

DTIC FILE COPY

AD

2

AD-A229 387

FLOOD INUNDATION MODELLING USING MILHY

Final Technical Report

by

L.Baird and M.G.Anderson

DTIC
S FCTE D
NOV 27 1990
U S

Volume 2
User Manual
September 1990

European Research Office

U.S. Corps of Engineers

London

England

CONTRACT NUMBER DAJA 45-87-C-0053

Professor M.G.Anderson

Approved for Public Release : Distribution Unlimited

VOLUME 2

76 11 26 291

i.

Preface

This is the user manual for the computer simulation model MILHY3. The volume should contain all the information a potential user requires to establish the data sets and run MILHY3. In addition, it provides detailed program information and the computer code. A basic review of the MILHY suite is provided and some guidelines on the selection of process are included. Detailed information on the development and validation of MILHY3 is contained within Volume 1 of this report. 2 to 72-1



Accession For	
NHS	CHAI
UHC	183
UHC	183
Justification	
E/	
D 183 183	
Annex 1, 183	
D 183 183	
A-1	

Contents

	Page
Preface	i
List of contents	ii
List of tables	iv
List of figures	v
1. MILHY3 - Model Details	1
1.1 MILHY3	1
1.1.1 Hydrological procedures	3
1.1.2 Model control procedures	14
1.2 The Physically Based Infiltration Model	19
1.2.1 The mathematical model	19
1.2.2 Basic structure of the infiltration model	24
1.2.3 Data requirements	24
1.2.4 Stochastic infiltration model	26
1.2.5 Implementation	33
2. MILHY3 - Data Sets	36
2.1 Introduction	36
2.2 Data Set 'data1'	36
2.3 Data Set 'data2'	51
2.4 Example Data Sets and Results File	55
3. MILHY3 - Program Details	82
3.1 Program Contents	82
3.2 Program Changes Since MILHY2	83
3.3 Subroutine Details	84
3.4 Infiltration Algorithm	120
3.4.1 Initial section	122
3.4.2 Dynamic section	128
3.4.3 Terminal section	136

	Page
4. MILHY3 - P.C. Version	139
4.1 Introduction	139
4.2 Random Number Generator	139
4.3 Character/Numeric Arrays	139
5. MILHY3 - Source Code	151
Literature cited	205

List of Tables

	Page
1.1 Alternative geometric definitions to incorporate segment interactions (after Knight and Hamed, 1984)	12
1.2 Bubbling pressure classified by soil texture (after Rawls <u>et al.</u> , 1982)	28
2.1 Date for legal commands of MILHY3 in 'datal' data set	47
2.2 Date requirements for 'data2'	56

List of Figures

	Page
1.1 Hydrological and control commands for the MILHY3 scheme	2
1.2 Generation of the unit hydrograph for MILHY3 (after Williams and Hann, 1973)	4
1.3 Two-stage channel parameter definition	13
1.4 Schematic structure of the infiltration algorithm	25
1.5 Derivation of the suction-moisture curve from soil texture information (after Brakensiek and Rawls, 1983)	27
1.6 Derivation of saturated hydraulic conductivity and saturated moisture content from soil texture information (after Brakensiek and Rawls, 1983)	29
1.7 Alternative procedures for derivation of the flood hydrograph utilising MILHY3	34
2.1 Data preparation and checking procedures for the MILHY3 scheme	37
2.2 Location of example simulation, River Fulda, West Germany	38
3.1 Structure of SOILM subroutine	121
3.2 Determination of top boundary conditions	133

Chapter 1

MILHY3 - Model Details

1.1 MILHY3

(cont)

→ It

MILHY contains a number of hydrological and model control procedures. Conveniently, each of these is contained within the program implementation in a separate subroutine.

The structure of the MILHY program (Williams and Hann, 1972, 1973) is outlined in figure 1.1.

→ Hydrological procedures (indicated in the lower row of figure 1.1) are invoked to generate the outflow hydrograph for a subcatchment area, to perform routing calculations through channels and reservoirs, and to calculate sediment yield. Model control procedures are used to instruct the program to begin, to store a measured hydrograph, travel time table, or rating curve, to add two hydrographs together, to provide hard copies of printed or plotted information, ^{and} to perform error analyses on hydrograph predictions, and to finish.

As modelling begins at the most upstream subcatchment, and proceeds downstream by cumulating hydrographs, it is not necessary to store all of the information which is generated. At any one time, the program stores up to six hydrographs and six rating curves in core memory.

The hydrological and model control procedures will now be examined in more detail.

→ Keywords: Floods/forecasting/models; Channels/
waterways/routing; Channel flow; Flow rate;
Computerized simulation; Hydrographs;
Hydraulics/gradients/conductivity; Drainage;
Runoff/travel time; Saturated soils; Mathematical models;
Soils/porosity; Hydrology; Computer programs;
Great Britain.

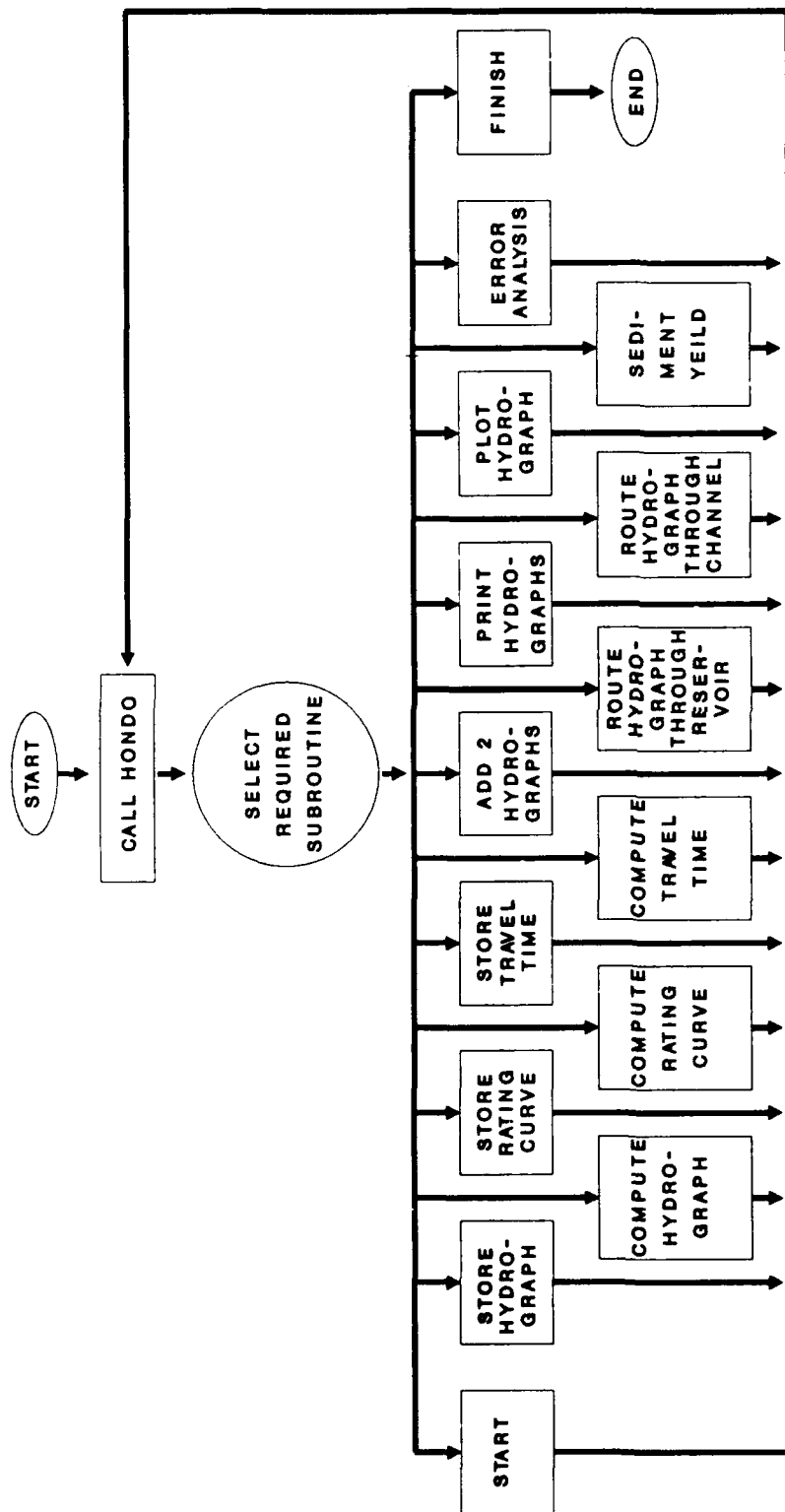


Figure 1.1
Hydrological and Control Commands for the MILHY3 Scheme

Chapter 1

1.1.1 Hydrological Procedures

There are four hydrological procedures in MILHY. (The compute rating curve, compute travel time, and route hydrograph through channel subroutines combine to form the flood routing hydrological procedure). It should be noted that all parameter units in this subsection are in imperial units.

Hydrograph Computation

A standard three stage procedure is used to generate the storm hydrograph for each subcatchment. Firstly, a unit hydrograph is derived synthetically for each subcatchment area from its physical characteristics. Secondly, direct or surface runoff is determined from either an empirically-based curve number routine, or a physically-based infiltration model (Anderson, 1982; Anderson and Howes, 1984), and, thirdly, these are convolved to produce the flood hydrograph for the subcatchment.

A dimensionless unit hydrograph method is used by MILHY. This has been synthesized from measured hydrographs from 34 catchments in Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee. These catchments range up to 16 square km in area. The synthesized dimensionless unit hydrograph (figure 1.2A) is described by a two parameter gamma distribution. For the beginning of the discharge rise ($t=0$) to the inflection point (t_0), discharge is given by:

$$u_t = u_p (t/t_p)^{(n-1)} e^{(1-n)(t/t_p - 1)} \quad (1.1)$$

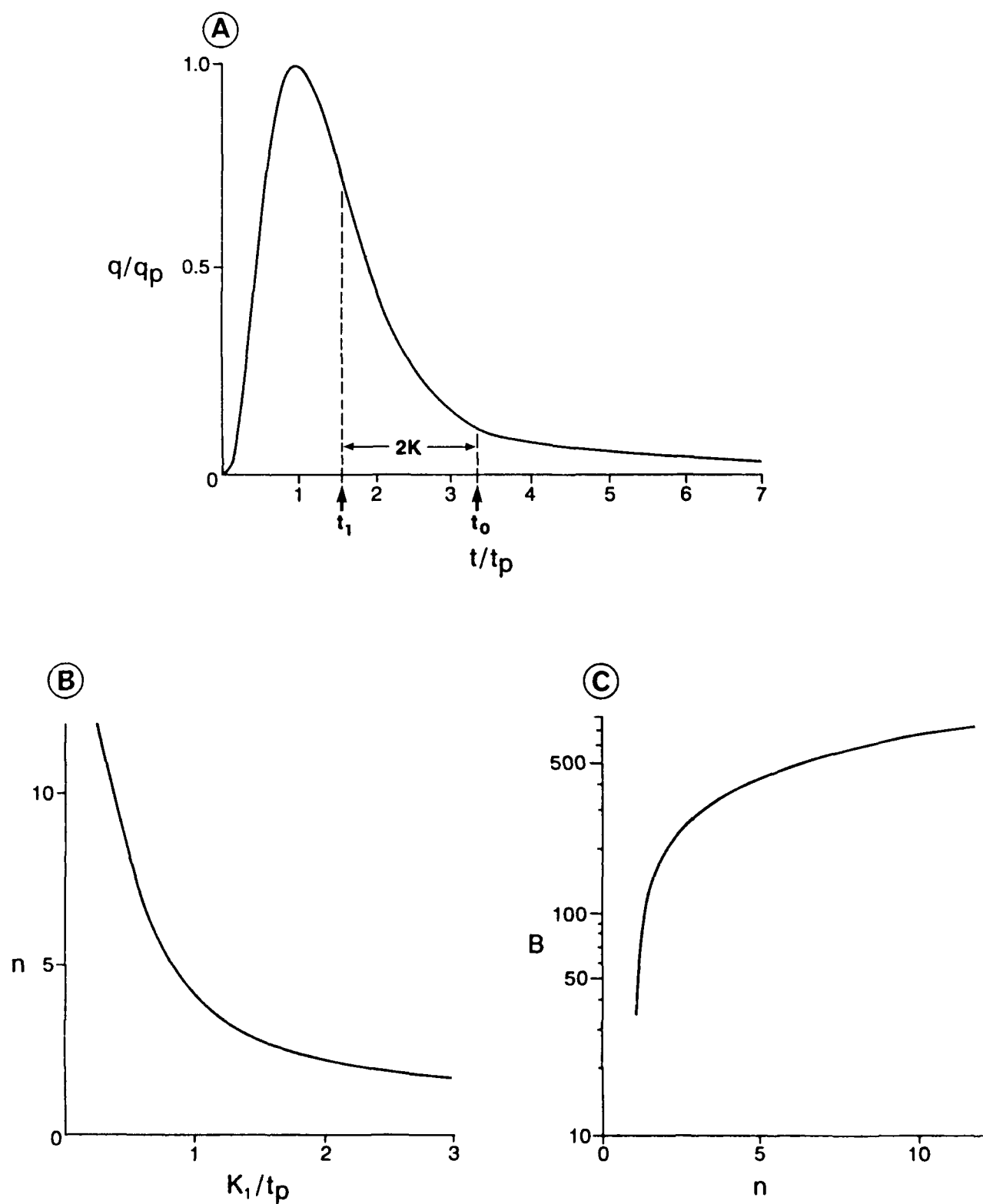


Figure 1.2
Generation of the Unit Hydrograph for MILHY3
 (after Williams and Hann, 1973)

Chapter 1

Where:

- u_t - unit hydrograph discharge at time t ($\text{ft}^3 \text{s}^{-1}$)
- u_p - unit hydrograph peak discharge ($\text{ft}^3 \text{s}^{-1}$)
- t_p - time to peak (hours)
- n - dimensionless parameter
(a function of k_1/t_p , figure 1.2B)
- k_1 - the first recession constant

For t_0 to t_1 , where

$$t_1 = t_0 + 2k_1 \quad (1.2)$$

the recession depletion equation becomes:

$$u_t = u_0 e^{((t-t_0)/k_1)} \quad (1.3)$$

Where:

- t_0 - time at inflection point (hours)
- u_0 - unit hydrograph discharge at inflection point ($\text{ft}^3 \text{s}^{-1}$)

Finally, for t_1 to infinity, the recession depletion equation becomes:

$$u_t = u_1 e^{((t_1-t)/k_2)} \quad (1.4)$$

Where:

- k_2 - the second recession coefficient $k_2 = 3k_1$
- u_1 - unit hydrograph discharge at t_1 ($\text{ft}^3 \text{s}^{-1}$)

Chapter 1

The actual catchment unit hydrograph associated with a particular storm event can be derived from this dimensionless hydrograph, provided that information for the peak discharge (u_p), the time to peak discharge (t_p) and the recession constant (k_1) can be provided. Where, for the ungauged catchment, these data are not available, the following relationships may be used which relate the three characteristics to measurable basin properties such as catchment area, length of main channel, and elevation difference, features which can be derived from a topographic map:

$$u_p = \frac{BAQ}{t_p} \quad (1.5)$$

Where:

- B - dimensionless watershed parameter, a function of n
(figure 1.2C)
- A - watershed area (miles²)
- Q - total storm runoff (inches)

$$k_1 = 27.0(A)^{0.23} (SLP)^{-0.777} (L/W)^{0.124} \quad (1.6)$$

Where:

- SLP - elevation difference (feet) between catchment outlet and most distant point, divided by main channel length (miles)

- L/W - watershed length, width ratio

$$t_p = 4.63(A)^{0.422} (SLP)^{-0.46} (L/W)^{0.133} \quad (1.7)$$

Chapter 1

Catchment incremental is derived using either on empirically based Curve Number routine (USDA SCS, 1972), or physically-based infiltration algorithm (Anderson, 1982), described in section 1.2.

In the Curve Number procedure rainfall, runoff and storage are related in the following manner:

$$\frac{P - Q}{S'} = \frac{Q}{P} \quad (1.8)$$

where: P = total precipitation
 S' = potential maximum storage
 Q = actual runoff

This solution is simplified by emitting rainfall losses prior to the soil surface, giving a final solution for Q of:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad (1.9)$$

where: I_a = initial abstraction
 $S = S' + I_a$

The relationship between I_a and S has been empirically derived by the SCS, and it is approximately:

$$I_a = 0.2S \quad (1.10)$$

Substituting this relationship into equation 1.9 gives

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \text{for } P > 0.2S \quad (1.11)$$

To apply equation 1.11, S is transformed by the following equation:

$$S = \frac{1000}{CN} - 10 \quad (1.12)$$

Chapter 1

where: $CN = 0$ when $S \rightarrow \infty$
 $CN = 100$ when $S = 0$

The value of CN for a catchment is usually derived from field or map surveys and the appropriate USDA tables. It represents the net effects of soil type, land use, hydrologic soil group, and the antecedent soil moisture condition.

Finally, the incremental runoff and unit hydrograph are convolved to form the outflow discharge hydrograph according to the following relationship:

$$q_t = \sum_{t=2}^n (r_t u_{(n-t)}) \quad \text{For } n > 2 \quad 1.13$$

where:

- n - number of time intervals of hydrograph
- q_t - flood hydrograph discharge at time t ($\text{ft}^3 \text{s}^{-1}$)
- r_t - runoff at time t (inches)

Channel Flood Routing

To perform channel flood routing, the user invokes the compute rating curve, compute travel time, and route hydrograph through channel subroutines.

A revised version of the Variable Storage Coefficient method has been incorporated into MILHY. This represents a compromise between very simple storage models and those methods based on the principles of hydraulics.

Chapter 1

Williams (1969) presents the Variable Storage Coefficient method, and provides a solution for it. In comparison to basic storage routing models, this method is considered to be a better approximation to reality as it does allow the storage coefficient and travel time to vary with river stage. It is considered to be reliable for a range of river flow conditions and reach lengths, and may be applied to routing of both channel and flood plain flows.

Application of this method requires a relationship between stage, end area, and discharge to be defined for the particular reach. If a measured relationship is not available, it can be derived by application of the Mannings equation, which is simple, easy to use, and not too demanding in terms of data. Discharge (q) is given by the following equation:

$$q = \frac{1.486}{n} (aR^{2/3} S_1^{1/2}) \quad 1.14$$

Where:

- n - Mannings coefficient of roughness
- a - cross section area (ft²)
- R - hydraulic radius (ft)
- S₁ - slope of energy gradient

Twenty values on the rating curve are established by MILHY.

Given the inflow hydrograph for a reach with discharge values at equal time intervals, the outflow hydrograph can be calculated from the following equations. As a variable storage coefficient and travel time are assumed, these equations are recalculated for each discharge:

Chapter 1

$$O_{t+\Delta t} = C_{t+\Delta t} [I + ((1/C_t) - 1)O_t] \quad 1.15$$

$$C_{t+\Delta t} = \frac{2 \Delta t}{2T_{t+\Delta t} + \Delta t} \quad 1.16$$

$$C_t = \frac{2 \Delta t}{2T_t + \Delta t} \quad 1.17$$

$$T_t = \left(\frac{L}{1800(Vi_t + Vo_t)} \right) \left(\frac{(L)(SLP_0)}{(L)(SLP_0) + Di_t - Do_t} \right)^{1/2} \quad 1.18$$

$$T_{t+\Delta t} = \left(\frac{L}{1800(Vi_{t+\Delta t} + Vo_{t+\Delta t})} \right) \left(\frac{(L)SLP_0}{(L)(SLP_0) + Di_{t+\Delta t} - Do_{t+\Delta t}} \right)^{1/2} \quad 1.19$$

Where:

- I_t - inflow discharge at time t ($ft^3 s^{-1}$)
- O - outflow discharge at time t ($ft^3 s^{-1}$)
- I - average inflow discharge during time interval t ($ft^3 s^{-1}$)
- $I = \frac{I_t + I_{t+\Delta t}}{2}$
- C - storage coefficient for particular discharge
- T - travel time for particular discharge (hrs)
- L - reach length (ft)
- Vi - velocity of inflow at time t (discharge divided by end area) ($ft s^{-1}$)
- Vo - velocity of outflow at time t ($ft s^{-1}$)
- SLP_0 - normal slope
- Di - depth of inflow at time t (ft)
- Do - depth of outflow at time t (ft)
- Δt - time interval, constant throughout (hrs)

The solution for these equations is iterative, but no convergence problems have been experienced.

Chapter 1

In the latest model version, MILHY3, the channel routing routine has been further developed to incorporate the effects of out-of-bank flows. A full description of the development and validation of these new routines is given in Volume I of this report. The impact of momentum exchange between the main channel and floodplain flow segments has been incorporated during the development of the rating curve. Four techniques are proposed, each of which incorporates a differing position and length of an imaginary shear interface across which momentum exchange takes place. The four techniques are defined in Table 1.1, and the parameters defined on Figure 1.3.

In addition to momentum exchange, multiple routing reaches have been incorporated, which allow the separate routing of channel and floodplain flows downstream. This is particularly useful where the main channel is very sinuous and floodplain flows take a more direct path downstream, or where channel and floodplain boundary roughness values are widely different.

Reservoir Routing

The Storage Indication method is used to route hydrographs through reservoirs (USDA SCS, 1972). This uses the relation:

$$O_{t+\Delta t} = 2(I + (S_t / \Delta t) - (S_{t+\Delta t} / \Delta t)) - O_t \quad 1.20$$

This method requires that a storage discharge relationship be specified for the reservoir.

Sediment Yield

The Universal Soil Loss equation, modified to allow sediment yield to be calculated for the individual storm, was incorporated into MILHY. This relation is given by:

$$Sy = 95.0[(q_p)(R)]^{0.56}(E)(Cr)(Pr)(LS) \quad 1.21$$

Table 1.1

Alternative geometric definitions to incorporate segment interactions
 (after Knight and Hamed, 1984)

Method	Flood Plain		Main Channel	
	Area	Wetted Perimeter	Area	Wetted Perimeter
1	$(H-h)(B-b)$	$B-b + H-h$	$2bH$	$2b + 2h$
2	$(H-h)(B-b)$	$B-b + 2(H-h)$	$2bH$	$2b + 2H$
3	$(H-h)(B-b/2)$	$B-b + H-h$	$b(H+h)$	$2b + 2h$
4	$(H-h)(B-b/2)$	$B-b + H-h$	$b(H+h)$	$\frac{2b + 2h + 2((H-h)^2 + b^2)^{1/2}}{2}$

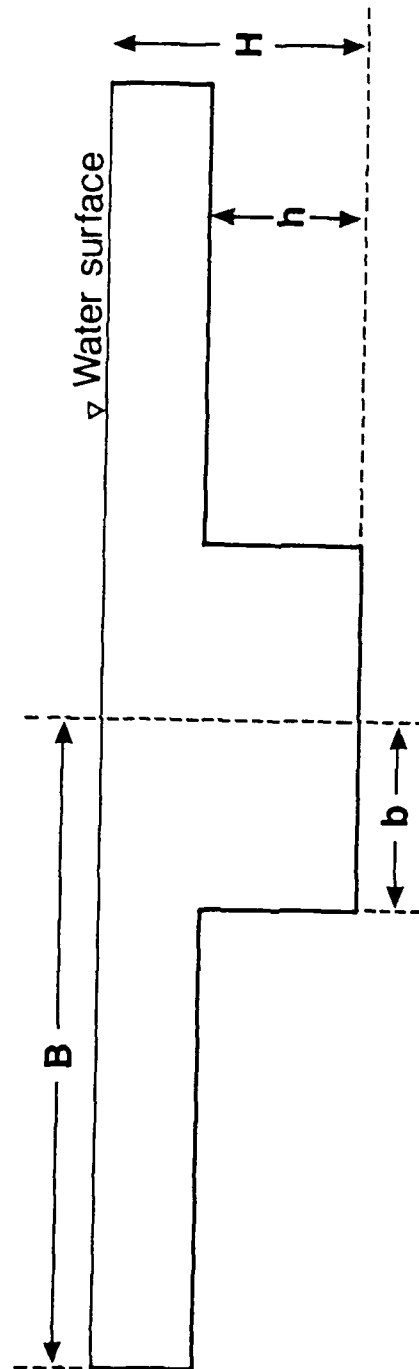


Figure 1.3
Two-Stage Channel Parameter Definition

Chapter 1

where:

- Sy - sediment yield (tons)
- q_p - peak discharge ($\text{ft}^3 \text{s}^{-1}$)
- R - runoff volume (acre ft)
- E - soil erodibility factor
- Cr - cropping management factor
- Pr - erosion control practice factor
- LS - slope length and gradient factor

1.1.2 Model control procedures

A number of model control procedures are also included in MILHY. These are illustrated in the upper row of figure 1.1. The user may select model control procedures in any order, or combination, to instruct the program to begin, to store a measured hydrograph or rating curve, to add two hydrographs together, to provide printed or plotted information, to analyse results and to terminate. A short description of each will serve to illustrate the flexibility which MILHY offers the user.

START - This provides the program with the start time for the simulation and instructs the program to begin.

STORE HYDROGRAPH - This allows the user to input a measured hydrograph for a particular subcatchment, directly into the computer memory. All hydrographs are limited to 300 points.

STORE RATING CURVE - This allows a measured rating curve for a particular cross section to be input directly into the computer memory. A maximum of twenty points to define the stage, end area, discharge relationship, are permitted.

Chapter 1

STORE TRAVEL TIME - This allows a previously computed travel time table to be input and stored in the program. A maximum of twenty points to define the depth, flow, travel time table, are permitted.

ADD TWO HYDROGRAPHS - MILHY initially calculates the hydrograph for the upstream subcatchment area and proceeds downstream by cumulating pairs of hydrographs. This model control procedure adds together the coordinates of two specified hydrographs.

PRINT HYDROGRAPH - According to the user's request, this procedure will either print out the whole of the hydrograph, or just the runoff volume and peak discharge rate values to a user specified peripheral.

PLOT HYDROGRAPH - This enables one or two hydrographs to be plotted out on the same axis. The plot is made on a line printer.

ERROR ANALYSIS - This model control procedure offers a number of indices which detail the goodness of fit of two hydrographs. The first two measures, the error standard deviation (ESD) and the percentage peak discharge error (PDE) were calculated in the original MILHY and are given by:

$$(ESD)^2 = \frac{\sum_{i=1}^n (qm_i - qc_i)^2}{n} \quad 1.22$$

where:

- n - number of pairs of discharge measurements
at equal time intervals
- qm_i - measured discharge ($ft^3 s^{-1}$)
- qc_i - calculated discharge ($ft^3 s^{-1}$)

Chapter 1

and:

$$\text{PDE} = \frac{q_p^m - q_p^c}{q_p^m} \times 100\% \quad 1.23$$

where:

$$\begin{aligned} q_p^m &= \text{measured peak discharge (ft}^3\text{s}^{-1}\text{)} \\ q_p^c &= \text{calculated peak discharge (ft}^3\text{s}^{-1}\text{)} \end{aligned}$$

A number of additional objective functions have been included:

Absolute sum of error (OF1):

$$\text{OF1} = \sum_{i=1}^n (qm_i - qc_i) \quad 1.24$$

Ordinary least squares (OF2):

$$\text{OF2} = \sum_{i=1}^n (qm_i - qc_i)^2 \quad 1.25$$

Log ordinary least squares (OF3):

$$\text{OF3} = \sum_{i=1}^n (\log(qm_i) - \log(qc_i))^2 \quad 1.26$$

Relative sum of errors (OF4):

$$\text{OF4} = \sum_{i=1}^n \left(\frac{(qm_i - qc_i)}{qm_i} \right)^2 \quad 1.27$$

Chapter 1

Absolute error difference (OF5):

$$OF5 = \sum_{i=1}^n ((qm_i - qm_{i-1}) - qc_i - qc_{i-1})^2 \quad 1.28$$

Relative error difference (OF6):

$$OF6 = \sum_{i=1}^n \left(\frac{((qm_i - qm_{i-1}) - (qc_i - qc_{i-1}))}{(qm_i - qm_{i-1})} \right)^2 \quad 1.29$$

Absolute error divided by variance (OF7):

$$OF7 = \frac{\sum_{i=1}^n (qm_i - qc_i)^2}{\sum_{i=1}^n (qm_i - \bar{qm})^2} \quad 1.30$$

where: $\bar{qm}$ - mean measured discharge

Relative error divided by variance (OF8):

$$OF8 = \frac{\sum_{i=1}^n ((qm_i - qc_i)/qm_i)^2}{\sum_{i=1}^n ((qm_i / \bar{qm}) - 1)^2} \quad 1.31$$

Chapter 1

Absolute error difference divided by variance (OF9):

$$\text{OF9} = \frac{\sum_{i=1}^n ((q_{m_i} - q_{m_{i-1}}) - (q_{c_i} - q_{c_{i-1}}))^2}{\sum_{i=1}^n ((q_{m_i} - q_{m_{i-1}}) - (q_{m_i} - q_{m_{i-1}}))^2} \quad 1.32$$

where:

$q_{m_i} - q_{m_{i-1}}$ - mean of difference of measured hydrograph

Relative error difference divided by variance (OF10):

$$\text{OF10} = \frac{\sum_{i=1}^n (((q_{m_i} - q_{m_{i-1}}) - (q_{c_i} - q_{c_{i-1}})) / (q_{m_i} - q_{m_{i-1}}))^2}{\sum_{i=1}^n (((q_{m_i} - q_{m_{i-1}}) / (\bar{q}_{m_i} - \bar{q}_{m_{i-1}})) - 1)^2} \quad 1.33$$

Pearsons correlation coefficient (OF11):

$$\text{OF11} = \frac{1}{n} \sum_{i=1}^n \left(\frac{q_{m_i} - \bar{q}_m}{\sigma_{qm}} \right) \left(\frac{q_{c_i} - \bar{q}_c}{\sigma_{qc}} \right) \quad 1.34$$

Chapter 1

where:

- $\bar{q}_c$ - mean calculated discharge
- σ_{qm} - standard deviation of measured discharge
- σ_{qc} - standard deviation of calculated discharge

FINISH - When all hydrological and model control procedures which are required by the user have been completed, this procedure instructs the program to terminate.

1.2 The Physically Based Infiltration Model

This infiltration model is a physically based and dynamic model which provides the capability to continuously simulate one-dimensional, near surface soil water movement. During a storm, water supplied to the surface may either infiltrate or accumulate on the surface, and when a specified surface detention capacity is exceeded, runoff occurs. When precipitation ceases, water is redistributed by drainage and evaporation. This model is not spatially distributed, but all soil types in the subcatchment can be represented and variability of soil hydraulic properties may be further included into the model using a stochastic Monte Carlo method.

The infiltration model is based upon that developed by Anderson (1982) and Anderson and Howes (1984). It should be noted that all parameter units in this section are metric.

1.2.1 The mathematical model

The law governing the flow of water through a rigid, homogeneous isotropic, and isothermal porous media, is derived from two equations, Darcy's Law, and the principle of continuity.

Chapter 1

Darcy's Law states that the flow of water through a porous medium is proportional to the hydraulic gradient and the conductivity:

$$v = -K \nabla \phi \quad 1.35$$

where:

v - macroscopic vector velocity of water (m s^{-1})
 $\nabla \phi$ - gradient of total potential (metres) in 3-dimensional space
 ∇ - denotes $\frac{\delta}{\delta x} + \frac{\delta}{\delta y} + \frac{\delta}{\delta z}$

and:

$$\phi = \psi - z \quad 1.36$$

where:

z - gravitational potential, depth from surface
 where downwards is positive (metres)

Darcy's Law holds for flow in unsaturated soils, but in slightly modified form, where K and ψ are functions of the soil moisture content (σ).

$$v = -K(\sigma) \nabla \phi \quad 1.37$$

$$\sigma = \psi(\sigma) - z \quad 1.38$$

The principle of continuity states that the difference between the inflow and outflow per unit time is equal to the rate of change in storage. The continuity equation is given by:

$$\frac{\delta \sigma}{\delta t} = -\nabla v \quad 1.39$$

Chapter 1

where:

t - time (seconds)

Combining equation 1.39 with equation 1.37 gives:

$$\frac{\delta \sigma}{\delta t} = \nabla (K(\sigma) \nabla \phi) \quad 1.40$$

Rewriting equation 1.40 in one dimension, for vertical flow, where z is the vertical distance taken downward as positive gives:

$$\frac{\delta \sigma}{\delta t} = \frac{\delta}{\delta z} (K(\sigma) \frac{\delta \phi}{\delta z}) \quad 1.41$$

Substituting equation 1.38 into equation 1.41 gives:

$$\frac{\delta \sigma}{\delta t} = \frac{\delta}{\delta z} (K(\sigma) \frac{\delta}{\delta z} (\psi(\sigma) - z)) \quad 1.42$$

$$\frac{\delta \sigma}{\delta t} = \frac{\delta}{\delta z} (K(\sigma) \frac{\delta \psi}{\delta z}(\sigma)) - \frac{\delta K}{\delta z}(\sigma) \quad 1.43$$

Equation 1.43 is equivalent to the Richards equation. To solve this equation for unsaturated conditions, the hydraulic conductivity function $K(\sigma)$ is required and is therefore derived numerically using the following relationship which has been established by Millington and Quirk (1959), and developed by Campbell (1974) and Jackson (1972). The relationship is described by:

$$K_i = K_s (\sigma_i / \sigma_s)^P \frac{\sum_{j=1}^m (2_j + 1 - 2_{-1}) \psi_j^{-2}}{\sum_{j=1}^m ((2_j - 1) \psi_j^{-2})} \quad 1.44$$

Chapter 1

where:

- K_s - saturated hydraulic conductivity (ms^{-1})
 σ_s - saturated soil moisture content ($\text{m}^3 \text{m}^{-3}$)
 m - number of equal sized increments of moisture content
 p - a constant, the pore interaction term

A value of unity for the pore interaction term has been assumed (Jackson, 1972).

Several points concerning the application of the Millington and Quirk method are relevant to this application:

1. To derive reliable results from the model, the soil moisture characteristic curve must be reliable, and should span a wide range of moisture values. The moisture curve should be a desorption curve; it has been observed that the pore size distribution is not well described by the wetting curve.
2. The method is not reliable for fine materials with a wide range of pore sizes, or for swelling soils. It is suitable for soils with stable structures.
3. The number of equal intervals (m , in equation 1.44) into which the soil water characteristic is divided was found by Kunze et al. (1968) to affect the prediction of the hydraulic conductivity function. Ten classes was found to be optimal.

The Richards equation is a nonlinear partial differential equation, to which exact solutions are available only for specific initial and boundary conditions. To solve equation 1.43, it is necessary to convert the mathematical model into a form which can be solved approximately by digital computer. After Hillel (1977), the equations are converted into explicit finite difference equations and solutions are defined at discrete points in space and time.

Chapter 1

Inaccuracies due to approximation by finite difference can be made very small by the proper use of the method. In any case, errors are usually outweighed by inaccuracies in the specification of subsurface hydrological parameters. An explicit method, otherwise known as a forward difference method, uses coefficient and variable values at the beginning of a time step to predict values of dependent variables at the end of the time step.

The explicit solution is a simple algorithm, but it does not display the best convergence or stability characteristics. It is usually only conditionally stable and convergence depends upon small time and space increments. Consequently, a large number of computations are necessary. As a check on stability, throughout the simulation, a mass water balance calculation is repeated to identify whether numerical errors are large, and, if so, to identify where they become a serious problem. The mass water balance calculation is described by the following equation:

$$BAL = \sigma_{end} - \sigma_{init} - ci + ce + cd \quad 1.45$$

where:

- Bal - numerical error ($m^3 m^{-3}$)
- σ_{end} - total water content of soil profile ($m^3 m^{-3}$) at end of simulation
- σ_{init} - initial total water content of entire profile ($m^3 m^{-3}$)
- ci - cumulative infiltration ($m s^{-1}$)
- ce - cumulative evaporation ($m s^{-1}$)
- cd - cumulative drainage ($m s^{-1}$)

If the value of (BAL) increases as the simulation proceeds, then either the time increment or the cell dimensions have to be reduced. In practice, the spatial and temporal increments must be kept small.

Chapter 1

1.2.2 Basic structure of the infiltration model

In order to apply the mathematical infiltration model which has been described in the previous section, each major soil type in the catchment is represented as a soil column. The structure of the soil column is indicated in figure 1.4. It is divided into up to three layers; each is permitted to have different hydrological properties. All layers are further divided into cells, and flow between the midpoints of each cell is simulated under both saturated and unsaturated conditions. Detention capacity, expressed as an equivalent depth of water on the soil surface has to be exceeded by rainfall excess before runoff begins. When precipitation ceases, this store is depleted by infiltration and evaporation. Detention capacity is the only model parameter which is not a measurable characteristic. It is not physically based, but represents the net effect of vegetation, interception, litter interception, and surface detention. Its value also reflects the antecedent moisture conditions of vegetation and litter. The model can accommodate dynamic changes in model structure; it allows water tables and perched water tables to develop and fluctuate through time.

1.2.3 Data requirements

The data which are required by the infiltration model are discussed in Chapter 2. The soil hydrological characteristics are parameters which may not be commonly available for the ungauged catchment. It is suggested that the series of charts and regression equations which were developed by Brakensiek and Rawls (1983) for the ungauged application of the Green and Ampt infiltration model, may prove very useful in deriving the soil hydrological parameters required by the Richards equation. These charts and equations also allow the routine use of the infiltration model for the ungauged catchment (Anderson and Howes, 1984; Anderson et al., 1985; Anderson and Howes, 1986).

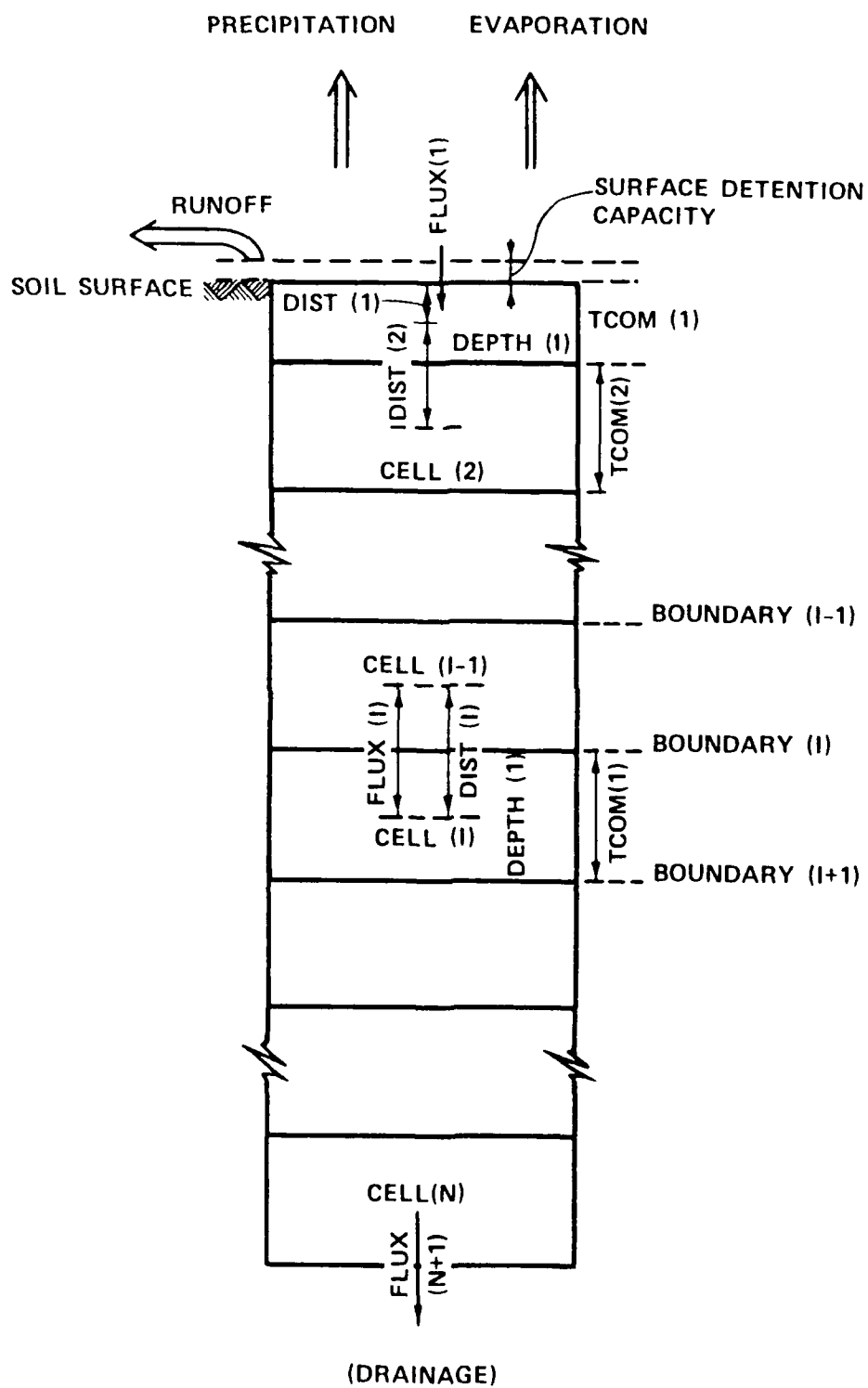


Figure 1.4
Schematic Structure of the Infiltration Algorithm

Chapter 1

The charts and regression equations were developed from simulations based upon approximately 5,000 soil data sets in the United States, and represent average soil conditions prior to a particular agronomic practice. Figure 1.5 indicates that information concerning the percentage sand, clay and organic matter of a soil is all that is required to derive the moisture contents corresponding to a broad selection of suction values. Soil texture data are used to derive the mineral bulk density; these together with the percentage organic matter are used to determine soil bulk density, and all are then used in the regression equations to provide the moisture content at a number of specified suction values. The soil water potential at air entry is derived from a table published by Rawls et al. (1982) and which is reproduced in part in Table 1.2, and this provides an additional point for the soil moisture characteristic curve. Figure 1.6 illustrates the two charts from which values of saturated hydraulic conductivity and saturated moisture content can be derived relating to the soil's percentage of clay and sand.

1.2.4 Stochastic infiltration model

One of the major problems in applying the infiltration equation to a catchment is the spatial variation of the soil's physical, and therefore hydrological, properties. This variability leads to a lack of confidence in a deterministic model and thus a stochastic approach can additionally be adopted. Such a framework has been introduced into the infiltration model in an attempt to incorporate estimates of known spatial variability within a soil type, and to establish its consequences upon the predicted hydrograph. Thus a probability distributed model has been developed.

The variability of the five soil hydrological properties necessary to operate the model: detention capacity, the soil moisture characteristic curve, saturated soil moisture content, saturated hydraulic conductivity, and initial soil moisture

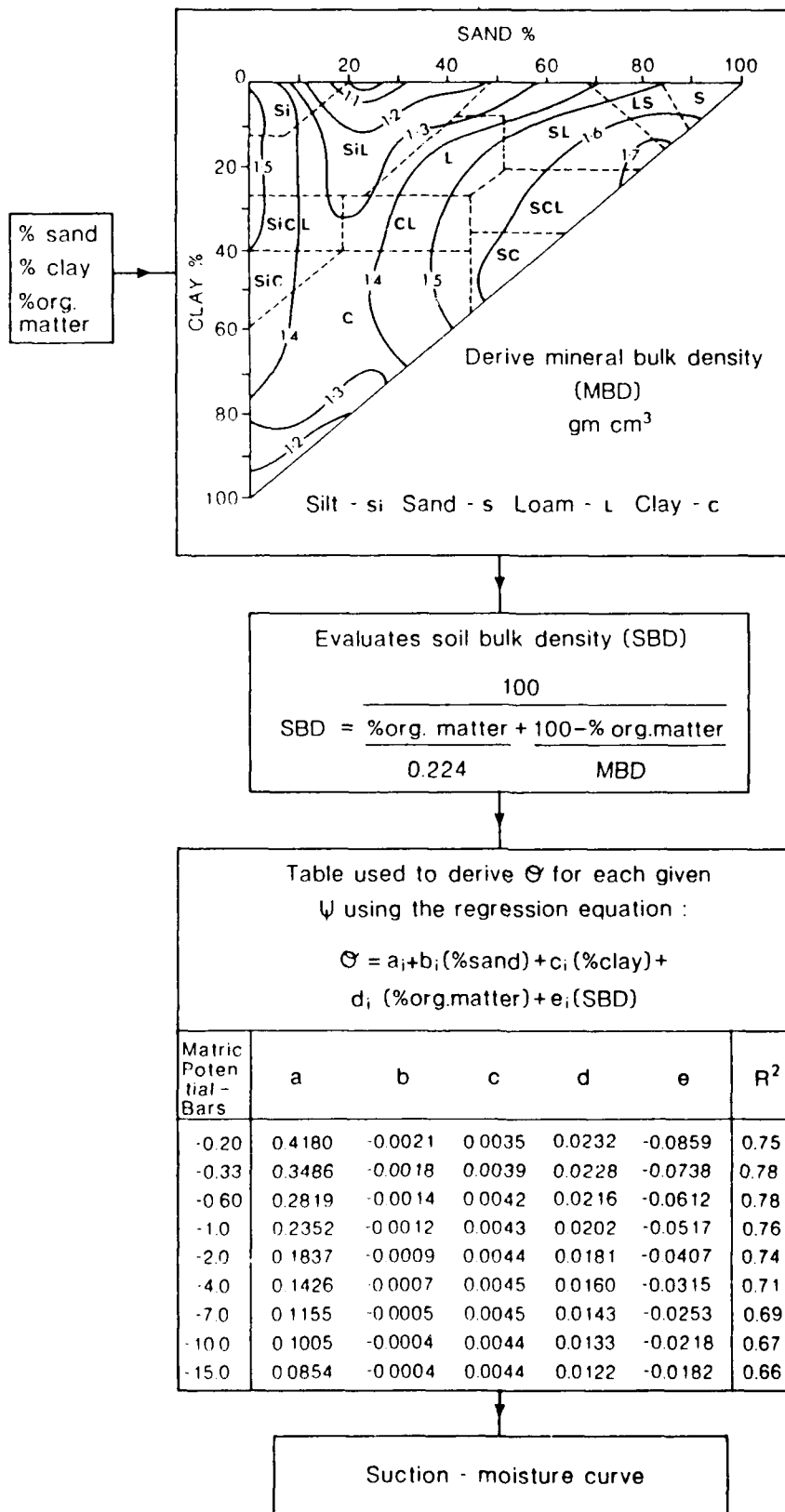


Figure 1.5
Derivation of the Suction-Moisture Curve from Soil Texture
Information

(after Brakensiek and Rawls, 1983)

Table 1.2

Bubbling pressure classified by soil texture
 (adapted from Rawls et al., 1982, Table 2)

Texture class	Sample size	Bubbling pressure (metres)
Sand	762	0.15
Loamy sand	338	0.21
Sandy loam	666	0.30
Loam	393	0.40
Silt loam	1206	0.51
Sandy clay loam	498	0.59
Clay loam	366	0.56
Silt clay loam	689	0.70
Sandy clay	45	0.79
Silty clay	127	0.77
Clay	291	0.86

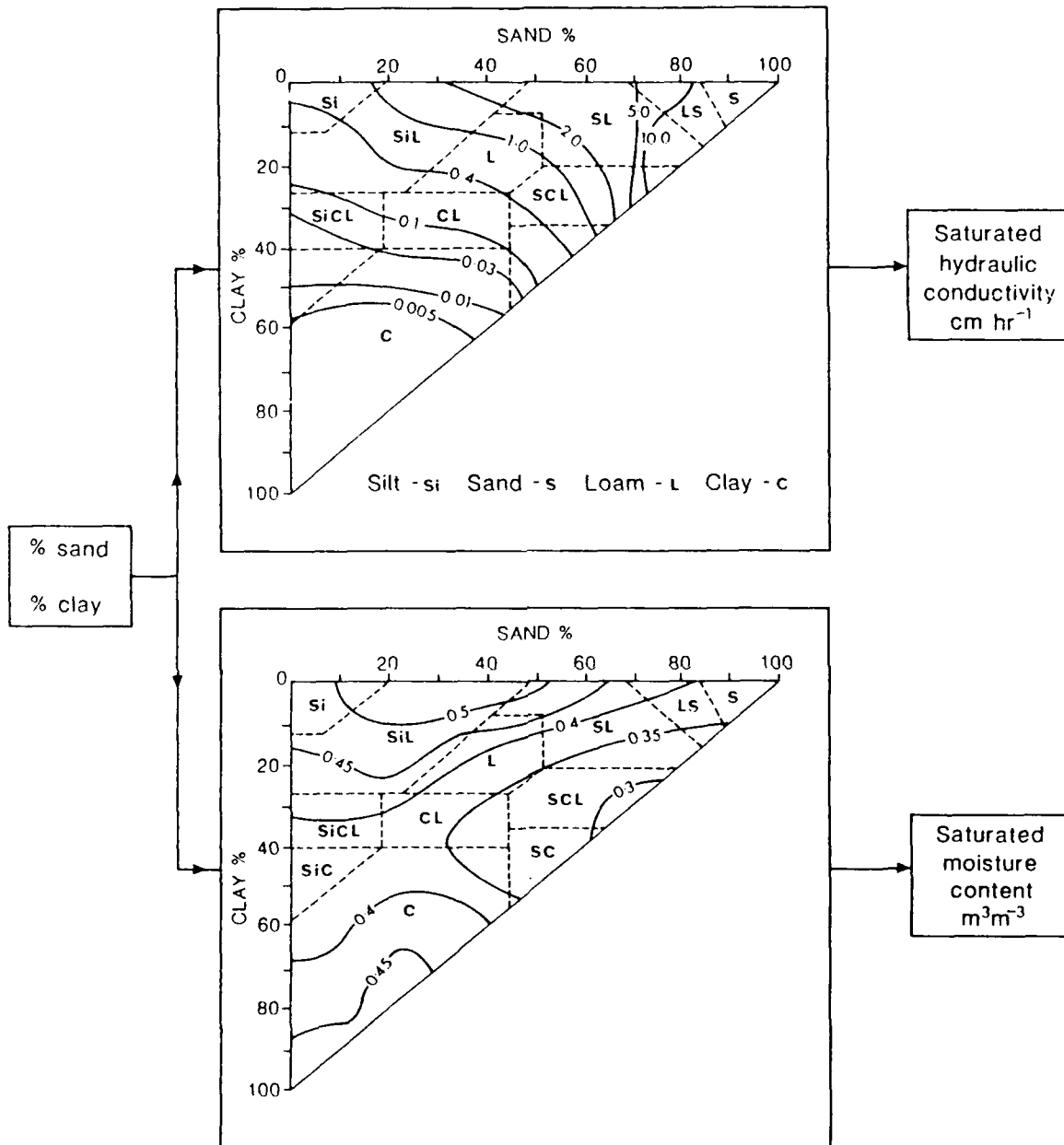


Figure 1.6
Derivation of Saturated Hydraulic Conductivity and
Saturated Moisture Content from Soil
Texture Information

Chapter 1

conditions, is described by conventional statistics. Each is considered to be an independent random variable and may be described by a suitable probability density function, derived from the literature. There is evidence that log-normally distributed hydraulic conductivity and other soil hydrological properties have been shown to display normal distributions. For this model, detention capacity was assumed to be normally distributed. It is acknowledged that catchment variability is not without spatial structure, but insufficient geostatistical information describing the characteristics of this structure is currently available for incorporation into the model. The assumption of independence will, however, provide predictions for the 'worst case' situation; incorporation of spatial autocorrelation would decrease model output variance.

A procedure has been built into the infiltration model program which generates random values for the five soil hydrological parameters. The random number generator which has been used is a NAG (Numerical Algorithm Group) routine, reference number G05DDF, which returns a 'pseudo-random' number from a normal probability distribution. There are three requirements to generate the random numbers in the infiltration model for each of the five input parameters:

1. The specification of a probability distribution.
This is an expression of the relative likelihood of different parameter values.
2. The mean and standard deviation.
The mean reflects the average value of the parameter and the standard deviation reflects the magnitude of error of the estimate.
3. The ranges of the physically allowable parameter values.
These reflect some knowledge of the possible field ranges.

Chapter 1

The NAG routine, G05DDF, is therefore called which returns the random value from a normal distribution provided that the mean and standard deviation are specified. The normal distribution in this algorithm is given by:

$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp \left(\frac{-(x-\bar{x})^2}{2\sigma^2} \right) \quad 1.46$$

where:

- $p(x)$ - probability of (x)
- σ - standard deviation
- $\bar{x}$ - mean

As neither the normal nor log-normal distributions are bounded at the tail, there is a small probability of randomly generated values assuming negative values. Checks are therefore performed on the generated values, to ensure physical consistency. Total independence of the five parameters cannot be assumed. Many checks which are enforced involve adjusting parameter values according to the values which have been generated for the other parameters.

The procedure for the stochastic variation of each of the five parameters will be discussed in turn.

Detention capacity

The random number generated from the normal distribution is constrained only by the condition that it cannot assume a value of less than zero. If the generated value does fall below this limit, it is set to zero.

Chapter 1

Saturated soil moisture content

As the infiltration model is capable of simulating up to three hydraulically different layers, three different means and standard deviations may be entered into the program. The value is generated randomly for each layer from the normal distribution and then checked against the largest moisture value in the soil moisture characteristic curve. If the saturated soil moisture content is smaller than this value, then it is reset equal to the largest moisture values in the curve.

Soil moisture characteristic curve

As for the saturated soil moisture content, up to three curves may be input to the model, one for each layer in the soil column. For each curve and for each tension the moisture content is allowed to vary according to the normal distribution with a given mean and standard deviation. The procedure begins with the smallest moisture content. If this randomly generated value is less than zero, then its value is set to 0.001. Random numbers are then generated for the other moisture contents. If any randomly generated value is less than or equal to the previous values, then it is set equal to the value plus a small increment. Thus reverse gradients are not allowed to develop in the curve. The largest moisture value is finally compared to the saturated soil moisture content as has been described.

An alternative method would be to randomly generate one moisture value, to then find the difference between the randomly generated moisture value and the mean, and finally to increment all moisture values by this difference. However, this procedure would not allow variation in the standard deviation with soil moisture tension and there is evidence in the literature that this may be the case.

Chapter 1

Saturated hydraulic conductivity

Again, a mean and standard deviation can be entered for each layer. As this parameter is considered to be log-normally distributed, for each layer, the logarithm of the mean is taken. This is used to generate the random number from the normal distribution and the antilogarithm of the generated number is then taken. There are no checks on the generated value.

Initial moisture content

The randomly generated value for initial moisture content is generated for each cell in the soil column. Each is compared to the saturated soil moisture content for the relevant layer. If it exceeds this value, then it is set equal to the limit. The initial moisture content is also checked against the moisture values in the soil moisture characteristic curve for the layer. To calculate unsaturated conductivity values, the initial moisture content of each cell must lie within this range.

1.2.5 Implementation

The infiltration model, which includes the option as to whether or not a stochastic application is required, was developed on a mainframe, the Honeywell 6800 under Multics. All further developmental work and validation was undertaken on the SUN 3/60 workstation under Unix. Figure 1.7 indicates the alternative procedures available within the MILHY model suite. The stochastic model does produce more than one hydrograph and these are all stored. All hydrographs produced may then be plotted out, or, alternatively, statistics which describe the characteristics and the variability of the predicted hydrographs may be calculated.

In application of the infiltration algorithm for runoff prediction to a catchment or subcatchment, the area does not have

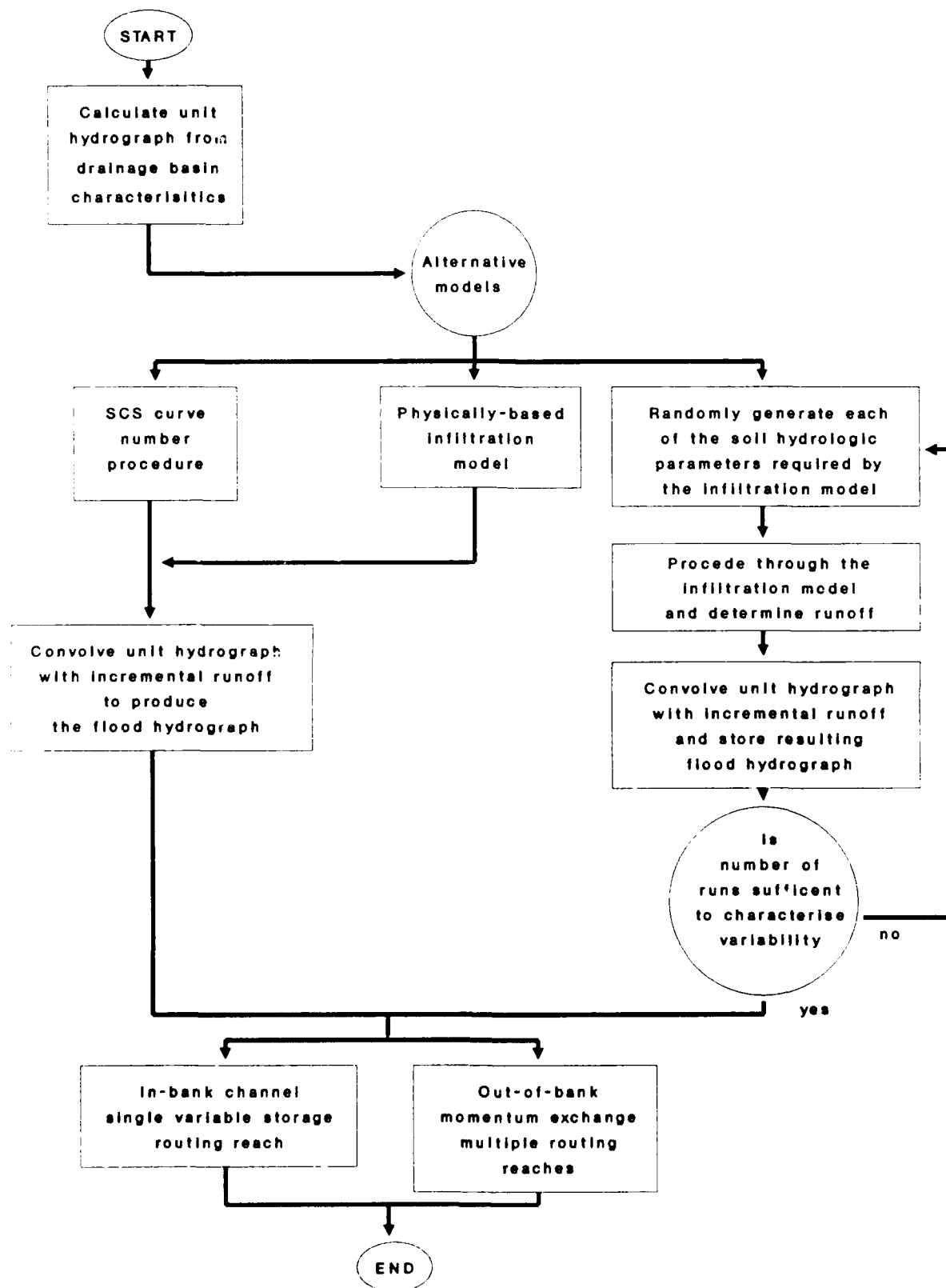


Figure 1.7
Alternative Procedures for Derivation of the
Flood Hydrograph Utilising MILHY3

Chapter 1

to be assumed to be homogeneous. Soil conditions can be represented by more than one soil column. Soil hydrological information for each of the major soil series or groups in the area is used to set up a soil column (figure 1.4) for each soil type. In order to combine the relative contributions of runoff provided by each of the soil types, the complete storm is applied to each of the soil columns, and the incremental runoff produced by each is weighted according to the percentage area of the catchment occupied by that particular soil type. These relative contributions are then summed to produce the total runoff volume derived from the subcatchment. It should be stressed, however, that the relative locations of each soil type are not explicitly taken into account.

Any decision concerning the number of soil columns which will be used to describe the subcatchment area will have to trade the advantages of a more complete representation of the conditions with the disadvantages of an increase in data acquisition and computer requirements and will depend upon the user's requirements. The user is recommended to read Chapter 7 in Volume 1 of this report, where guidelines are given for the selection of process modules in the MILHY3 suite.

Chapter 2

MILHY3 - Data Sets

2.1 Introduction

All input data for MILHY3 is contained in 'datal' and 'data2' data sets. The basic nature of these two data sets remains unchanged from MILHY2, where program commands and hydrological data are provided in 'datal' and soils data for the infiltration algorithm are provided in 'data2'. In MILHY3 both files are assumed to exist irrespective of the use of the infiltration algorithm. A summary of the nature of the data preparation and checking procedures is shown in Figure 2.1.

This chapter is split into three parts: a description of the two data sets, and a worked example with results.

2.2 Data Set 'datal'

The 'datal' data set contains all the hydrological procedures and consequent data requirements and the model control procedures for a simulation. There are fifteen legal commands accepted by MILHY3, which must be entered in columns 1-20 of the data set. No typing or spelling errors are accepted and on most machines the commands must be in upper case. The legal commands are:-

Model control procedures:

```
START
STORE HYD
STORE RATING CURVE
STORE TRAVEL TIME
ADD HYD
PRINT HYD
PLOT HYD
ERROR ANALYSIS
FINISH
```

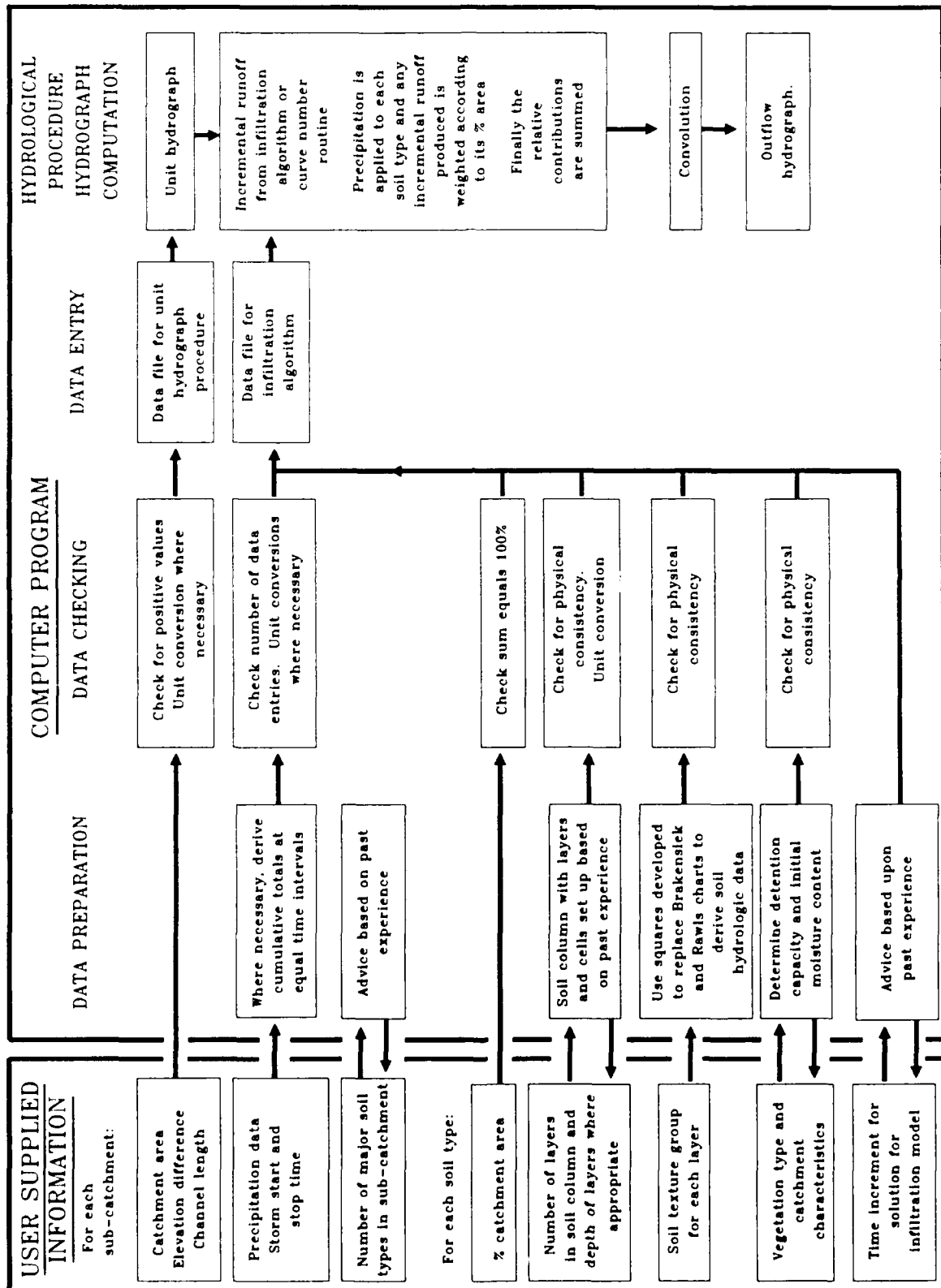


Figure 2.1

Data Preparation and Checking Procedures for the MILHY3 Scheme

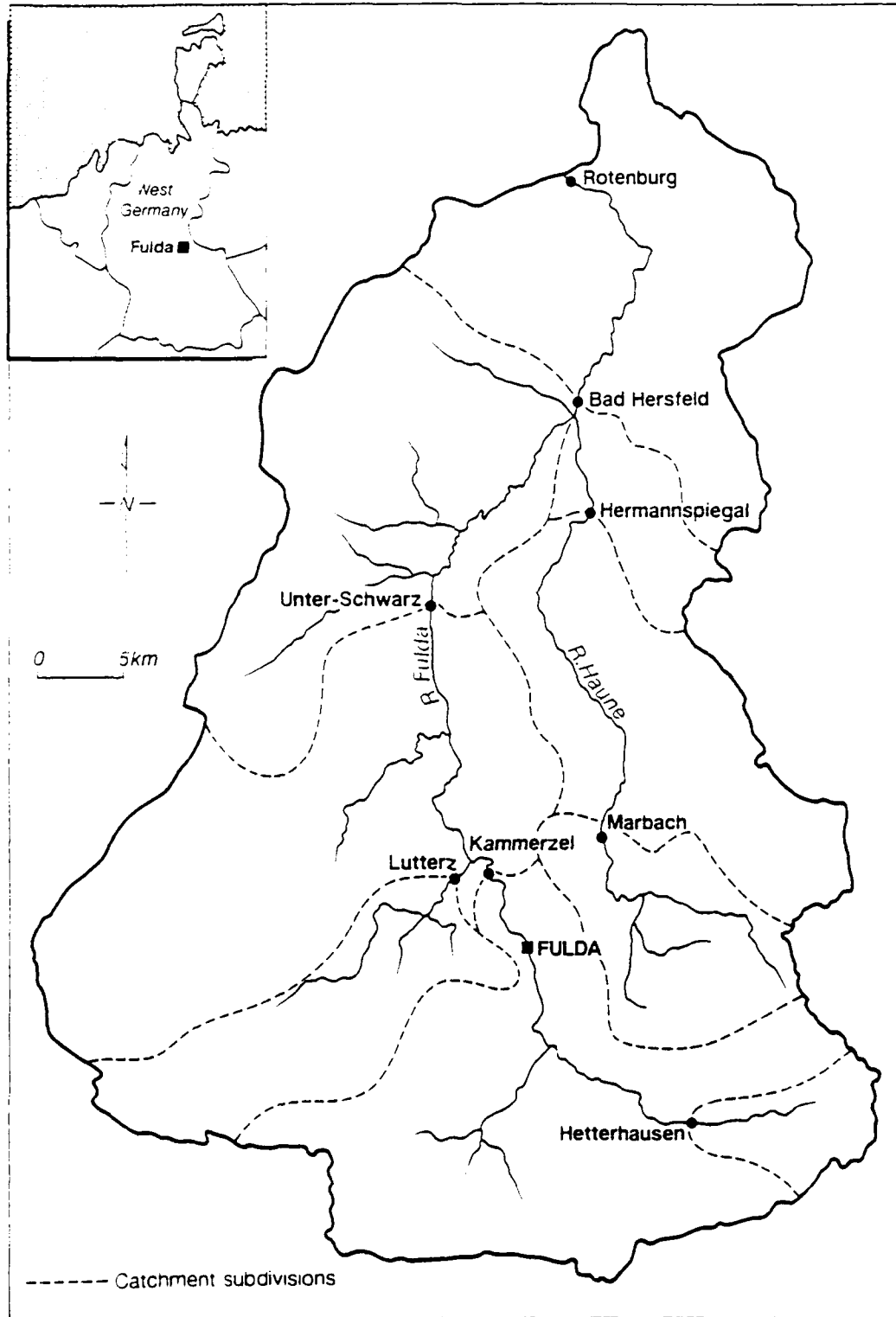


Figure 2.2
Location of example simulation, River Fulda, West Germany

Chapter 2

Hydrological procedures:

```
COMPUTE HYD  
COMPUTE RATING CURVE  
COMPUTE TRACEL TIME  
ROUTE  
ROUTE RESERVOIR  
SEDIMENT YIELD
```

An '*' in column 1 means that the line is a comment.

An '*' in column 80 means skip to a new page before writing to file.

Each of these commands requires some further identification data or field/topographic data. All data must be entered in columns 21-80, and it must appear in the order specified. The data may be surrounded by as much text as required by the user for identification, but care should be taken that such identifiers do not include any numbers. Data is separated by at least one blank space between each data item.

Six hydrographs can be stored in a MILHY program at a time. The hydrographs are identified by storage location numbers 1 through 6. Therefore, the same storage location number must be used for many hydrographs in a MILHY program. This is especially true when routing is done through large watersheds. However, no more than six hydrographs are ever needed at one time because MILHY programs begin at the head of a watershed and work downstream through one reach at a time. When a storage location number is used to store or compute another hydrograph, the first hydrograph is lost. The user should be sure that the hydrograph will not be referred to again before using the storage location number for another command.

To store, compute, or route a hydrograph, the user must specify the time increment. There are no rigid rules about selecting the time increment, but generally it should not be

Chapter 2

greater than one-fifth of the time to the peak of the hydrograph. This rule usually provides enough points to adequately define the hydrograph. All hydrographs are limited to 300 points.

For the commands STORE HYD, COMPUTE HYD, ROUTE and ROUTE RESERVOIR, the user must specify the number of the outflow hydrograph. The hydrograph identification numbers are used to designate specific routing reaches, incremental areas, reservoirs, and partial hydrographs. The partial hydrograph number is given to all hydrographs other than outflow hydrographs from reaches, incremental areas, or reservoirs. The recommended identification numbers for each group are:

Reaches.....	1-100
Partial hydrographs.....	101-300
Incremental areas.....	301-500
Reservoirs.....	501+

Each of the fifteen legal commands and their data requirements are now described in detail and summarised in Table 2.1. An example data set and results file is documented in section 2.4.

START

The first command for any watershed is START. The three data items associated with this command are the time start and the control data specifying the units of data input and output. A code of zero indicates imperial units are to be used, a value of 1 indicates metric units.

Chapter 2

STORE HYD

The STORE HYD command is used to store the coordinates of a hydrograph in the computer. It can be used for storing measured hydrographs or hydrographs computed by methods other than the ones used in MILHY. The input data required for STORE HYD are storage location number, hydrograph identification number, time increment, watershed area, and flow rates of the hydrograph at the specified time increment.

COMPUTE HYD

The COMPUTE HYD command is used to compute hydrographs from the incremental areas of the watershed. The first five items of data are storage location number, hydrograph identification number, time increment, watershed area, and SCS runoff curve number. A zero value is entered for the SCS CN if the infiltration algorithm is to be invoked. Normally, data items 6 and 7 are watershed height and main stream length. The height and length are used to compute the recession constant K and the time to peak t_p . However, if K and t_p are known or estimated by some other method, they can be entered directly into the program. This is accomplished by placing a minus sign before the values of K and t_p and entering them as data items 6 and 7, respectively. The remaining data items are values of the cumulative rainfall at the specified time increment.

Since most watersheds have a limited number of rain gauges, the same mass rainfall data may be used to develop several hydrographs.

PRINT HYD

The PRINT HYD command is used to print coordinates of a hydrograph, volume of runoff, and peak flow rate. The required input data are the storage location number, peak-volume code, rating

Chapter 2

curve storage location, number and format identifier. The peak-volume indicator is used to identify the form of hydrograph output. A zero value would produce just peak discharge and hydrograph volume data. A value of 1 would produce the whole discharge hydrograph, whilst a value of 2 would generate a stage hydrograph utilising the rating curve identified as the third data input. The format identifier if set to 1 will produce a hydrograph as a single column of data, without the time interval data. This enables easier transfer of data to graphics or statistical packages. A format value of zero will retain the normal five column MILHY output.

PLOT HYD

The PLOT HYD command is used to plot hydrographs in a MILHY program. It will plot one hydrograph on a set of axes, or if a comparison is desired, it will plot two hydrographs on the same set of axes. The required input data are the storage location numbers of the hydrographs to be plotted.

ADD HYD

The ADD HYD command adds the coordinates of any two hydrographs. The hydrographs are added at a time increment equal to that of the hydrograph with the shorter time increment. The only data required are the storage location number and hydrograph identification number of the added hydrograph and the storage location numbers of the two hydrographs to be added.

STORE RATING CURVE

The STORE RATING CURVE command is used to store rating curves that have been measured or computed previously. STORE RATING CURVE will save considerable computer time if measured or computed rating curves are available. The input data are the storage location number, valley section number and individual rating curve points

Chapter 2

described by elevation, end-area, and flow rate. The number of points used to describe a rating curve is limited to 20.

COMPUTE RATING CURVE

The COMPUTE RATING CURVE command is used to compute the stage-area-flow relationship for a valley section. The input data and storage location number, momentum exchange indicator, multiple routing indicator, valley section number, number of segments in the valley section, minimum elevation, maximum elevation, channel and flood-plain slopes, Manning's n value, and segment boundary point for each segment, and horizontal and vertical position of points describing the valley section.

The storage location numbers of the valley sections in a particular reach must begin with 1, and increase by one for each valley section in the reach. However, the numbers are assigned without regard to upstream or downstream order. The valley section identification number can be any number from 0.1 to 999.9. These rules concerning storage location and valley section identification numbers also apply to the STORE RATING CURVE command.

Normally, valley sections are divided into three segments (two flood-plain segments and channel segment) for computing the rating curve. However, some valley sections may have more than one channel, or may have an extreme variation in n values across the flood plain, thus requiring more than three segments. A maximum of six segments is permitted. Manning's values for each segment are input with segment boundary point (distance from the beginning of the valley section to the end of the segment). Flood-plain n values are positive and channel n values are negative.

Twenty points are used to define a rating curve. The location of the points is determined by dividing the difference between the maximum and minimum elevations into 19 equal increments.

Chapter 2

The momentum exchange indicator determines which of four techniques is used to develop the rating curve under out-of-bank conditions. A zero value will ensure the MILHY or MILHY2 version is utilised. Otherwise a value of 1,2,3 or 4 must be selected, where 1 introduces the least momentum exchange and 4 the most. Technique 4 will therefore reduce the computed discharge capacity at a particular stage elevation in comparison to technique 1.

The multiple routing indicator (set to 1 to invoke, 0 to not invoke) will cause separate rating curves to be developed for each flow segment. The flow segments can then be routed separately downstream using a COMPUTE TRAVEL TIME and ROUTE command for each flow segment.

COMPUTE TRAVEL TIME

The COMPUTE TRAVEL TIME command is used to compute the normal flow travel time relationship used in ROUTE. The input data are storage location number, reach identification number, number of valley sections in the reach, reach length, slope, multiple routing indicator, and rating curve segment identifiers. The reach identification number can be any number from 0.1 to 999.9. The maximum number of valley sections per reach is six. The slope can be either the channel or flood-plain slope or a weighted average of the two. If flow is confined to the channel, the channel slope is of course applicable. If most of the flow is in the flood plain, usually the flood-plain slope is used. However, a weighted slope based on the relative rates of flow in the channel and the flood plain may be used.

The COMPUTE TRAVEL TIME command considers each rating curve in the reach in computing the travel time flow relationship. COMPUTE TRAVEL TIME automatically selects the flow rates that are used in computing individual travel times. The flow rates of the rating curve with the lowest maximum flow rate are chosen. If the flow

Chapter 2

rates of any other rating curve in the reach were chosen, the rating curve with the lowest maximum flow rate would have to be extrapolated. The travel time table is limited to 19 points, because of the 20-point limit for rating curves.

If multiple routing is invoked, only two rating curve flow segments are investigated. These segment rating curves are identified using a two digit number. The first digit is the storage location number used in the COMPUTE RATING CURVE command when the segment rating curve was developed. The second digit is the segment number.

STORE TRAVEL TIME

The input data for STORE TRAVEL TIME are storage location number, reach identification number, reach length, slope, and individual points of the relationship defined by depth, flow, and travel time.

ROUTE

The ROUTE command is used to route floods through streams and valleys. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, time increment, and multiple routing indicator. The storage location number of the outflow hydrograph must be the same as the storage location number used in COMPUTE TRAVEL TIME for the reach. To prevent unnecessary program stoppage, ROUTE extrapolates the travel-time table when it is exceeded and writes the message, "TRAVEL TIME TABLE EXCEEDED".

If multiple routing is invoked, a separate ROUTE and COMPUTE TRAVEL TIME command is needed for each flow segment.

Chapter 2

ROUTE RESERVOIR

The ROUTE RESERVOIR command is used to route floods through reservoirs. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, and individual points of the reservoir's outflow-storage relationship. The outflow-storage relationship must be expressed in 20 points or less. If the outflow-storage relationship is exceeded, ROUTE RESERVOIR will extrapolate the relationship and write the message, "STORAGE-DISCHARGE TABLE EXCEEDED".

ERROR ANALYSIS

The ERROR ANALYSIS command is used to determine the error standard deviation and the percentage error in peak flow between any two hydrographs in a MILHY program. These functions make ERROR ANALYSIS useful in research. The input data are the storage location numbers of the two hydrographs to be analyzed.

SEDIMENT YIELD

The SEDIMENT YIELD command is used to compute the sediment yield at any point in a watershed. Input data required are storage location number of the hydrograph from the area, a soils factor, a crop factor, a slope length and gradient factor, and a conservation practice factor.

FINISH

The FINISH command is used to end MILHY programs. There are no data associated with FINISH.

Table 2.1

Data for legal commands of MILHY3
in 'datal' data set

HYDROLOGICAL PROCEDUREVariable used in subroutineCOMPUTE HYD

Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for rainfall data (hours)	DT(ID)
Watershed area (sqmi/km ²)	DA(ID)
Curve number (enter zero if not invoked)	CN
Watershed height, maximum difference (ft/m)	HT
Main stream length (mi/km)	XL
Rainfall, cumulative totals (inches/mm)	RAIN(300)

COMPUTE RATING CURVE

Storage location number for rating curve	ID
Turbulent exchange of momentum between segments (not invoked enter 0) (invoked, enter 1-4 depending on method)	IT
Multiple routing reaches (not invoked enter 0) (invoked enter 1)	MR
Valley section location number	VS
Number of segments in channel (max. of 6)	NSEG
Minimum elevation (ft/m)	ELO
Maximum elevation (ft/m)	EMAX
Channel slope	SLOPE1
Floodplain slope	SLOPE2
Manning 'n' for each segment (negative value for channel segments)	SEGN(NSEG)
Segment boundary points (horizontal distance) (ft/m)	DIST(NSEG)
Cross-section co-ordinates (distance then elevation) (ft/m)	DATA(12,311)

COMPUTE TRAVEL TIME

Storage location of travel time table	ID
Reach identification number	REACH
Number of valley sections in reach	NOVS
Reach length (ft/m)	XL
Slope (average for flow segments)	SLOPE
Multiple routing reaches (not invoked do not enter) (invoked enter one)	MR

Table 2.1 (cont.)

Inflow rating curve identification)	INRC
Outflow rating curve identification	LRC
(first digit is storage location of the rating curve, the second digit is the segment number)	

N.B. If multiple routing reaches not invoked
do not enter values for INRC and LRC

ROUTE

Storage location number of outflow hydrograph	ID
Hydrograph identification number of outflow hydrograph	NHD
Storage location number of inflow hydrograph	IDH
Time increment (hrs)	DT(ID)
Multiple routing reaches	MR
(not invoked, do not enter)	
(invoked, enter one)	

ROUTE RESERVOIR

Storage location number of outflow hydrograph	ID
Hydrograph identification number of outflow hydrograph	NHD
Storage location number of inflow hydrograph	IDH
Reservoir outflow storage relation (max 20 points)	DT(ID)

SEDIMENT YIELD

Storage location of number of hydrograph	ID
Soil, crop, conservation and gradient factors	SOIL, CROP, CP, SL

Table 2.1 (cont.)

MODEL CONTROL PROCEDURESSTART

Start time (hours)	TIME
Data input	KCODE
imperial enter zero	
metric enter one	
Data output	ICODE
imperial enter zero	
metric enter one	

STORE HYD

Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for discharge data (hrs)	DT(ID)
Watershed area (sq.mi/km ²)	DA(ID)
Baseflow (added to discharge) (cfs/m ³ s ⁻¹)	BSF
Discharge (300 points max.) (cfs/m ³ s ⁻¹)	OCFS(300,ID)

RECALL HYD

Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for discharge data (hours)	DT(ID)
Watershed area (sq.mi/km ²)	DA(ID)
Peak discharge (cfs/m ³ s ⁻¹)	PEAK(ID)
Runoff volume (cf/m ³)	ROIN(ID)
Number of points in hydrograph	IEND(ID)
Discharge (cfs/m ³ s ⁻¹)	OCFS(300,ID)

STORAGE RATING CURVE

Storage location number for rating curve	ID
Valley section number	VS
Rating curve points	
elevation (ft/m)	DEEP(20,ID)
end area (ft ² /m ²)	A(20,ID)
flow rate (cfs/m ³ s ⁻¹)	Q(20,ID)

STORAGE TRAVEL TIME

Storage location number for travel time table	ID
Reach identification number	NHD

Table 2.1 (cont.)

Length of reach (ft./m)	XL
Slope either channel or flood plain or weighted average of the two	SLOPE
Depth (ft/m)	DP(ID)
Discharge (cfs/m ³ s ⁻¹)	SCFS(20)
Storage coefficient	C(20)

ADD HYD

Storage location number for resultant hydrograph	ID
Hydrograph identification number of resultant	NHD
Storage location of two hydrographs to be added	ID1, ID2

PRINT HYD

Storage location number of hydrographs	ID
Specification of type of output	NPK
0 peak and volume only (cfs/m ³ s ⁻¹)	
1 discharge hydrograph (cfs/m ³ s ⁻¹)	
2 stage hydrograph (ft/m)	

Rating curve identification for conversion of hydrograph	IDR
---	-----

PLOT HYD

Storage location number of the 1 or 2 hydrographs to be plotted	ID1, ID2
--	----------

PUNCH HYD

Storage location number of hydrograph	ID
---------------------------------------	----

ERROR ANALYSIS

Storage location numbers of 2 hydrographs to be compared	ID1, ID2
---	----------

FINISH

No information required

Chapter 2

2.3 Data Set 'data2'

This data set contains all the information required by the infiltration algorithm. In contrast to the 'data1' data set, 'data2' contains variables separated by a space, no text or comment lines may appear. Data may be entered in columns 1 to 80 and must appear in the correct order. Table 2.2 summarizes the variables required by 'data2' and the order in which they must appear. Line numbers are not required in the data file but are provided here for convenience. A set of data for each soil column to be simulated must be entered. The runoff generated from each column is then weighted depending on the percentage contribution of that column in a particular subcatchment. Computations for each subcatchment are carried out individually in line with upstream to downstream progression utilised by all the MILHY3 models.

Each variable is now defined in turn. An example 'data2' dataset and corresponding results file is documented in section 2.4.

Line 1

<u>TIME</u>	simulation start time	)	
		)	
		)	
<u>ALR</u>	storm start time	)	
		)	hours and minutes
		)	where hours are 24 hour
<u>AMR</u>	storm stop time	)	clock and minutes are
		)	decimals of hours,
		)	e.g. 20.45 becomes
<u>SIMDUR</u>	simulation duration	)	20.75
		)	
		)	

Chapter 2

Line 2

IOUT printout control, 1 = full printout, 0 = restricted
printout

Line 3

AF simulation iteration periods (secs), for accuracy needs
to be small, as a guide try 60 secs iterations

WT write out interval (hours)

Line 4

NSCOL number of soil columns in particular subcatchment; if
more than 1, repeat lines 5-22 for each additional column

Line 5

LPAREA percentage area of subcatchment, represented by soil
column 1

Line 6 data from lines 6-22 is for soil column 1

NL number of cells

NL1 number of cells in layer (horizon) 1

NL2 number of cells in layer (horizon) 2

Line 7

TCOM (I), I = 1, NL

thickness of cells (m), entered for NL cells

Line 8

EMAX maximum midday evaporativity (ms^{-1})

ADETCAP mean surface detention capacity (m), double precision

SDETCAP standard deviation detention capacity, double precision -
set to zero if stochastic version not used

Chapter 2

Line 9

<u>ASRI</u>	mean saturated soil water content ($\text{m}^3 \text{m}^{-3}$) for layer (horizon) 1, double precision
<u>SSRI</u>	standard deviation of saturated soil water content for layer (horizon) 1, double precision, set to zero if stochastic model not used
<u>ASR2</u>	as above for layer 2
<u>SSR2</u>	as above for layer 2
<u>ASR3</u>	as above for layer 3
<u>SSR3</u>	as above for layer 3

Line 10

<u>ASATCON1</u>	mean saturated conductivity (ms^{-1}) for layer 1, double precision
<u>SSATCON1</u>	standard deviation saturated conductivity for layer 1, double precision, set to zero if stochastic model not used
<u>ASATCON2</u>	as above for layer 2
<u>SSATCON2</u>	as above for layer 2
<u>ASATCON3</u>	as above for layer 3
<u>SSATCON3</u>	as above for layer 3

Line 11ATHETA (I), I = 1, NL

mean initial soil water content ($\text{m}^3 \text{m}^{-3}$) for each of NL cells

Line 12

<u>STHETA</u>	standard deviation soil water content for soil column, double precision, set to zero if stochastic model not used
---------------	---

Chapter 2

Line 13

NQ number of observations in suction moisture curve

Line 14 line 14-16 - layer 1
 17-18 - layer 2
 20-22 - layer 3

AX(I), I = 1, NQ

mean soil moisture values ($\text{m}^3 \text{m}^{-3}$) for layer 1, NQ observations, at Y suction values, the last value needs to be the saturated soil water content, i.e. ASR1, double precision

Line 15

y1(I), I = 1, NQ

suction values (m) for layer 1, NQ observations corresponding to AX moisture values. As the last AX observation is at saturation, the last suction observation must be close to zero

Line 16

SCURV1 standard deviation of soil water content in suction moisture curve for layer 1, double precision. Set to zero if stochastic model not used

Line 17 AX2(I), I = 1, NQ

Line 18 y2(I), I = 1, NQ

Line 19 SCURV2

Line 20 AX3(I), I = 1, NQ

Line 21 y3(I), I = 1, NQ

Line 22 SCURV3

Chapter 2

For each column, lines 5-22 are repeated, for each subcatchment lines 1-22 $(+(5-22) \times \text{soil columns})$ are added. Each soil column or subcatchment follows directly from previous data entry; no extra spaces or lines are required.

If observed data for the soil hydrologic characteristics is not available, (e.g. AX, ASR), these may be generated from the Brakensiek and Rawl charts described in section 1.2.3.

2.4 Example Data Sets and Results File

The example shown here aims to generate a runoff hydrograph from the River Fulda shown in Figure 2.2. Observed inflows will be used, to input flow at Unter-Schwarz on the River Fulda, and to simulate flows from the tributary, the River Haune. MILHY3 will be used to simulate out-of-bank flows from these stations to the outflow at Rotenburg.

Table 2.2

Data requirements for 'data2'

Line
no.

```

1  TIME ALR AMR SIMDUR
2  IOUT
3  AF WT
4  NSCOL
5  IPAREA
6  NL NL1 NL2
7  TCOM(I),I=1,NL
8  EMAX ADETCAP SDETCAP
9  ASR1 SSR1 ASR2 SSR2 ASR3 SSR3
10 ASATCON SSATCON ASATCON1 SSATCON2 ASATCON3 SSATCON3
11 ATHETA(I),I=1,NL
12 STHETA
13 NQ
14 AX(I)mI=1,NQ
15 Y(I),I=1,NQ
16 SCURV1
17 AX2(I),I=1,NQ
18 Y2(I),I=1,NQ
19 SCURV2
20 AX3(I),I=1,NQ
21 Y3(I),I=1,NQ
22 SCURV3

```

If there is more than 1 soil column, then repeat from line 5, until all information is provided. No blank line is required between soil columns.

* EXAMPLE APPLICATION OF MILHY3

START 00.00 0 0

* OBSERVED INFLOW AT UNTER-SCHWARZ

STORE HYD ID=1 NHD=404 DT=2.0 DA=181 SQ MI BSF=0
 FLOW RATES(CFS)= 0 0 0 0 0 0 0 0 0 0 0 0
 9 58 144 268 422 620 847 1073 1252 1349
 1419 1467 1494 1503 1497 1475 1442 1401
 1355 1305 1241 1166 1106 1053 120

* ++++++

* ROUTE HYDROGRAPH FROM UNTER-SCHWARZ THROUGH REACH 3 TO BAD HERSFELD

* COMPUTE RATING CURVE FOR UNTER-SCHWARZ

COMPUTE RATING CURVE ID=1 IT=2 MR=0 VS NO=4 NO SEGS=3

MIN ELEV=708.7 MAX ELEV=738.2
 CH SLP=0.0007 FLDPL SLP=0.0005
 N=0.05 DIST=1312.4
 N=-.03 DIST=1371.7
 N=0.05 DIST=1420.9
 DIST ELEV
 0.0 738.2
 0.3 718.5
 1312.4 715.2
 1312.7 708.7
 1358.3 708.7
 1371.4 708.7
 1371.7 715.2
 1372.0 715.2
 1420.6 718.5
 1420.9 738.2

* COMPUTE RATING CURVE FOR BAD HERSFELD

COMPUTE RATING CURVE ID=2 IT=2 MR=0 VS=5 NO SEGS=3

MIN ELEV=637.6 MAX ELEV=657.6
 CH SLP=0.006 FLDPLN SLP=0.0075
 N=0.05 DIST=393.2
 N=-.03 DIST=492.1
 N=0.05 DIST=623.7
 DIST ELEV
 0.0 657.6
 0.4 651.3
 390.4 651.3
 390.8 651.6
 393.0 651.6
 393.2 651.3
 393.7 650.9
 406.8 644.4
 410.1 642.7
 413.4 641.1
 416.7 639.8
 420.0 639.8
 423.2 639.8
 426.5 639.8
 429.8 639.4
 433.1 639.1
 436.4 639.1
 439.6 638.8
 442.9 636.2
 446.2 638.5
 449.5 638.1
 452.8 638.1

456.0 637.8
 459.3 637.6
 462.6 638.1
 465.9 639.4
 469.2 641.7
 472.4 643.4
 475.7 645.0
 479.0 646.3
 482.3 648.0
 485.6 649.0
 488.9 650.0
 492.1 650.9
 495.4 651.9
 508.5 652.6
 524.9 652.2
 574.2 652.2
 590.6 652.6
 607.0 652.6
 623.4 625.2
 623.7 655.5

COMPUTE TRAVEL TIME ID=1 REACH NO=3 NO VS=2
 L=75443 FT SLP=0.0006
 MR=0

ROUTE ID=1 HYD NO=405 INFLOW ID=1
 DT=0.25HRS MR=0

*-----
 * COMPUTE RUNOFF HYDROGRAPH FROM SUBCATCHMENT 405
 COMPUTE HYD ID=2 HYD NO=405 DT=0.5HRS DA=152.2 SQ MI
 CN=90 HT=72.4 FT L=20.4 MI
 CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
 0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
 0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
 0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
 0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
 0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
 0.447 0.457 0.468 0.478 0.489 0.499 2.0

PRINT HYD ID=2 NPK=0 IDR=0 IN=0

*-----
 * COMPUTE OUTFLOW HYD FROM SUBCATCHMENT 405 FROM FULDA RIVER BAD HERSFELD

ADD HYD ID=1 HYD NO=405 ID=1 ID=2

PRINT HYD ID=1

* ++++++
 * ++++++

* OBSERVED INFLOW FOR RIVER HANE AT BAD HERSFELD

STORE HYD ID=2 NHD=408 DT=2.0 DA=27 SQ MI BSF=0
 FLOW RATES(CFS)=0 0 0 0 0 0 0 0 0 0 0
 42 1593 4247 2777 1993 1481 1176 1010
 902 817 743 674 609 549 492 440 394 354
 315 288 259 234 212 192

* ++++++

* ADD HYDROGRAPHS FROM FULDA AND HAUNE RIVERS AT BAD HERSFELD

ADD HYD ID=1 HYD NO=1 INFLOW ID=1 ID=2

* ++++++

* ROUTE OUTFLOW HYDROGRAPH AT BAD HERSFELD THROUGH REACH 6

* COMPUTE RATING CURVE FROM BAD HERSFELD

COMPUTE RATING CURVE ID=1 IT=2 MR=1 VS=5 NO SEGS=3
 MIN ELEV=637.6 MAX ELEV=657.6
 CH SLP=0.006 FLDPLN SLP=0.0075

N=0.05 DIST=393.2

N=-.03 DIST=492.1

N=0.05 DIST=623.7

DIST ELEV

0.0 657.6

0.4 651.3

390.4 651.3

390.8 651.6

393.0 651.6

393.2 651.3

393.7 650.9

406.8 644.4

410.1 642.7

413.4 641.1

416.7 639.8

420.0 639.8

423.2 639.8

426.5 639.8

429.8 639.4

433.1 639.1

436.4 639.1

439.6 638.8

442.9 636.2

446.2 638.5

449.5 638.1

452.8 638.1

456.0 637.8

459.3 637.6

462.6 638.1

465.9 639.4

469.2 641.7

472.4 643.4

475.7 645.0

479.0 646.3

482.3 648.0

485.6 649.0

488.9 650.0

492.1 650.9

495.4 651.9

508.5 652.6

524.9 652.2

574.2 652.2

590.6 652.6

607.0 652.6

623.4 625.2

623.7 655.5

* COMPUTE RATING CURVE FOR ROTENBURG

COMPUTE RATING CURVE ID=2 IT=2 MR=1 VS=8 NO SEGS=3 MIN ELEV= 587.3

MAX ELEV=618.1 CH SLP= 0.006 FLDPN SLP=0.0075

N=0.05 DIST=1056.4 N=-0.03 DIST=1191.0

N=0.05 DIST=1253.6

DIST ELEV

0.0 616.8

0.3 608.5

82.0 602.6

180.5 603.2

278.9 604.4

475.7 604.4

574.1 603.0
 771.0 603.6
 918.6 603.5
 1056.4 604.8
 1070.0 601.0
 1099.1 599.6
 1112.2 597.4
 1118.8 595.4
 1125.3 591.2
 1131.9 591.0
 1138.5 590.4
 1145.0 589.6
 1151.6 588.9
 1158.1 588.4
 1164.7 587.6
 1171.3 587.3
 1177.8 591.9
 1184.4 595.1
 1191.0 599.4
 1197.5 602.0
 1204.1 603.7
 1215.6 611.5
 1230.3 610.7
 1233.6 611.2
 1253.3 611.6
 1253.6 618.1

* LEFT FLOODPLAIN

COMPUTE TRAVEL TIME ID=3 REACH NO=6 NO VS=2
 L=55808FT SLP=0.0006
 MR=1 INRC=11 LRC=21
 ROUTE ID=3 NHD=409 IDH=1
 DT=0.25 MR=1

* CHANNEL

COMPUTE TRAVEL TIME ID=4 REACH NO=6 NO VS=2
 L=72550FT SLP=0.0007
 MR=1 INRC=12 LRC=22
 ROUTE ID=4 NHD=409 IDH=1
 DT=0.25 MR=1

* RIGHT FLOODPLAIN

COMPUTE TRAVEL TIME ID=5 REACH NO=6 NO VS=2
 L=55808 FT SLP=0.0006
 MR=1 INRC=13 LRC=23
 ROUTE ID=5 NHD=409 IDH=1
 DT=0.25HRS MR=1

ADD HYD ID=1 NHD=409 IDI=3 IDII=4
 ADD HYD ID=1 NHD=409 IDI=1 IDII=5

* -----
 * COMPUTE RUNOFF HYDROGRAPH FOR SUBCATCHMENT 409

COMPUTE HYD ID=2 HYD NO=409 DT=0.5HRS DA=155.5
 CN=0 HT=48.9FT L=15.1 MI
 CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
 0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
 0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
 0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
 0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
 0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
 0.447 0.457 0.468 0.478 0.489 0.499 2.0

* -----

* COMPUTE OUTFLOW HYDROGRAPH FROM SUBCATCHMENT 409, ROTENBURG

ADD HYD ID=1 HYD NO=409 ID=1 ID=2

PRINT HYD ID=1 NPK=2 IDR=2 IN=0

FINISH

```

00.00 00.00 25.50 25.50
1
10. 0.25
4
86.5
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.37 0.0 0.37 0.0 0.37 0.0
3.3E-5 0.0 3.3E-5 0.0 3.3E-5 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
2.0
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.51 0.0 0.51 0.0 0.51 0.0
4.2E-6 0.0 4.2E-6 0.0 4.2E-6 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.064 0.075 0.085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.064 0.075 0.085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.064 0.075 0.085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
4.8
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.37 0.0 0.37 0.0 0.37 0.0
6.9E-6 0.0 6.9E-6 0.0 6.9E-6 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0

```

8.6

10 4 2

0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15

0.0 0.0 0.0

0.37 0.0 0.37 0.0 0.37 0.0

3.6E-5 0.0 3.6E-5 0.0 3.6E-5 0.0

0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3

0.0

10

0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37

-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2

0.0

0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37

-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2

0.0

0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37

-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2

0.0

* EXAMPLE APPLICATION OF MILHY3

START 00.00 0 0

* OBSERVED INFLOW AT UNTER-SCHWARZ

STORE HYD ID=1 NHD=404 DT=2.0 DA=181 SQ MI BSF=0
 FLOW RATES(CFS)= 0 0 0 0 0 0 0 0 0 0 0 0
 9 58 144 268 422 620 847 1073 1252 1349
 1419 1467 1494 1503 1497 1475 1442 1401
 1355 1305 1241 1166 1106 1053 120

* ++++++

* ROUTE HYDROGRAPH FROM UNTER-SCHWARZ THROUGH REACH 3 TO BAD HERSFELD

* COMPUTE RATING CURVE FOR UNTER-SCHWARZ

COMPUTE RATING CURVE ID=1 IT=2 MR=0 VS NO=4 NO SEGS=3

MIN ELEV=708.7 MAX ELEV=738.2
 CH SLP=0.0007 FLDPL SLP=0.0005
 N=0.05 DIST=1312.4
 N=-.03 DIST=1371.7
 N=0.05 DIST=1420.9
 DIST ELEV
 0.0 738.2
 0.3 718.5
 1312.4 715.2
 1312.7 708.7
 1358.3 708.7
 1371.4 708.7
 1371.7 715.2
 1372.0 715.2
 1420.6 718.5
 1420.9 738.2

MOMENTUM EXCHANGE METHOD 2

RATING CURVE VALLEY SECTION 4.0

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
708.70	0.00	0.00
710.25	91.25	155.05
711.81	182.72	477.37
713.36	274.42	911.35
714.91	366.33	1431.72
716.46	787.68	2229.63
718.02	2185.81	4170.07
719.57	4342.65	8410.09
721.12	6547.91	14670.48
722.67	8753.25	22488.20
724.23	10958.65	31705.05
725.78	13164.14	42210.93
727.33	15369.69	53922.54
728.88	17575.32	66773.54
730.44	19781.03	80709.19
731.99	21986.80	95683.22
733.54	24192.65	111655.61
735.09	26398.57	128591.32
736.65	28604.57	146459.20
738.20	30810.64	165231.38

* COMPUTE RATING CURVE FOR BAD HERSFELD

COMPUTE RATING CURVE ID=2 IT=2 MR=0 VS=5 NO SEGS=3

MIN ELEV=637.6 MAX ELEV=657.6
 CH SLP=0.006 FLDPLN SLP=0.0075
 N=0.05 DIST=393.2

N=.03 DIST=492.1

N=0.05 DIST=623.7

DIST	ELEV
0.0	657.6
0.4	651.3
390.4	651.3
390.8	651.6
393.0	651.6
393.2	651.3
393.7	650.9
406.8	644.4
410.1	642.7
413.4	641.1
416.7	639.8
420.0	639.8
423.2	639.8
426.5	639.8
429.8	639.4
433.1	639.1
436.4	639.1
439.6	638.8
442.9	636.2
446.2	638.5
449.5	638.1
452.8	638.1
456.0	637.8
459.3	637.6
462.6	638.1
465.9	639.4
469.2	641.7
472.4	643.4
475.7	645.0
479.0	646.3
482.3	648.0
485.6	649.0
488.9	650.0
492.1	650.9
495.4	651.9
508.5	652.6
524.9	652.2
574.2	652.2
590.6	652.6
607.0	652.6
623.4	625.2
623.7	655.5

MOMENTUM EXCHANGE METHOD 2		
RATING CURVE VALLEY SECTION 5.0		
WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.00	0.00
638.65	74.59	273.51
639.71	116.87	498.71
640.76	179.74	934.63
641.81	248.52	1601.59
642.86	322.18	2442.78
643.92	400.82	3457.09
644.97	484.55	4641.50

646.02	573.72	5985.95
647.07	668.42	7531.72
648.13	768.22	9258.80
649.18	874.00	11109.36
650.23	986.35	13163.23
651.28	1105.39	15542.64
652.34	1645.10	19138.52
653.39	2293.44	25218.43
654.44	2949.69	32899.45
655.49	3606.02	41818.87
656.55	4262.43	51889.83
657.60	4918.91	63025.47

COMPUTE TRAVEL TIME ID=1 REACH NO=3 NO VS=2
 L=75443 FT SLP=0.0006
 MR=0

0

TRAVEL TIME TABLE
 REACH 3.0

WATER DEPTH FEET	FLOW RATE CFS	TRAVEL TIME HRS
1.59	274.	7.64
2.64	499.	6.39
3.94	935.	5.14
5.38	1602.	4.61
6.60	2443.	5.42
7.53	3457.	6.28
8.43	4642.	6.57
9.20	5986.	6.45
10.01	7532.	6.35
10.80	9259.	6.12
11.56	11109.	5.82
12.34	13163.	5.57
13.14	15543.	5.33
14.02	19139.	5.18
15.11	25218.	4.86
16.27	32899.	4.51
17.46	41819.	4.18
18.65	51890.	3.89
19.87	63025.	3.63

ROUTE ID=1 HYD NO=405 INFLOW ID=1
 DT=0.25HRS MR=0

CHECK- VOLUME OF OUTFLOW HYDROGRAPH 1 IS 100.000% OF INFLOW HYDROGRAPH 1

* COMPUTE RUNOFF HYDROGRAPH FROM SUBCATCHMENT 405

COMPUTE HYD ID=2 HYD NO=405 DT=0.5HRS DA=152.2 SQ MI
 CN=90 HT=72.4 FT L=20.4 MI
 CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
 0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
 0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
 0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
 0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
 0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
 0.447 0.457 0.468 0.478 0.489 0.499 2.0

Shape constant, N = 2.470

Unit peak = 1453.5 cms

PRINT HYD ID=2 NPK=0 IDR=0 IN=0

```

PRINT HYD          ID=2   NPK=0
0      HYDROGRAPH VOLUME=      329554912. CF
      PEAK      DISCHARGE RATE=      1588.CFS

```

```

* -----
* COMPUTE OUTFLOW HYD FROM SUBCATCHMENT 405 FROM FULDA RIVER BAD HERSFELD
ADD HYD          ID=1  HYD NO=405  ID=1  ID=2
PRINT HYD          ID=1
PRINT HYD          ID=1   NPK=0
0      HYDROGRAPH VOLUME=      238953904. CF
      PEAK      DISCHARGE RATE=      1591.CFS

```

```

* ++++++
* ++++++
* OBSERVED INFLOW FOR RIVER HANE AT BAD HERSFELD
STORE HYD          ID=2  NHD=408  DT=2.0  DA=27  SQ MI  BSF=0
      FLOW RATES(CFS)=0 0 0 0 0 0 0 0 0 0 0 0
      42 1593 4247 2777 1993 1481 1176 1010
      902 817 743 674 609 549 492 440 394 354
      315 288 259 234 212 192

```

```

* ++++++
* ADD HYDROGRAPHS FROM FULDA AND HAUNE RIVERS AT BAD HERSFELD
ADD HYD          ID=1  HYD NO=1  INFLOW ID=1  ID=2
* ++++++
* ROUTE OUTFLOW HYDROGRAPH AT BAD HERSFELD THROUGH REACH 6
* COMPUTE RATING CURVE FROM BAD HERSFELD
COMPUTE RATING CURVE ID=1  IT=2  MR=1  VS=5  NO SEGS=3
      MIN ELEV=637.6  MAX ELEV=657.6
      CH SLP=0.006  FLDPLN SLP=0.0075
      N=0.05  DIST=393.2
      N=-.03  DIST=492.1
      N=0.05  DIST=623.7
      DIST  ELEV
      0.0  657.6
      0.4  651.3
      390.4  651.3
      390.8  651.6
      393.0  651.6
      393.2  651.3
      393.7  650.9
      406.8  644.4
      410.1  642.7
      413.4  641.1
      416.7  639.8
      420.0  639.8
      423.2  639.8
      426.5  639.8
      429.8  639.4
      433.1  639.1
      436.4  639.1
      439.6  638.8
      442.9  636.2
      446.2  638.5
      449.5  638.1

```

452.8 638.1
 456.0 637.8
 459.3 637.6
 462.6 638.1
 465.9 539.4
 469.2 641.7
 472.4 643.4
 475.7 645.0
 479.0 646.3
 482.3 648.0
 485.6 649.0
 488.9 650.0
 492.1 650.9
 495.4 651.9
 508.5 652.6
 524.9 652.2
 574.2 652.2
 590.6 652.6
 607.0 652.6
 623.4 625.2
 623.7 655.5

MOMENTUM EXCHANGE METHOD 2

RATING CURVE FOR SEGMENT 11

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	0.0	0.0
639.71	0.0	0.0
640.76	0.0	0.0
641.81	0.0	0.0
642.86	0.0	0.0
643.92	0.0	0.0
644.97	0.0	0.0
646.02	0.0	0.0
647.07	0.0	0.0
648.13	0.0	0.0
649.18	0.0	0.0
650.23	0.0	0.0
651.28	0.0	0.0
652.34	406.4	1066.0
653.39	820.0	3427.8
654.44	1233.7	6758.8
655.49	1647.4	10925.3
656.55	2061.1	15844.1
657.60	2475.0	21456.1

RATING CURVE FOR SEGMENT 12

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	19.5	62.0
639.71	52.9	239.7
640.76	106.1	621.9
641.81	164.6	1228.8
642.86	227.3	2003.1
643.92	294.3	2943.6
644.97	365.7	4046.8

646.02	441.8	5302.6
647.07	522.9	6751.8
648.13	608.3	8374.2
649.18	699.1	10111.7
650.23	795.7	12043.9
651.28	898.2	14309.2
652.34	1002.3	17176.2
653.39	1106.4	20251.5
654.44	1210.5	23526.1
655.49	1314.6	26994.1
656.55	1418.7	30650.3
657.60	1522.8	34489.9

RATING CURVE FOR SEGMENT 13

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	55.1	211.5
639.71	64.0	259.1
640.76	73.6	312.7
641.81	83.9	372.8
642.86	94.9	439.7
643.92	106.6	513.6
644.97	118.9	594.9
646.02	131.9	683.7
647.07	145.6	780.4
648.13	159.9	885.1
649.18	174.9	998.3
650.23	190.6	1120.1
651.28	207.2	1234.4
652.34	236.4	897.5
653.39	367.1	1540.7
654.44	505.6	2616.6
655.49	644.1	3902.1
656.55	782.6	5398.8
657.60	921.1	7083.8

% DISCHARGE IN SEGMENT 11

ELEV	PERCENT
637.60	0.000
638.65	0.000
639.71	0.000
640.76	0.000
641.81	0.000
642.86	0.000
643.92	0.000
644.97	0.000
646.02	0.000
647.07	0.000
648.13	0.000
649.18	0.000
650.23	0.000
651.28	0.000
652.34	0.056
653.39	0.136
654.44	0.205
655.49	0.261
656.55	0.305
657.60	0.340

Z DISCHARGE IN SEGMENT 12

ELEV	PERCENT
637.60	0.000
638.65	0.227
639.71	0.481
640.76	0.665
641.81	0.767
642.86	0.820
643.92	0.851
644.97	0.872
646.02	0.886
647.07	0.896
648.13	0.904
649.18	0.910
650.23	0.915
651.28	0.921
652.34	0.897
653.39	0.803
654.44	0.715
655.49	0.645
656.55	0.591
657.60	0.547

Z DISCHARGE IN SEGMENT 13

ELEV	PERCENT
637.60	0.000
638.65	0.773
639.71	0.519
640.76	0.335
641.81	0.233
642.86	0.180
643.92	0.149
644.97	0.128
646.02	0.114
647.07	0.104
648.13	0.096
649.18	0.090
650.23	0.085
651.28	0.079
652.34	0.047
653.39	0.061
654.44	0.080
655.49	0.093
656.55	0.104
657.60	0.112

* COMPUTE RATING CURVE FOR ROTENBURG

COMPUTE RATING CURVE ID=2 IT=2 MR=1 VS=8 NO SEGS=3 MIN ELEV= 587.3

MAX ELEV=618.1 CH SLP= 0.006 FLDPN SLP=0.0075

N=0.05 DIST=1056.4 N=-0.03 DIST=1191.0

N=0.05 DIST=1253.6

DIST ELEV

0.0 616.8

0.3 608.5

82.0 602.6

180.5 603.2

278.9 604.4

475.7 604.4

574.1 603.0

771.0 603.6

918.6 603.5
 1056.4 604.8
 1070.0 601.0
 1099.1 599.6
 1112.2 597.4
 1118.8 595.4
 1125.3 591.2
 1131.9 591.0
 1138.5 590.4
 1145.0 589.6
 1151.6 588.9
 1158.1 588.4
 1164.7 587.6
 1171.3 587.3
 1177.8 591.9
 1184.4 595.1
 1191.0 599.4
 1197.5 602.0
 1204.1 603.7
 1215.6 611.5
 1230.3 610.7
 1233.6 611.2
 1253.3 611.6
 1253.6 618.1

MOMENTUM EXCHANGE METHOD 2

RATING CURVE FOR SEGMENT 21

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	0.0	0.0
590.54	0.0	0.0
592.16	0.0	0.0
593.78	0.0	0.0
595.41	0.0	0.0
597.03	0.0	0.0
598.65	0.0	0.0
600.27	0.0	0.0
601.89	0.0	0.0
603.51	121.8	152.7
605.13	1409.2	4525.1
606.75	3063.7	16270.9
608.37	4754.6	33365.7
609.99	6466.5	55591.0
611.62	8178.7	82144.9
613.24	9890.9	112649.2
614.86	11603.2	146844.9
616.48	13315.5	184526.2
618.10	15028.0	225706.0

RATING CURVE FOR SEGMENT 22

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	19.4	66.9
590.54	69.1	380.6
592.16	148.8	1088.7
593.78	242.0	2271.4

595.41	344.6	3833.1
597.03	458.1	5703.2
598.65	586.3	7838.2
600.27	736.8	9973.5
601.89	928.8	13238.6
603.51	1134.8	17935.1
605.13	1350.0	23407.8
606.75	1568.2	30047.3
608.37	1786.4	37333.6
609.99	2004.6	45239.2
611.62	2222.8	53740.6
613.24	2440.9	62817.6
614.86	2659.1	72452.5
616.48	2877.3	82629.6
618.10	3095.5	93334.8

RATING CURVE FOR SEGMENT 23

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	0.0	0.0
590.54	0.0	0.0
592.16	0.0	0.0
593.78	0.0	0.0
595.41	0.0	0.0
597.03	0.0	0.0
598.65	0.0	0.0
600.27	0.9	0.9
601.89	7.7	19.0
603.51	22.7	78.1
605.13	45.4	216.4
606.75	72.0	422.7
608.37	102.4	698.3
609.99	136.8	1047.5
611.62	189.0	970.1
613.24	290.1	1949.6
614.86	391.2	3160.6
616.48	492.5	4569.2
618.10	593.9	6150.5

% DISCHARGE IN SEGMENT 21

ELEV	PERCENT
587.30	0.000
588.92	0.000
590.54	0.000
592.16	0.000
593.78	0.000
595.41	0.000
597.03	0.000
598.65	0.000
600.27	0.000
601.89	0.000
603.51	0.008
605.13	0.161
606.75	0.348
608.37	0.467
609.99	0.546
611.62	0.600
613.24	0.635

614.86	0.660
616.48	0.679
618.10	0.694

1 DISCHARGE IN SEGMENT 22

ELEV	PERCENT
587.30	0.000
588.92	1.000
590.54	1.000
592.16	1.000
593.78	1.000
595.41	1.000
597.03	1.000
598.65	1.000
600.27	1.000
601.89	0.999
603.51	0.987
605.13	0.832
606.75	0.643
608.37	0.523
609.99	0.444
611.62	0.393
613.24	0.354
614.86	0.326
616.48	0.304
618.10	0.287

1 DISCHARGE IN SEGMENT 23

ELEV	PERCENT
587.30	0.000
588.92	0.000
590.54	0.000
592.16	0.000
593.78	0.000
595.41	0.000
597.03	0.000
598.65	0.000
600.27	0.000
601.89	0.001
603.51	0.004
605.13	0.008
606.75	0.009
608.37	0.010
609.99	0.010
611.62	0.007
613.24	0.011
614.86	0.014
616.48	0.017
618.10	0.019

* LEFT FLOODPLAIN

COMPUTE TRAVEL TIME ID=3 REACH NO=6 NO VS=2

L=55808FT SLP=0.0006

MR=1 INRC=11 LRC=21

MULTIPLE ROUTING INVOKED

TRAVEL TIME TABLE

REACH 6.0

WATER	FLOW	TRAVEL
DEPTH	RATE	TIME
FEET	CFS	HRS

2.23	1066.	19.44
2.84	3428.	7.39
3.49	6759.	4.52
4.17	10925.	3.32
4.87	15844.	2.67
5.60	21456.	2.28

ROUTE ID=3 NHD=409 IDH=1
DT=0.25 MR=1

0 INFLOW FOR SEGMENT 1
HOURS PERCENT CFS

NO FLOW IN SEGMENT

* CHANNEL

COMPUTE TRAVEL TIME ID=4 REACH NO=6 NO VS=2
L=72550FT SLP=0.0007
MR=1 INRC=12 LRC=22

0 MULTIPLE ROUTING INVOKED

0 TRAVEL TIME TABLE
REACH 6.0

WATER DEPTH FEET	FLOW RATE CFS	TRAVEL TIME HRS
1.98	62.	6.10
3.01	240.	4.19
4.18	622.	3.28
5.33	1229.	2.66
6.39	2003.	2.25
7.45	2944.	1.99
8.53	4047.	1.80
9.60	5303.	1.66
10.70	6752.	1.56
11.84	8374.	1.48
13.01	10112.	1.44
14.01	12044.	1.38
15.02	14309.	1.32
16.04	17176.	1.23
17.04	20251.	1.16
18.05	23526.	1.10
19.00	26994.	1.04
19.97	30650.	0.99
20.92	34490.	0.94

ROUTE ID=4 NHD=409 IDH=1
DT=0.25 MR=1

0 INFLOW FOR SEGMENT 2

HOURS	PERCENT	CFS
3.250	0.000	0.000
3.500	0.001	0.001
3.750	0.004	0.016
4.000	0.009	0.101
4.250	0.019	0.427
4.500	0.035	1.460
4.750	0.059	4.135
5.000	0.090	9.821

.....route...../continued

56.000 0.790 1547.975

56.250	0.739	1538.240
56.500	0.788	1528.520
56.750	0.788	1518.594
57.000	0.787	1508.691
57.250	0.786	1498.587
57.500	0.786	1488.507
57.750	0.785	1478.244
58.000	0.784	1467.999

CHECK- VOLUME OF OUTFLOW HYDROGRAPH 4 IS 78.449% OF INFLOW HYDROGRAPH 1

* RIGHT FLOODPLAIN

COMPUTE TRAVEL TIME ID=5 REACH NO=6 NO VS=2

L=55808 FT SLP=0.0006

MR=1 INRC=13 LRC=23

O MULTIPLE ROUTING INVOKED

O TRAVEL TIME TABLE

REACH 6.0

WATER DEPTH FEET	FLOW RATE CFS	TRAVEL TIME HRS
8.04	19.	18.61
9.17	78.	6.84
10.73	216.	3.98
12.67	423.	3.06
14.98	698.	2.62
17.50	1047.	2.35
16.98	970.	2.40
21.21	1950.	2.82
22.57	3161.	2.34
23.92	4569.	2.03
25.26	6151.	1.81

ROUTE ID=5 NHD=409 IDH=1

DT=0.25HRS MR=1

O INFLOW FOR SEGMENT 3

HOURS	PERCENT	CFS
3.250	0.000	0.000
3.500	0.003	0.004
3.750	0.013	0.056
4.000	0.031	0.346
4.250	0.064	1.456
4.500	0.119	4.983
4.750	0.200	14.117
5.000	0.308	33.529

.....route...../continued

55.750	0.210	413.179
56.000	0.210	412.213
56.250	0.211	411.275
56.500	0.212	410.324
56.750	0.212	409.336
57.000	0.213	408.328
57.250	0.214	407.291
57.500	0.214	406.233
57.750	0.215	405.141
58.000	0.216	404.035

CHECK- VOLUME OF OUTFLOW HYDROGRAPH 5 IS 20.180% OF INFLOW HYDROGRAPH 1

ADD HYD ID=1 NHD=409 IDI=3 IDII=4
 ADD HYD ID=1 NHD=409 IDI=1 IDII=5

* -----

* COMPUTE RUNOFF HYDROGRAPH FOR SUBCATCHMENT 409

COMPUTE HYD ID=2 HYD NO=409 DT=0.5HRS DA=155.5
 CN=0 HT=48.9FT L=15.1 MI
 CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
 0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
 0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
 0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
 0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
 0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
 0.447 0.457 0.468 0.478 0.489 0.499 2.0

Shape constant, N = 2.411

Unit peak = 1495.6 cms

INCREMENTAL RUNOFF-Parameter variability included

SD of detcap 0.000

SD of saturated soil content 0.000 layer 1

0.000 layer 2

0.000 layer 3

SD of suction moisture curve 0.000 layer 1

0.000 layer 2

0.000 layer 3

SD of sat conductivity 0.000 layer 1

0.000 layer 2

0.000 layer 3

SD of initial water content 0.000

GENERATED K-MOISTURE CURVE

Millington-Quirk Method

Layer 1			Layer 2			Layer 3		
Moisture	Suction	Unsat K	Moisture	Suction	Unsat K	Moisture	Suction	Unsat K
0.057	-150.000	0.000000000023	0.057	-150.000	0.000000000023	0.057	-150.000	0.000000000023
0.073	-78.421	0.000000000144	0.073	-78.421	0.000000000144	0.073	-78.421	0.000000000144
0.090	-45.387	0.000000000553	0.090	-45.387	0.000000000553	0.090	-45.387	0.000000000553
0.106	-30.058	0.000000001621	0.106	-30.058	0.000000001621	0.106	-30.058	0.000000001621
0.123	-19.035	0.000000004190	0.123	-19.035	0.000000004190	0.123	-19.035	0.000000004190
0.139	-13.544	0.000000009711	0.139	-13.544	0.000000009711	0.139	-13.544	0.000000009711
0.156	-9.416	0.000000020796	0.156	-9.416	0.000000020796	0.156	-9.416	0.000000020796
0.172	-7.768	0.000000040196	0.172	-7.768	0.000000040196	0.172	-7.768	0.000000040196
0.189	-6.121	0.000000071057	0.189	-6.121	0.000000071057	0.189	-6.121	0.000000071057
0.205	-4.970	0.000000117721	0.205	-4.970	0.000000117721	0.205	-4.970	0.000000117721
0.222	-3.858	0.000000187038	0.222	-3.858	0.000000187038	0.222	-3.858	0.000000187038
0.238	-3.087	0.000000288406	0.238	-3.087	0.000000288406	0.238	-3.087	0.000000288406
0.255	-2.658	0.000000427721	0.255	-2.658	0.000000427721	0.255	-2.658	0.000000427721
0.271	-2.230	0.000000608825	0.271	-2.230	0.000000608825	0.271	-2.230	0.000000608825
0.288	-1.847	0.000000837452	0.288	-1.847	0.000000837452	0.288	-1.847	0.000000837452
0.304	-1.518	0.000001119370	0.304	-1.518	0.000001119370	0.304	-1.518	0.000001119370
0.321	-1.188	0.000001465874	0.321	-1.188	0.000001465874	0.321	-1.188	0.000001465874
0.337	-0.859	0.000001913219	0.337	-0.859	0.000001913219	0.337	-0.859	0.000001913219
0.354	-0.529	0.000002609657	0.354	-0.529	0.000002609657	0.354	-0.529	0.000002609657
0.370	-0.200	0.000005070084	0.370	-0.200	0.000005070084	0.370	-0.200	0.000005070084

OSTART CONDITIONS

Simulation start time 0.0hrs

Precipitation begins at 0.0 and ends at 25.5

Rainfall data time increment = 0.5000 hrs
 Time increment for iteration period = 10.0 secs

Maximum evaporation during the day = 0.00000000 ms-1
 Surface detention capacity = 0.0000 m

INITIAL SOIL COLUMN CONDITIONS

	SAT THETA m3/m3	SAT HYD COND ms-1	CELL DEPTH NO m	INITIAL REL THETA SAT m3/m3
Layer 1	0.3710	0.000033000015	1 0.0750	0.3000 0.809
			2 0.2250	0.3000 0.809
			3 0.3750	0.3000 0.809
			4 0.5250	0.3000 0.809
Layer 2	0.3710	0.000033000015	5 0.6750	0.3000 0.809
			6 0.8250	0.3000 0.809
Layer 3	0.3710	0.000033000015	7 0.9750	0.3000 0.809
			8 1.1250	0.3000 0.809
			9 1.2750	0.3000 0.809
			10 1.4250	0.3000 0.809

SOIL COLUMN CONDITIONS 0.500 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.7490	0.2925	0.000000922	-0.000004233	0.788
2	0.2250	-1.6653	0.2967	0.000000993	-0.000003147	0.800
3	0.3750	-1.6249	0.2987	0.000001028	-0.000001820	0.805
4	0.5250	-1.6082	0.2996	0.000001042	-0.000000840	0.808
5	0.6750	-1.6023	0.2999	0.000001047	-0.000000317	0.808
6	0.8250	-1.6006	0.3000	0.000001049	-0.000000100	0.809
7	0.9750	-1.6001	0.3000	0.000001049	-0.000000027	0.809
8	1.1250	-1.6000	0.3000	0.000001049	-0.000000006	0.809
9	1.2750	-1.6000	0.3000	0.000001049	-0.000000002	0.809
10	1.4250	-1.6000	0.3000	0.000001049	0.000000000	0.809

Balance check on soil column water status = -0.0000006

Balance check as column water vol. = 0.0001306 %

Cumulative evaporation = 0.00000000

Cumulative precipitation = 0.0000

Cumulative infiltration = 0.000000

Cumulative drainage = 0.001888

Detention capacity exceeded

Runoff total in the last period 0.0000000 m

Runoff total in the last period 0.0000000 ins 0.500

SOIL COLUMN CONDITIONS 1.000 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.8336	0.2883	0.000000849	-0.000003008	0.777
2	0.2250	-1.7342	0.2933	0.000000934	-0.000002608	0.790
3	0.3750	-1.6719	0.2964	0.000000988	-0.000001988	0.799
4	0.5250	-1.6356	0.2982	0.000001019	-0.000001338	0.804
5	0.6750	-1.6162	0.2992	0.000001035	-0.000000797	0.806
6	0.8250	-1.6068	0.2997	0.000001043	-0.000000421	0.808

7	0.9750	-1.6026	0.2999	0.000001047	-0.000000199	0.808
8	1.1250	-1.6009	0.3000	0.000001048	-0.000000084	0.808
9	1.2750	-1.6003	0.3000	0.000001049	-0.000000033	0.809
10	1.4250	-1.6001	0.3000	0.000001049	-0.000000014	0.909

0Balance check on soil column water status = -0.0000016

Balance check as column water vol. = -0.0003621 %

Cumulative evaporation = 0.00000000

Cumulative precipitation = 0.0000

Cumulative infiltration = 0.000000

Cumulative drainage = 0.003777

Detention capacity exceeded

Runoff total in the last period 0.0000000 m

Runoff total in the last period 0.0000000 ins 1.000

0SOIL COLUMN CONDITIONS 1.500 HRS SINCE

SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.8826	0.2861	0.000000816	-0.000001740	0.771
2	0.2250	-1.7855	0.2907	0.000000890	-0.000001926	0.784
3	0.3750	-1.7160	0.2942	0.000000950	-0.000001701	0.793
4	0.5250	-1.5686	0.2966	0.000000990	-0.000001367	0.799
5	0.6750	-1.6383	0.2981	0.000001016	-0.000000996	0.803
6	0.8250	-1.6201	0.2990	0.000001032	-0.000000651	0.806
7	0.9750	-1.6099	0.2995	0.000001041	-0.000000402	0.807
8	1.1250	-1.6046	0.2998	0.000001045	-0.000000225	0.808
9	1.2750	-1.6021	0.2999	0.000001047	-0.000000121	0.808
10	1.4250	-1.6011	0.2999	0.000001048	-0.000000074	0.808

0Balance check on soil column water status = -0.0000029

Balance check as column water vol. = -0.0006496 %

Cumulative evaporation = 0.00000000

Cumulative precipitation = 0.0002

Cumulative infiltration = 0.000229

Cumulative drainage = 0.005664

Detention capacity exceeded

Runoff total in the last period 0.0000000 m

Runoff total in the last period 0.0000000 ins 1.500

0SOIL COLUMN CONDITIONS 2.000 HRS SINCE

SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.9232	0.2844	0.000000792	-0.000001402	0.766
2	0.2250	-1.8270	0.2886	0.000000855	-0.000001601	0.778
3	0.3750	-1.7541	0.2923	0.000000917	-0.000001488	0.788
4	0.5250	-1.7005	0.2950	0.000000963	-0.000001286	0.795
5	0.6750	-1.6628	0.2969	0.000000995	-0.000001034	0.800
6	0.8250	-1.6375	0.2981	0.000001017	-0.000000775	0.804
7	0.9750	-1.6214	0.2989	0.000001031	-0.000000544	0.806
8	1.1250	-1.6117	0.2994	0.000001039	-0.000000362	0.807
9	1.2750	-1.6064	0.2997	0.000001044	-0.000000238	0.808
10	1.4250	-1.6040	0.2998	0.000001046	-0.000000174	0.808

0Balance check on soil column water status = -0.0000039

Balance check as column water vol. = -0.0008873 %

Cumulative evaporation = 0.00000000

Cumulative precipitation = 0.0005
 Cumulative infiltration = 0.000508
 Cumulative drainage = 0.007549

Detention capacity exceeded
 Runoff total in the last period 0.0000000 m
 Runoff total in the last period 0.0000000 ins 2.000

.....compute hyd...../continued

OSOIL COLUMN CONDITIONS 25.000 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-2.8489	0.2473	0.000000399	-0.000000422	0.667
2	0.2250	-2.7653	0.2506	0.000000429	-0.000000413	0.675
3	0.3750	-2.6916	0.2534	0.000000455	-0.000000409	0.683
4	0.5250	-2.6268	0.2559	0.000000481	-0.000000419	0.690
5	0.6750	-2.5701	0.2581	0.000000507	-0.000000433	0.696
6	0.8250	-2.5216	0.2599	0.000000530	-0.000000441	0.701
7	0.9750	-2.4816	0.2615	0.000000548	-0.000000452	0.705
8	1.1250	-2.4504	0.2627	0.000000562	-0.000000456	0.708
9	1.2750	-2.4288	0.2635	0.000000572	-0.000000460	0.710
10	1.4250	-2.4175	0.2639	0.000000578	-0.000000460	0.711

0Balance check on soil column water status = -0.0000430

Balance check as column water vol. = -0.0111281 %

Cumulative evaporation = 0.00000000
 Cumulative precipitation = 0.0127
 Cumulative infiltration = 0.012674
 Cumulative drainage = 0.076113

Detention capacity exceeded
 Runoff total in the last period 0.0000000 m
 Runoff total in the last period 0.0000000 ins 25.000

OSOIL COLUMN CONDITIONS 25.500 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-0.2656	0.3669	0.000004996	0.000031808	0.989
2	0.2250	-0.8816	0.3364	0.000002054	0.000070547	0.907
3	0.3750	-1.8334	0.2888	0.000000927	0.000072419	0.778
4	0.5250	-2.4233	0.2639	0.000000575	0.000027042	0.711
5	0.6750	-2.5476	0.2590	0.000000518	0.000005381	0.698
6	0.8250	-2.5302	0.2596	0.000000526	0.000000531	0.700
7	0.9750	-2.4948	0.2610	0.000000542	-0.000000298	0.703
8	1.1250	-2.4645	0.2621	0.000000556	-0.000000429	0.707
9	1.2750	-2.4430	0.2630	0.000000566	-0.000000450	0.709
10	1.4250	-2.4318	0.2634	0.000000571	-0.000000453	0.710

0Balance check on soil column water status = -0.0000434

Balance check as column water vol. = -0.0102382 %

Cumulative evaporation = 0.00000000
 Cumulative precipitation = 0.0508
 Cumulative infiltration = 0.050800
 Cumulative drainage = 0.077147

Detention capacity exceeded

Runoff total in the last period 0.0000000 m

Runoff total in the last period 0.0000000 ins 25.500

* COMPUTE OUTFLOW HYDROGRAPH FROM SUBCATCHMENT 409, ROTENBURG

ADD HYD

ID=1 HYD NO=409 ID=1 ID=2

PRINT HYD

ID=1 NPK=2 IDR=2 IN=0

PRINT HYD

ID=1 NPK=2

TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT
0.000	587.300	15.000	590.303	30.000	594.314	45.000	593.921	60.000	592.550						
0.250	587.300	15.250	590.228	30.250	594.612	45.250	593.916	60.250	592.436						
0.500	587.300	15.500	590.155	30.500	594.819	45.500	593.912	60.500	592.325						
0.750	587.300	15.750	590.090	30.750	594.969	45.750	593.907	60.750	592.226						
1.000	587.300	16.000	590.033	31.000	595.069	46.000	593.902	61.000	592.115						
1.250	587.300	16.250	589.982	31.250	595.127	46.250	593.897	61.250	591.974						
1.500	587.300	16.500	589.935	31.500	595.154	46.500	593.892	61.500	591.846						
1.750	587.300	16.750	589.891	31.750	595.155	46.750	593.887	61.750	591.731						
2.000	587.300	17.000	589.850	32.000	595.135	47.000	593.882	62.000	591.616						
2.250	587.300	17.250	589.811	32.250	595.109	47.250	593.876	62.250	591.492						
2.500	587.300	17.500	589.774	32.500	595.082	47.500	593.871	62.500	591.358						
2.750	587.300	17.750	589.739	32.750	595.046	47.750	593.865	62.750	591.225						
3.000	587.300	18.000	589.705	33.000	595.004	48.000	593.858	63.000	591.111						
3.250	587.300	18.250	589.672	33.250	594.956	48.250	593.852	63.250	591.016						
3.500	587.300	18.500	589.640	33.500	594.904	48.500	593.846	63.500	590.935						
3.750	587.300	18.750	589.610	33.750	594.850	48.750	593.839	63.750	590.864						
4.000	587.300	19.000	589.564	34.000	594.794	49.000	593.832	64.000	590.799						
4.250	587.301	19.250	589.505	34.250	594.742	49.250	593.825	64.250	590.738						
4.500	587.303	19.500	589.453	34.500	594.696	49.500	593.818	64.500	590.682						
4.750	587.309	19.750	589.408	34.750	594.651	49.750	593.811	64.750	590.633						
5.000	587.324	20.000	589.370	35.000	594.607	50.000	593.803	65.000	590.589						
5.250	587.362	20.250	589.336	35.250	594.563	50.250	593.795	65.250	590.549						
5.500	587.440	20.500	589.306	35.500	594.520	50.500	593.788	65.500	590.474						
5.750	587.567	20.750	589.272	35.750	594.477	50.750	593.778	65.750	590.400						
6.000	587.745	21.000	589.232	36.000	594.434	51.000	593.767	66.000	590.334						
6.250	587.967	21.250	589.196	36.250	594.395	51.250	593.756	66.250	590.270						
6.500	588.245	21.500	589.167	36.500	594.362	51.500	593.745	66.500	590.206						
6.750	588.520	21.750	589.144	36.750	594.330	51.750	593.734	66.750	590.140						
7.000	588.959	22.000	589.124	37.000	594.300	52.000	593.722	67.000	590.076						
7.250	589.081	22.250	589.106	37.250	594.271	52.250	593.710	67.250	590.016						
7.500	589.243	22.500	589.090	37.500	594.243	52.500	593.698	67.500	589.960						

7.750	589.463	22.750	589.076	37.750	594.215	52.750	593.686	67.750	589.907
8.000	589.678	23.000	589.062	38.000	594.189	53.000	593.674	68.000	589.858
8.250	589.851	23.250	589.049	38.250	594.165	53.250	593.661	68.250	589.811
8.500	590.023	23.500	589.037	38.500	594.145	53.500	593.648	68.500	589.767
8.750	590.200	23.750	589.026	38.750	594.126	53.750	593.635	68.750	589.725
9.000	590.382	24.000	589.015	39.000	594.108	54.000	593.622	69.000	589.686
9.250	590.521	24.250	589.008	39.250	594.092	54.250	593.609	69.250	589.648
9.500	590.562	24.500	589.005	39.500	594.077	54.500	593.595	69.500	589.613
9.750	590.581	24.750	589.003	39.750	594.062	54.750	593.582	69.750	589.579
10.000	590.603	25.000	589.003	40.000	594.049	55.000	593.568	70.000	589.547
10.250	590.622	25.250	589.017	40.250	594.037	55.250	593.554	70.250	589.516
10.500	590.633	25.500	589.051	40.500	594.027	55.500	593.540	70.500	589.486
10.750	590.633	25.750	589.139	40.750	594.018	55.750	593.526	70.750	589.458
11.000	590.628	26.000	589.261	41.000	594.010	56.000	593.511	71.000	589.432
11.250	590.622	26.250	589.412	41.250	594.001	56.250	593.497	71.250	589.406
11.500	590.615	26.500	589.662	41.500	593.993	56.500	593.482	71.500	589.381
11.750	590.608	26.750	589.895	41.750	593.986	56.750	593.468	71.750	589.358
12.000	590.599	27.000	590.183	42.000	593.979	57.000	593.454	72.000	589.336
12.250	590.590	27.250	590.555	42.250	593.972	57.250	593.439	72.250	589.314
12.500	590.581	27.500	590.773	42.500	593.967	57.500	593.425	72.500	589.293
12.750	590.570	27.750	591.026	42.750	593.962	57.750	593.410	72.750	589.273
13.000	590.560	28.000	591.299	43.000	593.957	58.000	593.395	73.000	589.254
13.250	590.548	28.250	591.643	43.250	593.952	58.250	593.382	73.250	589.236
13.500	590.530	28.500	592.076	43.500	593.947	58.500	593.369	73.500	589.219
13.750	590.503	28.750	592.407	43.750	593.943	58.750	593.356	73.750	589.202
14.000	590.475	29.000	592.750	44.000	593.938	59.000	593.343	74.000	589.186
14.250	590.446	29.250	593.138	44.250	593.934	59.250	592.894	74.250	589.171
14.500	590.413	29.500	593.551	44.500	593.929	59.500	592.784	74.500	589.156
14.750	590.367	29.750	593.952	44.750	593.925	59.750	592.667	74.750	589.142

0 HYDROGRAPH VOLUME= 322645312. CF
PEAK ELEVATION = 595. FEET

FINISH

Chapter 3

MILHY3 : Program details3.1 Program Contents

MAIN
HONDO
STHYD
CMPHYD
SOILM
HYDCON
TWO
GRAD
SMCURV
PRTHYD
HPLOT
ADHYD
SRC
CMPRC
STT
CMPPTT
ROUTE
RESVO
ERROR
SEDT

Functions:

GIT
RMAX
RMIN.

BLOCK DATA.

Chapter 3

3.2 Program Changes Since MILHY2

The main changes made to the MILHY code have been to improve the predictive capability of the downstream conveyance estimation, specifically under out-of-bank conditions. In addition, a modular structure has been established which allows the user to select routines most appropriate to a particular application. The new routines introduced in MILHY3 require the user to select one of four methods of momentum exchange, and a single or multiple routing reach application. The user may also select either the Curve Number routine (reintroduced from the original MILHY code), or the infiltration algorithm utilized in MILHY2.

The structure of the MILHY3 code remains similar to that of MILHY2. The new capabilities are incorporated either in existing subroutines or are facilitated by the user in the 'datal' data set. It is important to note, therefore, that substantial changes must be made to the datal data set before the multiple routing routine can be utilized. The user is strongly recommended to study the example data set given in Chapter 2 of this volume.

Significant program changes have been made in the following subroutines:

CMPRC
ROUTE
PRTHYD

The introduction of the out-of-bank routing facilities and the selection of techniques have increased the amount of data that must be entered from the datal data set. The BLKDTA subroutine has been amended to enable this additional data to be read, and the COMMON BLOCKS have been restructured to improve the efficiency of the transfer of this data. Three COMMON BLOCKS are now utilised; the first contains control and read information, the second

Chapter 3

hydrograph information, and the third routing information. Array sizes have been increased in certain variables, notably A, Q and DEEP, and the definition of the variable C has changed. The punch code capabilities have been removed from MILHY3, and several bugs have been fixed.

The version documented in this volume runs on the SUN workstation and many other UNIX environments. Chapter 4 contains the changes necessary to MILHY3, to enable operation on an IBM-PC. These changes are minor except for the provision of a random number generating routine.

3.3 Subroutine Details

SUBROUTINE NAME: MAIN

SYNOPSIS: Opens files for input and output. Initialises certain variables. Calls appropriate subroutine according to command.

COMMAND:

INPUT: Two data files called 'data1' and 'data2' must exist.

'data1' - contains programme controls and data
'data2' - additional information for the infiltration algorithm

See Chapter 2 for details of these two data files

OUTPUT: Opens the output file 'results' to which the details of the simulation are to be sent.

VARIABLES USED:

Variables held in common block 'BLOCK1'

CTBLE(50,11)	command table
ITBLE(50,12)	integer table
ZALPHA (20)	alphanumeric code table
MAXNO	maximum number of data entries for any one command
NCODE	command number
ICC	continuation card
NCOMM	total number of legal commands

Chapter 3

Variables held in common block 'BLOCK2'

OCFS(300,6)	discharge
DATA(310)	data input for each command
RAIN(300)	cumulative precipitation at equal time increments
ROIN(6)	volume of discharge hydrograph
IEND(6)	number of points in hydrograph
DA(6)	drainage area
DT(6)	time increment
PEAK(6)	peak discharge of hydrograph
TIME	simulation start time
KCODE	measurement unit of input data (datal)
	KCODE = 0 imperial
ICODE	measurement unit of output
	ICODE = 0 imperial

Variables held in common block 'BLOCK3'

A(20,70)	end area
Q(20,70)	discharge
DEEP(20,70)	elevation of water surface
DP(20)	flow depth for previously computed travel time
	flow relationship
SCFS(20)	discharge for previously computed travel time
	flow relationship
C(20,6)	absolute stage elevations
DIST(6)	segment boundary point for each segment of a floodplain and channel cross-section
SEGN(6)	Mannings 'n' for segment of a floodplain and channel cross-section
ISG(6)	last elevation input for each segment
PERQ(20,70)	percentage discharge for segment of a floodplain and channel cross-section
TQ(20,6)	total discharge for cross-section
CC(20)	travel time coefficient for previously computed travel time relationship
LL(6)	number of zero discharge values for segment of a floodplain and channel cross-section
INRC	identification number for upstream segment rating curve
LRC	identification number for downstream segment rating curve

Chapter 3

CONSTRAINTS: The most important constraints in this program involve the limits to array size which are dimensioned in COMMON. For example, program can only hold 6 hydrographs or 6 rating curves at any one time. 15 commands which are defined in BLOCK DATA are used by MILHY2 (as in the original form of MILHY). The legal values for these are provided in HONDO and appendix I.

CALLED BY:

SUBROUTINES	HONDO
CALLED:	STHYD
	CMPHYD
	PRTHYD
	HPLOT
	ADHYD
	SRC
	CMPRC
	STT
	CMPTT
	ROUTE
	RESVO
	ERROR
	SEDIT

FUNCTIONS CALLED:

NOTES

Chapter 3

SUBROUTINE NAME: HONDO

SYNOPSIS: Reads in command and associated data from file 'data1' and by comparison to the legal commands contained in CTBLE (initialized in BLOCK DATA), it determines the command number (NCODE). It collects up the variables from the variable format data field.

COMMAND:

INPUT: Data is read in from file 'data1'. Command must be located in the first 20 columns on each line, and is read in variable ALPHA (11) (FORMAT 2A1,9A2). The data must be in columns 21 to 80, and is read into variable CHAR (60) (FORMAT (60A1)).

Legal commands are:

START
STORE HYD
COMPUTE HYD
PRINT HYD
PLOT HYD
ADD HYD
STORE RATING CURVE
COMPUTE RATING CURVE
STORE TRAVEL TIME
COMPUTE TRAVEL TIME
ROUTE
ROUTE RESERVOIR
ERROR ANALYSIS
SEDIMENT YIELD
FINISH

Additional legal entries to file 'data1' include:

'*' in column 1 - if the line is a comment line
'*' in column 80 - if a new page is required for output

OUTPUT: Writes out the command and associated data to file 'results', and returns the value of NCODE to MAIN which is then used to select the next subroutine to be called. All data which has been collected for the command is held in common, in the array DATA (310).

Chapter 3

VARIABLES USED: Variables held in common plus

CHAR(60)	data and associated text
ALPHA(11)	command
AUXA(10)	array used to collect up data
AUXB(10)	array used to collect up data

CONSTRAINTS: The form of the data file 'datal' must be strictly adhered to. HONDO will not tolerate spelling mistakes.

The command and data must also be entered into the correct columns. The data must be in the order which is expected by HONDO (these details are provided in Chapter 2).

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED: GIT

NOTES

Chapter 3

SUBROUTINE NAME; STHYD

SYNOPSIS: A model control procedure. Stores the coordinates of a measured hydrograph and adds a constant baseflow discharge to all data points.

COMMAND:

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
DT(ID)
DA(ID)
BSF
OCFS(300,ID)

OUTPUT: Stores discharge hydrograph (time and associated discharge values), runoff volume, and peak discharge:

OCFS(300,ID)
ROIN(ID)
PEAK(ID)

VARIABLES USED: Variables held in common plus

ID	storage location number
NHD	hydrograph identification number
BSF	baseflow discharge
DUMMY(300)	discharge values converted to metric units

CONSTRAINTS: Only 6 hydrographs at any one time can be stored by this program. In any one hydrograph, a maximum of 300 points are allowed.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES: If the addition of baseflow is not required, a zero value must be entered.

Chapter 3

SUBROUTINE NAME: CMPHYD

SYNOPSIS: Hydrological procedure.
 Develops unit hydrograph and convolves it with incremental runoff to produce the discharge hydrograph. Runoff is derived by calling subroutine SOILM, utilizing the infiltration, or using the curve number routine

COMMAND: COMPUTE HYD

INPUT: Data has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
 NHD
 DT(ID)
 DA(ID)
 CN
 HT
 XL
 RAIN(300)

OUTPUT: Stores the calculated discharge hydrograph, runoff volume, and peak discharge

OCFS(300,ID)
 ROIN(ID)
 PEAK(ID)

VARIABLES USED: Variables held in common plus
 ID storage location number
 NHD hydrograph identification number
 HT difference in elevation
 XL length of main channel

CONSTRAINTS: A maximum of 6 hydrographs can be stored.
 A maximum of 300 data can be included in the precipitation data.

CALLED BY: MAIN

SUBROUTINES SOILM
 CALLED:

FUNCTIONS
 CALLED:

NOTES: This subroutine has been updated to permit the user to select the curve number routine or the infiltration algorithm. To select the infiltration algorithm, a CN value of zero must be entered.

Chapter 3

SUBROUTINE NAME: SOILM

SYNOPSIS: Simulation of infiltration and hence incremental runoff associated with a particular storm event, and redistribution of soil water after precipitation ceases. Includes a stochastic methodology for incorporating spatial variability of soil hydrological properties.

COMMAND:

INPUT: Certain data has been passed from CMPHYD to SOILM:

DT(ID)
IR
CUMRAIN

Remaining variables are read directly into SOILM from data file 'datal'. The details of the form of this data file and the information which is required by SOILM are elsewhere in this volume.

OUTPUT: Provides incremental runoff which is located in DATA(300) and which is passed back to CMPHYD. This runoff is at the same time interval as the precipitation data which has been supplied (DT(ID)).

VARIABLES USED:	DT(ID)	Time increment for precipitation and hence runoff data
	IR	number of rainfall observations
	CUMRAIN(251)	cumulative rainfall totals
	TIME	time when simulation begins
	SIMDUR	simulation duration (hours)
	ALR	rain start time (hours)
	AMR	rain stop time (hours)
	AF	simulation iteration period (seconds)
	NLA	number of cells in layer 1 in soil column
	NLS	number of cells in layer 2 in soil column
	NLB	number of cells in layer 2 in soil column
	NL	number of cells in soil column
	TCOM(20)	thickness of each cell (metres)
	NSCOL	number of soil columns
	IPCAREA	percent area occupied by soil column
	SR1	soil water content at saturation, layer 1 in soil column
	SR2	soil water content at saturation, layer 2 in soil column
	SR3	soil water content at saturation, layer 3 in soil column

Chapter 3

ASR1	Same variable definitions as the three above, but variable types are DOUBLE PRECISION rather than REAL
ASR2	
ASR3	
SSR1	Standard deviation of SR1
SSR2	Standard deviation of SR2
SSR3	Standard deviation of SR3
SATCON	saturated hydraulic conductivity (metres per second) layer 1
SATCON2	saturated hydraulic conductivity (metres per second) layer 2
SATCON3	saturated hydraulic conductivity (metres per second) layer 3
ASATCON	Same variable definitions as the three above, but variable types are DOUBLE PRECISION rather than REAL
ASATCON2	
ASATCON3	
SSATCON1	Standard deviation of SATCON1
SSATCON2	Standard deviation of SATCON2
SSATCON3	Standard deviation of SATCON3
DETCAP	surface detention capacity (metres)
ADETCAP	DOUBLE PRECISION surface detention capacity
SDETCAP	Standard deviation of detention capacity
THETA(20)	initial soil water content for each cell (cubic metres per cubic metres)
ATHETA(20)	DOUBLE PRECISION initial soil water content (cubic metres per cubic metres)
STHETA	Standard deviation of THETA(20)
NQ	number of observations on soil moisture characteristics curve
X(20)	moisture values on soil moisture characteristic curve for layer 1 (cubic metres per cubic metres)
Y(20)	suction values on soil moisture characteristic curve for layer 1 (metres)
X2(20)	moisture values on soil moisture characteristic curve for layer 2 (cubic metres per cubic metres)
Y2(20)	suction values on soil moisture characteristic curve for layer 2 (metres)

Chapter 3

X3(20)	moisture values on soil moisture characteristic curve for layer 3 (cubic metres per cubic metres)
Y3(20)	suction values on soil moisture characteristic curve for layer 3 (metres)
AX(20)	Same variable definitions as the X(20), X2(20), and X3(20) above, but variable types are DOUBLE PRECISION rather than REAL
AX2(20)	
AX3(20)	
SCURV1	Standard deviation of soil moisture characteristic curve for layer 1
SCURV2	Standard deviation of soil moisture characteristic curve for layer 2
SCURV3	Standard deviation of soil moisture characteristic curve for layer 3
EMAX	maximum evaporation during the day (metres per second)
WT	write-out time interval (hours)
IOUT	determines amount of output if (IOUT=1) total output if (IOUT=0) shorter output
CONSTRAINTS:	A maximum of 10 soil columns for any one subcatchment area is permitted. The soil moisture characteristic curve can be defined by up to a maximum of 20 points. The soil column can have a maximum of 20 cells. The initial soil moisture contents, defined for each cell at the start of simulation, must lie within the range of the soil moisture characteristic curve.
CALLED BY:	CMPHYD
SUBROUTINES CALLED:	HYDCON TWO GRAD SMCURV G05DDF(NAG subroutine)
FUNCTIONS CALLED:	RMAX RMIN
NOTES:	

Chapter 3

SUBROUTINE NAME: HYDCON

SYNOPSIS: Calculates hydraulic conductivity for a particular layer in the soil column from the soil moisture characteristic curve, using the Millington and Quirk method.

COMMAND:

INPUT: Variables passed from SOILM:

X(20)
Y(20)
SATCON
SR

OUTPUT: Unsaturated hydraulic conductivity values are passed back to SOILM in Z(20).

VARIABLES USED:	X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
	Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres)
	SATCON	saturated hydraulic conductivity for the particular layer
	SR	saturated soil moisture content for the particular layer
	Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above.

CONSTRAINTS: Maximum points on the soil moisture characteristic curve, and hence the hydraulic function is 20.

CALLED BY: SOILM

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES

Chapter 3

SUBROUTINE NAME: TWO

SYNOPSIS: Calculates the soil water pressure, hydraulic potential, and hydraulic conductivity for each cell in the soil column, associated with a particular soil water content.

COMMAND:

INPUT: Variables passed from SOILM:

NA
NB
G(20)
GZ(20)
Z(20)
X(20)
Y(20)
DEPTH(20)

OUTPUT: Soil water pressure, hydraulic potential, and hydraulic conductivity are passed back to SOILM

SWP(20)
HPOT(20)
COND(20)

VARIABLES USED:	NA	number of cells in layer 1
	NB	number of cells in layer 2
	THETA(20)	initial soil moisture content of each cell
	G(20)	gradient of soil moisture characteristic curve, ie grad between each pair of points
	GZ(20)	gradient of hydraulic function, ie grad between each pair of points
	X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
	Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres) values
	Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above
	DEPTH(20)	distance from surface to the midpoint of each cell
	SWP(20)	soil water pressure of each cell
	HPOT(20)	hydraulic potential of each cell
	COND(20)	conductivity of each cell

Chapter 3

CONSTRAINTS: A maximum of 20 cells in the soil column is
 permitted

CALLED BY: SOILM

SUBROUTINES
COMMAND:

FUNCTIONS
COMMAND:

NOTES;

Chapter 3

SUBROUTINE NAME: GRAD

SYNOPSIS: Calculates the gradient of the soil moisture characteristic curve, and hydraulic conductivity function.

INPUT: Variables passed from SOILM:

X(20)
Y(20)
Z(20)

OUTPUT: Variables containing gradients passed back to SOILM.

G(20)
GZ(20)

VARIABLES USED:	X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
	Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres) values
	Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above
	G(20)	gradient of soil moisture characteristic curve, i.e. gradient between each pair of points
	GZ(20)	gradient of hydraulic function, i.e. gradient between each pair of points

CONSTRAINTS: A maximum of 20 cells in the soil column is permitted

CALLED BY: SOILM

SUBROUTINES
COMMAND:

FUNCTIONS
COMMAND:

NOTES

Chapter 3

SUBROUTINE NAME: SMCURV

SYNOPSIS: Generates new soil moisture characteristic curve based on the randomly generated moisture values.

INPUT: Variables passed from SOILM:

AX(20)
Y(20)
SCURV
SR
NQ

OUTPUT: Coordinates of new soil moisture characteristic curve passed back to SOILM:

XNEW(20)
YNEW(20)

VARIABLES USED:	AX(20)	values of soil moisture on input soil moisture characteristic curve DOUBLE PRECISION variable type
	Y(20)	values of suction on input soil moisture characteristic curve
	SCURV	standard deviation of soil moisture characteristic curve in DOUBLE PRECISION
	SR	saturated soil moisture content
	NQ	number of coordinates defining soil moisture characteristic curve
	XNEW(20)	generated soil moisture content on new soil moisture characteristic curve
	YNEW(20)	generated suction values on new soil moisture characteristic curve

CONSTRAINTS: A maximum of 20 points to define the soil moisture characteristic curve

CALLED BY: SOILM

SUBROUTINES CALLED: GO5DDF (NAG subroutine)

FUNCTIONS CALLED: RMIN
RMAX

NOTES

Chapter 3

SUBROUTINE NAME; PRTHYD

SYNOPSIS: Model control procedure.
 Prints out the coordinates of a hydrograph and/or the peak value and runoff volume.
 Converts OCFS(300,ID) to a stage array, S(300,ID) using a recalled rating curve.

COMMAND: PRINT HYD.

INPUT: The data input for this command has been read into OCFS(300,ID) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
 NPK
 IDR
 IN

Details of the hydrograph are held in common and are referenced by ID.

OUTPUT: Discharge, DUMMY(300) or stage, S(300,ID) hydrograph are written to output file 'results'.

DUMMY(300)
 S(300,ID)
 ROIN1
 PEAK1
 PEAKS

VARIABLES USED: Variables in common plus

ID	storage location number
NPK	form of output required
	0 peak and volume only
	1 discharge hydrograph
	2 stage hydrograph
IDR	identification number of rating curve or segment to be used for conversion to a stage hydrograph
IN	format of output
	0 five columns across page
	1 single column
DUMMY(300)	discharge array (converted to metric units if required)
S(300,ID)	stage array (converted to metric units if required)
PEAK1	peak discharge
ROIN1	volume of hydrograph
PEAKS	peak stage

Chapter 3

CONSTRAINTS: Maximum of 300 points define the hydrograph. For conversion to stage hydrograph, rating curve must have been computed. A stage hydrograph cannot be computed if multiple routing is invoked.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES: Conversion to a stage hydrograph uses a previously computed rating curve.

Chapter 3

SUBROUTINE NAME: HPLOT

SYNOPSIS: Model control procedure.
Plots either 1 or 2 hydrographs on a set of axis.

COMMAND: PLOT HYD.

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:-

ID1

ID2

Details of the 2 hydrographs are held in common variables and are references by ID1 and ID2

OUTPUT: Discharge plots and axis are written to output file 'results'.

CFS(300)

VARIABLES USED: Variables in common plus

ID1

ID2

CONSTRAINTS: If the time interval of the two hydrographs to be plotted is not equal, the larger increment is selected and the other hydrograph points are interpolated at this increment.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: ADHYD

SYNOPSIS: Model control procedure
Adds together the coordinates of two hydrographs

COMMAND: ADD HYD

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
ID1
ID2

Details of the 2 hydrographs are held in common variables and are referenced by ID1 and ID2

OUTPUT: The discharge coordinates, peak discharge, and runoff volume of the resultant hydrograph:

OCFS(300,ID)
PEAK(ID)
ROIN(ID)

VARIABLES USED: Variables in common plus

ID	storage location number for resultant hydrograph
NHD	hydrograph identification number of resultant hydrograph
ID1, ID2	storage location numbers of the two hydrographs to be added

CONSTRAINTS: If the time interval of the two hydrographs to be added is not equal, then the smaller increment is selected and the other hydrograph points are interpolated at this increment.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES;

Chapter 3

SUBROUTINE NAME: SRC

SYNOPSIS: A model control procedure
Stores a rating curve in form of elevation, end
area, discharge table

COMMAND: STORE RATING CURVE

INPUT: The data input for this command has been read into
DATA(310) by HONDO and is transferred from this
array into the following variables which are used
in this subroutine:

ID
VS
DEEP(20,ID)
A(20,ID)
Q(20,ID)

OUTPUT: Stores the rating curve in variables held in
common:

DEEP(20,ID)
A(20,ID)
Q(20,ID)

VARIABLES USED: Variables held in common plus

ID	storage location number of rating curve
VS	valley cross section number

CONSTRAINTS: Only 6 rating curves can be held within the program
at any one time.
Maximum number of points defining rating curve are
20.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: CMPRC

SYNOPSIS: A hydrological procedure.
 Computes rating curve for valley cross section using Mannings equation. If turbulent exchange routines are invoked calculates rating curve incorporating momentum transfer between channel and floodplain flows during out-of-bank conditions. If multiple routing reaches are invoked calculates separate rating curves for each segment of the cross-section and computes the percentage of total flow which would occur in each segment at the twenty stage computation points.

COMMAND: COMPUTE RATING CURVE

INPUT: The data input for this comm: _ has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
 IT
 MR
 VS
 NSEG
 ELO
 EMAX
 SLOPE1
 SLOPE2
 SEGN(NSEG)
 DIST(NSEG)
 DATA(10:310)

OUTPUT: Stores the rating curve and percentage flow in each segment in variables held in common

A(20,ID)
 Q(20,ID)
 C(20,ID)
 DEEP(20,ID)
 PERQ(20,ID)
 TQ(20,ID)

VARIABLES USED: Variables held in common plus

ID	storage location number for rating curve
IT	turbulent exchange between main channel and floodplains invoked
MR	multiply routing reaches invoked

Chapter 3

VS	valley section identification number
NSEG	number of segments in valley section
ELO	lowest elevation
EMAX	maximum elevation
SLOPE1	channel slope
SLOPE2	flood plain slope
DATA (10:310)	alternate distances and elevations (defining cross section)

CONSTRAINTS: Maximum number of segments in a cross section is 6.
 Maximum number of points in a rating curve is 20.
 Turbulent exchange and multiple routing reaches may be invoked independently but for either to operate there must be a floodplain segment on either side of channel segments. For accuracy the user is recommended to have cross-sectional positional data (DIST and ELEV) close to segment boundaries. If momentum exchange is not or cannot be invoked, the MILHY2 version using IT = 2 is used.

CALLED BY: MAIN

SUBROUTINES
 CALLED:

FUNCTIONS
 CALLED:

NOTES: The user is recommended to study the example data1 data set in Chapter 2 of this volume before undertaking multiple routing applications.

Chapter 3

SUBROUTINE NAME: STT

SYNOPSIS: Model control procedure.
Stores a depth, flow, travel time table (used in flood routing).

COMMAND: STORE TRAVEL TIME

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
REACH
XL
SLOPE
MET1
DP(20)
SCFS(20)
CC(20)

OUTPUT: Stores travel time table in following common variables:

DP(20)
SCFS(20)
CC(20)

VARIABLES USED: Variables held in common plus

ID	storage location number
REACH	reach identification number
XL	length of reach
SLOPE	slope of reach

CONSTRAINTS: A maximum of 20 points are allowed to define a travel time table.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: CMPTT

SYNOPSIS: Hydrological procedure.
Compute travel time table.

COMMAND: COMPUTE TRAVEL TIME

INPUT: Data has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
REACH
NOVS
XL
SLOPE
MR
INRC
LRC.

OUTPUT: Stores the travel time table in following common variables:

DP(20)
SCFS(20)
CC(20)

VARIABLES USED: Variables held in common plus

ID	storage location number
REACH	reach identification number
NOVS	number of valley sections in the reach
XL	length of reach
SLOPE	Slope of reach
MR	multiple routing invoked
INRC	upstream segment rating curve identification number
LRC	downstream segment rating curve identification number

CONSTRAINTS: A maximum of 20 points are allowed to define a travel time table.
A maximum of 6 valley sections are permitted in a reach, except where multiple routing reaches are invoked where two segment section must be identified.

CALLED BY: MAIN

Chapter 3

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

If multiple routing reaches are invoked, a compute travel time table and route command must be entered for each segment routing reach (see Chapter 2 of this volume).

Chapter 3

SUBROUTINE NAME: ROUTE

SYNOPSIS: A hydrological procedure.
 Routes a hydrograph through a reach using the variable storage coefficient method.
 If multiple routing reaches are invoked, routes a hydrograph through a segment routing reach.
 Also calculates inflow hydrograph for segment reach using PERQ(20) from rating curve.

COMMAND: ROUTE

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
 NHD
 IDH
 DT(ID)
 MR

Details of the hydrograph to be routed are held in common variables and are referenced by IDH.
 Details of the inflow segments rating curve are held in common variables and are referenced by:

PERQ(20)
 TQ(20)
 C(20,INRC)
 INRC.

OUTPUT: Stores the calculated outflow hydrograph, its peak discharge, and runoff volume in common variables:

OCFS(300,ID)
 PEAK(ID)
 ROIN(ID)

Proportional discharge for each time increment value (if multiple routing reaches are invoked) written to output file 'results'.

DOCF(300,ID)

VARIABLES USED: Variables held in common plus

ID	storage location number of calculated outflow hydrograph
NHD	hydrograph identification number of outflow hydrograph

Chapter 3

IDH	storage location number of inflow hydrograph
DT(ID)	iteration period of outflow hydrograph
MR	multiple routing invoked
DOCFS	dummy discharge area to prevent overwriting of inflow array
P	percentage of inflow in multiple routing reach segment

CONSTRAINTS: Discharges included in the inflow hydrograph must be within the limits of the travel time table, otherwise there is no way to define the travel time coefficient. If the solution to the routing equations fails to converge after 10 iterations, convergence is forced.

If multiple routing reaches are invoked the inflow hydrograph must not exceed the rating curve used to compute proportional inflow in segment.

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES: If multiple routing reaches are invoked, a compute travel time table and route command must be entered for each segment routing reach. Also the identification number of the inflow and outflow hydrographs must not be the same (see Chapter 2 of this volume).

Chapter 3

SUBROUTINE NAME: RESVO

SYNOPSIS: A hydrological procedure.
Routes hydrograph through a reservoir.

COMMAND: ROUTE RESERVOIR

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
IDH
SCFS(20)
STORE

Details of the inflow hydrograph are held in common variables and are referenced by ID:

DT(ID)
DA(ID)

OUTPUT: The calculated outflow hydrograph, peak discharge, and runoff volume is stored in common variables:

OCFS(300,ID)
PEAK(ID)
ROIN(ID)

VARIABLES USED: Variables held in common plus

ID	storage location number of calculated outflow hydrograph
NHD	hydrograph identification number of outflow hydrograph
IDH	storage location number of inflow hydrograph
SCFS(20)	discharge values of the storage discharge relationship defined for the reservoir
STORE	storage values of the storage discharge relationship defined from the reservoir

CONSTRAINTS: The discharge of the inflow hydrograph must be within the storage discharge relationship defined from the reservoir. A maximum of 20 points are allowed to define this relationship.

Chapter 3

CALLED BY: MAIN

SUBROUTINES
CALLED:FUNCTIONS
CALLED:NOTES:

Chapter 3

SUBROUTINE NAME: ERROR

SYNOPSIS: Model control procedure.
 Calculates a number of indices or objective functions which detail the degree of fit between two hydrographs.

COMMAND: ERROR

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID1
 ID2

Details of the 2 hydrographs are held in common variables and are referenced by ID1 and ID2

OUTPUT: The values of MILHY's original error statistics plus an additional 13 objective functions are written to output file 'results'.

ESDEV
 PCTER
 OF1
 OF2
 OF3
 OF4
 OF5
 OF6
 OF7
 OF8
 OF9
 OF10
 OF11

VARIABLES USED: Variables in common plus

ID1	storage location number of first hydrograph (usually assumed to be measured)
ID2	storage location number of second hydrograph (usually assumed to be calculated)
ERR	error (measured - calculated discharge)
ESDEV	error standard deviation
PCTER	percentage peak discharge error

Chapter 3

OF1	absolute sum of errors
OF2	ordinary least squares
OF3	log of ordinary least squares
OF4	relative sum of errors
OF5	absolute error difference
OF6	relative error difference
OF7	absolute error divided by variance
OF8	relative error divided by variance
OF9	absolute error difference divided by variance
OF10	relative error difference divided by variance
OF11	Pearsons correlation coefficient

CONSTRAINTS: The first hydrograph (ID1) is taken to be the measured. All indices are printed out in file 'results' in metric units.

CALLED BY: MAIN

SUBROUTINES

CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: SED

SYNOPSIS: A hydrological procedure.
Computes sediment yield for a field using the
Universal soil loss equation.

COMMAND: SEDIMENT YIELD

INPUT: The data input for this command has been read into
DATA(310) by HONDO and is transferred from this
array into the following variables which are used
in this subroutine:

ID
SOIL
CROP
CP
SL

Details of the hydrograph are held in common
variables and are referenced by ID:

ROIN(ID)
DA(ID)
PEAK(ID)

OUTPUT: Writes out the sediment yield to the output file
'results':

SED

VARIABLES USED: Variables held in common plus

ID	storage location number of hydrographs
SOIL	soil erodibility factor
CROP	the cropping management factor
CP	The erosion control practice factor
SL	the slope length and gradient factor

CONSTRAINTS:

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

Chapter 3

FUNCTION NAME: GIT (TCARD, J, JLAST, SHIFT).

SYNOPSIS: Converts alphabetic array to floating point number.

INPUT: TCARD(10)
J
JLAST
SHIFT
A(10) CONVERTS TO NUMBERS

OUTPUT: GIT

VARIABLES USED: TCARD
J
JLAST
SHIFT
A(10)

CONSTRAINTS:

CALLED BY: HONDO

Chapter 3

FUNCTION NAME: RMAX(X,NQ)

SYNOPSIS: Returns the maximum element in a REAL array.

INPUT: X(NQ) X is a REAL array of size NQ

OUTPUT: RMAX

VARIABLES USED: X(NQ)
RMAX

CONSTRAINTS:

CALLED BY: SOILM

FUNCTION NAME: RMIN(X,NQ)

SYNOPSIS: Returns the minimum element in a REAL array.

INPUT: X(NQ) X is a REAL array of size NQ

OUTPUT: RMAX

VARIABLES USED: X(NQ)
RMAX

CONSTRAINTS:

CALLED BY: SOILM

NOTES:

Chapter 3

SUBROUTINE NAME: BLOCK DATA

SYNOPSIS: Initializes certain variables. These variables are used to determine the number of commands, the command, the command number, the maximum number of data entries which are associated with the command, and the data which is entered in the variable format data entry area.

INPUT:

OUTPUT: Initialized arrays:

ZALFA(20)
 CTBLE(50,11)
 ITBLE(50,2)
 NCOMM

VARIABLES USED: ZALFA(20) alphanumeric code table containing:
 1234567890 *.,-(filled with blanks)

CTBLE(50,11) command table containing:
 START (filled with blanks)
 STORE HYD
 COMPUTE HYD
 PRINT HYD
 PLOT HYD
 ADD HYD
 STORE RATING CURVE
 COMPUTE RATING CURVE
 STORE TRAVEL TIME
 COMPUTE TRAVEL TIME
 ROUTE
 ROUTE RESERVOIR
 ERROR ANALYSIS
 SEDIMENT YIELD
 FINISH
 (filled with blanks)

ITBLE(50,2) integer table containing:

1 4
 2 305
 3 310
 4 4
 5 2
 6 4
 7 62
 8 310

Chapter 3

9	45
10	8
11	5
12	4
13	2
14	5
15	0

NCOMM

number of commands contains:
15

CONSTRAINTS:

CALLED BY:

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

3.4 Infiltration Algorithm

The basic structure of the computer implementation of the infiltration model is illustrated in figure 3.1. It has been written in Fortran 77 so as to be compatible with MILHY.

This document provides more details of the subroutines SOILM, HYDCON, TWO, GRAD, and SMCURV, which are included in the listing of MILHY3. Together these subroutines comprise the code for the physically based infiltration model.

Substantial comments exist within the computer code.

The subroutine SOILM is divided into three parts, an initial, dynamic, and terminal section. Each of these will be discussed in turn. However, primarily, three series of operations are undertaken:

- 1 SOILM comprises firstly, a series of declaration statements including DIMENSION and variable type statements.
- 2 The first four lines of the data file 'data2' (unit number 25) are then read into the program. These lines include the variables which control the soil moisture simulation, such as the simulation start time (TIME), storm start time (ALR), storm stop time (AMR), simulation duration (SIMDUR), a variable which indicates the amount of output required (IOUT), simulation iteration time (AF), write-out interval (WT), and the number of soil columns in the particular subcatchment (NSCOLS).
- 3 The real array CUMRAIN(251) which has been passed from CMPHYD is then transformed from cumulative precipitation totals (in inches) at equal time intervals (DT), into precipitation totals (in mm) for each time increment:

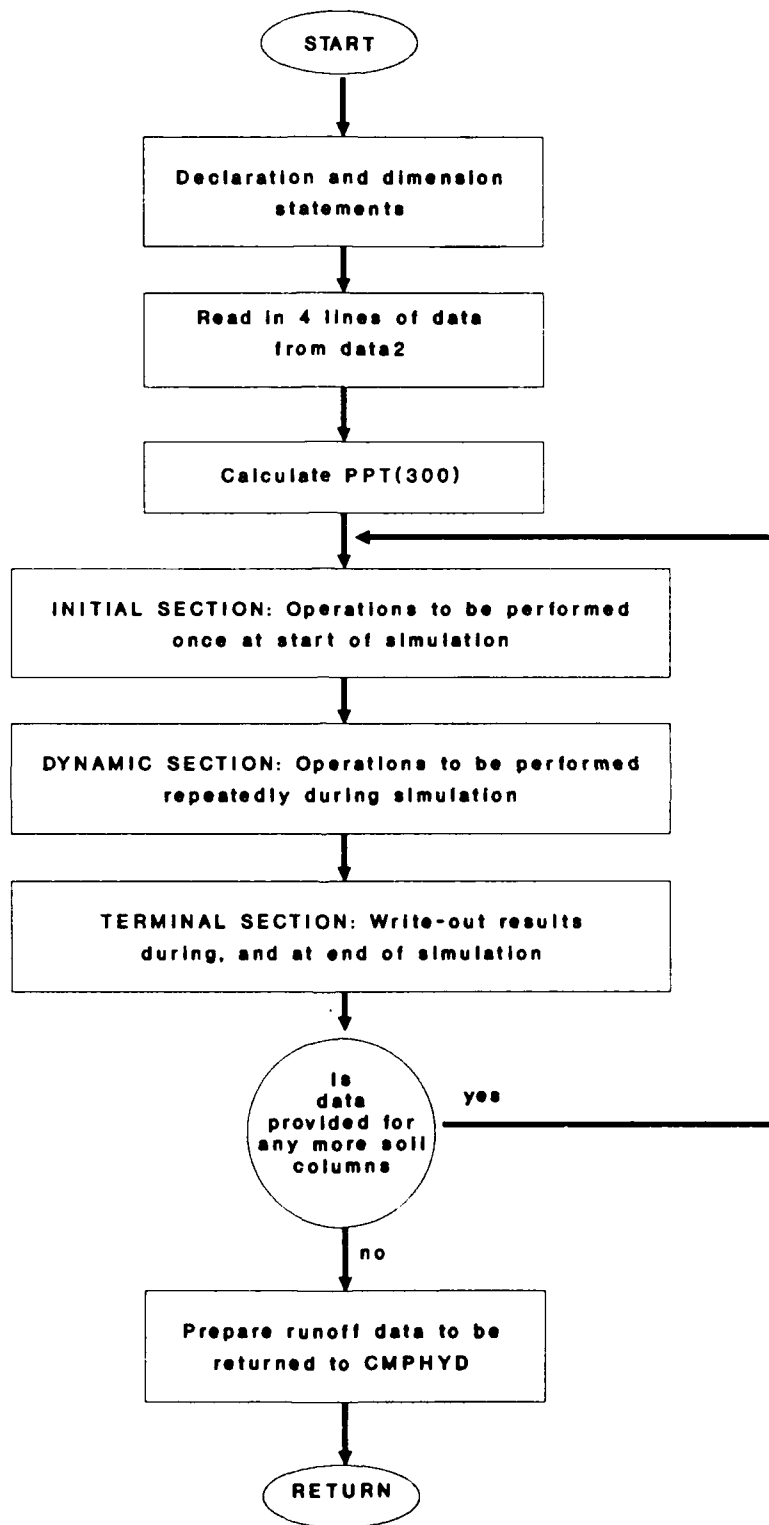


Figure 3.1
Structure of SOILM Subroutine

Chapter 3

```

      IRR=IR+1
      DO 100 I=1,IRR
100   PPT(I)=(CUMRAIN(I+1)-CUMRAIN(I))*0.0254

```

3.4.1 Initial section

1 Read in data.

The data relating to a single soil column are read into the program. All of the details to operate the stochastic version of the model are also read in at this stage. If the deterministic version of the infiltration model is required, then enter all standard deviations as zero.

2 *If the storm start and stop have been entered as 12 hour clock rather than 24 hour clock, it is possible that the storm may start before it stops; the following calculation prevents this. Assume that times entered in 'data2' are correct:*

```

      IF(AMR.LT.ALK)THEN
          AMR=AMR+24
      ENDIF

```

3 Check data inputs.

A series of checks are performed on the data which has just been read in. When an error occurs, the value of NERROR is increased by one and the checks continue. At the end of this section of the code, if NERROR exceeds 0, then the program stops. This allows all of the data for the soil column to be checked during one run of the program.

Details of the checks which are performed are well documented in the code.

Chapter 3

4. DEPTH calculation.

DEPTH the distance from the ground level to the midpoint
 of each cell in the soil column.

DIST the distance between the midpoints of any two
 adjacent cells

TCOM(20) thickness of each cell (input in 'data2')

5. Parameter variability calculations

The five input variables:

DETCAP *detention capacity*

THETA(20) soil moisture content of each cell

SR saturated soil moisture content of each layer

SATCON saturated hydraulic conductivity of each layer

X(20) moisture content of each point on the soil
 moisture characteristic curve

are all varied stochastically. The NAG function G05DDF is called which returns a randomly selected variable from a normal distribution according to a given mean and standard deviation.

This section of the code generates one set of randomly distributed variables and the simulation continues using these values. To represent variability in the hydrograph response, however, this random selection and the use of these generated values must be repeated many times.

A series of checks are performed on randomly generated values to ensure physical realism.

Chapter 3

DETCAP

DETCAP=GO5DDF(ADETCAP,SETCAP) Call NAG routine. ADETCAP is a DOUBLE PRECISION mean value of detention capacity. Therefore, DETCAP is the randomly generated value of detention capacity which will be used in this simulation.

IF(DETCAP.LT.0.)DETCAP=0 If the randomly generated value is less than zero, then set it to zero, as zero is a physically impossible value for this variable

SD=SETCAP The details are written out to the output file 'results'.
 WRITE(6,1180)SD
 1180 FORMAT ('.....')

SR

The procedure for this variable is as for DETCAP.

X(20)

The generation of the stochastic soil moisture curve is achieved by calling subroutine SMCURV. In this subroutine, firstly, arrays are dimensioned, and variables declared.

X(1)=GO5DDF(AX(1),SCURV) The first moisture value on the curve (the driest point) is first used to generate its random value.

Chapter 3

<pre> IF(X(1).LT.0.)X(1)=0.001 </pre>	Random value prevented from being zero or negative.
<pre> DO 100 I=2,NQ X(I) = G05DDF(AX(I),SCURV) 100 IF(X(I).LE.X(I-1)) X(I)=X(I-1)+0.001 </pre>	For the remaining moisture values, generate random values The soil moisture curve is prevented from assuming a reverse gradient
<pre> IF(X(NQ).GE.SR)SR=X(NQ)+0.001 </pre>	The wettest point of the soil moisture curve is prevented from assuming a value greater than the saturated soil moisture content determined for that layer

The gradients (G(20)) of this new soil moisture characteristic curve are then calculated.

The maximum and minimum moisture values of the curve are then calculated by referencing the functions RMAX and RMIN. The size of equal intervals in the moisture values are thus determined.

The new values of moisture and suction (at equal moisture intervals) are then evaluated XNEW(20) and YNEW(20). These are passed back to SOILM, where they are read into arrays X(20) and Y(20).

This procedure is repeated for each soil moisture characteristic curve (maximum 3).

Chapter 3

SATCON

The procedure for generating random values for SATCON is similar to DETCAP, except that the DOUBLE PRECISION mean values for SATCON and logged as SATCOM, are assumed to have a log-normal distribution.

THETA(20)

The procedure for generating random values for initial moisture is the same as for DETCAP. More checks on the randomly generated values are performed.

For the cells in each layer

1 - NLA	in layer 1	
NLAA - NLH	in layer 2	(NLAA=NLA+1)
NLBB - NL	in layer 3	(NLBB=NLH+1)

The initial moisture content is not permitted to exceed those moisture values in the soil moisture characteristic curve.

6. The unsaturated hydraulic conductivity function is derived from the soil moisture characteristic curve using the Millington and Quirk equation. This calculation is carried out in subroutine HYDCON, which is called for each soil layer. HYDCON is a straight translation of the Millington and Quirk equation.
7. The initial conditions are written out to data file 'results'. The following information is displayed:
 - (a) The moisture, suction and unsaturated hydraulic conductivity values.
 - (b) The start conditions TIME, ALR, AMR, DT, AF, EMAX, DETCAP

Chapter 3

The initial relative saturation for each cell is calculated as the initial moisture content divided by the saturated soil moisture content for the layer.

(c) The initial soil conditions for each cell in the soil column.

8. Certain variables are initialised:

WDATA(300,10)	a real array which contains the runoff produced by each soil column (up to 10 is permitted) and which is weighted by the percentage area which the soil type occupies in the subcatchment
WATI	initial water content of soil column - a variable used in the water balance check
ANFLUX(20)	net flux of soil water between two adjacent cells
CTIME	current time in seconds
SRAINI	variable used to calculate rainfall excess
CUMDRN	cumulative drainage out of the bottom cell in the soil column
CINFIL	cumulative infiltration
SUMD	rainfall excess
ICOUNT	integer count
EVAPI	cumulative evaporation
SOG	relative saturation of cell 1
RTOT	runoff total
ANFILT	infiltration into cell 1
PPTT	cumulative precipitation
TG	the length of time (in seconds) since the simulation began

Chapter 3

9. A calculation is performed to determine the initial soil moisture content of the soil column (WATI). This is used as a check on the numerical stability of the solution of the Richards equation.
10. The gradients of the soil moisture characteristic curve (G(20)) and the hydraulic conductivity function (GZ(20)) are calculated by calling subroutine GRAD. This subroutine is called for each layer in turn.

3.4.2 Dynamic section

This comprises a series of operations located in loop number 9995, which are performed repeatedly at each time step. This time interval is specified in 'data2' by the value of variable AF.

- 1 ITMAX the number of iterations which are required
 (SIMDUR is input in hours and therefore must be
 converted to seconds. AF is in seconds).
- 2 Loop number 9995 is the major loop in this simulation. An
internal clock is set and updated as the simulation proceeds.
- 3 Calculate water volume of each cell

Loop number 300 determines the volume of each cell by multiplying soil moisture content by cell thickness.

For each cell, the moisture content is known from the initial conditions provided by the user, or from the calculations performed in the previous time interval.

Chapter 3

4 24-hour clock

The real time for the current iteration period is calculated. CTIME was initialised in the initial section, in point number 8 above.

5 Calculation of soil water pressure, conductivity, and hydraulic potential for each cell.

These variables are calculated by calling subroutine TWO. This subroutine is called three times, once for each layer in the soil column:

1 - NLA	cells in layer 1
NLAA - NLH	cells in layer 2
NLBB - NL	cells in layer 3

Firstly, the soil water pressure (SWP(20)) which corresponds to the moisture content (THETA(20)) of each cell is derived from a linear interpolation procedure from the known points on the moisture characteristic relation.

Secondly, unsaturated hydraulic conductivity (COND(20)) is derived by similar means from the hydraulic conductivity function.

Thirdly, the hydraulic potential of each cell (HPOT(20)) is given by the following equation:

$$\text{HPOT}(I) = \text{SWP}(I) - \text{DEPTH}(I)$$

where DEPTH(I) represents the depth from the surface to the midpoint of each cell.

Chapter 3

6. Determine rainfall

Rainfall for the current time step is derived from the rainfall data input.

$T1 = T * AF / 3600.0$ $T1$ is the time in hours when the current iteration period ends

IF($T1 \leq (ALR - TIME)$.OR. $T1 > (AMR - TIME)$) THEN

A check that the end of the current iteration period occurs during the storm period. Note that the simulation start (TIME) may be defined as some period of time before the storm starts (ALR and that the simulation duration (SIMDUR) may be longer than the storm period (AMR-ALR).

$SRAIN = 0.0$. If $T1$ is outside storm period then there is obviously no rain.

ELSE

If $T1$ is within storm period,

$T2 = T1 (AF / 3600.0)$

$IELEM = ((T2 - (ALR - TIME)) / DT) + 1$ $IELEM$ the element in the array PPT which corresponds to $T1$

$SRAIN = PPT(IELEM) / DT * 3600.0$ $SRAIN$ the precipitation (per second) which occurs in this iteration period

ENDIF

Chapter 3

PPTT=PPTT+(SRAIN*AF) PPTT cumulative precipitation
 (initialised in initial section, point 8
 above)

7 Average conductivity of each cell

The average conductivity determines the rate of flow between adjacent cells. Loop number 210 determines this property (AVCOND(I), where I=2,NL. AVCOND(I) is given by the following relation

$$AVCOND(I) = (COND(I-1)*TCOM(I-1) + COND(I)*TCOM(I)) / (TCOM(I-1) + TCOM(I))$$

where:

COND(I) hydraulic conductivity of each cell
 TCOM(I) thickness of each cell

8 Bottom boundary condition

The flux out of the bottom cell (FLUX(NLL)) is assumed to be equal to the hydraulic conductivity of that cell (COND(NL)), although other bottom boundary conditions could be specified.

Note: NLL=NL+1 initialised after the READ statements near to the beginning of this subroutine.

9 Flux between cells

The flux into each cell, except for the surface cell, is given by Darcy's law, which in discrete form and for the flux from cell (I-1) into cell (I) becomes:

$$FLUX(I) = (HPOT(I-1) - HPOT(I)) * AVCOND(I) / DIST(I)$$

Chapter 3

10 Top boundary condition

The determination of the flux into the top cell is crucial for this application.

For each iteration period, the following variables are calculated:

BNCAP	infiltration capacity
SUMD	precipitation excess
DETAIN	the amount detailed on the surface
EVAP	evaporation rate
ANFILT	infiltration rate into cell 1
RUNOFF	runoff in the iteration period
RTOT	cumulative runoff total

The structure of this section of SOILM is illustrated in figure 3.2.

Firstly, the infiltration capacity is calculated. This depends on the characteristics of cell 1. BNCAP is the Darcian flux into the middle of the first cell from a saturated soil surface at which the pressure potential is assigned a value of zero:

$$BNCAP = (0.0 - HPOT(1)) * 0.5 * (SATCON + COND(1)) / DIST(1)$$

Secondly, the precipitation excess (SUMD) is then calculated and cumulated throughout the simulation duration.

If SUMD is positive, it represents excess water which is detained on the surface (DETAIN).

The next section considers rainfall:

If it is raining: Evaporation (EVAP) is set to zero.

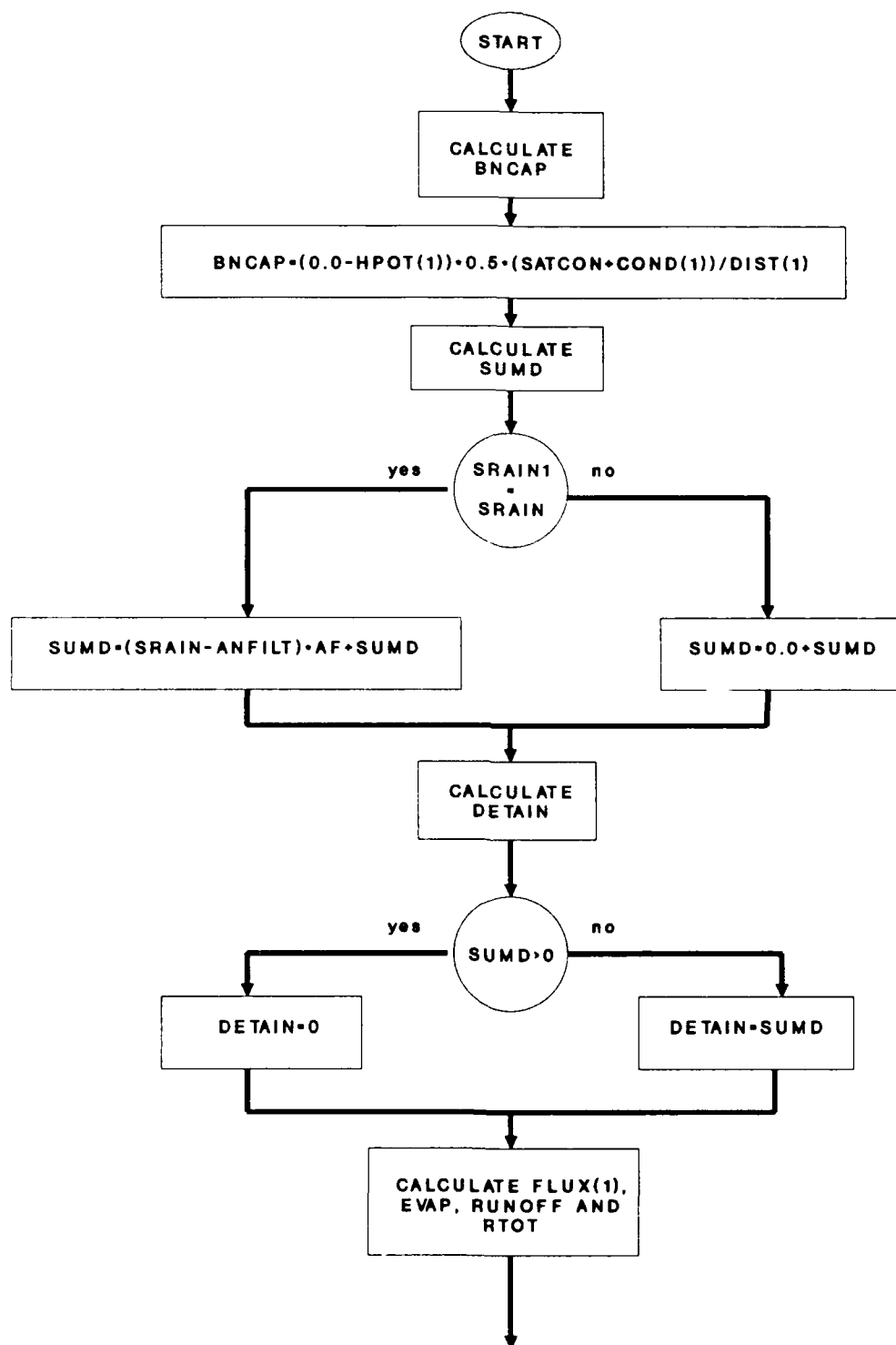


Figure 3.2
Determination of Top Boundary Conditions

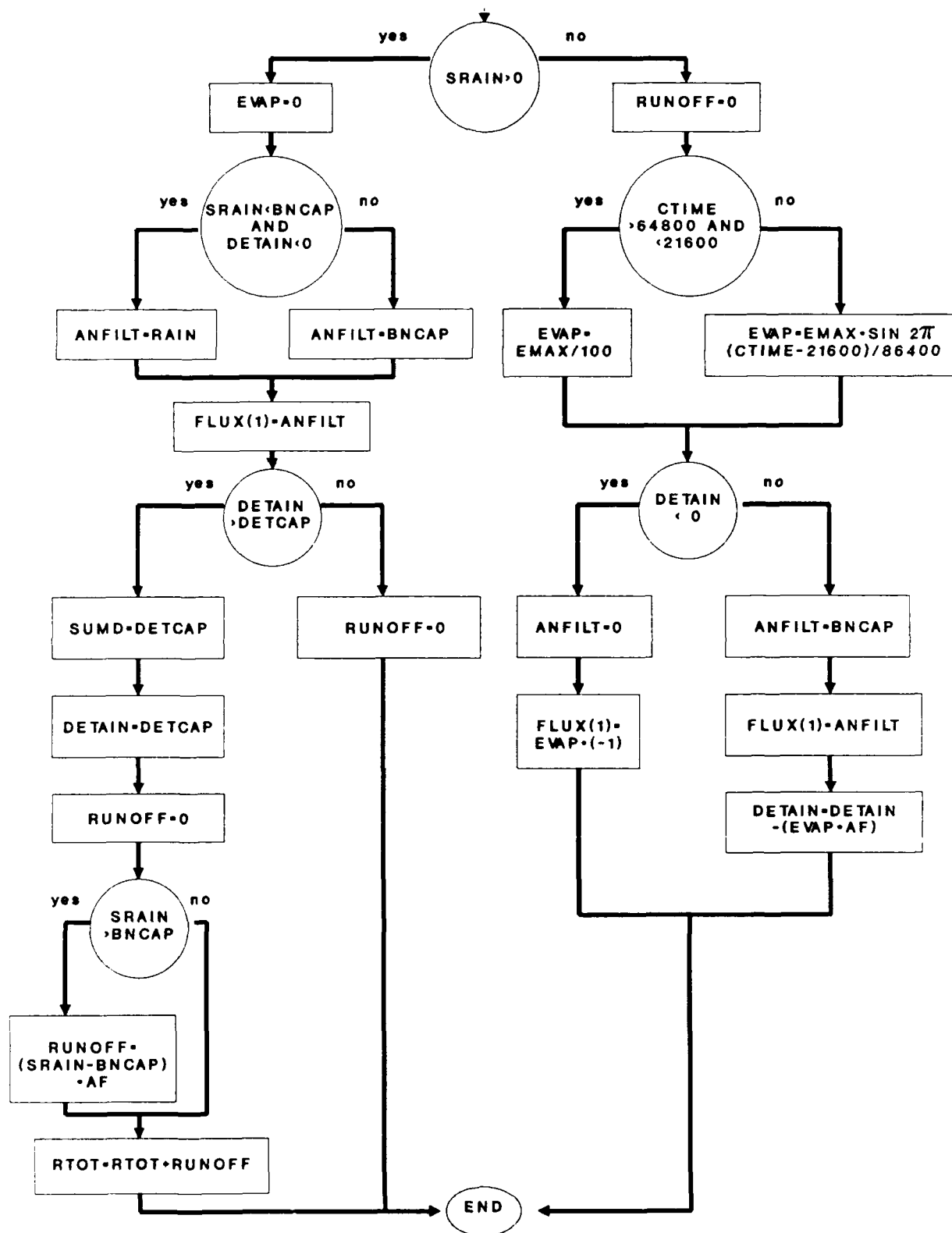


Figure 3.2 (cont.)
Determination of Top Boundary Conditions

Chapter 3

Provided that the rainfall rate for the current iteration period (SRAIN) is smaller than the infiltration capacity (BNCAP), and there is no surface detention (DETAIN=0), the flux into cell 1 (ANFILT) equals the rainfall rate (SRAIN). If these conditions are not met, then the flux (ANFILT) equals the infiltration capacity (BNCAP).

If there is surface detention (DETAIN), and this exceeds the detention capacity (DETCAP), and the rainfall rate (SRAIN) exceeds the infiltration capacity (BNCAP) then runoff occurs (RUNOFF).

If it is not raining: Runoff is set to zero.

The evaporation rate (EVAP) is derived from a simple isothermal relation

If there is no water detailed on the surface (DETAIN), then water may move out of cell 1 at a rate equal to the evaporation rate. If there is water remaining on the surface from the storm, water moves into cell 1 at a rate equal to the infiltration capacity. The evaporation and infiltration which occurred during the iteration period are then deducted from the surface detention (DETAIN).

Chapter 3

When the fluxes (FLUX(20)) have been determined, the moisture content of each cell is recalculated in consideration of these fluxes. The net change in the moisture content of each cell is given by ANFLUX(20)):

$$\text{ANFLUX(I)} = \text{FLUX(I)} - \text{FLUX(I+1)}$$

The new moisture content is thus given as:

$$\text{THETA(I)} = (\text{VOL(I)} + \text{ANFLUX(I)}) / \text{TCOM(I)}$$

During recalculation of new moisture contents, it is possible that the newly calculated THETA(20) may exceed the saturated soil moisture content for the cell, therefore a series of checks are performed to ensure that THETA(20) does not exceed SR, and that the associated soil water pressure SWP(20) is also set to zero (saturation).

12 Cumulative totals.

Updates are then provided for:

CUMDRN	cumulative drainage
EVAPI	cumulative evaporation
CINFIL	cumulative infiltration
SOG	relative saturation of cell 1

3.4.3 Terminal section

In this section, a write out of current conditions of each cell in the soil column, the precipitation, and any surface storage, runoff or evaporation which may have occurred is performed.

Chapter 3

- 1 The program checks the time on its internal clock against the time interval for which a printed copy of the soil column conditions is required (this will normally equal the time interval of rainfall data). If the two do not agree, the program moves to statement number 9995, and returns to the beginning of the dynamic section. If they do agree, then the program proceeds to the terminal section.

- 2 T the current time. This is written out to file unit number 6, 'results'.

- 3 If IOUT (defined in 'data2') is zero, then only a limited amount of written output data is required, and the program moves to statement number 305 where the water balance calculation is undertaken and details written to 'results'. If IOUT does not equal 0, then the full details are required.

- 4 Write-out conditions of the soil column.

 The conditions of each cell in the soil column are written out at time T.

- 5 Water balance check.
 The water content of the soil column is recalculated and BAL is calculated.

- 6 If IOUT equals zero, then again, the program moves to statement number 305, where the details of runoff are written to 'results'.

- 7 The cumulative totals of EVAPI, PPTT, CINFIL, CUMDRN are written to 'results'.

- 8 Details of the runoff and water detained on the surface are written to 'results'.

- 9 Creation of array containing runoff data.

Chapter 3

WDATA(300,10) contains the runoff which is converted into inches for passing back to CMPHYD, which has been derived for each soil column in the subcatchment (maximum of 10), and which has been weighted according to the percentage area which that soil column occupies:

$$\text{WDATA}(\text{MMM},\text{W}) = (\text{RTOT}/.0254) * (\text{IPCAREA}/100.0)$$

MMM the MMMth runoff value
 W the Wth soil column
 RTOT the runoff which occurred in the period
 IPCAREA the percentage area which the soil column occupies

10 34543 CONTINUE

This marks the end of the simulation for one soil column. If there is another, then the subroutine is repeated from the place where the soil information is read in from 'data2'.

If there are no further soil columns, the subroutine proceeds out of loop number 34543.

The final operation in this subroutine is to sum the weighted runoff contained in WDATA(300,10) to derive the total runoff to be passed back to CYMPHD. Loop 76567 undertakes this calculation, and the runoff data is finally stored in DATA(300).

IR is returned to CMPHYD as the number of elements in the array DATA(300).

Chapter 4

MILHY3 : P.C. Version

4.1 Introduction

This chapter summarizes the main program changes necessary to run MILHY3 at the P.C. level. MILHY3 will run on an IBM-AT, or similar. The main changes required are related to the provision of a random number generator for the stochastic version and the conversion of mixed numeric and character arrays.

4.2 Random Number Generator

MILHY3 calls a library routine g05ddf, part of the NAG library to generate random values within a distribution determined from the mean and standard deviation entered in the 'data2' data set. These values are used to analyse the error band in the predicted runoff hydrograph, usually associated with field or instrument inaccuracies. The routine g05ddf calls in turn a routine g05caf which is machine specific.

If the stochastic version is not required, then CALL statements to the library may be simply commented out. The CALL statements are located in the SOILM subroutine. If the stochastic capability is to be retained, then another random number generator must be provided.

4.3 Character/Numeric Arrays

MILHY was originally written in FORTRAN 66, utilizing mixed character and numeric arrays. This ability was used in the 'data1' data set, where numeric and character fields are read together. At the PC-level, the character and numeric arrays must be separated. This is achieved using the least changes possible to the

Chapter 4

program code and, therefore, is not necessarily the most efficient method.

A new common block /BLOCK4/ is introduced in routines BLKDTA, MAIN, HONDO and GIT and new CHARACTER arrays are dimensioned. In BLKDTA the variables ZALPHA and CTBLE are redefined using three new variables ZALPHA2, CTBLE1 and CTBLE2. In HONDO, these changes are pursued with changes to the READ and WRITE statements. In HPLOT, the CHARACTER arrays are dimensioned and MAX is updated for a narrower printer. A copy of the IBM version of these routines is now included.

```

C -----
C
C      MAIN
C -----
C
C      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
&MAXNO,NCODE,ICC,NCOMM
C
C      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
&IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
C      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
&SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
&TQ(20,6),CC(20),LL(6),INRC,LRC
C
C      COMMON/BLOCK4/ZALPH2(20),CTBL1(50,2),CTBL2(50,9)
CHARACTER*1 ZALPH2,CTBL1
CHARACTER*2 CTBL2
C
C      OPEN (1,STATUS='OLD',FILE='data1')
OPEN(25,STATUS='OLD',FILE='data2')
OPEN(6,STATUS='NEW',FILE='results')
NCODE=0
ICC=0
1   NER=0
CALL HONDO
IF (NER) 2,2,17
2   GO TO (3,4,5,6,7,8,9,10,11,12,13,14,15,16,17), NCODE
3   TIME=DATA(1)
KCODE=DATA(2)
ICODE=DATA(3)
GO TO 1
4   CALL STHYD
GO TO 1
5   CALL CMPHYD
GO TO 1
6   CALL PRTHYD
GO TO 1
7   CALL HPLOT
GO TO 1
8   CALL ADHYD
GO TO 1
9   CALL SRC
GO TO 1
10  CALL CMFRC
GO TO 1
11  CALL STT
GO TO 1
12  CALL CMPTT
GO TO 1
13  CALL ROUTE
GO TO 1
14  CALL RESVO
GO TO 1
15  CALL ERROR
GO TO 1
16  CALL SEDT

```

17 GO TO 1
STOP
END

```

C
C
C -----
C
C      SUBROUTINE HONDO
C
C -----
C
C This subroutine reads in the data from 'data1', searches an alphanumeric
C code table to determine the NCODE of the required operation, and collects
C variables from the freefloating data field.
C
C The command table (CTBLE), integer table (ITBLE), number of commands
C (NCOMM) and alphanumeric array (ZALPHA) are initialized in BLOCK DATA
C located at the end of this listing.
C
C
C      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
&MAXNO,NCODE,ICC,NCOMM
C
C      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
&IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
C      COMMON/BLOCK4/ZALPH2(20,CTBL1(50,2),CTBL2(50,9)
CHARACTER*1 ZALPH2,CTBL1,CHAR(60),ALPHA1(2),AUXA(10),AUXB(10)
CHARACTER*2 CTBL2,ALPHA2(9)
C
C      IF (ICC) 1,1,3
C      READ IN DATA CARD
1  READ (1,42) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
C      IF FIRST CHARACTER IS BLANK THE CARD IS A CONTINUATION OF
C      PREVIOUS CARD.
      IF (ALPHA1(1)-ZALPH2(11)) 2,9,2
2  IF (ICC) 3,3,40
C      ASTERISK IN COL. 80 MEANS SKIP TO NEW PAGE BEFORE PRINTING CARD
3  IF (CHAR(60)-ZALPH2(11)) 4,5,4
4  WRITE (6,43)
5  WRITE (6,44) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
C      IF FIRST CHARACTER IS A * THE PREVIOUS CARD WAS A COMMENT CARD
      IF (ALPHA1(1).NE.ZALPH2(12)) GOTO 10
6  ICC=0
      GO TO 1
9  WRITE (6,44) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
      GO TO 24
C      SEARCH FIRST TWO ALPHAMERIC CHARACTERS TO SEE IF THEY ARE NUMBERS
10  ICC=1
      DO 12 I=1,10
      IF (ALPHA1(1).EQ.ZALPH2(I)) GOTO 15
11  IF (ALPHA1(2).EQ.ZALPH2(I)) GOTO 15
12  CONTINUE
C      STATEMENT NUMBER 7 IS BRANCHED TO IF NUMBERS ARE PRESENT
C      IF NOT NUMBER SEARCH COMMAND TABLE FOR MATCH
C      CALL FIRST 10 VALUES FROM PERMANENT DATA STORAGE
      DO 14 I=1,NCOMM
      DO 13 J=1,11
      IF (CTBL1(I,J).NE.ALPHA1(J)) GOTO 14
13  CONTINUE

```

```

DO 131 J=1,9
IF(CTBL2(I,J).NE.ALPHA2(J)) GOTO 14
131 CONTINUE
C IF THIS LOOP IS COMPLETED WE HAVE COMPLETE MATCH- CALL NCODE
C AND MAX NUMBER AND EXIT LOOP
NCODE=ITBLE(I,1)
MAXNO=ITBLE(I,2)
GO TO 21
14 CONTINUE
C IF MAJOR LOOPS FINISHED WITHOUT A MATCH WRITE ERROR MESSAGE
C AND SET NER = 1
NER=1
WRITE (6,46)
RETURN
C CONVERT DIGIT INPUT CODE FROM ALPHAMERIC TO INTEGER FORM
15 NCODE=GIT(ALPHA1,1,2,1.)*0.5
C FIND MAX NUMBER OF DATA ITEMS FOR THIS NCODE
DO 17 I=1,NCOMM
IF (ITBLE(I,1)-NCODE) 17,16,17
16 MAXNO=ITBLE(I,2)
GO TO 21
17 CONTINUE
C SEARCH DATA ROUTINE
C SEE IF ANY DATA FOR THIS CARD
DO 19 I=1,NCOMM
IF (ITBLE(I,1)-NCODE) 19,18,19
18 MAXNO=ITBLE(I,2)
GO TO 20
19 CONTINUE
20 CONTINUE
21 IF (MAXNO) 23,22,23
22 RETURN
C ZERO ARRAYS AND COUNTERS
23 DO 47 I=1,310
47 DATA (I)=0.
NDATA=1
24 NCHAR=0
25 DO 26 I=1,10
AUXA(I)="*"
26 AUXB(I)="*"
IT1=1
IT2=1
SIGN=1.
LDGIT=0
KDGIT=0
C CARRY OUT DIGIT BY DIGIT SEARCH AND ACCUMULATION
27 NCHAR=NCHAR+1
C HAVE WE CONSIDERED ALL CHARACTERS - RETURN IF SO
IF (NCHAR-60) 28,32,1
28 DO 29 I=1,15
IF (CHAR(NCHAR)>EQ.ZALPH2(I)) GOTO 30
29 CONTINUE
GO TO 32
30 GO TO (33,33,33,33,33,33,33,33,33,33,32,27,36,32,31,27), I
C SN 39 HANDLES SIGN CONTROL ON 1130 VERSION
31 SIGN=-1.0
GO TO 27
C CHARACTER IS BLANK OR COMMA - DOES IT FOLLOW A DIGIT

```

```

32  GO TO (27,48), IT1
C   CHARACTER IS A DIGIT - HAS A DECIMAL BEEN ENCOUNTERED
33  GO TO (34,35), IT2
34  LDGIT=LDGIT+1
    IT1=2
    AUXA(LDGIT)=CHAR(NCHAR)
    GO TO 27
35  KDGIT=KDGIT+1
    AUXB(KDGIT)=CHAR(NCHAR)
    GO TO 27
C   CHARACTER IS A DECIMAL - DOES IT FOLLOW A DIGIT
36  GO TO (37,38), IT1
37  IT1=2
    LDGIT=1
38  IT2=2
    GO TO 27
C   ROUTINE TO CONVERT ALPHABETIC ARRAY TO FLOATING POINT NUMBER
48  DATA (NDATA)=GIT(AUXA,1,LDGIT,1.)+GIT(AUXB,1,10,0.)
    DATA (NDATA)=DATA(NDATA)*SIGN
C   IS ALL DATA FURNISHED YES-RETURN NO INCREASE N DATA KEEP ON
    IF (NDATA-MAXNO) 41,39,39
39  ICC=0
40  RETURN
41  NDATA=NDATA+1
    GO TO 25
C
42  FORMAT (2A1,9A2,60A1)
43  FORMAT (1H1)
44  FORMAT (5X,2A1,9A2,60A1)
46  FORMAT (10X,20HCOMMAND NOT IN TABLE)
    END

```

```

C
C
C -----
C
      FUNCTION GIT (TCARD,J,JLAST,SHIFT)
C
C -----
C
C Converts alphabetic array to floating point number
C
      CHARACTER*1 TCARD(10), A(10),TTEST
      DATA A(1)/1H1/,A(2)/1H2/,A(3)/1H3/,A(4)/1H4/,A(5)/1H5/,A(6)/1H6/
      DATA A(7)/1H7/,A(8)/1H8/,A(9)/1H9/,A(10)/1H0/
C
      GIT=0.
      TEN=10.
      SUM=0.
      DO 3 JNOW=J,JLAST
      TTEST=TCARD(JNOW)
C      CHECK FOR LAST ENTRY
      IF (TTEST.EQ."*") GO TO 4
C      FIND NUMBER AND COMPUTE VALUE
      DO 2 NUMB=1,10
      IF (TTEST-A(NUMB)) 2,1,2
1      ZTEST=NUMB
      IF (ZTEST.EQ.10.) ZTEST=0.
      SUM=SUM*TEN+ZTEST
      GO TO 3
2      CONTINUE
3      CONTINUE
4      IF (SHIFT) 6,5,6
5      FI=JNOW-1
      SUM=SUM*(0.1**FI)
6      GIT=SUM
      RETURN
      END

```

```

C
C
C -----
C
C      SUBROUTINE H PLOT
C
C -----
C
C      THIS SUBROUTINE PLOTS EITHER 1 OR 2 HYDROGRAPHS ON A SET OF AXIS
C
C      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
&IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C      CHARACTER*1 ZERO,PLUS,BLANK,DASH,DOT
C      CHARACTER*1 CCFS(132)
C
C      ID1=DATA(1)
C      ID2=DATA(2)
C      DATA ZERO, PLUS, BLANK, DASH, DOT/'0','+',',','-','.'/
C      MAX=69
C      J=1
C      ARE THERE 1 OR 2 HYDROGRAPHS
C      IF (ID2) 1,1,2
C      DETERMINE HIGHEST PEAK IF 2 HYDROGRAPHS
1      QMAX=PEAK(ID1)
      GO TO 14
2      IF (PEAK(ID1)-PEAK(ID2)) 3,3,4
3      QMAX=PEAK(ID2)
      GO TO 5
4      QMAX=PEAK(ID1)
C      IF 2 HYDROGRAPHS DETERMINE LARGEST DT AND INTERPOLATE OTHER
C      HYDROGRAPH IF NECESSARY
5      IF (DT(ID1)-DT(ID2)) 6,13,7
6      L=ID1
      K=ID2
      GO TO 8
7      L=ID2
      K=ID1
8      M=IEND(L)
      TID=DT(K)
      TIDH=0.
      DO 11 I=2,M
      TIDH=TIDH+DT(L)
      IF (TID-TIDH) 10,9,11
9      J=J+1
      CFS(J)=OCFS(I,L)
      TID=TID+DT(K)
      GO TO 11
10     J=J+1
      CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
&)
      TID=TID+DT(K)
11     CONTINUE
      IEND(L)=J
      DT(L)=DT(K)
      DO 12 I=2,J
12     OCFS(I,L)=CFS(I)
13     IF (IEND(ID1)-IEND(ID2)) 14,14,15

```

```

14  M=IEND(ID1)
    GO TO 16
15  M=IEND(ID2)
16  XM = M
C   DETERMINE TIME SCALE
    XSCL = XM / 120.
    YSCL=QMAX/50.
C   PLOT HYDROGRAPHS
    DO 20 I=1,MAX
20  CFS(I)=DASH
    IF(ICODE.EQ.0)GO TO 49
    WRITE(6,50)
50  FORMAT(T2,"FLOW RATE (CMS)")
    QMAX1=QMAX*0.02832
    WRITE(6,41)QMAX1,DOT,(CFS(I),I=1,MAX),DOT
    GO TO 51
49  WRITE(6,48)
48  FORMAT(T2,'FLOW RATE (CFS)')
    WRITE(6,41)QMAX,DOT,(CFS(I),I=1,MAX),DOT
51  Q1=QMAX
    J1=10
    DO 37 J=1,50
    IF (J-J1) 23,21,23
21  DO 22 I=1,MAX
22  CFS(I)=DASH
    GO TO 25
23  DO 24 I=1,MAX
24  CFS(I)=BLANK
25  Q2=Q1-YSCL
    DO 28 I=2,M
    IF (OCFS(I,ID1)-Q1) 26,27,28
26  IF (OCFS(I,ID1)-Q2) 28,28,27
27  XI = I
    K = XI / XSCL + 1.
    CFS(K)=ZERO
28  CONTINUE
    WRITE (6,44) DOT,(CFS(I),I=1,MAX),DOT
    IF (ID2) 34,34,29
29  DO 18 I = 1, MAX
18  CFS(I) = BLANK
    DO 33 I=1,M
    IF (OCFS(I,ID2)-Q1) 30,31,33
30  IF (OCFS(I,ID2)-Q2) 33,33,31
31  XI = I
    K = XI / XSCL + 1.
    CFS(K)=PLUS
33  CONTINUE
    WRITE (6,42) (CFS(I),I=1,MAX)
34  IF (J-J1) 36,35,36
35  J1=J1+10
    IF(ICODE.EQ.0)GO TO 52
    QD=Q2*0.02832
    WRITE(6,43)QD
    GO TO 36
52  WRITE(6,43)Q2
36  Q1=Q2
37  CONTINUE
    CFS(1)=TIME

```

```
      DTT=DT(ID1)*(XM - 1.) / 12.  
C      PUT TIME ARRAY IN CFS AND WRITE TIME SCALE  
      DO 38 I=2,13  
38      CFS(I)=CFS(I-1)+DTT  
          WRITE (6,45) (CFS(I),I=1,13)  
          WRITE (6,46)  
          RETURN  
C  
41      FORMAT(1X,F7.0,123A1)  
42      FORMAT(1H+,8X,121A1)  
43      FORMAT (1H+,F7.0)  
44      FORMAT(8X,123A1)  
45      FORMAT(T3,13F10.2)  
46      FORMAT(49X,'TIME HOURS'///)  
      END
```

```

C -----
C
C      BLOCK DATA
C
C -----

C      BLOCK DATA SUBPROGRAM USED TO INITIALIZE ZALPHA,CTBLE,ITBLE
C      AND NCOMM.

      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
&MAXNO,NCODE,ICC,NCOMM
      COMMON/BLOCK4/ZALPH2(70),CTBL1(50,2),CTBL2(50,9)
      CHARACTER*1 ZALPH2,CTBL1
      CHARACTER*2 CTBL2

      DATA ZALPH2/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,
&1H*,1H.,1H.,1H-,1H ,1H ,1H ,1H ,1H /

      DATA NCOMM/15/

      DATA CTBL1/1HS,1HS,1HC,1HP,1HP,1HA,1HS,1HC,1HS,1HC,1HR,
&1HR,1HE,1HS,1HF,35*1H ,
&1HT,1HT,1HO,1HR,1HL,1HD,1HT,1HO,1HT,1HO,1HO,1HO,1HR,
&1HE,1HI,35*1H /

C
      DATA CTBL2/
&2HAR,2HOR,2HMP,2HIN,2HOT,2HD ,2HOR,2HMP,2HOR,2HMP,
&2HUT,2HUT,2HRO,2HDI,2HNI,35*2H ,
&2HT ,2HE ,2HUT,2HT ,2H H,2HHY,2HE ,2HUT,2HE ,2HUT,
&2HE ,2HE ,2HR ,2HME,2HSH,35*2H ,
&2H ,2HHY,2HE ,2HHY,2HYD,2HD ,2HRA,2HE ,2HTR,2HE ,
&2H ,2HRE,2HAN,2HNT,2H ,35*2H ,
&2H ,2HD ,2HHY,2HD ,2H ,2H ,2HTI,2HRA,2HAV,2HTR,
&2H ,2HSE,2HAL,2H Y,2H ,35*2H ,
&2H ,2H ,2HD ,2H ,2H ,2H ,2HNG,2HTI,2HEL,2HAV,
&2H ,2HRV,2HYS,2HIE,2H ,35*2H ,
&6*2H ,2H C,2HNG,2H T,2HEL,2H ,2HOI,2HIS,2HLD,36*2H ,
&6*2H ,2HUR,2H C,2HIM,2H T,2H ,2HR ,38*2H ,
&6*2H ,2HVE,2HUR,2HE ,2HIM,40*2H ,
&7*2H ,2HVE,2H ,2HE ,40*2H /

      DATA ITBLE/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,35*1H ,
&3,310,310,4,2,4,100,310,100,8,7,25,2,5,0,35*1H /

      END

```

Chapter 5

```

1 C -----
2 C
3 C           MILHY3 - a mathematical flood forecasting model for
4 C                   ungauged catchments
5 C
6 C -----
7 C
8 C Program:      MILHY3
9 C                (MILHY2) including two-stage channel modelling.
10 C              With improved out-of-bank flood modelling incorporating
11 C              MOMENTUM EXCHANGE between in and out of bank flows and
12 C              MULTIPLE ROUTING REACHES -allowing separate pathways for
13 C              channel and floodplain flows.
14 C
15 C Coded by:     Laura Baird
16 C              University of Bristol
17 C
18 C NOTES        Upgraded subroutines
19 C                ADHYD
20 C                STHYD
21 C                CMPRC
22 C                STT
23 C                CMPTT
24 C                ROUTE
25 C                PRTHYD
26 C                BLKDTA
27 C
28 C Notes        The structure of the code remains unaltered.
29 C              All additional computations occur within existing
30 C              subroutines.
31 C              HOWEVER, there are significant changes in the manner in
32 C              which the data set DATA1 must be set out to facilitate
33 C              utilisation of the new capabilities.
34 C              All punch card capabilities have been removed.
35 C
36 C UNITS        All computations (except in the infiltration algorithm)
37 C              are carried out in imperial units, irrespective of KCODE
38 C              and ICODE.
39 C -----
40 C
41 C
42 C      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
43 C      &MAXNO,NCODE,ICC,NCOMM
44 C
45 C      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
46 C      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
47 C
48 C      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
49 C      &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
50 C      &TQ(20,6),CC(20),LL(6),INRC,LRC
51 C
52 C Definition of variables in common 1
53 C control variables
54 C CTBLE      Command table
55 C ITBLE      Integer table
56 C ZALPHA     Alphanumeric code table
57 C MAXNO      Max. number of data expected for any command
58 C NCODE      Number of command

```

```

59 C ICC      Continuation line
60 C NCOMM    Total number of legal commands
61 C
62 C Definition of variables in common 2
63 C hydrograph variables
64 C OCFS      Hydrograph discharge
65 C DATA     Data associated with each command
66 C RAIN      Cumulative precipitation values
67 C ROIN      Volume of discharge hydrograph
68 C          note: this variable is no longer divided by area
69 C IEND      Number of points in the hydrograph
70 C DA        Drainage area
71 C DT        Time increment for rainfall or discharge
72 C PEAK      Peak discharge for hydrograph
73 C TIME      Start time of simulation
74 C KCODE     Measurement unit of input
75 C          0 - imperial
76 C          not 0 - metric
77 C ICODE     Measurement unit of output
78 C          0 - imperial
79 C          not 0 - metric
80 C
81 C Definition of variables in common 3
82 C rating curve and routing variables
83 C A         Cross-sectional area
84 C Q         Discharge
85 C DEEP      Elevation
86 C SCFS      Discharge from previously computed rating curve
87 C C         Absolute stage elevations
88 C DIST      Flow segment width
89 C SEGN      Manning's n for flow segment
90 C ISG       Last elevation input in flow segment
91 C PERQ      Percentage discharge in flow segment
92 C TQ        Total discharge
93 C CC        Travel time coefficient
94 C LL        Number of zero discharge values in rating curve segment
95 C INRC      Inflow rating curve identifier (multiple routing)
96 C LRC       Outflow rating curve identifier (multiple routing)
97
98 OPEN (1,STATUS='OLD',FILE='data1')
99 OPEN(25,STATUS='OLD',FILE='data2')
100 OPEN(6,STATUS='NEW',FILE='results')
101 NCODE=0
102 ICC=0
103 1  NER=0
104 CALL HONDO
105 IF (NER) 2,2,17
106 2  GO TO (3,4,5,6,7,8,9,10,11,12,13,14,15,16,17), NCODE
107 3  TIME=DATA(1)
108     KCODE=DATA(2)
109     ICODE=DATA(3)
110     GO TO 1
111 4  CALL STHYD
112     GO TO 1
113 5  CALL CMPHYD
114     GO TO 1
115 6  CALL PRTHYD
116     GO TO 1

```

```

117 7    CALL HPLLOT
118      GO TO 1
119 8    CALL ADHYD
120      GO TO 1
121 9    CALL SRC
122      GO TO 1
123 10   CALL CMFRC
124      GO TO 1
125 11   CALL STT
126      GO TO 1
127 12   CALL CMPTT
128      GO TO 1
129 13   CALL ROUTE
130      GO TO 1
131 14   CALL RESVO
132      GO TO 1
133 15   CALL ERROR
134      GO TO 1
135 16   CALL SEDT
136      GO TO 1
137 17   STOP
138      END
139 C
140 C
141 C -----
142 C
143      SUBROUTINE HONDO
144 C
145 C -----
146 C
147 C This subroutine reads in the data from 'datal', searches an alphanumeric
148 C code table to determine the NCODE of the required operation, and collects
149 C variables from the freefloating data field.
150 C
151 C The command table (CTBLE), integer table (ITBLE), number of commands
152 C (NCOMM) and alphanumeric array (ZALPHA) are initialized in BLOCK DATA
153 C located at the end of this listing.
154 C
155 C
156      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
157      &MAXNO,NCODE,ICC,NCOMM
158 C
159      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
160      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
161 C
162      DIMENSION CHAR(60), ALPHA(11),AUXA(10),AUXB(10)
163 C
164      IF (ICC) 1,1,3
165 C      READ IN DATA CARD
166 1      READ (1,42) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)
167 C      IF FIRST CHARACTER IS BLANK THE CARD IS A CONTINUATION OF
168 C      PREVIOUS CARD.
169      IF (ALPHA(1)-ZALPHA(11)) 2,9,2
170 2      IF (ICC) 3,3,40
171 C      ASTERISK IN COL. 80 MEANS SKIP TO NEW PAGE BEFORE PRINTING CARD
172 3      IF (CHAR(60)-ZALPHA(11)) 4,5,4
173 4      WRITE (6,43)
174 5      WRITE (6,44) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)

```

```

175 C      IF FIRST CHARACTER IS A * THE PREVIOUS CARD WAS A COMMENT CARD
176      IF (ALPHA(1)-ZALPHA(12)) 10,6,10
177 6      ICC=0
178      GO TO 1
179 9      WRITE (6,44) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)
180      GO TO 24
181 C      SEARCH FIRST TWO ALPHAMERIC CHARACTERS TO SEE IF THEY ARE NUMBERS
182 10     ICC=1
183      DO 12 I=1,10
184      IF (ALPHA(1)-ZALPHA(I)) 11,15,11
185 11     IF (ALPHA(2)-ZALPHA(I)) 12,15,12
186 12     CONTINUE
187 C      STATEMENT NUMBER 7 IS BRANCHED TO IF NUMBERS ARE PRESENT
188 C      IF NOT NUMBER SEARCH COMMAND TABLE FOR MATCH
189 C      CALL FIRST 10 VALUES FROM PERMANENT DATA STORAGE
190      DO 14 I=1,NCOMM
191      DO 13 J=1,11
192      IF (CTBLE(I,J)-ALPHA(J)) 14,13,14
193 13     CONTINUE
194 C      IF THIS LOOP IS COMPLETED WE HAVE COMPLETE MATCH- CALL NCODE
195 C      AND MAX NUMBER AND EXIT LOOP
196      NCODE=ITBLE(I,1)
197      MAXNO=ITBLE(I,2)
198      GO TO 21
199 14     CONTINUE
200 C      IF MAJOR LOOPS FINISHED WITHOUT A MATCH WRITE ERROR MESSAGE
201 C      AND SET NER = 1
202      NER=1
203      WRITE (6,46)
204      RETURN
205 C      CONVERT DIGIT INPUT CODE FROM ALPHAMERIC TO INTEGER FORM
206 15     NCODE=GIT(ALPHA,1,2,1.)+0.5
207 C      FIND MAX NUMBER OF DATA ITEMS FOR THIS NCODE
208      DO 17 I=1,NCOMM
209      IF (ITBLE(I,1)-NCODE) 17,16,17
210 16     MAXNO=ITBLE(I,2)
211      GO TO 21
212 17     CONTINUE
213 C      SEARCH DATA ROUTINE
214 C      SEE IF ANY DATA FOR THIS CARD
215      DO 19 I=1,NCOMM
216      IF (ITBLE(I,1)-NCODE) 19,18,19
217 18     MAXNO=ITBLE(I,2)
218      GO TO 20
219 19     CONTINUE
220 20     CONTINUE
221 21     IF (MAXNO) 23,22,23
222 22     RETURN
223 C      ZERO ARRAYS AND COUNTERS
224 23     DO 47 I=1,310
225 47     DATA (I)=0.
226      NDATA=1
227 24     NCHAR=0
228 25     DO 26 I=1,10
229      AUXA(I)=0.
230 26     AUXB(I)=0.
231      IT1=1
232      IT2=1

```

```

233      SIGN=1.
234      LDGIT=0
235      KDGIT=0
236 C    CARRY OUT DIGIT BY DIGIT SEARCH AND ACCUMULATION
237 27    NCHAR=NCHAR+1
238 C    HAVE WE CONSIDERED ALL CHARACTERS - RETURN IF SO
239      IF (NCHAR-60) 28,32,1
240 28    DO 29 I=1,15
241      IF (CHAR(NCHAR)-ZALPHA(I)) 29,30,29
242 29    CONTINUE
243      GO TO 32
244 30    GO TO (33,33,33,33,33,33,33,33,33,33,32,27,36,32,31,27), I
245 C    SN 39 HANDLES SIGN CONTROL ON 1130 VERSION
246 31    SIGN=-1.0
247      GO TO 27
248 C    CHARACTER IS BLANK OR COMMA - DOES IT FOLLOW A DIGIT
249 32    GO TO (27,48), IT1
250 C    CHARACTER IS A DIGIT - HAS A DECIMAL BEEN ENCOUNTERED
251 33    GO TO (34,35), IT2
252 34    LDGIT=LDGIT+1
253      IT1=2
254      AUXA(LDGIT)=CHAR(NCHAR)
255      GO TO 27
256 35    KDGIT=KDGIT+1
257      AUXB(KDGIT)=CHAR(NCHAR)
258      GO TO 27
259 C    CHARACTER IS A DECIMAL - DOES IT FOLLOW A DIGIT
260 36    GO TO (37,38), IT1
261 37    IT1=2
262      LDGIT=1
263 38    IT2=2
264      GO TO 27
265 C    ROUTINE TO CONVERT ALPHABETIC ARRAY TO FLOATING POINT NUMBER
266 48    DATA (NDATA)=GIT(AUXA,1,LDGIT,1.)+GIT(AUXB,1,10,0.)
267      DATA (NDATA)=DATA(NDATA)*SIGN
268 C    IS ALL DATA FURNISHED YES-RETURN NO INCREASE N DATA KEEP ON
269      IF (NDATA-MAXNO) 41,39,39
270 39    ICC=0
271 40    RETURN
272 41    NDATA=NDATA+1
273      GO TO 25
274 C
275 42    FORMAT (2A1,9A2,60A1)
276 43    FORMAT (1H1)
277 44    FORMAT (5X,2A1,9A2,60A1)
278 46    FORMAT (10X,20HCOMMAND NOT IN TABLE)
279      END
280 C
281 C
282 C -----
283 C
284      FUNCTION GIT (TCARD,J,JLAST,SHIFT)
285 C
286 C -----
287 C
288 C Converts alphabetic array to floating point number
289 C
290      DIMENSION TCARD(10), A(10)

```

```

291      DATA A(1)/1H1/,A(2)/1H2/,A(3)/1H3/,A(4)/1H4/,A(5)/1H5/,A(6)/1H6/
292      DATA A(7)/1H7/,A(8)/1H8/,A(9)/1H9/,A(10)/1H0/
293 C
294      GIT=0.
295      TEN=10.
296      SUM=0.
297      DO 3 JNOW=J,JLAST
298      TTEST=TCARD(JNOW)
299 C      CHECK FOR LAST ENTRY
300      IF (TTEST.EQ.0.) GO TO 4
301 C      FIND NUMBER AND COMPUTE VALUE
302      DO 2 NUMB=1,10
303      IF (TTEST-A(NUMB)) 2,1,2
304 1      ZTEST=NUMB
305      IF (ZTEST.EQ.10.) ZTEST=0.
306      SUM=SUM*TEN+ZTEST
307      GO TO 3
308 2      CONTINUE
309 3      CONTINUE
310 4      IF (SHIFT) 6,5,6
311 5      FI=JNOW-1
312      SUM=SUM*(0.1**FI)
313 6      GIT=SUM
314      RETURN
315      END
316 C
317 C
318 C =====
319 C
320      SUBROUTINE STHYD
321 C
322 C =====
323 C
324 C      THIS SUBROUTINE STORES THE COORDINATES OF HYDROGRAPHS,
325 C      AND ADDS BASEFLOW TO HYDROGRAPH STORED
326 C
327      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
328      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
329 C
330      ID=DATA(1)
331      NHD=DATA(2)
332      DT(ID)=DATA(3)
333      IF(KCODE.EQ.0)GO TO 10
334      DATA(4)=DATA(4)/2.590
335      DATA(5)=DATA(5)/0.02832
336      DO 11 J=6,306
337 11      DATA(J)=DATA(J)/.02832
338 10      DA(ID)=DATA(4)
339      BSF=DATA(5)
340 C      BASEFLOW
341      J=6
342 C      REMAINING DATA ARE FLOW RATES
343      OCFS(1,ID)=DATA(J)+BSF
344      PEAK(ID) = 1.
345      RO = DATA(J)
346      DO 4 I=2,300
347      J=J+1
348      OCFS(I,ID)=DATA(J)+BSF

```

```

349      RO = RO + OCFS(I,ID)
350 C      IS FLOW RECEDING
351      IF (OCFS(I,ID)-OCFS(I-1,ID)) 1,2,2
352 C      HAS FLOW RECEDED TO CUTOFF RATE
353 1      IF (OCFS(I,ID)) 5,5,4
354 C      DETERMINE PEAK FLOW
355 2      IF(OCFS(I,ID) - PEAK(ID)) 4,4,3
356 3      PEAK(ID) = OCFS(I,ID)
357 4      CONTINUE
358 5      IEND(ID)=I-1
359      M=IEND(ID)
360      ROIN(ID)=RO*DT(ID)*3600
361      RETURN
362      END
363 C
364 C
365 C =====
366 C
367      SUBROUTINE CMPHYD
368 C
369 C =====
370 C
371 C This subroutine develops a unit hydrograph, converts rainfall data
372 C into runoff by calling the soil moisture finite difference model,
373 C or the Curve Number routine,
374 C and sums these two to produce the storm runoff hydrograph.
375 C
376      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
377      &IEND(6),LA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
378 C
379      DIMENSION CFS(300)
380 C      CFS      Unit hydrograph discharge
381      TEMP=0.
382 C
383 C Input data read into subroutine
384      ID=DATA(1)
385      NHD=DATA(2)
386      DT(ID)=DATA(3)
387      IF(KCODE.NE.0)THEN
388 C          Convert metric to imperial
389          DATA(4)=DATA(4)/2.590
390          IF(DATA(6).LT.0)GO TO 40
391          DATA(6)=DATA(6)/0.3048
392          DATA(7)=DATA(7)/1.6
393      ENDIF
394 40      DA(ID)=DATA(4)
395      CN=DATA(5)
396 C Data items 6 and 7 normally hold watershed height and length and
397 C from these the constants XK(recession constant) and Tp(time to peak)
398 C can be calculated.
399 C If XK and Tp are known however, they can be entered instead
400 C and a negative sign is put before their values.
401      IF (DATA(6).LT.0.)THEN
402          XK=-DATA(6)
403          TP=-DATA(7)
404      ELSE
405          HT=DATA(6)
406          XL=DATA(7)

```

```

407      SLOPE=HT/XL
408      XLDW=(XL**2.)/DA(ID)
409      XK=27.0*(DA(ID)**.231)*(SLOPE**(-.777))*(XLDW**.124)
410      TP=4.63*(DA(ID)**.422)*(SLOPE**(-.46))*(XLDW**.133)
411      ENDIF
412 C The storm runoff array and unit hydrograph array are intialised to 0,
413 C and peak of hydrograph to 1
414      DO 4 I=1,300
415          CFS(I)=0
416 4      OCFS(I,ID)=0.
417          PEAK(ID)=1.
418 C Compute unit hydrograph parameters
419 C Compute 'N' by iteration
420      XN=5.0
421      XKTP=XK/TP
422      DO 6 I=1,50
423          TINF=1.+SQRT(1./(XN-1.))
424          XN1=.05/(XKTP*(ALOG(TINF/(TINF+.05))+.05))+1.
425          DIFF=ABS(XN1-XN)
426          IF (DIFF-.001) 7,7,5
427 5      XN=XN1
428 6      CONTINUE
429      WRITE (6,29)
430 29      FORMAT(' N DID NOT CONVERGE AFTER 50 ITERATIONS. ')
431      GO TO 28
432 C Compute 'C1'
433 /      DELT=TINF/100.
434      TC1=0.
435      XN1P=XN-1.
436      XN1M=1.-XN
437      DO 8 I=2,101
438          TC1=TC1+DELT
439 8      CFS(I)=(TC1**XN1P)*EXP(XN1M*(TC1-1.))
440      SUM=CFS(101)/2.
441      DO 9 I=2,100
442 9      SUM=SUM+CFS(I)
443      C1=SUM*DELT
444 C Compute 'B'
445      CFSII=CFS(101)
446      TTINF=TINF*TP
447      TREC1=TTINF+2.*XK
448      EEE=EXP((TTINF-TREC1)/XK)
449      XK1=3.*XK
450      B=645.333/(C1+CFSII*(XKTP*(1.-EEE)+EEE*(XK1/TP)))
451 C Compute 'QP' and 'CFSI'
452      QP=(B*DA(ID))/TP
453      CFSI=QP*CFS(101)
454      CFSR1=CFSI*EEE
455      IF(ICODE.EQ.0)GO TO 45
456      QP1=QP*.02832
457      WRITE(6,38)XN,QP1
458 38      FORMAT(' Shape constant, N = ',F6.3/' Unit peak = ',F10.1,1X
459          &,'cms'/)
460      GO TO 44
461 45      WRITE (6,30) XN,QP
462 30      FORMAT(' Shape constant, N = ',F6.3/' Unit peak = ',F10.1,1X
463          *,'cms'/)
464 C

```

```

465 44  CONTINUE
466 C
467 C Determine the incremental runoff
468 C
469     IF(KCODE.NE.0)THEN
470         IF(DATA(8).LT.0)GO TO 13
471 C         Convert rainfall data from mm to inches.
472         DO 34 K=8,308
473 34     DATA(K)=DATA(K)/25.4
474     ENDIF
475 35     J=8
476     IF (DATA(J)) 13,10,10
477 10     RAIN(1)=DATA(J)
478         DO 11 I=2,300
479             J=J+1
480             RAIN(I)=DATA(J)
481             IF (RAIN(I)-RAIN(I-1)) 12,11,11
482 11     CONTINUE
483 12     NUMB=I-1
484 C
485 C     Curve number routine
486 13     IF(CN.LE.0)GOTO 201
487 C     STORAGE
488     R=1000./CN-10
489     B1=.2*R
490     DO 15 I=1,NUMB
491     IF(RAIN(I)-B1)33,33,14
492 33     DATA(I)=0
493     Q1=0
494     GOTO 15
495 14     Q2=((RAIN(I)-B1)**2.)/(RAIN(I)+.8*R)
496     DATA(I)=Q2-Q1
497     Q1=Q2
498 15     CONTINUE
499     GOTO 202
500 C
501 C     Soil moisture algorithm
502 201 DO 5555 I=1,300
503 5555 DATA(1)=0
504     TEMP=DT(ID)
505 C
506     CALL SOILM(TEMP,NUMB,RAIN,DATA)
507
508 C Subroutine returns a vector of runoff values from the soil moisture model
509 C If no runoff has been generated by the soil water model, then the simulation
510 C stops.
511
512     DO 100 I=1,NUMB
513     IF(DATA(I).EQ.0.)GOTO 100
514     GOTO 200
515 100 CONTINUE
516     WRITE(6,300)
517 300     FORMAT(' Soil water model generated no runoff'/
518         &' Simulation terminates')
519     STOP
520 200 CONTINUE
521 C
522 C Compute unit hydrograph

```

```

523 202      T2=0.
524          CFS(1)=0.
525          DO 20 I=2,300
526              T2=T2+DT(ID)
527              IF (T2-TTINF) 16,16,17
528 16          CFS(I)=QP*((T2/TP)**XN1P)*EXP(XN1M*(T2/TP-1.))
529              GO TO 20
530 17          IF (T2-TREC1) 18,18,19
531 18          CFS(I)=CFSI*EXP((TTINF-T2)/XK)
532              GO TO 20
533 19          CFS(I)=CFSR1*EXP((TREC1-T2)/XK1)
534              IF (CFS(I)-1.) 21,21,20
535 20          CONTINUE
536              I=300
537 21          ICND=I
538          C
539          C
540          C Compute the storm runoff hydrograph by summing the unit hydrograph and
541          C the runoff from the soil moisture model.
542          C
543          C
544              DO 24 J=2,NUMB
545                  N=J+ICND-2
546                  IF (N-300) 23,23,22
547 22          N=300
548 23          I = 2
549              DO 24 K= J,N
550                  OCFS(K,ID)=OCFS(K,ID)+DATA(J)*CFS(I)
551                  I=I+1
552 24          CONTINUE
553          C
554          C Compute the runoff volume and determine the peak.
555          C
556          C
557              RO = 0.
558              DO 26 I = 2,N
559                  RO = RO + OCFS(I,ID)
560                  IF (OCFS(I,ID)-PEAK(ID))26,26,25
561 25          PEAK(ID)= OCFS(I,ID)
562 26          CONTINUE
563              IEND (ID) = N
564              ROIN(ID)=RO*DT(ID)*3600
565          C
566 28          RETURN
567          END
568          C
569          C
570          C =====
571          C
572          SUBROUTINE SOILM(DT,IR,CUMRAIN,DATA)
573          C
574          C =====
575          C
576          C A physically based parameter infiltration model which simulates near surface
577          C soil water movement, and hence runoff.
578          C
579          C Variables used in this subroutine
580          C

```

```

581 C    TIME          Time when simulation begins (hours).
582 C    SR1           Soil water content at saturation layer 1.
583 C    SR2           (m3/m3) layer 2.
584 C    SR3           layer 3.
585 C    NLA          Number of cells in layer 1.
586 C    NLB          Number of cells in layer 2.
587 C    NL           Total number of cells in column
588 C    SATCON        Saturated permeability (ms-1) layer 1.
589 C    SATCON2       layer 2.
590 C    SATCON3       layer 3.
591 C    EMAX          Maximum evaporation during the day (ms-1).
592 C    SIMDUR        Simulation duration (hours).
593 C    DETCAP        Surface detention capacity (m).
594 C    AF            Simulation iteration period (secs).
595 C    WT            Write-out time period (hrs).
596 C    THETA         Initial soil water content for each cell (m3/m3).
597 C    TCOM          Thickness of each cell.
598 C    ALR           Rain start time (hours).
599 C    AMR           Rain stop time.
600 C    NQ           Number of observations on suction moisture curve.
601 C    X             Moisture values....layer 1 (m3/m3).
602 C    Y             Suction values.....layer 1 (bars).
603 C    X2           layer 2.
604 C    Y2           layer 2.
605 C    X3           layer 3.
606 C    Y3           layer 3.
607 C    IR           Number of rainfall observations.
608 C    DT           Rainfall data time increments (hours).
609 C    CUMRAIN       Cumulative rainfall data at DT time increments (inches).
610 C    NSCOL        Number of soil columns.
611 C    IPCAREA       Percent area of soil column.
612 C    IOUT         Determines amount of output.
613 C                1 - total output
614 C                0 - shorter
615 C
616 C    Note:
617 C        If SR1, SR2, SR3, SATCON, SATCON2, SATCON3, DETCAP, THETA, X, X2, or X3
618 C        are preceded by an 'A', then the variable type is double precision
619 C        rather than real. If SR1, SR2, SR3, SATCON, SATCON2, SATCON2, DETCAP,
620 C        OR THETA are preceded by an 'S', then the variable represents the
621 C        standard deviation of that particular soil hydrological characteristic.
622 C
623 C    SCURV1          Standard deviation of soil moisture curve for layer 1
624 C    SCURV2          layer 2
625 C    SCURV3          layer 3
626 C
627 C
628 C    -----
629 C    INITIAL SECTION
630 C    -----
631 C
632 C
633 C    DIMENSION FLUX(20),TCOM(20),SWP(20),THETA(20),COND(20)
634 C    DIMENSION VOL(20),ANFLUX(20),AVCOND(20),DEPTH(20),DIST(20)
635 C    DIMENSION X(20),Y(20),G(20),GZ(20)
636 C    DIMENSION CUMRAIN(251),Z(20),PPT(250)
637 C    DIMENSION DATA(300),WDATA(300,10),HPOT(20)
638 C    DIMENSION G2(20),Y2(20),X2(20),GZ2(20),Z2(20)

```

```

639     DIMENSION G3(20),Y3(20),X3(20),GZ3(20),Z3(20)
640     DIMENSION RSAT(20)
641     DIMENSION AX(20),AX2(20),AX3(20),ATHETA(20)
642     DIMENSION XNEW(20),YNEW(20),X2NEW(20),Y2NEW(20),
643     &         X3NEW(20),Y3NEW(20)
644     DOUBLE PRECISION G05DDF
645     DOUBLE PRECISION DLOG10
646     DOUBLE PRECISION ATHETA,AX,AX2,AX3,ADETCAP,ASR1,ASR2,ASR3,
647     *   ASATCON,ASATCON2,ASATCON3,BSATCON,BSATCON2,BSATCON3,
648     *   SDETCAP,SSR1,SSR2,SSR3,STHETA,SSATCON,SSATCON2,SSATCON3,
649     *   SCURV1,SCURV2,SCURV3
650 C
651 C     READ IN DATA
652 C     -----
653 C
654     READ(25,*)TIME,ALR,AMR,SIMDUR
655     READ(25,*)IOUT
656     READ(25,*)AF,WT
657     READ(25,*)NSCOL
658 C
659 C The array RAIN which is passed to the subroutine as a cumulative
660 C rainfall total is in inches.This has to be transfered to array
661 C PPT which is in m and represents the total for each time increment.
662     IRR=IR-1
663     DO 100 I=1,IRR
664 100   PPT(I)=(CUMRAIN(I+1)-CUMRAIN(I))*0.0254
665     DO 34543 W=1,NSCOL
666 C   For each soil column in turn, read in data and proceed through
667 C   simulation to determine runoff
668     READ(25,*)IPCAREA
669     READ(25,*)NL,NLA,NLB
670     READ(25,*)(TCOM(I),I=1,NL)
671     READ(25,*)EMAX,ADETCAP,SDETCAP
672     READ(25,*)ASR1,SSR1,ASR2,SSR2,ASR3,SSR3
673     READ(25,*)ASATCON,SSATCON,ASATCON2,SSATCON2,ASATCON3,SSATCON3
674     READ(25,*)(ATHETA(I),I=1,NL)
675     READ(25,*)STHETA
676     READ(25,*)NQ
677     READ(25,*)(AX(I),I=1,NQ)
678     READ(25,*)(Y(I),I=1,NQ)
679     READ(25,*)SCURV1
680     READ(25,*)(AX2(I),I=1,NQ)
681     READ(25,*)(Y2(I),I=1,NQ)
682     READ(25,*)SCURV2
683     READ(25,*)(AX3(I),I=1,NQ)
684     READ(25,*)(Y3(I),I=1,NQ)
685     READ(25,*)SCURV3
686     NQJ=NQ
687     NLL=NL+1
688     IF(AMR.LT.ALOR)THEN
689         AMR=AMR+24.0
690     ENDIF
691 C
692 C     CHECK DATA INPUTS
693 C     -----
694 C
695     NERROR=0
696 C Check number of cells in soil column

```

```

697         IF(NLA+NLB.GE.NL)THEN
698             WRITE(6,1015)
699 1015         FORMAT(' Error-NLA,NLB,NL')
700             NERROR=NERROR+1
701         ENDIF
702     C
703     C Check dimensions of input vectors
704         IF(NQ.GT.20.OR.NL.GT.20.OR.IR.GT.250)THEN
705             WRITE(6,1020)
706 1020         FORMAT(' Error-limit exceeded,NQ,NL,IR')
707             NERROR=NERROR+1
708         ENDIF
709     C
710     C Check rainfall passed from CMPHYD
711         KN=IR-1
712         DO 50 I=1,KN
713             IF(CUMRAIN(I+1).LT.CUMRAIN(I))THEN
714                 WRITE(6,1030)
715 1030             FORMAT(' Error-not cumulative rainfall totals')
716                 NERROR=NERROR+1
717             ENDIF
718         50     CONTINUE
719     C
720     C Check that initial moisture content of each cell lies within the range of
721     C the suction moisture curve and does not exceed stated saturated moisture
722     C content.
723         DO 51 I=1,NLA
724             IF(ATHETA(I).GT.ASR1)THEN
725                 WRITE(6,1050)
726 1050             FORMAT(' Error-THETA larger then sat moisture content(1)')
727                 NERROR=NERROR+1
728             ENDIF
729             IF (ATHETA(I).GT.AX(NQ).OR.ATHETA(I).LT.AX(1))THEN
730                 WRITE(6,1055)
731 1055             FORMAT(' Error-THETA outside range of curves-(1)')
732             ENDIF
733         51     CONTINUE
734         NLAA=NLA+1
735         NLH=NLA+NLB
736         DO 52 I=NLAA,NLH
737             IF(ATHETA(I).GT.ASR2)THEN
738                 WRITE(6,1060)
739 1060             FORMAT(' Error-THETA larger than sat moisture content(2)')
740                 NERROR=NERROR+1
741             ENDIF
742             IF(ATHETA(I).GT.AX2(NQ).OR.ATHETA(I).LT.AX2(1))THEN
743                 WRITE(6,1065)
744 1065             FORMAT(' Error-THETA outside range of curve-(2)')
745                 NERROR=NERROR+1
746             ENDIF
747         52     CONTINUE
748         NLBB=NLB+NLA+1
749         DO 53 I=NLBB,NL
750             IF(ATHETA(I).GT.ASR3)THEN
751                 WRITE(6,1070)
752 1070             FORMAT(' Error-THETA larger than sat moisture content(3)')
753             STOP
754         ENDIF

```

```

755         IF(ATHETA(I).GT.AX3(NQ).OR.ATHETA(I).LT.AX3(1))THEN
756             WRITE(6,1075)
757 1075         FORMAT(' Error-THETA outside range of curve -(2)')
758             NERROR=NERROR+1
759         ENDIF
760 53     CONTINUE
761 C
762         IF (NERROR.NE.0)THEN
763             WRITE(6,1076)NERROR
764 1076         FORMAT(' SOILM:  number of input data errors  ',I2,
765             &'Simulation terminates')
766             STOP
767         ENDIF
768 C
769 C         DEPTH CALCULATION
770 C         -----
771 C
772 C The variable DEPTH is calculated. This refers to the distance from
773 C ground level to any cell midpoint.
774 C DIST refers to the distance between any two adjacent cell midpoints.
775 C
776         DIST(1)=TCOM(1)/2.
777         DEPTH(1)=DIST(1)
778         DO 110 I=2,NL
779             DEPTH(I)=DEPTH(I-1)+0.5*(TCOM(I-1)+TCOM(I))
780 110     DIST(I)=0.5*(TCOM(I-1)+TCOM(I))
781 C
782 C         PARAMETER VARIABILITY
783 C         -----
784 C
785 C Five input variables, detention capacity, soil water content at
786 C saturation, soil moisture content at given tensions, saturated conductivity
787 C and initial moisture content are varied stochastically.
788 C NAG functions are called which return a 'psuedo random' value from a
789 C distribution with a given standard deviation and mean.
790 C All are assumed to have a normal distribution except the saturated
791 C conductivity which takes on a lognormal.
792 C
793 C Generate only one set of stochastic variables to run in MILHY.
794 C
795 C         RANDOM PARAMETER VALUE
796 C         -----
797 C
798         WRITE(6,1079)
799 1079     FORMAT(' INCREMENTAL RUNOFF-Parameter variability included'///)
800 C
801 C         Detention capacity.
802         DETCAP=G05DDF(ADETCAP,SDETCAP)
803         IF(DETCAP.LT.0.)DETCAP=0.0
804         SD=SDETCAP
805         WRITE(6,1180)SD
806 1180     FORMAT(' SD of detcap ',F5.3)
807 C
808 C         Soil water content at saturation
809         SR1=G05DDF(ASR1,SSR1)
810         SR2=G05DDF(ASR2,SSR2)
811         SR3=G05DDF(ASR3,SSR3)
812         SD1=SSR1

```

```

813          SD2=SSR2
814          SD3=SSR3
815          WRITE(6,1181)SD1,SD2,SD3
816 1181      FORMAT(' SD of saturated soil content',F5.3,' layer 1'/
817          &          ' ,F5.3,' layer 2'/
818          &          ' ,F5.3,' layer 3')
819 C
820 C      Soil moisture content at given tensions
821 C      Layer 1
822          CALL SMCURV(SR1,NQ,AX,Y,XNEW,YNEW,SCURV1)
823          DO 120 I=1,20
824              X(I)=XNEW(I)
825 120      Y(I)=YNEW(I)
826 C      Layer 2
827          CALL SMCURV(SR2,NQ,AX2,Y2,X2NEW,Y2NEW,SCURV2)
828          DO 130 I=1,20
829              X2(I)=X2NEW(I)
830 130      Y2(I)=Y2NEW(I)
831 C      Layer 3
832          CALL SMCURV(SR3,NQ,AX3,Y3,X3NEW,Y3NEW,SCURV3)
833          DO 140 I=1,20
834              X3(I)=X3NEW(I)
835 140      Y3(I)=Y3NEW(I)
836          SD1=SCURV1
837          SD2=SCURV2
838          SD3=SCURV3
839          WRITE(6,1182)SD1,SD2,SD3
840 1182      FORMAT(' SD of suction moisture curve', F5.3,' layer 1'/
841          &          ' , F5.3,' layer 2'/
842          &          ' , F5.3,' layer 3')
843 C
844 C Saturated conductivity for each layer
845          BSATCON=DLOG10(ASATCON)
846          SATCON=G05DDF(BSATCON,SSATCON)
847          SATCON=10**SATCON
848          BSATCON2=DLOG10(ASATCON2)
849          SATCON2=G05DDF(BSATCON2,SSATCON2)
850          SATCON2=10**SATCON2
851          BSATCON3=DLOG10(ASATCON3)
852          SATCON3=G05DDF(BSATCON3,SSATCON3)
853          SATCON3=10**SATCON3
854          SD1=SSATCON
855          SD2=SSATCON2
856          SD3=SSATCON3
857          WRITE(6,1183)SD1,SD2,SD3
858 1183      FORMAT(' SD of sat conductivity',F5.3,' layer 1'/
859          &          ' , F5.3,' layer 2'/
860          &          ' , F5.3,' layer 3')
861 C
862 C Initial moisture content
863          DO 150 I=1,NL
864 150      THETA(I)=G05DDF(ATHETA(I),STHETA)
865 C      Check on initial soil moisture values
866          DO 160 I=1,NLA
867              IF(THETA(I).GE.X(20))THETA(I)=X(20)-0.001
868 160      IF(THETA(I).LE.X(1))THETA(I)=X(1)+0.001
869          DO 170 I=NLA,NLH
870              IF(THETA(I).GE.X2(20))THETA(I)=X2(20)-0.001

```

```

871 170      IF(THETA(I).LE.X2(1))THETA(I)=X2(1)+0.001
872          DO 180 I=NLBB,NL
873              IF(THETA(I).GE.X3(20))THETA(I)=X3(20)-0.001
874 180      IF(THETA(I).LE.X3(1))THETA(I)=X3(1)+0.001
875          SD=STHETA
876          WRITE(6,1184)SD
877 1184      FORMAT(' SD of initial water content',F5.3)
878 C
879 C          HYDRAULIC CONDUCTIVITY CALCULATION
880 C          -----
881 C
882 C The hydraulic conductivity is calculated from suction moisture
883 C data for each layer.
884          NQJ=NQ
885          CALL HYDCON(X,SATCON,SR1,Z,Y)
886          CALL HYDCON(X2,SATCON2,SR2,Z2,Y2)
887          CALL HYDCON(X3,SATCON3,SR3,Z3,Y3)
888 C
889 C          WRITE-OUT INITIAL CONDITIONS
890 C          -----
891 C
892 C Write-out suction moisture curve and generated K-values.
893 C
894          WRITE(6,1080)
895 1080      FORMAT('OGENERATED K-MOISTURE CURVE'/
896          &' Millington-Quirk Method'/
897          &' Layer 1',26X,'Layer 2',26X,'Layer 3'/
898          &3(' Moisture Suction      Unsat K      '))
899          DO 175 I=1,20
900 175      WRITE(6,1090)X(I),Y(I),Z(I),X2(I),Y2(I),Z2(I),X3(I),Y3(I),Z3(I)
901 1090      FORMAT(1H ,3(F6.3,2X,F8.3,F15.12,2X))
902 C Write-out start conditions.
903 C
904          WRITE(6,1100)
905 1100      FORMAT('OSTART CONDITIONS '//)
906          WRITE(6,1110)TIME
907 1110      FORMAT(' Simulation start time',F4.1,'hrs')
908          WRITE(6,1130)ALR,AMR
909 1130      FORMAT(' Precipitation begins at ',F4.1,2X,'and ends at ',F4.1)
910          WRITE(6,1140)DT
911 1140      FORMAT(' Rainfall data time increment = ',F6.4,2X,'hrs')
912          WRITE(6,1120)AF
913 1120      FORMAT(' Time increment for iteration period = ',F6.1,
914          &2X,'secs'//)
915          WRITE(6,1150)EMAX,DETJAP
916 1150      FORMAT(' Maximum evaporation during the day = ',F10.8,2X,'ms-1'/
917          &' Surface detention capacity = ',F6.4,2X,'m'//)
918 C
919 C Calculate initial relative saturation of each cell in soil column
920          DO 1151 I=1,NL
921              IF(I.LE.NLA)RSAT(I)=THETA(I)/SR1
922              IF(I.GT.NLA.AND.I.LT.NLBB)RSAT(I)=THETA(I)/SR2
923              IF(I.GE.NLBB)RSAT(I)=THETA(I)/SR3
924 1151      CONTINUE
925          WRITE(6,1152)
926 1152      FORMAT(' INITIAL SOIL COLUMN CONDITIONS'//)
927          WRITE(6,1153)
928 1153      FORMAT(11X,'SAT',8X,'SAT HYD',6X,'CELL',1X,'DEPTH',

```

```

929      &2X,'INITAL',2X,'REL' /
930      &1H ,10X,'THETA',7X,'COND',9X,'NO',10X,'THETA',2X,'SAT' /
931      &1H ,10X,'m3/m3',7X,'ms-1',14X,'m',5X,'m3/m3' /)
932      WRITE(6,1154)SR1,SATCON,DEPTH(1),THETA(1),RSAT(1)
933 1154  FORMAT(' Layer 1 ',F7.4,1X,F15.12,3X,'1',2X,F6.4,1X,F7.4,1X,F5.3)
934      IF(NLA.GT.1)THEN
935          DO 1155 I=2,NLA
936              WRITE(6,1156)I,DEPTH(I),THETA(I),RSAT(I)
937 1156          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
938 1155          CONTINUE
939      ENDIF
940      WRITE(6,1157)SR2,SATCON2,NLAA,DEPTH(NLAA),THETA(NLAA),RSAT(NLAA)
941 1157  FORMAT(' Layer 2 ',F7.4,1X,F15.12,2X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
942      IF(NLB.GT.1)THEN
943          DO 1158 I=NLAA+2,NLH
944              WRITE(6,1159)I,DEPTH(I),THETA(I),RSAT(I)
945 1159          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
946 1158          CONTINUE
947      ENDIF
948      WRITE(6,1160)SR3,SATCON3,NLH+1,DEPTH(NLH+1),THETA(NLH+1),
949      &RSAT(NLH+1)
950 1160  FORMAT(' Layer 3 ',F7.4,1X,F15.12,2X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
951      IF((NL-NLH).GT.1)THEN
952          DO 1161 I=NLH+2,NL
953              WRITE(6,1162)I,DEPTH(I),THETA(I),RSAT(I)
954 1162          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
955 1161          CONTINUE
956      ENDIF
957  C
958  C      INITIALISATION OF VARIABLES
959  C      -----
960  C
961      DO 184 I=1,300
962 184      IWWW=W
963      WDATA(I,IWWW)=0.0
964      WATI=0.0
965      MMI2
966      DO 185 I=2,NL
967 185      ANFLUX(I)=0.0
968      CTIME=TIME*3600
969      SRRAIN1=0.0
970      CUMDRN=0.
971      CINFIL=0.
972      SUMD=0.
973      ICOUNT =0
974      BR=AMR-ALR
975      EVAPI=0.0
976      SOG=THETA(1)/SR1
977      RTOT=0.0
978      ANFILT=0.0
979      PPTT=0.0
980      TG=0.0
981  C
982  C      BALANCE CHECK
983  C      -----
984  C
985  C A calculation for the water balance check.
986  C The initial soil water content of the soil column.

```

```

987 C
988      DO 190 I=1,NL
989 190      WATI=TCOM(I)*THETA(I)+WATI
990 C
991 C          CURVE GRADIENTS
992 C          -----
993 C
994 C Calculations of the gradients of the suction-moisture curve and the
995 C K-moisture curve for each layer.
996 C
997      CALL GRAD(G,GZ,Y,X,Z)
998      CALL GRAD(G2,GZ2,Y2,X2,Z2)
999      CALL GRAD(G3,GZ3,Y3,X3,Z3)
1000 C
1001 C
1002 C          -----
1003 C          DYNAMIC SECTION - SIMULATION
1004 C          -----
1005 C
1006 C
1007 C This loop is completed for each time increment until end of simulation.
1008 C
1009      ITMAX=SIMDUR*3600/AF
1010      DO 9995 II=1,ITMAX
1011      ICOUNT=ICOUNT+AF
1012      TG=TG+AF
1013      T=II
1014 C
1015 C          CALCULATE WATER VOLUME OF EACH CELL
1016 C          -----
1017 C
1018      DO 200 I=1,NL
1019 200      VOL(I)=TCOM(I)*THETA(I)
1020 C
1021 C          24-HOUR CLOCK
1022 C          -----
1023 C
1024 C Calculate REAL TIME for current iteration period using the 24-hour clock
1025 C
1026      CTIME=CTIME+AF
1027      IF (CTIME.GE.86400)THEN
1028          CTIME=CTIME-86400
1029      ENDIF
1030 C
1031 C          SWP,HPOT,COND CALCULATIONS
1032 C          -----
1033 C
1034 C Calculate the soil water pressure, hydraulic potential and conductivity
1035 C for each cell as conditions change during the simulation.
1036 C
1037      CALL TWO(1,NLA,THETA,X,SWP,Y,G,HPOT,DEPTH,GZ,COND,Z)
1038      CALL TWO(NLAA,NLB,THETA,X2,SWP,Y2,G2,HPOT,DEPTH,GZ2,COND,Z2)
1039      CALL TWO(NLBB,NL,THETA,X3,SWP,Y3,G3,HPOT,DEPTH,GZ3,COND,Z3)
1040 C
1041 C          DETERMINE RAINFALL
1042 C          -----
1043 C
1044 C Determine rainfall per second at end of the current iteration

```

```

1045 C period.
1046 C T1 is the time in hours when the current iteration period ends.
1047 C Check that T1 is between the rain start and stop.
1048 C If it is, decide which element of PPT array the data is to be taken from
1049 C and make SRAIN equal to that precipitation per second.
1050 C If it is not within the storm period, set SRAIN to 0.
1051 C
1052 C
1053       T1=T*AF/3600.0
1054       IF(T1.LE.(ALR-TIME).OR.T1.GT.(AMR-TIME))THEN
1055           SRAIN=0.0
1056       ELSE
1057           T2=T1-(AF/3600.)
1058           IELEM=((T2-(ALR-TIME))/DT)+1
1059           SRAIN=PPT(IELEM)/(DT*3600.0)
1060       ENDIF
1061 c
1062 C Increment precipitation total by amount of precipitation in current
1063 C iteration period.
1064 C
1065       PPTT=PPTT+(SRAIN*AF)
1066 C
1067 C       AVERAGE HYDRAULIC CONDUCTIVITY
1068 C       -----
1069 C
1070 C Average hydraulic conductivity for flow through boundary between
1071 C adjoining cells is weighted according to its thickness.
1072 C
1073       DO 210 I=2,NL
1074 210   AVCOND(I)=(COND(I-1)*TCOM(I-1)+COND(I)*TCOM(I))
1075       &/(TCOM(I-1)+TCOM(I))
1076 C
1077 C       BOTTOM BOUNDARY CONDITION
1078 C       -----
1079 C
1080 C Determine the bottom boundary condition under the assumption that
1081 C water is flowing out of the soil column under gravity.
1082 C
1083       FLUX(NLL)=COND(NL)
1084 C
1085 C       FLUX BETWEEN CELLS
1086 C       -----
1087 C
1088 C The flux between each cell then follows Darcy's law in discrete form.
1089 C
1090       DO 220 I=2,NL
1091 220   FLUX(I)=(HPOT(I-1)-HPOT(I))*AVCOND(I)/DIST(I)
1092 C
1093 C       DETERMINE TOP BOUNDARY CONDITIONS
1094 C       -----
1095 C
1096 C Calculate the infiltration capacity.
1097 C
1098       BNCAP=(0.0-HPOT(1))*0.5*(SATCON+COND(1))/DIST(1)
1099 C
1100 C Calculate precipitation excess
1101 C
1102       IF(SRAIN1.EQ.SRAIN)THEN

```

```

1103      SUMD=(SRAIN-ANFILT)*AF+SUMD
1104      ELSE
1105          SUMD=0.0+SUMD
1106      ENDIF
1107      SRAIN1=SRAIN
1108  C
1109  C Calculate amount detained on the surface.
1110  C
1111      IF(SUMD.LT.0.0)THEN
1112          DETAIN=0.0
1113      ELSE
1114          DETAIN=SUMD
1115      ENDIF
1116  C
1117  C Calculate evaporation, the flux into cell 1 and runoff.
1118  C
1119      IF(SRAIN.GT.0.0) THEN
1120  C
1121          EVAP= 0.0
1122  C
1123          IF(SRAIN.LT.BNCAP.AND.DETAIN.LE.0.0)THEN
1124              ANFILT=SRAIN
1125          ELSE
1126              ANFILT=BNCAP
1127          ENDIF
1128          FLUX(1)=ANFILT
1129  C
1130          IF(DETAIN.GT.DETCAP)THEN
1131              SUMD=DETCAP
1132              DETAIN=DETCAP
1133              RUNOFF=0.0
1134              IF(SRAIN.GT.BNCAP)RUNOFF=(SRAIN-BNCAP)*AF
1135              RTOT=RTOT+RUNOFF
1136          ELSE
1137              RUNOFF=0.0
1138          ENDIF
1139  C
1140          ELSE
1141  C
1142              RUNOFF=0.0
1143  C CORRECTED VERSION MILHY3
1144              IF(CTIME.GT.64800.OR.CTIME.LE.21600)THEN
1145                  EVAP=EMAX/100.
1146              ELSE
1147                  EVAP=EMAX*SIN(2.*3.14159*(CTIME-21600.)/86400.)
1148              ENDIF
1149  C
1150              IF(DETAIN.LE.0.)THEN
1151                  ANFILT=0.0
1152                  FLUX(1)=EVAP*(-1.)
1153              ELSE
1154                  ANFILT=BNCAP
1155                  FLUX(1)=ANFILT
1156                  DETAIN=DETAIN-(EVAP*AF)
1157              ENDIF
1158  C
1159          ENDIF
1160  C

```

```

1161 C      CHANGES IN SOIL MOISTURE CONTENT
1162 C      -----
1163 C
1164      SWP(NLL)=-102.0
1165      DO 230 I=1,NL
1166 C      If SWP in cell is greater than 0, it is saturated and flux must
1167 C      therefore be 0.
1168      IF(SWP(I+1).GE.0.0)FLUX(I+1)=0.0
1169 C      ANFLUX represents the net change in moisture content in the cell.
1170      ANFLUX(I)=FLUX(I)-FLUX(I+1)
1171      ANFLUX(I)=ANFLUX(I)*AF
1172 C      Recalculate theta according to the change influx(per unit area).
1173      THETA(I)=(VOL(I)+ANFLUX(I))/ICOM(I)
1174 C      Due to recalculation, theta may be greater than possible water content
1175 C      at saturation and therefore it is necessary to reset SWP to
1176 C      0 and theta to the water content at saturation, the value of which is
1177 C      entered into the model.
1178      IF (THETA(I).GE.SR1.AND.I.LE.NLA)SWP(I)=0.0
1179      IF (THETA(I).GE.SR2.AND.I.GT.NLA.AND.I.LE.NLH)SWP(I)=0.0
1180      IF(THETA(I).GE.SR3.AND.I.GT.NLH)SWP(I)=0.0
1181      IF(THETA(I).GE.SR1.AND.I.LE.NLA)THETA(I)=SR1
1182      IF(THETA(I).GE.SR2.AND.I.GT.NLA.AND.I.LE.NLH)THETA(I)=SR2
1183 230 IF(THETA(I).GE.SR3.AND.I.GT.NLB)THETA(I)=SR3
1184 C
1185 C      CALCULATE CUMULATIVE TOTALS
1186 C      -----
1187 C
1188      CUMDRN=CUMDRN+FLUX(NLL)*AF
1189      EVAPI=EVAP*AF+EVAPI
1190      CINFIL=CINFIL+ANFILT*AF
1191      SOG=THETA(1)/SR1
1192 C
1193 C
1194 C      -----
1195 C      TERMINAL SECTION WRITE OUT
1196 C      -----
1197 C
1198 C
1199 C To print out data for every time increment for which PPT data is
1200 C entered, check ICOUNT to see if that period has passed by.
1201      IF(ICOUNT.LT.(DT*3600)) GOTO 9995
1202      ICOUNT=0
1203 C
1204 C      CALCULATE TIME FROM THE START
1205 C      -----
1206 C
1207      T=T*AF/3600
1208      WRITE(6,1170)T
1209 1170 FORMAT('0SOIL COLUMN CONDITIONS ',F7.3,1X,'HRS SINCE
1210      & SIMULATION BEGAN')
1211      IF(TG.EQ.86400.0)TG=0.0
1212 C
1213 C      WRITE-OUT CONDITIONS OF SOIL COLUMN
1214 C      -----
1215 C
1216      IF(IOUT.EQ.0)GOTO 305
1217
1218      WRITE(6,7780)

```

```

1219 7780 FORMAT(' Cell Depth   SWP   Theta   Hyd cond   Net',1X,
1220      &'flux   Rel sat')
1221      DO 300 I=1,NL
1222      IF(I.LE.NLA)SOG=THETA(I)/SR1
1223      IF(I.GT.NLA.AND.I.LT.NLBB)SOG=THETA(I)/SR2
1224      IF(I.GE.NLBB)SOG=THETA(I)/SR3
1225 300      WRITE(6,1190)I,DEPTH(I),SWP(I),THETA(I),COND(I),ANFLUX(I),SOG
1226 1190 FORMAT(I6,3F8.4,2F14.9,F9.3)
1227 C
1228 C      WATER BALANCE CHECK
1229 C      -----
1230 C
1231 C Philips (1964) simple water balance;
1232 C -----
1233 C
1234 C      Amount added
1235 C      (Initial soil)-(Current soil) =      by      - Evaporation- Drainage
1236 C      ( moisture ) ( moisture ) infiltration      loss      loss
1237 C
1238 305      WATN=0.
1239      DO 310 I=1,NL
1240 310      WATN=TCOM(I)*THETA(I)+WATN
1241      BAL=WATN-WATI-CINFIL+EVAPI+CUMDRN
1242      WRITE(6,1200)BAL
1243 1200 FORMAT('0Balance check on soil column water status =',F12.7)
1244      BAL=(BAL*100.)/WATN
1245      WRITE(6,1210)BAL
1246 1210 FORMAT(' Balance check as column water vol.   =',F12.7,' %')
1247 C
1248 C
1249      IF(IOUT.EQ.0)GOTO 306
1250
1251      WRITE(6,1220)EVAPI,PPTT,CINFIL,CUMDRN
1252 1220 FORMAT(' Cumulative evaporation   = ',F12.8/
1253      &' Cumulative precipitation = ',F8.4/
1254      &' Cumulative infiltration   = ',F10.6/
1255      &' Cumulative drainage       = ',F10.6/)
1256 306      IF(DETAIN.EQ.DETCAP)THEN
1257      WRITE(6,1222)
1258 1222      FORMAT(' Detention capacity exceeded')
1259      WRITE(6,1230)RTOT,RTOT/.0254,T
1260 1230      FORMAT(' Runoff total in the last period',F10.7,2X,'m' /
1261      & ' Runoff total in the last period',F10.7,2X,'ins',
1262      $ F7.3/)
1263      ELSE
1264      WRITE(6,1221)DETAIN
1265 1221      FORMAT(' Surface water = ',F10.6)
1266      WRITE(6,1226)
1267 1226      FORMAT(' No runoff')
1268      ENDIF
1269 C
1270 C      CREATION OF ARRAY DATA
1271 C      -----
1272 C
1273 C Runoff is recorded in array WDATA
1274 C The runoff for each soil column is weighted according to the
1275 C percentage area which it occupies in the catchment area
1276      [WWW-W

```

```

1277      WDATA(MMM,IWWW)=(RTOT/.0254)*(IPCAREA/100.)
1278      RTOT=0.0
1279      MMM=MMM+1
1280 9995 CONTINUE
1281 C
1282 C End of simulation of single soil column, it more than one, then return to
1283 C to the beginning of this subroutine to repeat for next soil column
1284 C
1285 34543 CONTINUE
1286      DO 76567 I=1,MMM
1287 C      Sum the weighted runoff for each soil column to derive total runoff
1288 C      passed back to CMPHYD as DATA
1289      CUMDATA=0.
1290      DO 54345 J=1,NSCOL
1291      CUMDATA=WDATA(I,J)+CUMDATA
1292 54345 CONTINUE
1293      DATA(I)=CUMDATA
1294 76567 CONTINUE
1295      IR=MMM-1
1296 C
1297      RETURN
1298      END
1299 C
1300 C
1301 C -----
1302 C
1303      SUBROUTINE HYDCON(X,SATCON,SR,Z,Y)
1304 C
1305 C =====
1306 C
1307 C This subroutine calculates hydraulic conductivity for each layer
1308 C from the given soil moisture characteristic curve.
1309 C Uses the Millington and Quirk method
1310 C
1311      DIMENSION X(20),Y(20),Z(20)
1312      DO 845 I=1,20
1313      IIJ=20-I+1
1314      XII=X(IIJ)
1315      TOPS=0.
1316      BOTS=0.
1317      DO 846 J=1,20
1318      JF=20-J+1
1319      YJJ=Y(JF)
1320 846      BOTS=((2*J-1)*YJJ**(-2))+BOTS
1321      II=I
1322      DO 847 J=II,20
1323      JF=20-J+1
1324      YJJ=Y(JF)
1325 847      TOPS=((2*J+1-2*I)*YJJ**(-2))+TOPS
1326      JT=20-I+1
1327 845 Z(JT)=SATCON*(X(II)/SR)*TOPS/BOTS
1328      RETURN
1329      END
1330 C
1331 C
1332 C -----
1333 C
1334      SUBROUTINE TWO(NA,NB,THETA,X,SWP,Y,G,HPOT,DEPTH,GZ,COND,Z)

```

```

1335 C
1336 C -----
1337 C
1338 C This subroutine calculates soil water pressure, hydraulic potential
1339 C and hydraulic conductivity for each cell as conditions change
1340 C during simulation.
1341
1342     DIMENSION THETA(20),X(20),SWP(20),Y(20),G(20),HPOT(20),
1343     &DEPTH(20),GZ(20),COND(20),Z(20)
1344     DO 15 I=NA,NB
1345         DO 16 J=1,19
1346             IF(THETA(I).GE.X(J).AND.THETA(I).LT.X(J+1))SWP(I)=Y(J)+G(J)*
1347             & (THETA(I)-X(J))
1348         16 CONTINUE
1349         HPOT(I)=SWP(I)-DEPTH(I)
1350         DO 17 J=1,19
1351             IF(THETA(I).GT.X(J).AND.THETA(I).LE.X(J+1))COND(I)=Z(J)+GZ(J)*
1352             & (THETA(I)-X(J))
1353         17 CONTINUE
1354     15 CONTINUE
1355     RETURN
1356     END
1357 C
1358 C
1359 C -----
1360 C
1361     SUBROUTINE GRAD(G,GZ,Y,X,Z)
1362 C
1363 C -----
1364 C
1365 C This subroutine calculates the gradients of the suction-moisture
1366 C and hydraulic conductivity-moisture curves.
1367 C
1368     DIMENSION G(20),GZ(20),Y(20),X(20),Z(20)
1369     DO 261 I=1,19
1370         G(I)=(Y(I+1)-Y(I))/(X(I+1)-X(I))
1371     261 GZ(I)=(Z(I+1)-Z(I))/(X(I+1)-X(I))
1372     RETURN
1373     END
1374 C
1375 C
1376 C -----
1377 C
1378     SUBROUTINE SMCURV(SR,NQ,AX,Y,XNEW,YNEW,SCURV)
1379 C
1380 C -----
1381 C
1382 C Generates a stochastic suction moisture curve to be fed into
1383 C soil moisture model
1384 C
1385     DOUBLE PRECISION G05DDF
1386     DOUBLE PRECISION AX,SCURV
1387     DIMENSION AX(20),X(20),XNEW(20),YNEW(20),G(20),Y(20)
1388 C
1389 C Determine the stochastic values of moisture
1390 C
1391     X(1)=G05DDF(AX(1),SCURV)
1392     IF(X(1).LT.0.)X(1)=0.001

```

```

1393 C
1394      DO 100 I=2,NQ
1395          X(I)=G05DDF(AX(I),SCURV)
1396 100  IF(X(I).LE.X(I-1))X(I)=X(I-1)+0.001
1397          IF(X(NQ).GE.SR)SR=X(NQ)+0.001
1398 C
1399 C Calculate gradients of this new suction-moisture curve
1400 c
1401      NNQ=NQ-1
1402      DO 200 I=1,NNQ
1403 200  G(I)=(Y(I+1)-Y(I))/(X(I+1)-X(I))
1404 C
1405 C Calculate max and min moisture values, and determine the size of
1406 C equal intervals.
1407 C
1408      XMAX=RMAX(X,NQ)
1409      XMIN=RMIN(X,NQ)
1410      XINT=(XMAX-XMIN)/19.
1411 C
1412 C Determine the new values of moisture-equal intervals
1413 C
1414      XNEW(1)=XMIN
1415      DO 300 I=2,19
1416 300  XNEW(I)=XNEW(1)+(XINT*(I-1))
1417      XNEW(20)=XMAX
1418 C
1419 C Determine the associated new values of suction
1420 C
1421      DO 350 I=1,19
1422          DO 400 J=1,NNQ
1423              IF(XNEW(I).GE.X(J).AND.XNEW(I).LT.X(J+1))
1424  &      YNEW(I)=Y(J)+G(J)*(XNEW(I)-X(J))
1425 400  CONTINUE
1426 350  CONTINUE
1427      YNEW(20)=Y(NQ)
1428 C
1429      RETURN
1430      END
1431 C
1432 C
1433 C -----
1434 C
1435      FUNCTION RMAX (X,NQ)
1436 C
1437 C -----
1438 C
1439 C Determines the maximum real in an array
1440 C
1441      DIMENSION X(NQ)
1442      RMAX=X(1)
1443      DO 10 I=2,NQ
1444 10  IF(X(I).GT.RMAX)RMAX=X(I)
1445 C
1446      RETURN
1447      END
1448 C
1449 C
1450 C -----

```

```

1451
1452      FUNCTION RMIN(X,NQ)
1453 C
1454 C -----
1455 C
1456 C Determines minimum real in an array
1457      DIMENSION X(NQ)
1458      RMIN=X(1)
1459      DO 10 I=2,NQ
1460 10   IF(X(I).LT.RMIN)RMIN=X(I)
1461 C
1462      RETURN
1463      END
1464 C
1465 C
1466 C -----
1467 C
1468      SUBROUTINE PRTHYD
1469 C
1470 C -----
1471 C
1472 C      THIS SUBROUTINE PRINTS THE CORRDINATES OF A HYDROGRAPH
1473 C      CONVERTS Q HYDROGRAPH TO STAGE HYDROGRAPH FOR SPECIFIED X-SECTION
1474 C
1475 C      ID=Q HYD INPUT
1476 C      IDR=CROSS SECTION ID
1477 C      HYDROGRAPH FORM
1478 C      NPK=2 OR GREATOR FOR CONVERSION Q/STAGE
1479 C      NPK=1 Q HYD
1480 C      NPK=0 Q PEAK AND VOLUME ONLY
1481 C      IN = FORMAT OF OUTPUT
1482 C      IN =0 REGULAR FORMAT
1483 C      IN=1 PRINT DISCHARGE ONLY IN SINGLE ENTRY PER LINE
1484 C
1485      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
1486      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
1487 C
1488      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
1489      &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
1490      &TQ(20,6),CC(20),LL(6),INRC,LRC
1491 C
1492      DIMENSION DUMMY(300),S(300,6),PEAKS
1493      DIMENSION ISG(6)
1494 C New variables used
1495 C S stage equivalent of OCFS
1496 C PEAKS peak stage (equivalent of PEAK)
1497 C
1498      ID=DATA(1)
1499      NPK=DATA(2)
1500      IDR=DATA(3)
1501      IN=DATA(4)
1502      M=IEND(ID)
1503      WRITE(6,40)ID,NPK
1504      TIME1=0
1505      IF(NPK.LT.1)GOTO 32
1506      IF(NPK.LT.2)GOTO 2
1507 C      CONVERSION TO STAGE HYDROGRAPH
1508 C      CHECK RATING CURVE ENTERED

```

```

1509      IF(IDR.EQ.0)THEN
1510      WRITE(6,*)'NEED TO ENTER RATING CURVE ID'
1511      RETURN
1512      ENDIF
1513  C      Checkk if segment or cross-section
1514      IF(IDR.GT.6) GOTO 51
1515  C      Check if multiple routing invoked
1516      IF(TQ(20,IDR).GT.0)THEN
1517      DO 50 I=1,20
1518  50      Q(I,IDR)=TO(I,IDR)
1519      ENDIF
1520      JJ=IDR
1521      GOTO 7
1522  C      Use segment to convert
1523  51      JJ=IDR/10
1524  7      DO 3 I=1,M
1525      J=1
1526  6      IF(OCFS(I,ID).LE.Q(J,IDR))GOTO 4
1527      J=J+1
1528      IF(J.GT.20)THEN
1529      WRITE(6,*)'RATING CURVE EXCEEDED, STOPPED'
1530      RETURN
1531      ENDIF
1532      GOTO 6
1533  4      IF(OCFS(I,ID).EQ.Q(J,IDR))THEN
1534      S(I,ID)=C(J,JJ)
1535      GOTO 3
1536      ENDIF
1537  C      INTERPOLATE
1538      S(I,ID)=C(J,JJ)-((C(J,JJ)-C(J-1,JJ))*(Q(J,IDR)-OCFS(I,ID))/
1539      &(Q(J,IDR)-Q(J-1,IDR)))
1540  3      CONTINUE
1541  C      TIME ARRAY
1542  2      DO 8 I=1,M
1543      DATA(I)=TIME1
1544  8      TIME1=TIME1+DT(ID)
1545      J=0
1546      M4=M+4
1547      M5=M4/5
1548      IF(NPK.LT.2)GOTO 27
1549      IF(ICODE.EQ.0)THEN
1550      WRITE(6,9)
1551      GOTO 10
1552      ENDIF
1553      WRITE(6,11)
1554  10      IF(IN.GT.0)THEN
1555      IF(ICODE.EQ.0)THEN
1556      DO 38 I=1,M
1557  38      WRITE(6,28)S(I,ID)
1558      RETURN
1559      ENDIF
1560      DO 43 I=1,M
1561      S(I,ID)=S(I,ID)*0.3048
1562  43      WRITE(6,28)S(I,ID)
1563      RETURN
1564      ENDIF
1565      IF(ICODE.GT.0)THEN
1566      DO 45 I=1,M

```

```

1567 45  S(I,ID)=S(I,ID)*0.3048
1568      ENDIF
1569 39  J=J+1
1570      WRITE(6,30)(DATA(I),S(I,ID),I=J,M,M5)
1571      IF(J-M5)39,13,13
1572 13  ROIN1=ROIN(ID)
1573      DO 16 I=1,20
1574      IF(Q(I,IDR)-PEAK(ID))16,17,17
1575 16  CONTINUE
1576 17  IF(Q(I,IDR).EQ.PEAK(ID))THEN
1577      PEAKS=C(I,JJ)
1578      GOTO 18
1579      ENDIF
1580      PEAKS=C(I,JJ)-((C(I,JJ)-C(I-1,JJ))*(Q(I,IDR)-PEAK(ID))/
1581      &(Q(I,IDR)-Q(I-1,IDR)))
1582 18  IF(ICODE.EQ.0)THEN
1583      WRITE(6,14)ROIN1,PEAKS
1584      RETURN
1585      ENDIF
1586      PEAKS=PEAKS*0.3048
1587      ROIN1=ROIN(ID)*0.0283168
1588      WRITE(6,15)ROIN1,PEAKS
1589      RETURN
1590 C    DISCHARGE HYDROGRAPHS
1591 27  IF(ICODE.EQ.1)THEN
1592 C    METRIC
1593      WRITE(6,21)
1594      DO 23 I=1,M
1595 23  DUMMY(I)=OCFS(I,ID)*0.0283168
1596      PEAK1=PEAK(ID)*0.0283168
1597      ROIN1=ROIN(ID)*0.0283168
1598      GOTO 20
1599      ENDIF
1600 C    IMPERIAL
1601 19  WRITE(6,25)
1602      DO 26 I=1,M
1603 26  DUMMY(I)=OCFS(I,ID)
1604      PEAK1=PEAK(ID)
1605      ROIN1=ROIN(ID)
1606 20  IF(IN.GT.0)THEN
1607      DO 29 I=1,M
1608 29  WRITE(6,28)DUMMY(I)
1609      RETURN
1610      ENDIF
1611 31  J=J+1
1612      WRITE(6,30)(DATA(I),DUMMY(I),I=J,M,M5)
1613      IF(J-M5)31,32,32
1614 32  IF(ICODE.NE.0)GOTO 34
1615      ROIN1=ROIN(ID)
1616      PEAK1=PEAK(ID)
1617      WRITE(6,35)ROIN1,PEAK1
1618      RETURN
1619 34  ROIN1=ROIN(ID)*0.0283168
1620      PEAK1=PEAK(ID)*0.0283168
1621      WRITE(6,36)ROIN1,PEAK1
1622      RETURN
1623
1624 21  FORMAT(10X,"TIME",6X," FLOW",11X,"TIME",6X," FLOW",11X,"TIME",

```

```

1625      &6X,"FLOW",11X,"TIME",6X,"FLOW",11X,"TIME",6X,"FLOW"/11X,"HRS",
1626      &7X," MS",12X,"HRS",7X," MS",12X,"HRS",7X," MS",12X,"HRS",
1627      &7X," MS",12X,"HRS",7X," MS")
1628 25    FORMAT(10X,"TIME",6X," FLOW",11X,"TIME",6X," FLOW",11X,"TIME",
1629      &6X,"FLOW",11X,"TIME",6X,"FLOW",11X,"TIME",6X,"FLOW"/11X,"HRS",
1630      &7X," CFS ",10X,"HRS",7X," CFS ",10X,"HRS",7X," CFS ",10X,"HRS",
1631      &7X," CFS ",10X,"HRS",7X," CFS ")
1632 30    FORMAT (5(5X,F10.3,F10.3))
1633 40    FORMAT( 'PRINT HYD',T21,'ID=',I1,T29,'NPK=',I1)
1634 36    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CUMEC  "/10X,"PEAK
1635      &DISCHARGE RATE =",F10.0,"CMS"////)
1636 35    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CF  "/10X,"PEAK
1637      &DISCHARGE RATE=",F10.0,"CFS"////)
1638 14    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CF  "/10X,"PEAK
1639      &ELEVATION      =",F10.0," FEET"////)
1640 15    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0,"CUMEC"/10X,"PEAK
1641      &ELEVATION      =",F10.0,"METRES"////)
1642 11    FORMAT(10X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",
1643      & 6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV"/11X,"HRS",
1644      & 7X,"M ",12X,"HRS",7X,"M ",12X,"HRS",7X,"M ",12X,"HRS",
1645      & 7X,"M ",12X,"HRS",7X,"M ")
1646 9      FORMAT(10X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",
1647      & 6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV"/11X,"HRS",
1648      & 7X,"FT",12X,"HRS",7X,"FT",12X,"HRS",7X,"FT",12X,"HRS",
1649      & 7X,"FT",12X,"HRS",7X,"FT")
1650 28    FORMAT(F10.3)
1651      END
1652 C
1653 C
1654 C -----
1655 C
1656      SUBROUTINE HPLLOT
1657 C
1658 C -----
1659 C
1660 C      THIS SUBROUTINE PLOTS EITHER 1 OR 2 HYDROGRAPHS ON A SET OF AXIS
1661 C
1662      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
1663      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
1664 C
1665      DIMENSION CFS(300)
1666      ID1=DATA(1)
1667      ID2=DATA(2)
1668      DATA ZERO, PLUS, BLANK, DASH, DOT/'0','+',',','-','.'/
1669      MAX=121
1670      J=1
1671 C      ARE THERE 1 OR 2 HYDROGRAPHS
1672      IF (ID2) 1,1,2
1673 C      DETERMINE HIGHEST PEAK IF 2 HYDROGRAPHS
1674 1      QMAX=PEAK(ID1)
1675      GO TO 14
1676 2      IF (PEAK(ID1)-PEAK(ID2)) 3,3,4
1677 3      QMAX=PEAK(ID2)
1678      GO TO 5
1679 4      QMAX=PEAK(ID1)
1680 C      IF 2 HYDROGRAPHS DETERMINE LARGEST DT AND INTERPOLATE OTHER
1681 C      HYDROGRAPH IF NECESSARY
1682 5      IF (DT(ID1)-DT(ID2)) 6,13,7

```

```

1683 6      L=ID1
1684      K=ID2
1685      GO TO 8
1686 7      L=ID2
1687      K=ID1
1688 8      M=IEND(L)
1689      TID=DT(K)
1690      TIDH=0.
1691      DO 11 I=2,M
1692      TIDH=TIDH+DT(L)
1693      IF (TID-TIDH) 10,9,11
1694 9      J=J+1
1695      CFS(J)=OCFS(I,L)
1696      TID=TID+DT(K)
1697      GO TO 11
1698 10     J=J+1
1699      CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
1700      &)
1701      TID=TID+DT(K)
1702 11     CONTINUE
1703      IEND(L)=J
1704      DT(L)=DT(K)
1705      DO 12 I=2,J
1706 12     OCFS(I,L)=CFS(I)
1707 13     IF (IEND(ID1)-IEND(ID2)) 14,14,15
1708 14     M=IEND(ID1)
1709      GO TO 16
1710 15     M=IEND(ID2)
1711 16     XM = M
1712 C      DETERMINE TIME SCALE
1713      XSCL = XM / 120.
1714      YSCL=QMAX/50.
1715 C      PLOT HYDROGRAPHS
1716      DO 20 I=1,MAX
1717 20     CFS(I)=DASH
1718      IF(ICODE.EQ.0)GO TO 49
1719      WRITE(6,50)
1720 50     FORMAT(T2,"FLOW RATE (CMS)")
1721      QMAX1=QMAX*0.02832
1722      WRITE(6,41)QMAX1,DOT,(CFS(I),I=1,MAX),DOT
1723      GO TO 51
1724 49     WRITE(6,48)
1725 48     FORMAT(T2,"FLOW RATE (CFS)")
1726      WRITE(6,41)QMAX,DOT,(CFS(I),I=1,MAX),DOT
1727 51     Q1=QMAX
1728      J1=10
1729      DO 37 J=1,50
1730      IF (J-J1) 23,21,23
1731 21     DO 22 I=1,MAX
1732 22     CFS(I)=DASH
1733      GO TO 25
1734 23     DO 24 I=1,MAX
1735 24     CFS(I)=BLANK
1736 25     Q2=Q1-YSCL
1737      DO 28 I=2,M
1738      IF (OCFS(I,ID1)-Q1) 26,27,28
1739 26     IF (OCFS(I,ID1)-Q2) 28,28,27
1740 27     XI = I

```

```

1741      K = XI / XSCL + 1.
1742      CFS(K)=ZERO
1743 28    CONTINUE
1744      WRITE (6,44) DOT,(CFS(I),I=1,MAX),DOT
1745      IF (ID2) 34,34,29
1746 29    DO 18 I = 1, MAX
1747 18    CFS(I) = BLANK
1748      DO 33 I=1,M
1749      IF (OCFS(I,ID2)-Q1) 30,31,33
1750 30    IF (OCFS(I,ID2)-Q2) 33,33,31
1751 31    XI = I
1752      K = XI / XSCL + 1.
1753      CFS(K)=PLUS
1754 33    CONTINUE
1755      WRITE (6,42) (CFS(I),I=1,MAX)
1756 34    IF (J-J1) 36,35,36
1757 35    J1=J1+10
1758      IF(ICODE.EQ.0)GO TO 52
1759      QD=Q2*0.02832
1760      WRITE(6,43)QD
1761      GO TO 36
1762 52    WRITE(6,43)Q2
1763 36    Q1=Q2
1764 37    CONTINUE
1765      CFS(1)=TIME
1766      DTT=DT(ID1)*(XM - 1.) / 12.
1767 C      PUT TIME ARRAY IN CFS AND WRITE TIME SCALE
1768      DO 38 I=2,13
1769 38    CFS(I)=CFS(I-1)+DTT
1770      WRITE (6,45) (CFS(I),I=1,13)
1771      WRITE (6,46)
1772      RETURN
1773 C
1774 41    FORMAT(1X,F7.0,123A1)
1775 42    FORMAT(1H+,8X,121A1)
1776 43    FORMAT (1H+,F7.0)
1777 44    FORMAT(8X,123A1)
1778 45    FORMAT(T3,13F10.2)
1779 46    FORMAT(49X,'TIME HOURS' ///)
1780      END
1781 C
1782 C
1783 C -----
1784 C
1785      SUBROUTINE ADHYD
1786 C
1787 C -----
1788 C
1789 C      THIS SUBROUTINE ADDS TWO HYDROGRAPHS.
1790 C
1791      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
1792      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
1793
1794      ID=DATA(1)
1795      NHD=DATA(2)
1796      ID1=DATA(3)
1797      ID2=DATA(4)
1798      KK=0

```

```

1799 C    CHECK ARRAYS ARE NOT EMPTY
1800      IF(IEND(ID1).EQ.0.OR.IEND(ID2).EQ.0)THEN
1801        WRITE(6,101)
1802      IF(IEND(ID1).EQ.0)THEN
1803        K=ID2
1804      GOTO 29
1805      ENDIF
1806      K=ID1
1807 29    DO 30 I=1,IEND(K)
1808 30      OCFS(I,ID)=OCFS(I,K)
1809      PEAK(ID)=PEAK(K)
1810      ROIN(ID)=ROIN(K)
1811      DA(ID)=DA(K)
1812      IEND(ID)=IEND(K)
1813      DT(ID)=DT(K)
1814      GOTO 27
1815      ENDIF
1816      IF(DT(ID1).EQ.DT(ID2))GOTO 31
1817      IF(ID.NE.ID1.AND.ID.NE.ID2)GOTO 31
1818 C    DANGER OF CONFUSION IN DT, ALTER ID TO KK
1819 32    DO 33 KK=1,6
1820      IF(KK.EQ.ID1)GOTO 33
1821      IF(KK.EQ.ID2)GOTO 33
1822      GOTO 34
1823 33    CONTINUE
1824 34    ID=KK
1825 31    PEAK(ID) = 1.
1826 C    MAKE TIME INCREMENTS EQUAL IF NOT EQUAL. USE SMALLER INCREMENT
1827      IF (DT(ID1)-DT(ID2)) 1,3,2
1828 1      DT(ID)=DT(ID1)
1829      L=ID1
1830      K=ID2
1831      GO TO 6
1832 2      DT(ID)=DT(ID2)
1833      L=ID2
1834      K=ID1
1835      GO TO 6
1836 3      DT(ID)=DT(ID1)
1837      IF (IEND(ID1)-IEND(ID2)) 4,4,5
1838 4      M3=IEND(ID1)
1839      K1=ID2
1840      IEND(ID)=IEND(ID2)
1841      GO TO 18
1842 5      M3=IEND(ID2)
1843      K1=ID1
1844      IEND(ID)=IEND(ID1)
1845      GO TO 18
1846 C    DETERMINE DURATIONS OF FLOW
1847 6      XIEND1=IEND(ID1)-1
1848      XIEND2=IEND(ID2)-1
1849      DUR1=XIEND1*DT(ID1)
1850      DUR2=XIEND2*DT(ID2)
1851      IF (DUR1-DUR2) 7,8,8
1852 7      IEND(ID)=DUR2/DT(ID)+1.
1853      M3=DUR1/DT(ID)+1.
1854      K1=ID2
1855      GO TO 9
1856 8      IEND(ID)=DUR1/DT(ID)+1.

```

```

1857      M3=DUR2/DT(ID)+1.
1858      K1=ID1
1859  9      IF (IEND(ID)-300) 11,11,10
1860 10      IEND(ID)=300
1861 11      M2=IEND(K)
1862      J=1
1863  C      INTERPOLATE ONE HYDROGRAPH IF NECESSARY
1864      TIDH=0.
1865      TID=DT(ID)
1866      DO 15 I=2,M2
1867      TIDH=TIDH+DT(K)
1868 12      IF (TIDH-TID) 15,13,14
1869 13      J=J+1
1870      DATA (J)=OCFS(I,K)
1871      TID=TID+DT(ID)
1872      IF (J-300) 15,16,16
1873 14      J=J+1
1874      DATA (J)=OCFS(I-1,K)+((TID-TIDH+DT(K))/DT(K))*(OCFS(I,K)-OCFS(I-1,
1875      &K))
1876      TID=TID+DT(ID)
1877      IF (J-300) 12,16,16
1878 15      CONTINUE
1879 16      IEND(K)=J
1880      DO 17 I=2,J
1881 17      OCFS(I,K)=DATA(I)
1882 18      M=IEND(ID)
1883      RO = 0.
1884  C      ADD HYDROGRAPHS
1885  C      CONVERT KK TO ID
1886      IF(KK.GT.0)THEN
1887      ID=DATA(1)
1888      DT(ID)=DT(L)
1889      ENDIF
1890      DO 20 I=1,M3
1891      OCFS(I,ID)=OCFS(I,ID1)+OCFS(I,ID2)
1892      IF (OCFS(I,ID) - PEAK(ID)) 20,20,19
1893 19      PEAK(ID) = OCFS(I,ID)
1894 20      RO = RO + OCFS(I,ID)
1895      DA(ID)=DA(ID1)+DA(ID2)
1896      IF (PEAK(ID) - PEAK(K1)) 21,22,22
1897 21      PEAK(ID) = PEAK(K1)
1898 22      IF (M-M3) 25,25,23
1899 23      M3 = M3 + 1
1900      DO 24 I = M3,M
1901      OCFS(I,ID) = OCFS (I,K1)
1902 24      RO = RO + OCFS(I,ID)
1903 25      ROIN(ID) =RO * DT(ID)*3600
1904 27      RETURN
1905  C
1906 28      FORMAT( 'ADD HYD',T21,'ID=',I1,T29,' HYD NO=',I3,T45,' ID I=',I1,
1907      &T60,' ID II=',I1)
1908 101      FORMAT(T10,'ONE HYDROGRAPH BEING ADDED IS ZERO')
1909      END
1910  C
1911  C
1912  C -----
1913  C
1914      SUBROUTINE SRC

```

```

1915 C
1916 C -----
1917 C
1918 C   THIS SUBROUTINE STORES AN ELEVATION - END AREA - FLOW TABLE.
1919 C
1920 C   COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
1921 C   &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
1922 C
1923 C   COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
1924 C   &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
1925 C   &TQ(20,6),CC(20),LL(6),INRC,LRC
1926 C
1927 C   ID=DATA(1)
1928 C   VS=DATA(2)
1929 C   VALLEY SECTION NUMBER
1930 C   REMAINING DATA ARE ELEVATION, AREA, AND FLOW FOR EACH POINT OF
1931 C   THE RATING CURVE
1932 C   IF(KCODE.EQ.0)GO TO 2
1933 C   J=3
1934 C   DO 3 I=1,20
1935 C     DATA(J)=DATA(J)/0.3048
1936 C     DATA(J+1)=DATA(J+1)/0.093
1937 C     DATA(J+2)=DATA(J+2)/0.02832
1938 C     J=J+3
1939 C   CONTINUE
1940 C   EMIN=DATA(3)
1941 C   J=3
1942 C   DO 1 I=1,20
1943 C     DEEP(I,ID)=DATA(J)-EMIN
1944 C     A(I,ID)=DATA(J+1)
1945 C     Q(I,ID)=DATA(J+2)
1946 C     J=J+3
1947 C   CONTINUE
1948 C   RETURN
1949 C   END
1950 C
1951 C
1952 C -----
1953 C
1954 C   SUBROUTINE CMFRC
1955 C
1956 C -----
1957 C
1958 C   THIS SUBROUTINE COMPUTES THE DISCHARGE END-AREA ELEVATION
1959 C   RELATIONSHIP FOR A VALLEY SECTION.
1960 C
1961 C   IF MUTIPLE ROUTING INVOKED -
1962 C   COMPUTES SEPARATE RATING CURVES FOR EACH SEGMENT
1963 C   ALSO % FLOW AT EACH ELEVATION FOR SEPARATE SEGMENTS
1964 C
1965 C   IF MOMENTUM EXCHANGE INVOKED
1966 C   COMPUTES THE RATING CURVE USING REDEFINED AREA AND WETTED
1967 C   PERIMETER CALCULATION - KNIGHT TECHNIQUE
1968 C   FOUR OPTIONS
1969 C
1970 C   NOTE --- MOMENTUM EXCHANGE REDEFINITIONS USED "ONLY "
1971 C   FOR OUT-OF-BANK ELEVATIONS
1972 C

```

```

1973 C    MULTIPLE ROUTING AND MOMENTUM EXCHANGE OPERATES INDEPENDANTLY
1974 C
1975      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
1976      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
1977 C
1978      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
1979      &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
1980      &TQ(20,6),CC(20),LL(6),INRC,LRC
1981      DIMENSION MMM(6),W(6),XM(70)
1982      INTEGER COUNT
1983 C
1984 C    NEW VARIABLES USED
1985 C    MM1-1 LEFT FLOODPLAIN ADJACENT TO CHANNEL
1986 C    MM2-2 CHANNEL
1987 C    MM3-3 RIGHT FLOODPLAIN ADJACENT TO CHANNEL
1988 C    W WIDTH OF CHANNEL SEGMENT
1989 C    H CHANNEL BANKFULL DEPTH (WHERE ADJACENT SEGMENT IS INUNDATED)
1990 C    XM MINIMUM ELEVATION IN SEGMENT
1991 C
1992      ID=DATA(1)
1993 C    STORAGE LOCATION NUMBER. (1-6)
1994      IT=DATA(2)
1995 C    MOMENTUM EXCHANGE INCLUSION
1996      MR=DATA(3)
1997 C    MULTIPLE ROUTING INCLUSION
1998      VS=DATA(4)
1999 C    VALLEY SECTION IDENTIFICATION NUMBER.
2000      NSEG=DATA(5)
2001 C    NUMBER OF SEGMENTS IN THE VALLEY SECTION.
2002      IF(KCODE.EQ.0)GOTO 1
2003      DATA(6)=DATA(6)/0.3048
2004      DATA(7)=DATA(7)/0.3048
2005 1      ELO=DATA(6)
2006      LMAX=DATA(7)
2007 C    MAXIMUM ELEVATION FOR COMPUTATIONS.
2008      SLOPE1=DATA(8)
2009 C    CHANNEL SLOPE.
2010      SLOPE2=DATA(9)
2011 C    FLOODPLAIN SLOPE.
2012      DIF=(EMAX-ELO)/16.
2013      C(1,ID)=ELO
2014      DO 2 I=2,20
2015 2      C(I,ID)=C((I-1),ID)+DIF
2016 C    SET AREA AND DISCHARGE ARRAYS = 0.
2017      DO 3 K=1,NSEG
2018      W(K)=0
2019 3      MMM(K)=0
2020      IF(MR.GT.0.0)THEN
2021      DO 4 I=1,20
2022      A(I,ID)=0
2023 4      Q(I,ID)=0
2024      ELSE
2025      DO 5 J=10*ID+1,10*ID+NSEG
2026      DO 5 I=1,20
2027      A(I,ID)=0
2028      Q(I,J)=0
2029      TQ(I,ID)=0
2030 5      PERQ(I,J)=0

```

```

2031      ENDIF
2032      J=10
2033      COUNT=0
2034 C      READ N VALUES AND SEGMENT BORDER POINTS.
2035      DO 6 I=1,NSEG
2036      SEGN(I)=DATA(J)
2037      IF(SEGN(I).LT.0)COUNT=1
2038      IF(KCODE.NE.0)DATA(J+1)=DATA(J+1)/0.3048
2039      DIST(I)=DATA(J+1)
2040 6      J=J+2
2041      IF(COUNT.EQ.0)WRITE(6,7)
2042 C      REMAINING DATA ITEMS ARE DISTANCES AND ELEVATIONS.
2043      IF(KCODE.EQ.0)GOTO 8
2044      DO 9 I=J,310
2045 9      DATA(I)=DATA(I)/0.3048
2046 8      JJJ=J
2047      DO 10 I=1,NSEG
2048 11      J=J+2
2049      IF (DATA(J)-DIST(I))11,12,12
2050 12      ISG(I) = J + 1
2051 10      CONTINUE
2052 C      COMPUTE CHANNEL WIDTH
2053      IF(IT.LT.1.AND.COUNT.EQ.1)WRITE(6,13)
2054      IT=2
2055      IF(COUNT.EQ.1.AND.IT.GT.0)WRITE(6,14)IT
2056      J=10
2057      DO 15 K=1,NSEG
2058      SELEV=0
2059      IF(SEGN(K))16,17,17
2060 17      IF(K.EQ.1)GOTO 21
2061      IF(SEGN(K-1))18,18,18
2062 18      GOTO 15
2063 21      IF(SEGN(K+1))20,15,15
2064 C      LEFT HAND FLOODPLAIN
2065 20      M*M(K)=1
2066      GOTO 15
2067 C      CHANNEL
2068 16      IF(K.EQ.1.OR.K.EQ.NSEG)THEN
2069      WRITE(6,70)
2070      IT=2
2071      GOTO 68
2072      ENDIF
2073      W(K)=(DATA(ISG(K)-1)-DATA(ISG(K-1)-1))/2
2074      M*M(K)=2
2075      GOTO 15
2076 C      RIGHT HAND FLOODPLAIN
2077 19      M*M(K)=3
2078 15      CONTINUE
2079 C      COMPUTE DISCHARGES AND END AREAS FOR EACH SEGMENT.
2080 68      DO 22 K=1,NSEG
2081      J=JJJ
2082      JJJ1=JJJ+1
2083      IF (SEGN(K)) 23,23,24
2084 23      SLOPE=SLOPE1
2085      GO TO 25
2086 24      SLOPE=SLOPE2
2087 25      SLPN=1.486*SLOPE**.5
2088 C      COMPUTE AREA AND DISCHARGE FOR SEGMENT.

```

```

2089      DO 26 I=2,20
2090      AA=0.
2091      P=0.
2092      J=JJJ-1
2093      DEP2=0.
2094 27      J=J+2
2095          IF (J-ISG(K)) 28,28,29
2096 29      IF(AA-.001)26,26,37
2097 28      IF(DATA(J)-C(I,ID)) 32,27,27
2098 32      DEP1=C(I,ID)-DATA(J)
2099          IF (J-JJJ1) 33,33,34
2100 34      XL=DATA(J-1)-DATA(J-3)
2101          DEP3=ABS(DATA(J-2)-DATA(J))
2102          XL=XL*DEP1/DEP3
2103 35      AA=AA+XL*(DEP1+DEP2)/2.
2104          P=P+SQRT((DEP1-DEP2)**2+XL**2)
2105 33      DEP2=DEP1
2106          J=J+2
2107          IF (J-ISG(K)) 36,36,37
2108 36      IF (DATA(J)-C(I,ID)) 38,38,39
2109 38      DEP1=C(I,ID)-DATA(J)
2110          XL=DATA(J-1)-DATA(J-3)
2111          GOTO 35
2112 39      DEP1=0
2113          XL=DATA(J-1)-DATA(J-3)
2114          DEP3=ABS(DATA(J-2)-DATA(J))
2115          XL=XL*DEP2/DEP3
2116          AA=AA+XL*(DEP1+DEP2)/2.
2117          P=P+SQRT((DEP1-DEP2)**2+XL**2)
2118          DEP2=0.
2119          GOTO 27
2120 C      CHECK IF MOMENTUM EXCHANGE INVOKED
2121 C      CHECK IF OUT-OF-BANK
2122 37      IF(MMM(K).LT.1)GOTO 40
2123          IF(MMM(K).EQ.1)GOTO 41
2124          IF(MMM(K).EQ.3)GOTO 42
2125 C      CHANNEL
2126 C      CHECK OUT-OF-BANK
2127          IF(C(I,ID).LE.DATA(ISG(K)).AND.C(I,
2128 &ID).LE.DATA(ISG(K-1)))GOTO40
2129          H=(DATA(ISG(K))+DATA(ISG(K-1)))/2-ELO
2130          IF(IT.LE.2)GOTO 43
2131 C      AREA METHOD 3 AND 4
2132          AA=AA/2+(W(K)*H)
2133 43      IF(IT.EQ.1.OR.IT.EQ.3)THEN
2134 C      WETTED PERIMETER METHOD 1 AND 3
2135          P=P-(2*(C(I,ID)-C((I-1),ID)))+2*H
2136          ENDIF
2137          IF(IT.EQ.4)THEN
2138 C      WETTED PERIMETER METHOD4
2139          P=P+(2*((C(I,ID)-C((I-1),ID))**2+W(K)**2)**0.5)
2140          ENDIF
2141          GOTO 40
2142 C      LEFT HAND FLOODPLAIN
2143 41      L=K+1
2144          GOTO 44
2145 C      RIGHT HAND FLOODPLAIN
2146 42      L=K-1

```

```

2147 44 IF(IT.LT.3)GOTO 45
2148 AA=AA+((C(I,ID)-C((I-1),ID))*W(L)/2)
2149 45 IF(IT.EQ.2)THEN
2150 P=P+(C(I,ID)-C((I-1),ID))
2151 ENDF
2152 40 R=AA/P
2153 C REMOVED ALOGGRITHM BELOW
2154 C SGN=SEGN(K) - .0025*R
2155 IF(SEGN(K).LT.0.0)THEN
2156 SGN=-SEGN(K)
2157 GOTO 46
2158 ENDF
2159 SGN=SEGN(K)
2160 46 IF(MR.LT.1) GOTO 47
2161 C COMPUTE SEPARATE R.CURVES FOR EACH SEGMENT
2162 II=10*ID+K
2163 Q(I,II)=Q(I,II)+AA*R**.6667*SLPN/SGN
2164 A(I,II)=A(I,II)+AA
2165 GOTO 26
2166 C ADD DISCHARGES AND AREAS FOR ALL SEGMENTS TO OBTAIN TOTALS FOR
2167 C VALLEY SECTION.
2168 47 Q(I,ID)=Q(I,ID)+AA*R**.6667*SLPN/SGN
2169 A(I,ID)=A(I,ID)+AA
2170 26 CONTINUE
2171 JJJ=J-3
2172 22 CONTINUE
2173 IF(ICODE.EQ.0)GO TO 48
2174 IF(MR.LT.1)GOTO 49
2175 C FIND MIN ELEV IN EACH SEGMENT
2176 J=13+2*NSEG
2177 DO 50 M=1,NSEG
2178 IF(M.EQ.1)THEN
2179 XM(10*ID+M)=DATA(ISG(M))
2180 GOTO 51
2181 ENDF
2182 XM(10*ID+M)=DATA(ISG(M-1))
2183 51 IF(J.GT.ISG(M))GOTO 50
2184 IF(DATA(J).LT.XM(10*ID+M))THEN
2185 XM(10*ID+M)=DATA(J)
2186 ENDF
2187 J=J+2
2188 GOTO 51
2189 50 CONTINUE
2190 DO 52 J=10*ID+1,10*ID+NSEG
2191 WRITE(6,30)J
2192 DO 52 I=1,20
2193 C1=C(I,ID)*0.3048
2194 A1=A(I,J)*0.093
2195 Q1=Q(I,J)*0.02832
2196 DEEP(I,J)=C(I,ID)-XM(J)
2197 IF(DEEP(I,J).LT.0)THEN
2198 DEEP(I,J)=0
2199 ENDF
2200 WRITE(6,55) C1,A1,Q1
2201 52 CONTINUE
2202 GOTO 53
2203 49 WRITE(6,31)VS
2204 DO 54 I=1,20

```

```

2205      C1=C(I,ID)*0.3048
2206      A1=A(I,ID)*0.093
2207      Q1=Q(I,ID)*0.02832
2208      DEEP(I,ID)=C(I,ID)-ELO
2209      WRITE(6,55)C1,A1,Q1
2210  54    CONTINUE
2211      RETURN
2212  48    IF(MR.LT.1)GOTO 56
2213  C      FIND MIN ELEV IN SEGMENT
2214      J=13+2*NSEG
2215      DO 57 M=1,NSEG
2216      IF(M.EQ.1)THEN
2217      XM(10*ID+M)=DATA(1SG(M))
2218      GOTO 58
2219      ENDIF
2220      XM(10*ID+M)=DATA(1SG(M-1))
2221  58    IF(J.GT.1SG(M))GOTO 57
2222      IF(DATA(J).LT.XM(10*ID+M))THEN
2223      XM(10*ID+M)=DATA(J)
2224      ENDIF
2225      J=J+2
2226      GOTO 58
2227  57    CONTINUE
2228      DO 59 J=10*ID+1,10*ID+NSEG
2229      WRITE(6,60) J
2230      DO 59 I=1,20
2231      DEEP(I,J)=C(I,ID)-XM(J)
2232      IF(DEEP(I,J).LT.0)THEN
2233      DEEP(I,J)=0
2234      ENDIF
2235      WRITE(6,61) C(I,ID),A(I,J),Q(I,J)
2236  59    CONTINUE
2237      GOTO 53
2238  56    WRITE(6,62)VS
2239      DO 63 I=1,20
2240      DEEP(I,ID)=C(I,ID)-ELO
2241      WRITE (6,55) C(I,ID),A(I,ID),Q(I,ID)
2242  63    CONTINUE
2243      RETURN
2244  C      COMPUTE % FLOW IN EACH SEGMENT
2245  53    DO 64 I=10*ID+1,10*ID+NSEG
2246      DO 64 J=1,20
2247      TQ(J,ID)=TQ(J,ID)+Q(J,I)
2248  64    CONTINUE
2249      DO 65 I=1,NSEG
2250      II=10*ID+I
2251      WRITE(6,66)II
2252      DO 65 J=1,20
2253      PERQ(J,II)=Q(J,II)/TQ(J,ID)
2254      IF(J.EQ.1) THEN
2255      PERQ(J,II)=0
2256      ENDIF
2257      IF(PERQ(2,II).EQ.1.0)THEN
2258      PERQ(1,II)=1.0
2259      ENDIF
2260      IF(ICODE.GT.0)THEN
2261      C(J,ID)=C(J,ID)*0.3048
2262      ENDIF

```

```

2263      WRITE(6,67) C(J,ID),PERQ(J,II)
2264      IF(ICODE.GT.0)THEN
2265        C(J,ID)=C(J,ID)/0.3048
2266      ENDIF
2267 65    CONTINUE
2268      RETURN
2269
2270 62    FORMAT(T42,'RATING CURVE VALLEY SECTION ',F5.1/T46,'WATER',T56,
2271      &'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',T66,'RATE'/T46,'ELEV',
2272      &T56,'SQ FT',T66,'CFS')
2273 60    FORMAT(T42,'RATING CURVE FOR SEGMENT ',I5.1/T46,'WATER',T56,
2274      &'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',T66,'RATE'/T46,'ELEV',
2275      &T56,'SQ FT',T66,'CFS')
2276 31    FORMAT(T42,'RATING CURVE VALLEY SECTION',F5.1/T46,
2277      &'WATER',T56,'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',
2278      &T66,'RATE'/T46,'ELEV',T56,'SQ M',T66,'CMS')
2279 30    FORMAT(T42,'RATING CURVE FOR SEGMENT ',I5.1/T46,
2280      &'WATER',T56,'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',
2281      &T66,'RATE'/T46,'ELEV',T56,'SQ M',T66,'CMS')
2282 61    FORMAT (40X,F10.2,2F10.1)
2283 55    FORMAT (40X,3F10.2)
2284 66    FORMAT (T42,'% DISCHARGE IN SEGMENT ',I2.1/T46,
2285      &'ELEV',T55,'PERCENT')
2286 67    FORMAT(40X,F10.2,2F10.3)
2287 70    FORMAT(T10,'ERROR - NEED FLD PLAIN SEG BOTH SIDES OF CHANNEL',
2288      &'- USING METHOD 2')
2289 14    FORMAT(T42,'MOMENTUM EXCHANGE METHOD',1X,I5.1)
2290 13    FORMAT(T10,'NO MOMENTUM EXCHANGE ROUTINE SELECTED',/T10,
2291      &'- USING METHOD 2')
2292 7     FORMAT(T10,'NO CHANNEL SEGMENTS SPECIFIED ',/T10,
2293      &' - USING METHOD 2')
2294      END
2295 C
2296 C
2297 C -----
2298 C
2299      SUBROUTINE STT
2300 C
2301 C -----
2302
2303 C      THIS SUBROUTINE STORES A DEPTH - FLOW - TRAVEL TIME TABLE.
2304
2305      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
2306      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
2307
2308      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
2309      &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
2310      &TQ(20,6),CC(20),LL(6),INRC,LRC
2311
2312      ID=DATA(1)
2313      REACH=DATA(2)
2314      MET1=DATA(5)
2315      IF(MET1.EQ.0)GO TO 2
2316      DATA(3)=DATA(3)/0.3048
2317      J=8
2318      DO 3 I=1,19
2319        DATA(J)=DATA(J)/0.3048
2320        DATA(J+1)=DATA(J+1)/0.02832

```

```

2321 3      J=J+3
2322 2      XL=DATA(3)
2323        SLOPE=DATA(4)
2324        DIST(ID)=SLOPE*XL
2325        J=6
2326        DO 1 I=1,19
2327          DP(I)=DATA(J)
2328          SCFS(I)=DATA(J+1)
2329          CC(I)=DATA(J+2)
2330 1      J=J+3
2331        RETURN
2332        END
2333 C
2334 C
2335 C -----
2336 C
2337        SUBROUTINE CMPTT
2338 C
2339 C -----
2340
2341 C      THIS SUBROUTINE COMPUTES THE TRAVEL TIME AT GIVEN
2342 C      DISCHARGE RATES
2343 C
2344 C      IF MULTIPLE ROUTING INVOKED, COMPUTES TRAVEL TIME TABLE FOR
2345 C      THE ONE SEGMENT SPECIFIED - OTHERWISE ALL SEGMENTS TOGETHER
2346 C
2347 C      NOTE -- FOR MULTIPLE ROUTINE NEED TO REPEAT THIS ROUTINE AND ROUTE
2348 C      FOR "EACH" SEGMENT
2349
2350        COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
2351        &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
2352
2353        COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
2354        &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
2355        &TQ(20,6),CC(20),LL(6),INRC,LRC
2356
2357        DIMENSION CFS(300)
2358
2359        ID=DATA(1)
2360        REACH=DATA(2)
2361        NOVS=DATA(3)
2362        IF(KCODE.NE.0)DATA(4)=DATA(4)/0.3048
2363        XL=DATA(4)
2364        SLOPE=DATA(5)
2365        DIST(ID)=SLOPE*XL
2366        XLD36 = XL / 3600.
2367        MR=DATA(6)
2368 C      MULTIPLE ROUTING
2369        INRC=DATA(7)
2370 C      RATING CURVE AT TOP OF REACH
2371        LRC=DATA(8)
2372 C      RATING CURVE AT DOWNSTREAM END
2373 C      ZERO ARRAYS
2374        IF(NOV.GT.2.AND.MR.GT.0)THEN
2375          WRITE(6,40)
2376          RETURN
2377        ENDIF
2378        DO 1 J=1,20

```

```

2379      DATA (J)=0.
2380  1      CFS(J)=0.
2381  C      MULTIPLE ROUTING COMPUTATION
2382      IF(MR.LT.1)GOTO 30
2383      WRITE(6,37)
2384      ID1=INRC
2385      GOTO 2
2386  30      ID1=1
2387  C      FIND RATING CURVE WITH SMALLEST MAXIMUM FLOW RATE
2388  2      QMIN=Q(20,ID1)
2389      MIN=ID1
2390      GO TO 4
2391  31      ID1=LRC
2392      GOTO 32
2393  3      ID1=ID1+1
2394  32      IF (QMIN-Q(20,ID1)) 4,4,2
2395  4      IF(MR.LT.1)GOTO33
2396      IF(ID1.EQ.INRC)GOTO 31
2397      IF(ID1.EQ.LRC)GOTO5
2398      WRITE(6,=)'ERROR only two r.curves allowed for m.routing'
2399      RETURN
2400  33      IF (ID1-NOVS) 3,5,5
2401  5      I=1
2402      LL(ID)=0
2403  C      SET SCFS ARRAY EQUAL TO Q ARRAY OF LOWEST RATING CURVE
2404      DO 6 J=2,20
2405      SCFS(I)=Q(J,MIN)
2406      IF(MR.LT.1)GOTO 6
2407      IF(PERQ(J,MIN).LT.0.001)THEN
2408      LL(ID)=LL(ID)+1
2409      ENDIF
2410  6      I=I+1
2411  C      COMPUT END AREA AND DEPTH
2412      DO 9 ID1=1,NOVS
2413      IF(MR.LT.1) GOTO 34
2414      IF(ID1.EQ.1)THEN
2415      ID1=INRC
2416      GOTO 34
2417      ENDIF
2418      ID1=LRC
2419  34      M=1+LL(ID)
2420      N=2+LL(ID)
2421      DO 36 J=M,19
2422      DO 7 I=N,20
2423      IF (Q(I,ID1)-SCFS(J)) 7,17,8
2424  7      CONTINUE
2425  17      DATA (J)=A(I,ID1)+DATA(J)
2426      CFS(J)=DEEP(I,ID1)+CFS(J)
2427      GO TO 36
2428  8      XY=(SCFS(J)-Q(I-1,ID1))/(Q(I,ID1)-Q(I-1,ID1))
2429      DATA (J)=A(I-1,ID1)+XY*(A(I,ID1)-A(I-1,ID1))+DATA(J)
2430      CFS(J)=DEEP(I-1,ID1)+XY*(DEEP(I,ID1)-DEEP(I-1,ID1))+CFS(J)
2431  36      CONTINUE
2432      IF(MR.LT.1) GOTO 9
2433      IF(ID1.EQ.LRC)GOTO 35
2434      ID1=1
2435  9      CONTINUE
2436  35      XNOVS=NOVS

```

```

2437      IF(ICODE.EQ.0)GO TO 19
2438      WRITE(6,20)REACH
2439      GO TO 21
2440 19     WRITE(6,13)REACH
2441      ID1=MIN
2442 21     DO 10 I=M,19
2443      AVAREA = DATA (I) / XNOVS
2444      DP (I) = CFS(I) / XNOVS
2445      S = AVAREA * XLD36
2446      CC(I)=S/SCFS(I)
2447      IF(SCFS(I).EQ.0) THEN
2448      CC(I)=0
2449      ENDIF
2450      IF(ICODE.EQ.0)GO TO 24
2451      DP1=DP(I)*0.3048
2452      SCFS1=SCFS(I)*0.02832
2453      WRITE(6,14)DP1,SCFS1,CC(I)
2454      GO TO 10
2455 24     WRITE(6,14)DP(I),SCFS(I),CC(I)
2456 10     CONTINUE
2457      RETURN
2458  C
2459 13     FORMAT(1H0,T46,'TRAVEL TIME TABLE'/T54,'REACH',F5.1//T46,'WATER',T
2460      &56,'FLOW',T65,'TRAVEL'/T46,'DEPTH',T56,'RATE',T66,'TIME'/T46,'FEET
2461      &',T56,'CFS',T66,'HRS')
2462 14     FORMAT (40X,F10.2,F10.0,F10.2)
2463 20     FORMAT(1H0,T46,'TRAVEL TIME TABLE'/T54,'REACH',F5.1//T46,'WATER',T
2464      &56,'FLOW',T65,'TRAVEL'/T46,'DEPTH',T56,'RATE',T66,'TIME'/T46,
2465      &"METER",T56,'CMS',T66,'HRS')
2466 37     FORMAT(1H0,T24,'MULTIPLE ROUTING INVOKED')
2467 40     FORMAT(T10,'ONLY TWO RATING CURVES REQUIRED FOR MULTIPLE ROUTING')
2468      END
2469  C
2470  C
2471  C -----
2472  C
2473      SUBROUTINE ROUTE
2474  C
2475  C -----
2476
2477  C      THIS SUBROUTINE ROUTES A HYDROGRAPH THROUGH A REACH WITH THE
2478  C      NEW VSC METHOD OF FLOOD ROUTING. THIS METHOD ACCOUNTS FOR THE
2479  C      VARIATION IN WATER SURFACE SLOPE.
2480  C
2481  C      IF MULTIPLE ROUTING INVOKED - COMPUTES PROPORTION INFLOW
2482  C      FOR ONE SEGMENT
2483  C
2484  C      BUT ----- ONLY ROUTES ONES SEGMENT AT A TIME
2485  C      REPEAT TRAVEL TIME TABLE AND ROUTE COMMANDS FOR EACH SEGMENT
2486  C      AND ADD OUTFLOWS
2487
2488      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
2489      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
2490
2491      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
2492      &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
2493      &TQ(20,6),CC(20),LL(6),INRC,LRC
2494

```

```

2495      DIMENSION DOCFS(300,6),CFS(300)
2496
2497  C      New variables used
2498  C      DOCFS copy inflow array (preserve original OCFS)
2499  C      P percentage of OCFS (multiple routing)
2500  C      DTDI copy inflow time increment (preserves DT(IDH))
2501  C      TM increments DT
2502      ID=DATA(1)
2503      NHD=DATA(2)
2504      IDH=DATA(3)
2505      DT(ID)=DATA(4)
2506      DTDI=DT(IDH)
2507      DA(ID)=DA(IDH)
2508      M=IEND(IDH)
2509      MR=DATA(5)
2510  C      CHECK: IF M.ROUTING ID.NE.IDH
2511      IF(MR.GT.0.AND.ID.EQ.IDH)THEN
2512      WRITE(6,*)'ERROR - FOR M.ROUTING ID MUST NOT BE SAME AS IDH'
2513      RETURN
2514      ENDIF
2515  C      MULTIPLE ROUTING INCLUDED
2516  C      SET UP DUMMY ARRAY
2517      DO 51 I=1,IEND(IDH)
2518 51      DOCFS(I,IDH)=OCFS(I,IDH)
2519  C      MULTIPLE ROUTING
2520  C      COMPUTE DISTRIBUTED FLOW IN SEGMENT
2521      IF(MR.LT.1)GOTO 50
2522      II=INRC/10
2523      NN=INRC-10*II
2524      IF(ICODE.GT.0)GOTO 53
2525      WRITE(6,60)NN
2526      GOTO 55
2527 53      WRITE(6,61)NN
2528 55      TM=TIME-DTDI
2529      JJJJ=0
2530      DO 52 J=1,IEND(IDH)
2531      TM=TM+DTDI
2532      DO 56 K=2,20
2533      IF(DOCFS(J,IDH)-TQ(K,II))57,58,56
2534 56      CONTINUE
2535      WRITE(6,*)'FAILED - RATING CURVE EXCEEDED'
2536      RETURN
2537 58      DOCFS(J,IDH)=PERQ(J,INRC)*DOCFS(J,IDH)
2538      GOTO 54
2539 57      ST=C(K,II)-(((TQ(K,II)-DOCFS(J,IDH))*(C(K,II)-C((K-1),II)))/(TQ
2540      &(K,II)-TQ(K-1,II)))
2541      P=PERQ(K,INRC)-(((C(K,II)-ST)*(PERQ(K,INRC)-PERQ((K-1),
2542      &INRC)))/(C(K,II)-C((K-1),II)))
2543      DOCFS(J,IDH)=P*DOCFS(J,IDH)
2544 54      IF(DOCFS(J,IDH).EQ.0)THEN
2545      JJJJ=JJJJ+1
2546      IF(JJJJ.EQ.IEND(IDH))THEN
2547      WRITE(6,*)' NO FLOW IN SEGMENT'
2548      RETURN
2549      ENDIF
2550      GOTO 52
2551      ENDIF
2552      IF(ICODE.GT.0)THEN

```

```

2553      DOCFS(J, IDH)=DOCFS(J, IDH)*0.0283168
2554      ENDIF
2555      WRITE(6, 59) TM, P, DOCFS(J, IDH)
2556      IF (ICODE.GT.0) THEN
2557          DOCFS(J, IDH)=DOCFS(J, IDH)/0.0283168
2558      ENDIF
2559 52      CONTINUE
2560 C      IF ID AND IDH ARE EQUAL, ADD 1 TO IDH
2561 50      IF (MR.LT.1) THEN
2562          LL(ID)=0
2563      ENDIF
2564          IF (ID-IDH) 3, 1, 3
2565 1          IDORG=IDH
2566          IDH=IDH+1
2567          DO 2 I=1, M
2568 2          DOCFS(I, IDH)=DOCFS(I, IDH-1)
2569          DT(IDH)=DT(IDH-1)
2570          PEAK(IDH)=PEAK(IDH-1)
2571 3          NERRT=0
2572          PEAK(ID) = 1.
2573          RO = 0.
2574          N=19
2575          OCFS(1, ID)=0.
2576          S = 0.
2577          T1 = CC(1)
2578          J=1
2579          GUES = 1.
2580          CFS(1)=0.
2581 C      IF ROUTING INTERVAL IS NOT EQUAL TO TIME INCREMENT OF INFLOW
2582 C      HYDROGRAPH, INTERPOLATE
2583          IF (DT(ID)-DT(IDH)) 8, 15, 4
2584 4          TID=DT(ID)
2585          TIDH=0.
2586          DO 7 I=2, M
2587          TIDH=TIDH+DT(IDH)
2588          IF (TID-TIDH) 6, 5, 7
2589 5          J=J+1
2590          CFS(J)=DOCFS(I, IDH)
2591          TID=TID+DT(ID)
2592          GO TO 7
2593 6          J=J+1
2594          CFS(J)=DOCFS(I-1, IDH)+((TID-TIDH+DT(IDH))/DT(IDH))*(DOC
2595          &FS(I, IDH)-DOCFS(I-1, IDH))
2596          TID=TID+DT(ID)
2597 7          CONTINUE
2598          GO TO 13
2599 8          TIDH=0.
2600          TID=DT(ID)
2601          DO 12 I=2, M
2602          TIDH=TIDH+DT(IDH)
2603 9          IF (TIDH-TID) 12, 10, 11
2604 10         J=J+1
2605          CFS(J)=DOCFS(I, IDH)
2606          TID=TID+DT(ID)
2607          IF (J-300) 12, 13, 13
2608 11         J=J+1
2609          CFS(J)=DOCFS(I-1, IDH)+((TID-TIDH+DT(IDH))/DT(IDH))*(DOC
2610          &FS(I, IDH)-DOCFS(I-1, IDH))

```

```

2611      TID=TID+DT(ID)
2612      IF (J-300) 9,13,13
2613 12     CONTINUE
2614 13     DT(IDH)=DT(ID)
2615      M=J
2616      DO 14 I=2,M
2617 14     DOCFS(I,IDH)=CFS(I)
2618 C      IF INFLOW IS ZERO, SO IS OUTFLOW
2619 15     DO 16 L=2,M
2620      IF (DOCFS(L,IDH)) 16,16,49
2621 16     OCFS(L,ID)=0.
2622 C      ROUTE
2623 49     DATA (L-1) = 0.
2624      DO 42 I=L,300
2625      IF (I-M) 18,18,17
2626 17     DOCFS(I,IDH)=DOCFS(I-1,IDH)*.9
2627 18     AVIN=(DOCFS(I,IDH)+DOCFS(I-1,IDH))/2.
2628      SIA = AVIN + S
2629      J=1
2630 C      DETERMINE DEPTH AND TRAVEL TIME OF INFLOW
2631      IF (DOCFS(I,IDH)-SCFS(1+LL(ID))) 19,23,20
2632 19     DI2 = (DOCFS(I,IDH) / SCFS(1+LL(ID))) * DP(1+LL(ID))
2633      TI2 = CC(1+LL(ID))
2634      GO TO 25
2635 20     JJJ=2
2636      IF(LL(ID).GT.0)THEN
2637      JJJ=LL(ID)+2
2638      ENDIF
2639      DO 21 J=JJJ,N
2640      IF (DOCFS(I,IDH)-SCFS(J)) 24,23,21
2641 21     CONTINUE
2642      IF (NERRT) 22,22,36
2643 22     WRITE (6,46)
2644      NERRT=1
2645      GO TO 36
2646 23     DI2=DP(J)
2647      TI2 = CC(J)
2648      GO TO 25
2649 24     RATIO=(DOCFS(I,IDH)-SCFS(J-1))/(SCFS(J)-SCFS(J-1))
2650      DI2=DP(J-1)+RATIO*(DP(J)-DP(J-1))
2651      TI2=CC(J-1)+RATIO*(CC(J)-CC(J-1))
2652 25     DO 35 IT=1,10
2653      J=1
2654 C      DETERMINE DEPTH AND TRAVEL TIME OF OUTFLOW
2655      IF (GUES-SCFS(1+LL(ID))) 26,29,27
2656 26     DO2 = (GUES / SCFS(1+LL(ID))) * DP(1+LL(ID))
2657      TO2 = CC(1+LL(ID))
2658      GO TO 31
2659 27     DO 28 J=JJJ,N
2660      IF (GUES-SCFS(J)) 30,29,28
2661 28     CONTINUE
2662      J=N
2663 29     DO2=DP(J)
2664      TO2=CC(J)
2665      GO TO 31
2666 30     RATIO=(GUES-SCFS(J-1))/(SCFS(J)-SCFS(J-1))
2667      DO2=DP(J-1)+RATIO*(DP(J)-DP(J-1))
2668      TO2=CC(J-1)+RATIO*(CC(J)-CC(J-1))

```

```

2669 C      FIND WATER SURFACE SLOPE
2670 31      DDD=DIST(ID)/(DIST(ID)+DI2-DO2)
2671        IF (DDD-.01) 32,32,33
2672 32      GUES=OCFS(I-1,IDH)
2673        GO TO 35
2674 33      T2 = .5 * (TI2 + TO2)
2675        T2=T2*SQRT(DDD)
2676        T = T1 + T2
2677 C      COMPUTE ROUTING COEFFICIENT
2678        COEF =(2. * DT(ID)) / (T+DT(ID))
2679        O2 = COEF * SIA
2680        TRY1 = GUES
2681        RATIO=O2/(GUES+.1E-20)
2682        DIFF=ABS(1.-RATIO)
2683 C      TEST FOR CONVERGENCE
2684        IF (DIFF-0.001) 37,37,34
2685 34      GUES=O2
2686 35      CONTINUE
2687        OCFS(I,ID)=DATA(I-1)*SIA
2688        DATA(I) = DATA(I-1)
2689        WRITE (6,47) I,OCFS(I,ID)
2690        GO TO 38
2691 36      OCFS(I,ID)=DATA(I-1)*SIA
2692        DATA(I) = DATA(I-1)
2693        GO TO 38
2694 37      OCFS(I,ID)=O2
2695        DATA (I) = COEF
2696 C      COMPUTE NEW STORAGE
2697 38      S = SIA - OCFS(I,ID)
2698        T1 = T2
2699        RO = RO + OCFS (I,ID)
2700        IF (OCFS(I,ID) - OCFS(I-1,ID)) 39,40,40
2701 39      IF(OCFS(I,ID) -1.) 43,43,42
2702 40      IF(OCFS(I,ID) - PEAK(ID)) 42,42,41
2703 41      PEAK(ID)=OCFS (I,ID)
2704 42      CONTINUE
2705        I=300
2706 43      IEND(ID)=I
2707        ROIN(ID) = RO*DT(ID)*3600
2708 C      COMPUTE % VOLUME OUTFLOW/VOLUME INFLOW
2709        IF(IDORG.NE.0)IDH=IDORG
2710        DIFF1=ABS(ROIN(ID)/ROIN(IDH))*100
2711        WRITE(6,62)ID,DIFF1,IDH
2712        DT(IDH)=DTDT
2713        RETURN
2714 C
2715 46      FORMAT(1H0, 'TRAVEL TIME TABLE EXCEEDED')
2716 47      FORMAT(T10,'PROBLEM FAILED TO CONVERGE AFTER 10 ITERATIONS. CONVERG
2717 &ENCE WAS FORCED.'/T20,'OUTFLOW NUMBER = ',I4,'RATE = ',F10.2)
2718 60      FORMAT(1H0,T40,'INFLOW FOR SEGMENT',I5.1/T30,'HOURS',T40,
2719 &'PERCENT',T52,'CFS')
2720 61      FORMAT(1H0,T40,'INFLOW FOR SEGMENT',I5.1/T30,'HOURS',
2721 &T40,'PERCENT',T52,'C/MECS')
2722 59      FORMAT(25X,F10.3,2F10.3,3F10.3)
2723 62      FORMAT(T6,'CHECK- VOLUME OF OUTFLOW HYDROGRAPH',I2,' IS',F10.3,
2724 S'X OF INFLOW HYDROGRAPH',2I2)
2725        END
2726 C

```

```

2727 C
2728 C -----
2729 C
2730 SUBROUTINE RESVO
2731 C
2732 C -----
2733
2734 C THIS SUBROUTINE ROUTES A HYDROGRAPH THROUGH A RESERVOIR WITH THE
2735 C STORAGE-INDICATION METHOD.
2736
2737 COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
2738 &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
2739
2740 COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
2741 &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
2742 &TQ(20,6),CC(20),LL(6),INRC,LRC
2743
2744 ID=DATA(1)
2745 NHD=DATA(2)
2746 IDH=DATA(3)
2747 NERES=0
2748 DT(ID)=DT(IDH)
2749 RO = 0.
2750 DA(ID)=DA(IDH)
2751 PEAK(ID) = 1.
2752 J=1
2753 I=4
2754 C REMAINING DATA ARE FLOW AND STORAGE VALUES
2755 IF(KCODE.EQ.0)GO TO 25
2756 DATA(I)=DATA(I)/0.02832
2757 DATA(I+1)=DATA(I+1)/1.21968
2758 25 SCFS(J)=DATA(I)
2759 STORE1=DATA(I+1)*12.1
2760 STORE=STORE1
2761 C COMPUTE STORAGE COEFFICIENT ARRAY C
2762 1 CC(J)=(SCFS(J)/2.)+(STORE/DT(ID))
2763 I=I+2
2764 J=J+1
2765 IF (I-20) 2,2,3
2766 2 IF(KCODE.EQ.0)GO TO 26
2767 DATA(I)=DATA(I)/0.02832
2768 DATA(I+1)=DATA(I+1)/1.21968
2769 26 SCFS(J)=DATA(I)
2770 STORE=DATA(I+1)*12.1
2771 IF (SCFS(J)-.001) 3,3,1
2772 3 N=J-1
2773 OCFS(1,ID)=0.
2774 S=STORE1/DT(ID)
2775 C ROUTE
2776 DO 15 I=2,150
2777 IF (I-IEND(IDH)) 5,5,4
2778 4 OCFS(I,IDH)=0.0
2779 5 AVIN=(OCFS(I,IDH)+OCFS(I-1,IDH))/2.
2780 SIA=S+AVIN
2781 C DETERMINE PROPER C
2782 DO 6 J=1,N
2783 IF (SIA-CC(J)) 10,9,6
2784 6 CONTINUE

```

```

2785      IF (NERES) 7,7,8
2786  7    WRITE (6,19)
2787      NERES=1
2788  8    RESC=SCFS(N)/CC(N)
2789  C    COMPUT OUTFLOW
2790      OCFS(I,ID)=RESC*SIA
2791      GO TO 11
2792  9    OCFS(I,ID)=SCFS(J)
2793      GO TO 11
2794 10    OCFS(I,ID)=SCFS(J-1)+((SIA-CC(J-1))/(CC(J)-CC(J
2795      & -1)))*(SCFS(J)-SCFS(J-1))
2796  C    DETERMINE NEW STORAGE
2797 11    S=SIA-OCFS(I,ID)
2798      RO = RO + OCFS(I,ID)
2799      IF (OCFS(I,ID)-OCFS(I-1,ID)) 12,13,13
2800 12    IF (OCFS(I,ID)-1.) 16,16,15
2801 13    IF(OCFS(I,ID) - PEAK(ID)) 15,15,14
2802 14    PEAK(ID) = OCFS(I,ID)
2803 15    CONTINUE
2804      I=150
2805 16    IEND(ID)=I
2806      ROIN(ID) = RO * DT(ID)*3600
2807      RETURN
2808  C
2809 19    FORMAT (1H0,33HSTORAGE-DISCHARGE TABLE EXCEEDED.)
2810      END
2811  C
2812  C
2813  C =====
2814  C
2815      SUBROUTINE ERROR
2816  C
2817  C =====
2818
2819  C This subroutine determines the error standard deviation and the peak flow
2820  C error for 2 hydrographs (original program retained).
2821  C Assumes that measured is ID1
2822  C In addition, 10 other measures of goodness of fit are calculated.
2823  C All indices are printed out in metric units.
2824
2825      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
2826      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
2827
2828      real CFS(300)
2829      ID1=L..IA(1)
2830      ID2=DATA(2)
2831      SSE=0.
2832      WRITE(6,21)
2833 21    FORMAT(1H0,T33,'TIME',T55,'FLOW 1',T76,
2834      & 'FLOW 2',T95,'ERROR'/T34,
2835      & 'HRS',T57,'CMS',T78,'CMS',T97,'CMS')
2836
2837 22    J=1
2838  C If the time increments are not equal, interpolate.
2839
2840      IF (DT(ID1)-DT(ID2)) 1,8,2
2841  1    L=ID1
2842      K=ID2

```

```

2843      GO TO 3
2844 2     L=ID2
2845      K=ID1
2846 3     M=IEND(L)
2847      TID=DT(K)
2848      TIDH=0.
2849      DO 6 I=2,M
2850          TIDH=TIDH+DT(L)
2851          IF (TID-TIDH) 5,4,6
2852 4     J=J+1
2853          CFS(J)=OCFS(I,L)
2854          TID=TID+DT(K)
2855          GO TO 6
2856 5     J=J+1
2857          CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
2858      &)
2859          TID=TID+DT(K)
2860 6     CONTINUE
2861          IEND(L)=J
2862          DT(L)=DT(K)
2863          DO 7 I=2,J
2864 7     OCFS(I,L)=CFS(I)
2865 8     IF (IEND(ID1)-IEND(ID2)) 9,9,10
2866 9     M=IEND(ID1)
2867          GO TO 11
2868 10    M=IEND(ID2)
2869 11    T2=TIME
2870
2871      IF (KCODE.EQ.0)THEN
2872          DO 997 I=1,M
2873              OCFS(I,ID1)=OCFS(I,ID1)*.02832
2874 997      OCFS(I,ID2)=OCFS(I,ID2)*.02832
2875      ENDIF
2876
2877  C Determine error - original method
2878
2879      DO 12 I=1,M
2880          ERR=OCFS(I,ID1)-OCFS(I,ID2)
2881          WRITE(6,16)T2,OCFS(I,ID1),OCFS(I,ID2),ERR
2882 16      FORMAT (6X,F12.3,3F12.0)
2883 25      T2=T2+DT(ID1)
2884
2885  C Sum of squares of error
2886
2887 12     SSE=SSE+ERR*ERR
2888      XM=M
2889
2890  C Error variance
2891
2892      EVAR=SSE/XM
2893
2894  C Error standard deviation
2895
2896      ESDEV=SQRT(EVAR)
2897
2898  C Percent error for peak discharge
2899
2900      ERPK=ABS(PEAK(ID1)-PEAK(ID2))

```

```

2901      PCTER=(ERPK/PEAK(ID1))*100.
2902
2903      C Other goodness of fit calculations...
2904
2905      SUM01=0.
2906      SUM0=0.
2907      SUM1=0.
2908      SUM2=0.
2909      SUM3=0.
2910      SUM4=0.
2911      SUM5=0.
2912      SUM6=0.
2913      SUM7=0.
2914      SUM8=0.
2915      SUM9=0.
2916      SUM10=0.
2917      SUM11=0.
2918      SUM12=0.
2919
2920      DO 77 I=1,M
2921          ERR=OCFS(I,ID1)-OCFS(I,ID2)
2922          IF(OCFS(I,ID1).EQ.0.0.AND.OCFS(I,ID2).NE.0.0)THEN
2923              LOGERR=ALOG(OCFS(I,ID2))
2924          ELSE IF(OCFS(I,ID1).NE.0.0.AND.OCFS(I,ID2).EQ.0.0)THEN
2925              LOGERR=ALOG(OCFS(I,ID1))
2926          ELSE IF(OCFS(I,ID1).EQ.0.0.AND.OCFS(I,ID2).EQ.0.0)THEN
2927              LOGERR=0.
2928          ELSE
2929              LOGERR=ALOG(OCFS(I,ID1))-ALOG(OCFS(I,ID2))
2930          ENDIF
2931          SUM0=OCFS(I,ID1)+SUM0
2932          SUM01=OCFS(I,ID2)+SUM01
2933          SUM1=ERR+SUM1
2934          SUM2=ERR**2+SUM2
2935          SUM3=LOGERR**2+SUM3
2936          IF(OCFS(I,ID1).EQ.0.)OCFS(I,ID1)=1.
2937          SUM4=((ERR/OCFS(I,ID1))**2)+SUM4
2938      77  CONTINUE
2939
2940      DO 13 I=2,M
2941          DIFF1=OCFS(I,ID1)-OCFS(I-1,ID1)
2942          DIFF2=OCFS(I,ID2)-OCFS(I-1,ID2)
2943          SUM5=((DIFF1-DIFF2)**2)+SUM5
2944          SUM7=DIFF1+SUM7
2945          IF(DIFF1.EQ.0.)DIFF1=1.
2946          SUM6=((DIFF1-DIFF2)/DIFF1)**2)+SUM6
2947      13  CONTINUE
2948
2949
2950      SIMMEAN=SUM01/M
2951      OBSMEAN=SUM0/M
2952      DIFFM1=SUM7/M
2953
2954      DO 14 I=2,M
2955          SUM8=((OCFS(I,ID1)-OCFS(I-1,ID1))-DIFFM1)**2)+SUM8
2956          SUM9=((OCFS(I,ID1)-OCFS(I-1,ID1))/DIFFM1-1)**2)+SUM9
2957      14  CONTINUE
2958

```

```

2959      DO 73 I=1,M
2960          SUM10=((OCFS(I, ID1)-OBSMEAN)**2)+SUM10
2961          SUM11=((OCFS(I, ID1)/OBSMEAN)-1)**2)+SUM11
2962          SUM12=((OCFS(I, ID2)-SIMMEAN)**2)+SUM12
2963 73      CONTINUE
2964
2965      SDM=SQRT(SUM10/(M-1))
2966      SDS=SQRT(SUM12/(M-1))
2967
2968      DO 115 I=1,M
2969 115      SUM13=((OCFS(I, ID1)-OBSMEAN)/SDM)*((OCFS(I, ID2)-
2970 &      SIMMEAN)/SDS)+SUM13
2971
2972
2973      OF1=SUM1
2974      OF2=SUM2
2975      OF3=SUM3
2976      OF4=SUM4
2977      OF5=SUM5
2978      OF6=SUM6
2979      OF7=SUM2/SUM10
2980      OF8=SUM4/SUM11
2981      OF9=SUM5/SUM8
2982      OF10=SUM6/SUM9
2983      AM=M
2984      OF11=(1./AM)*SUM13
2985
2986      WRITE(6,95)
2987 95      FORMAT(1H0,10X,'-----')
2988      WRITE(6,50)
2989 50      FORMAT(15X,' MEASURES OF FIT ' '//)
2990      WRITE(6,91)
2991 91      FORMAT(10X,'-----')
2992      WRITE(6,51)OF1
2993 51      FORMAT(10X,'SUM OF ERRORS          ',F20.5)
2994      WRITE(6,52)OF2
2995 52      FORMAT(10X,'OLSQ                      ',F20.5)
2996      WRITE(6,53)OF3
2997 53      FORMAT(10X,'LOG LSQ                    ',F20.5)
2998      WRITE(6,54)OF4
2999 54      FORMAT(10X,'RELATIVE ERROR              ',F20.5)
3000      WRITE(6,55)OF5
3001 55      FORMAT(10X,'ABS ERROR - DIFF          ',F20.5)
3002      WRITE(6,56)OF6
3003 56      FORMAT(10X,'REL ERROR - DIFF          ',F20.5)
3004      WRITE(6,57)OF7
3005 57      FORMAT(10X,'ABS ERROR/VAR              ',F20.5)
3006      WRITE(6,58)OF8
3007 58      FORMAT(10X,'REL ERROR/VAR              ',F20.5)
3008      WRITE(6,59)OF9
3009 59      FORMAT(10X,'ABS ERROR(diff)/VAR        ',F20.5)
3010      WRITE(6,60)OF10
3011 60      FORMAT(10X,'REL ERROR(diff)/VAR        ',F20.5)
3012      WRITE(6,61)OF11
3013 61      FORMAT(10X,'PEARSONS r                ',F20.5)
3014      WRITE(6,92)ESDEV
3015 92      FORMAT(10X,'ERR STANDARD DEV          ',F20.5)
3016      WRITE(6,93)PCTER

```

```

3017 93  FORMAT(10X,'PEAK Q ERROR          ',F20.5)
3018      WRITE(6,96)
3019 96  FORMAT(10X,'-----')
3020
3021      WRITE (6,98)
3022 98  FORMAT (//10X,'NOTE:  All indicies are in metric units')
3023
3024      IF (KCODE.EQ.0)THEN
3025          DO 9969 I=1,M
3026              OCFS(I,ID1)=OCFS(I,ID1)/.02832
3027 9969      OCFS(I,ID2)=OCFS(I,ID2)/.02832
3028      ENDIF
3029
3030      RETURN
3031 C
3032      END
3033 C
3034 C
3035 C -----
3036 C
3037      SUBROUTINE SEDT
3038 C
3039 C -----
3040
3041 C      THIS SUBROUTINE COMPUTES THE SEDIMENT YIELD FOR A FLOOD
3042
3043      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
3044      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
3045
3046      ID=DATA(1)
3047      SOIL=DATA(2)
3048      CROP=DATA(3)
3049      CP=DATA(4)
3050      SL=DATA(5)
3051      WRITE(6,*)'** CHECK THIS IS CORRECT AREA',DA(ID)
3052      WRITE(6,*)'ESPECIALLY IF MULTIPLE ROUTING UTILIZED'
3053 C      COMPUTE SEDIMENT YIELD
3054      X=ROIN(ID)*DA(ID)*53.333*PEAK(ID)
3055      SED=95.*X*.56*SOIL*CROP*CP*SL
3056      IF(ICODE.EQ.0)GO TO 5
3057      SED1=SED*0.9072
3058      WRITE(6,6)SED1
3059      GO TO 2
3060 5      WRITE (6,3) SED
3061 2      RETURN
3062 3      FORMAT (10X, 'SEDIMENT YIELD = ', F10.1, ' TONS')
3063 6      FORMAT(10X,"SEDIMENT YIELD=",F10.1,"METRIC TON")
3064      END
3065 C
3066 C
3067 C -----
3068 C
3069      BLOCK DATA
3070 C
3071 C -----
3072
3073 C      BLOCK DATA SUBPROGRAM UZED TO INITIALIZE ZALPHA,CTBLE,ITBLE
3074 C      AND NCOMM.

```

```

3075
3076      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
3077      &MAXNO,NCODE,ICC,NCOMM
3078      DATA ZALPHA/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,
3079      &1H*,1H.,1H.,1H-,1H ,1H ,1H ,1H ,1H /
3080
3081      DATA NCOMM/15/
3082
3083      DATA CTBLE/1HS,1HS,1HC,1HP,1HP,1HA,1HS,1HC,1HS,1HC,1HR,
3084      &1HR,1HE,1HS,1HF,35*1H ,
3085      &1HT,1HT,1HO,1HR,1HL,1HD,1HT,1HO,1HT,1HO,1HO,1HO,1HR,
3086      &1HE,1HI,35*1H ,
3087      &2HAR,2HOR,2HMP,2HIN,2HOT,2HD ,2HOR,2HMP,2HOR,2HMP,
3088      &2HUT,2HUT,2HRO,2HDI,2HNI,35*2H ,
3089      &2HT ,2HE ,2HUT,2HT ,2H H,2HHY,2HE ,2HUT,2HE ,2HUT,
3090      &2HE ,2HE ,2HR ,2HME,2HSH,35*2H ,
3091      &2H ,2HHY,2HE ,2HHY,2HYD,2HD ,2HRA,2HE ,2HTR,2HE ,
3092      &2H ,2HRE,2HAN,2HNT,2H ,35*2H ,
3093      &2H ,2HD ,2HHY,2HD ,2H ,2H ,2HTI,2HRA,2HAV,2HTR,
3094      &2H ,2HSE,2HAL,2H Y,2H ,35*2H ,
3095      &2H ,2H ,2HD ,2H ,2H ,2H ,2HNG,2HTI,2HEL,2HAV,
3096      &2H ,2HRV,2HYS,2HIE,2H ,35*2H ,
3097      &6*2H ,2H C,2HNG,2H T,2HEL,2H ,2HOI,2HIS,2HLD,36*2H ,
3098      &6*2H ,2HUR,2H C,2HIM,2H T,2H ,2HR ,38*2H ,
3099      &6*2H ,2HVE,2HUR,2HE ,2HIM,40*2H ,
3100      &7*2H ,2HVE,2H ,2HE ,40*2H /
3101
3102      DATA ITBLE/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,35*1H ,
3103      &3,310,310,4,2,4,100,310,100,8,7,25,2,5,0,35*1H /
3104      END

```

Literature cited

- Anderson, M.G. (1982), Assessment and implementation of drainage basin runoff models. U.S. Army European Research Office, Final Technical Report, DAJA 37-81-C-0221, 130pp.
- Anderson, M.G. and Howes, S. (1984), Streamflow modelling. U.S. Army European Research Office, Final Technical Report DAJA 37-81-C-0221, 130pp.
- Anderson, M.G., Howes, S., Kneale, P.E. and Shen, J.M. (1985), On soil retention curves and hydrological forecasting in ungauged catchments. Nordic Hydrology, 16, 11-32.
- Anderson, M.G. and Howes, S. (1986), Hillslope hydrology for forecasting in ungauged watersheds. Abrahams, A. (ed.) Hillslope Processes, George Allen and Unwin, 161-186.
- Brakensiek, D.L. and Rawls, W.J. (1983), Use of infiltration procedures for estimating runoff. Paper presented to the United States Department of Agriculture Soil Conservation Service, National Engineering Workshop, Tempe, Arizona, USA, 23pp.
- Campbell, G.S. (1974), A simple method for determining unsaturated conductivity from moisture retention data. Soil Science, 117, 311-314.
- Hillel, D. (1977), Computer Simulation of Soil Water Dynamics, Ottawa: International Development Research Centre, Canada, 214pp.
- Jackson, R.D. (1972), On the calculation of hydraulic conductivity. Soil Science Society America Proceedings, 36, 380-382.
- Knight, D.W. and Hamed, M.E. (1984), Boundary shear in symmetrical channels. Journal of Hydraulic Engineering, Proceedings of the American Society of Civil Engineers, 110, 1412-1430.
- Kunze, R.J., Uehara, G. and Graham, K. (1968), Factors important in the calculation of hydraulic conductivity. Soil Science Society America Proceedings, 32, 760-765.
- Millington, R.J. and Quirk, J.P. (1959), Permeability of porous media. Nature, 183, 387-388.
- Rawls, W.J. Brakensiek, D.L. and Saxton, K.E. (1982), Estimation of soil water properties. Transactions American Society Agricultural Engineers, 24, 1526-1566.
- USDA, SCS, (1972), National Engineering Handbook, Section 4, Hydrology.

Williams, J.R. (1969), Flood routing with variable travel time or variable storage coefficient. Transactions American Society Agricultural Engineers, 12, 100-103.

Williams, J.R. and Hann, R.W. (1972), HYMO - A problem oriented computer language for building hydrologic models. Water Resources Research, 8, 79-86.

Williams, J.R. and Hann, R.W. (1973) 'HYMO - A problem oriented computer language for hydrologic modelling. USDA ARS, report ARS-S-9, 76pp.