered in chronologic sequence by the variable CN. The arrays UP and UD are initialized to zero. Hence, if all 12 units of data for UP and UD are zero, the card may be omitted from the input card deck, but its card sequence number for this day must be taken into account in listing CN on subsequent cards. At least one unit rainfall card must be included for each rain gage for every unit day, even if no rain occurred during that day.

Card Group 8

Cards for unit rainfall data

One of two different formats are used in coding unit rainfall data, depending on the value of PTIME on card group 7. If PTIME is less than 5.0 minutes, use format 8a. If PTIME is greater than or equal to 5.0 minutes, use format 8b.

Format 8a

Input item	Program variable	Format	Card columns
Unit rainfall station number (same as on card group 7)	STAD	I8	1-8
Date on which discharge occurred:			
year	YR	I2	9-10
month	MØ	I2	11-12
day	DY	I2	13-14

Input item	Program variable	Format	Card columns
Time interval, in minutes (must equal PTIME on card group 7).	CT	I2	15-16
Card sequence number	CN	I3	17-19
Rainfall expressed in hundredths of an inch (12 data items per card)	UD	12F5.0	20-79
Data type (CØDE=1 in column 80)	CØDE	I1	80
	Format 8b		
Unit rainfall station number (same as on card group 7)	STAD	I8	1-8
Date on which discharge occurred:			
year	YR	I2	9-10
month	MØ	I2	11-12
day	DY	I2	13-14
Time interval, in minutes (must equal PTIME on card group 7).	CT	I2	15-16
Card sequence number	CN	I2	17-18
Rainfall expressed in hundredths of an inch (12 data items per card)	UD	12F5.0	19-78
Data type (CØDE=1 in column 80)	CØDE	I1	80

At the end of data for a rain gage, when data for another rain gage are to be used, insert a card between the sets of rain-gage data with a CØDE of 8 punched in column 80. If no unit discharge data are to be read-in (ØPT = 1), insert a card at the end of the final rain-gage data with a CØDE of 9 punched in column 80.

Input item	Program variable	Format	Card columns

Card Group 9

Cards for storm discharge data

(If ØPT=1 on card group 1, skip to card group 10.)

One of two different formats are used in coding data, depending on the value of PTIME on card group 7. If PTIME is less than 5.0 minutes, use format 9a. If PTIME is greater than or equal to 5.0 minutes, use format 9b.

Format 9a

Input item	Program variable	Format	Card columns
Discharge station number (same as on card group 3)	STAD	I8	1-8
Date on which discharge occurred:			
year	YR	I2	9-10
month	MØ	I2	11-12
day	DY	I2	13-14
Time interval, in minutes (must equal PTIME on card group 7).	CT	I2	15-16
Card sequence number	CN	I3	17-19
Discharge, in ft^3/s (12 data items per card)	UD	12F5.0	20-79
Data type (CØDE=2 in column 80)	CØDE	I1	80

Format 9b

Input item	Program variable	Format	Card columns
Discharge station number (same as on card group 3)	STAD	I8	1-8
Date on which discharge occurred:			
year	YR	I2	9-10
month	MØ	I2	11-12
day	DY	I2	13-14
Time interval, in minutes (must equal PTIME on card group 7).	CT	I2	15-16

Input item	Program variable	Format	Card columns
Card sequence number	CN	I2	17-18
Discharge, in ft^3/s (12 data items per card)	UD	12F5.0	19-78
Data type (CØDE=2 in column 80)	CØDE	I1	80

At the end of the unit discharge data, insert a card with a CØDE of 9 punched in column 80.

Card Group 10

Cards for daily rainfall data

Daily rainfall station number (same as card group 4)	STAP	I8	1-8
Year and month for data	YR MØ	I2 I2	9-10 11-12
Card sequence number (1 or 2)	CN	I1	13
Daily rainfall in inches (up to and including 16 items per card)	DP	16F4.2	14-77
Data type (CØDE=3 in column 80)	CØDE	I1	80

Two cards are required for listing a complete month of daily rainfall or daily evaporation. Use as many cards as necessary to list data for all months. The card format for listing these daily data provides 16 fields: the first 16 days of data are listed on the first card, identified by the card sequence number CN=1, and the remaining days of data in the month on the second card CN=2. For unit days insert a negative number as the daily rainfall for that day on the daily rainfall card. A negative value signals the model that unit rainfall is listed for that day.

It may be desirable to skip a large gap in time rather than continue with daily soil-moisture accounting (for example, no winter records). In such cases a 9999 should be punched as the daily rainfall for the first and last day of the gap in record. No daily rainfall cards are required for intervening days. SMS and BMS are set equal to zero immediately following a gap in the daily precipitation record. Therefore, the model should be run for 1 to 2 months on daily soil-moisture accounting basis between the end of a gap in record and the first subsequent unit day.

Input item	Program variable	Format	Card columns

Card Group 11

Cards for daily evaporation data

Input item	Program variable	Format	Card columns
Daily evaporation station number (same as on card group 5)	STAE	I8	1-8
Year and month for data	YR MØ	I2 I2	9-10 11-12
Card sequence number (1 or 2)	CN	I1	13
Daily evaporation in inches (up to and including 16 items per card)	DE	16F4.2	14-77
Data type (CØDE=4 in column 80)	CØDE	I1	80

At the end of the daily evaporation data, insert a card with a CØDE of 9 punched in column 80.

Card Group 12

Optimization card

Input item	Program variable	Format	Card columns
Number of parameters in the soil-moisture accounting and rainfall-excess components	EØ	I4	1-4
Number of parameters to be adjusted	FØ	I4	5-8
Number of trial adjustments per parameter	K	I4	9-12
Initial step size multiplier for parameter adjustment (usually set to 0.05)	EPSLN	F8.0	13-20

EØ should be 7 if the basin is to be treated as one soil type or 13 if the basin is to be divided into parts with differing infiltration and soil-moisture parameters. If two different soil types are used, each overland-flow segment is assigned one or the other soil type by card group 16. If two soil types are used, up to 13 parameters can be optimized; however, this is not a recommended procedure. The two soil types option is only allowed if PTIME (card group 7) is greater than or equal to 5 minutes.

Input item	Program variable	Format	Card columns
	Card Group 13		
	Parameter values (E∅ cards)		
Initial magnitude	X(I)	F10.0	1-10
Lower limit	G(I)	F10.0	11-20
Upper limit	H(I)	F10.0	21-30

The initial magnitude and the magnitudes for the upper and lower limits for all parameters must be furnished. Suggested magnitudes are given in table 3. These magnitudes are grouped in the following order for each parameter: initial, lower limit, upper limit. The groups are listed for each parameter according to the order shown in table 3. For simulations with one soil type the first seven parameters must be input. For simulations with two soil types all 13 parameters should be input to the program. Upper and lower limits of parameters must be specified, even if no optimization is performed. The section on determining model parameters should be consulted when determining initial parameter values. Initial values of all parameters should not be equal to either the upper or lower limits. The initial value of EAC should always be set to 1.0.

Table 3.--List of soil-moisture and rainfall-excess parameters in order of input

Parameter	Parameter number	Typical lower limit	Typical upper limit	Unit
PSP	1	0.5	8.0	inches
KSAT	2	0.05	1.2	inches per hour
RGF	3	5.0	20.0	dimensionless
BMSN	4	2.0	6.0	inches
EVC	5	.5	1.0	dimensionless
RR	6	.7	.95	dimensionless
EAC	7	.85	1.15	dimensionless

If E∅ equals 13, parameters 1-6 are repeated, but numbered 8-13. Parameters 8-13 represent soil type 2 on the watershed.

Input item	Program variable	Format	Card columns
	Card Group 14		
	Parameters adjusted (1 card)		
Parameter numbers from table 3 for parameters to be optimized (should be FØ in number). Parameters should be listed in ascending order. If no optimization is performed, insert a blank card.	ØPTNØ	13I2	1-2 3-4 etc.

If EAC (parameter number 7) is included in the optimization, it should be noted that this factor only affects the simulated rainfall excess for optimization. No adjustment is made to the segment data given by card group 16. It is left to the user to make apropriate modifications to the segment data based on the results of the optimization of EAC. No storms should be routed, if EAC is not equal to 1.0.

Input item	Program variable	Format	Card columns

<u>Card Group 15</u>

<u>Model control (1 card)</u>

Number of different segments used to describe basin (2 to 99)	NSEG	I5	1-5
Time interval, in minutes, used in flow routing (Δt)	DT	F5.0	6-10
Ratio of the sum of the pervious and noneffective impervious areas to the pervious area. RAT should be greater than or equal to 1.0.	RAT	F5.0	11-15
Number of rain gages (1 to 3)	NRG	I5	16-20
Maximum impervious retention (in.)	IMP	F5.0	21-25
Alpha adjustment. Segment α's computed from segment data are multiplied by ALPADJ. Exceptions are the α's for overbank flow (see columns 66-70 of card group 16), which are not affected by changes in ALPADJ and can only be manually changed. ALPADJ is a calibration factor for routing and should be initially set to 1.0.	ALPADJ	F5.0	26-30
Model parameter WX corresponds to weighting factor (W) on space derivative in implicit finite difference method ($0.5 < WX \leq 1.0$).	WX	F5.2	31-35

The value of DT is restricted to certain values depending on the value of PTIME on card group 7:

PTIME, in minutes	Allowable DT, in minutes
1-4	0.1, 0.2, 0.5, 1.0
5 or 10	0.1, 0.2, 0.5, 1.0, 2.5, 5.0
15-60	0.1, 0.2, 0.5, 1.0, 2.5, 5.0, 7.5, 15.0

Input item	Program variable	Format	Card columns

Card Group 16

Segment characteristics (1 card for each segment)

Cards may be initially arranged in any order and the model will establish an appropriate computational sequence. However, if the segment flow data are to be used for a subsequent DR3M-QUAL run, then prior to storing the flow data on disk the segment cards should be rearranged to have the same order as shown in the model output under the heading "computation sequence." Attachment E and the previous sections in the manual on segmentation and determining the segment parameters should be consulted for assistance with this card group.

Input item	Program variable	Format	Card columns
Alphanumeric identification for segment (required for all segments; any alphanumeric identification can be used).	ISEG(I)	A4	1-4
Alphanumeric identification for up to 3 segments which contribute inflow to the upstream end of this segment (leave blank where upstream segments are not present).	IUP(I,J) J = 1,3	3A4	5-8 9-12 13-16
Alphanumeric identification for up to 4 segments which contribute uniform lateral inflow into this segment (leave blank where lateral inflow segments are not present).	ILAT(I,J) J = 1,4	4A4	17-20 21-24 25-28 29-32
Type of segment	ITYPE(I)	I2	33-34

1 = a gutter

2 = a pipe

3 = a triangular cross section

4 = to specify explicitly the kinematic channel parameters α and m

5 = overland-flow segment (turbulent)

6 = overland-flow segment (laminar)

Input item	Program variable	Format	Card columns
7 = a junction			
8 = a detention reservoir (modified-Puls)			
9 = a detention reservoir (linear storage)			
10 = an input-hydrograph point (only one input-hydrograph point is accepted by model; see card groups 23 and 24)			
11 = an input-discharge point (only one input-discharge point is accepted by model; see card group 19)			
Kinematic routing solution method			
0 = explicit finite difference method	METH(I)	I1	35
1 = method of characteristics			
2 = implicit finite difference method			
Outflow print-out indicator	IPR(I)	I1	36
1 = the outflow hydrograph for this segment is to be printed			
0 = the outflow hydrograph for this segment is not to be printed			
For segment types 1-6 and finite difference routing, NDX is the number of intervals into which total length of segment is divided. For segment type 8, NDX is the number of points in the storage-outflow relationship. Otherwise, leave blank. The maximum value of NDX for any segment is 10.	NDX(I)	I2	37-38
Length of segment (ft)	FLGTH(I)	F5.0	39-43
Slope of segment (ft/ft)	SLØPE(I)	F5.0	44-48

Input item	Program variable	Format	Card columns
Roughness coefficient for segment	FRN(I)	F5.0	49-53

For segments of type 1, 2, 3, or 5, this is a parameter similar to Manning's n. For segments of type 6, this is an empirical coefficient for laminar overland flow. Leave blank for segments of type 4 or 7 to 11.

A pair of parameters which depend on type of segment	PARAM(I,J) J = 1,2	2F5.0	54-58 59-63

Segment Type	Parameter Definitions
1	PARAM(I,1) = gutter cross slope (ft horizontal/ft vertical)
	PARAM(I,2) = leave blank
2	PARAM(I,1) = diameter (ft)
	PARAM(I,2) = leave blank
3	PARAM(I,1) = channel side slope on one side (ft horizontal/ ft vertical)
	PARAM(I,2) = channel side slope on other side (ft horizontal/ ft vertical)
4	PARAM(I,1) = α
	PARAM(I,2) = m
5 or 6	The values for PARAM (I,1) and PARAM (I,2) depend on whether the overland-flow plane is represented by a single roughness coefficient or two roughness coefficients, one for impervious surfaces and one for pervious surfaces.

One roughness coefficient

PARAM (I,1) should be set to 1.0 and PARAM (I,2) should be set to the effective imperviousness as a fraction. For example, for an overland-flow segment consisting of 15 percent effective impervious land cover, PARAM (I,2) = 0.15.

Two roughness coefficients

For the two roughness coefficient case, PARAM (I,1) for the impervious segment should be equal to the effective imperviousness as a fraction and PARAM (I,1) for the pervious segment should be equal to 1.0 minus the effective imperviousness.

Input item	Program variable	Format	Card columns

PARAM (I,2) for the impervious segment should be 1.0 and for the pervious segment should be 0.0. An example is included in Attachment E.

7	PARAM(I,1)	= leave blank
	PARAM(I,2)	= leave blank
8	PARAM(I,1)	= leave blank
	PARAM(I,2)	= permanent pool capacity (ft^3/s-hours)
9	PARAM(I,1)	= constant K in S=KO relationship (hours)
	PARAM(I,2)	= leave blank
10 or 11	PARAM(I,1)	= leave blank
	PARAM(I,2)	= leave blank

Input item	Program variable	Format	Card columns
Designation of soil type for overland-flow segments	KPSET(I)	I2	64-65

If EØ = 7 on card group 12, enter a 1. If EØ = 13, KPSET(I) equals 1 if soil parameters 1-6 apply (see table 3). KPSET(I) equals 2 if soil parameters 8-13 apply. Leave blank for segment types 1-4 and 7-11.

Input item	Program variable	Format	Card columns
This parameter should be coded for channel segments of type 4 which are to have two sets of α and m and for overland-flow segments.	RCØEF(I,J), J=1,NRG	3F5.0	66-70 71-75 76-80

Segment Type	Parameter Definitions
4	Columns 66-70 should contain the value of α for the range of discharges above some specified breakpoint discharge. Columns 71-75 should contain the value of m for the upper range of discharges and columns 76-80 should contain the breakpoint discharge in cubic feet per second. This second set of α and m is only used if the finite difference methods are used for flow routing.
5 or 6	"Thiessen coefficients" for overland-flow segments should be specified for each rain gage. These "Thiessen coefficients" are adjustment coefficients for weighting the rainfall excess from each rain gage and should sum to 1.0. In fact, if data from more than one rain gage is input to the program, it is recommended that a single rain gage be designated for each overland-flow segment rather than using a weighted-sum of multiple rain gages.

Input item	Program variable	Format	Card columns

Card Group 17

Outflow-storage data cards

If there are no segments of type 8, skip to the next card group. Otherwise, for each modified-Puls detention segment, in the order in which the detention segments are read in card group 16, input the outflow-storage relationship. There should be NDX(I) cards for each type 8 segment. The first value of outflow and storage for a reservoir should be 0.0. Each value of outflow or storage should be greater than the previous value.

For detention reservoirs that have a permanent pool, the model assumes that the reservoirs are at their permanent pool capacity at the start of a storm (specified in columns 59-63 of card group 16). In order to specify this permanent pool capacity in the outflow-storage relationship, the second value of storage should be the permanent pool capacity and the second value of outflow should be a very small positive number such as 0.0001.

Outflow (in ft^3/s)	Ø2(I,II)	F10.0	1-10
Storage (in ft^3/s-hours)	S2(I,II), II=1,NDX(I)	F10.0	11-20

Card Group 18

Storm-sequencing card(s)

Number of storms (maximum of 60)	I	I2	1-2
Number of storms in the continuous sequence of storm days containing a given storm.	NF(K) K=1, I	39I2	3-4 5-6 etc.

The following example should assist in explaining card group 18. Suppose eight storms are to be simulated by the model. These storms occur on the following days:

Input item	Program variable	Format	Card columns

Storm Number	Date
1	March 1, 1976
2	March 1, 1976
3	May 20, 1976
4	June 1, 1976
5	June 1-2, 1976
6	June 2, 1976
7	April 1, 1977
8	April 2, 1977

Then, the following numbers would be punched on the card representing card group 18:

Card Column:	2	4	6	8	10	12	14	16	18
Number:	8	2	2	1	3	3	3	2	2

Notice that the number of storms in a set of storm days is entered as many times as there are storms in the set.

Card Group 19

Storm identification (1 card for each storm)

Input item	Program variable	Format	Card columns
Starting time increment for storm	KS	I4	1-4
Ending time increment for storm	KE	I4	5-8
If volumes are supplied, set VØLI equal to runoff volume (inches). Otherwise, leave blank.	VØLI	F7.2	9-15
If an input-discharge segment (type 11) is used, enter a constant discharge to be input to the model flow computations for this storm. Otherwise, leave blank.	DISCH	F5.2	16-20

Input item	Program variable	Format	Card columns

There should be one storm-separation card for each of the I storms shown on card group 18. Starting and ending time increments are specified as the number of the time interval in the sequence of days containing the storm. The value of KS or KE can be calculated using the following formula:

$$KS \text{ or } KE = \frac{[60 \cdot HR + MIN + 1440\ (NDSD-1)]}{PTIME}$$

where HR is the hour of the day (from 0 to 24), MIN is the minutes past the hour, and NDSD is the number of the storm day in the sequence of storm days. For example, if the time interval is 15 minutes and the starting time of a storm is 0700 on the first day of a sequence of storm days, KS should be specified as 28. Likewise, if the starting time was 0700 on the second day of a sequence of storm days, KS should be specified as 124. Other examples are shown in table 4. Care should be taken to assure that the value of KE is not so large as to represent a day for which unit data have not been input to model.

Table 4.--Examples of KS and KE

				PTIME = 1.0 minutes		PTIME = 5.0 minutes	
Storm Number	Date	Starting time (24-hour)	Ending time (24-hour)	KS	KE	KS	KE
1	March 1, 1976	0700	1115	420	675	84	135
2	March 1, 1976	1305	1610	785	970	157	194
3	May 20, 1976	1205	1425	725	865	145	173
4	June 1, 1976	0010	0555	10	355	2	71
5	June 1-2, 1976	2310	0105	1390	1505	278	301
6	June 2, 1976	0810	0955	1930	2035	386	407
7	April 1, 1977	1015	1235	615	755	123	151
8	April 2, 1977	1055	1400	2095	2280	419	456

Card Group 20

Routing card(s)

1 = routing performed for storm	KØUT(I)	40I2	1-2
0 = no routing for storm	I = 1,NØFE		3-4 etc.

Input item	Program variable	Format	Card columns
	Card Group 21		
	Optimization card(s)		
0 = storm not used in computation of objective function	TESTNØ(I), I=1,NØFE	40I2	1-2 3-4 etc.
1 = storm used in computation of objective function			
	Card Group 22		
	Plotting card(s)		
0 = no plotting of outlet discharge data for storm	IPL(I) I=1,NØFE	40I2	1-2 3-4 etc.
1 = outlet discharge data are plotted for storm			

All plots include measured runoff data (minus assumed baseflow) when they are input to program.

Input item	Program variable	Format	Card columns
	Card Group 23		
	Input-hydrograph-indicator card(s)		
0 = storm has no input hydrograph	IHYD(I), I=1,NØFE	40I2	1-2 3-4 etc.
1 = storm has input hydrograph			

Card group 23 is needed for all runs even if no input hydrograph points are included in model.

Input item	Program variable	Format	Card columns

Card Group 24

Cards specifying input hydrograph

No cards are necessary if there are no input-hydrograph segments (ITYPE(I) = 10 on card group 16). Otherwise, the input hydrographs for each storm indicated on card group 23 should be read in the order in which the storms occur. An inflow of 0 cubic feet per second is assumed if no values for a time period are read.

Input item	Program variable	Format	Card columns
1 = last input hydrograph card for storm	ICØDE	I1	1
0 = not last input hydrograph card for storm			
Starting time increment for values of inflow specified on this card (same convention as card group 19)	JJJ	I4	2-5
Inflow, in ft^3/s (10 values per card)	X2(I) I=1,10	10F5.3	6-55

ATTACHMENT B

PROGRAM DEBUGGING AND INTERPRETATION

Experience with the program has indicated that great care must be exercised in preparing the input card deck. The time and effort used to carefully prepare and check an input data deck can save considerable frustration later when using the model.

Even with painstaking effort, some errors may occur. Many diagnostic messages are contained within the program in the event of errors. Most of the input data are output by the program soon after being read. Hence, where the program is located in outputting data will often give a clue as to the location of the error in the input data. This is particularly true of the rainfall, runoff, and evaporation data. For this reason, it is highly recommended that ØPTIØN = LIST on card group 1 during program debugging.

If erroneous data are input to the program, errors may occur in the program output even though the program appeared to run correctly. For example, impervious retention might be mistakenly read into the program as 0.5 inches, rather than the intended value of 0.05 inches. These types of errors can be identified by carefully checking much of the output against the data that are assumed to be input to the program. Particularly important items to check include the drainage area computations, the computation sequence, and the "Summary of Measured Data."

Drainage areas output by the program include the furnished and computed drainage area, and the computed percent effective impervious area, percent noneffective impervious area, and percent pervious area. The furnished drainage area is that input on card group 3, while the computed drainage area is based on the model segment data. A message is output by the model, if the computed and measured drainage areas differ by more than 1 percent. The model uses the computed drainage area for all computations.

The segment data are input to the program using card group 16. Segments can be arranged in any order during input. The model computes a computational sequence based on the segment interrelationships. This sequence is output by the model and should be checked as well as the table of segment characteristics. If an input-hydrograph segment is used, this can be checked by listing the flow from this segment and its upstream segment(s) (if any) and noting the difference.

The "Summary of Measured Data" lists the computed rainfall at each gage and, if input to the program, the measured direct runoff, peak discharge (minus baseflow), and assumed baseflow for each storm. These values should be checked. The measured values of direct runoff may be either user specified or computed by the model using unit discharge data. If unit discharge data are supplied to the model, direct runoff is calculated by a simple hydrograph-separation technique which assumes a constant base flow equal to the lowest measured discharge for the storm event.

It is recommended that the soil-moisture accounting and rainfall-excess parameters be optimized first (if this is to be done). Once a satisfactory fit has been achieved, a separate routing run can then be made. Because the segment data for routing are independent of the value of EAC, it is recommended that during optimization the watershed be treated as a single overland-flow segment draining to a single channel segment. Upon determining the optimum value of EAC, the value of the segment characteristics can be changed appropriately (as well as the value of RAT) and EAC can be set to 1.0 for routing.

For an optimization run, the objective function value and associated parameter values are printed for each successful trial. Also, a listing by storm event of the simulated and measured data are output at the start of each stage. Important items here include the simulated pervious area rainfall excess, the simulated rainfall excess, and the measured direct runoff. A comparison of the simulated pervious and total rainfall excesses can be used to assess the validity of including the soil-moisture-accounting and infiltration parameters in the optimization. A comparison of the simulated rainfall excesses and measured direct runoffs and the contribution of each storm to the objective function can be used to assess the effectiveness of the optimization for each storm. It should be recognized that simulated rainfall excess is based only on the unrouted surface runoff from overland-flow planes. Storage in reservoirs and channels and the contribution of an input hydrograph or input discharge are not taken into account. However, these effects are included for routed storms under the heading "simulated runoff volume at outlet."

If measured runoff data are input to DR3M, then the output from the model includes a plot of simulated versus measured runoff volumes and peak flows. These plots can be used to check for bias in runoff prediction. If parameter optimization is performed during the run, then only runoff periods included in the optimization are shown on the runoff-volume plots.

The cost of using DR3M is very sensitive to the number of routing intervals (ΔT's) and the number of segments. Prior to running a long-term rainfall record through the model, attempts should be made to reduce the number of segments. In addition, a sensitivity analysis of Δt (DT on card group 15) should be made so that it can be set to the largest reasonable value. Consideration should also be given to setting KE for each storm on card group 19 to as small a value as needed to obtain the peak discharges for long-term simulation.

ATTACHMENT C

COMPUTER REQUIREMENTS

The program, as dimensioned, will handle 99 segments, 3 rain gages, 60 storms comprising at most 150 unit days, and 7,310 days (20 years) of record. Each simulated storm can be routed through as many as 1442 Δt's (approximately 24 hours for Δt = 1 minute). Many of the program's limits can be changed easily by redimensioning the program. Several examples are given below.

Period of record: The maximum period of record simulated by the program can be changed by setting NDYS to the desired maximum period of record in days (see line A 470 in Attachment G), and by changing the array sizes of DP and DE to the value of NDYS.

Number of rain gages: The array P(2881,3) in CØMMØN C4 can be reduced to P(2881,2) if only two rain gages are used, and to P(2881,1) if only one rain gage is used. Extending the program's capability to more than three rain gages would require many changes to the source code, however.

Number of unit time intervals: If PTIME on card group 7 is always 5 minutes or greater, then the UD and QIH arrays can be reduced from 2881 to 1441 and the UPR array can be reduced from 8643 to NRG*1441 where NRG is the number of rain gages. IUNIT (see line A 460 in Attachment G) should then be set to 1441.

Number of soil types: If only one soil type is simulated, then P(2881,NRG) can be reduced to P(1441,NRG) where NRG is the number of rain gages.

Number of routing intervals: The limit on the number of routing intervals (1442) can be changed by redimensioning the Q, R, FLW, FLAT, and FUP arrays to the desired limit. The value of NDTS (see line A 480 in Attachment G) should also be set to the desired limit. The maximum number of routing intervals needed by the model can be determined by finding the maximum value of

$$(KS - KE + 1)\cdot(PTIME/DT)$$

for a storm.

Number of input-hydrograph values: If an input-hydrograph point (segment type 10) is not used, QIH(2881) can be redimensioned as QIH(1). No other changes are necessary.

The execution time for DR3M is a function of many variables and no simple rule can be stated. In general, however, a flow routing run will require more time than an optimization run. The time for a routing run will depend very much on the number of segments, the number of events routed, the length of each event, the size of Δt, and the flow routing solution method that is selected. When setting up an input data deck, it is wise to keep all these factors in mind and to strive for efficiency. By making an effort to re-use model segments where possible, and limiting the length each event is routed to only what is necessary, it is usually possible to realize significant savings.

JCL Information for Geological Survey Computer

The load module for DR3M has been stored in the partitioned data set AG4254J.URBAN.LMOD under member name J347. It resides on WRD system disk CCD810. To execute the program on the USGS Amdahl[2/] computer, use the JCL cards shown in figure 7.

Where

FT05F001	is a card reader,
FT06F001	is a printer,
FT25F001	is a temporary work file for segment discharge data,
FT26F001	is a temporary work file for unit discharge data,
FT28F001	is a temporary work file for unit rainfall data from gage 1,
FT29F001	is a temporary work file for unit rainfall data from gage 2, and
FT30F001	is a temporary work file for unit rainfall data from gage 3.

Files 26 to 30 are sequential files on magnetic disk and are used for temporary storage during program execution. The space defined in figure 7 for these files is sufficient to provide storage for any possible run, with the program's present dimensions. File 25 is a direct-access file. It requires special attention when setting up JCL for a DR3M run.

Disk Storage of Segment Discharge Data

During flow routing runs, discharge hydrographs from each model segment must be temporarily stored. Storage is by means of a direct access file. The direct access--rather than sequential--organization is necessary because file records are accessed in a nonconsecutive sequence that is defined by the ordering and re-using of segments.

The direct access data set is defined by a DEFINE FILE statement in the program and by the FT25 card in the JCL string. The DEFINE FILE statement and the FT25 card each indicate the amount of space that is required to store the data set. The form of the DEFINE FILE statement is as follows:

```
DEFINE FILE  25(JRECDS,480,L,IRECD)
```

where JRECDS is the number of records in the data set and 480 is the number of bytes (characters) per record. Parameters L and IRECD are standard descriptors and do not vary. The 25 establishes the connection between the program and the FT25 card in the JCL.

The program (Subroutine FILES) contains many DEFINE FILE statements of the form given above with JRECDS defined between 50 and 10,000. This range of record numbers is provided to accomodate users that might have very different storage

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2/ The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

```
//xxxxxxxx JOB (xxxxxxxxx,DR3M,-,-),'xxxxxxxxxx',CLASS=x
// EXEC PGM=J347,REGION=370K
//STEPLIB DD DSN=AG4254J.URBAN.LMOD,DISP=SHR
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458)
//FT25F001 DD UNIT=SYSDK,DISP=(,PASS),DCB=DSORG=DA,
      SPACE=(480,(?????,10),RLSE)
//FT26F001 DD UNIT=SYSDK,DISP=(,PASS),
      SPACE=(11520,(60,10),RLSE)
//FT28F001 DD UNIT=SYSDK,DISP=(,PASS),
      SPACE=(11520,(60,10),RLSE)
//FT29F001 DD UNIT=SYSDK,DISP=(,PASS),
      SPACE=(11520,(60,10),RLSE)
//FT30F001 DD UNIT=SYSDK,DISP=(,PASS),
      SPACE=(11520,(60,10),RLSE)
//FT05F001 DD *

      INPUT DATA CARDS FOR DR3M PROGRAM

/*
```

Figure 7.--JCL to execute DR_3M on Geological Survey computer.

requirements. The model selects the appropriate DEFINE FILE statement for each run. However, the user is responsible to specify the value of JRECDS on the FT25 card in the JCL. For a particular model run, JRECDS on the FT25 card defines the number of records available for storing segment hydrographs. In order that JRECDS be compatible with the DEFINE FILE statements in subroutine FILES, it should be greater than or equal to the number of records specified in the DEFINE FILE statement.

For an optimization run, no storage on FT25 is required so JRECDS in the JCL on the FT25 card can be set equal to the minimum value of 50. For a routing run the number of records required for storage (NRECDS) can be computed from the following formula:

$$\mathrm{NRECDS} = \left[\mathrm{INTEGER} \left(\frac{T}{120\,\Delta t} \right) + 1 \right] \cdot \mathrm{NSEG}$$

where

T = the total routing time of the <u>longest</u> storm in minutes (with routing time defined by (KE - KS + 1)·PTIME)

NSEG = the number of model segments

Δt = the routing time step, in minutes

JRECDS is determined by rounding up the number of records to the nearest 100 if less than 500, or to the nearest 500 if greater than 500.

It is not necessary for the user to solve the above equation because it is computed for each storm by the model and included in the output under the heading "Records required for routing." The necessary value of JRECDS then corresponds to the maximum of these values among the storms routed and rounded up as previously described. Alternatively, and to simplify matters, it is recommended that JRECDS be set to 1000 for most runs. The model user should still inspect the model output and increase this value of JRECDS if necessary.

Semipermanent Storage of Segment Discharge Data

The above information on computing JRECDS applies to most applications of DR3M. However, if DR3M is to be linked with a distributed DR3M-QUAL run, then the segment discharge data must be stored semipermanently on disk. JRECDS in this case is first computed as the sum of the values of NRECDS for each storm to be routed. That is, the values output by the model under the heading "Records required for routing" should be summed for all storms to be routed. This number plus 3 (to allocate space for a header array) is then rounded to the nearest 100 if less than 500 or to the nearest 500 if greater than 500. The first reference to the data set will take the following form:

```
//FT25F001 DD DSN=Azzzzzz.aaaaaaaa,DISP=(NEW,CATLG),UNIT=3330-1,

     VØL=SER=CCD810,SPACE=(480,(?????,10),RLSE),DCB=DSØRG=DA
```

where

zzzzzz are the six characters of an account name

aaaaaaaa is any 1 to 8 character name used to designate the name of the data set

????? is the JRECDS parameter that defines the number of records required for storage

This JCL will store the data set on WRD disk CCD810. Once established, subsequent accessing of the data set will require modifying the underlined parameters in the above JCL. The FT25 card will then read:

```
//FT25F001 DD DSN=Azzzzzz.aaaaaaaa,DISP=OLD
```

A semipermanent data set will remain on magnetic disk until it is destroyed (erased) by the user. It is an important responsibility of the user to keep track of data sets and destroy them when they are no longer needed. To destroy a data set, simply execute the following job.

```
//EXEC PGM=IEFBR14
//DD1 DD DSN=Azzzzzz.aaaaaaaa,DISP=(OLD,DELETE)
/*
//
```

A computer program that will output the attributes of a semipermanently stored data set is shown in figure 8.

JPUN on Card Group 1

JPUN on card group 1 should normally be left blank. However, it may be desired to obtain the outlet hydrographs simulated by DR_3M for a subsequent lumped DR_3M-QUAL run or other applications. This can be achieved by setting JPUN to the file where the outlet hydrographs are to be stored and to include a card in the JCL to define the sequential file where the values are to be stored. The outlet hydrograph will then be stored in the format of card group 9 except the discharge data will be output as 12F5.1 rather than 12F5.0.

The outlet hydrographs can be output as punched cards by setting JPUN=7 and adding the following card to the JCL.

```
//FT07F001 DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
```

This assumes the typical convention of assigning file 7 to the card punch. If a different file is assigned to the card punch, then JPUN and the 07 on the JCL card should be set to this file number.

```
C   PROGRAM TO READ HEADER ARRAY CREATED BY USGS RAINFALL RUNOFF MODEL
C
      INTEGER HEAD1(120),HEAD2(60,2),BD(3),ED(3),HEAD3(60)
      DATA IFILE/25/
      DEFINE FILE 25(3,480,L,IRECD)
C
      IRECD=1
      READ (IFILE'IRECD) HEAD1,HEAD2,HEAD3
      BD(3)=HEAD1(20)/10000
      BD(1)=(HEAD1(20)/100)-(BD(3)*100)
      BD(2)=HEAD1(20)-(BD(3)*10000)-(BD(1)*100)
      ED(3)=HEAD1(21)/10000
      ED(1)=(HEAD1(21)/100)-(ED(3)*100)
      ED(2)=HEAD1(21)-(ED(3)*10000)-(ED(1)*100)
      K=HEAD1(18)
      KK=HEAD1(17)
C
      WRITE (6,12) (HEAD1(I),I=1,19),(BD(I),I=1,3),(ED(I),I=1,3)
      N=K+21
      WRITE (6,13) (HEAD1(J),J=22,N)
      WRITE (6,14)
      DO 11 I=1,KK
      BD(3)=HEAD3(I)/10000
      BD(1)=(HEAD3(I)/100)-(BD(3)*100)
      BD(2)=HEAD3(I)-(BD(3)*10000)-(BD(1)*100)
   11 WRITE (6,15) I,BD,HEAD2(I,1),HEAD2(I,2)
      STOP
C
   12 FORMAT (1H1,44H ***** HEADER RECORDS FROM RUNOFF FILE *****,//,29H
     1  STREAMFLOW STATION NUMBER -,2A4,/,17H  STATION NAME - ,13A4,//,3
     20H  NUMBER OF RECORDS IN FILE = ,I6,/,27H  NUMBER OF STORM EVENTS
     3= ,I3,/,23H  NUMBER OF SEGMENTS = ,I3,/,30H  TIME INCREMENT IN SEC
     4ONDS = ,I5,/,38H  BEGINNING DATE OF SIMULATION =        ,I2,1H/,I2,1
     5H/,I2,/,30H  ENDING DATE OF SIMULATION = ,I2,1H/,I2,1H/,I2,//,13H
     6 SEGMENT ID )
   13 FORMAT (5X,A4)
   14 FORMAT (1H1,//,72H  STORM NUMBER       DATE      STARTING RECORD NUM
     1BER    NUMBER OF VALUES )
   15 FORMAT (/,7X,I2,8X,I2,1H/,I2,1H/,I2,11X,I5,16X,I7)
      END
```

Figure 8.--Computer program to read header array of semipermanent data set.

Considerations for Other Computer Systems

With the exception of the plotting routine and the direct access files, the program will run on most computers with sufficient core storage. The plotting routine included in the program listing (Attachment G) is IBM-System dependent. This plotting routine can be eliminated by removing lines AF 40 through AF 330 from subroutine PLT and removing subroutine PRPLOT (lines AG 10 through AG 2000).

Subroutine FILES contains the DEFINE FILE statements for the direct access file. Since the direct access file organization is often unique to a particular computer system, subroutine FILES may require reprogramming if the program is used at a computer system other than the USGS. On an IBM system the program will only compile without revision on the FORTRAN G level compiler because of the use of multiple DEFINE FILE statements. To the authors' knowledge the only other extension beyond the ANSI standard is the use of mixed-mode expressions and the T format code.

ATTACHMENT D

CHANGES TO CONVERT AN INPUT DATA DECK FROM THE 1978 VERSION

Despite the many changes to the computer program, changes to the input requirements of DR3M since its original release in 1978 have been kept to a minimum. In order to convert a data deck that works on the 1978 version to one that works on the present version, the following changes are needed:

Card Group 12

If two soil types are simulated, EØ should be changed from 14 to 13.

Card Group 13

Parameter number 7 is now EAC and parameter number 14 is no longer used. The parameter DRN is no longer input to the program, but is instead always set within the program to 1.0.

Card Group 14

Remember, parameter number 7 is now EAC and parameter number 14 has been dropped.

Card Group 15

The parameter DT is restricted to the values listed in the discussion of this card group. The parameter ØSI is no longer used and should be replaced by a value for RAT.

Card Group 16

Segment types 15 and 16 are no longer allowed. The meaning of segment types 1 and 3 has been changed. The meaning of PARAM(I,J), J=1,2 has changed for many of the segment types.

Card Group 19

The model parameter IPL has been removed from card group 19.

Card Group 22

Card group 22 is now used to indicate which storms are to be plotted.

Card Group 23

Card group 23 is the old card group 22.

Card Group 24

Card group 24 is the old card group 23 except the format for ICØDE and JJJ has been changed.

The above changes are only those that are necessary to make an old input data deck compatible with the new version of the program. There are also additional changes that can be made to make use of new capabilities in the model. These can be identified by closely examining the data input specifications in Attachment A.

ATTACHMENT E

EXAMPLE OF SIMPLIFIED SEGMENTATION

Figure 9 shows a hypothetical watershed divided into eight subareas contributing to six channels and table 5 lists some of their characteristics. One possible segmentation of this watershed is shown in figure 9B. Note that subareas 1 to 4 have all been labeled as FP01, subareas 5 and 6 have both been labeled as FP02, subareas 7 and 8 have been labeled as FP03, and C1 and C2 have both been labeled as CH01. These simplifications reduce the total number of segments from 14 to 8. However, because FP02 has considerable pervious area, it has been decided to divide that segment into a pervious and impervious portion, labeled PP02 and IP02, respectively. This results in nine segments. Some of the data needed on the segment characteristics card (card group 16) have been listed in table 6.

Any potential user of DR_3M should be sure to understand table 6. Note that channel segment CH01 was used twice. This occurred because in both places it was used with the same upstream (e.g., none) and lateral segments (e.g., FP01 twice). Note also that CH01 is listed twice in table 6 as an upstream segment of CH02.

The length of CH01 was computed as the average length of C1 and C2. All other channel segment lengths remained the same as their counterparts in figure 9A. The lengths of the overland-flow segments were computed using equations 25 and 26. The computations for each of these lengths are as follows:

$$\text{Length of FP01} = \frac{9130 + 9210 + 9700 + 9460}{2(125) + 2(125)} = 75 \text{ ft}$$

$$\text{Length of PP02} = \frac{24960 + 45600}{2(200) + 160} = 126 \text{ ft}$$

$$\text{Length of IP02} = \text{Length of PP02}$$

$$\text{Length of FP03} = \frac{11080 + 10920}{2(50) + 2(60)} = 100 \text{ ft}$$

Effective imperviousness values were determined by weighting the effective imperviousness of each of the subareas comprising an overland-flow segment by area. For example,

Effective imperviousness of FP03 =

$$\frac{(0.75)(11080) + (0.81)(10920)}{22000} = 0.780$$

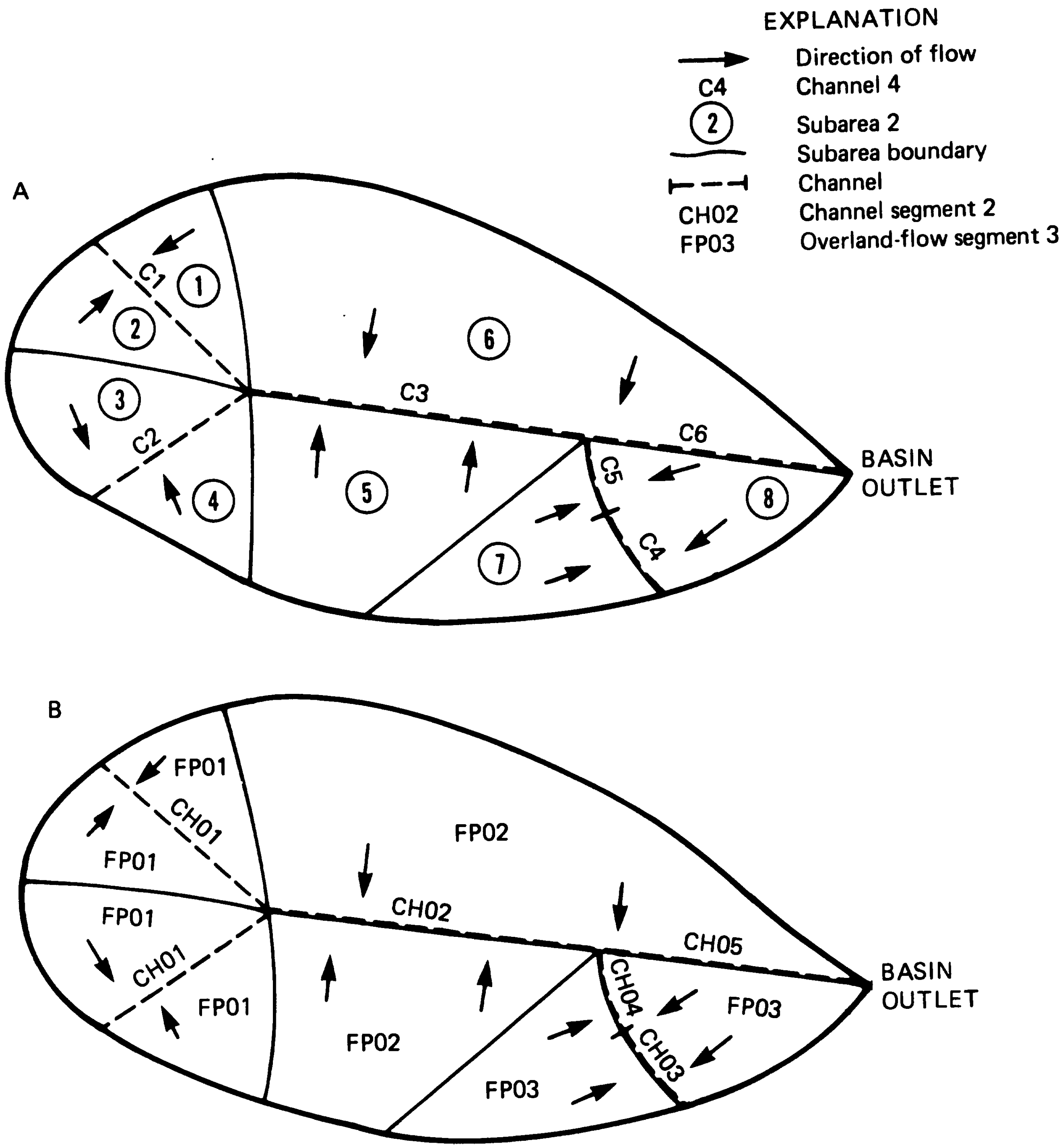


Figure 9.--Example of simplified segmentation.

Likewise, the area-weighted effective imperviousness of FP02 was 0.224. However, overland-flow plane FP02 was subdivided into a pervious (PP02) and impervious (IP02) segment. This was achieved by setting PARAM (I,1) and PARAM (I,2) to their special values as described in the input specifications for card group 16.

Table 5.--Example subarea and channel characteristics

Subarea Characteristics

Subarea number	Area, in square feet	Percent effective imperviousness
1	9,130	62
2	9,210	75
3	9,700	70
4	9,460	85
5	24,960	25
6	45,600	21
7	11,080	75
8	10,920	81

Channel Characteristics

Channel number	Length, in feet
C1	120
C2	130
C3	200
C4	50
C5	60
C6	160

Table 6.--Example segment characteristics for card group 16

Segment	Upstream segments	Adjacent segments	Length, in feet	PARAM (I,1)	PARAM (I,2)
FP01	--	--	75	1.0	.731
PP02	--	--	126	.776	0.0
IP02	--	--	126	.224	1.0
FP03	--	--	100	1.0	.780
CH01	--	FP01 FP01	125	--	--
CH02	CH01 CH01	PP02 PP02 IP02 IP02	200	--	--
CH03	--	FP03 FP03	50	--	--
CH04	CH03	FP03 FP03	60	--	--
CH05	CH02 CH04	PP02 IP02	160	--	--

ATTACHMENT F

DEFINITIONS OF SELECTED VARIABLES

(A) Alphanumeric, (I) Integer, (R) Real

ALPHA -- Array of α's for segments. (R)

ALPADJ -- A routing parameter that is used to adjust the ALPHA array. (R)

AP -- Excess precipitation per minute on impervious area of a segment. (R)

AMAX -- Array of maximum cross-sectional areas of flow from segments. (R)

BDY -- Beginning day of record. (I)

BMØ -- Beginning month of record. (I)

BMS -- Base soil-moisture storage. (R)

BMSN -- Maximum value of BMS. (R)

BYR -- Beginning year of record (last two digits). (I)

B3 -- Indicator of continuing parameter adjustment (0--continuing, 1--terminated). (I)

CHG -- Indicator of whether rain occurred in preceeding time interval or not (0--Yes, 1--No). A 1 requires re-evaluation of PS. (I)

CN -- Card sequence number for various data types. (I)

CØDE -- Identifier of data type. (I)

CØRF -- Time interval of rainfall-excess computations, in minutes, assigned as follows:

If PTIME < 5.0 min., CØRF = 1.0
If 5.0 min. ≤ PTIME < 15.0 min., CØRF = 5.0
If PTIME ≥ 15.0 min., CØRF = 15.0. (R)

DA1 -- Effective impervious area of watershed. (R)

DA2 -- Noneffective impervious area of watershed. (R)

DA3 -- Pervious area of watershed. (R)

CT -- Recording interval of unit data, in minutes. (I)

DA -- Drainage area of basin, in square miles. (R)

DATE -- Julian date relative to January 1, 1901. (I)

DATERF -- Julian date for beginning of record. (I)

DATERL -- Julian date for end of record. (I)

DE -- Array containing daily evaporation data. (R)

DELTAT -- Time interval, in fraction of an hour, for reservoir routing. (R)

DEL5 -- Number of CØRF-minute intervals in unit-time interval. (I)

DIMP -- A two-dimensional array of drainage areas. (R)

DIMP(NRGI,1) is total effective impervious area covered by rain gage NRGI
DIMP(NRGI,2) is total effective impervious area covered by rain gage NRGI on subbasins of soil type 2
DIMP(NRGI+3,1) is pervious area covered by rain gage NRGI on subbasins of soil type 1.
DIMP(NRGI+3,2) is pervious area covered by rain gage NRGI on subbasins of soil type 2.
DIMP(NRGI+6,1) is noneffective impervious area covered by rain gage NRGI on subbasins of soil type 1.
DIMP(NRGI+6,2) is noneffective impervious area covered by rain gage NRGI on subbasins of soil type 2.

DP -- Array containing daily precipitation data. (R)

DT -- (a) Time interval (Δt) used in finite-difference calculations, in minutes. (R)

(b) Three-dimensional array of interim drainage areas used in calculation of DT's. (R)

DTS -- Time interval (Δt) used in finite-difference calculations, in seconds. (R)

DX -- Array of length intervals (Δx), in ft, used in finite-difference calculations. (R)

DY -- Day of observed record. (I)

EAC -- Adjustment factor for effective impervious area. (R)

ECØMP -- Parameter to indicate number of CØRF-minute interval during routing. (R)

EDY -- Ending day of record. (I)

EM -- Array of m's for segments. (R)

EMØ -- Ending month of record. (I)

EØ -- Number of infiltration parameters. (I)

EP -- Excess precipitation per minute on pervious area. (R)

EPSLN -- Step size for parameter and adjustment at beginning of each stage in optimization. (R)

EVC -- Pan coefficient. (R)

EYR -- Ending year of record (last two digits). (I)

FLGTH -- Array of segment flow lengths. (R)

FLW -- Array of outflows from a segment in ft^3/s. (R)

FØ -- Number of parameters to be adjusted. (I)

FPK -- Array of measured peaks for storm events, in ft^3/s. (R)

FR -- Infiltration rate, in inches per CØRF-minutes. (R)

FRN -- Array of friction coefficients for segments. (R)

FVØL -- Array of measured volumes for storm events, in inches. (R)

G -- Array containing lower limits of infiltration parameters. (R)

H -- Array containing upper limits of parameters. (R)

ICØDE -- Indicator for termination of input-hydrograph data for a flood event (1--termination, 0--continuing). (I)

ICNT -- Counter for PTIME-minute intervals. (I)

ICT -- Counter for DT-minute intervals. (I)

IHYD -- Array containing indicator of whether or not storm event has an input hydrograph (1--Yes, 0--No). (I)

IJK -- CØRF-minute interval within sequence of days at which a storm ends. (I)

IJKS -- CØRF-minute interval within sequence of days at which a storm starts. (I)

IK -- Identifier of PTIME-minute interval within a storm. (I)

ILAT -- Array of lateral inflow segments into indexed downstream segment (A)

IMP -- Maximum impervious retention depth, in inches. (R)

IMPRET -- Array of CØRF-minute incremental depths added to impervious retention, in inches. (R)

IMPSTØ -- Array of impervious retention storage for rain gages during previous time interval, in inches. (R)

IPL -- Array containing indicator of whether or not outflow from the drainage basin is to be plotted for a storm. (1--Yes, 0--No). (I)

IPR -- Array of indicators of outflow hydrograph printing for segments (1--print outflow hydrograph, 0--do not print outflow hydrograph). (I)

IPRNT -- Number of DT's (Δt) in CØRF minutes. (I)

ISEG -- Alphanumeric identifier for segment. (A)

ITYPE -- Array of segment types. (I)

IUP -- Array of upstream inflow segments into indexed downstream segment. (A)

IW -- Counter for days during simulation. (I)

JLAT -- Array of lateral inflow segments which have been renumbered from ILAT to correspond to ISEG identifications. (I)

JUP -- Array of upstream inflow segments which have been renumbered from IUP to correspond to ISEG identifications. (I)

KE -- Ending unit time interval for storm. (I)

KINIT -- (a) Indicator for calling subroutine INIT to initialize segment (1--Yes, 0--No).

(b) Consecutive storm day. (I)

KNN -- Number of storm events used in optimization. (I)

KØUT -- Indicator of whether or not storm is to be routed (1--Yes, 0--No). (I)

KPSET -- Array of soil types for segments (1--soil type 1, 2--soil type 2). (I)

KR -- Indicator of whether or not precipitation has occurred yet during a storm (1--Yes, 0--No). (I)

KS -- (a) Starting unit-time interval for storm.

(b) Array of segments which are not overland-flow segments. (I)

KSAT -- Effective hydraulic conductivity of saturated soil. (R)

KSEG -- Array of segments ordered in downstream order. (I)

K1 -- Array of beginning times of detailed storms. (I)

K2 -- Array of ending times of detailed storms. (I)

LEAP -- Indicator of leap year (1--Yes, 0--No). (I)

MØ -- Month of observed record. (I)

N -- (a) Dummy variable used for boundary in finite-difference calculations.

(b) Indicator of whether segment has an upstream segment which has not been sequenced in downstream order yet (1--Yes, 0--No). (I)

ND -- Number of CØRF-minute intervals in a day. (I)

NDATE -- Array of storm dates. (I)

NDELS -- Number of unit time intervals in a day. (I)

NDX -- (a) Number of intervals (Δx) for finite-difference routing. (I)

(b) Number of points in storage-outflow relationship for a modified-Puls detention reservoir.

NF -- Array of number of storms in the sequence of days containing a given storm. (I)

NFE -- Array of ending CØRF-minute intervals for storms. (I)

NFS -- Array of starting CØRF-minute intervals for storms. (I)

NK -- Total number of iterations in an optimization round. (I)

NØFE -- Number of storm events. (I)

NØPT1 -- Indicator of whether or not daily rainfalls are to be modified for irrigation (1--Yes, 0--No). (I)

NØUD -- Array containing sequence date for I-th day of unit discharge, I = 1,...,NUDD. (I)

NØUP -- Array containing sequence date of I-th day of unit precipitation, I = 1,...,NUPD. (I)

NØUT -- Maximum number of consecutive storm days allowed by dimensions of program. (I)

NØ8 -- Number of modified-Puls detention reservoir segments. (I)

NØ9 -- Ten + the number of linear-storage detention reservoir segments. (I)

NPAR -- Number of soil types. (I)

NRG -- Number of rain gages. (I)

NSD -- Number of storm sequences. (I)

NSEG -- Number of segments. (I)

NU -- Counter for consecutive storm days. (I)

NUDD -- Number of days of unit discharge. (I)

NUPD -- Number of days of unit rainfall. (I)

ØPT -- Option to read in storm volumes. (A)

ØPTIØN -- Option to list data (ØPTIØN = LIST--all unit and daily data are printed. (A)

ØPTNØ -- Array containing subscripts to identify parameters to be adjusted in round of optimization. (I)

ØSI -- Surcharging indicator. (R)

Ø2 -- Array of outflows in outflow-storage relationship for modified-Puls detention reservoir segments. (R)

P -- Array of excess precipitation during CØRF-minute intervals from each rain gage. (R)

PARAM -- Pair of parameters for a segment. (R)

PØBS -- Array of measured rainfall volumes for storm events. (R)

PS -- Product of capillary suction and moisture differential at wetting front. (R)

PSP -- Minimum effective magnitude of PS for soil type 1 (occurs at field capacity, BMS=BMSN). (R)

PSP2 -- Minimum effective magnitude of PS for soil type 2. (R)

PTIME -- Time increment for unit data, in minutes. (R)

Q -- Array of times for plotting. (R)

QIH -- Array of input-hydrograph discharges. (R)

QMX -- Peak flow during a storm. (R)

QR -- (a) Excess rainfall in CØRF-minute interval.

(b) Baseflow. (R)

QSUM -- Sum of upstream inflows to segment. (R)

QSUML -- Sum of lateral inflows to segment. (R)

QUP -- Upstream inflow. (R)

R -- Array of discharges for plotting. (R)

RAT -- Ratio of pervious area + noneffective impervious area to pervious area. (R)

RCØEF -- Array of Theissen coefficients for segments. (R)

RGF -- Ratio of maximum PS (at wilting point) to minimum PS (at field capacity) for soil type 1. (R)

RGF2 -- Ratio of maximum PS to minimum PS for soil type 2. (R)

RITE -- Indicator of progress in parameter adjustment (0--continuing, 1--end of stage in optimization). (I)

RØDYS -- Number of days from start to end of record. (I)

RR -- Ratio of daily infiltration to daily rainfall for soil type 1. (R)

RR2 -- Ratio of daily infiltration to daily rainfall for soil type 2. (R)

SFPK -- Array containing maximum simulated discharge for storm events, in cubic feet per second. (R)

SFVØL -- Array containing simulated runoff volume for storm events, in basin inches. (R)

SLØPE -- Array of segment slopes. (R)

SMAX -- Array of maximum storage during a flood event for detention reservoirs. (R)

SMS -- Soil moisture storage in saturated zone (volume of infiltration during period). (R)

SR -- CØRF-minute rainfall supply rate to pervious surfaces (adjusted for contribution from noneffective impervious surfaces). (R)

SRP -- CØRF-minute rainfall supply rate to effective impervious surfaces. (R)

S2 -- Array of storages in outflow-storage relationship for modified-Puls detention reservoir segments. (R)

T -- Time in finite-difference routing. (R)

TESTNØ -- Array containing indicator of whether or not storm event is used in computing objective function (1--Yes, 0--No). (I)

TRYCT -- Iteration count for set of parameters. (I)

UD -- Array containing unit discharge data. (R)

UPD -- Sequence date of unit rainfall. (I)

UPR -- Array containing storm precipitation data. (R)

VØLI -- Furnished volume of storm runoff, in inches. (R)

W -- Counter for day of record. (I)

WX -- Weighting factor on space derivative for kinematic routing with implicit finite difference solution method. (R)

X -- Array containing magnitudes of infiltration parameters. (R)

XMAX -- Value of abscissa at the rightmost grid line. (R)

XMIN -- Value of abscissa at the leftmost grid line. (R)

YMAX -- Value of ordinate at the uppermost grid line. (R)

YMIN -- Value of ordinate at the lowermost grid line. (R)

YN -- Array containing cumulative number of days counted from January 1, 1901, at end of preceding year. (I)

YR -- Year (last two digits). (I)

ATTACHMENT G

PROGRAM LISTING

```
      ****************************************************************

C     ****************************************************************
C     *                                                              *
C     *      J347--DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL         *
C     *                          (VERSION 2)                         *
C     *                                                              *
C     ****************************************************************
      INTEGER EO,FO,B3,TRYCT,OPTION,OPT,RITE,RODYS,OPTNO,DEL5,DEL5P,E,F
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(50)
      INTEGER STAD1,STAD,NF(60),NFE(60),NFS(60),TESTNO(60)
      REAL IMP,IMPRET,IMPSTO,IN2,ISEG,IUP,ILAT,POBS(60,3)
      DIMENSION K1(60), K2(60)
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C2/ STAD1,STAD
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QJP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ T1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OJTVOL(60)
      COMMON /D1/ DP(7310),RODYS,NSD,IUNIT,NDYS,NDTS,ICK(60)
      COMMON /E1/ IMPRET(3),IMPSTO(3)
      COMMON /E2/ SMAX(99),IN2,S202(99),ALP,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NO8,WS(11),I30,I40,IJ,QIH(2881),QINPT(60)
      COMMON /E4/ WV(99,10),S1(99,10),C1(99,10)
      COMMON /E5/ S2(99,10),S(99,10),C(99,10)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F2/ FLW(1442),FLAT(1442),FJP(1442)
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECDS,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,N09,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NJPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      COMMON /Z3/ K1,KP,NF,NFE,NFS,POBS,TESTNO
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(50,3),X(40),DF,IEAC
      DATA IBLANK/4H    /
      WRITE (6,21)
      B3=0
      RITE=1
C           SET SEQUENTIAL FILE NUMBERS
      IFILED=26
      IFILEP=28
C           SET ARRAY LIMITS
      IUNIT=2881
      NDYS=7310
      NDTS=1442
C           INITIALIZE HEADER ARRAYS FOR DIRECT ACCESS FILE
      DO 11 I=22,120
```

```
      ************************************************************
   11 HEAD1(I)=IBLANK
      DO 12 J=1,50
      HEAD2(J,1)=0
      HEAD2(J,2)=0
   12 HEAD3(J)=0
      NRECDS=3
      NSTRMS=0
C              CALL PROGRAM SUBROUTINES
      CALL INPUT1
      IF (OPT.EQ.0) REWIND IFILED
      DO 13 I=1,NRG
      IFP=IFILEP+I-1
      REWIND IFP
   13 CONTINUE
      CALL INITOP
      CALL CTCHMT
      CALL AM
      CALL SEQ(DA,DIMP)
      CALL INPUT2(JPERM,JRECDS)
      IF (JRECDS.GT.0) CALL FILES
      GO TO 15
   14 CALL OPTIMZ
   15 CONTINUE
      CALL SIMUL
      IF (R3.EQ.0) GO TO 14
C          END OF SIMULATION LOOP
      IF (JPUN.GE.1) WRITE (JPUN,27)
C          COMPUTE CORRELATION COEFFICIENT FOR PEAKS
      IF (OPT.EQ.0) CALL CORR(NOFE,SFPK,FPK)
C              PLOT SIM. VS. MEAS. VOLUMES
C              AND SIM. VS. MEAS. PEAKS
      DO 19 K=1,2
      YMAX=0.0
      N=0
      DO 18 I=1,NOFE
      IF (K.EQ.2) GO TO 16
      IF (SFVOL(I).LE.0.0.OR.FVOL(I).LE.0.0) GO TO 18
      IF (NK.GT.0.AND.TESTNO(I).NE.1) GO TO 18
      N=N+1
      Q(N)=FVOL(I)
      R(N)=SFVOL(I)
      GO TO 17
   16 IF (SFPK(I).LE.0.0.OR.FPK(I).LE.0.0) GO TO 18
      N=N+1
      Q(N)=FPK(I)
      R(N)=SFPK(I)
   17 IF (Q(N).GT.YMAX) YMAX=Q(N)
      IF (R(N).GT.YMAX) YMAX=R(N)
   18 CONTINUE
      IF (N.LT.2) GO TO 19
```

```
      ******************************************************************
      PTIME=100.
      CALL PLT(Q,R,N,1,YMAX)
      WRITE (6,24)
      IF (K.EQ.1) WRITE (6,25)
      IF (K.EQ.2) WRITE (6,26)
   19 CONTINUE
      IF (JPERM.EQ.0) STOP
C              IF JPERM=1, STORE AND OUTPUT HEADER ARRAYS
      WRITE (6,22)
      NS=0
      DO 20 I=1,NOFE
      IF (KOUT(I).EQ.0) GO TO 20
      NS=NS+1
      WRITE (6,23) I,(NDATE(I,III),III=1,3),HEAD2(NS,1),HEAD2(NS,2)
   20 CONTINUE
      HEAD1(16)=NRECDS
      HEAD1(17)=NSTRMS
      IRECD=1
      WRITE (IFILE'IRECD) HEAD1,HEAD2,HEAD3
      STOP
C
   21 FORMAT (1H1,41X,43(1H*)/42X,1H*,10X,22HU.S. GEOLOGICAL SURVEY,9X,1
     1H*/42X,43H*DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL*/42X,1H*,12X,
     217HVERSION   3/ 8/82,12X,1H*/42X,43(1H*))
   22 FORMAT (1H1,32H ***** RUNOFF FILES STORED *****/1H0,17HSTORM NO.
     1  DATE,5X,34HSTARTING RECORD   NUMBER OF VALUES)
   23 FORMAT (I5,I8,1H/,I2,1H/,I2,7X,I5,13X,I5)
   24 FORMAT (16X,50HPLOT OF MEAS.(HORIZ. AXIS) VERSUS SIM.(VERT. AXIS))
   25 FORMAT (16X,7HVOLUMES)
   26 FORMAT (16X,5HPEAKS)
   27 FORMAT (79X,1H9)
      END
```

SUBROUTINE SIMUL

```
      SUBROUTINE SIMUL
C     ****************************************************************
C     *                  SIMULATION ROUTINE                          *
C     ****************************************************************
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(60)
      INTEGER RITE,W,B3,EO,FO,OPTION,TRYCT,CHG,FLAG,DEL5P,TESTNO(60)
      INTEGER NF(60),NFE(60),NFS(60),RODYS,DEL5,OPT,E,F,OPTNO
      REAL INC2,INC,KSAT,KSAT2,KDRAIN
      REAL SMSB(3,2),BMSB(3,2),POBS(60,3)
      REAL IMP,IMPRET,IMPSTT,IMPSTO,ISEG,IUP,ILAT,IN2
      DIMENSION K1(60), K2(60)
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /D1/ DP(7310),RODYS,NSD,IUNIT,NDYS,NDTS,ICK(60)
      COMMON /E1/ IMPRET(3),IMPSTO(3)
      COMMON /E2/ SMAX(99),IN2,S202(99),ALPH,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NO8,QS(11),I3Q,I4Q,IJ,QIH(2881),QINPT(60)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F2/ FLW(1442),FLAT(1442),FUP(1442)
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECD6,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NJPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      COMMON /Z3/ K1,K2,NF,NFE,NFS,POBS,TESTNO
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      DATA FLAG/1/
C              INITIALIZE
      U1=0.0
      U2=0.0
      VCOEF=26.8888889*DA*NDELS
      NO2=NOFE+NOFE
      DO 1 I=1,NOFE
      OUTVOL(I)=0.0
    1 SFVOL(I)=0.0
      DO 3 NRGI=1,NRG
      DO 2 I=1,NO2
    2 PSUM(I,NRGI)=0.0
    3 CONTINUE
      I1=1
      SMS=0.0
      BMS=0.0
      CHG=1
```

SUBROUTINE SIMUL

```
C             ESTABLISH CURRENT INFILTRATION PARAMETER VALUES
      PSP=X(1)
      KSAT=X(2)*(CORF/60.)
      RGF=X(3)
      BMSN=X(4)
      EVC=X(5)
      RR=X(6)
      DRN24=X(2)*24.0
      EAC=X(7)
      PAC=1.0
      IF (IEAC.EQ.1) CALL ADJUST(EAC,PAC)
      IF (NPAR.EQ.1) GO TO 4
      PSP2=X(8)
      KSAT2=X(9)*(CORF/60.)
      RGF2=X(10)
      BMSN2=X(11)
      EVC2=X(12)
      RR2=X(13)
      DRN242=X(9)*24.0
      DRAIN2=DRN242/NDELS
      COEF2=(RGF2-1.0)/BMSN2
    4 KDRAIN=DRN24/NDELS
      COEF=(RGF-1.0)/BMSN
C             INITIALIZE VARIABLES
      DO 6 NP=1,NPAR
      DO 5 I=1,NRG
      SMSB(I,NP)=0.0
    5 BMSB(I,NP)=0.0
    6 CONTINUE
      KP=1
C             BEGIN SIMULATION
      APRNT=(CORF+.0001)/DT
      IPRNT=APRNT
      DSI=0.0
      KINIT=0
      NFD=0
      NFD1=0
      W=0
      DO 65 IW=1,RODYS
      W=W+1
      IF (W.GT.RODYS) GO TO 65
C             FOR GAP IN RECORD, INITIALIZE SOIL MOISTURE TO ZERO
      IF (W.NE.INDP(KP)) GO TO 9
      LJ=KP+1
      W=INDP(LJ)+1
      KP=KP+2
      BMS=0.0
      SMS=0.0
      DO 8 NP=1,NPAR
      DO 7 LJ=1,NRG
```

```
      BMSB(LJ,NP)=0.0
    7 SMSB(LJ,NP)=0.0
    8 CONTINUE
    9 CONTINUE
      PW=RR*DP(W)
      IF (NPAR.EQ.2) PW2=RR2*DP(W)
      ETW=EVC*DE(W)
      IF (NPAR.EQ.2) ETW2=EVC2*DE(W)
      IF (PW.LT.0.0) GO TO 45
C             IF FLAG=0, DO STORM COMPUTATIONS
C             IF FLAG=1, DO DAILY MOISTURE ACCOUNTING
      IF (FLAG.NE.0) GO TO 43
C             SET-UP FOR ROUTING THE GENERATED EXCESS PRECIPITATION
      NFD1=0
      NFD=NFD+1
      KIN=0
   10 IF (I1.GT.NOFE) GO TO 42
      IF (IHYD(I1).EQ.0.OR.B3.EQ.0) GO TO 14
      DO 11 I=1,IUNIT
   11 QIH(I)=0.0
   12 READ (5,67) ICODE,JJJ,(X2(I),I=1,10)
      DO 13 I=1,10
      QIH(JJJ)=X2(I)
   13 JJJ=JJJ+1
      IF (ICODE.EQ.0) GO TO 12
      I30=JJJ-1
   14 IF (B3.EQ.0.OR.KOUT(I1).EQ.0) KINIT=0
      IJKS=NFS(I1)
      IJK=NFE(I1)
      I12=I1+NOFE
      IK=K1(I1)
C              COMPUTE PERVIOUS RAINFALL EXCESS
      DO 15 I=IJKS,IJK
      KDY=I+1441
      DO 15 NRGI=1,NRG
      PSUM(I1,NRGI)=PSUM(I1,NRGI)+P(I,NRGI)
   15 IF (NPAR.NE.1) PSUM(I12,NRGI)=PSUM(I12,NRGI)+P(KDY,NRGI)
      QMX=0.0
      IF (KOUT(I1).EQ.0.OR.B3.EQ.0) GO TO 38
      IF (KNN.GT.0.AND.IEAC.EQ.1) WRITE (6,70)
      IF (KNN.GT.0.AND.IEAC.EQ.1) STOP
      NSTRMS=NSTRMS+1
      HEAD2(NSTRMS,1)=NRECDS+1
      NSTRCD=HEAD2(NSTRMS,1)
      IF (JPERM.EQ.0) NSTRCD=1
C                ** FLOW ROUTING **
      IF (IPR(NSEG).GT.0) WRITE (6,69)
C             ROUTE EACH SEGMENT
      DO 31 NSGA=1,NSEG
      KK=KSEG(NSGA)
```

SUBROUTINE SIMUL

```
      KINIT=1
      IF (NSGA.EQ.1) GO TO 23
      DO 16 I=1,ICT
      FLAT(I)=0.0
   16 FUP(I)=0.0
      DO 19 J=1,4
      IF (JLAT(KK,J)) 19,19,17
   17 JJ=JLAT(KK,J)
      IRECD=NSTRCD+NRPSEG*(JJ-1)
      READ (IFILE'IRECD) (FLW(I),I=1,ICT)
      DO 18 I=1,ICT
   18 FLAT(I)=FLAT(I)+FLW(I)
   19 CONTINUE
      DO 22 J=1,3
      IF (JUP(KK,J)) 22,22,20
   20 JJ=JUP(KK,J)
      IRECD=NSTRCD+NRPSEG*(JJ-1)
      READ (IFILE'IRECD) (FLW(I),I=1,ICT)
      DO 21 I=1,ICT
   21 FUP(I)=FUP(I)+FLW(I)
   22 CONTINUE
   23 CONTINUE
      IK=K1(I1)
      I40=0
      IJ=1
      ICT=0
      IF (NFD1.GT.0) GO TO 25
      IF (ITYPE(KK).LT.5) GO TO 25
      IF (ITYPE(KK).GT.6) GO TO 25
      DO 24 NRGI=1,NRG
   24 IMPSTO(NRGI)=0.0
C              ROUTE FOR EACH TIME STEP
   25 DO 29 I=IJKS,IJK
      IF (ITYPE(KK).LT.5.OR.ITYPE(KK).GT.6) GO TO 28
C               CALCULATE IMPERVIOUS RETENTION
      DO 27 NRGI=1,NRG
      IF (IMPSTO(NRGI).EQ.IMP) GO TO 26
      I2=NDAY*(NRGI-1)+IK
      IMPSTT=IMPSTO(NRGI)+UPR(I2)/DEL5/3.
      IF (IMPSTT.GT.IMP) IMPSTT=IMP
      IMPRET(NRGI)=IMPSTT-IMPSTO(NRGI)
      IMPSTO(NRGI)=IMPSTT
      GO TO 27
   26 IMPRET(NRGI)=0.0
   27 CONTINUE
C                **ROUTE OVER TIME INT. = CORF
   28 CALL FLOW(I)
      ECOMP=ECOMP+CORF
C              DETERMINE WHETHER OR NOT AT END OF UNIT-TIME INTERVAL
      IJ=IJ+1
```

```
      IF (IJ.NE.DELSP) GO TO 29
      IK=IK+1
      OSI=0.0
      I40=0
      IJ=1
   29 CONTINUE
      IF (JPERM.EQ.0.AND.NSGA.EQ.NSEG) GO TO 30
      IF (NSGA.EQ.1) NRPSEG=ICT/120+1-(1-MIN0(1,MOD(ICT,120)))
      IRECD=NSTRCD+NRPSEG*(KK-1)
      WRITE (IFILE'IRECD) (FLW(I),I=1,ICT)
      NRECDS=NRECDS+NRPSEG
      IF (NSGA.EQ.NSEG) GO TO 30
      IF (IPR(KK).EQ.0) GO TO 31
   30 CALL PRFL(IJKS,IJK,ICNT,SRV,QMX)
      IF (NSGA.NE.NSEG) GO TO 31
      IF (JPUN.LE.0) GO TO 31
C            PUNCH OUT FLOW DATA
      LL=K1(I1)
      CALL PUNCH(LL,NDATE,NDELS,CORF,PTIME,JPUN,I1,ICNT)
   31 CONTINUE
C            COMPUTE OUTLET VOLUME
      OUTVOL(I1)=SRV/VCOEF
      HEAD2(NSTRMS,2)=ICT
C          WRITE OUT MAXIMUM STORAGE IN RESERVOIRS
      IF (NO8.EQ.0) GO TO 33
      DO 32 JJ=1,NO8
      K5=IRES(JJ)
   32 WRITE (6,69) ISEG(K5),I1,SMAX(K5)
   33 IF (NO9.EQ.10) GO TO 35
      DO 34 JJJ=11,NO9
      K5=IRES(JJJ)
   34 WRITE (6,69) ISEG(K5),I1,SMAX(K5)
   35 CONTINUE
      IF (IPL(I1).EQ.0) GO TO 38
C             ** PLOT **
      YMAX=QMX
      IF (QMX.LT.FPK(I1)) YMAX=FPK(I1)
      CALL PLT(Q,R,ICNT,1,YMAX)
      IF (OPT.EQ.1) GO TO 37
      JJ=0
      LK=K1(I1)
      LJ=K2(I1)
      DO 36 KQ=LK,LJ
      JJ=JJ+1
      R(JJ)=JD(KQ)
   36 IF (TRYCT.GT.0) R(JJ)=R(JJ)-BFL(I1)
      CALL PLT(Q,R,ICNT,2,YMAX)
   37 CONTINUE
      CALL PLT(Q,R,ICNT,3,YMAX)
   38 CONTINUE
```

```
C              COPY SIMULATED STORM RUNOFF VOLUME AND PEAK
C              FOR I-TH EVENT INTO STORAGE ARRAYS SFVOL AND SFPK.
      QCW=0.0
      DO 39 LK=1,NRG
      LJ=LK+3
      QCW=QCW+EAC*DIMP(LK,1)*(POBS(I1,LK)-IMP)+PAC*(DIMP(LJ,1)*PSUM(I1,L
     1K)+DIMP(LJ,2)*PSUM(I12,LK))
      IF (NFD1.EQ.0) GO TO 39
      QCW=QCW+EAC*DIMP(LK,1)*IMP
   39 CONTINUE
      SFVOL(I1)=QCW/(5280.0*5280.0*DA)
      SFPK(I1)=QMX
      IF (TESTNO(I1).NE.1) GO TO 40
      IF (SFVOL(I1).EQ.0) GO TO 40
      IF (FVOL(I1).EQ.0.0) GO TO 40
      U2=U2+ALOG(SFVOL(I1)/FVOL(I1))**2
   40 IF (QMX.EQ.0.) GO TO 41
      IF (FPK(I1).EQ.0.0) GO TO 41
      U1=U1+ALOG(QMX/FPK(I1))**2
   41 I1=I1+1
      NFD1=NFD1+1
C              IF HAVE ANALYZED ALL EVENTS OF SET OF EVENTS, GO TO 716
      IF (NF(NFD).EQ.NFD1) GO TO 42
      IJK=IJK+1
      IJKS=NFS(I1)
      KIN=0
C              IF NEXT STORM BEGINS IMMEDIATELY AFTER LAST STORM, KIN=1
      IF (IJK.EQ.IJKS.AND.KOUT(I1-1).EQ.1) KIN=1
      GO TO 10
   42 NFD=NFD+NFD1-1
      IF (W.GT.RODYS) GO TO 65
      FLAG=1
      NFD1=0
      CHG=1
C              ** DAILY  ACCOUNTING **
   43 INC=PW-ETW
      IF (NPAR.EQ.2) INC2=PW2-ETW2
      DO 44 III=1,NRG
      CALL DSM(SMSB(III,1),BMSB(III,1),INC,DRN24,BMSN)
      IF (NPAR.EQ.2) CALL DSM(SMSB(III,2),BMSB(III,2),INC2,DRN242,BMSN2)
   44 CONTINUE
C              FINISHED WITH DAY
      GO TO 65
C            ** DETERMINE TIME-SERIES OF RAINFALL EXCESS
   45 FLAG=0
      NFD1=NFD1+1
      IF (NFD1.GT.1) GO TO 49
      IFP=IFILEP
      IUNIT3=IUNIT*NRG
      DO 46 I=1,IUNIT3
```

```
   46 UPR(I)=0.0
      DO 47 III=1,NRG
      READ (IFP) K4ST,K4DAY,(UPR(I),I=K4ST,K4DAY)
      IFP=IFP+1
   47 CONTINUE
      IF (OPT.GT.0) GO TO 48
      IF (TRYCT.GT.0.AND.B3.EQ.0) GO TO 48
      READ (IFILED) K4DAY,(UD(I),I=1,K4DAY)
   48 IF (TRYCT.EQ.0) CALL STORM
   49 DO 64 NP=1,NPAR
      DRAIN=KDRAIN
      IF (NP.EQ.2) DRAIN=DRAIN2
      BMST=BMSN
      IF (NP.EQ.2) BMST=BMSN2
      IF (W.GT.RODYS) GO TO 64
      ETDEL=PDEL*ETW
      IF (NP.EQ.2) ETDEL=PDEL*ETW2
      IF (NP.EQ.1) KINIT=KINIT+1
      K=NDELS*(KINIT-1)+1
      DO 63 III=1,NRG
      CHG=1
      KDAY=ND*(KINIT-1)+1
C             COMPUTE SMS,BMS FOR AREAS FOR EACH RAIN GAGE, SOIL TYPE
      SMS=SMSB(III,NP)
      BMS=BMSB(III,NP)
      KKK=K+(III-1)*NOUT*NDELS
      K4DAY=KKK+NDELS-1
      DO 62 KK=KKK,K4DAY
      IF (UPR(KK).LE.0.0) GO TO 56
      SRP=UPR(KK)/DELS
      SR=SRP*RAT
      IF (CHG.NE.1) GO TO 50
C             BEGIN COMPUTATION OF INFILTRATION
C             REDETERMINE PS AFTER BREAK IN RAINFALL
      PS=PSP*(RGF-COEF*BMS)
      IF (NP.EQ.2) PS=PSP2*(RGF2-COEF2*BMS)
      CHG=0
   50 CONTINUE
C             DEFINE CORF-MIN. RAINFALL SUPPLY RATE
      IF (SMS.LE.0.01) GO TO 51
C             IF SATURATED ZONE EXISTS
      FR=KSAT*(1.0+PS/SMS)
      IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SMS)
      GO TO 52
C             IF NO SATURATED ZONE EXISTS
   51 FR=KSAT*(1.0+PS/SR)
      IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SR)
C             DETERMINE EXCESS PPT. IN UNIT TIME
   52 DO 55 NKL=1,DELS
      IF (SR.GE.FR) GO TO 53
```

```
      QR=(SR*SR)/(2.0*FR)
      GO TO 54
C             PONDED CONDITION
   53 QR=SR-FR/2.0
   54 SMS=SMS+SR-QR
C             KDAY IS CORF-MIN. INTERVAL IN A DETAILED STORM
      KDY=KDAY
      IF (NP.EQ.2) KDY=KDY+1441
      P(KDY,III)=QR
      KDAY=KDAY+1
C             SMS= NEW MOISTURE CONTENT OF SATURATED ZONE
      FR=KSAT*(1.0+PS/SMS)
   55 IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SMS)
      GO TO 62
C             DEPLETION OF SOIL MOISTURE BY ET DURING UNIT-TIME
C             INTERVALS OF NO PPT.
   56 CONTINUE
      IF (SMS.LE.ETDEL) GO TO 57
      SMS=SMS-ETDEL
      GO TO 58
   57 BMS=BMS+SMS-ETDEL
      SMS=0.0
C             CHECK FOR COMPLETE SOIL DRYING
      IF (BMS.LE.0.0) BMS=0.0
C             REDISTRIBUTION OF SOIL MOISTURE WITH FLOW FROM
C             SATURATED TO UNSATURATED ZONE
   58 IF (SMS.LE.DRAIN) GO TO 59
      SMS=SMS-DRAIN
      BMS=BMS+DRAIN
C             BMS= NEW SOIL MOISTURE CONTENT OF UNSATURATED ZONE
      GO TO 60
   59 BMS=BMS+SMS
      SMS=0.0
C             DRAINAGE TO LOWER LYING ZONE
   60 IF (BMS.GT.BMST) BMS=BMST
C             BREAK IN UNIT RAINFALL
      CHG=1
C             NO EXCESS PRECIPITATION
      DO 61 NKL=1,DEL5
      KDY=KDAY
      IF (NP.EQ.2) KDY=KDY+1441
      P(KDY,III)=0.0
   61 KDAY=KDAY+1
C             144 ENDS RAIN GAGE III FOR UNIT PPT. DAY.
   62 CONTINUE
C             COMPUTE SMS AND BMS FOR AREAS COVERED BY EACH RAIN GAGE
      SMSB(III,NP)=SMS
      BMSB(III,NP)=BMS
C             148 ENDS UNIT PPT. DAY
   63 CONTINUE
```

```
   64 CONTINUE
C             147 ENDS ALL DAYS, W= 1,RODYS
   65 CONTINUE
      IF (OPT.EQ.0.AND.TRYCT.EQ.0) REWIND IFILED
      DO 66 III=1,NRG
      IFP=IFILEP+III-1
      REWIND IFP
   66 CONTINUE
      U(1)=U1
      U(2)=U2
      U(3)=U1+0.5*U2
C             * RITE ROUTINE *
      IF (TRYCT.EQ.0) CALL PROUT(1,PAC)
      IF (RITE.NE.1) RETURN
      CALL PROUT(2,PAC)
      RITE=0
      RETURN
C
   67 FORMAT (I1,I4,10F5.3)
   68 FORMAT (1H0,40HMAXIMUM STORAGE IN DETENTION RESERVOIR   ,A4,10H FOR
     1 STORM,I3,4H WAS,F8.3,10H CFS-HOURS)
   69 FORMAT (1H1)
   70 FORMAT (1H0,51HOPTIMIZ. AND ROUTING RUNS SHOULD BE DONE SEPARATELY
     1,27H SINCE EAC CHANGES ARE MADE)
      END
```

SUBROUTINE DSM(SMS,BMS,INC,DRN24,BMSN)

```
      SUBROUTINE DSM(SMS,BMS,INC,DRN24,BMSN)
C             THIS SUBROUTINE DOES SOIL MOISTURE ACCOUNTING
C             ON DAYS OF DAILY RAINFALL. IT ADDS DAILY RAINFALL TO SMS,
C             SUBTRACTS ET FROM SMS OR (IF SMS=0) FROM BMS, AND
C             DRAINS SMS DOWNWARD TO BMS
      REAL SMS,BMS,DRN24,INC,BMSN
      IF (INC.LE.0.0) GO TO 1
C             ADD EXCESS MOISTURE TO SATURATED ZONE
      SMS=SMS+INC
      GO TO 3
C             DEDUCT MOISTURE DEFICIENCY FROM SATURATED ZONE
    1 IF ((SMS+INC).GE.0.0) GO TO 2
C             EVAPOTRANSPIRATION FROM UNSATURATED ZONE
      BMS=BMS+SMS+INC
      SMS=0.0
C             CHECK FOR COMPLETE SOIL DRYING
      IF (BMS.LT.0.0) BMS=0.0
      GO TO 3
C             EVAPOTRANSPIRATION FROM SATURATED ZONE
    2 SMS=SMS+INC
C             REDISTRIBUTION OF SOIL MOISTURE WITH FLOW FROM
C             SATURATED TO UNSATURATED ZONE
    3 IF (SMS.LE.DRN24) GO TO 4
C             MOISTURE IN SATURATED ZONE ABOVE FIELD CAPACITY
      SMS=SMS-DRN24
      BMS=BMS+DRN24
      GO TO 5
C             SATURATED ZONE COMPLETELY DEPLETED
    4 BMS=BMS+SMS
C             BMS= NEW MOISTURE CONTENT OF UNSATURATED ZONE
      SMS=0.0
C             DRAINAGE TO DEEPER LYING ZONE
    5 IF (BMS.GT.BMSN) BMS=BMSN
      RETURN
      END
```

SUBROUTINE FLOW(I)

```
      SUBROUTINE FLOW(I)
C             THIS SUBROUTINE COMPUTES SEGMENT OUTFLOWS AT T+DT
      REAL ISEG,IUP,IN1,IN2
      INTEGER DEL5,TRYCT
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /E2/ SMAX(99),IN2,S202(99),ALP,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,N08,QS(11),I3Q,I4,IJ,QIH(2881),QINPT(60)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),K
      COMMON /F2/ FLW(1442),FLAT(1442),FUP(1442)
      COMMON /MOC/ XL,DTS1,JTYPE
      COMMON /FD/ XA(11),XQ(11),XSEG
      COMMON /LINRES/ QOUT2,CONST
      IF (KINIT.NE.1) GO TO 2
      CALL INIT
      IMDE=0
      IF (METH.NE.1) GO TO 1
      XL=FLGTH(K)
      JTYPE=ITYPE(K)
      DTS1=DTS
      CALL KWMOC1(0.,0.)
      GO TO 2
    1 IF (METH.EQ.0) GO TO 2
      XSEG=ISEG(K)
      CALL KWFD1(DX(K))
    2 T=T+DT
      ICT=ICT+1
      IF (ITYPE(K).GE.7) GO TO 12
      N=NDX(K)+1
      CALL UP(K,I)
      CALL LAT(K,I)
      ALAT=QLAT*DTS
      XQ(1)=QUP
      XA(1)=(QUP/ALP)**(XEM)
      IF (METH.NE.1) GO TO 3
C
C           METHOD OF CHARACTERISTICS
      CALL KWMOC(Q2,AD,XA(1),QLAT)
      GO TO 20
    3 CONTINUE
      B1=ALP*YEM*DTSX
      B2=YEM-1.
      DO 6 J=2,N
```

SUBROUTINE FLOW(I)

```
      IF (YEM.EQ.1.AND.METH.GE.2) GO TO 5
C
C          EXPLICIT FINITE DIFFERENCE METHOD
      IF (AR(J-1).LE.0..AND.QLAT.LE.0.) GO TO 4
      IF ((ALAT*1.E3).LE.AR(J-1)) THETA=B1*AR(J-1)**B2
      IF ((ALAT*1.E3).GT.AR(J-1)) THETA=ALPV(QLAT*DX(K))*((ALAT+AR(J-1))
     1**YEM-AR(J-1)**YEM)
      IF (THETA.LT.1) GO TO 4
      XQ(J)=XQ(J-1)+(ALAT+AR(J-1)-XA(J-1))/DTSX
      XA(J)=(XQ(J)/ALP)
      IF (XA(J).LT.1.E-20) XA(J)=0.0
      IF (YEM.NE.1.) XA(J)=XA(J)**(XEM)
      GO TO 6
    4 XA(J)=AR(J)+ALAT+DTSX*(QS(J-1)-QS(J))
      IF (XA(J).LT.1.E-20) XA(J)=0.0
      XQ(J)=ALP*XA(J)
      IF (YEM.NE.1.) XQ(J)=ALP*(XA(J)**YEM)
      IF (METH.EQ.0.OR.ABS(XA(J)).LT.1.E-20) GO TO 6
C
C          IMPLICIT FINITE DIFFERENCE METHOD
    5 CALL KWFD(J)
    6 CONTINUE
C             SELECT ALPHA AND M FOR NEXT ROUTING
      IF (ITYPE(K).NE.4) GO TO 10
      IF (RCOEF(K,3).LT.0.01) GO TO 10
      IF (IMDE.GT.0) GO TO 7
      IF (XQ(N).LT.RCOEF(K,3)) GO TO 10
      ALP=RCOEF(K,1)
      YEM=RCOEF(K,2)
      XEM=1./YEM
      IMDE=1
      GO TO 8
    7 IF (XQ(N).GT.RCOEF(K,3)) GO TO 10
      ALP=ALPHA(K)
      YEM=EM(K)
      XEM=1./YEM
      IMDE=0
    8 DO 9 J=1,N
      XA(J)=(XQ(J)/ALP)
      IF (XA(J).LT.1.E-20) XA(J)=0.0
      IF (YEM.NE.1.) XA(J)=XA(J)**(XEM)
    9 CONTINUE
   10 DO 11 J=1,N
      AR(J)=XA(J)
      QS(J)=XQ(J)
   11 CONTINUE
      Q2=XQ(N)
      GO TO 20
   12 CALL UP(K,I)
      IF (ITYPE(K)-8) 13,14,15
```

SUBROUTINE FLOW(I)

```
13 Q2=QUP
   GO TO 20
14 CALL PULS(K)
   GO TO 20
15 IF (ITYPE(K)-9) 17,16,17
16 IN1=IN2
   IN2=QUP
   QOUT1=QOUT2
   QOUT2=CONST*((IN1+IN2)/2.-QOUT1)+QOUT1
   Q2=QOUT2
   STO(K)=PARAM(K,1)*Q2
   IF (STO(K).LT.SMAX(K)) GO TO 20
   SMAX(K)=STO(K)
   GO TO 20
17 IF (ITYPE(K)-10) 19,18,19
18 IP=(I-IJ+DEL5)/DEL5
   IF (IHYD(I1).EQ.0.OR.IP.GT.I3Q) GO TO 13
   I4Q=I4Q+1
   IF (IP.EQ.1) Q2=(DT/PTIME)*I4Q*QIH(IP)+QUP
   IF (IP.GT.1) Q2=(DT/PTIME)*I4Q*(QIH(IP)-QIH(IP-1))+QIH(IP-1)+QUP
   GO TO 20
19 Q2=QINPT(I1)+QUP
20 CONTINUE
   FLW(ICT)=Q2
   IF (T.LT.ECOMP) GO TO 2
   RETURN
   END
```

SUBROUTINE KWMOC1(AA,AB)

```
      SUBROUTINE KWMOC1(AA,AB)
C
C     SUBROUTINE KWMOC1 MUST BE CALLED ONCE PRECEDING A STORM FOR
C     EACH SEGMENT TO DEFINE INITIAL CONDITIONS USED
C     IN THE METHOD OF CHARACTERISTICS SOLUTION FOR FLOW ROUTING.
C
      REAL M,IN2
      COMMON /KWM/ X(100),A(100),NGRIDS
      COMMON /E2/ SMAX(99),IN2,S2O2(99),ALPHA,DTSX,XEM,M,IMDE,WX,METH
      COMMON /MOC/ XL,DTS,ITYPE
      COMMON /MOC1/ D1,D2,D3
C
C     ..... DEFINE CONSTANTS .....
      D1=ALPHA*M*DTS
      D2=M-1.
      D3=ALPHA*DTS
C
C     ..... DEFINE INITIAL CONDITIONS FOR STORM .....
      NGRIDS=6
      X(1)=0.
      X(NGRIDS)=XL
      A(1)=AA
      A(NGRIDS)=AB
C
      N=NGRIDS-1
      DX=XL/N
      DA=(AA-AB)/N
      DO 1 I=2,N
      X(I)=X(I-1)+DX
      A(I)=A(I-1)+DA
    1 CONTINUE
      RETURN
      END
```

SUBROUTINE KWMOC(QD,AD,AC,QLAT)

```
      SUBROUTINE KWMOC(QD,AD,AC,QLAT)
C
C     SUBROUTINE KWMOC - KINEMATIC WAVE ROUTING BY METHOD OF
C     CHARACTERISTICS
C     THIS SUBROUTINE OPERATES ON A TIME STEP BASIS. IT RETURNS
C     THE VALUES OF DISCHARGE (QD) AND AREA (AD) AT THE D/S END
C     OF THE SEGMENT AFTER A TIME STEP OF DTS (SECONDS).
C
      REAL M,IN2
      COMMON /KWM/ X(100),A(100),NGRIDS
      COMMON /E2/ SMAX(99),IN2,S202(99),ALPHA,DTSX,XEM,M,IMDE,WX,METH
      COMMON /MOC/ XL,DTS,ITYPE
      COMMON /MOC1/ D1,D2,D3
C
      ALAT=QLAT*DTS
C     CHECK THAT ARRAY DIMENSIONS WILL NOT BE EXCEEDED
      IF (NGRIDS.EQ.100) CALL DIMEN
C     IF QLAT AND A(1) EQ 0. DON'T ADD CHARACTERISTIC
      L=1
      IF (QLAT.LE.1.E-20.AND.A(1).EQ.0.) L=0
      NGRIDS=NGRIDS-(1-L)
C
C     ..... ADVANCE CHARACTERISTICS .....
      N=NGRIDS+2
      DO 5 K=1,NGRIDS
      I=N-K
      IF (M.EQ.1) GO TO 2
      IF ((ALAT*1.E3).GT.A(I-L)) GO TO 1
      X(I)=X(I-L)+D1*A(I-L)**D2
      A(I)=A(I-L)
      GO TO 4
    1 X(I)=X(I-L)+ALPHA/QLAT*((ALAT+A(I-L))**M-A(I-L)**M)
      GO TO 3
    2 X(I)=X(I-L)+D3
    3 A(I)=A(I-L)+ALAT
C
C     ..... KEEP TRACK OF LAST CHARACTERISTIC THAT LEAVES SEGMENT .....
    4 IF (X(I).GE.XL) II=I
    5 CONTINUE
C
C     ..... ASSIGN AREA AT U/S BOUNDARY .....
      A(1)=AC
C
C     ..... INTERPOLATE FOR AREA AT D/S BOUNDARY AND ASSIGN NGRIDS .....
      AD=A(II)-(A(II)-A(II-1))*((X(II)-XL)/(X(II)-X(II-1)))
      QD=ALPHA*AD**M
      NGRIDS=II
      X(NGRIDS)=XL
      A(NGRIDS)=AD
      IF (ITYPE.EQ.5.OR.ITYPE.EQ.6.OR.M.EQ.1.0.OR.NGRIDS.LE.2) GO TO 11
```

```
      SUBROUTINE KWMOC(QD,AD,AC,QLAT)
C
C     ..... TAKE CARE OF SHOCKS .....
      I=NGRIDS-1
    6 IF (X(I).LE.X(I-1)) GO TO 7
      GO TO 10
    7 K=I-1
      IF (A(K).EQ.0.) GO TO 8
      X(K)=(X(I)+X(K))/2.
      A(K)=(A(I)+A(K))/2.
    8 NGRIDS=NGRIDS-1
      DO 9 K=I,NGRIDS
      X(K)=X(K+1)
      A(K)=A(K+1)
    9 CONTINUE
   10 I=I-1
      IF (I.LE.2) GO TO 11
      GO TO 6
C
   11 RETURN
      END
```

SUBROUTINE DIMEN

```
      SUBROUTINE DIMEN
C
C     SUBROUTINE DIMEN DROPS OJT CHARACTERISTICS FROM A SEGMENT
C     IF THE DIMENSIONS OF THE X AND A ARRAYS ARE GOING TO BE EXCEEDED
C
      COMMON /KWM/ X(100),A(100),NGRIDS
      J=2
      DO 1 I=4,100,2
      J=J+1
      X(J)=X(I)
      A(J)=A(I)
    1 CONTINJE
      NGRIDS=51
      RETURN
      END
```

```
      SUBROUTINE KWFD1(DX)
C
C     SUBROUTINE KWFD1 MUST BE CALLED ONCE PRECEDING A STORM FOR
C     EACH SEGMENT WHERE THE NONLINEAR FINITE DIFFERENCE METHOD
C     IS USED FOR FLOW ROUTING. CONSTANTS USED IN THE FINITE
C     DIFFERENCE SOLUTION ARE DEFINED.
C
      REAL M,IN2
      COMMON /E2/ SMAX(99),IN2,S202(99),ALPHA,DTSX,XEM,M,IMDE,WX,METH
      COMMON /FD1/ C1,A1,A2,A3,A4,A5,A6,A7
      DATA WT/0.5/
      WT1=1.-WT
      A0=1./(DTSX*WX)
      C1=WT*A0
      A1=A0*WT1
      A2=(1.-WX)/WX
      A3=M-1.
      A4=M-2.
      A5=DX/WX
      A6=ALPHA*M
      A7=ALPHA*M*A3
      RETURN
      END
```

SUBROUTINE KWFD(J)

```
      SUBROUTINE KWFD(J)
C
C     SUBROUTINE KWFD SOLVES FOR THE UNKNOWN FLOW AREA XA(J) BY AN
C     ITERATIVE NONLINEAR FINITE DIFFERENCE SCHEME. NEWTON'S 2ND ORDER
C     METHOD IS USED TO SOLVE FOR THE ROOT OF THE NONLINEAR EQUATION.
C
      REAL M,IN2,ISEG
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /E2/ SMAX(99),IN2,S202(99),C0,DTSX,XEM,M,IMDE,WX,METH
      COMMON /E3/ DELTAT,NDB,QS(11),I3Q,I4Q,IJ,QIH(2881),QINPT(60)
      COMMON /FD/ XA(11),XQ(11),ISEG
      COMMON /FD1/ C1,A1,A2,A3,A4,A5,A6,A7
      DATA NITER/15/
      X0=XA(J)
      C2=A1*(XA(J-1)-AR(J-1))-C1*AR(J)+A2*(QS(J)-QS(J-1))-XQ(J-1)-QLAT*A
     15
      IF (M.EQ.1.) GO TO 4
      DO 1 I=1,NITER
      FX=C0*X0**M+C1*X0+C2
      FPX=A6*X0**A3+C1
      FPPX=A7*X0**A4
      IF (ABS(FX).LT.1.E-15) GO TO 2
      IF (ABS(FPX).LT.1.E-15) CALL MESSGE(1,XA(J),I,FPX,X0,J)
      H=-FPX/FX+.5*FPPX/FPX
      X=X0+1./H
      IF (X.LE.0.) GO TO 2
      IF (ABS(X-X0)/X0.LE..05) GO TO 3
      X0=X
    1 CONTINUE
      CALL MESSGE(2,XA(J),I,FX,X,J)
    2 X=X0
    3 XA(J)=X
      GO TO 5
    4 XA(J)=-C2/(C0+C1)
    5 XQ(J)=C0*XA(J)**M
      RETURN
      END
```

SUBROUTINE MESSGE(IGO,X0,I,F,X,J)

```
      SUBROUTINE MESSGE(IGO,X0,I,F,X,J)
C
C     SUBROUTINE MESSGE IS CALLED FROM WITHIN NEWTON'S METHOD
C     WHENEVER THE NUMBER OF ITERATIONS EXCEEDS THE SPECIFIED
C     LIMIT OR THE FIRST DERIVATIVE APPROACHES ZERO
C
      REAL ISEG
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /FD/ XA(11),XQ(11),ISEG
      J1=J-1
      GO TO (1,2), IGO
    1 WRITE (6,4) ISEG,T,J1,X0,I,F,X
      GO TO 3
    2 WRITE (6,5) ISEG,T,J1,X0,I,F,X
    3 RETURN
C
    4 FORMAT (//,32H *** DERIVATIVE APPROACHES ZERO ,/,11H SEGMENT = A4,
     1/,8H TIME = ,F6.1,/,15H GRID NUMBER = ,I3,/,17H INITIAL GUESS = ,E
     215.8,/,20H NO OF ITERATIONS = ,I3,/,14H DERIVATIVE = ,E15.8,/,10H
     3LAST A = ,E15.8)
    5 FORMAT (//,30H **** ITERATIONS EXCEED LIMIT ,/,11H SEGMENT = ,A4,/
     1,8H TIME = ,F6.1,/,15H GRID NUMBER = ,I3,/,17H INITIAL GUESS = ,E1
     25.8,/,20H NO OF INTERATIONS =,I3,/,8H F(A) = ,E15.8,/,10H LAST A =
     3 ,E15.8)
      END
```

SUBROUTINE LAT(K,I)

```
      SUBROUTINE LAT(K,I)
C              THIS SUBROUTINE COMPUTES LATERAL INFLOW FROM OVERLAND
C              FLOW SEGMENTS OR FROM RAINFALL
      INTEGER DEL5,TRYCT,B3,EO,FO,OPT,OPTION,RITE,DEL5P
      REAL ISEG,IUP,ILAT,IMPRET,IMPSTO,IMP
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /E1/ IMPRET(3),IMPSTO(3)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F2/ FLW(1442),FLAT(1442),FUP(1442)
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,N09,OPT,IOUT(2),NDAY,NDEL
     1S,NUFE,NUPO,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
C              COMPUTE LAT. INFLOW RATE FROM OVERLAND FLOW TO SEGMENT K
      QLAT=0.
      IF (ITYPE(K)-5) 1,3,1
    1 IF (ITYPE(K)-6) 2,3,2
    2 QPR=QSUML
      QLAT=FLAT(ICT)
      QSUML=QLAT
      QLAT=(QLAT+QPR)/2.
      RETURN
C              COMPUTE LATERAL INFLOW RATE FROM RAIN
    3 EP=0.0
      AP=0.0
      IPAR=I
      IF (KPSET(K).EQ.2) IPAR=IPAR+1441
      DO 4 III=1,NRG
      I2=NDAY*(III-1)+IK
      EP=EP+(RCOEF(K,III)*P(IPAR,III))/CORF
    4 AP=AP+(RCOEF(K,III)*(UPR(I2)/DEL5-IMPRET(III)))/CORF
      QLAT=PARAM(K,1)*(PARAM(K,2)*AP+((1.-PARAM(K,2))/RAT)*EP)/720.
C              THE CONSTANT 720 CONVERTS SQFT-IN/MINUTE TO CFS
      QSUML=QLAT
      RETURN
      END
```

```
      SUBROUTINE UP(K,I)
C           THIS SUBROUTINE COMPUTES UPSTREAM INFLOW TO SEGMENT K
      REAL ILAT,ISEG,IUP
      INTEGER DEL5
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F2/ FLW(1442),FLAT(1442),FUP(1442)
      QUP=0.
      QPR=QSUM
      IF (KK.EQ.KSEG(1)) GO TO 1
      QUP=FUP(ICT)
    1 CONTINUE
      QSUM=QUP
      IF (ITYPE(K).EQ.8.OR.ITYPE(K).EQ.9) GO TO 12
      IF (QUP-QMAX(K)) 7,7,2
    2 IF (QPR-QMAX(K)) 3,6,6
    3 PDT=(QUP-QMAX(K))/(QUP-QPR)
      STO(K)=STO(K)-(DTS*(QMAX(K)-QPR)/2.0)*(1.0-PDT)
      IF (STO(K)) 4,5,5
    4 STO(K)=0.
    5 STO(K)=STO(K)+(DTS*(QUP-QMAX(K))/2.0)*PDT
      GO TO 13
    6 STO(K)=STO(K)+(((QPR+QUP)/2.)-QMAX(K))*DTS
      GO TO 13
    7 IF (QPR-QMAX(K)) 8,8,10
    8 IF (STO(K)) 11,11,9
    9 STO(K)=STO(K)-(QMAX(K)-((QPR+QUP)/2.))*DTS
      IF (STO(K)) 11,13,13
   10 PDT=(QPR-QMAX(K))/(QPR-QUP)
      STO(K)=STO(K)+((QPR-QMAX(K))*PDT*DTS/2.0)-((QMAX(K)-QUP)*(1.0-PDT)
     1*DTS/2.0)
      IF (STO(K)) 11,13,13
   11 STO(K)=0.
   12 CONTINUE
      RETURN
   13 QUP=QMAX(K)
      IF (OSI.GT.0.0) GO TO 14
      OSI=20.
      J=I/DEL5
      IF (DEL5.GT.1) J=J+1
      WRITE (6,15) ISEG(K),J
   14 CONTINUE
      RETURN
```

```
      SUBROUTINE UP[illegible](K,I)
C
   15 FORMAT (1X,8HSEGMENT ,A4,22H IS SURCHARGING AT I= ,I6)
      END
```

SUBROUTINE INIT

```
      SUBROUTINE INIT
C              THIS SUBROUTINE INITIALIZES SEGMENT AT START OF STORM
      REAL IN2,ISEG,IUP,ILAT,IMP
      INTEGER DEL5,B3,EO,FO,OPT,OPTION,RITE,DEL5P
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /E2/ SMAX(99),IN2,S2O2(99),ALP,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,N08,QS(11),I3Q,I4Q,IJ,QIH(2881),QINPT(60)
      COMMON /E5/ S2(99,10),S(99,10),C(99,10)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,N09,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NUPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /LINRES/ QOUT2,CONST
      T=0.
      KINIT=0
      ECOMP=CORF
      K=KK
      QSUM=0.
      QSUML=0.
      SMAX(K)=0.0
      IN2=0.0
      IF (ITYPE(K).GE.7) GO TO 2
      ALP=ALPHA(K)
      DTSX=DTS/DX(K)
      YEM=EM(K)
      XEM=1./YEM
      STO(K)=0.0
      N=NDX(K)+1
      METH=IMETH(K)
      DO 1 J=1,N
      QS(J)=0.0
    1 AR(J)=0.0
      RETURN
    2 IF (KIN.EQ.1) RETURN
      IF (ITYPE(K).NE.8) GO TO 3
      CALL TABLE(K,PARAM(K,2),S2,S,C,Q2,NDX(K))
      S2O2(K)=PARAM(K,2)/DELTAT+Q2/2.
    3 STO(K)=PARAM(K,2)
      IF (ITYPE(K).NE.9) GO TO 5
      QOUT2=0.
      CRES=DELTAT/PARAM(K,1)
      IF (CRES.LE.2.) GO TO 4
      DDMIN=2.*PARAM(K,1)
      WRITE (6,6) K,DDMIN
```

SUBROUTINE INIT

```
    4 CONST=(2.*CRES)/(2.+CRES)
    5 RETURN
C
    6 FORMAT (1H ,40HROUTING INTERVAL FOR DETENTION RESERVOIR,I3,42H IS
     1TOO LARGE, REDUCE TO A VALUE LESS THAN,F6.3,6H HOURS)
      END
```

SUBROUTINE PULS(K)

```
      SUBROUTINE PULS(K)
C              THIS SUBROUTINE PERFORMS MODIFIED PULS ROUTING
      REAL IN1,IN2
      COMMON /C3/ IPRNT,I,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSJML,STO(99)
      COMMON /E2/ SMAX(99),IN2,S202(99),ALPH,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NOB,QS(11),I3Q,I4Q,IJ,QIH(2881),QINPT(60)
      COMMON /E4/ WV(99,10),S1(99,10),C1(99,10)
      IN1=IN2
      IN2=QSJM
      AVIN=(IN1+IN2)/2.
      S202(K)=S202(K)+AVIN
      CALL TABLE(K,S202(K),WV,S1,C1,Q2,NDX(K))
      IF (Q2.LT.0.0) Q2=0.0
      STO(K)=(S202(K)-Q2/2.)*DELTAT
      S202(K)=S202(K)-Q2
      IF (STO(K).LT.SMAX(K)) GO TO 1
      SMAX(K)=STO(K)
    1 CONTINUE
      RETURN
      END
```

SUBROUTINE TABLE(K,F1,F3,S3,C3,F2,J)

```
      SUBROUTINE TABLE(K,F1,F3,S3,C3,F2,J)
C             THIS SUBROUTINE PERFORMS LINEAR INTERPOLATION FOR
C              MODIFIED PULS ROUTING
      DIMENSION F3(99,10), S3(99,10), C3(99,10)
      DO 1 I=2,J
      IF (F1.LT.F3(K,I)) GO TO 2
    1 CONTINUE
      I=J
    2 F2=S3(K,I)*F1+C3(K,I)
      RETURN
      END
```

SUBROUTINE CTCHMT

```
      SUBROUTINE CTCHMT
C     ******************************************************************
C     *                     CATCHMENT  ROUTINE                         *
C     ******************************************************************
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(50)
      DIMENSION Q2(99,10)
      INTEGER B3,EO,FO,OPT,OPTION,RITE,DEL5P,DEL5
      REAL ISEG,IUP,ILAT,IMP,IN2
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /E2/ SMAX(99),IN2,S202(99),ALPH,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NO8,QS(11),I32,I42,IJ,QIH(2881),QINPT(60)
      COMMON /E4/ WV(99,10),S1(99,10),C1(99,10)
      COMMON /E5/ S2(99,10),S(99,10),C(99,10)
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECDS,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NUPO,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z4/ DE(7310),UD(2881),X2(15),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      EQUIVALENCE (Q2(1,1),P(1,1))
      READ (5,20) NSEG,DT,RAT,NRG,IMP,ALPADJ,WX
      IF (NSEG.LE.99) GO TO 1
      WRITE (6,28)
      STOP
    1 IF (RAT.LT.1.0) RAT=1.0
      IF (ALPADJ.LE.0.0) ALPADJ=1.0
      DTS=DT*60.
      IDTS=INT(DTS+.001)
      HEAD1(18)=NSEG
      HEAD1(19)=IDTS
      WRITE (6,21) NSEG,DT,NRG,NPAR,IMP,RAT,ALPADJ,WX
C              CHECK FOR VALID DT
      CORFS=CORF*60.
      ICORF=INT(CORFS+0.001)
      IF (MOD(ICORF,IDTS).EQ.0) GO TO 2
      WRITE (6,31)
      STOP
    2 WRITE (6,22)
      NO8=0
      NO9=10
      DO 8 I=1,NSEG
      I21=I+21
      READ (5,26) ISEG(I),(IUP(I,J),J=1,3),(ILAT(I,J),J=1,4),ITYPE(I),IM
```

```
 1ETH(I),IPR(I),NDX(I),FLGTH(I),SLOPE(I),FRN(I),(PARAM(I,J),J=1,2),K
 2PSET(I),HEAD1(I21),(RCOEF(I,J),J=1,3)
  IF (ITYPE(I).EQ.15.OR.ITYPE(I).EQ.16) GO TO 6
  IF (ITYPE(I).EQ.4) RCOEF(I,1)=RCOEF(I,1)*ALPADJ
  IF (ITYPE(I).EQ.8) NO8=NO8+1
  IF (ITYPE(I).EQ.5.AND.KPSET(I).LT.1) KPSET(I)=1
  IF (ITYPE(I).EQ.6.AND.KPSET(I).LT.1) KPSET(I)=1
  IF (NO8.LE.10) GO TO 3
  WRITE (6,30)
  STOP
3 IF (ITYPE(I).EQ.8) IRES(NO8)=I
  IF (ITYPE(I).EQ.9) NO9=NO9+1
  IF (ITYPE(I).EQ.9) IRES(NO9)=I
  IF (NDX(I)) 4,4,5
4 NDX(I)=10
5 DX(I)=FLGTH(I)/NDX(I)
  IF (NDX(I).LE.10) GO TO 7
  WRITE (6,29) ISEG(I)
  STOP
6 WRITE (6,17)
  STOP
7 IF (I.EQ.51) WRITE (6,22)
8 WRITE (6,27) ISEG(I),(IUP(I,J),J=1,3),(ILAT(I,J),J=1,4),ITYPE(I),I
 1METH(I),IPR(I),NDX(I),FLGTH(I),SLOPE(I),FRN(I),(PARAM(I,J),J=1,2),
 2KPSET(I),(RCOEF(I,J),J=1,3)
  DELTAT=DT/60.
  IF (NO8.EQ.0) GO TO 14
C          SET UP FOR MOD-PULS ROUTING
  DO 13 I2=1,NO8
  K=IRES(I2)
  DDMIN=DELTAT
  J=NDX(K)
  DO 9 II=1,J
  READ (5,19) O2(K,II),S2(K,II)
  WV(K,II)=S2(K,II)/DELTAT+O2(K,II)/2.
  TEST=WV(K,II)-O2(K,II)
  IF (TEST.GE.0.0) GO TO 9
  DDT=S2(K,II)/(O2(K,II)/2.0)
  IF (DDT.LT.DDMIN) DDMIN=DDT
  WRITE (6,23) K,DDMIN
9 CONTINUE
  DO 12 II=2,J
  IIM=II-1
  IF (O2(K,II).LE.O2(K,IIM)) GO TO 10
  IF (S2(K,II).GT.S2(K,IIM)) GO TO 11
10 WRITE (6,18)
  STOP
11 S1(K,II)=(O2(K,II)-O2(K,II-1))/(WV(K,II)-WV(K,II-1))
  C1(K,II)=O2(K,II)-S1(K,II)*WV(K,II)
  S(K,II)=(O2(K,II)-O2(K,II-1))/(S2(K,II)-S2(K,II-1))
```

SUBROUTINE DTCHMT

```
      C(K,II)=O2(K,II)-S(K,II)*S2(K,II)
   12 CONTINUE
      WRITE (6,24) ISEG(K)
      WRITE (6,25) (O2(K,II),S2(K,II),WV(K,II),II=1,J)
   13 CONTINUE
   14 IF (NRG.EQ.3) GO TO 16
C           SET THEISSEN COEFFICIENTS FOR UNUSED RAIN GAGES TO ZERO
      NRG1=NRG+1
      DO 15 J=NRG1,3
      DO 15 K=1,NSEG
      IF (ITYPE(K).EQ.4) GO TO 15
      RCOEF(K,J)=0.0
   15 CONTINUE
   16 CONTINUE
      RETURN
C
   17 FORMAT (1H ,39HERROR IN SEGMENT DATA FOR TYPE 15 OR 16)
   18 FORMAT (1X,29HERROR IN OUTFLOW-STORAGE DATA)
   19 FORMAT (3F10.0)
   20 FORMAT (I5,F5.0,F5.0,I5,2F5.0,F5.2)
   21 FORMAT (//50X,20HNUMBER OF SEGMENTS =,I4/50X,4HDT =,F6.2,8H MINUTE
     1S/50X,22HNUMBER OF RAIN GAGES =,I2/50X,22HNUMBER OF SOIL TYPES =,I
     22/50X,22HIMPERVIOUS RETENTION =,F5.2,7H INCHES/50X,5HRAT =,F7.3/50
     3X,8HALPADJ =,F5.2/50X,4HWX =,F5.2)
   22 FORMAT (1H1,64X,6HLENGTH,10X,9HROUGHNESS,20X,19HTHIESSEN COEFFICNT
     1S/8H SEGMENT,1X,17HUPSTREAM SEGMENTS,3X,17HADJACENT SEGMENTS,1X,4H
     2TYPE,1X,4HMETH,1X,3HIPR,1X,3HNDX,1X,6H(FEET),3X,5HSLOPE,2X,9HPARAM
     3ETER,2X,15HOTHER PARAMETERS,I4,4(1X,I4))
   23 FORMAT (1H ,40HROUTING INTERVAL FOR DETENTION RESERVOIR,I3,42H IS
     1TOO LARGE, REDUCE TO A VALUE LESS THAN,F6.3)
   24 FORMAT (1H0,9X,18HRESERVOIR SEGMENT ,A4)
   25 FORMAT (1H0,5X,7HOUTFLOW,5X,7HSTORAGE,5X,10HS2/DT+O2/2,//(1X,3(F9.
     12,4X)))
   26 FORMAT (8A4,I2,2I1,I2,5F5.0,I2,T1,A4,T66,3F5.0)
   27 FORMAT (2X,A4,3X,3(1X,A4),3X,4(1X,A4),I3,I5,2I4,F8.1,F8.4,1X,E10.3
     1,F8.3,F9.3,I2,3X,5F5.2)
   28 FORMAT (1H0,25HNSEG SHOULD NOT EXCEED 99)
   29 FORMAT (1H0,16HNDX FOR SEGMENT ,A4,15H IS MORE THAN 10)
   30 FORMAT (1H0,34HA MAX. OF 10 PULS SEGMENTS ALLOWED)
   31 FORMAT (1H0,15HINVALID DT USED)
      END
```

SUBROUTINE INPUT1

```
      SUBROUTINE INPUT1
C     ******************************************************************
C     *                   CARD INPUT  ROUTINE1                         *
C     ******************************************************************
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(60)
      INTEGER MOUT(2),B3,E0,F0,RITE,DEL5P,TRYCT,MN(13)
      INTEGER PCCN,DCCN,RODYS,DEL5,DPD,DED,DATERF,DATERL,BTIME,DATE
      INTEGER STA,STAD,STAD1,STAUP,STAUP1,STAP,STAP1,STAE,STAE1
      INTEGER YR,MO,DY,BYR,BMO,BDY,EYR,EMO,EDY,CN,CT,CODE,OPTION,OPT
      INTEGER NOUD(150),YN(99),UPD,UDD
      REAL ISEG,IUP,ILAT,IRR,IMP
      COMMON /C2/ STAD1,STAD
      DIMENSION TITLD(50), TITLUP(50), TITLP(50), TITLE(50)
      DIMENSION IRR(12)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /D1/ DP(7310),RODYS,NSD,IUNIT,NDYS,NDTS,ICK(60)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECDS,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      COMMON /Z1/ B3,DA,E0,F0,NK,NN,ND,IMP,KNN,ND9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NUPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      DATA MN/0,31,59,90,120,151,181,212,243,273,304,334,365/
      DATA MOUT/4HLIST,4H  NO/
      DATA PCCN/0/,DCCN/0/,UPD/0/,UDD/0/
      DO 1 J=1,2
      IOUT(J)=MOUT(J)
    1 CONTINUE
      B3=0
C              JULIAN DATE FOR JAN. 1 OF EACH YEAR
C              STARTING FROM JAN. 1, 1901
      YN(1)=0
      DO 2 I=2,99
      YN(I)=YN(I-1)+365
      IF (MOD(I-1,4).EQ.0) YN(I)=YN(I)+1
    2 CONTINUE
      NRG=0
      DO 3 I=1,12
    3 IRR(I)=0.0
      NDAY=0
      IUNIT3=IUNIT*3
      DO 4 I=1,IUNIT3
    4 UPR(I)=0.0
      DO 5 I=1,IUNIT
    5 UD(I)=0.0
      DO 6 I=1,NDYS
```

```
      DP(I)=0.0
    6 DE(I)=0.0
C            OPTION=IOUT(1) LISTS INPUT DATA.
      READ (5,64) OPTION,OPT,NOPT1,JPERM,JRECDS,JPUN
      IF (NOPT1.EQ.0) GO TO 8
      READ (5,62) (IRR(I),I=1,12)
      DO 7 I=1,12
    7 IRR(I)=IRR(I)/7.
      WRITE (6,63) (IRR(I),I=1,12)
C            READ-IN STA.NOS. AND NAMES,DA,UNIT TIME, BEGIN AND END
C            DATES.   STATION NUMBERS READ 2A4 FOR IBM WORD SIZE.
    8 READ (5,65) STAD1,STAD,TITLD,DA,(HEAD1(I),I=1,15)
      READ (5,65) STAP1,STAP,TITLP
      READ (5,65) STAE1,STAE,TITLE
      READ (5,67) BYR,BMO,BDY,EYR,EMO,EDY
      HEAD1(20)=BYR*10000+BMO*100+BDY
      HEAD1(21)=EYR*10000+EMO*100+EDY
C            INITIALIZE VARIABLES
      NUDD=0
      NUPD=0
      DO 9 I=1,150
      NOUD(I)=0
    9 NOUP(I)=0
   10 UPD=0
      PCCN=0
      NRG=NRG+1
      IF (NRG.EQ.1) GO TO 12
      WRITE (6,80)
      WRITE (IFP) K4ST,K4DAY,(UPR(I),I=K4ST,K4DAY)
      DO 11 I=1,K4DAY
   11 UPR(I)=0.0
   12 IFP=IFILEP+NRG-1
      READ (5,66) STAUP1,STAUP,TITLUP,PTIME
C            DETERMINE JULIAN DATE FOR BEGIN AND END OF RECORD.
      IF (MOD(BYR,4).NE.0) GO TO 13
      IF (BMO-2) 13,13,14
   13 LEAP=0
      GO TO 15
   14 LEAP=1
   15 DATERF=YN(BYR)+MN(BMO)+BDY+LEAP
      IF (MOD(EYR,4).NE.0) GO TO 16
      IF (EMO-2) 16,16,17
   16 LEAP=0
      GO TO 18
   17 LEAP=1
   18 DATERL=YN(EYR)+MN(EMO)+EDY+LEAP
C            CALCULATE NUMBER OF DAYS OF RECORD
      RODYS=DATERL-DATERF+1
      IF (RODYS.LE.NDYS) GO TO 19
      WRITE (6,78) NDYS
```

```
      STOP
   19 WRITE (6,68) STAD1,STAD,TITLD,STAUP1,STAUP,TITLUP,STAP1,STAP,TITLP
     1,STAE1,STAE,TITLE,DA,PTIME,BMO,BDY,BYR,DATERF,EMO,EDY,EYR,DATERL
      WRITE (6,69) JPUN,JPERM,OPT
C             COMPUTE TIME PARAMETERS
C             NDAY IS SET TO STARTING TIME ELEMENT FOR A RAIN GAGE
      CORF=5.0
      IF (PTIME.LT.4.9) CORF=1.0
      IF (PTIME.GT.14.9) CORF=15.0
      PDEL=PTIME/1440.0
C     SET LIMIT ON NUMBER OF CONSECUTIVE DAYS
      NDELS=1440/PTIME
      NOUT=IUNIT/NDELS
C     TO ALLOW SPACE FOR 2 SOIL TYPES
      IF (PTIME.GE.5.0) NOUT=NOUT/2
      ND=1440/CORF
      NDAY=NOUT*NDELS*(NRG-1)
      K4ST=NDAY+1
      NUPD=0
      BTIME=PTIME
      DPD=DATERF-1
      DED=DPD
      DEL5=BTIME
      DEL5=DEL5/CORF
      DEL5P=DEL5+1
C             READ IN DATA FROM A CARD
C             PERFORM EDIT CHECK ON STATION NO., UNIT TIME, AND
C             CHRONOLOGICAL SEQUENCE OF CARD
C             ENTER DATA INTO ARRAYS ACCORDING TO CODING
C             CHECK LAST FOUR CHARACTERS OF STATION NOS. ONLY
C             DATES FOR CODES 1 AND 2
      IF (OPTION.EQ.IOUT(1)) WRITE (6,80)
      KP=0
      NU=1
      NSD=1
   20 CONTINUE
      IF (CORF.GT.4.9) GO TO 21
      READ (5,70) STA1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      GO TO 22
   21 READ (5,71) STA1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
   22 IF (CODE.EQ.8) GO TO 10
      IF (CODE.NE.9) GO TO 26
      IF (OPT.EQ.1) GO TO 24
      WRITE (IFILED) K4DAY,(JD(I),I=1,K4DAY)
      DO 23 I=1,K4DAY
   23 JD(I)=0.0
      GO TO 45
   24 WRITE (IFP) K4ST,K4DAY,(JPR(I),I=K4ST,K4DAY)
      DO 25 I=1,K4DAY
   25 JPR(I)=0.0
```

```
      ICK(NSD)=NJ
      GO TO 45
   26 IF (MOD(YR,4).NE.0) GO TO 27
      IF (MO-2) 27,27,28
   27 LEAP=0
      GO TO 29
   28 LEAP=1
   29 DATE=YN(YR)+MN(MO)+DY+LEAP
      IF (CODE.EQ.2) GO TO 36
C              DATA ENTRIES FOR CODE 1
      IF (STA.NE.STAUP) GO TO 56
      IF (CT.NE.BTIME) GO TO 56
      IF (DATE-UPD) 56,33,30
   30 NUPD=NUPD+1
      IHYD(NUPD)=MO
      KOUT(NUPD)=DY
      IPL(NUPD)=YR
      NOUP(NUPD)=DATE
      UPD=DATE
      PCCN=CN
      IF (NUPD.EQ.1) GO TO 34
      ITES=NOUP(NUPD)-NOUP(NUPD-1)
      IF (ITES.EQ.1) GO TO 32
      ICK(NSD)=NJ
      NU=1
      WRITE (IFP) K4ST,K4DAY,(UPR(I),I=K4ST,K4DAY)
      NSD=NSD+1
      DO 31 I=1,K4DAY
   31 UPR(I)=0.0
      GO TO 34
   32 NU=NJ+1
      IF (NU.LE.NOUT) GO TO 34
      WRITE (6,77) NOUT,PTIME
      STOP
   33 IF (CN.LE.PCCN) GO TO 56
      PCCN=CN
   34 K4DAY=NDELS*(NU-1)+12*CN+NDAY
      KK=K4DAY-11
      I=0
      DO 35 K=KK,K4DAY
      I=I+1
      X2(I)=X2(I)/100.0
   35 UPR(K)=X2(I)
      IF (OPTION.NE.IOUT(1)) GO TO 20
      WRITE (6,72) STAUP1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      GO TO 20
C              DATA ENTRIES FOR CODE 2
   36 IF (STA.NE.STAD) GO TO 56
      IF (CT.NE.BTIME) GO TO 56
      IF (DATE-UDD) 56,42,37
```

SUBROUTINE INPUT1

```
   37 NUDD=NUDD+1
      NOUD(NUDD)=DATE
      UDD=DATE
      OCCN=CN
      IF (NUDD.GT.1) GO TO 39
      ICK(NSD)=NJ
      NU=1
      WRITE (IFP) K4ST,K4DAY,(UPR(I),I=K4ST,K4DAY)
      DO 38 I=1,K4DAY
   38 UPR(I)=0.0
      GO TO 43
   39 ITES=NOUD(NUDD)-NOUD(NUDD-1)
      IF (ITES.EQ.1) GO TO 41
      NU=1
C             IF AT END OF A SEQUENCE OF STORM DAYS,
C             WRITE UD TO IFILED
      WRITE (IFILED) K4DAY,(UD(I),I=1,K4DAY)
      DO 40 I=1,K4DAY
   40 UD(I)=0.0
      GO TO 43
   41 NU=NU+1
      GO TO 43
   42 IF (CN.LE.OCCN) GO TO 56
      OCCN=CN
   43 K4DAY=NDELS*(NU-1)+12*CN
C               ENTER DATA INTO ARRAYS ACCORDING TO CODE TYPE
      KK=K4DAY-11
      I=0
      DO 44 K=KK,K4DAY
      I=I+1
   44 UD(K)=X2(I)
      IF (OPTION.NE.IOUT(1)) GO TO 20
      WRITE (6,72) STAD1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      GO TO 20
C               DATES FOR CODES 3+4
   45 READ (5,73) STAD1,STA,YR,MO,CN,(X2(I),I=1,16),CODE
      IF (CODE.EQ.9) GO TO 57
      IF (CODE.EQ.4) GO TO 47
      DO 46 I=1,16
      IF (X2(I).GE.IRR(MO).OR.X2(I).LT.0.0) GO TO 46
      X2(I)=IRR(MO)
   46 CONTINUE
   47 CONTINUE
      IF (OPTION.NE.IOUT(1)) GO TO 48
      WRITE (6,74) STAD1,STA,YR,MO,CN,(X2(I),I=1,16),CODE
   48 CONTINUE
      LEAP=0
      IF (MOD(YR,4).EQ.0) LEAP=1
      IF (CN.LT.2) GO TO 50
      DATE=YN(YR)+MN(MO)+17
```

SUBROUTINE INPUT1

```
      IF (MO.LE.2) GO TO 49
      DATE=DATE+LEAP
   49 II=YN(YR)+MN(MO+1)-DATE+1
      IF (MO.LE.1) GO TO 52
      II=II+LEAP
      GO TO 52
   50 DATE=YN(YR)+MN(MO)+1
      IF (MO.LE.2) GO TO 51
      DATE=DATE+LEAP
   51 II=15
   52 IF (CODE.EQ.4) GO TO 54
C           DATA ENTRIES FOR CODE 3
      IF (STA.NE.STAP) GO TO 56
      IF (DATE.LE.DPD) GO TO 56
      DPD=DATE
      II=II+DPD-DATERF
      KK=DPD-DATERF+1
      I=0
      DO 53 K=KK,II
      I=I+1
C           CHECK FOR GAP IN DAILY RECORD
      IF (X2(I).NE.99.99) GO TO 53
C           IF THERE IS A GAP SET UP INDICATORS FOR THIS
      KP=KP+1
      INDP(KP)=K
      X2(I)=0.0
   53 DP(K)=X2(I)
      GO TO 45
C           DATA ENTRIES FOR CODE 4
   54 IF (STA.NE.STAE) GO TO 56
      IF (DATE.LE.DED) GO TO 56
      DED=DATE
      II=II+DED-DATERF
      KK=DED-DATERF+1
      I=0
      DO 55 K=KK,II
      I=I+1
   55 DE(K)=X2(I)
      GO TO 45
C           PRINT CARD WITH INCONSISTENT DATA
   56 WRITE (6,75) MO,YR,CN,CODE
      STOP
   57 CONTINUE
      INDP(KP+1)=II+1
      I=0
      J=1
C           CHECK FOR INPUT DATA ERRORS
      IDATE=IPL(NUPD)*10000+IHYD(NUPD)*100+KOUT(NUPD)
      IF (HEAD1(21).GT.IDATE) GO TO 58
      WRITE (6,79)
```

```
      STOP
   58 L=NOUD(1)
      M=NOUP(1)
      K=0
      IF (OPT.EQ.1) RETURN
      IF (L.EQ.M) GO TO 60
   59 WRITE (6,76) K,L,M
      STOP
   60 DO 61 K=DATERF,DATERL
      I=I+1
      IF (DP(I).GE.0.0) GO TO 61
      IF (K.NE.L) GO TO 59
      IF (K.NE.M) GO TO 59
      J=J+1
      L=NOUD(J)
      M=NOUP(J)
   61 CONTINUE
      RETURN

   62 FORMAT (12F5.3)
   63 FORMAT (1H ,1X,36HDAILY IRRIGATION LOADS IN INCHES ARE/1H ,2X,4HJA
     1N.,2X,4HFEB.,1X,5HMARCH,1X,5HAPRIL,3X,3HMAY,2X,4HJUNE,2X,4HJULY,2X
     2,4HAUG.,1X,5HSEPT.,2X,4HOCT.,2X,4HNOV.,2X,4HDEC./1H ,12(1X,F5.3))
   64 FORMAT (A4,2I1,I2,I7,5X,I2)
   65 FORMAT (2A4,50A1,F7.3,T1,14A4,A2)
   66 FORMAT (2A4,50A1,F5.0)
   67 FORMAT (20X,3I3,3X,3I3)
   68 FORMAT (1H0,22HDISCHARGE STATION     ,2A4,50A1/1H ,20HUNIT PRECIP.
     1 STATION,2X,2A4,50A1/1H ,22HDAILY PRECIP. STATION ,2A4,50A1/1H ,18
     2HPAN-EVAPO. STATION,4X,2A4,50A1/1H ,14HDRAINAGE AREA=,F7.3,8H SQ.
     3MI./1H ,16HUNIT DATA ARE IN,F9.3,18H MINUTE INCREMENTS/1H ,29HTHE
     4PERIOD OF RECORD IS FROM ,I2,1H-,I2,1H-,I2,6H (DAY=,I7,5H) TO ,I2,
     51H-,I2,1H-,I2,6H (DAY=,I7,1H))
   69 FORMAT (1H0,6HUPON =,I3/1H ,8HUPERM = ,I1/1H ,5HOPT =,I2)
   70 FORMAT (2A4,4I2,I3,12F5.0,I1)
   71 FORMAT (2A4,5I2,12F5.0,1X,I1)
   72 FORMAT (1H ,2A4,5I3,12F8.2,I3)
   73 FORMAT (2A4,2I2,I1,16F4.2,2X,I1)
   74 FORMAT (1H ,2A4,2I3,I2,16(1X,F4.2),I3)
   75 FORMAT (1H0,29HERROR ON A UNIT OR DAILY CARD/1H ,35HDATE,CN, AND C
     1ODE OF THIS CARD ARE:,5X,I4,1H/,I2,5X,3HCN=,I4,5X,5HCODE=,I2)
   76 FORMAT (20X,3I6/1H0,27HUNIT DAYS SPECIFIED ON UNIT,28HAND DAILY CA
     1RDS DO NOT MATCH)
   77 FORMAT (1H ,37HPROGRAM IS DIMENSIONED FOR A MAX. OF ,I2,23H CONSEC
     1UTIVE STORM DAYS,11H FOR PTIME=,F5.1)
   78 FORMAT (1H0,30HPERIOD OF RECORD CANNOT EXCEED,I5,5H DAYS)
   79 FORMAT (1H0,56HEND OF RECORD MUST BE AT LEAST 1 DAY AFTER LAST UNI
     1T DAY)
   80 FORMAT (1H1)
      END
```

SUBROUTINE INPUT2(JPERM,JRECDS)

```
      SUBROUTINE INPUT2(JPERM,JRECDS)
      INTEGER TRYCT,RODYS,DEL5,OPT,EO,FO,B3,OPTION,RITE,TESTNO(60)
      INTEGER NF(60),NFE(60),NFS(60)
      REAL ISEG,IUP,ILAT,IN2,IMP,POBS(60,3)
      DIMENSION K1(60), K2(60)
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /D1/ OP(7310),RODYS,NSD,IUNIT,NDYS,NDTS,ICK(60)
      COMMON /E2/ SMAX(99),IN2,S2O2(99),ALPHDTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NO8,QS(11),I3Q,I4Q,IJ,QIH(2881),QINPT(60)
      COMMON /E4/ WV(99,10),S1(99,10),C1(99,10)
      COMMON /E5/ S2(99,10),S(99,10),C(99,10)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     15,NOFE,NJPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z3/ K1,K2,NF,NFE,NFS,POBS,TESTNO
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      INTVAL=(PTIME+0.001)/DT
      NOFE=1
      I1=1
      NSDD=0
C             INITIALIZE VARIABLES
      DO 1 I=1,60
      FPK(I)=0.0
      FVOL(I)=0.0
    1 CONTINUE
C             FOR EACH SET OF EVENTS, THE NO. OF EVENTS IN THE SET
C             IS ENTERED FOR AS MANY TIMES AS THERE ARE EVENTS IN THE
C             SET. A SET OF EVENTS CONSISTS OF A FRACTION OF A DAY OR
C             A SERIES OF CONTINUOUS DAYS.
      READ (5,12) I,(NF(K),K=1,I)
      WRITE (6,13) I,(NF(K),K=1,I)
C             BEGIN ANALYSIS OF A SET OF EVENTS
    2 DO 3 I=I1,NUPD
      IF (NOUP(I+1).NE.(NOUP(I)+1)) GO TO 4
    3 CONTINUE
    4 NFI1=NF(NOFE)
      I4=I1
      I1=I+1
      NSDD=NSDD+1
C             BEGIN ANALYSIS OF A STORM
    5 READ (5,11) KS,KE,VOLI,DISCH
```

```
      SUBROUTINE INPUT2(JPERM,JRECDS)
C          DETERMINE NO. OF RECORDS FOR STORM
      JRCS=(KE-KS+1)*INTVAL
      IF (JRCS.LT.NDTS) GO TO 6
      WRITE (6,20) NOFE,NDTS
      STOP
    6 JRCS=JRCS/120+1-(1-MIN0(1,MOD(JRCS,120)))
      JRCS=JRCS*NSEG
      IF (DISCH.EQ.0.0) WRITE (6,14) NOFE,KS,KE,JRCS
      IF (DISCH.GT.0.0) WRITE (6,15) NOFE,KS,KE,JRCS,DISCH
      ITES=NDELS*ICK(NSDD)
      IF (KE.LE.ITES) GO TO 7
      WRITE (6,22) NOFE,ITES
      STOP
    7 FVOL(NOFE)=VOLI
      QINPT(NOFE)=DISCH
      ITEST(NOFE)=JRCS
      K1(NOFE)=KS
      K2(NOFE)=KE
      LJ=KS
      LM=KE
      NFI1=NFI1-1
      KS=(KS-1)*DELS+1
      KE=KE*DELS
      NFS(NOFE)=KS
      NFE(NOFE)=KE
      DO 8 III=1,NRG
    8 POBS(NOFE,III)=0.0
C          NDATE IS USED FOR PRINTING OUT THE DATE OF STORM
      I3=I4+LJ/NDELS
      NDATE(NOFE,1)=IHYD(I3)
      NDATE(NOFE,2)=KOUT(I3)
      NDATE(NOFE,3)=IPL(I3)
      NOFE=NOFE+1
C          CHECK FOR MORE STORMS IN SET OF EVENTS
      IF (NFI1.GT.0) GO TO 5
C          CHECK TO SEE IF ALL EVENTS HAVE BEEN ANALYZED
      IF (NUPD.GE.I1) GO TO 2
      NOFE=NOFE-1
      READ (5,12) (KOUT(I),I=1,NOFE)
      WRITE (6,16) (KOUT(I),I=1,NOFE)
      READ (5,12) (TESTNO(I),I=1,NOFE)
      WRITE (6,17) (TESTNO(I),I=1,NOFE)
      KNN=0
      READ (5,12) (IPL(I),I=1,NOFE)
      WRITE (6,18) (IPL(I),I=1,NOFE)
      READ (5,12) (IHYD(I),I=1,NOFE)
      NRC=0
      WRITE (6,19) (IHYD(I),I=1,NOFE)
      DO 10 I=1,NOFE
      IF (IPL(I).EQ.1.AND.KOUT(I).EQ.0) IPL(I)=0
```

```
      SUBROUTINE INPUT2(JPERM,JRECDS)
      IF (KOUT(I).EQ.0) GO TO 9
      IF (JPERM.EQ.1) NRC=NRC+ITEST(I)
      IF (JPERM.EQ.0.AND.NRC.LT.ITEST(I)) NRC=ITEST(I)
    9 IF (TESTNO(I).NE.1) GO TO 10
      KNN=KNN+1
   10 CONTINUE
      NRC=NRC+3*JPERM
      JRECDS=NRC
      WRITE (6,21) JRECDS
      RETURN
C
   11 FORMAT (2I4,F7.2,F5.2)
   12 FORMAT (40I2)
   13 FORMAT (//1H0,9HTHERE ARE,I4,32H STORM EVENTS GROUPED AS FOLLOWS,1
     1016/5(46X,10I6/))
   14 FORMAT (1H ,9HSTORM NO.,I3,22H STARTS AT TIME PERIOD,I5,12H AND EN
     1DS AT,I5,7X,31HRECORDS REQUIRED FOR ROUTING = ,I4)
   15 FORMAT (1H ,9HSTORM NO.,I3,22H STARTS AT TIME PERIOD,I5,12H AND EN
     1DS AT,I5,7X,31HRECORDS REQUIRED FOR ROUTING = ,I4,8X,7HDISCH =,F7.
     23,4H CFS)
   16 FORMAT (1H0,27HDETAILED OUTPUT FOR STORMS ,30I3/28X,30I3)
   17 FORMAT (1H0,34HSTORM EVENTS IN THE OBJ. FCT. ARE ,30I3/35X,30I3)
   18 FORMAT (1H0,29HTHE STORM EVENTS PLOTTED ARE ,30I3/30X,30I3)
   19 FORMAT (1H0,29HINPUT HYDROGRAPHS FOR STORMS ,30I3/30X,30I3)
   20 FORMAT (1H0,25HNUMBER OF DT'S FOR STORM ,I3,8H EXCEEDS,I5)
   21 FORMAT (1H0,47HNUMBER OF RECORDS USED FOR DIRECT ACCESS FILE =,I5)
   22 FORMAT (1H0,12HKE FOR STORM,I3,18H SHOULD NOT EXCEED,I5)
      END
```

SUBROUTINE PROUT(IV,PAC)

```
      SUBROUTINE PROUT(IV,PAC)
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(60)
      INTEGER RITE,B3,EO,FO,OPTION,TRYCT,DEL5P,TESTNO(60)
      INTEGER NF(60),NFE(60),NFS(60),OPT,E,F,OPTNO
      REAL SMSB(3,2),BMSB(3,2),POBS(60,3),IMP
      DIMENSION K1(60), K2(60)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECDS,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NJPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      COMMON /Z3/ K1,K2,NF,NFE,NFS,POBS,TESTNO
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),OF,IEAC
      IF (IV.GT.1) GO TO 3
      LL=0
      WRITE (6,12)
      DO 2 I=1,NOFE
      WRITE (6,15) I,(NDATE(I,III),III=1,3)
      WRITE (6,16) (III,POBS(I,III),III=1,NRG)
      IF (FVOL(I).EQ.0.0) GO TO 1
      WRITE (6,17) FVOL(I)
      IF (FPK(I).EQ.0.0) GO TO 1
      WRITE (6,18) FPK(I),BFL(I)
    1 IF (KOUT(I).EQ.1) LL=LL+1
      IF (KOUT(I).EQ.1) HEAD3(LL)=NDATE(I,3)*10000+NDATE(I,1)*100+NDATE(
     1I,2)
    2 CONTINUE
      RETURN
    3 CONTINUE
      IF (KNN.EQ.0) GO TO 5
      IF (B3.NE.1) WRITE (6,14)
      IF (B3.NE.1) GO TO 5
      WRITE (6,13)
      WRITE (6,19) U(NN)
      DO 4 I=1,EO
      WRITE (6,20) I,X(I),G(I),H(I)
    4 CONTINUE
      IF (IEAC.EQ.1) WRITE (6,21) RAT
    5 WRITE (6,22)
      DO 11 I=1,NOFE
      I12=I+NOFE
      QCW=0.0
      DO 6 III=1,NRG
      LJ=III+3
```

SUBROUTINE PROUT(IV,PAC)

```
    6 QCW=QCW+DIMP(LJ,1)*PSUM(I,III)+DIMP(LJ,2)*PSUM(I12,III)
      QCW=QCW/(5280.*5280.*DA)*PAC
      IF (SFVOL(I).LT.QCW) SFVOL(I)=QCW
      IF (TESTNO(I).EQ.1) GO TO 9
      IF (FVOL(I).EQ.0.0) GO TO 7
      WRITE (6,23) I,(NDATE(I,III),III=1,3),QCW,SFVOL(I),FVOL(I),OUTVOL(
     1I),FPK(I),SFPK(I)
      GO TO 11
    7 IF (SFPK(I).GT.0.0) GO TO 8
      WRITE (6,23) I,(NDATE(I,III),III=1,3),QCW,SFVOL(I)
      GO TO 11
    8 WRITE (6,24) I,(NDATE(I,III),III=1,3),QCW,SFVOL(I),SFPK(I)
      GO TO 11
    9 VR=0.0
      IF (FVOL(I).EQ.0.0.OR.SFVOL(I).EQ.0.0) GO TO 10
      VR=ALOG(FVOL(I)/SFVOL(I))**2
   10 WRITE (6,23) I,(NDATE(I,III),III=1,3),QCW,SFVOL(I),FVOL(I),OUTVOL(
     1I),FPK(I),SFPK(I),VR
   11 CONTINUE
      IF (U(1).GT.0.0) WRITE (6,25) U(1)
      RETURN

   12 FORMAT (1H1,45X,24HSUMMARY OF MEASURED DATA)
   13 FORMAT (1H1,11X,44HEND OF RUN--RESULTS OF LAST SUCCESSFUL TRIAL)
   14 FORMAT (1H1,50X,18HBEGINNING OF STAGE)
   15 FORMAT (1H0/1H ,26HSTORM-RUNOFF EVENT NUMBER ,I3,7H  DATED,I3,1H/,
     1I2,1H/,I2)
   16 FORMAT (1H ,31HMEASURED RAINFALL   GAGE NUMBER,3(I3,3H = ,F9.3,7H
     1INCHES))
   17 FORMAT (1H ,24HMEASURED DIRECT RUNOFF =,F9.3,7H INCHES)
   18 FORMAT (1H ,25HMEASURED PEAK DISCHARGE =,F9.2,4H CFS/1H ,18HBASEFL
     1OW ASSUMED =,F7.3,4H CFS)
   19 FORMAT (1H ,20HOBJECTIVE FUNCTION =,F12.3/1H0,12X,5HFINAL,6X,5HLOW
     1ER,6X,5HUPPER/1H ,9HPARAMETER,3X,5HVALUE,6X,5HBOUND,5X,5HBOUND)
   20 FORMAT (1H ,I5,1X,3(F11.4))
   21 FORMAT (1H0,21HNEW VALUE FOR RAT IS ,F6.3/)
   22 FORMAT (/1H0,22X,9HSIMULATED/21X,13HPERVIOUS AREA,6X,9HSIMULATED,8
     1X,8HMEASURED,8X,9HSIMULATED,5X,8HMEASURED,3X,9HSIMULATED/1H ,6H ST
     2ORM,13X,15HRAINFALL EXCESS,2X,15HRAINFALL EXCESS,2X,15H DIRECT RUN
     3OFF ,2X,13HRUNOFF VOLUME,5X,4HPEAK,7X,4HPEAK,6X,12HCONTRIBUTION/1H
     4 ,6HNUMBER,4X,4HDATE,9X,8H(INCHES),8X,8H(INCHES),9X,8H(INCHES),5X,
     515HAT OUTLET (IN.),4X,5H(CFS),6X,5H(CFS),5X,12HTO OBJ. FCT.)
   23 FORMAT (1H ,I4,I6,1H/,I2,1H/,I2,F14.3,F16.3,2F17.3,2F12.2,F15.3)
   24 FORMAT (1H ,I4,I6,1H/,I2,1H/,I2,F14.3,F16.3,46X,F12.2)
   25 FORMAT (1H0,30HOBJECTIVE FUNCTION FOR PEAKS =,F12.3)
      END
```

SUBROUTINE PRFL(IJKS,IJK,ICNT,SRV,QMX)

```
      SUBROUTINE PRFL(IJKS,IJK,ICNT,SRV,QMX)
C             THIS SUBROUTINE  OUTPUTS DETAILED SIMULATED DATA
C             AND SETS UP DATA FOR PLOTTING
      INTEGER B3,TRYCT,DEL5,OPT,OPTION,EO,FO,RITE,DEL5P
      REAL ISEG,IUP,ILAT,IMP
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /F2/ FLW(1442),FLAT(1442),FUP(1442)
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NUPD,PDEL,RITE,DEL5P,EPSLN,OPTION,CORF
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      DIMENSION RT(5), IHR(5), TMN(5), TOUT(5), MOUT(5)
      K=KK
      IF (IPR(K).LT.1) GO TO 1
      WRITE (6,8) I1
      WRITE (6,7) ISEG(K)
      WRITE (6,9)
    1 IJJ=0
      I5=0
      ICT=0
      ICNT=0
      SRV=0.
      QMX=0.
      DO 6 I=IJKS,IJK
      IJJ=IJJ+1
      ICT=ICT+IPRNT
      IF (IJJ.NE.DEL5) GO TO 6
      IJJ=0
      I5=I5+1
      RT(I5)=FLW(ICT)
      MOUT(I5)=I/ND
      IRV=MOUT(I5)*ND
      TOUT(I5)=((I-IRV)*CORF)/60.
      IF (IPR(K).LT.1) GO TO 2
      IHR(I5)=INT(TOUT(I5))
      TMN(I5)=AMOD(TOUT(I5),1.)*60.
    2 IF (I5.LT.5.AND.I.LT.IJK) GO TO 6
      IF (IPR(K).LT.1) GO TO 3
      WRITE (6,10) (IHR(IV),TMN(IV),RT(IV),IV=1,I5)
    3 IF (K.NE.KSEG(NSEG)) GO TO 5
C          FIND OUTLET PEAK AND VOLUME OF RUNOFF
C          SET UP FOR PLOTTING OUTLET HYDROGRAPH
      DO 4 J=1,I5
      ICNT=ICNT+1
```

```
                    SUBROUTINE PRFLW(IJKS,IJK,ICNT,SRV,QMX)
      R(ICNT)=RT(J)
      SRV=SRV+RT(J)
      IF (RT(J).GT.QMX) QMX=RT(J)
      IF (IPL(I1).EQ.0) GO TO 4
      Q(ICNT)=TOUT(J)+MOUT(J)*24.
    4 CONTINUE
    5 I5=0
    6 CONTINUE
      RETURN
C
    7 FORMAT (1H ,40X,8HSEGMENT ,A4/)
    8 FORMAT (1H0,40X,12HSTORM NUMBER,I3)
    9 FORMAT (5(7X,4HTIME,5X,5H FLOW,1X)/5(7X,5H(HRS),4X,6H( CFS)))
   10 FORMAT (5(5X,I2,1H:,F3.0,F10.3))
      END
```

SUBROUTINE STORM

```
      SUBROUTINE STORM
C     *                    STORM  ANALYSIS  ROUTINE                    *
      INTEGER TRYCT,RODYS,DELS,OPT,OPTION,B3,EO,FO,RITE,DELSP
      INTEGER NF(60),NFE(60),NFS(60),TESTNO(60)
      REAL ISEG,IUP,ILAT,IN2,IMP,POBS(50,3),I2CFSP
      DIMENSION K1(60), K2(60)
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DELS,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALFADJ
      COMMON /C6/ DT,DTS,QUP,DX(99),PSUM(120,3),SFVOL(60),SFPK(60)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /CH/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /D1/ OP(7310),RODYS,NSD,IUNIT,NDYS,NDTS,ICK(60)
      COMMON /E2/ SMAX(99),IN2,S2O2(99),ALP,DTSX,XEM,YEM,IMDE,WX,METH
      COMMON /E3/ DELTAT,NOB,QS(11),I33,I43,IJ,QIH(2881),QINPT(60)
      COMMON /E4/ WV(99,10),S1(99,10),C1(99,10)
      COMMON /E5/ S2(99,10),S(99,10),C(99,10)
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NJPD,PDEL,RITE,DELSP,EPSLN,OPTION,CORF
      COMMON /Z3/ K1,K2,NF,NFE,NFS,POBS,TESTNO
      COMMON /Z4/ OE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IHFS(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
C           NDAY IS SET TO NUMBER OF TIME INTERVALS FOR A RAIN GAGE
      NDAY=NOUT*NDELS
C           5280**2/12*60*60*24=26.888:  CONVERTS INCHES TO CFS
      I2CFSP=26.8888889*DA*NDELS
      NOFT=NOFE
      I4=I1
      NOFE=I1
C           BEGIN ANALYSIS OF A SET OF EVENTS
      DO 1 I=I1,NUPD
      IF (NOUP(I+1).NE.(NOUP(I)+1)) GO TO 2
    1 CONTINUE
    2 NFI1=NF(NOFE)
      I1=I+1
C           BEGIN ANALYSIS OF A STORM
C           FIND PEAK DISCHARGE
    3 QR=0.0
      QMX=0.0
      SRV=0.0
      LJ=K1(NOFE)
      LM=K2(NOFE)
      NFI1=NFI1-1
C         COMPUTE TOTAL RAINFALL FOR STORM AND
C         REVISE START OF STORM TO COINCIDE WITH
C          FIRST RAINFALL
```

```
      KR=0
      DO 5 L=LJ,LM
      DO 4 I=1,NRG
      I2=NDAY*(I-1)+L
      POBS(NOFE,I)=POBS(NOFE,I)+UPR(I2)
      IF (KR.GT.0) GO TO 4
      IF (POBS(NOFE,I).EQ.0.0) GO TO 4
      KR=L
      IF (KR.EQ.LJ) GO TO 4
      K1(NOFE)=KR
      NFS(NOFE)=(KR-1)*DEL5+1
      WRITE (6,12) NOFE,KR
    4 CONTINUE
    5 CONTINUE
      IF (OPT.EQ.1) GO TO 11
      DO 6 K=LJ,LM
      Q3=UD(K)
      IF (K.EQ.LJ) QR=Q3
      IF (Q3.LE.QMX) GO TO 6
      QMX=Q3
    6 CONTINUE
C             FIND RUNOFF VOLUME ABOVE BASEFLOW
      DO 8 L=LJ,LM
C             CHECK UNIT DISCHARGE FOR VALUES LESS THAN BASEFLOW
C             IF FOUND SET BASEFLOW TO MINIMUM UNIT DISCHARGE
      IF (UD(L).GE.QR) GO TO 7
      QR=UD(L)
    7 SRV=SRV+UD(L)
    8 CONTINUE
      SRV=SRV-QR*(LM-LJ+1)
      FVOL(NOFE)=SRV/I2CFSP
C             FIND PEAK DISCHARGE ABOVE BASEFLOW
      FPK(NOFE)=QMX-QR
      IF (QR.EQ.0.0) GO TO 10
      DO 9 K=LJ,LM
    9 UD(K)=UD(K)-QR
   10 CONTINUE
   11 BFL(NOFE)=QR
      NOFE=NOFE+1
C             CHECK FOR MORE STORMS IN SET OF EVENTS
      IF (NFI1.GT.0) GO TO 3
      NOFE=NOFT
      I1=I4
      RETURN
C
   12 FORMAT (///19X,22H START OF STORM NUMBER,I3,24H HAS BEEN CHANGED T
     1O KS=,I5/20X,32HTHIS CORRESPONDS TO 1ST RAINFALL/20X,35HIF OUTPUT
     2FROM THIS MODEL SERVES AS,24H INPUT TO QUALITY MODEL,/20X,44HTHEN
     3USE REVISED KS VALUE FOR START OF STORM)
      END
```

SUBROUTINE INITOP

```
      SUBROUTINE INITOP
C     **************************************************************
C     *               INITIAL OPTIMIZATION ROUTINE                 *
C     **************************************************************
      INTEGER B3,EO,FO,OPTNO,TRYCT,OPT,OPTION,RITE,DELSP
      REAL ISEG,IUP,IMP
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C8/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFF,NUPD,PDEL,RITE,DELSP,EPSLN,OPTION,CORF
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),DF,IEAC
      REAL FMTP(9),FMTP1(10)
      DATA FMTP1/3HPSP,4HKSAT,3HRGF,4HBMSN,3HEVC,2HRR,3HEAC,4H,3X,,3H1H+
     1,1H /
      DATA FMTP/4H(1H ,4H,I3,,4H3X,F,4H12.5,4H,3X,,2HA4,1H ,1H ,1H)/
      DF=1.0E+29
      DO 1 I=1,3
    1 U(I)=0.0
      READ (5,11) EO,FO,K,EPSLN
      NN=2
      NPAR=1
      IF (EO.GT.7) NPAR=2
      DO 2 I=1,EO
    2 READ (5,12) X(I),G(I),H(I)
      READ (5,18) (OPTNO(I),I=1,FO)
      IFOP1=FO+1
      DO 3 I=IFOP1,EO
    3 OPTNO(I)=0
C              SET MAXIMUM TRYCT
      NK=K*FO
      IF (NK.EQ.0) B3=1
      DO 4 I=1,200
    4 A(I)=0.0
      DO 5 I=1,14
      D(I)=0.0
      E(I)=0
    5 F(I)=0
      TRYCT=0
C              CHECK IF INITIAL PARAMETER VALUE WITHIN OUTER BOUNDARY
      DO 7 I=1,EO
      XX=X(I)
      IF (XX.LE.G(I)) GO TO 6
      IF (XX.GE.H(I)) GO TO 6
C              STORE INITIAL PARAMETER VALUES
      X(EO+I)=XX
      GO TO 7
C              IF PARAMETER VALUES NOT WITHIN BOUNDARY VALUES
C              PRINT ERROR MESSAGE
```

SUBROUTINE INITOP

```
    6 WRITE (6,13) I,G(I),X(I),H(I)
      STOP
    7 CONTINUE
      DO 8 I=1,EO
      L=2*EO+I
      G(L)=0.0
      H(L)=0.0
      K=EO+I
C             COMPUTE INNER BOUNDARY VALUES
      GOE=(H(I)-G(I))*0.0001
      G(K)=G(I)+GOE
    8 H(K)=H(I)-GOE
C             ENTER A(I) = 0.0 INTO ARRAY
      L=FO+1
      DO 9 I=1,FO
      LJ=L*I
      A(LJ)=1.0
C             COMPUTE INITIAL STEP SIZE
      J=OPTNO(I)
      A(I)=X(J)*EPSLN
    9 CONTINUE
C             DESCRIBE INFILTRATION PARAMETERS
      WRITE (6,14)
      J=1
      IEAC=0
      DO 10 I=1,EO
      FMTP(7)=FMTP1(10)
      FMTP(8)=FMTP1(10)
      K=I
      IF (I.GT.7) K=I-7
      IF (I.NE.OPTNO(J)) GO TO 10
      IF (I.EQ.7) IEAC=1
      FMTP(7)=FMTP1(8)
      FMTP(8)=FMTP1(9)
      J=J+1
   10 WRITE (6,FMTP) I,X(I),FMTP1(K)
      IF (X(7).NE.1.0) IEAC=1
      NO=0
      IF (NK.EQ.0) RETURN
      WRITE (6,15)
      WRITE (6,16) (A(I),I=1,FO)
      WRITE (6,17) NK,EPSLN
      RETURN
C
   11 FORMAT (3I4,F8.0)
   12 FORMAT (3F10.0)
   13 FORMAT (1H ,27HBOUNDARY CHECK OF PARAMETER,I3,3F10.3)
   14 FORMAT (1H1,24HINITIAL PARAMETER VALUES,2X,45H(PARAMETERS TO BE OP
     1TIMIZED ARE MARKED WITH A,3H *)/)
   15 FORMAT (///1H ,28HINITIAL STEP SIZE INCREMENTS/)
```

SUBROUTINE INITOP

```
16 FORMAT (1X,10F12.6)                                                   V1010
17 FORMAT (1H //1H ,31HTHE MAX. NUMBER OF ITERATIONS= ,I4//1H ,58HINI   V1020
  1TIALLY AND AFTER EACH VECTOR MATRIX ORTHONORMALIZATION,/1H ,40HTHE   V1030
  2 PARAMETRIC VECTOR INCREMENT SIZE IS,F7.3,19H OF THE VECTOR SIZE/)   V1040
18 FORMAT (40I2)                                                         V1050
   END                                                                   V1060-
```

SUBROUTINE OPTIMZ

```
      SUBROUTINE OPTIMZ
C     ******************************************************************
C     *            MODIFIED ROSENBROCK OPTIMIZATION ROUTINE            *
C     ******************************************************************
      INTEGER EO,FO,OPTNO,B3,TRYCT,E,F,RITE,OPTION,OPT,DELSP
      REAL IMP
      COMMON /CB/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OJTVOL(60)
      COMMON /Z1/ B3,DA,EO,FO,NK,NN,NO,IMP,KNN,NO9,OPT,IOUT(2),NDAY,NDEL
     1S,NOFE,NJPD,PDEL,RITE,DELSP,EPSLN,OPTION,CORF
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      COMMON /Z4/ DE(7310),UD(2881),X2(16),DIMP(9,2),FPK(60),FVOL(60),IP
     1R(99),INDP(45),IRES(30),NOUP(150),NDATE(60,3),X(40),OF,IEAC
      DATA B1/0.0/,B2/0.0/
      UU=U(NN)
C             CHECK FOR IMPROVEMENT IN OBJECTIVE FUNCTION
      IF (UU.GT.OF) GO TO 6
C                NEW OBJECTIVE FUNCTION LESS THAN OLD OBJ. FUNCTION
      DO 3 I=1,FO
      M=OPTNO(I)
      XX=X(M)
      K=EO+M
      L=2*EO+M
C             CHECK ON INNER LOWER BOUNDARY
      IF (XX.GE.G(K)) GO TO 1
      GD=(G(K)-XX)/(G(K)-G(M))
      HD=UU-G(L)
      GO TO 2
C             CHECK ON INNER UPPER BOUNDARY
    1 IF (XX.LE.H(K)) GO TO 3
      GD=(XX-H(K))/(H(M)-H(K))
      HD=UU-H(L)
    2 UU=UU+((-2.0*GD+4.0)*GD-3.0)*GD*HD
      IF (UU.GT.OF) GO TO 6
    3 CONTINUE
C             SET OF TO NEW OBJ. FCT.
      OF=UU
      DO 4 I=1,FO
C             STORE OLD PARAMETER VALUE IN LAST THIRD OF MATRIX
      M=OPTNO(I)
      XX=X(M)
      K=EO+M
      L=2*EO+M
      X(L)=XX
C             CHECK ON INNER BOUNDARIES
      IF (XX.GT.H(K)) GO TO 4
      IF (XX.LT.G(K)) GO TO 4
C             ENTER CURRENT OBJ. FCT. IN G + H ARRAYS
      G(L)=UU
      H(L)=UU
    4 CONTINUE
```

SUBROUTINE OPTIMZ

```
      IF (NO.EQ.0) GO TO 5
C              F(I)=1 IF NEW PARAMETER VALUE IMPROVES OBJ. FCT.
      F(NO)=1
      E(NO)=0
C              COMPUTE CUMULATIVE STEP SIZE
      D(NO)=D(NO)+A(NO)
C              COMPUTE NEXT FORWARD STEP SIZE
      A(NO)=3.0*A(NO)
    5 WRITE (6,35) TRYCT,U(2)
      WRITE (6,36)
      WRITE (6,37) (X(I),I=1,EO)
      IF (TRYCT.NE.NK) GO TO 9
      B3=1
      RITE=1
      RETURN
C              IF NEW OBJ. FCT. EXCEEDS OLD OBJ. FCT.
C              SET PARAMETER TO PREVIOUS VALUE
    6 M=2*FO
      DO 7 I=1,FO
      K=OPTNO(I)
      LK=K+M
    7 X(K)=X(LK)
      GO TO 15
C              ROUTINE TO COMPUTE NEW PARAMETER VALUE
    8 IF (TRYCT.NE.NK) GO TO 9
      GO TO 5
    9 TRYCT=TRYCT+1
      OPTION=IOUT(2)
      IF (NO.EQ.FO) GO TO 10
      NO=NO+1
      GO TO 11
   10 NO=1
   11 DO 14 I=1,FO
      K=OPTNO(I)
      IFO=FO*I+NO
      XX=X(K)+A(IFO)*A(NO)
      IF (XX.LE.G(K).OR.XX.GE.H(K)) GO TO 12
      X(K)=XX
      GO TO 14
   12 L=2*FO
      IF (I.EQ.1) GO TO 15
      II=I-1
      DO 13 IJ=1,II
      I2=II+1-IJ
      K=OPTNO(I2)
      LK=L+K
   13 X(K)=X(LK)
      GO TO 15
   14 CONTINUE
      RETURN
```

SUBROUTINE OPTIMZ

```
C             COMPUTES BACK STEP LENGTH(WHEN NEW OBJ. FCT. > OLD)
   15 IF (TRYCT.NE.NK) GO TO 16
      B3=1
      RITE=1
      RETURN
C             COMPUTE NEXT BACKWARD STEP SIZE
   16 A(NO)=-0.5*A(NO)
C             E(I)=1 INDICATES PARAMETER VALUE CHANGED BY BACKWARD
C             STEP SIZE
      E(NO)=E(NO)+1
C             DETERMINE IF BOTH BACKWARD AND FORWARD STEP SIZE
C             ADJUSTMENTS FAILED TO IMPROVE OBJ. FCT.
      DO 17 I=1,FO
      LJ=E(I)*F(I)
      IF (LJ.LE.0) GO TO 8
   17 CONTINUE
C             VECTOR ORTHONORMALIZED WHEN IREF.GT.0 FOR ALL I
      DO 18 I=1,FO
      L=FO*(I+1)
      A(L)=D(FO)*A(L)
      K=FO*I
      IF (FO.EQ.1) GO TO 19
      LJ=FO-1
      DO 18 LK=1,LJ
      J2=FO-LK
      L=K+J2
   18 A(L)=D(J2)*A(L)+A(L+1)
C             NORMALIZE VECTOR LENGTHS TO 1.0
   19 BD=0.0
      DO 20 I=1,FO
      LJ=FO*I+1
   20 BD=A(LJ)**2+BD
      B1=SQRT(BD)
      DO 21 I=1,FO
      L=FO*I+1
   21 A(L)=A(L)/B1
C             RECOMPUTE STEP SIZE INCREMENT
      SF=0.0
      DO 22 I=1,FO
      K=OPTNO(I)
      L=FO*I+1
   22 SF=SF+ABS(A(L))*X(K)
      A(1)=SF*EPSLN
      BD=0.0
      DO 23 I=1,FO
      IK=FO*I+2
   23 BD=A(IK)**2+BD
      B2=SQRT(BD)/B1
      WRITE (6,38) B1,B2
      J=2
```

```
24 IF (FO.LT.J) GO TO 32
   K=1
   BD=0.0
25 IF (K.GE.J) GO TO 28
   DO 26 I=1,FO
   L=FO*I
   LJ=L+J
   LK=L+K
26 BD=BD+A(LJ)*A(LK)
   DO 27 I=1,FO
   L=FO*I+J
   LJ=L-J+K
27 A(L)=A(L)-A(LJ)*BD
   K=K+1
   BD=0.0
   GO TO 25
28 DO 29 I=1,FO
   LJ=FO*I+J
29 BD=A(LJ)**2+BD
   BD=SQRT(BD)
   DO 30 I=1,FO
   L=FO*I+J
30 A(L)=A(L)/BD
   SF=0.0
   DO 31 I=1,FO
   K=OPTNO(I)
   L=FO*I+J
31 SF=SF+ABS(A(L))*X(K)
   A(J)=SF*EPSLN
   J=J+1
   GO TO 24
32 WRITE (6,39)
   DO 33 I=1,FO
   LJ=I*FO+1
   LK=I*FO+FO
33 WRITE (6,40) (A(IJ),IJ=LJ,LK)
   NO=0
   WRITE (6,41) (A(I),I=1,FO)
   DO 34 I=1,FO
   D(I)=0.0
   F(I)=0
   K=OPTNO(I)
   LJ=EO+K
34 X(LJ)=X(K)
   RITE=1
   RETURN

35 FORMAT (1H0,16HAT ITERATION NO.,I3,21H OBJECTIVE FUNCTION=,F11.6)
36 FORMAT (1H ,20HPARAMETER VALUES ARE)
37 FORMAT (1H ,7F12.6/1H ,7F12.6)
```

SUBROUTINE OPTIMZ

```
38 FORMAT (1H ,4HB1 =,F9.6,3X,4HB2 =,F9.5)                                W2010
39 FORMAT (1H ,24HNEW ORTHONORMAL BASIS    )                              W2020
40 FORMAT (1H ,16F8.5)                                                    W2030
41 FORMAT (1H ,35HSTART OF STAGE STEP SIZE INCREMENTS/1H ,13F10.6)        W2040
   END                                                                    W2050-
```

SUBROUTINE SEQ(DA,DIMP)

```
      SUBROUTINE SEQ(DA,DIMP)
C              THIS SUBROUTINE SETS UP COMPUTATIONAL SEQUENCE
      REAL ISEG,IUP,ILAT
      REAL DIMP(9,2)
      INTEGER DEL5
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),BFL(60),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
C              NUMBER CONTRIBUTING SEGMENTS (IUP,ILAT) USING SUBROUTINE
C              ITRAN WHICH GIVES THE CONTRIBUTING SEGMENTS THE SAME
C              NUMBER AS THE ORDER OF THE SEGMENTS (I.E., I)
      DO 2 I=1,NSEG
      ITEST(I)=0
      DO 1 J=1,3
      X=IUP(I,J)
      JUP(I,J)=ITRAN(X)
    1 CONTINUE
      DO 2 J=1,4
      X=ILAT(I,J)
      JLAT(I,J)=ITRAN(X)
    2 CONTINUE
      II=0
C              ORDER OVERLAND FLOW SEGMENTS FIRST
      DO 7 I=1,NSEG
      IF (ITYPE(I)-5) 3,4,3
    3 IF (ITYPE(I)-6) 7,4,7
    4 DO 6 J=1,3
      IF (JUP(I,J)) 6,6,5
    5 GO TO 28
    6 CONTINUE
      II=II+1
      KSEG(II)=I
      ITEST(I)=1
    7 CONTINUE
      NONCH=II
C              CHECK EACH SEGMENT TO SEE IF IT HAS BEEN SEQUENCED
      I=1
      NIT=0
    8 IF (ITEST(I)) 12,12,9
    9 I=I+1
C              CHECK IF SEGMENT SEQUENCING IS COMPLETED AND FOR ERRORS
      IF (I-NSEG) 8,8,10
   10 I=1
      NIT=NIT+1
      IF (NIT-3*NSEG) 11,11,28
   11 IF (II-NSEG) 8,20,20
   12 N=0
```

```
      SUBROUTINE SEQ(DA,DIMP)
C               CHECK SEGMENT FOR UPSTREAM SEGMENTS WHICH HAVE NOT
C               BEEN SEQUENCED YET
      DO 15 J=1,3
      IF (JUP(I,J)) 15,15,13
   13 K=JUP(I,J)
      IF (ITEST(K)) 14,14,15
   14 N=1
   15 CONTINUE
C               CHECK SEGMENT FOR ANY LATERAL INFLOW SEGMENTS WHICH
C               HAVE NOT BEEN SEQUENCED YET
      DO 18 J=1,4
      IF (JLAT(I,J)) 18,18,16
   16 K=JLAT(I,J)
      IF (ITEST(K)) 17,17,18
   17 N=1
   18 CONTINUE
C               IF SEGMENT HAS NO UNSEQUENCED UPSTREAM OR LATERAL INFLOW
C               SEGMENTS,SEQUENCE IT NEXT
      IF (N) 19,19,9
   19 II=II+1
      KSEG(II)=I
      ITEST(I)=1
      IF (II-NSEG) 9,20,20
C               OUTPUT COMPUTATION SEQUENCE
   20 N=0
      WRITE (6,30)
      DO 27 I=1,NSEG
      K=KSEG(I)
      IF (ITYPE(K).EQ.8) GO TO 21
      IF (ITYPE(K)-4) 21,21,26
C               CHECK FOR CHANNELS WITH MISSING INFLOW SEGMENT
   21 NN=0
      DO 24 J=1,3
      IF (JLAT(K,J)) 22,22,23
   22 IF (JUP(K,J)) 24,24,23
   23 NN=1
   24 CONTINUE
      IF (NN) 25,25,26
   25 N=1
      WRITE (6,31) K,ISEG(K)
      GO TO 27
   26 WRITE (6,32) K,ISEG(K),ALPHA(K),EM(K)
C               CHECK FOR INPUT DATA ERROR
   27 CONTINUE
      IF (N) 29,29,28
   28 WRITE (6,33)
      STOP
   29 CONTINUE
      CALL AREA(DA,DIMP,NONCH)
      RETURN
```

```
                         SUBROUTINE SEQ(DA,DIMP)
C                                                                       X1010
   30 FORMAT (1H1,10X,20HCOMPUTATION SEQUENCE,16X,26HKINEMATIC WAVE  PAR X1020
     1AMETERS//12X,5HINDEX,3X,7HSEGMENT,19X,5X,5HALPHA,6X,1HM)          X1030
   31 FORMAT (52X,I3,6X,A4,6X,22HMISSING INFLOW SEGMENT)               X1040
   32 FORMAT (13X,I3,5X,A4,F31.2,F10.3)                                X1050
   33 FORMAT (1H0,29HERROR IN ORDERING OF SEGMENTS)                    X1060
      END                                                              X1070-
```

SUBROUTINE AREA(DA,DIMP,NONCH)

```
      SUBROUTINE AREA(DA,DIMP,NONCH)
C           1. CHECKS COMPUTED DRAINAGE AREA VERSUS FURNISHED
C           DRAINAGE AREA. 2. DETERMINES PERVIOUS AND IMPERVIOUS
C           AREAS COVERED BY EACH RAIN GAGE FOR EACH SOIL TYPE
      INTEGER DEL5,TRYCT,E,F,OPTNO
      REAL DIMP(9,2),DT(200,6,2),ISEG,IUP,ILAT
      DIMENSION KS(99)
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C3/ IPRNT,T,AR(11),HFL(50),FLGTH(99),KSEG(99),NDX(99),Q2,Q
     1SUM,QSUML,STO(99)
      COMMON /C4/ DEL5,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      COMMON /C8/ T1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OJTVOL(60)
      COMMON /Z2/ A(200),D(14),E(14),F(14),G(40),H(40),U(3),OPTNO(14)
      DA1=0.0
      DA2=0.0
      DA3=0.0
      DO 1 J=1,2
      DO 1 I=1,9
    1 DIMP(I,J)=0.0
      KLL=NSEG+100
      DO 4 L=1,NPAR
      DO 3 I=1,KLL
      DO 2 J=1,6
    2 DT(I,J,L)=0.0
    3 CONTINUE
    4 CONTINUE
      DAT=0.0
C           CALCULATE PERVIOUS AND IMPERVIOUS DRAINAGE AREA FROM
C           OVERLAND FLOW SEGMENTS INTO EACH CHANNEL FOR EACH RAIN
C           GAGE AND SOIL TYPE
      DO 9 I=1,NSEG
      IF (ITYPE(I).NE.5.AND.ITYPE(I).NE.6) GO TO 9
      DO 8 KL=1,NSEG
      DO 7 KM=1,4
      KL1=KL+NSEG
      IF (I.NE.JLAT(KL,KM)) GO TO 7
      RK=0.0
      DO 5 KMM=1,NRG
    5 RK=RK+RCOEF(I,KMM)
      IF (RK.LT.0.98.OR.RK.GT.1.02) WRITE (6,23)
      DO 6 KK=1,NPAR
      PK=0.0
      IF (KPSET(I).EQ.KK) PK=1.0
      DO 6 KMM=1,3
      KMM1=KMM+3
      DTEMP=FLGTH(KL)*FLGTH(I)*RCOEF(I,KMM)*PK*PARAM(I,1)
      DT(KL,KMM1,KK)=DT(KL,KMM1,KK)+DTEMP*PARAM(I,2)
      DT(KL1,KMM1,KK)=DT(KL1,KMM1,KK)+DTEMP*(1.0-PARAM(I,2))
```

SUBROUTINE AREA(DA,DIMP,NONCH)

```
      DTEMP=DTEMP/RK
      DT(KL,KMM,KK)=DT(KL,KMM,KK)+DTEMP*PARAM(I,2)
      DT(KL1,KMM,KK)=DT(KL1,KMM,KK)+DTEMP*(1.-PARAM(I,2))
    6 CONTINUE
    7 CONTINUE
    8 CONTINUE
    9 CONTINUE
C              AGGREGATE DRAINAGE AREA FOR EACH CHANNEL SEGMENT FOR
C              EACH RAIN GAGE FOR EACH SOIL TYPE
      KM1=NSEG-NONCH
      IF (KM1.EQ.1) GO TO 15
      DO 10 I=1,KM1
      NONCH=NONCH+1
      KS(I)=KSEG(NONCH)
   10 CONTINUE
      KM1=KM1-1
      DO 14 KI=1,KM1
      KJ=KS(KI)
      KJJ=KJ+NSEG
      KP1=KI+1
      K=KM1+1
      DO 13 I=KP1,K
      JK=KS(I)
      JKK=JK+NSEG
      DO 12 KMK=1,3
      IF (JUP(JK,KMK).NE.KJ) GO TO 12
      DO 11 KMM=1,NRG
      KMM1=KMM+3
      DO 11 KK=1,NPAR
      DT(JK,KMM,KK)=DT(JK,KMM,KK)+DT(KJ,KMM,KK)
      DT(JK,KMM1,KK)=DT(JK,KMM1,KK)+DT(KJ,KMM1,KK)
      DT(JKK,KMM,KK)=DT(JKK,KMM,KK)+DT(KJJ,KMM,KK)
      DT(JKK,KMM1,KK)=DT(JKK,KMM1,KK)+DT(KJJ,KMM1,KK)
   11 CONTINUE
   12 CONTINUE
   13 CONTINUE
   14 CONTINUE
C              CALCULATE TOTAL DRAINAGE AREA AND TOTAL PERVIOUS AND
C              IMPERVIOUS AREA FOR EACH RAIN GAGE AND SOIL TYPE
   15 K=KSEG(NSEG)
      KP=K+NSEG
      DTEMP1=0.0
      DO 17 KMM=1,3
      KMP=KMM+3
      KMQ=KMM+6
      DO 16 KK=1,NPAR
      DAT=DAT+DT(K,KMM,KK)+DT(KP,KMM,KK)
      DTEMP1=DTEMP1+DT(K,KMP,KK)+DT(KP,KMP,KK)
      DIMP(KMM,KK)=DT(K,KMM,KK)
      DIMP(KMP,KK)=DT(KP,KMM,KK)/DAT
```

SUBROUTINE AREA(DA,DIMP,NONCH)

```
      DIMP(KMQ,KK)=DT(KP,KMM,KK)-DIMP(KMP,KK)
   16 CONTINUE
      DIMP(KMM,1)=DIMP(KMM,1)+DIMP(KMM,2)
   17 CONTINUE
      DO 18 III=1,NRG
      KMP=III+3
      KMQ=KMP+3
      DA1=DA1+DIMP(III,1)/DAT*100.
      DA3=DA3+(DIMP(KMP,1)+DIMP(KMP,2))/DAT*100.
      DA2=DA2+(DIMP(KMQ,1)+DIMP(KMQ,2))/DAT*100.
   18 CONTINUE
C           CHECK COMPUTED DRAINAGE AREA WITH FURNISHED  DRAINAGE AREA
      DAT=DAT/(5280.*5280.)
      DAT1=DAT/DA
      DAT2=DA/DAT
      WRITE (6,20) DA,DAT
      IF (DAT1.LT.1.01.AND.DAT2.LT.1.01) GO TO 19
      WRITE (6,21)
   19 WRITE (6,22) DA1,DA2,DA3
      DA=DAT
      DA1=DA1*DA/100.
      DA2=DA2*DA/100.
      DA3=DA3*DA/100.
      RETURN
C
   20 FORMAT (//1H0,25HFURNISHED DRAINAGE AREA =,F8.4,2X,12HSQUARE MILES
     1/1H ,25HCOMPUTED  DRAINAGE AREA =,F8.4,2X,12HSQUARE MILES)
   21 FORMAT (1H ,39H THESE DIFFER BY MORE THAN ONE PERCENT)
   22 FORMAT (1H0,22HTHE DRAINAGE BASIN IS ,F4.1,29H PERCENT EFF. IMPERV
     1IOUS AREA/1H ,22X,F4.1,32H PERCENT NONEFF. IMPERVIOUS AREA/1H ,22X
     2,F4.1,22H PERCENT PERVIOUS AREA/1X)
   23 FORMAT (1H0,33HTHEISSEN COEFS. FOR OVERLAND-FLOW,27H SEGMENTS SHOU
     1LD SUM TO 1.0)
      END
```

SUBROUTINE ADJUST(EAC,PAC)

```
      SUBROUTINE ADJUST(EAC,PAC)
C              ADJUSTMENT TO AREAS FOR EAC
      COMMON /C7/ ECOMP,KINIT,NOUT,NRG,OSI,JPUN,KIN,RAT,DA1,DA2,DA3
      DIFF=(EAC-1.0)*DA1
      DA1NEW=DA1+DIFF
      DA2NEW=DA2-DIFF
      DA3NEW=DA3
      IF (DA2NEW.GT.0.0) GO TO 1
      DA3NEW=DA3+DA2NEW
      IF (DA3NEW.LT.0.0) GO TO 3
      DA2NEW=0.0
    1 IF (DA3NEW.EQ.0.0) GO TO 2
      RAT=(DA2NEW+DA3NEW)/DA3NEW
    2 IF (DA3.EQ.0.0) RETURN
      PAC=DA3NEW/DA3
      RETURN
    3 WRITE (6,4)
      STOP
C
    4 FORMAT (1H0,31HUPPER LIMIT ON EAC IS TOO LARGE)
      END
```

FUNCTION ITRAN(X)

```
      FUNCTION ITRAN(X)
C              THIS FUNCTION NUMBERS LATERAL AND UPSTREAM INFLOW
C              SEGMENTS TO CORRESPOND TO THEI ISEG'S
      REAL ISEG,IUP
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      I=1
    1 IF (X-ISEG(I)) 3,2,3
    2 ITRAN=I
      RETURN
    3 I=I+1
      IF (I-NSEG) 1,1,4
    4 ITRAN=0
      RETURN
      END
```

SUBROUTINE AM

```
      SUBROUTINE AM
C              THIS SUBROUTINE COMPUTES THE PARAMETERS ALPHA AND EM
C              AND THE FULL-SEGMENT FLOW FOR EACH SEGMENT
      INTEGER DELS
      REAL ISEG,IUP,ILAT
      COMMON /C1/ NSEG,ISEG(99),IUP(99,3),NPAR,KPSET(99),IMETH(99)
      COMMON /C4/ DELS,ISVE,QCW,QLAT,ILAT(99,4),ITEST(99),ITYPE(99),JLAT
     1(99,4),JUP(99,3),P(2881,3),PARAM(99,2),RCOEF(99,3),UPR(8643)
      COMMON /C5/ ALPHA(99),EM(99),FRN(99),QMAX(99),SLOPE(99),ALPADJ
      DO 8 I=1,NSEG
      N=ITYPE(I)
      IF (N.GE.8) N=7
      GO TO (1,2,3,4,5,7,6), N
    1 SIDE=SQRT(PARAM(I,1))/(1.+SQRT(1.+PARAM(I,1)**2))
      ALPHA(I)=1.18/FRN(I)*SQRT(SLOPE(I))*SIDE**(2./3.)
      EM(I)=1.33
      QMAX(I)=100000.
      GO TO 8
    2 AMAX=3.14*PARAM(I,1)**2/4.
      QFULL=1.49/FRN(I)*AMAX*(PARAM(I,1)/4.)**(2./3.)*SQRT(SLOPE(I))
      ALPHA(I)=QFULL/AMAX
      EM(I)=1.
      QMAX(I)=QFULL
      GO TO 8
    3 SIDE=SQRT(PARAM(I,1)+PARAM(I,2))/(SQRT(1.+PARAM(I,1)**2)+SQRT(1.+P
     1ARAM(I,2)**2))
      ALPHA(I)=1.18/FRN(I)*SQRT(SLOPE(I))*SIDE**(2./3.)
      QMAX(I)=100000.
      EM(I)=1.33
      GO TO 8
    4 ALPHA(I)=PARAM(I,1)
      EM(I)=PARAM(I,2)
      QMAX(I)=100000.
      GO TO 8
    5 ALPHA(I)=1.49/FRN(I)*SQRT(SLOPE(I))
      QMAX(I)=100000.
      EM(I)=1.67
      GO TO 8
    6 QMAX(I)=100000.
      ALPHA(I)=0.
      EM(I)=0.
      GO TO 8
    7 QMAX(I)=100000.
      ALPHA(I)=4.*64.4*SLOPE(I)/(FRN(I)*.0000141)
      EM(I)=3.
    8 ALPHA(I)=ALPHA(I)*ALPADJ
      RETURN
      END
```

SUBROUTINE PUNCH(LL,NDATE,NDELS,CORF,PTIME,JPUN,I1,ICNT)

```
      SUBROUTINE PUNCH(LL,NDATE,NDELS,CORF,PTIME,JPUN,I1,ICNT)
      DIMENSION X2(12), IDAYS(12), NDATE(60,3)
      INTEGER STAD1,STAD
      COMMON /C2/ STAD1,STAD
      COMMON /F1/ ICT,Q(1442),R(1442),IPL(150),KK
      DATA IDAYS/31,28,31,30,31,30,31,31,30,31,30,31/
      NCN=120.1/PTIME
      IPUN=0
      IP=PTIME
      ICODE=2
      GO TO 2
    1 LL=LL-NDELS
    2 IF (LL.GT.NDELS) GO TO 1
      IMO=NDATE(I1,1)
      IDY=NDATE(I1,2)
      IYR=NDATE(I1,3)
    3 CONTINUE
      DO 6 I=1,NCN
      IF (IPUN.EQ.ICNT) GO TO 8
      I12=12*I
      IF (LL.GT.I12) GO TO 6
      I12=I12-12
      DO 4 J=1,12
      X2(J)=0.0
      IF (IPUN.EQ.ICNT) GO TO 4
      I12=I12+1
      IF (LL.GT.I12) GO TO 4
      IPUN=IPUN+1
      X2(J)=R(IPUN)
    4 CONTINUE
      IF (CORF.GE.5.0) GO TO 5
      WRITE (JPUN,9) STAD1,STAD,IYR,IMO,IDY,IP,I,(X2(K),K=1,12),ICODE
      GO TO 6
    5 WRITE (JPUN,10) STAD1,STAD,IYR,IMO,IDY,IP,I,(X2(K),K=1,12),ICODE
    6 CONTINUE
      LL=0
      IDY=IDY+1
      IF (IDAYS(IMO).GE.IDY) GO TO 3
      IF (IMO.NE.2) GO TO 7
      IF (MOD(IYR,4).NE.0) GO TO 7
      IF (IDY.LE.29) GO TO 3
    7 IMO=IMO+1
      IDY=1
      IF (IMO.LE.12) GO TO 3
      IMO=1
      IYR=IYR+1
      GO TO 3
    8 CONTINUE
      RETURN
```

```
      SUBROUTINE PUNCH(LL,NDATE,NDELS,CORF,PTIME,JPUN,I1,ICNT)

    9 FORMAT (2A4,4I2,I3,12F5.1,I1)                                    AC 510
   10 FORMAT (2A4,5I2,12F5.1,I2)                                       AC 520
      END                                                              AC 530-
```

SUBROUTINE CORR(NOFE,SFPK,FPK)

```
      SUBROUTINE CORR(NOFE,SFPK,FPK)
      DIMENSION SFPK(60), FPK(60)
      AN=0.
      SUMX=0.
      SUMY=0.
      SUMXX=0.
      SUMYY=0.
      SUMXY=0.
      DO 1 I=1,NOFE
      X=SFPK(I)
      Y=FPK(I)
      IF (X.LE.0.0001.OR.Y.LE.0.0001) GO TO 1
      AN=AN+1.
      SUMX=SUMX+X
      SUMY=SUMY+Y
      SUMXX=SUMXX+X*X
      SUMYY=SUMYY+Y*Y
      SUMXY=SUMXY+X*Y
    1 CONTINUE
      IF (AN.LT.3.) RETURN
      VAR=(AN*SUMXX-SUMX*SUMX)/(AN*(AN-1.))
      SD1=SQRT(VAR)
      VAR=(AN*SUMYY-SUMY*SUMY)/(AN*(AN-1.))
      SD2=SQRT(VAR)
      COV=(AN*SUMXY-SUMX*SUMY)/(AN*(AN-1.))
      COR=COV/(SD1*SD2)
      WRITE (6,2) COR
      RETURN
C
    2 FORMAT (1H ,29HCORRELATION COEF. FOR PEAKS =,F8.3)
      END
```

SUBROUTINE FILES

```
      SUBROUTINE FILES
C             CREATES SPACE ON THE DIRECT ACCESS FILE FOR THE
C             NUMBER OF RECORDS REQUESTED (JRECDS).
      INTEGER HEAD1(120),HEAD2(60,2),HEAD3(50)
      COMMON /F3/ IFILE,IFILED,IFILEP,JRECDS,IRECD,NRECDS,HEAD1,HEAD2,HE
     1AD3,NSTRMS,JPERM
      IFILE=25
      IF (JRECDS.LE.50) GO TO 2
      IF (JRECDS.LE.100) GO TO 3
      IF (JRECDS-500) 1,7,8
    1 IGO=JRECDS/100+1-(1-MIN0(1,MOD(JRECDS,100)))
      GO TO (3,4,5,6,7), IGO
C
    2 CONTINUE
      DEFINE FILE 25(50,480,L,IRECD)
      GO TO 28
    3 CONTINUE
      DEFINE FILE 25(100,480,L,IRECD)
      GO TO 28
    4 CONTINUE
      DEFINE FILE 25(200,480,L,IRECD)
      GO TO 28
    5 CONTINUE
      DEFINE FILE 25(300,480,L,IRECD)
      GO TO 28
    6 CONTINUE
      DEFINE FILE 25(400,480,L,IRECD)
      GO TO 28
    7 CONTINUE
      DEFINE FILE 25(500,480,L,IRECD)
      GO TO 28
    8 IGO=JRECDS/500-(1-MIN0(1,MOD(JRECDS,500)))
      IF (JRECDS.GT.10000) GO TO 29
      GO TO (9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27), I
     1GO
C
    9 CONTINUE
      DEFINE FILE 25(1000,480,L,IRECD)
      GO TO 28
   10 CONTINUE
      DEFINE FILE 25(1500,480,L,IRECD)
      GO TO 28
   11 CONTINUE
      DEFINE FILE 25(2000,480,L,IRECD)
      GO TO 28
   12 CONTINUE
      DEFINE FILE 25(2500,480,L,IRECD)
      GO TO 28
   13 CONTINUE
      DEFINE FILE 25(3000,480,L,IRECD)
```

SUBROUTINE FILES

```
      GO TO 28
   14 CONTINUE
      DEFINE FILE 25(3500,480,L,IRECD)
      GO TO 28
   15 CONTINUE
      DEFINE FILE 25(4000,480,L,IRECD)
      GO TO 28
   16 CONTINUE
      DEFINE FILE 25(4500,480,L,IRECD)
      GO TO 28
   17 CONTINUE
      DEFINE FILE 25(5000,480,L,IRECD)
      GO TO 28
   18 CONTINUE
      DEFINE FILE 25(5500,480,L,IRECD)
      GO TO 28
   19 CONTINUE
      DEFINE FILE 25(6000,480,L,IRECD)
      GO TO 28
   20 CONTINUE
      DEFINE FILE 25(6500,480,L,IRECD)
      GO TO 28
   21 CONTINUE
      DEFINE FILE 25(7000,480,L,IRECD)
      GO TO 28
   22 CONTINUE
      DEFINE FILE 25(7500,480,L,IRECD)
      GO TO 28
   23 CONTINUE
      DEFINE FILE 25(8000,480,L,IRECD)
      GO TO 28
   24 CONTINUE
      DEFINE FILE 25(8500,480,L,IRECD)
      GO TO 28
   25 CONTINUE
      DEFINE FILE 25(9000,480,L,IRECD)
      GO TO 28
   26 CONTINUE
      DEFINE FILE 25(9500,480,L,IRECD)
      GO TO 28
   27 CONTINUE
      DEFINE FILE 25(10000,480,L,IRECD)
   28 CONTINUE
      RETURN
   29 WRITE (6,30)
      STOP

   30 FORMAT (1H0,45H*****ERROR--JRECDS IS GREATER THAN 10000*****)
      END
```

SUBROUTINE PLT(Q,R,ICNT,IEND,YMAX)

```
      SUBROUTINE PLT(Q,R,ICNT,IEND,YMAX)
C              THIS SUBROUTINE SETS UP FOR LINE PRINTER PLOTTING
      DIMENSION Q(ICNT), R(ICNT)
      INTEGER TRYCT
      COMMON /CB/ I1,IK,TRYCT,KOUT(150),IHYD(150),PTIME,ND,OUTVOL(60)
      LOGICAL *1IMAGE(5200)
      GO TO (1,4,5), IEND
    1 IX=Q(1)
      IY=Q(ICNT)
      XMIN=IX
      XMAX=IY+1
      DIV=10.
      IF (YMAX.LT.10.) DIV=0.1
      IF (YMAX.LT.0.1) DIV=0.01
      IF (YMAX.LT.0.01) DIV=0.001
      AJ=YMAX/DIV
      IAJ=AJ
      YMAX=(IAJ+1.)*DIV
      WRITE (6,7)
C              FOR FINAL PLOTS
      IF (PTIME.LT.70.) GO TO 2
      XMIN=0.0
      XMAX=YMAX
      GO TO 3
    2 WRITE (6,6) I1
    3 CALL PLOT2(IMAGE,XMAX,XMIN,YMAX,0.0,5)
      CALL PLOT3(1HC,Q,R,ICNT)
      IF (PTIME.GT.70.) CALL PLOT4(2,24   )
      RETURN
    4 CALL PLOT3(1H0,Q,R,ICNT)
      RETURN
    5 CONTINUE
      CALL PLOT4(11,11HFLOW IN CFS)
      RETURN
C
    6 FORMAT (30X,15H** STORM NUMBER,I3)
    7 FORMAT (1H1)
      END
```

SUBROUTINE PRPLOT

```
      SUBROUTINE PRPLOT
      IMPLICIT LOGICAL*1(W),LOGICAL*1(K)
      DIMENSION NSCALE(5), ABNOS(25), X(1), Y(1)
      LOGICAL *1NOS(10)/'0','1','2','3','4','5','6','7','8','9'/
      LOGICAL *1IMAGE(1),CH,LABEL(1),ERR1,ERR3,ERR5
      LOGICAL *1VC,HC,FOR1(19),FOR2(15),FOR3(19),NC,BL,HF,HF1
      REAL *8FOX1(3),FOX2(2),FOX3(3)
      INTEGER *2VCR
      EQUIVALENCE (FOR1(1),FOX1(1)), (FOR2(1),FOX2(1)), (FOR3(1),FOX3(1)
     1), (VC,VCR)
      INTEGER FILE
      DATA HC/'-'/,NC/'+'/,BL/' '/,HF/'F'/,HF1/'.'/
      DATA FOX1/'(1XA1,F9','.2,  121','A1)     '/
      DATA FOX2/'(1XA1, 9','X121A1) '/
      DATA FOX3/'(1H0F   .',' ,  F   ','. )     '/
      DATA VCR/Z4F00/
      DATA KPLOT1/.FALSE./,KPLOT2/.FALSE./
      DATA KABSC,KORD,KBOTGL/3*.FALSE./

      ENTRY PLOT1(NSCALE,NHL,NSBH,NVL,NSBV)
      IFL=FILE
      ERR1=.FALSE.
      ERR3=.FALSE.
      ERR5=.FALSE.
      KPLOT1=.TRUE.
      KPLOT2=.FALSE.
      NH=IABS(NHL)
      NSH=IABS(NSBH)
      NV=IABS(NVL)
      NSV=IABS(NSBV)
      NSCL=NSCALE(1)
      IF (NH*NSH*NV*NSV.NE.0) GO TO 1
      KPLOT=.FALSE.
      ERR1=.TRUE.
      RETURN
    1 KPLOT=.TRUE.
      IF (NV.LE.25) GO TO 2
      KPLOT=.FALSE.
      ERR3=.TRUE.
      RETURN
    2 CONTINUE
      NVM=NV-1
      NVP=NV+1
      NDH=NH*NSH
      NDHP=NDH+1
      NDV=NV*NSV
      NDVP=NDV+1
      NIMG=(NDHP*NDVP)
      IF (NDV.LE.120) GO TO 3
      KPLOT=.FALSE.
```

SUBROUTINE PRPLOT

```
      ERR5=.TRUE.
      RETURN
    3 CONTINUE
      IF (NSCL.EQ.0) GO TO 4
      FSY=10.**NSCALE(2)
      FSX=10.**NSCALE(4)
      IY=MIN0(IABS(NSCALE(3)),7)+1
      IX=MIN0(IABS(NSCALE(5)),9)+1
      GO TO 5
    4 FSY=1.
      FSX=1.
      IY=4
      IX=4
    5 FOR1(10)=NOS(IY)
      NA=MIN0(IX,NSV)-1
      NS=NA-MIN0(NA,120-NOV)
      NB=11-NS+NA
      I1=NB/10
      I2=NB-I1*10
      FOR3(6)=NOS(I1+1)
      FOR3(7)=NOS(I2+1)
      FOR3(9)=NOS(NA+1)
      IF (NV.GT.0) GO TO 7
      DO 6 J=11,18
    6 FOR3(J)=BL
      GO TO 8
    7 I1=NV/10
      I2=NV-I1*10
      FOR3(11)=NOS(I1+1)
      FOR3(12)=NOS(I2+1)
      FOR3(13)=HF
      I1=NSV/100
      I3=NSV-I1*100
      I2=I3/10
      I3=I3-I2*10
      FOR3(14)=NOS(I1+1)
      FOR3(15)=NOS(I2+1)
      FOR3(16)=NOS(I3+1)
      FOR3(17)=HF1
      FOR3(18)=FOR3(9)
    8 IF (KPLOT1) RETURN
      KPLOT1=.TRUE.
C
      ENTRY PLOT2(IMAGE,XMAX,XMIN,YMAX,YMIN,NFILE)
      IFL=FILE
      KPLOT2=.TRUE.
      IF (KPLOT1) GO TO 9
      NSCL=0
      NH=5
      NSH=10
```

SUBROUTINE PRPLOT

```
      NV=10
      NSV=10
      GO TO 1
    9 CONTINUE
      IF (KPLOT) GO TO 10
      IF (ERR1) WRITE (IFL,30)
      IF (ERR3) WRITE (IFL,31)
      IF (ERR5) WRITE (IFL,32)
      RETURN
   10 YMX=YMAX
      DH=(YMAX-YMIN)/FLOAT(NDH)
      DV=(XMAX-XMIN)/FLOAT(NDV)
      DO 11 I=1,NVP
   11 ABNOS(I)=(XMIN+FLOAT((I-1)*NSV)*DV)*FBX
      DO 12 I=1,NIMG
   12 IMAGE(I)=BL
      DO 16 I=1,NDHP
      I2=I*NDVP
      I1=I2-NDV
      KNHOR=MOD(I-1,NSH).NE.0
      IF (KNHOR) GO TO 14
      DO 13 J=I1,I2
   13 IMAGE(J)=HC
   14 CONTINUE
      DO 16 J=I1,I2,NSV
      IF (KNHOR) GO TO 15
      IMAGE(J)=NC
      GO TO 16
   15 IMAGE(J)=VC
   16 CONTINUE
      XMIN1=XMIN-DV/2.
      YMIN1=YMIN-DH/2.
      RETURN

      ENTRY PLOT3(CH,X,Y,N3)
      IF (KPLOT2) GO TO 18
   17 WRITE (IFL,33)
   18 CONTINUE
      IF (.NOT.KPLOT) RETURN
      IF (N3.GT.0) GO TO 19
      KPLOT=.FALSE.
      WRITE (IFL,34)
      RETURN
   19 DO 26 I=1,N3
      IF (DV) 21,20,21
   20 DUM1=0
      GO TO 22
   21 CONTINUE
      DUM1=(X(I)-XMIN1)/DV
   22 IF (DH) 24,23,24
```

SUBROUTINE PRPLOT

```
23 DUM2=0
   GO TO 25
24 CONTINUE
   DUM2=(Y(I)-YMIN1)/DH
25 CONTINUE
   IF (DUM1.LT.0..OR.DUM2.LT.0.) GO TO 26
   IF (DUM1.GE.NDVP.OR.DUM2.GE.NDHP) GO TO 26
   NX=1+INT(DUM1)
   NY=1+INT(DUM2)
   J=(NDHP-NY)*NDVP+NX
   IMAGE(J)=CH
26 CONTINUE
   RETURN
C
   ENTRY PLOT4(NL,LABEL)
   ENTRY FPLOT4(NL,LABEL)
   IF (.NOT.KPLOT) RETURN
   IF (.NOT.KPLOT2) GO TO 17
   DO 28 I=1,NDHP
   IF (I.EQ.NDHP.AND.KBOTSL) GO TO 28
   WL=BL
   IF (I.LE.NL) WL=LABEL(I)
   I2=I*NDVP
   I1=I2-NDV
   IF (MOD(I-1,NSH).EQ.0.AND..NOT.KORD) GO TO 27
   WRITE (IFL,FOR2) WL,(IMAGE(J),J=I1,I2)
   GO TO 28
27 CONTINUE
   ORDNO=(YMX-FLOAT(I-1)*DH)*FSY
   IF (I.EQ.NDHP) ORDNO=YMIN
   WRITE (IFL,FOR1) WL,ORDNO,(IMAGE(J),J=I1,I2)
28 CONTINUE
   IF (KABSC) GO TO 29
   WRITE (IFL,FOR3) (ABNOS(J),J=1,NVP)
29 RETURN
C
   ENTRY OMIT(LSW)
   KABSC=MOD(LSW,2).EQ.1
   KORD=MOD(LSW,4).GE.2
   KBOTSL=LSW.GE.4
   RETURN
C
C
C
30 FORMAT (T5,'SOME PLOT1 ARG. ILLEGALLY 0')
31 FORMAT (T5,'NO. OF VERTICAL LINES >25')
32 FORMAT (T5,'WIDTH OF GRAPH >121')
33 FORMAT (T5,'PLOT2 MUST BE CALLED')
34 FORMAT (T5,'PLOT3, ARG2 ) 0')
   END
```

ATTACHMENT H

SAMPLE RUNS

Three example computer runs of DR_3M are shown on the following pages. For each of these runs the input data deck is listed followed by the output from the program. The first two runs are an optimization and routing run, respectively, for the Sand Creek tributary basin near Denver, Colorado. In the optimization run the watershed has been discretized as a single overland-flow segment draining to a channel segment. In the routing run the watershed is discretized into 18 segments as shown in figure 10.

The third run includes a reservoir segment and is used to semipermanently store the segment flow files on disk for future access by DR_3M-QUAL. A distributed DR_3M-QUAL run using these flow files is included in Attachment F of the DR_3M-QUAL users manual (Alley and Smith, report in preparation).

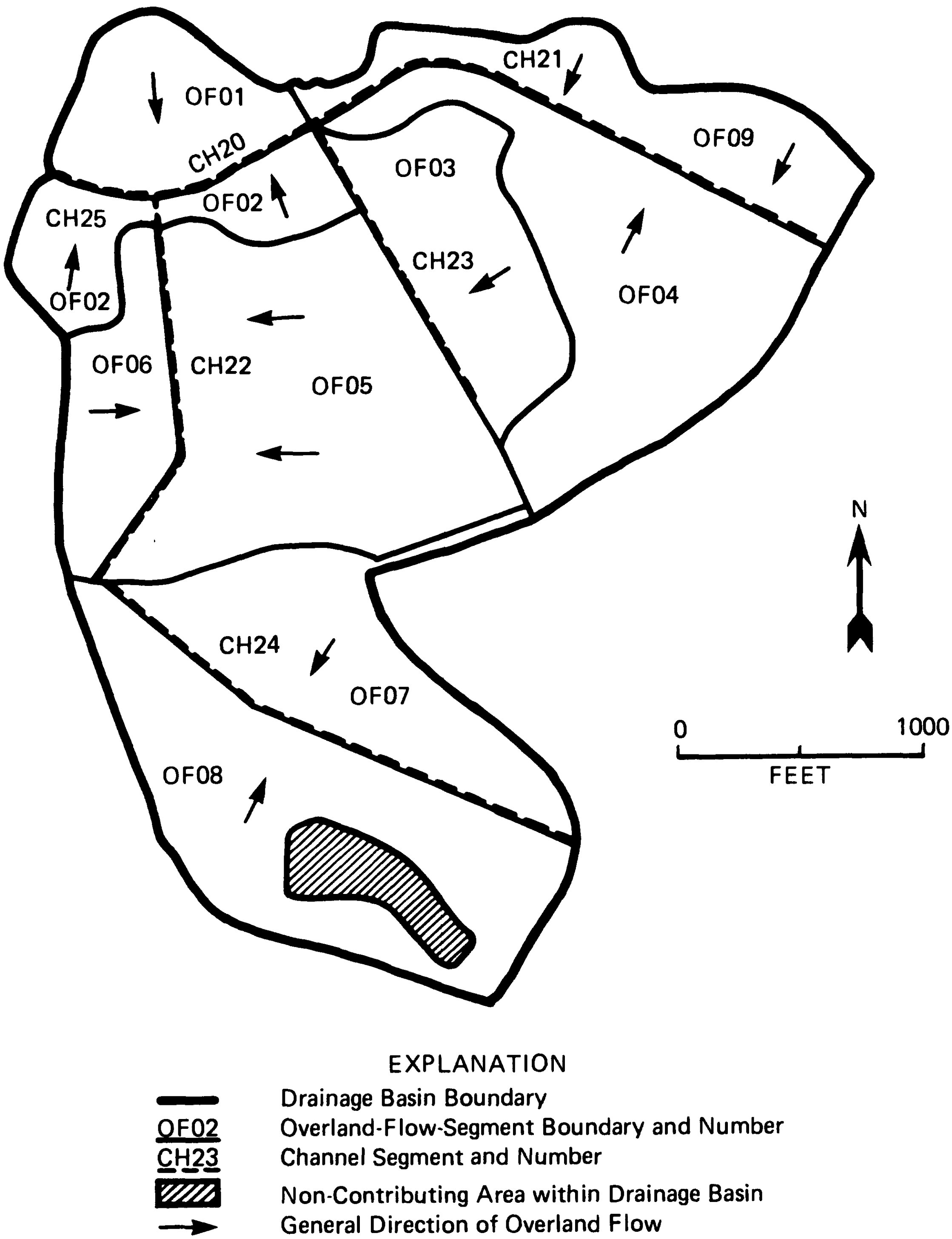


Figure 10.--Schematic of Sand Creek tributary basin at Denver, Colorado, showing segmentation for rainfall-runoff modeling.

INPUT FOR RUN NUMBER 1

```
I N P U T  D A T A ----- P R O G R A M   J R 3 M                            PAGE  1

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

LIST1
06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.        0.377
06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.
06712990  CHERRY CREEK LAKE
                     77 04 01    79 08 27
06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.       5.0
0671160077 6 5 523              9    8   10    6    4    1    1    2    2    3 1
0671160077 6 5 524    2    2    1    2    2    2    0    1    1    0    0    1 1
0671160077 6 6 5 1                                                             1
0671160077 720 520                                                9    4    2 1
0671160077 720 521    2    1    1    1    2    2    4    5    4    4    3    2 1
0671160077 720 522    3    1    3    1    2    1    1    1    1    1    1    1 1
0671160077 720 523    1    2    1    1    1    1    0    0    1    0    0    1 1
0671160077 720 524    0    0    1    0    0    0    0    0    1                1
0671160077 721 5 1                                     0    0    0    0    0 1
0671160077 725 516                                     6    7    5    9    4 1
0671160077 725 517    1    1    0    1    1    1    0    2    1    1    1    0 1
0671160077 725 518    0    0    4    7    1    1    0    1    0    0    1    0 1
0671160077 725 519    1    0    0    0    0    0    0    0    2    4    2    1 1
0671160077 725 520    1    1    0    0    0    1    3    2    1                1
0671160079 7 4 518    0    0    0    0    0    0    0    0   25   27   23   10 1
0671160079 7 4 519   15    4    1    3    2    0    1    0    0    0    0    0 1
0671160079 810 5 5    1    0    0    0    1    0    3    2    3   10    6    3 1
0671160079 810 5 6    3    3    1    2    2    2    2    0    0    0    1    1 1
0671160079 810 5 7    2    0    1    0    0    1    0    0    0    1    0    0 1
0671160079 810 5 8    0    1    2    3    4    1    1    1    0    0    1    0 1
0671160079 810 5 9    0    0    1    0    0    0    0    0    0    0    0    0 1
0671160079 819 517    0    0    0    0    0    0    0    0    0    0    0    2 1
0671160079 819 518   11    3    5   12    5    7    8    5   13    6    3    1 1
0671160079 819 519    0    1    0    1    0    0    0    0    0    0    0    0 1
                                                                               9
0671160077 41   0   1  28   0   0   0   0   0   0   0  31  18   1   1  69   0  3
0671160077 42   0   2  70  11   0   0   0   0   0   0   0   2   0   0          3
0671160077 51   3   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0  3
0671160077 52   0   0   0   9   0   0   0   0   0   0   0  11   1   0   0      3
0671160077 61   0   0   0   0-100-100   0   0   4   0   7   0   0   0   0   0  3
0671160077 62   0   3   2   1   0   0   0   0   0   1   1   0   0   0          3
0671160077 71   0   0   0   0  16   0   0   0   0   0   0   0   0   0   0   0  3
0671160077 72   0   0   2-100-100   0   1   0-100   0   0   0   0   09999      3
0671160079 519999 148  23   2   0   1  15  16   0  46   1   4   1   1   1   1  3
0671160079 52   0   1   0  50   1   3   1   0  30   4   1   1   2  53   5      3
0671160079 61   2   1   0   0   0   0 147  89  28   0   1   1   1   1   9   1  3
0671160079 62   8   1   5   0   1   1  20   1   1   1   1   0   2   0          3
0671160079 71   0   0   0-100   5   0   0   1   0   1   0   1   0   1   1   2  3
0671160079 72   0   0   0   0   2   1   4   0   0   0   0   1   2   1   0      3

12345678901234567890123456789012345678901234567890123456789012345678901234567890
         1         2         3         4         5         6         7         8
```

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

0671160079 81   0    0    0    0    0    0    0    2   5-100   0    0    1   75    1   15   3
0671160079 82   6    5-100     1    6    1    0    1    1  27    4    0    0    0    0        3
0671299077041 .15 .13 .18 .20 .22 .21 .26 .18 .12 .12 .12 .18 .16 .12 .09 .10  4
0671299077042 .23 .23 .20 .21 .16 .26 .20 .26 .22 .18 .17 .14 .10 .17 .26      4
0671299077051 .26 .19 .24 .23 .35 .22 .25 .28 .30 .16 .28 .28 .22 .22 .17 .28  4
0671299077052 .33 .35 .35 .29 .18 .14 .22 .36 .37 .29 .12 .29 .08 .21 .57      4
0671299077061 .27 .33 .24 .35 .25 .45 .20 .18 .27 .18 .34 .26 .30 .20 .37 .42  4
0671299077062 .28 .34 .24 .25 .25 .24 .33 .30 .36 .31 .42 .36 .25 .50          4
0671299077071 .25 .38 .38 .34 .33 .13 .30 .37 .27 .30 .35 .29 .31 .21 .39 .33  4
0671299077072 .39 .40 .37 .27 .24 .06 .15 .22 .26 .15 .23 .26 .30 .36 .35      4
0671299079051 .09 .17 .17 .14 .25 .40 .08 .17 .17 .12 .14 .02 .22 .30 .19 .21  4
0671299079052 .11 .14 .30 .06 .11 .13 .14 .13 .18 .14 .22 .23 .14 .17 .17      4
0671299079061 .10 .11 .33 .19 .23 .25 .31 .31 .     .28 .    .27 .27 .37 .26 .26  4
0671299079062 .28 .29 .25 .29 .33 .32 .18 .26 .33 .32 .34 .26 .35 .40          4
0671299079071 .13 .29 .22 .44 .33 .31 .22 .38 .26 .33 .35 .46 .29 .44 .45 .25  4
0671299079072 .30 .05 .23 .39 .32 .22 .28 .31 .31 .27 .34 .24 .33 .16 .29      4
0671299079081 .16 .28 .36 .36 .41 .42 .50 .25 .39 .39 .08 .27 .25 .06 .30 .19  4
0671299079082 .29 .17 .28 .28 .16 .23 .15 .22 .19 .16 .15 .24 .21 .25 .23      4
                                                                               9
   7    1   10      .06
 0.0        0.5         8.0
 0.25       0.1         0.6
 10.        5.0         20.
 4.0        2.0         6.0
 0.7        0.5         1.0
 0.8        0.7         0.95
 1.0        0.85        1.15
 7
    2  0.5 1.29     1   .05 1.00
FP01                                   500 13240. .20 .016 1.0  .25   1  1.0
CH01                FP01               400 13240.          3.2 1.3
 6 1 1 1 1 1 1
 267 320 .116
 238 297 .160
 188 252 .159
 213 244 .215
  49 108 .127
 204 240 .214
 0 0 0 0 0 0
 1 1 1 1 1 1
 0 0 0 0 0 0
 0 0 0 0 0 0

12345678901234567890123456789012345678901234567890123456789012345678901234567890
         1         2         3         4         5         6         7         8
```

OUTPUT FOR RUN NUMBER 1

```
*****************************************
*          U.S. GEOLOGICAL SURVEY       *
*DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL*
*            VERSION   3/23/82          *
*****************************************

DISCHARGE STATION      06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.
UNIT PRECIP. STATION   06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.
DAILY PRECIP. STATION  06711600  SANDERSON GULCH TRIBUTARY AT LAKEWOOD, CO.
PAN-EVAPO. STATION     06712990  CHERRY CREEK LAKE
DRAINAGE AREA=  0.377 SQ. MI.
UNIT DATA ARE IN    5.000 MINUTE INCREMENTS
THE PERIOD OF RECORD IS FROM  4- 1-77 (DAY=  27850) TO  8-27-79 (DAY=  28728)

JPUN =  0
JPERM = 0
OPT = 1
```

06711600	77	6	5	5	23	0.0	0.0	0.09	0.08	0.10	0.06	0.04	0.01	0.01	0.02	0.02	0.03	1
06711600	77	6	5	5	24	0.02	0.02	0.01	0.02	0.02	0.02	0.0	0.01	0.01	0.0	0.0	0.01	1
06711600	77	6	6	5	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
06711600	77	7	20	5	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.04	0.02	1
06711600	77	7	20	5	21	0.02	0.01	0.01	0.01	0.02	0.02	0.04	0.05	0.04	0.04	0.03	0.02	1
06711600	77	7	20	5	22	0.03	0.01	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1
06711600	77	7	20	5	23	0.01	0.02	0.01	0.01	0.01	0.01	0.0	0.0	0.01	0.0	0.0	0.01	1
06711600	77	7	20	5	24	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	1
06711600	77	7	21	5	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
06711600	77	7	25	5	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.07	0.05	0.09	0.04	1
06711600	77	7	25	5	17	0.01	0.01	0.0	0.01	0.01	0.01	0.0	0.02	0.01	0.01	0.01	0.0	1
06711600	77	7	25	5	18	0.0	0.0	0.04	0.07	0.01	0.01	0.0	0.01	0.0	0.0	0.01	0.0	1
06711600	77	7	25	5	19	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.02	0.01	1
06711600	77	7	25	5	20	0.01	0.01	0.0	0.0	0.0	0.01	0.03	0.02	0.01	0.0	0.0	0.0	1
06711600	79	7	4	5	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.25	0.27	0.23	0.10	1
06711600	79	7	4	5	19	0.15	0.04	0.01	0.03	0.02	0.0	0.01	0.0	0.0	0.0	0.0	0.0	1
06711600	79	8	10	5	5	0.01	0.0	0.0	0.0	0.01	0.0	0.03	0.02	0.03	0.10	0.06	0.03	1
06711600	79	8	10	5	6	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.0	0.0	0.0	0.01	0.01	1
06711600	79	8	10	5	7	0.02	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.01	0.0	0.0	1
06711600	79	8	10	5	8	0.0	0.01	0.02	0.03	0.04	0.01	0.01	0.01	0.0	0.0	0.01	0.0	1
06711600	79	8	10	5	9	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
06711600	79	8	19	5	17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	1
06711600	79	8	19	5	18	0.11	0.03	0.05	0.12	0.05	0.07	0.08	0.05	0.13	0.06	0.03	0.01	1
06711600	79	8	19	5	19	0.0	0.01	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1

06711600	77	4	1	0.0	0.01	0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.31	0.18	0.01	0.01	0.69	0.0	3
06711600	77	4	2	0.0	0.02	0.70	0.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	3
06711600	77	5	1	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	3
06711600	77	5	2	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.01	0.0	0.0	0.0	3
06711600	77	6	1	0.0	0.0	0.0	0.0	****	****	0.0	0.0	0.04	0.0	0.07	0.0	0.0	0.0	0.0	0.0	3
06711600	77	6	2	0.0	0.03	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	3
06711600	77	7	1	0.0	0.0	0.0	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3
06711600	77	7	2	0.0	0.0	0.02	****	****	0.0	0.01	0.0	****	0.0	0.0	0.0	0.0	0.0	****	0.0	3
06711600	79	5	1	****	1.48	0.23	0.02	0.0	0.01	0.15	0.16	0.0	0.46	0.01	0.04	0.01	0.01	0.01	0.01	3
06711600	79	5	2	0.0	0.01	0.0	0.50	0.01	0.03	0.01	0.0	0.30	0.04	0.01	0.01	0.02	0.53	0.05	0.0	3
06711600	79	6	1	0.02	0.01	0.0	0.0	0.0	0.0	1.47	0.89	0.28	0.0	0.01	0.01	0.01	0.01	0.09	0.01	3
06711600	79	6	2	0.08	0.01	0.05	0.0	0.01	0.01	0.20	0.01	0.01	0.01	0.01	0.0	0.02	0.0	0.0	0.0	3
06711600	79	7	1	0.0	0.0	0.0	****	0.05	0.0	0.0	0.01	0.0	0.01	0.0	0.01	0.0	0.01	0.01	0.02	3
06711600	79	7	2	0.0	0.0	0.0	0.0	0.02	0.01	0.04	0.0	0.0	0.0	0.0	0.01	0.02	0.01	0.0	0.0	3
06711600	79	8	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.05	****	0.0	0.0	0.01	0.75	0.01	0.15	3
06711600	79	8	2	0.06	0.05	****	0.01	0.05	0.01	0.0	0.01	0.01	0.27	0.04	0.0	0.0	0.0	0.0	0.0	3
06712990	77	4	1	0.15	0.13	0.18	0.20	0.22	0.21	0.26	0.18	0.12	0.12	0.12	0.18	0.16	0.12	0.09	0.10	4
06712990	77	4	2	0.23	0.23	0.20	0.21	0.15	0.26	0.20	0.26	0.22	0.18	0.17	0.14	0.10	0.17	0.26	0.0	4
06712990	77	5	1	0.26	0.19	0.24	0.23	0.35	0.22	0.25	0.28	0.30	0.16	0.28	0.28	0.22	0.22	0.17	0.28	4
06712990	77	5	2	0.33	0.35	0.35	0.29	0.18	0.14	0.22	0.36	0.37	0.29	0.12	0.29	0.08	0.21	0.57	0.0	4
06712990	77	6	1	0.27	0.33	0.24	0.35	0.25	0.45	0.20	0.18	0.27	0.18	0.34	0.26	0.30	0.20	0.37	0.42	4
06712990	77	6	2	0.28	0.34	0.24	0.25	0.25	0.24	0.33	0.30	0.36	0.31	0.42	0.36	0.25	0.50	0.0	0.0	4
06712990	77	7	1	0.25	0.38	0.39	0.34	0.33	0.13	0.30	0.37	0.27	0.30	0.35	0.29	0.31	0.21	0.39	0.33	4
06712990	77	7	2	0.39	0.40	0.37	0.27	0.24	0.06	0.15	0.22	0.26	0.15	0.23	0.26	0.30	0.36	0.35	0.0	4
06712990	79	5	1	0.09	0.17	0.17	0.14	0.25	0.40	0.08	0.17	0.17	0.12	0.14	0.02	0.22	0.30	0.19	0.21	4
06712990	79	5	2	0.11	0.14	0.30	0.06	0.11	0.13	0.14	0.13	0.18	0.14	0.22	0.23	0.14	0.17	0.17	0.0	4
06712990	79	6	1	0.10	0.11	0.33	0.19	0.23	0.25	0.31	0.31	0.0	0.28	0.0	0.27	0.27	0.37	0.26	0.26	4
06712990	79	6	2	0.28	0.29	0.26	0.29	0.33	0.32	0.18	0.26	0.33	0.32	0.34	0.26	0.35	0.40	0.0	0.0	4
06712990	79	7	1	0.13	0.29	0.22	0.44	0.33	0.31	0.22	0.38	0.26	0.33	0.35	0.46	0.29	0.44	0.45	0.25	4
06712990	79	7	2	0.30	0.05	0.23	0.39	0.32	0.22	0.28	0.31	0.31	0.27	0.34	0.24	0.33	0.16	0.29	0.0	4
06712990	79	8	1	0.16	0.28	0.36	0.36	0.41	0.42	0.50	0.25	0.39	0.39	0.08	0.27	0.25	0.06	0.30	0.19	4
06712990	79	8	2	0.29	0.17	0.28	0.28	0.15	0.23	0.15	0.22	0.19	0.16	0.15	0.24	0.21	0.25	0.23	0.0	4

```
INITIAL PARAMETER VALUES  (PARAMETERS TO BE OPTIMIZED ARE MARKED WITH A +)

  1        6.000000   PSP
  2        0.250000   KSAT
  3       10.000000   R3F
  4        4.000000   BMSN
  5        0.700000   EVC
  6        0.800000   RR
  7        1.000000   EAC     +


INITIAL STEP SIZE INCREMENTS

    0.060000


THE MAX. NUMBER OF ITERATIONS=   10

INITIALLY AND AFTER EACH VECTOR MATRIX ORTHONORMALIZATION,
THE PARAMETRIC VECTOR INCREMENT SIZE IS,  0.060 OF THE VECTOR SIZE


                                                  NUMBER OF SEGMENTS =   2
                                                  DT =  0.50 MINUTES
                                                  NUMBER OF RAIN GAGES = 1
                                                  NUMBER OF SOIL TYPES = 1
                                                  IMPERVIOUS RETENTION = 0.05 INCHES
                                                  RAT =  1.290
                                                  ALPADJ = 1.00
                                                  WX = 0.0
```

SEGMENT	UPSTREAM SEGMENTS	ADJACENT SEGMENTS	TYPE	METH	IPR	NDX	LENGTH (FEET)	SLOPE	ROUGHNESS PARAMETER	OTHER PARAMETERS			THIESSEN COEFFICNTS		
FP01			5	0	0	1	3240.0	0.2000	0.160E-01	1.000	0.250	1	1.00	0.0	0.0
CH01		FP01	4	0	0	1	3240.0	0.0	0.0	3.200	1.300	0	0.0	0.0	0.0

```
COMPUTATION SEQUENCE                      KINEMATIC WAVE  PARAMETERS

  INDEX    SEGMENT                             ALPHA       M
    1       FP01                               41.65      1.670
    2       CH01                                3.20      1.300


FURNISHED DRAINAGE AREA =  0.3770  SQUARE MILES
COMPUTED  DRAINAGE AREA =  0.3765  SQUARE MILES

THE DRAINAGE BASIN IS 25.0 PERCENT EFF. IMPERVIOUS AREA
                      16.9 PERCENT NONEFF. IMPERVIOUS AREA
                      58.1 PERCENT PERVIOUS AREA


THERE ARE   6 STORM EVENTS GROUPED AS FOLLOWS     1     1     1     1     1     1
STORM NO.  1 STARTS AT TIME PERIOD  267 AND ENDS AT  320      RECORDS REQUIRED FOR ROUTING =   10
STORM NO.  2 STARTS AT TIME PERIOD  238 AND ENDS AT  297      RECORDS REQUIRED FOR ROUTING =   10
STORM NO.  3 STARTS AT TIME PERIOD  188 AND ENDS AT  252      RECORDS REQUIRED FOR ROUTING =   12
STORM NO.  4 STARTS AT TIME PERIOD  213 AND ENDS AT  244      RECORDS REQUIRED FOR ROUTING =    6
STORM NO.  5 STARTS AT TIME PERIOD   49 AND ENDS AT  108      RECORDS REQUIRED FOR ROUTING =   10
STORM NO.  6 STARTS AT TIME PERIOD  204 AND ENDS AT  240      RECORDS REQUIRED FOR ROUTING =    8

DETAILED OUTPUT FOR STORMS   0  0  0  0  0  0

STORM EVENTS IN THE OBJ. FCT. ARE   1  1  1  1  1  1

THE STORM EVENTS PLOTTED ARE   0  0  0  0  0  0

INPUT HYDROGRAPHS FOR STORMS   0  0  0  0  0  0

NUMBER OF RECORDS USED FOR DIRECT ACCESS FILE =    0
```

SUMMARY OF MEASURED DATA

```
STORM-RUNOFF EVENT NUMBER   1  DATED  6/ 5/77
MEASURED RAINFALL   GAGE NUMBER  1 =     0.600 INCHES
MEASURED DIRECT RUNOFF =    0.116 INCHES

STORM-RUNOFF EVENT NUMBER   2  DATED  7/20/77
MEASURED RAINFALL   GAGE NUMBER  1 =     0.740 INCHES
MEASURED DIRECT RUNOFF =    0.140 INCHES

STORM-RUNOFF EVENT NUMBER   3  DATED  7/25/77
MEASURED RAINFALL   GAGE NUMBER  1 =     0.750 INCHES
MEASURED DIRECT RUNOFF =    0.159 INCHES

STORM-RUNOFF EVENT NUMBER   4  DATED  7/ 4/79
MEASURED RAINFALL   GAGE NUMBER  1 =     1.110 INCHES
MEASURED DIRECT RUNOFF =    0.215 INCHES

STORM-RUNOFF EVENT NUMBER   5  DATED  8/10/79
MEASURED RAINFALL   GAGE NUMBER  1 =     0.660 INCHES
MEASURED DIRECT RUNOFF =    0.127 INCHES

STORM-RUNOFF EVENT NUMBER   6  DATED  8/19/79
MEASURED RAINFALL   GAGE NUMBER  1 =     0.830 INCHES
MEASURED DIRECT RUNOFF =    0.214 INCHES
```

BEGINNING OF STAGE

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	6/ 5/77	0.003	0.141	0.116	0.0	0.0	0.0	0.037
2	7/20/77	0.003	0.176	0.160	0.0	0.0	0.0	0.009
3	7/25/77	0.004	0.179	0.159	0.0	0.0	0.0	0.014
4	7/ 4/79	0.043	0.308	0.215	0.0	0.0	0.0	0.130
5	8/10/79	0.002	0.155	0.127	0.0	0.0	0.0	0.039
6	8/19/79	0.012	0.207	0.214	0.0	0.0	0.0	0.001

AT ITERATION NO. 0 OBJECTIVE FUNCTION= 0.229949
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 1.000000

AT ITERATION NO. 2 OBJECTIVE FUNCTION= 0.185256
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 0.970000

AT ITERATION NO. 3 OBJECTIVE FUNCTION= 0.105002
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 0.880000

B1 = 0.120000 B2 = 0.0
NEW ORTHONORMAL BASIS
-1.00000
START OF STAGE STEP SIZE INCREMENTS
0.052800

BEGINNING OF STAGE

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	6/ 5/77	0.004	0.125	0.116	0.0	0.0	0.0	0.005
2	7/20/77	0.004	0.155	0.160	0.0	0.0	0.0	0.001
3	7/25/77	0.005	0.159	0.159	0.0	0.0	0.0	0.000
4	7/ 4/79	0.049	0.282	0.215	0.0	0.0	0.0	0.073
5	8/10/79	0.003	0.137	0.127	0.0	0.0	0.0	0.005
6	8/19/79	0.014	0.185	0.214	0.0	0.0	0.0	0.020

AT ITERATION NO. 4 OBJECTIVE FUNCTION= 0.105002
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 0.880000

AT ITERATION NO. 7 OBJECTIVE FUNCTION= 0.100958
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 0.866800

B1 = 0.013200 B2 = 0.0
NEW ORTHONORMAL BASIS
-1.00000
START OF STAGE STEP SIZE INCREMENTS
0.052008

BEGINNING OF STAGE

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	6/ 5/77	0.004	0.123	0.116	0.0	0.0	0.0	0.003
2	7/20/77	0.004	0.153	0.160	0.0	0.0	0.0	0.002
3	7/25/77	0.005	0.156	0.159	0.0	0.0	0.0	0.000
4	7/ 4/79	0.049	0.279	0.215	0.0	0.0	0.0	0.068
5	8/10/79	0.003	0.135	0.127	0.0	0.0	0.0	0.004
6	8/19/79	0.014	0.193	0.214	0.0	0.0	0.0	0.024

AT ITERATION NO. 8 OBJECTIVE FUNCTION= 0.100959
PARAMETER VALUES ARE
6.000000 0.250000 10.000000 4.000000 0.700000 0.800000 0.866800

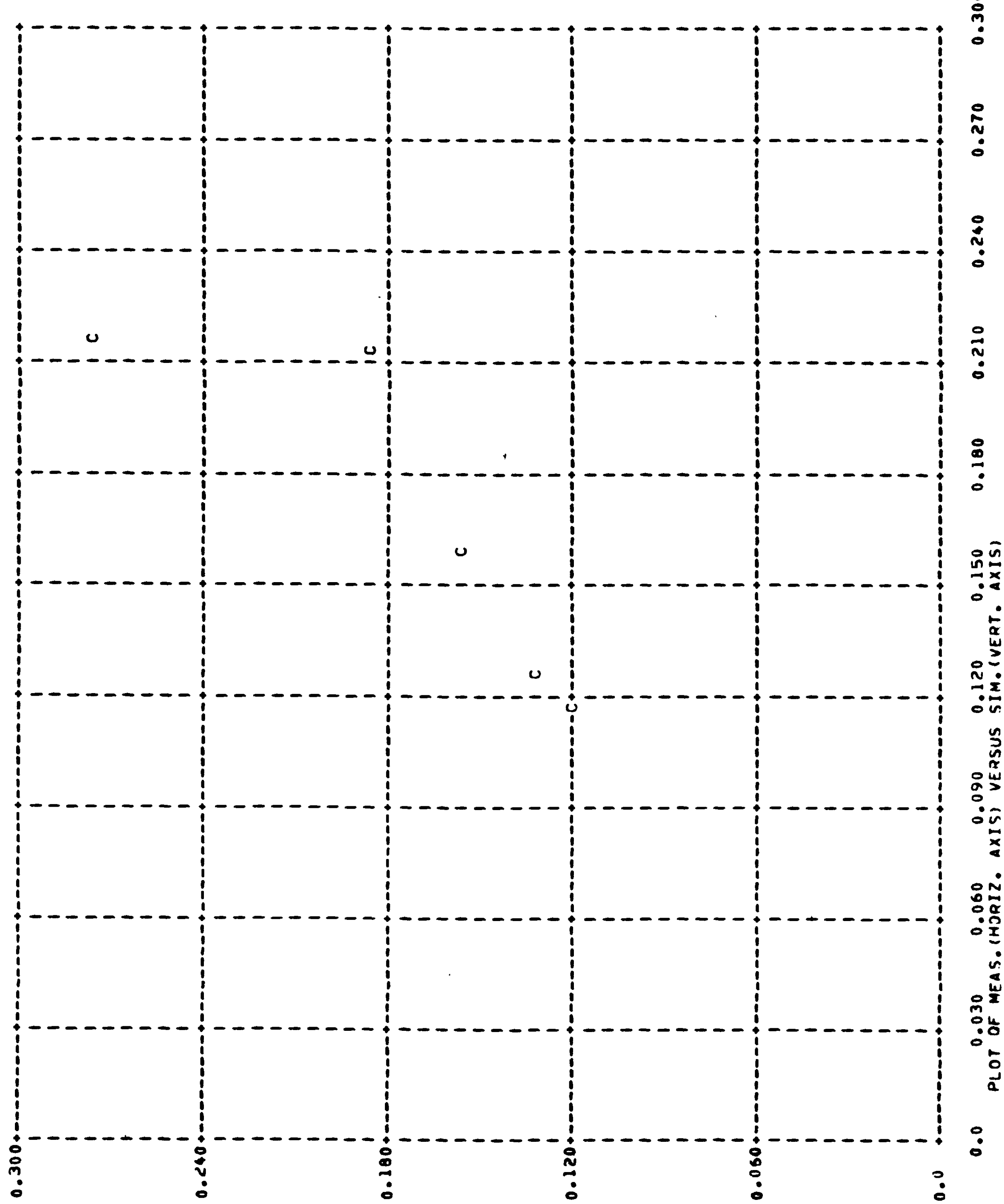
END OF RUN--RESULTS OF LAST SUCCESSFUL TRIAL

OBJECTIVE FUNCTION = 0.101

PARAMETER	FINAL VALUE	LOWER BOUND	UPPER BOUND
1	6.0000	0.5000	8.0000
2	0.2500	0.1000	0.6000
3	10.0000	5.0000	20.0000
4	4.0000	2.0000	6.0000
5	0.7000	0.5000	1.0000
6	0.8000	0.7000	0.9500
7	0.8668	0.8500	1.1500

NEW VALUE FOR RAT IS 1.347

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	6/ 5/77	0.004	0.123	0.116	0.0	0.0	0.0	0.003
2	7/20/77	0.004	0.153	0.160	0.0	0.0	0.0	0.002
3	7/25/77	0.005	0.156	0.159	0.0	0.0	0.0	0.000
4	7/ 4/79	0.049	0.279	0.215	0.0	0.0	0.0	0.068
5	8/10/79	0.003	0.135	0.127	0.0	0.0	0.0	0.004
6	8/19/79	0.014	0.183	0.214	0.0	0.0	0.0	0.024


0.0
0.060
0.120
0.180
0.240
0.300
0.0
0.030
0.060
0.090
0.120
0.150
0.180
0.210
0.240
0.270
0.300
PLOT OF MEAS.(HORIZ. AXIS) VERSUS SIM.(VERT. AXIS)
VOLUMES

INPUT FOR RUN NUMBER 2

```
L-SUMMI  D-A-T-A ----- P R O G R A M   U R S M                          PAGE  1

          1         2         3         4         5         6         7         9
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

06714310   SAND CREEK TRIBUTARY AT DENVER, COLORADO         0.286
06714310   SAND CREEK TRIBUTARY AT DENVER, COLORADO
40350010   FORT COLLINS
                    73 05 01     74 07 31
06714310   SAND CREEK TRIBUTARY AT DENVER, COLORADO         5.0
067143107307120519                                                    7     5     1 1
067143107307120520    4     9     4     2     1                                     1
067143107307190521    0     0     0     0     0     0    29    23     4     2     1     2 1
067143107307190522    1     1     1     0     0     0     0     0     0     0     0     0 1
067143107307220514                                                                 11 1
067143107307220515    9     2     1                                                   1
067143107307240519    7    25    28     7     1     7     3     1     0     0     0     1 1
067143107307240520    1     2     1     0     0     0     1     2     2     1     2     1 1
067143107307240521    2     0     0     0     0     0     0     0     0     0     0     0 1
067143107307300519                      4     1                                       1
067143107307300520   16     9     4                                                   1
067143107308070517    0     0    10    47    33    36    25    25     3     2     8     3 1
067143107308070518    1     0     0     0     0     0     0     0     0     0     0     0 1
067143107407220501                            2     2     1     1     1     5    23    19 1
067143107407220502   20    12     5     5     3     3     1     1     1     1           1
067143107407300506                                              4    26    33    33    22 1
067143107407300507   10     6     3     1                                               1
0671431073 712 519 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 8.20 9.50 2
0671431073 712 520 9.8019.0026.0032.0025.00 9.80 6.50 5.50 4.50 3.90 3.20 3.00 2
0671431073 712 521 2.50 2.00 1.50 1.00 0.80 0.40 0.10 0.00 0.00 0.00 0.00 0.00 2
0671431073 719 521 0.00 0.00 0.00 0.00 0.00 0.00 5.0052.0068.0056.0033.0024.00 2
0671431073 719 52217.0014.0014.0013.0011.00 9.00 7.00 6.00 5.00 4.50 4.00 3.00 2
0671431073 719 523 2.00 1.50 1.00 0.50 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431073 722 514 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431073 722 51517.0022.0013.00 9.40 7.5012.00 9.40 5.50 4.50 4.00 3.00 2.30 2
0671431073 722 516 1.80 1.20 0.80 0.20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431073 724 519 0.0025.0092.00  10484.0054.0048.0033.0026.0020.0016.0014.00 2
0671431073 724 52011.0011.0011.0012.0010.00 8.00 6.20 6.10 8.00 9.6012.0013.00 2
0671431073 724 52114.0013.0011.00 9.00 7.60 6.00 5.00 4.50 4.00 3.00 2.00 1.80 2
0671431073 724 522 1.50 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431073 730 519 0.00 0.00 0.00 2.00 3.70 5.20 7.30 4.10 3.50 2.50 1.80 1.60 2
0671431073 730 520 3.5032.0029.0018.0012.00 6.80 3.50 2.80 2.00 1.60 1.00 0.50 2
0671431073 730 521 0.20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431073 8 7 517 0.00 0.00 0.0033.00  155  236  230  215  206  16898.0058.00 2
0671431073 8 7 51842.0027.0020.0015.0013.0011.00 9.00 7.00 6.00 4.00 3.00 2.00 2
0671431073 8 7 519 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
0671431074 722 5 1 0.00 0.00 0.00 0.00 0.00 9.2010.0011.00 8.90 7.5018.0049.00 2
0671431074 722 5 242.0099.0053.0027.0019.0016.0015.00 9.20 7.80 6.50 5.80 5.10 2
0671431074 722 5 3 4.10 2.90 2.00 1.20 0.50 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2

12345678901234567890123456789012345678901234567890123456789012345678901234567890
          1         2         3         4         5         6         7         8
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[illegible] ----- PROGRAM [illegible]                                            PAGE  2

          1         2         3         4         5         6         7         8
12345678901234567890123455789012345678901234567890123456789012345678901234567890

0671431074 730 5 6 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0036.00  233  251 2
0671431074 730 5 7  183  152  11375.0044.0023.0015.0012.00 7.50 6.50 5.30 4.70 2
0671431074 730 5 8 3.00 2.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
                                                                               9
0671431073 51   0 .06   0   0 .394.00 .01   0   0   0   0   0   0   0   0   0 3
0671431073 52   0   0   0 .01 .12 .29   0 .05   0   0   0   0 .01 .79   0     3
0671431073 61   0   0 .05 .07 .01   0   0 .01   0   0   0   0   0 .02   0   0 3
0671431073 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0         3
0671431073 71   0   0   0   0   0   0   0   0   0   0   0-100   0 .03 .01   0 3
0671431073 72   0 .01-100 .12 .03-100   0-100 .01   0   0   0 .01-100   0     3
0671431073 81   0   0   0   0 .01   0-100   09999                             3
0671431074 519999   0   0 .01   0   0   0   0   0   0   0   0   0   0   0   0 3
0671431074 52   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0     3
0671431074 61   0   0   0   0   0 .01 .02 .99 .01   0   0   0 .01   0   0   0 3
0671431074 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0         3
0671431074 71   0   0   0   0   0   0   0   0   0   0 .15 .16   0   0 .04   0 3
0671431074 72   0   0   0   0   0-100   0   0 .01 .01   0   0   0-100   0     3
4035001073 51 .18 .18 .17 .15 .19 .16 .13 .16 .17 .15 .19 .21 .19 .16 .16 .19 4
4035001073 52 .17 .17 .15 .14 .16 .16 .15 .14 .15 .15 .15 .18 .16 .20 .19     4
4035001073 61 .12 .27 .25 .29 .34 .22 .30 .34 .30 .40 .12 .18 .19 .13 .27 .31 4
4035001073 62 .33 .55 .25 .21 .22 .24 .28 .17 .24 .24 .18 .25 .20 .23         4
4035001073 71 .29 .27 .29 .24 .28 .29 .31 .17 .19 .31 .24 .31 .18 .11 .13 .17 4
4035001073 72 .21 .16 .21 .27 .21 .11 .21 .15 .20 .20 .19 .19 .20 .10 .12     4
4035001073 81 .17 .20 .14 .23 .14 .19 .16 .18 .25 .19 .14 .19 .21 .24 .28 .25 4
4035001074 51 .26 .26 .13 .22 .23 .26 .26 .30 .25 .17 .33 .25 .29 .33 .26 .28 4
4035001074 52 .16 .20 .24 .31 .24 .24 .22 .19 .24 .29 .29 .28 .32 .37 .24     4
4035001074 61 .23 .30 .29 .32 .17 .08 .08 .24 .22 .26 .28 .26 .31 .29 .27 .13 4
4035001074 62 .16 .21 .28 .30 .34 .14 .21 .29 .27 .21 .24 .24 .24 .30         4
4035001074 71 .30 .35 .35 .34 .31 .30 .26 .28 .24 .28 .23 .35 .07 .06 .17 .20 4
4035001074 72 .28 .27 .39 .32 .25 .13 .19 .22 .24 .27 .26 .34 .19 .20 .20     4
                                                                               9
    7
 3.0       0.5       8.0
 0.30      0.1       0.6
 10.       5.0       20.
 5.0       2.0       6.0
 0.7       0.5       1.0
 0.8       0.7       0.95
 1.0       0.85      1.15

    18  1.0 1.14    1  .05 1.0
0P01                                5 010 454. .005 .20   .83  0.0 1  1.0
0I01                                5 0 7 454. .005 .013  .17  1.0 1   1.
0F02                                5 0 5 392. .022 .015  1.0  .40 1  1.0
0F03                                5 0 6 480. .024 .016  1.0  .34 1  1.0

12345678901234567890123456789012345678901234567890123456789012345678901234567890
          1         2         3         4         5         6         7         8
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          1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

OF04                            5 0 7 593. .018 .016  1.0  .34 1  1.0
OF05                            5 0 91006. .022 .016  1.0  .30 1  1.0
OF06                            5 0 7 295. .004 .016  1.0  .47 1  1.0
OP07                            5 010 372. .012 .20   .82  0.0 1  1.0
OI07                            5 0 5 372. .012 .013  .18  1.0 1  1.0
OP08                            5 010 699. .007 .20   .95  0.0 1  1.0
OI08                            5 0 8 699. .007 .013  .05  1.0 1  1.0
OF09                            5 0 6 340. .010 .016  1.0  .22 1  1.0
CH20CH23CH21     OP01OI01OF02   1 0 3 700. .005 .016  11.
CH21             OF04OF09       3 0 42240. .007 .016  11.
CH22CH24         OF05OF06       3 0 31580. .008 .016  4.3
CH23             OF03           3 0 21270. .029 .013  31.
CH24             OP07OI07OP08OI08 3 0 62225. .005 .013  50.
CH25CH22CH20     OP01OI01OF02   3 1 2 420. .005 .016  11.
 8 1 1 1 1 1 1 1 1
 226 250
 247 275
 158 190
 217 260
 220 250
 195 225
   5  35
  58  90
 1 1 1 1 0 0 0 0
 0 0 0 0 0 0 0 0
 0 1 0 0 0 0 0 0
 0 0 0 0 0 0 0 0

12345678901234567890123456789012345678901234567890123456789012345678901234567890
          1         2         3         4         5         6         7         8
```

OUTPUT FOR RUN NUMBER 2

```
*****************************************
*          U.S. GEOLOGICAL SURVEY        *
*DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL*
*            VERSION   3/23/82           *
*****************************************

DISCHARGE STATION      06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
UNIT PRECIP. STATION   06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
DAILY PRECIP. STATION  06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
PAN-EVAPO. STATION     40350010  FORT COLLINS
DRAINAGE AREA=  0.286 SQ. MI.
UNIT DATA ARE IN    5.000 MINUTE INCREMENTS
THE PERIOD OF RECORD IS FROM  5- 1-73 (DAY=  26419) TO  7-31-74 (DAY=  26875)

JPUN =  0
JPERM = 0
DPT = 0
```

```
INITIAL PARAMETER VALUES  (PARAMETERS TO BE OPTIMIZED ARE MARKED WITH A *)

  1       3.000000   PSP
  2       0.300000   KSAT
  3      10.000000   RSF
  4       5.000000   BMSN
  5       0.700000   EVC
  6       0.800000   RR
  7       1.000000   EAC

                         NUMBER OF SEGMENTS =  18
                         DT =  1.00 MINUTES
                         NUMBER OF RAIN GAGES = 1
                         NUMBER OF SOIL TYPES = 1
                         IMPERVIOUS RETENTION = 0.05 INCHES
                         RAT =  1.140
                         ALPADJ = 1.00
                         WX = 0.0
```

SEGMENT	UPSTREAM SEGMENTS	ADJACENT SEGMENTS	TYPE	METH	IPR	NDX	LENGTH (FEET)	SLOPE	ROUGHNESS PARAMETER	OTHER PARAMETERS			THIESSEN COEFFICNTS		
OP01			5	0	0	10	454.0	0.0050	0.200E+00	0.530	0.0	1	1.00	0.0	0.0
OI01			5	0	0	7	454.0	0.0050	0.130E-01	0.170	1.000	1	1.00	0.0	0.0
OF02			5	0	0	5	382.0	0.0220	0.160E-01	1.000	0.400	1	1.00	0.0	0.0
OF03			5	0	0	6	480.0	0.0240	0.160E-01	1.000	0.340	1	1.00	0.0	0.0
OF04			5	0	0	7	593.0	0.0180	0.160E-01	1.000	0.340	1	1.00	0.0	0.0
OF05			5	0	0	9	1006.0	0.0220	0.160E-01	1.000	0.300	1	1.00	0.0	0.0
OF06			5	0	0	7	295.0	0.0040	0.160E-01	1.000	0.470	1	1.00	0.0	0.0
OP07			5	0	0	10	372.0	0.0120	0.200E+00	0.520	0.0	1	1.00	0.0	0.0
OI07			5	0	0	5	372.0	0.0120	0.130E-01	0.180	1.000	1	1.00	0.0	0.0
OP08			5	0	0	10	699.0	0.0070	0.200E+00	0.950	0.0	1	1.00	0.0	0.0
OI08			5	0	0	8	699.0	0.0070	0.130E-01	0.050	1.000	1	1.00	0.0	0.0
OF09			5	0	0	6	340.0	0.0100	0.160E-01	1.000	0.220	1	1.00	0.0	0.0
CH20	CH23 CH21	OP01 OI01 OF02	1	0	0	3	700.0	0.0050	0.160E-01	11.000	0.0	0	0.0	0.0	0.0
CH21		OF04 OF09	3	0	0	4	2240.0	0.0070	0.160E-01	11.000	0.0	0	0.0	0.0	0.0
CH22	CH24	OF05 OF06	3	0	0	3	1580.0	0.0080	0.160E-01	4.300	0.0	0	0.0	0.0	0.0
CH23		OF03	3	0	0	2	1270.0	0.0290	0.130E-01	31.000	0.0	0	0.0	0.0	0.0
CH24		OP07 OI07 OP08 OI08	3	0	0	6	2225.0	0.0050	0.130E-01	50.000	0.0	0	0.0	0.0	0.0
CH25	CH22 CH20	OP01 OI01 OF02	3	0	1	2	420.0	0.0050	0.160E-01	11.000	0.0	0	0.0	0.0	0.0

COMPUTATION SEQUENCE		KINEMATIC WAVE PARAMETERS	
INDEX	SEGMENT	ALPHA	M
1	OP01	0.53	1.670
2	OI01	8.10	1.670
3	OF02	13.81	1.670
4	OF03	14.43	1.670
5	OF04	12.49	1.670
6	OF05	13.81	1.670
7	OF06	5.89	1.670
8	OP07	0.82	1.670
9	OI07	12.56	1.670
10	OP08	0.62	1.670
11	OI08	9.59	1.670
12	OF09	9.31	1.670
14	CH21	2.61	1.330
16	CH23	4.82	1.330
17	CH24	1.72	1.330
13	CH20	2.21	1.330
15	CH22	3.48	1.330
18	CH25	2.21	1.330

FURNISHED DRAINAGE AREA = 0.2860 SQUARE MILES
COMPUTED DRAINAGE AREA = 0.2896 SQUARE MILES
THESE DIFFER BY MORE THAN ONE PERCENT

THE DRAINAGE BASIN IS 24.9 PERCENT EFF. IMPERVIOUS AREA
9.2 PERCENT NONEFF. IMPERVIOUS AREA
65.9 PERCENT PERVIOUS AREA

THERE ARE 8 STORM EVENTS GROUPED AS FOLLOWS 1 1 1 1 1 1 1 1
STORM NO. 1 STARTS AT TIME PERIOD 226 AND ENDS AT 250 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 2 STARTS AT TIME PERIOD 247 AND ENDS AT 275 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 3 STARTS AT TIME PERIOD 168 AND ENDS AT 190 RECORDS REQUIRED FOR ROUTING = 18
STORM NO. 4 STARTS AT TIME PERIOD 217 AND ENDS AT 260 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 5 STARTS AT TIME PERIOD 220 AND ENDS AT 250 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 6 STARTS AT TIME PERIOD 195 AND ENDS AT 225 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 7 STARTS AT TIME PERIOD 5 AND ENDS AT 35 RECORDS REQUIRED FOR ROUTING = 36
STORM NO. 8 STARTS AT TIME PERIOD 68 AND ENDS AT 90 RECORDS REQUIRED FOR ROUTING = 18

DETAILED OUTPUT FOR STORMS 1 1 1 1 0 0 0 0

STORM EVENTS IN THE OBJ. FCT. ARE 0 0 0 0 0 0 0 0

THE STORM EVENTS PLOTTED ARE 0 1 0 0 0 0 0 0

INPUT HYDROGRAPHS FOR STORMS 0 0 0 0 0 0 0 0

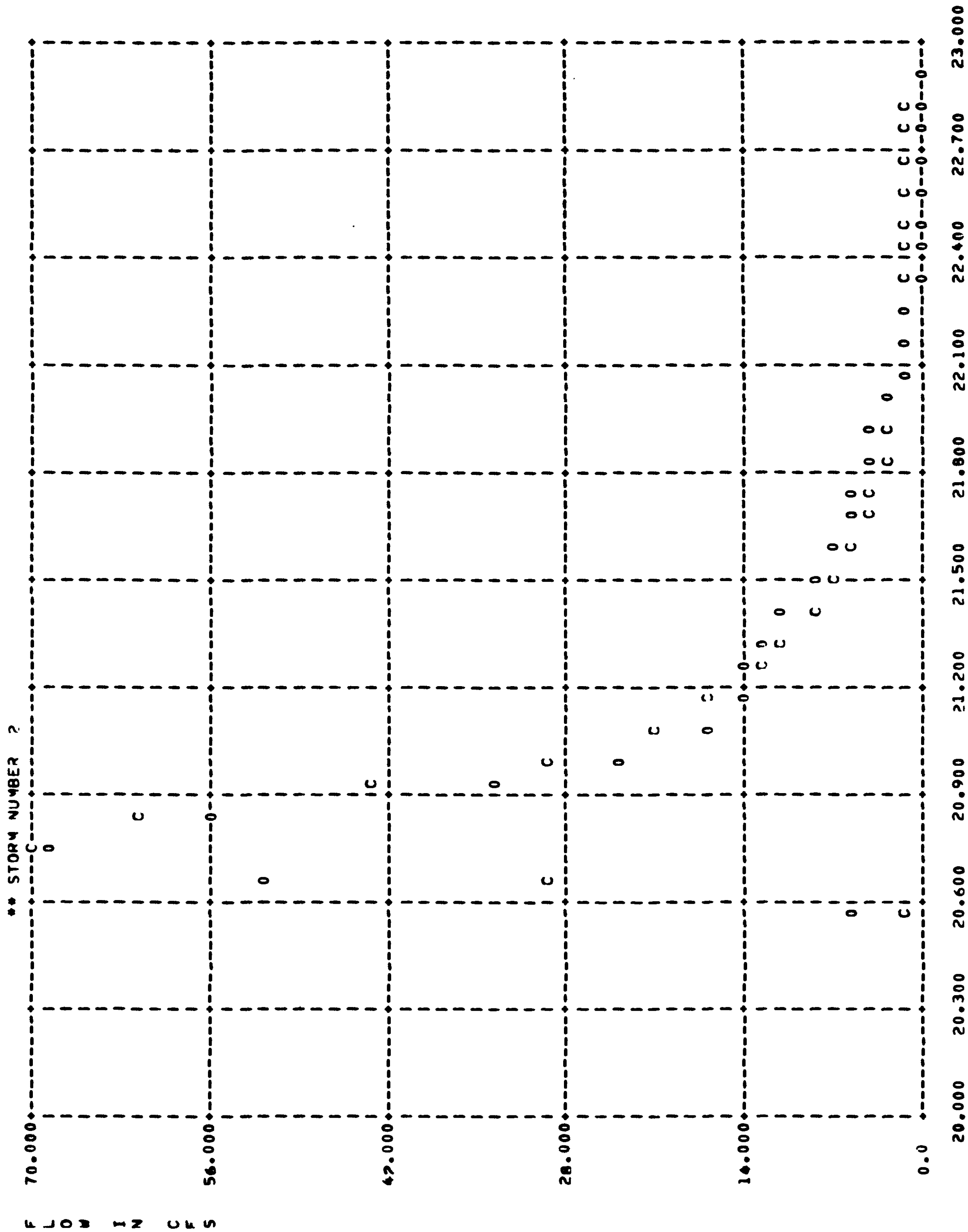
NUMBER OF RECORDS USED FOR DIRECT ACCESS FILE = 36

STORM NUMBER 1
SEGMENT CM25

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
18:50.	0.028	18:55.	0.388	19: 0.	1.668	19: 5.	3.587	19:10.	7.217
19:15.	14.631	19:20.	19.522	19:25.	19.624	19:30.	16.940	19:35.	13.429
19:40.	10.350	19:45.	7.972	19:50.	6.201	19:55.	4.891	20: 0.	3.915
20: 5.	3.186	20:10.	2.531	20:15.	2.201	20:20.	1.864	20:25.	1.595
20:30.	1.378	20:35.	1.200	20:40.	1.053	20:45.	0.930	20:50.	0.826

STORM NUMBER 2
SEGMENT CH25

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
20:35.	1.381	20:40.	29.592	20:45.	69.650	20:50.	61.804	20:55.	42.838
21: 0.	29.492	21: 5.	21.579	21:10.	16.463	21:15.	13.121	21:20.	10.750
21:25.	8.734	21:30.	7.083	21:35.	5.775	21:40.	4.747	21:45.	3.935
21:50.	3.297	21:55.	2.789	22: 0.	2.382	22: 5.	2.053	22:10.	1.784
22:15.	1.564	22:20.	1.381	22:25.	1.229	22:30.	1.100	22:35.	0.992
22:40.	0.899	22:45.	0.820	22:50.	0.751	22:55.	0.692		


** STORM NUMBER 2
FLOW IN CFS
70.000
56.000
42.000
28.000
14.000
0.0
20.000
20.300
20.600
20.900
21.200
21.500
21.800
22.100
22.400
22.700
23.000

STORM NUMBER 3
SEGMENT CH25

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
14: 0.	0.081	14: 5.	1.490	14:10.	6.955	14:15.	11.528	14:20.	12.554
14:25.	11.298	14:30.	9.363	14:35.	7.514	14:40.	5.975	14:45.	4.764
14:50.	3.827	14:55.	3.114	15: 0.	2.564	15: 5.	2.138	15:10.	1.803
15:15.	1.537	15:20.	1.323	15:25.	1.149	15:30.	1.006	15:35.	0.887
15:40.	0.788	15:45.	0.704	15:50.	0.632				

STORM NUMBER 4
SEGMENT CH25

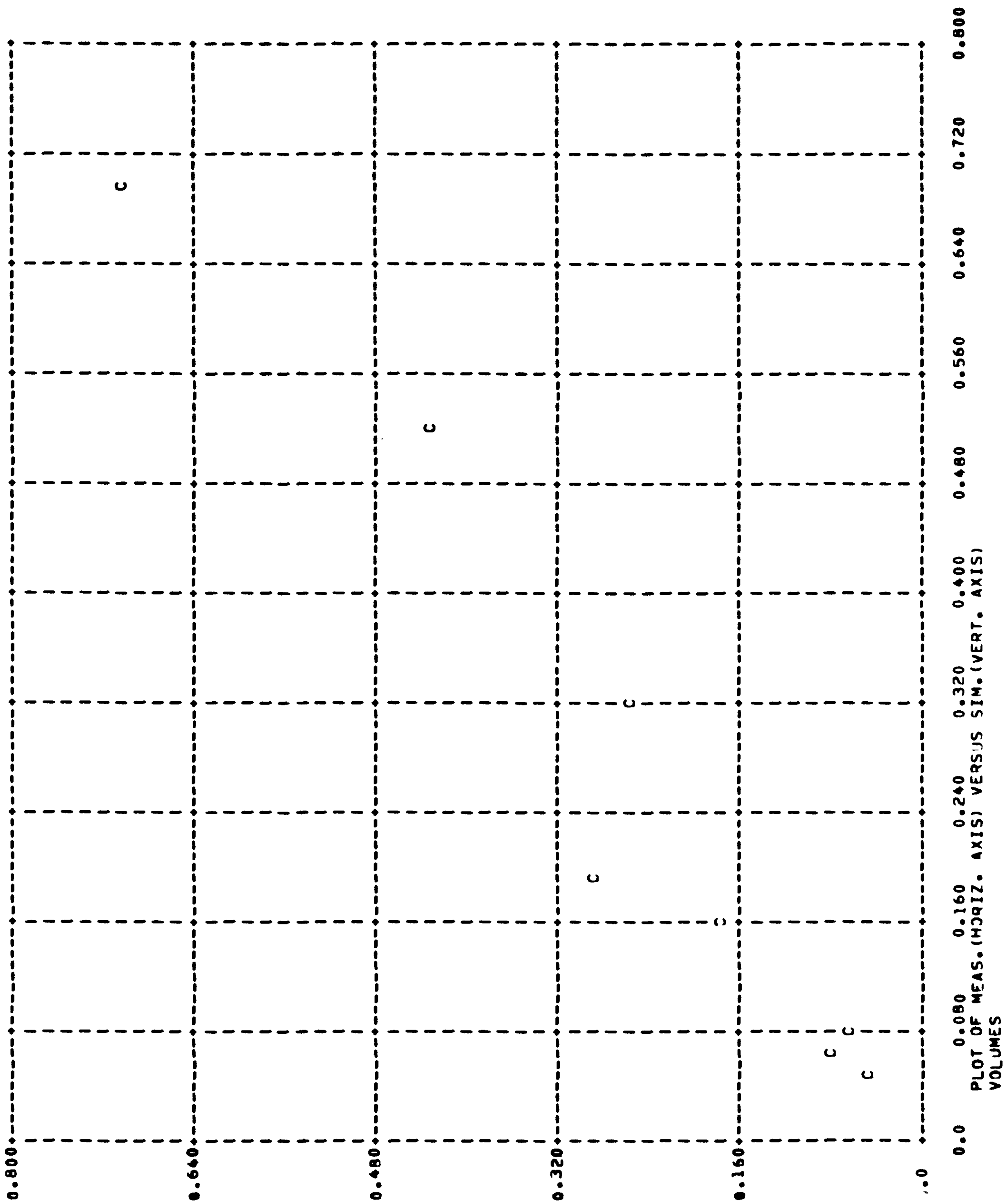
TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
18: 5.	0.028	18:10.	2.550	18:15.	39.828	18:20.	89.632	18:25.	76.527
18:30.	52.905	18:35.	40.581	18:40.	31.318	18:45.	23.595	18:50.	17.486
18:55.	13.000	19: 0.	9.985	19: 5.	8.178	19:10.	7.227	19:15.	6.932
19:20.	6.625	19:25.	6.014	19:30.	5.282	19:35.	4.657	19:40.	4.444
19:45.	4.787	19:50.	5.429	19:55.	6.045	20: 0.	6.710	20: 5.	7.229
20:10.	7.570	20:15.	7.167	20:20.	6.341	20:25.	5.444	20:30.	4.613
20:35.	3.892	20:40.	3.292	20:45.	2.798	20:50.	2.394	20:55.	2.064
21: 0.	1.794	21: 5.	1.572	21:10.	1.389	21:15.	1.236	21:20.	1.108
21:25.	0.999	21:30.	0.907	21:35.	0.828	21:40.	0.760		

SUMMARY OF MEASURED DATA

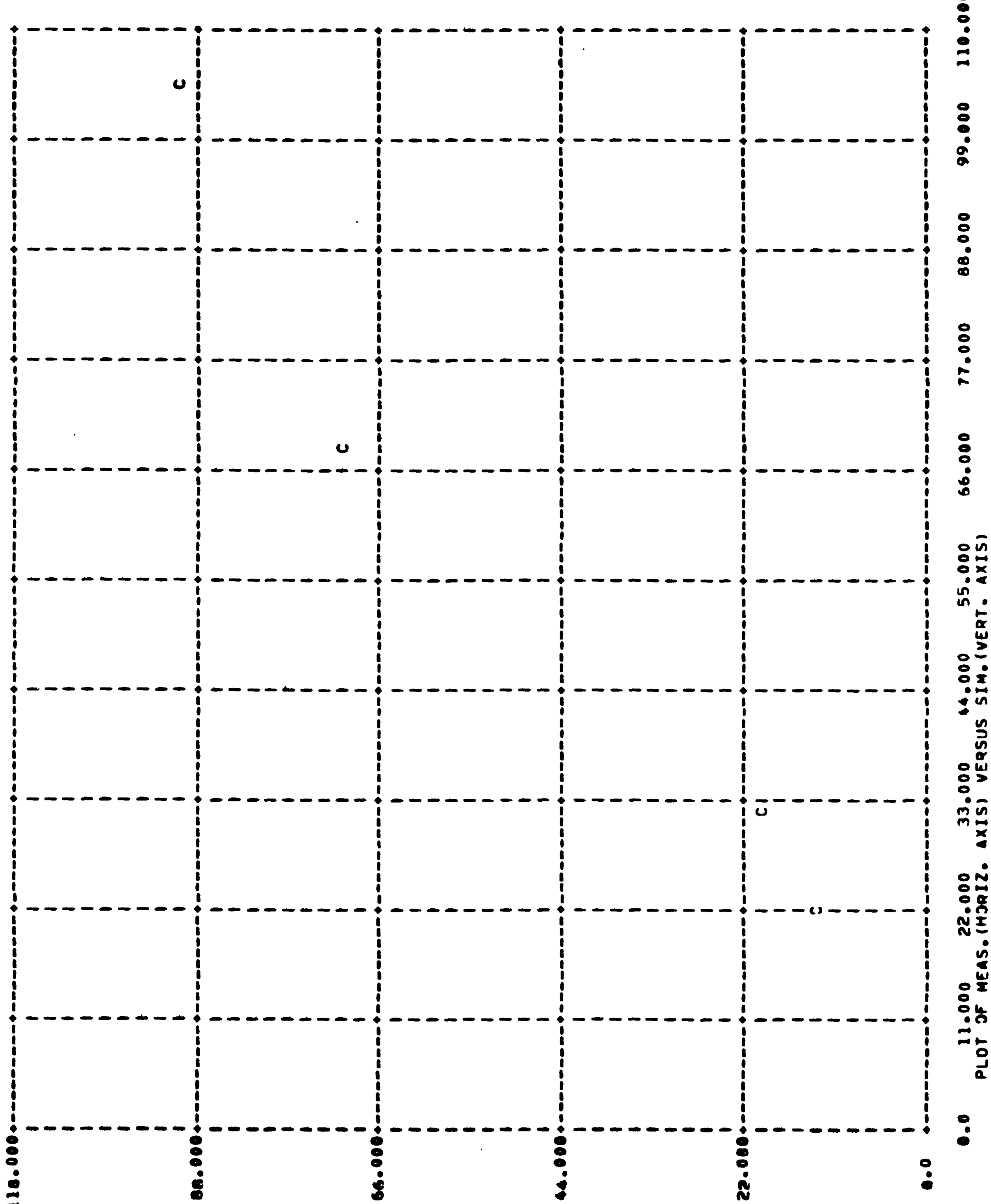
```
STORM-RUNOFF EVENT NUMBER   1  DATED  7/12/73
MEASURED RAINFALL    GAGE NUMBER  1 =      0.330 INCHES
MEASURED DIRECT RUNOFF =     0.077 INCHES
MEASURED PEAK DISCHARGE =    32.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   2  DATED  7/19/73
MEASURED RAINFALL    GAGE NUMBER  1 =      0.630 INCHES
MEASURED DIRECT RUNOFF =     0.156 INCHES
MEASURED PEAK DISCHARGE =    69.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   3  DATED  7/22/73
MEASURED RAINFALL    GAGE NUMBER  1 =      0.230 INCHES
MEASURED DIRECT RUNOFF =     0.051 INCHES
MEASURED PEAK DISCHARGE =    22.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   4  DATED  7/24/73
MEASURED RAINFALL    GAGE NUMBER  1 =      0.950 INCHES
MEASURED DIRECT RUNOFF =     0.320 INCHES
MEASURED PEAK DISCHARGE =   104.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   5  DATED  7/30/73
MEASURED RAINFALL    GAGE NUMBER  1 =      0.340 INCHES
MEASURED DIRECT RUNOFF =     0.064 INCHES
MEASURED PEAK DISCHARGE =    32.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   6  DATED  8/ 7/73
MEASURED RAINFALL    GAGE NUMBER  1 =      1.940 INCHES
MEASURED DIRECT RUNOFF =     0.595 INCHES
MEASURED PEAK DISCHARGE =   235.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   7  DATED  7/22/74
MEASURED RAINFALL    GAGE NUMBER  1 =      1.060 INCHES
MEASURED DIRECT RUNOFF =     0.191 INCHES
MEASURED PEAK DISCHARGE =    99.00 CFS
BASEFLOW ASSUMED =  0.0   CFS

STORM-RUNOFF EVENT NUMBER   8  DATED  7/30/74
MEASURED RAINFALL    GAGE NUMBER  1 =      1.390 INCHES
MEASURED DIRECT RUNOFF =     0.520 INCHES
MEASURED PEAK DISCHARGE =   251.00 CFS
BASEFLOW ASSUMED =  0.0   CFS
```

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	7/12/73	0.002	0.071	0.077	0.066	32.00	19.62	
2	7/19/73	0.024	0.168	0.156	0.155	68.00	69.65	
3	7/22/73	0.002	0.046	0.051	0.041	22.00	12.55	
4	7/24/73	0.026	0.250	0.320	0.237	104.00	89.63	
5	7/30/73	0.004	0.076	0.064	0.0	32.00	0.0	
6	8/ 7/73	0.232	0.702	0.695	0.0	236.00	0.0	
7	7/22/74	0.036	0.287	0.191	0.0	98.00	0.0	
8	7/30/74	0.101	0.431	0.520	0.0	251.00	0.0	

OBJECTIVE FUNCTION FOR PEAKS = 0.577
CORRELATION COEF. FOR PEAKS = 0.982



0.0
0.080
0.160
0.240
0.320
0.400
0.480
0.560
0.640
0.720
0.800
0.0
0.160
0.320
0.480
0.640
0.800
PLOT OF MEAS.(HORIZ. AXIS) VERSUS SIM.(VERT. AXIS)
VOLUMES



0.0
11.000
22.000
33.000
44.000
55.000
66.000
77.000
88.000
99.000
110.000
PLOT OF MEAS.(HORIZ. AXIS) VERSUS SIM.(VERT. AXIS)
PEAKS
0.0
22.000
44.000
66.000
88.000
110.000
C
C
C
C

INPUT FOR RUN NUMBER 3

```
I N P U T   D A T A ----- P R O G R A M   D R 3 M                         PAGE  1

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

    1  1
22222222 HYPOTHETICAL EXAMPLE FOR LINK WITH DR3M-QUAL      0.2
06714310
40350010
                     71 06 01    72 06 16
06714310                                                  5.0
0671431071 725 519                   26   35    8    1
0671431072 6 4 522                                                         10   2
0671431072 6 4 523    8    7    4    0    1    0    0    1    0    0    0    0 1
0671431072 6 4 524    1    0    0    1    0    0    0    0    0    0    1      1
0671431072 6 5 5 1                                                             1
                                                                               9
0671431071 61   0   0   0   0   0   0   2   2   1   0   0   0   0   0   0   0 3
0671431071 62   0   0   0   0   0   0   0   0   0   0   0   0   0   9         3
0671431071 71   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0 3
0671431071 72   0   2   9   0   0   0  17   0 -70   09999   0   0   0   0     3
0671431072 41   09999   8   0   0   0   0   0   0   0   0   0   7  14   0   0 3
0671431072 42   0   0   6   6   1   0   0   0   0  57  39   1   5   1         3
0671431072 51   0   0   0   0   0   2   0   0   8   0  24   1   2   0   0   0 3
0671431072 52   0   0   2   0   0   0   0   0   0   0  10   1   0   0   0     3
0671431072 61   0   0 105 -54 -56  46   0   0   0   0  77  39   1   1   1  56 3
4035001071 61 .18 .15 .16 .17 .20 .20 .11 .18 .11 .14 .13 .19 .12 .11 .13 .22 4
4035001071 62 .16 .25 .18 .18 .22 .20 .20 .24 .23 .33 .29 .26 .24 .26         4
4035001071 71 .20 .20 .19 .15 .20 .19 .24 .21 .19 .18 .24 .28 .19 .24 .21 .29 4
4035001071 72 .25 .26 .18 .23 .15 .16 .23 .21 .19 .14 .26 .07 .21 .18 .23     4
4035001072 41 .15 .18 .17 .16 .21 .18 .21 .13 .13 .14 .15 .13 .17 .16 .19 .17 4
4035001072 42 .17 .16 .18 .18 .17 .18 .19 .17 .20 .17 .22 .18 .16 .17         4
4035001072 51 .16 .16 .17 .17 .12 .12 .12 .08 .06 .09 .03 .14 .17 .19 .20 .19 4
4035001072 52 .24 .21 .17 .20 .21 .29 .19 .20 .22 .22 .12 .08 .18 .23 .20     4
4035001072 61 .23 .22 .18 .18 .02 .14 .19 .22 .23 .28 .14 .24 .19 .19 .18 .22 4
                                                                               9
    7   0   0    0.0
 3.0        0.5        6.0
 0.20       0.05       1.2
 10.0       5.0        20.0
 4.0        2.0        6.0
       0.7        0.5        1.0
 0.8        0.7        0.95
 1.0        0.9        1.2

     5  2.5  1.0     1  .05  1.0
FP02                                5 0 42323. .020 .016  1.0  0.6 1  1.0
IP01                                5 0 42323. .022 .016  0.3  1.0 1  1.0
PP01                                5 0 82323. .022 .10  0.7  0.0  1 1.0
CH01              FP02IP01PP01      4 1 41200.           5.0  1.3

12345678901234567890123456789012345678901234567890123456789012345678901234567890
         1         2         3         4         5         6         7         8
```

```
I N P U T   D A T A ----- P R O G R A M   D R 3 M                         PAGE  2

          1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890

46  DE01CH01                          8 1 5
47    0.0         0.0
48    10.        3.63
49    20.         10.9
50    30.         23.
51    50.         39.3
52    2 1 1
53    219 252
54    263 300
55    1 1
56    0 0
57    0 0
58    0 0

    12345678901234567890123456789012345678901234567890123456789012345678901234567890
              1         2         3         4         5         6         7         8
```

OUTPUT FOR RUN NUMBER 3

```
*******************************************
*          U.S. GEOLOGICAL SURVEY         *
*DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL*
*             VERSION   3/23/82           *
*******************************************

DISCHARGE STATION     22222222 HYPOTHETICAL EXAMPLE FOR LINK WITH DR3M-QUAL
UNIT PRECIP. STATION  06714310
DAILY PRECIP. STATION 06714310
PAN-EVAPO. STATION    40350010
DRAINAGE AREA=  0.200 SQ. MI.
UNIT DATA ARE IN    5.000 MINUTE INCREMENTS
THE PERIOD OF RECORD IS FROM  6- 1-71 (DAY=  25719) TO  6-16-72 (DAY=  26100)

JPUN =  0
JPERM = 1
OPT = 1
```

```
INITIAL PARAMETER VALUES  (PARAMETERS TO BE OPTIMIZED ARE MARKED WITH A +)

  1        3.000000   PSP
  2        0.200000   KSAT
  3       10.000000   RGF
  4        4.000000   BMSN
  5        0.700000   EVC
  6        0.800000   RR
  7        1.000000   EAC

                         NUMBER OF SEGMENTS =    5
                         DT =  2.50 MINUTES
                         NUMBER OF RAIN GAGES = 1
                         NUMBER OF SOIL TYPES = 1
                         IMPERVIOUS RETENTION = 0.05 INCHES
                         RAT =  1.000
                         ALPADJ = 1.00
                         WX = 0.0
```

SEGMENT	UPSTREAM SEGMENTS	ADJACENT SEGMENTS	TYPE	METH	IPR	NDX	LENGTH (FEET)	SLOPE	ROUGHNESS PARAMETER	OTHER PARAMETERS			THIESSEN COEFFICNTS		
FP02			5	0	0	4	2323.0	0.0200	0.160E-01	1.000	0.600	1	1.00	0.0	0.0
IP01			5	0	0	4	2323.0	0.0220	0.160E-01	0.300	1.000	1	1.00	0.0	0.0
PP01			5	0	0	8	2323.0	0.0220	0.100E+00	0.700	0.0	1	1.00	0.0	0.0
CH01		FP02 IP01 PP01	4	0	1	4	1200.0	0.0	0.0	5.000	1.300	0	0.0	0.0	0.0
DE01	CH01		9	0	1	5	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0

RESERVOIR SEGMENT DE01

OUTFLOW	STORAGE	S2/DT+O2/2
0.0	0.0	0.0
10.00	3.63	92.12
20.00	10.90	271.60
30.00	23.00	567.00
50.00	39.30	968.20

COMPUTATION SEQUENCE		KINEMATIC WAVE PARAMETERS	
INDEX	SEGMENT	ALPHA	M
1	FP02	13.17	1.670
2	IP01	13.81	1.670
3	PP01	2.21	1.670
4	CH01	5.00	1.300
5	DE01	0.0	0.0

```
FURNISHED DRAINAGE AREA =  0.2000  SQUARE MILES
COMPUTED  DRAINAGE AREA =  0.2000  SQUARE MILES

THE DRAINAGE BASIN IS 45.0 PERCENT EFF. IMPERVIOUS AREA
                       0.0 PERCENT NONEFF. IMPERVIOUS AREA
                      55.0 PERCENT PERVIOUS AREA


THERE ARE   2 STORM EVENTS GROUPED AS FOLLOWS     1     1
STORM NO.  1 STARTS AT TIME PERIOD  219 AND ENDS AT  252       RECORDS REQUIRED FOR ROUTING =    5
STORM NO.  2 STARTS AT TIME PERIOD  263 AND ENDS AT  300       RECORDS REQUIRED FOR ROUTING =    5

DETAILED OUTPUT FOR STORMS   1  1

STORM EVENTS IN THE OBJ. FCT. ARE   0  0

THE STORM EVENTS PLOTTED ARE   0  0

INPUT HYDROGRAPHS FOR STORMS   0  0

NUMBER OF RECORDS USED FOR DIRECT ACCESS FILE =   13
```

STORM NUMBER 1
SEGMENT CH01

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
18:15.	4.494	18:20.	36.298	18:25.	65.129	18:30.	66.840	18:35.	54.913
18:40.	41.932	18:45.	31.867	18:50.	24.570	18:55.	19.302	19: 0.	15.448
19: 5.	12.575	19:10.	10.394	19:15.	8.709	19:20.	7.385	19:25.	6.331
19:30.	5.479	19:35.	4.783	19:40.	4.208	19:45.	3.728	19:50.	3.324
19:55.	2.982	20: 0.	2.689	20: 5.	2.437	20:10.	2.219	20:15.	2.029
20:20.	1.863	20:25.	1.717	20:30.	1.588	20:35.	1.473	20:40.	1.371
20:45.	1.279	20:50.	1.197	20:55.	1.123	21: 0.	1.057		

STORM NUMBER 1
SEGMENT DE01

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
18:15.	0.312	18:20.	4.029	18:25.	12.141	18:30.	18.128	18:35.	21.705
18:40.	23.469	18:45.	24.348	18:50.	24.593	18:55.	24.408	19: 0.	23.934
19: 5.	23.269	19:10.	22.482	19:15.	21.619	19:20.	20.714	19:25.	19.655
19:30.	18.163	19:35.	16.750	19:40.	15.421	19:45.	14.180	19:50.	13.025
19:55.	11.955	20: 0.	10.966	20: 5.	10.056	20:10.	8.515	20:15.	7.202
20:20.	6.122	20:25.	5.232	20:30.	4.496	20:35.	3.887	20:40.	3.380
20:45.	2.958	20:50.	2.504	20:55.	2.308	21: 0.	2.057		

MAXIMUM STORAGE IN DETENTION RESERVOIR DE01 FOR STORM 1 WAS 16.458 CFS-HOURS

STORM NUMBER 2
SEGMENT CM01

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
21:55.	0.438	22: 0.	7.451	22: 5.	18.576	22:10.	27.166	22:15.	32.394
22:20.	31.076	22:25.	27.232	22:30.	23.031	22:35.	18.955	22:40.	16.135
22:45.	13.738	22:50.	11.496	22:55.	9.687	23: 0.	8.230	23: 5.	7.418
23:10.	6.698	23:15.	5.850	23:20.	5.443	23:25.	5.067	23:30.	4.516
23:35.	4.027	23:40.	3.607	23:45.	3.242	23:50.	2.926	23:55.	2.880
0: 0.	2.837	0: 5.	2.609	0:10.	2.388	0:15.	2.191	0:20.	2.015
0:25.	1.856	0:30.	1.714	0:35.	1.585	0:40.	1.470	0:45.	1.365
0:50.	1.269	0:55.	1.182	1: 0.	1.103				

STORM NUMBER 2
SEGMENT DE01

TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)	TIME (HRS)	FLOW (CFS)
21:55.	0.029	22: 0.	0.694	22: 5.	3.314	22:10.	7.368	22:15.	11.054
22:20.	13.341	22:25.	15.048	22:30.	16.142	22:35.	16.660	22:40.	16.743
22:45.	16.547	22:50.	16.117	22:55.	15.514	23: 0.	14.801	23: 5.	14.039
23:10.	13.285	23:15.	12.524	23:20.	11.774	23:25.	11.070	23:30.	10.390
23:35.	9.466	23:40.	8.304	23:45.	7.301	23:50.	6.433	23:55.	5.703
0: 0.	5.123	0: 5.	4.630	0:10.	4.191	0:15.	3.800	0:20.	3.451
0:25.	3.139	0:30.	2.860	0:35.	2.611	0:40.	2.388	0:45.	2.188
0:50.	2.009	0:55.	1.848	1: 0.	1.703				

MAXIMUM STORAGE IN DETENTION RESERVOIR DE01 FOR STORM 2 WAS 8.532 CFS-HOURS

SUMMARY OF MEASURED DATA

STORM-RUNOFF EVENT NUMBER 1 DATED 7/25/71
MEASURED RAINFALL GAGE NUMBER 1 = 0.700 INCHES

STORM-RUNOFF EVENT NUMBER 2 DATED 6/ 4/72
MEASURED RAINFALL GAGE NUMBER 1 = 0.540 INCHES

STORM NUMBER	DATE	SIMULATED PERVIOUS AREA RAINFALL EXCESS (INCHES)	SIMULATED RAINFALL EXCESS (INCHES)	MEASURED DIRECT RUNOFF (INCHES)	SIMULATED RUNOFF VOLUME AT OUTLET (IN.)	MEASURED PEAK (CFS)	SIMULATED PEAK (CFS)	CONTRIBUTION TO OBJ. FCT.
1	7/25/71	0.028	0.320				24.59	
2	6/ 4/72	0.006	0.227				16.74	

***** RUNOFF FILES STORED *****

STORM NO.	DATE	STARTING RECORD	NUMBER OF VALUES
1	7/25/71	4	68
2	6/ 4/72	9	76