United States
Environmental Protection
Agency

Office of
Water Programs Operations
Washington DC 20460 (WH-595)

EPA-430/9-79-004
February 10, 1979

Water

EPA

1978 Needs Survey

Continuous Stormwater Pollution Simulation System– Users Manual

DISTRIBUTION STATEMENT

Additional copies of this document may be purchased from:

National Technical Information Service
Springfield, Virginia 22151
Telephone: 703-557-4650

To obtain a copy of the source deck of the computer program described in this users manual from EPA, contact:

National Technical Information Service
Springfield, Virginia 22151
Telephone: 703-557-4763

or

Mr. Richard Kezer
Facility Requirements Division (WH-595)
Office of Water Program Operations
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460
Telephone: 202-426-4443

1978 NEEDS SURVEY
CONTINUOUS STORMWATER POLLUTION
SIMULATION SYSTEM
USERS MANUAL

Project Officer

Philip H. Graham
Facility Requirements Division
Office of Water Program Operations
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Contract No. 689-01-3993
EPA Report No. 430/9-79-004
FRD Report No. 4

February 10, 1979

CONTENTS

CONTENTS--Continued

TABLES

FIGURES

Figure

ACKNOWLEDGEMENTS

This report was prepared by CH2M HILL, Inc. Michael J. Mara served as project systems analyst and was responsible for development of the computer code. Michael G. Cullum and Norman N. Hatch were instrumental in the formulation of the dissolved lead response portion of the receiving water module. Typing and editorial services were provided by the Gainesville Office Word Processing Center. Ronald L. Wycoff served as project manager and was responsible for overall design of the simulation program.

Chapter 1
INTRODUCTION AND OVERVIEW

The Continuous Storm-water Pollution Simulation System (CSPSS) has been developed for use in the 1978 Facilities Needs Estimate for Control of Pollution from Combined Sewer Overflow (CSO), Category V, and for Urban Storm-water Runoff, Category VI. The model has been applied to 14 selected urban area/receiving water systems and used to estimate the impact of CSO and urban runoff on receiving water quality on a continuous, long-term basis. The three main objectives of these studies are (1) determine if a particular urban area/ receiving water system is presently experiencing a receiving water quality water problem, (2) determine how much of the problem, if any, is due to CSO and urban stormwater runoff, and (3) determine the level of pollutant removal required to achieve selected water quality goals.

SYSTEM STRUCTURE

The Continuous Stormwater Pollution Simulation System is structured as a series of modules, each designed to perform a certain set of hydrologic or water quality computations. These modules are nested; that is, output of one may become input to another. In some cases, more than one option is available to perform a given function, and the system is structured such that additional modules may be developed and added in the future with a minimum of changes to the existing modules.

Basic functions which may be simulated on a continuous basis are listed as follows.

1. Local rainfall.
2. Local runoff.
3. Pollutant washoff.
4. Sewer system infiltration.
5. Storage/treatment.
6. Dry-weather wastewater flow.
7. Receiving water streamflow.
8. Receiving water quality response.

These modules may be executed in logical sequential order to produce the desired simulation. A general flow chart of the simulation system is shown in Figure 1-1.

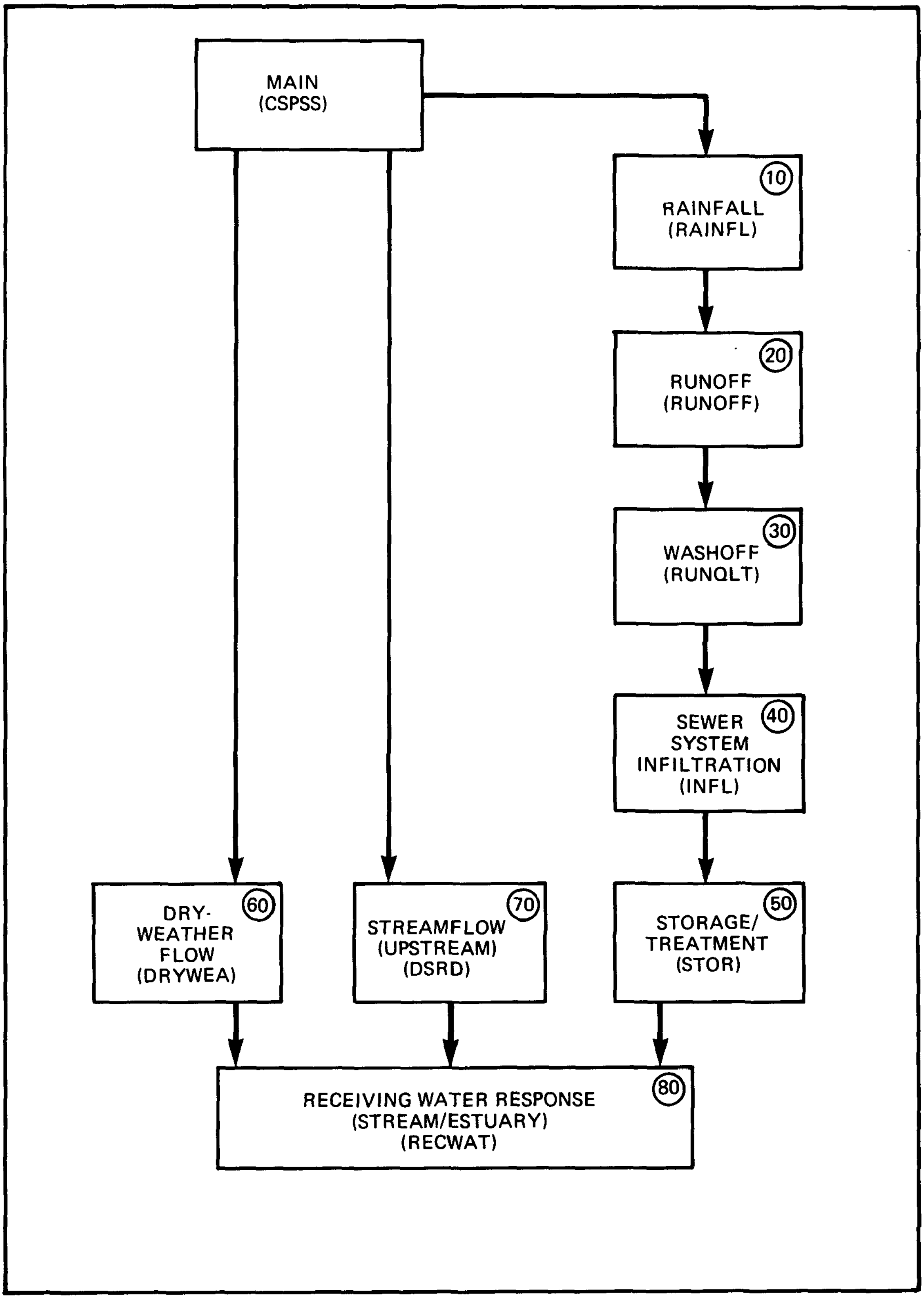

FIGURE 1-1. General flow chart of CSPSS.

The numbers given in each box on Figure 1-1 are module identifiers which are associated with each computation routine. The series 10 through 50 (rainfall through storage/treatment) constitutes the urban runoff and combined sewer system pollution generation simulation. The 60 module and 70 module generate wastewater treatment flow and upstream receiving water flow, respectively. Output from the 10 through 50 series and modules 60 and 70 are input to module 80 which computes receiving water quality resulting from these inputs.

COMPUTATIONAL SEQUENCE

The basic computational sequence involves the generation of a number of arrays. The first array is the rainfall array, developed in the rainfall module (10), which drives the remainder of the urban runoff pollution generation sequence.

The runoff module (20) converts the rainfall array to a runoff array which represents the hydrologic response of the urban area. Either one or two watersheds may be represented, and, therefore, either one or two runoff arrays may be generated.

The washoff module (30) simulates the processes of pollution accumulation and subsequent pollutant washoff for four constituents: suspended solids (SS), five-day biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), and lead (Pb). Thus, four runoff quality arrays are defined for each watershed.

The sewer system infiltration module (40) is optional and applies to sewer systems subject to infiltration-induced overflow. This module will generate an infiltration array based on the recent time history of daily rainfall. Quality arrays for SS, BOD, TKN, and Pb are also developed, and these arrays are combined with the runoff quantity and quality arrays.

The storage/treatment module (50) simulates the effects of a storage/treatment system on the runoff hydrograph and on runoff quality.

The receiving water response module (80) determines the water quality response of the receiving stream immediately downstream of the urban area to all waste sources, including urban stormwater runoff, combined sewer overflow, wastewater treatment plant effluent, and upstream flow. Constituents simulated include suspended solids concentrations, minimum dissolved oxygen concentrations, and total and dissolved lead concentrations.

MAIN PROGRAM

The main program referred to as module CSPSS in Appendix B is a control module which reads the input data, calls the proper subroutine at the proper time, and transfers information from one module to the next. Only basic control data are used directly by main. These data include the number of years in the simulation, the time step of the simulation, the number of urban watersheds in the simulation (1 or 2), a starting value for the random number generator, and a listing of the option modules selected.

Allowable time steps are 4, 6, 8, 12, and 24 hours. A shorter time step could be used with a program modification to increase all array sizes. However, for the purpose of the Needs Survey, a minimum time step of 4 hours was used.

Option selection is specified by a series of two-digit integer numbers which correspond to the module indentifier numbers previously discussed. Option identification numbers which are currently available are defined in Table 1-1.

Currently most major functions have only one computational module available to simulate the process. However, the main program logic is structured such that up to 10 modules can be developed for each function and added to the simulation system with a minimum amount of effort required in recoding the program logic control.

For example, the runoff module (20) is based on the Soil Conservation Service rainfall/runoff equation. If a future user preferred to compute runoff based on Horton's infiltration equation, then a routine could be written to compute the runoff from the infiltration equation based on the watershed infiltration constants and the rainfall array. This module could then be assigned an identifier in the range of 21 to 29. The main program would be modified to accept this new identifier and to call the new runoff computation module when the new identifier is specified.

The main program logic provides a framework for future expansion of CSPSS which could enhance the usefulness and flexibility of the system.

INPUT DATA FOR MAIN

The input data required specifically for the logic control functions of the main program are:

1. Location, i.e., city name.

2. Number of years in simulation.

3. Time step of simulation in hours.

4. Number of watersheds.

Table 1-1
Module Code Definitions

Code	
10	Stochastic rainfall simulator
20	Runoff by Soil Conservation Service rainfall/ runoff technique
30	Watershed pollution accumulation/washoff
40	Excess sewer infiltration
50	Storage/treatment
60	Dry-weather wastewater treatment plant flow
70	Daily streamflow
71	Stochastic monthly streamflow simulator
80	Suspended solids response
81	Suspended solids and dissolved oxygen response
82	Suspended solids, dissolved oxygen, and dissolved lead response

5. Starting value for random number generator.

6. List of options selected.

The starting value for the random number generator should be a 7-digit odd integer. Coding instructions for MAIN may be found in Appendix A.

Chapter 2
RAINFALL SIMULATOR (MODULE 10)

PURPOSE

The purpose of the rainfall simulator is to develop an array of rainfall depths for a period of 1 year which is representative of point rainfall for the urban area under consideration. The rainfall array is developed for the time step used in the simulation (i.e., 4 hours or 24 hours) and preserves certain statistical characteristics of observed rainfall events. It is assumed that all precipitation occurs as rainfall. Snowmelt is not simulated.

Two seasons are defined for the purpose of rainfall simulation, which means that rainfall depths are assumed to belong to one of two different statistical populations, depending on time of occurrence. These two populations may represent a wet season and a dry season or a summer season and a winter season as defined by the user. Certain rainfall statistics for each season must be defined and input by the user.

DEFINITIONS AND ASSUMPTIONS

Rainfall simulation is based on the assumption that adjacent rainfall events are independent and that the time between events, the duration of events, and rainfall depths can be represented by certain standard distribution models. Independence among rainfall events is a function of the time between rainstorms. Therefore, in order to assure independence, a minimum time between storms or interevent time must be defined. The minimum interevent time varies from 8 to 24 hours depending upon the time step chosen, and is discussed further in the last section of this chapter entitled "Input Requirements."

Figure 2-1 is a definition sketch which illustrates the terms used in the simulation. The time between storms (TBS) is defined as the time interval from the end of one rainfall event to the beginning of the next rainfall event, and the duration of the storm (DS) is defined as the time interval from the beginning of rainfall to the end of rainfall within a given event. TBS values and DS values will always be even multiples of the time step (IDT) used in the simulation.

Rainfall depths ($RD_1 \ldots RD_n$) for each time unit within a single rainfall event are developed based on the assumption that adjacent rainfall depths within a single event are interrelated. However, each rainfall event is considered to be independent of all other rainfall events.

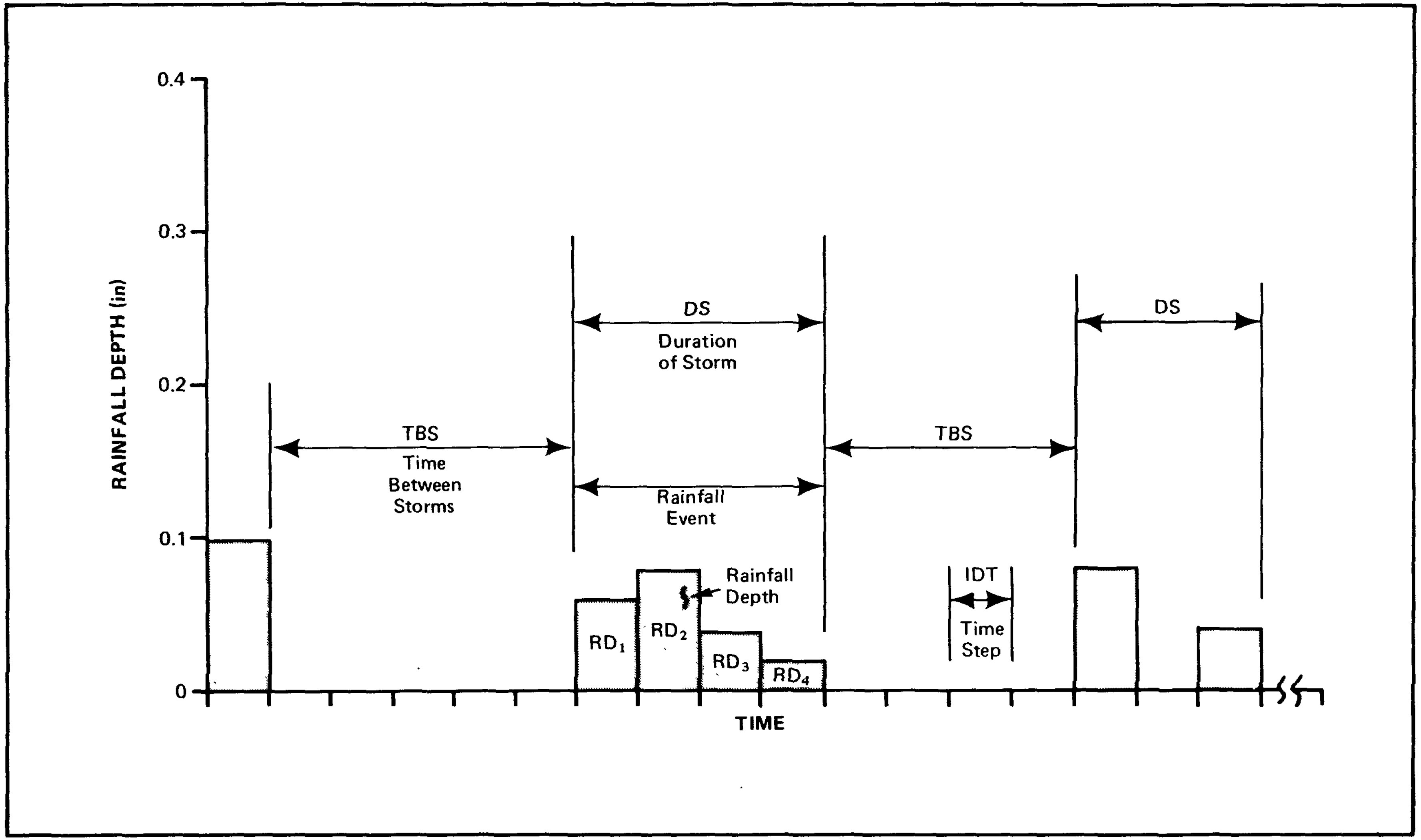

FIGURE 2-1. Rainfall array definition sketch.

MATHEMATICAL MODELS

Synthetic observations of the time between storms and duration of storms (TBS and DS) are generated by Monte Carlo sampling of an exponential distribution. The transformation function is given as follows for TBS (1,2).

$$TBS = -\ln(RN)TBSA \qquad (2\text{-}1)$$

where

- TBS = a random observation of the time between storms in hours.
- RN = a uniformly distributed random number on the interval 0 to 1.0.
- TBSA = the average time between storms in hours for a given season as determined from analysis of a sample rainfall record.

The transformation function used for the duration of storms (DS) is mathematically identical to Equation 2-1. Thus, the distribution for TBS and DS are fully defined by the mean.

Synthetic observations of rainfall depths for each time period within a given event are generated by a two-step procedure. First the rainfall depth for the first time period (RN_1) is generated by Monte Carlo sampling of a log normal distribution. The transformation function is as follows (2).

$$RD_1 = EXP(NV \cdot \sigma_d + RDM) \qquad (2\text{-}2)$$

where

- RD_1 = a random observation of rainfall depth in inches for the first time period of an event.
- NV = normally distributed random variable with a mean of zero and a standard deviation of 1, N(0,1).
- σ_d = log transformation of the standard deviation of rainfall depths for a given season and time interval (IDT).
- RDM = log transformation of the mean of the rainfall depths for a given season and time interval (IDT).

Values for σ_d and RDM are determined from analysis of a sample rainfall record. First the mean (μ_x) and standard deviation (σ_x) are computed from the sample rainfall record. These sample statistics are then transformed to the log normal distribution parameters σ_d and RDM by application of the proper transformation relationship. These parameter transformation relationships are discussed in a subsequent section of this chapter.

Once the rainfall depth for the first time interval of an event (RD_1) has been established, then the rainfall depth for all subsequent time intervals of the same rainfall event ($RD_2 \ldots RD_n$) are computed by application of a first-order Markov model. This procedure is described by the following equations (2,3).

$$y_{i-1} = \ln(RD_{i-1}) \qquad (2\text{-}3)$$

$$y_i = RDM + \rho_d(y_{i-1} - RDM) + NV\sigma_d \sqrt{(1 - \rho_d^2)} \qquad (2\text{-}4)$$

$$RD_i = EXP(y_i) \qquad (2\text{-}5)$$

where

y_{i-1} = the natural logarithm of the preceding rainfall depth RD_{i-1}.

y_i = the natural logrithm of the current rainfall depth RD_i.

ρ_d = log transformation of the correlation coefficient between adjacent rainfall depths (i.e., lag 1 correlation coefficient).

The terms RDM, NV, and σ_d are as previously defined.

Equation 2-4 states that the rainfall depth for time period i, where i is greater than 1, is a function of the previous rainfall depth, the average rainfall depth, and a random process. The random process is a function of the standard deviation of rainfall depths and the correlation coefficient between adjacent rainfall depths. The transformed correlation coefficient, ρ_d, is a weighting factor which determines the relative importance of the dependent, or deterministic, component of the simulation and the independent, or random, component of the simulation. If ρ_d is near 1.0, then all rainfall depths for a given event will be nearly equal to the rainfall depth for the first time period. If ρ_d is near 0.0, then adjacent rainfall depths will approach independence and *Equations 2-4 and 2-5* will approach the Monte Carlo sampling technique given in Equation 2-2.

LOG TRANSFORMATIONS

As previously discussed, the distribution of rainfall depths is assumed to be log-normal. The estimated parameters of a log normal distribution (RDM, σ_d, and ρ_d) cannot be computed directly from a sample of rainfall depths, but are related to the raw data sample statistics by a set of transformation functions.

For convenience, let us define the rainfall data set as a series of observations $x_1, x_2, x_3 \ldots x_n$ and their logarithms as $y_1, y_2, y_3 \ldots y_n$. Then the following parameters are defined for the rainfall data and the log-normal distribution of rainfall depth.

μ_x = mean rainfall depth.

σ_x = standard deviation of rainfall depths.

ρ_x = lag 1 correlation coefficient of rainfall depths.

μ_y = RDM = mean of log-normal distribution model of rainfall depths.

$\sigma_y = \sigma_d$ = standard deviation of log-normal distribution model of rainfall depths.

$\rho_y = \rho_d$ = lag 1 correlation coefficient of logarithms of rainfall depth.

Given μ_x, σ_x, and ρ_x, then μ_y, σ_y, and ρ_y are determined as follows (2,3).

$$\mu_y = \ln \mu_x - \sigma_y^2/2 \qquad (2\text{-}6)$$

$$\sigma_y = \left[\ln\left(\frac{\sigma_x^2}{\mu_x^2} + 1 \right) \right]^{1/2} \qquad (2\text{-}7)$$

$$\rho_y = \frac{\ln[\rho_x \, \mathrm{EXP}(\sigma_y^2) - \rho_x + 1]}{\sigma_y^2} \qquad (2\text{-}8)$$

SIMULATION PROCESS

The rainfall simulation process for one year can be described in 11 steps as follows.

1. Read input data and initialize.

2. Set time equal to zero.

3. Compute parameters of log-normal distribution of rainfall, using Equations 2-6, 2-7, and 2-8.

4. Generate time between storms.

5. Set rainfall depths between storms equal to zero.

6. Determine month and season.

7. Generate duration of storm.

8. Generate depth of rain for each time period of storm.

9. Repeat steps 4 through 8 until annual array is filled.

10. Output annual rainfall summary.

11. Return to main program.

INPUT REQUIREMENTS

Input data required for the rainfall simulation are listed below. Coding instruction are given in Appendix A.

1. Months in season 1.

2. Months in season 2.

3. Mean time between storms in hours for seasons 1 and 2.

4. Mean duration of storms in hours for seasons 1 and 2.

5. μ_x, σ_x, and ρ_x for rainfall depths observed in the selected time interval (IDT) for season 1 and for season 2. Rainfall depths are measured in inches.

The season definition is left to the judgment of the user. However, fairly obvious breakpoints can usually be determined from a bar graph of monthly rainfall. Figure 2-2 is such a bar graph for Des Moines, Iowa. In this case, season 1 is defined as months 1, 2, 3, 11, and 12 (winter) and season 2 is defined as months 4, 5, 6, 7, 8, 9, and 10 (summer). Occasionally there will be some question concerning in which season a month near the breakpoint should be placed. From a practical standpoint, it probably does not matter a great deal which season includes the transitional month.

The choice of time interval (IDT) is also a decision which is influenced by judgment. In general, the choice of a time step should be a function of the dissolved oxygen response of the receiving water. If a given receiving stream responds quickly to

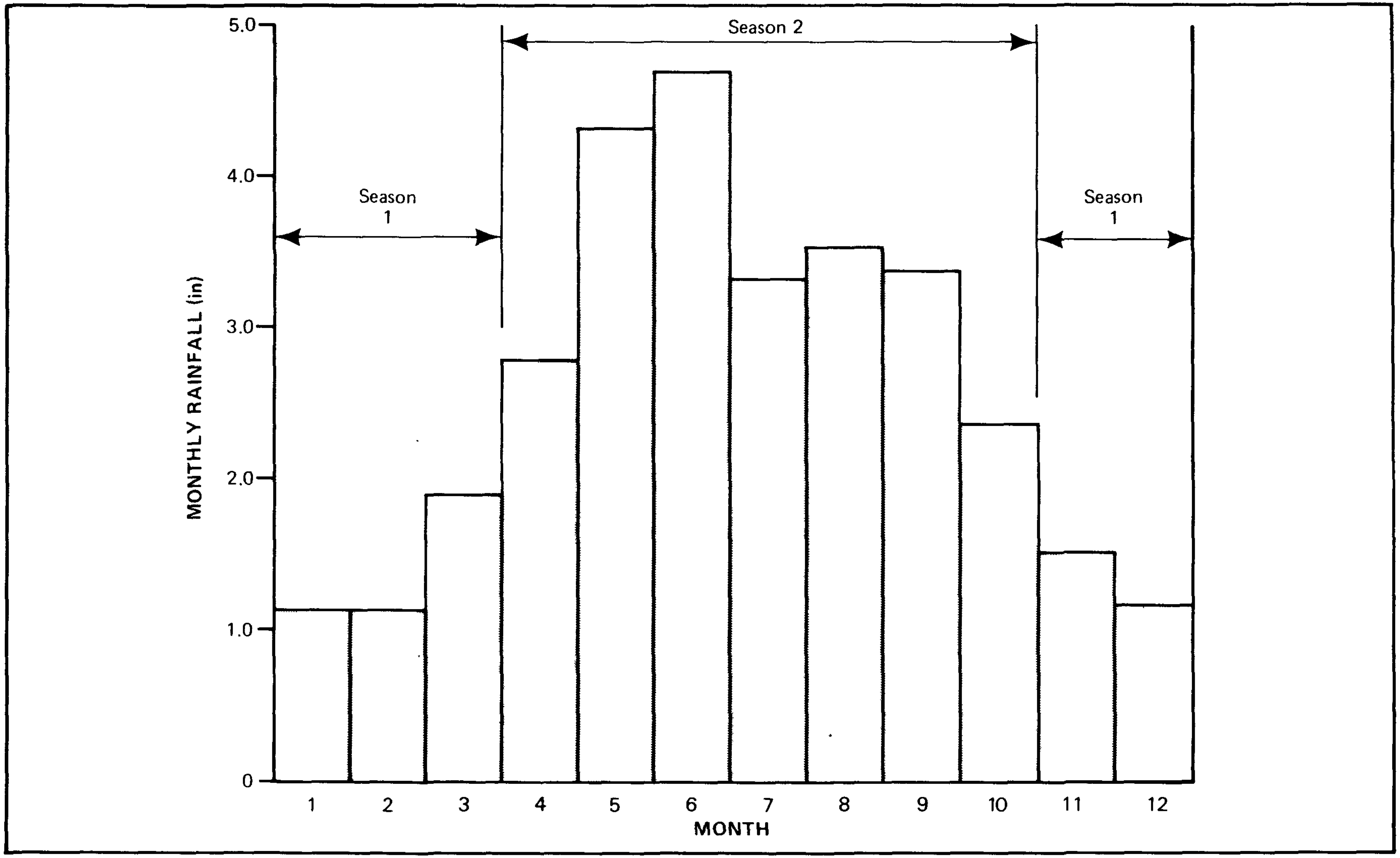

FIGURE 2-2. Monthly rainfall and season definition for Des Moines, Iowa.

wasteloads, then the computation time interval should be short. However, if the receiving water response is sluggish, then a longer time interval is acceptable. For the purpose of the Needs Survey, a 4-hour computation time interval was used on all free flowing freshwater stream systems, and a 24-hour computation time interval was used on all tidal river/estuary receiving water systems.

Once a time interval is established, then a minimum interevent time must be chosen before a sample rainfall set is analyzed. The "minimum interevent time" is defined as the minimum number of dry hours which must be observed before rainfall events are considered to be independent. That is, if a dry period less than the minimum interevent time is observed, the rainfall amounts (both preceding and following the dry period) are considered to be part of the same event. If a dry period greater than the minimum interevent time is observed, then the rainfall amounts preceding and following the dry period are considered to be independent rainfall events. The minimum interevent times used in the Needs Survey are given as follows.

IDT (hours)	Minimum Interevent Time (hours)
4	8
6	8
8	8
12	12
24	24

Once the seasons, time step, and the minimum interevent time are established, then data sets can be defined by examination of the sample rainfall records. Statistical analysis of these data sets will yield the required input data.

Chapter 3
WATERSHED RUNOFF (MODULE 20)

The purpose of this portion of the simulation is to transform the annual rainfall array into an annual runoff array. One or two runoff arrays may be generated. In general, one runoff array will represent the hydrologic response of the urban area served by combined sewers, and the other runoff array will represent the hydrologic response of the urban area served by separate sewers. However, in the case of an urban area which does not have any combined sewer service area, the user has the option of generating two runoff arrays, each of which represents the hydrologic response of a portion of the urban area, or the user may generate only one runoff array which represents the entire urban area.

The method used is based on a rainfall runoff relationship developed by the Soil Conservation Service (SCS). The SCS rainfall/runoff relationship was chosen because it is a simple relationship which accounts for the major factors influencing direct surface runoff such as land use, soil type, antecedent rainfall, initial losses, and variation of the rainfall/runoff ratio during a given event. Other simpler relationships, such as the rational method, do not account for all of the above factors, and more sophisticated procedures require continuous soil moisture accounting which is computationally complex and requires detailed knowledge of watershed characteristics.

Once the runoff arrays are generated, then a simple hydrologic routing (time-area) may be applied to each array to account for watershed storage. This step will redistribute the flows with respect to time. However, the total volumes will remain unchanged.

SCS RAINFALL-RUNOFF PROCEDURE

The SCS rainfall-runoff equation is given as follows (4).

$$RUN = \frac{(RAIN - 0.2S)^2}{RAIN + 0.8S} \qquad (3\text{-}1)$$

where

RUN = cumulative runoff in inches.

RAIN = cumulative rainfall in inches.

S = potential soil water storage in inches.

In the SCS method, the potential soil water storage, S, is related to antecedent precipitation and watershed characteristics by the watershed curve number or CN value. This empirical relationship is given as follows (4).

$$S = (1{,}000/CN) - 10 \qquad (3\text{-}2)$$

Thus, if the CN value is zero, potential soil water storage is infinite and runoff would always be zero. If the CN value is equal to 100, potential soil water storage is zero and runoff will always be 100%.

In the SCS method, the initial loss or minimum amount of rainfall necessary to produce runoff is assumed to be 0.2S. Therefore, Equation 3-1 applies only if the total event rainfall is greater then 0.2S. If total event rainfall is less than this value, runoff does not occur.

Equation 3-1 relates total runoff to total rainfall for a given watershed and antecedent condition. In order to determine runoff volumes for each time period in a runoff-producing rainfall event, it is necessary to construct a cumulative rainfall curve for the event, as illustrated on Figure 3-1. Equation 3-1 is applied at the end of each time period, which results in the development of a cumulative runoff curve also illustrated on Figure 3-1. The difference between adjacent cumulative runoff values defines the runoff occurring in each time period.

This computational process is illustrated in Table 3-1 which is based on a total rainfall amount of 1.8 inches and a CN value of 90 as per Figure 3-1.

Table 3-1
Rainfall Runoff Computations

Time Period	Rainfall (inches)	Cumulative Rainfall (inches)	Cumulative Runoff (inches)	Runoff (inches)
1	0.3	0.30	0.01	0.01
2	0.5	0.80	0.20	0.19
3	0.5	1.30	0.53	0.33
4	0.3	1.60	0.76	0.23
5	0.2	1.80	0.93	0.17

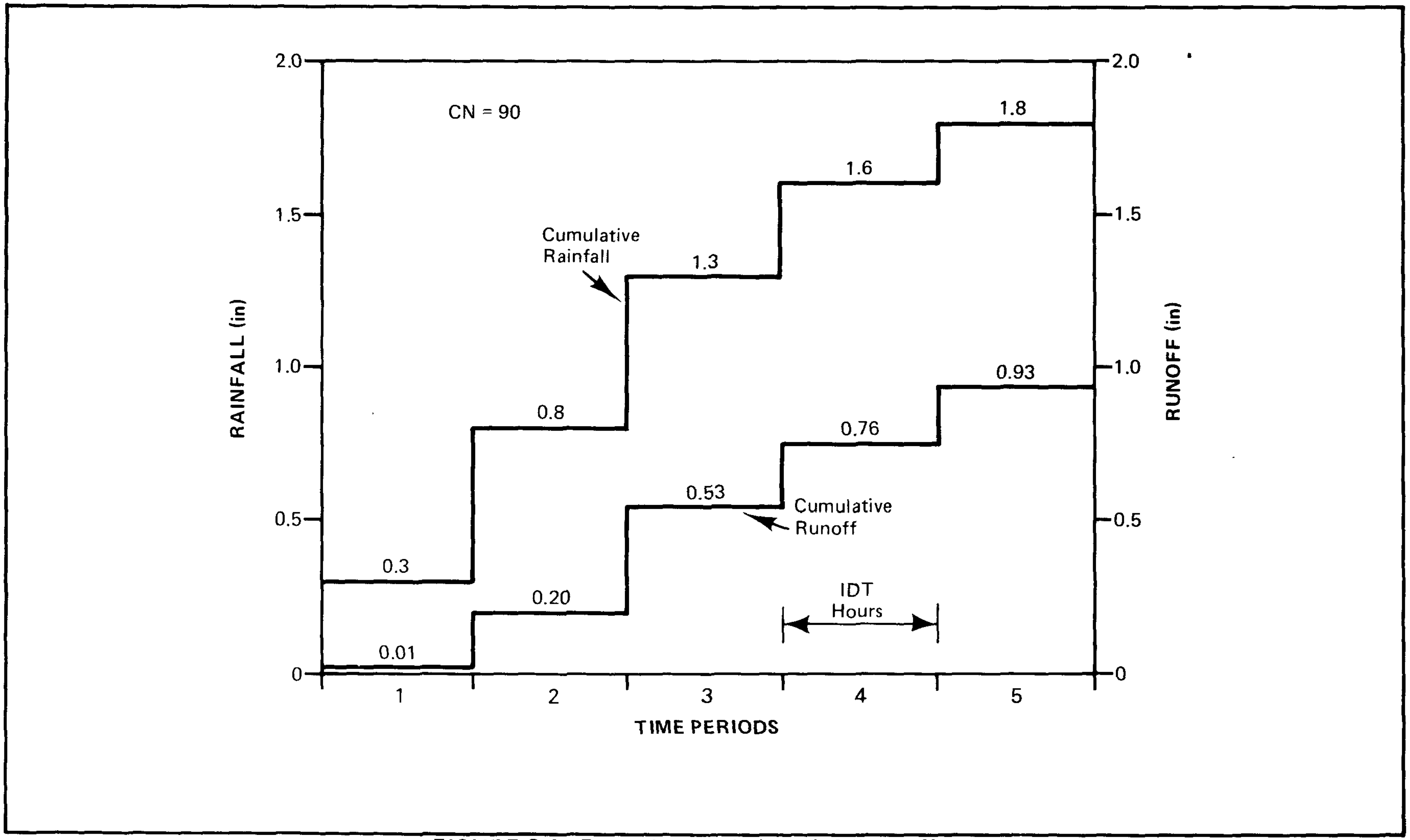

FIGURE 3-1. Example cumulative rainfall runoff curves.

Runoff computations in module 20 are based on the above equations and procedures.

CN values are user supplied and may be considered runoff calibration parameters. The suggested procedure is to estimate the CN value for normal antecedent moisture conditions (AMC II) and to assign CN values for dry conditions (AMC I) and wet conditions (AMC III) based on the CN value selected for AMC II. The relationship between CN values for the three antecedent moisture conditions is given in Table 3-2.

Given the average annual rainfall and an estimated or observed annual runoff, the CN value for AMC II can be estimated from Figure 3-2. The curves illustrated in Figure 3-2 were developed by numerous applications of the runoff module while varying rainfall and CN values. CN values should be adjusted until the simulated annual runoff is representative of the prototype.

The selection of a CN value to be applied to a given rainfall event (i.e., CN I, CN II, or CN III) is a function of the antecedent 5-day precipitation. The objective of the selection procedure is to choose CN II approximately two-thirds of the time. CN I (dry) and CN III (wet) should be selected about one-sixth of the time each. Criteria for this selection are internal to the simulation process, which should work well where annual rainfall is in the range of 25 to 40 inches. Outside of this range CN I or CN III may be selected more often than is reasonable. If the user believes this to be the case, the option may be bypassed by assigning a constant value (CN II) to all CN values. In this manner, CN II will be used in all runoff computations regardless of antecedent conditions.

TIME-AREA ROUTING

In a case where the hydrologic response time (i.e., time of concentration) is large compared to the simulation time step (IDT), an approximate hydrologic routing by the time-area method is included.

The parameter used to determine if routing is necessary is the lag factor (LF) defined as follows.

$$LF = TC/IDT \qquad (3\text{-}3)$$

where

LF = lag factor.

TC = time of concentration in hours.

IDT = simulation time step in hours.

Table 3-2
CN Values (from Reference 4)

AMC II (Normal)	AMC I (Dry)	AMC III (Wet)
100	100	100
99	97	100
98	94	99
97	91	99
96	89	99
95	87	98
94	85	98
93	83	98
92	81	97
91	80	97
90	78	96
89	76	96
88	75	95
87	73	95
86	72	94
85	70	94
84	68	93
83	67	93
82	66	92
81	64	92
80	63	91
79	62	91
78	60	90
77	59	89
76	58	89
75	57	88

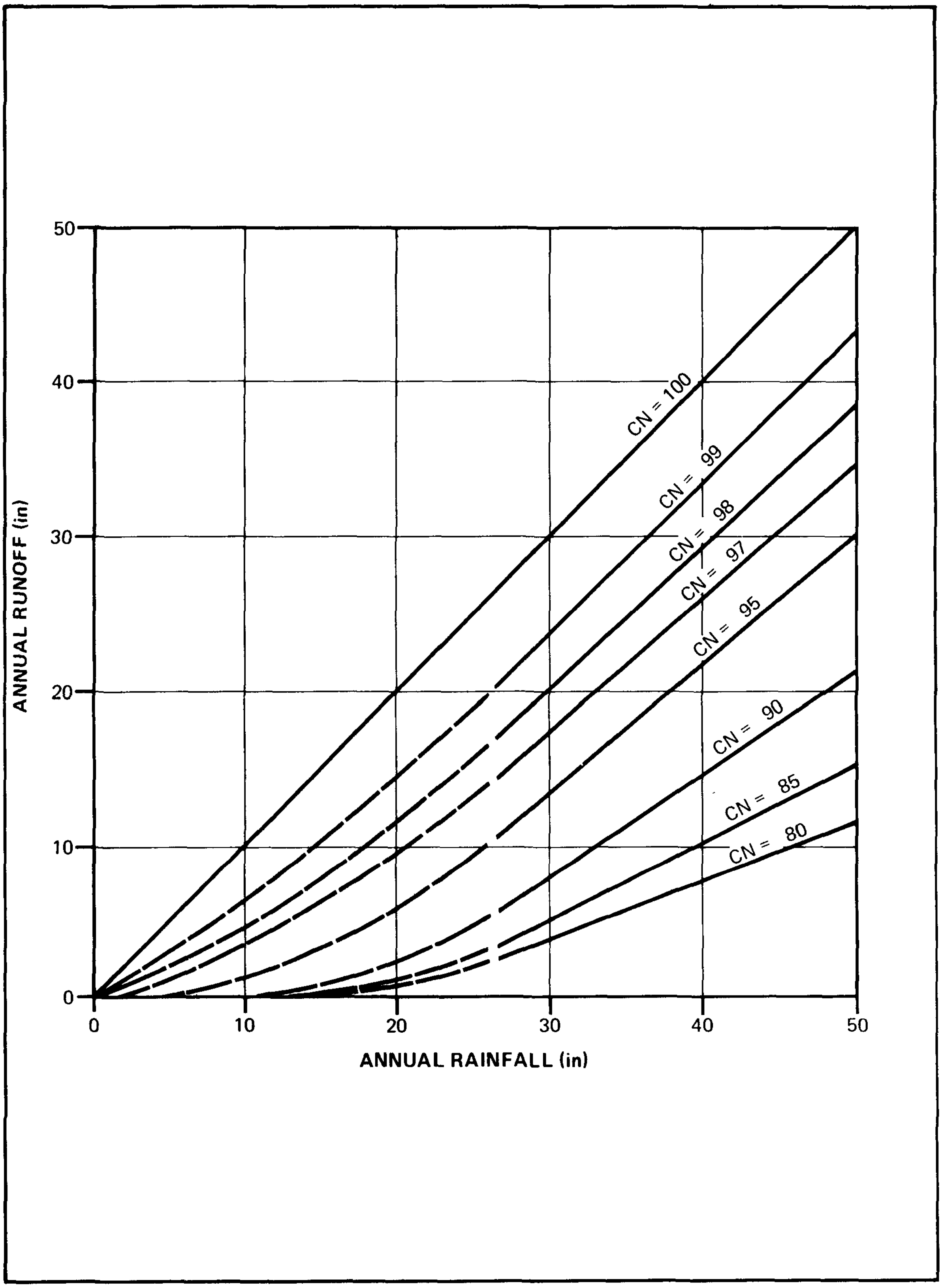

FIGURE 3-2. Chart for selection of CN II values.

If LF is less then 1.5, all runoff occurring in a given time interval is assumed to appear as runoff at the watershed outlet during that time period, and hydrologic routing is not performed. However, if LF is greater than or equal to 1.5, then hydrologic routing by the time-area method is performed.

The time-area method as defined here is actually an averaging method whereby the discharge occurring at the outlet is a weighted average of the runoff values generated by the preceding n time units where n equals the lag factor rounded to the nearest whole unit.

Consider, for example, a case were TC = 8 hours and IDT = 4 hours. In this case LF = 2 and routing will occur. The runoff for any time period, t in this case, is computed as follows.

$$RUN(t) = \frac{RUN(t) + RUN(t-1)}{2} \qquad (3\text{-}4)$$

Applying this routing procedure to the runoff values developed in Table 3-1 yields the routed values given in Table 3-3.

Table 3-3
Example Time-Area Routing for LF = 2

Time Interval	Runoff (inches)	Routed Runoff (inches)
1	0.01	0.005
2	0.19	0.100
3	0.33	0.260
4	0.23	0.280
5	0.17	0.200
6	0.00	0.085
7	0.00	0.000

The routing illustrated above increased the total period of runoff from five time periods to six, and reduced the maximum runoff rates from 0.33 inches per IDT to 0.28 inches per IDT.

COMPUTATIONAL PROCESS

The computational process for the runoff module for each watershed can be described in 16 steps as follows.

1. Search rainfall array for rainfall depth greater than 0.0.

2. Set runoff array = 0.0 for rainless time periods.

3. Determine duration of rainfall event.

4. Determine total storm rainfall.

5. Determine 5-day antecedent rainfall.

6. Determine antecedent moisture condition and select CN value.

7. Determine if rainfall event produces runoff.

8. If rainfall event did not produce runoff, set runoff array = 0.0 for storm period and go to step 1.

9. Determine runoff volume for each time period in storm.

10. Repeat steps 1 through 9 until runoff for entire year has been computed.

11. Compute lag factor and determine if routing is required.

12. If routing is not required, go to step 14.

13. Route annual runoff array by time-area method.

14. Convert all flows from inches per IDT to cfs.

15. Output annual runoff summary.

16. Return to main program.

INPUT DATA

Input data required for the runoff module are:

1. Months in dormant (winter) season.

2. Months in growing (summer) season.

3. Watershed data as follows.

    a. CN values (CN I, CN II, and CN III).

b. Drainage area in acres.

c. Time of concentration in hours.

d. Washoff coefficient in inches^{-1}.

Coding instructions may be found in Appendix A.

Season definitions are required because the AMC selection criteria are slightly different for winter and summer. This is an attempt to account for slightly greater initial losses during periods of active plant growth. This definition of seasons need not correspond to the seasons defined for the purpose of rainfall simulation.

The drainage area should correspond to the total urban area tributary to the subject receiving water served by the type of drainage system (i.e., combined sewer or separate sewer) being simulated.

If the total drainage area is adjusted by an areawide runoff coefficient and if all CN values are read in at a value of 100, then the runoff array generated would be identical to a runoff array generated by application of the runoff coefficient directly to the rainfall array (i.e., rational method). That is, runoff would always be a constant portion of rainfall. This technique may be appropriate when applied to highly impervious watersheds where the areawide runoff coefficient is greater than approximately 80%. However, the user should be aware that some summaries produced by the program are related to the drainage area read as input and, therefore, must be adjusted by the ratio of the drainage area read in to the actual drainage area to be correct. The summaries in question are those that show runoff or overflows in inches per year. All other data will be accurate as printed.

The washoff coefficient (item d above) is considered a watershed parameter and is, therefore, part of the watershed input data. However, it is not used in the runoff computations but is used in pollutant washoff computations. Selection of an appropriate washoff coefficient is discussed in Chapter 4, "Pollution Accumulation and Washoff."

Chapter 4
POLLUTION ACCUMULATION AND WASHOFF (MODULE 30)

The objective of the pollution accumulation and washoff module is to simulate the process of pollutant accumulation or buildup on the watershed during dry periods and subsequent pollutant washoff during periods of runoff. Pollutants considered are those which are evaluated in the receiving water impact analysis and include suspended solids (SS), five-day biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), and lead (Pb). The accumulation and removal of each of the above pollutants are computed for each time step in the year, and annual quality arrays for each are developed.

ACCUMULATION

Watershed pollutant accumulation at the end of any time period, t, is related to the accumulation at the end of the previous time period, t-1, by the following recursion formula (5).

$$L_{(t)} = L_{(t-1)}*(1 - R) + Y \qquad (4\text{-}1)$$

where

$L_{(t)}$ = pollutant accumulation at time t in lb/acre.

$L_{(t-1)}$ = pollutant accumulation at time t-1 in lb/acre.

R = pollutant removal or decay rate in fraction removed per simulation time step.

Y = pollutant accumulation rate in lb/acre per simulation time step.

If R is a nonzero value, then the pollution accumulation function given above is nonlinear. If R equals zero, then the accumulation function becomes linear and a constant unbounded accumulation rate of Y lb/acre/Δt is assumed. Figure 4-1 illustrates the pollution accumulation and washoff functions for the case where R = 0 and for the case where $R \neq 0$. Selection of the R parameter is discussed in detail in a subsequent section of this chapter.

WASHOFF

Watershed pollutant washoff at the end of any time period, t, is related to the accumulation at the end of the previous time

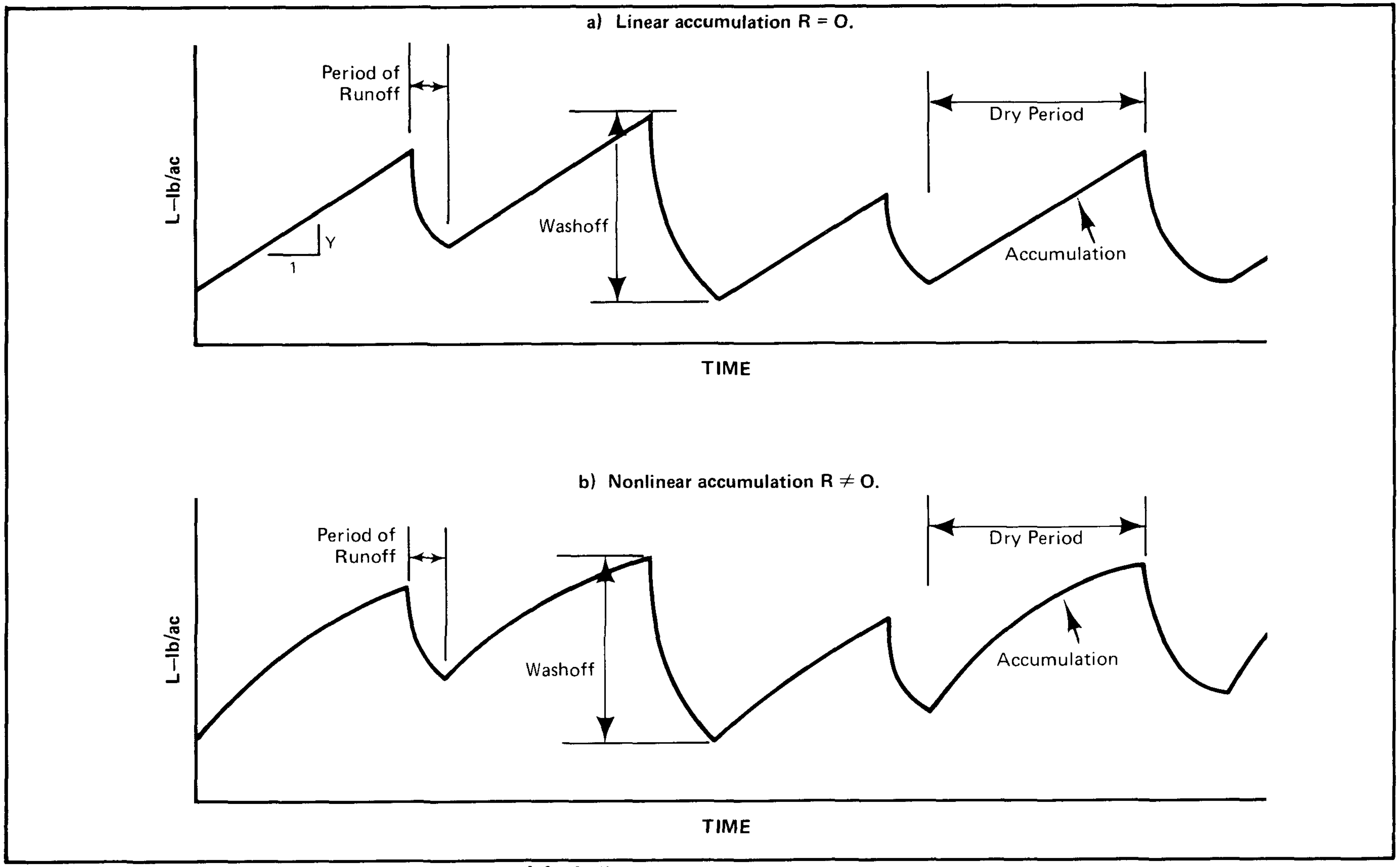

FIGURE 4-1. Pollution accumulation washoff functions.

period, t-1, and to runoff during time period t, by the following equation (5).

$$M_{(t)} = L_{(t-1)}[1 - EXP(-K_w*RUN_{(t)})] \quad (4-2)$$

where

$M_{(t)}$ = pollutant washoff for time period t, in lb/acre.

K_w = watershed washoff coefficient, in $inches^{-1}$.

$RUN_{(t)}$ = runoff for time period t in inches.

The washoff component of the simulation is also illustrated on Figure 4-1.

INPUT DATA

Input data required for the pollution accumulation washoff module for each watershed are as follows.

1. Pollutant loading rates (Y) for BOD, SS, TKN, and Pb in pounds per acre per day.

2. Pollutant decay rates (R) for BOD, SS, TKN, and Pb expressed as fraction removed per day.

Coding instructions are given in Appendix A. The watershed washoff coefficient is part of the input data required for Module 20 as discussed in Chapter 3.

SELECTION OF THE WATERSHED WASHOFF COEFFICIENT K_w

If observed runoff hydrographs and pollutographs for the subject watershed are available, then the watershed washoff coefficient, which is a first-order exponential decay coefficient, can be derived from the observed data. If such data are unavailable, then the washoff coefficient must be estimated by the user.

In general, washoff coefficient values range from approximately 1.4 to 4.6. The higher values are associated with steep highly impervious watersheds while the lower values are associated with flat, pervious watersheds.

The chart presented on Figure 4-2 may be used to select an appropriate watershed washoff coefficient for an urban watershed if observed hydrographs and pollutographs are not available. The chart applies to urban watersheds served by separate sewer systems.

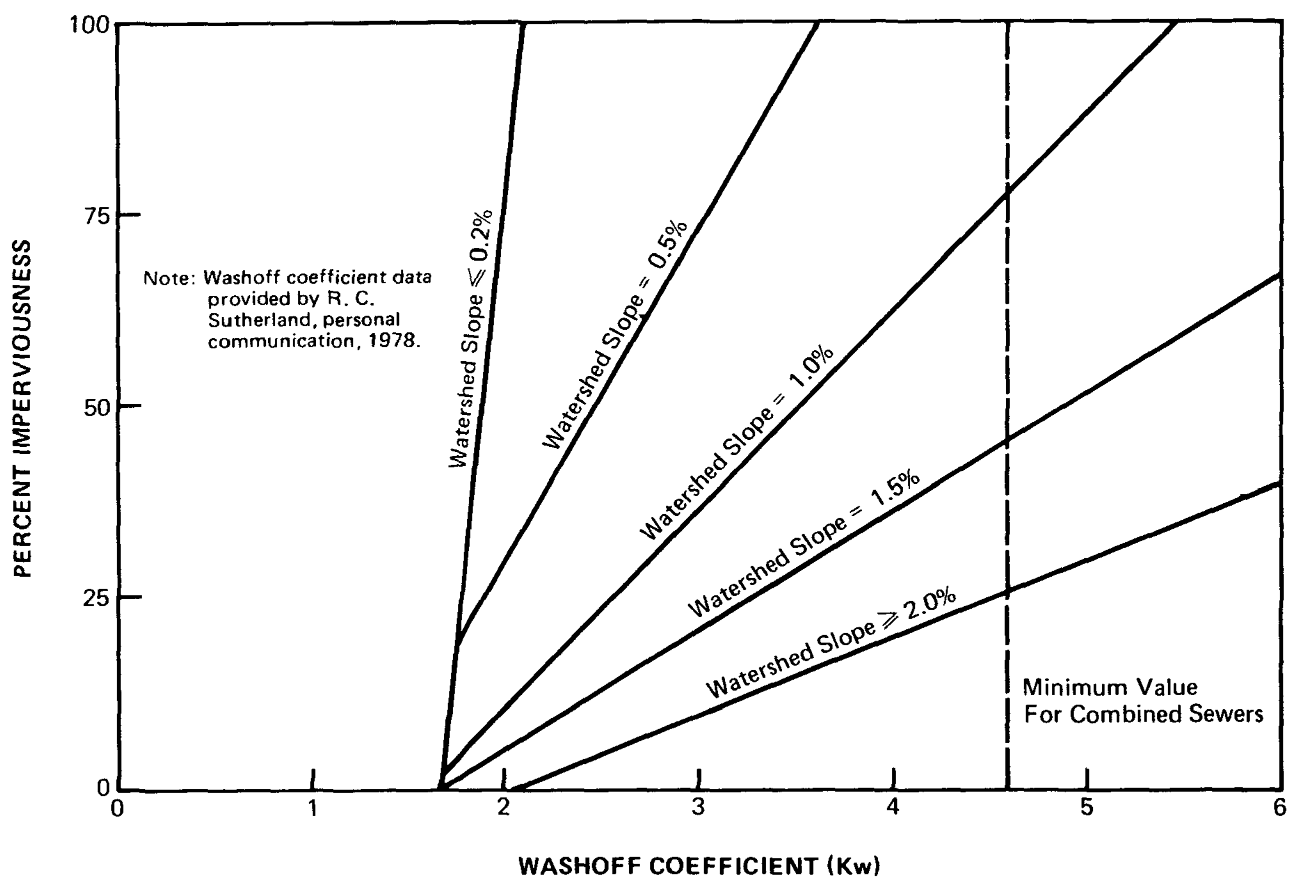

FIGURE 4-2. Chart for selection of Kw values.

For combined sewer systems where the major portion of the pollutants accumulate in the collection system, a minimum value of 4.6 should be used. A default value of 4.6 is built into the program and will be used in the washoff computations if the user does not supply a site specific value.

SELECTION OF POLLUTANT DECAY RATES

Selection of appropriate pollutant decay rates is largely a matter of judgment. Some investigators believe that all pollution accumulation is linear and, therefore, decay rates are zero; while others believe that pollution accumulation is nonlinear and approaches some maximum limiting value during long dry periods.

If the pollutant decay rate (Rd) is expressed as fraction removed per day, then the reciprocal of Rd (1.0/Rd) is equal to the ratio of the maximum possible watershed load to the daily accumulation rate (Y).

The decay rates used in the Needs Survey simulations are specified as follows.

Pollutant	Decay Rate (Rd)
BOD	0.0667
TKN	0.0667
SS	0.0
Pb	0.0

The concept of a decay or removal rate R may also be used to simulate the effects of best management practices (BMP). R may be expressed in terms of a removal component (Rr) and a decay component (Rd) as follows.

$$R = Rr + Rd \qquad (4\text{-}3)$$

where

R = total pollutant removal rate.

Rr = pollutant removal rate due to physical particle removal, i.e., streetsweeping.

Rd = pollutant removal rate due to decay or other natural processes.

Previous discussion has focused on the component Rd which is equal to the total R if BMP's are not practiced. However, if a management practice can be associated with an Rr value, then the effect of this management practice on washoff quality can be simulated by increasing the total R value used in the simulation.

For example, consider a homogeneous storm sewered urban watershed served by curbs and gutters. It may be desirable to evaluate a proposed streetsweeping program whereby one-quarter of the watershed streets are swept every day by vacuum-type sweepers. Assuming that the vacuum sweeper pickup efficiency is 80% and that one-half of all watershed pollutants are located in the street gutter, then Rr may be evaluated as Rr = 0.80 x 1/4 x 1/2 = 0.10. That is, Rr is equal to the sweeper pickup efficiency times the fraction of watershed swept each day times the pollutant availability factor. In this case, 10% of all watershed pollutants would be removed by sweeping each day. If the pollutant of interest were BOD and the background decay rate Rd were equal to 0.067, then the total pollutant removal rate R would be 0.167.

SELECTION OF POLLUTANT ACCUMULATION RATE

The pollution accumulation rate is a calibration parameter which, when adjusted, will affect the total annual pollution yield generated by a watershed. The objective, then, is to choose an accumulation rate which will simulate prototype pollutant production as closely as possible.

If total annual pollutant yield of the prototype is unknown, then it must be estimated by emperical methods. A suggested method is reported in Table 4-1 (6). The method presented in Table 4-1 will give estimates of total pollutant yield in terms of lb/acre/year for BOD, SS, TKN, and Pb. If the watershed decay rate R is zero (SS and Pb), then a first approximation of Y may be estimated by Equation 4-4.

$$Y = M/360 \qquad (4\text{-}4)$$

where M is the annual yield as determined by application of the procedures outlined in Table 4-1.

If the watershed decay rate is 0.067 (BOD and TKN), then Y may be estimated by Equation 4-5.

$$Y = 2.25\ M/360 \qquad (4\text{-}5)$$

where all terms are as previously defined. Y values should be adjusted until the desired annual pollutant yields are obtained.

The procedure outlined in Table 4-1 was originally developed by Heaney, Huber, and Nix (6) for BOD, SS, VS, PO_4, and total N.

Table 4-1
Estimating Annual Pollutant Yield
(Adapted from Heaney, Huber, and Nix, 1976)

The following equations may be used to predict annual average loading rates as a function of land use, precipitation, and population density.

Separate Areas

$$M_s = \alpha(i,j) \cdot P \cdot f_2(PD_d) \quad \frac{lb}{acre\text{-}yr}$$

Combined Areas

$$M_c = \beta(i,j) \cdot P \cdot f_2(PD_d) \quad \frac{lb}{acre\text{-}yr}$$

where

M = pounds of pollutant j generated per acre of land use i per year

P = annual precipitation, inches per year

PD_d = developed population density, persons per acre

α, β = factors given in table below

$f_2(PD_d)$ = population density function

Land Uses

i = 1	Residential
i = 2	Commercial
i = 3	Industrial
i = 4	Other developed, e.g., parks, cemeteries, schools (assume PD_d = 0)

Population Functions

i = 1	$f_2(PD_d) = 0.142 + 0.218 \cdot PD_d^{0.54}$
i = 2,3	$f_2(PD_d) = 1.0$
i = 4	$f_2(PD_d) = 0.142$

Pollutants

j = 1	BOD_5
j = 2	Suspended solids (SS)
j = 3	Total Kjeldahl nitorgen (TKN)
j = 4	Lead (Pb)

Table 4-1--Continued

Factors α and β for Equations

Separate factors, α, and combined factors, β, have units lb/acre-in. To convert to kg/ha-cm, multiply by 0.442.

	Land Use, i	Pollutant, j			
		1. BOD_5	2. SS	3. TKN	4. Pb
Separate Areas, α	1. Residential	0.799	16.3	0.089	0.0216
	2. Commercial	3.20	22.2	0.200	0.0866
	3. Industrial	1.21	29.1	0.188	0.0328
	4. Other	0.113	2.70	0.041	0.0031
Combined Areas, β	1. Residential	3.29	67.2	0.505	0.0216
	2. Commercial	13.2	91.8	1.140	0.0866
	3. Industrial	5.00	120.0	1.065	0.0328
	4. Other	0.467	11.1	0.234	0.0031

The α and β values presented here for TKN and Pb were developed from statistical analysis of available data summaries specifically for the Needs Survey application.

COMPUTATIONAL SEQUENCE

The computational sequence for the watershed pollution accumulation and washoff module is described in eight steps as follows.

1. Read pollution accumulation rates removal rates and washoff coefficient for each watershed.

2. Initialize watershed pollutant loads.

3. Calculate watershed pollutant load at end of time period using Equation 4-1.

4. If runoff for time period is greater than zero, calculate watershed pollutant washoff using Equation 4-2.

5. Subtract washoff (if any) obtained in step 4 from accumulation obtained in step 3 to obtain actual watershed load at end of time period.

6. Repeat steps 3 through 5 for entire year.

7. Convert washoff quality arrays from units of pounds per acre per time period to mg/l.

8. Compute loading summaries and return to main program.

Chapter 5
SEWER SYSTEM INFILTRATION (MODULE 40)

The purpose of the infiltration component is to construct a daily array of excess sewer infiltration values for wastewater collection systems. This array is added to the runoff array before processing by the storage/treatment model or receiving water model. Thus, it is primarily intended for use in combined sewer systems.

The infiltration module is optional and should be used when there is evidence that infiltration alone will cause treatment plant bypass or overflow and when the annual quantity of such overflows are known or can be estimated.

Sewer system infiltration rates are dependent on many factors such as soil type, ground-water table elevations, type of collection system, and age and condition of collection system as well as local rainfall. There are no general mathematical models available which account for all of the above parameters. Therefore, simulation of sewer system infiltration is subject to much uncertainty, and the results must be reviewed by the user for reasonableness.

INFILTRATION QUANTITY

Total infiltration quantity is computed from the daily rainfall array by an emperical equation developed from analysis of observed rainfall and infiltration data for the City of Baltimore, Maryland (7).

```
INF(J) = 2.4 + 11.3*DRAIN(J) + 11.6*DRAIN(J-1)
         + 5.5*DRAIN(J-2) + 6.4*DRAIN(J-3)
         + 4.8*DRAIN(J-4) + 3.6*DRAIN(J-5)
         + 1.0*DRAIN(J-6) + 1.5*DRAIN(J-7)
         + 1.4*DRAIN(J-8) + 1.8*DRAIN(J-9)          (5-1)
```

where

INF(J) = sewer system infiltration rate for day J in gallons per minute per inch of pipe diameter per mile of sewer.

DRAIN(J) to DRAIN(J-9) = daily rainfall in inches from the current day (J) to the 9th day previous (J-9).

Total infiltration production rate given above (gpm/inch/mile) is converted to total infiltration rate in cubic feet per second (cfs) for the prototype by application of the following equation.

$$INF(J) = INF(J)*DIA*LENGTH*INFADJ*0.002228 \qquad (5\text{-}2)$$

where

DIA = average sewer diameter in inches.

LENGTH = total sewer system length in miles.

INFADJ = a calibration factor which can be used to adjust the annual infiltration volume generated by the model to prototype conditions.

Application of Equations 5-1 and 5-2 to a given daily rainfall array and sewer system will produce a daily total infiltration array. However, a substantial portion of this infiltration may be intercepted and treated by existing dry-weather treatment facilties, which generally have treatment capacities three to four times greater than expected average sanitary wastewater flow rates. Thus, only those flows greater than the excess treatment plant capacity will result in untreated overflow. The excess treatment plant capacity is given by Equation 5-3.

$$EXCAP = (DWFR - 1.0)DWF \qquad (5\text{-}3)$$

where

EXCAP = excess treatment plant capacity in cfs.

DWFR = ratio of the treatment plant capacity to the average sanitary wastewater flow rate (dry-weather flow).

DWF = expected average dry-weather flow rate generated by the combined sewer area in cfs.

The value EXCAP is subtracted from each value in the total infiltration array to produce the excess or infiltration overflow array. This concept is illustrated in Figure 5-1.

INFILTRATION QUALITY

Infiltration is assumed to be pure water which mixes with the sanitary wastewater in the collection system. Based on this assumption, infiltration quality arrays are developed for BOD, SS, TKN, and Pb by a simple dilution calculation. Initial concentrations in the sanitary wastewaters are assumed as follows.

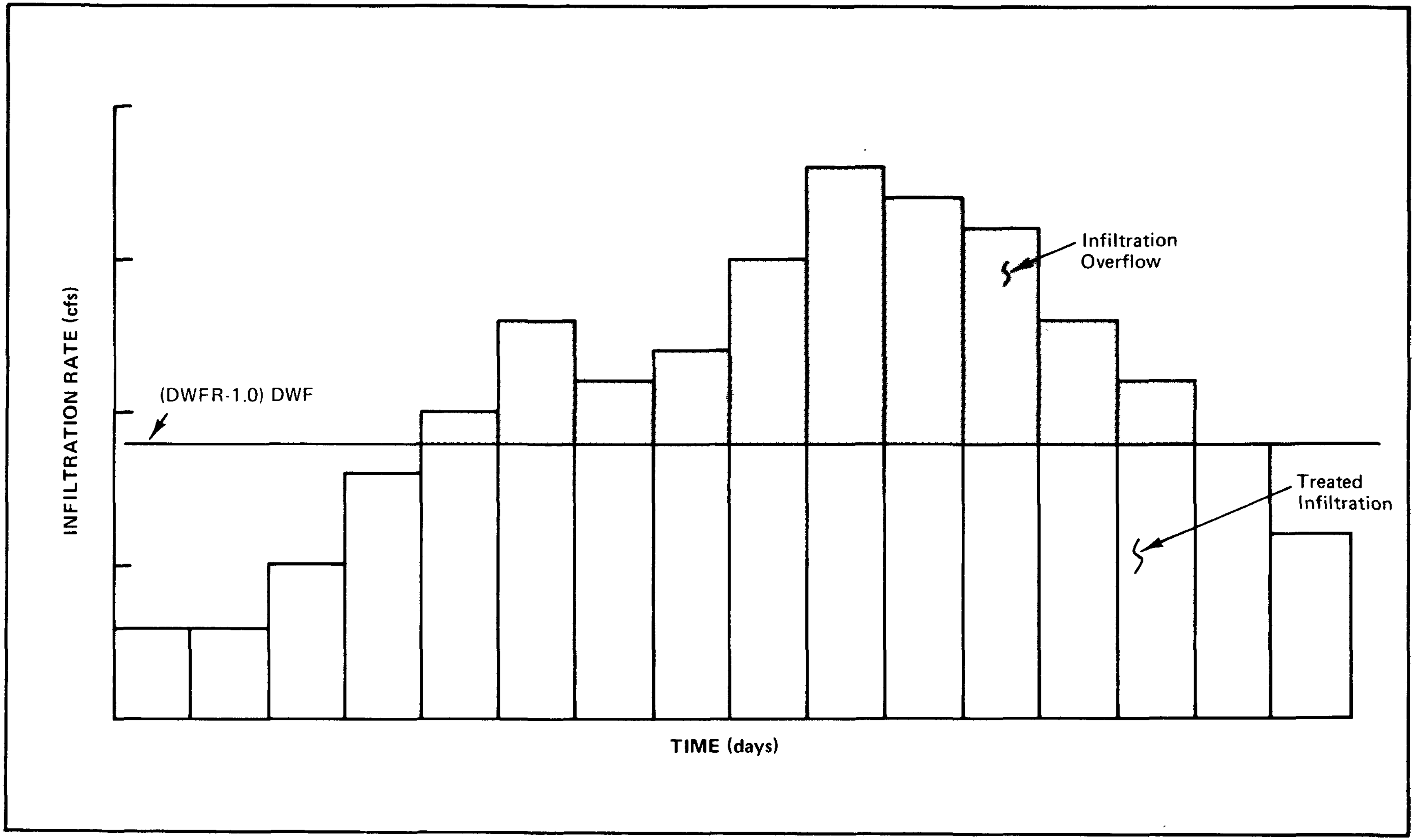

FIGURE 5-1. Definition sketch illustrating infiltration overflow array.

Pollutant	Strength
BOD	200 mg/l
SS	200 mg/l
TKN	40 mg/l
Pb	0.04 mg/l

The dilution factor for each day with excess infiltration is computed by Equation 5-4.

$$DILFAC = [EXINF(J) + DWF*DWFR]/DWF \qquad (5-4)$$

where

DILFAC = dilution factor.

EXINF(J) = excess infiltration for time period J in cfs.

All other terms are as previously defined. The excess infiltration quality arrays are then computed as follows.

$$IOBOD(J) = 200/DILFAC \qquad (5-5)$$

$$IOSS(J) = 200/DILFAC \qquad (5-6)$$

$$IOTKN(J) = 40/DILFAC \qquad (5-7)$$

$$IOPb(J) = 0.04/DILFAC \qquad (5-8)$$

Where IOBOD, IOSS, IOTKN, and IOPb sub J are the quality values for each time period J with infiltration overflow.

COMPUTATIONAL SEQUENCE

The computational sequence for the combined sewer infiltration module may be described in 7 steps as follows.

1. Read input data.

2. Develop daily rainfall array from IDT rainfall array.

3. Compute total infiltration array by application of equations 5-1 and 5-2.

4. Compute infiltration overflow array by application of Equation 5-3.

5. Compute infiltration overflow quality arrays for BOD, SS, TKN, and Pb.

6. Add excess infiltration quantity and quality arrays to runoff quantity and quality arrays developed for the wastershed by modules 20 and 30.

7. Return to main program.

INPUT DATA

Input data required for the combined sewer infiltration computation are listed below. Coding instructions are given in Appendix A.

1. Watershed number (1 or 2).

2. Computation code: 0 = infiltration is not computed, 1 = infiltration computed.

3. Average diameter of sewers in inches.

4. Total length of sewer system in miles.

5. Average domestic wastewater flow generated by sewered area in cfs.

6. Ratio of sewer flow to dry-weather flow at which overflow occurs.

7. Infiltration adjustment factor. This factor is equal to 1.0 if adjustment to computed infiltration array is unnecessary.

Pisano and Queiroz (8) have developed the following equations which relate total length of sewer systems to area served.

$$L = 168.95A^{.928} \quad (5\text{-}9)$$

$$L = 239.41A^{.928} \quad (5\text{-}10)$$

where

L = total sewer length in feet.

A = total area served in acres.

Equation 5-9 applies to low population density systems (10-20 persons/acre), whereas Equation 5-10 applies to high population density systems (30-60 persons/acre). The correlation coefficient of the above equation is 0.906. Similar relationships for average sewer diameter are not available.

Limited experience to date indicates that the infiltration overflow array generated by application of the procedure described herein is relatively large and that an infiltration adjustment factor (INFADJ) on the interval 0.2 to 0.8 is generally required to produce reasonable values of total annual overflow volume and total annual duration of overflow.

Chapter 6
STORAGE/TREATMENT (MODULE 50)

The purpose of the storage/treatment module is to modify the runoff quantity and quality arrays in such a manner as to simulate the operation of stormwater runoff storage and treatment facilities.

Computation of storage, treatment, and overflow is accomplished on a simulation time step basis throughout the year. For every time period in which runoff occurs, the treatment facilities are utilized to treat as much runoff as possible. When the runoff rate exceeds the treatment rate, storage is utilized to contain the runoff. When runoff is less than the treatment rate, the excess treatment rate is utilized to diminish the storage level. If the storage capacity is exceeded, all excess runoff is considered overflow and does not pass through the storage facility. This overflow is lost from the system and cannot be treated later. The treated runoff array is then added to the overflow array and the combined quality is computed to produce the new modified runoff arrays. This concept is illustrated in Figure 6-1.

The quality of the runoff waters in storage is considered to be the quality of the composite mixture during any time step. Thus, storage will have an attenuation effect on both the quantity and quality of runoff. However, actual removal of pollutants from the runoff waters in storage is not simulated. Thus, the treatment which occurs in storage is assumed to be negligible.

The physical, chemical, and biological aspects of wastewater treatment are not simulated directly in this module. Instead, effluent quality for each constituent is computed by application of a user-supplied treatment efficiency to the stored runoff waters.

COMPUTATIONAL PROCESS

The storage/treatment simulation computations can be described in 7 steps as follows.

1. Read storage/treatment input data.
2. Generate storage inflow, storage outflow, and overflow arrays (see Figure 6-1).
3. Generate storage volume and storage quality arrays.
4. Generate treated outflow quality arrays.

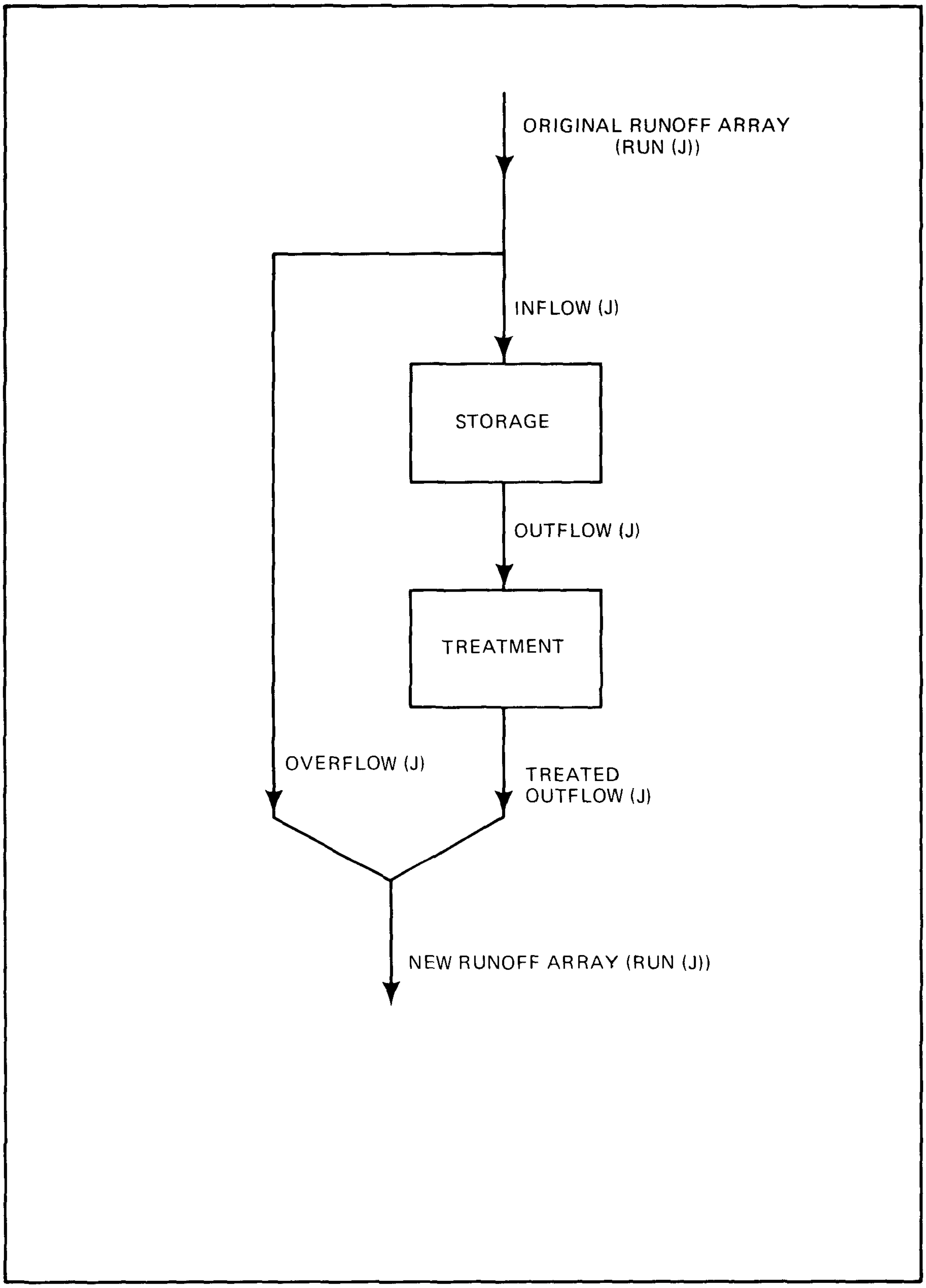

FIGURE 6-1. Definition sketch storage/treatment system.

5. Sum overflow and treated outflow arrays (quantity and quality) to form new runoff arrays.

6. Summarizes annual discharges, overflow events, overflow volumes, and output results.

7. Return to main program.

INPUT DATA

The required input data for each watershed are listed as follows. Coding instructions may be found in Appendix A.

1. Design treatment rate for stormwater treatment facility in cfs.

2. Maximum storage volume of storage facility in ft^3.

3. Initial volume in storage at the beginning of the simulation in ft^3.

4. Quality (BOD, SS, TKN, and Pb) of initial stormwater in storage in mg/l.

5. Treatment plant pollutant removal efficiencies at the design treatment rate for each constituent (BOD, SS, TKN, and Pb) expressed as fraction of each pollutant removed by the treatment process.

Items 3 and 4 above apply at the beginning of time step 1, year 1. For subsequent years, the residual values in storage at the end of the previous year's simulation, if any, will be used as initial values for the following year. For the purpose of the Needs Survey, Items 3 and 4 were read in as zero values.

Chapter 7
DRY-WEATHER WASTEWATER TREATMENT PLANT FLOW (MODULE 60)

The purpose of the dry-weather flow module is to create an array of flow values which represents base wastewater flow generated by the entire urban area. Both domestic and industrial waste sources should be considered. Average values of wastewater effluent quality for SS, BOD, TKN, and Pb are applied to the time variant flow array in order to generate representative dry-weather point source wasteloads to the receiving water.

FLOW RATIOS

Dry-weather point source flow magnitude is varied by hour of the day and by day of the week by application of the appropriate flow ratios. These flow ratios are multiplied by the mean dry-weather wastewater effluent flow rate to obtain a representative time variant flow rate. The ratios used are the standard national average default values used in the "STORM" model (9), as presented in Tables 7-1 and 7-2.

INPUT DATA

Input data required for the dry-weather flow module are described as follows. Coding instructions may be found in Appendix A.

1. Mean dry-weather wastewater flow rate in cfs. This value should include all municipal and industrial WWTP's serving the urban area which discharge to the receiving water.

2. Flow-weighted average effluent quality of point sources included in Item 1, in mg/l. The parameters of interest are:

    a. BOD

    b. SS

    c. TKN

    d. Pb

    e. DO deficit

Table 7-1
Hourly Flow Ratios (After Reference 9)

Hour of Day	Ratio	Hour of Day	Ratio
1	0.6	13	1.3
2	0.5	14	1.3
3	0.5	15	1.3
4	0.5	16	1.2
5	0.5	17	1.2
6	0.8	18	1.1
7	0.8	19	1.1
8	1.4	20	1.0
9	1.5	21	1.0
10	1.5	22	0.8
11	1.4	23	0.7
12	1.4	24	0.6

Table 7-2
Daily Flow Ratio (After Reference 9)

Day of Week	Ratio
Monday	1.08
Tuesday	1.04
Wednesday	0.92
Thursday	1.03
Friday	1.00
Saturday	0.96
Sunday	0.95

Chapter 8
UPSTREAM FLOW (MODULES 70 AND 71)

The purpose of the streamflow modules is to provide an array of flow values which is representative of the upstream flow entering the urban area. Only quantitative aspects of the upstream flow are considered in this portion of the simulation system. Upstream flow quality is considered in the receiving water response module which is discussed in Chapter 9.

There are two options available for upstream flow. The first (module 70) reads in and stores an array of observed daily flow values for a period of up to 5 years. The second (module 71) is a stochastic streamflow simulator which will generate synthetic values of monthly flows. Module 71 is similar in structure to the rainfall generator presented in Chapter 2.

For the purpose of the Needs Survey, module 70 was used for all site studies since the time distribution of streamflow is better defined on a daily basis than on a monthly basis.

The term upstream flow as used here refers to all waters entering the upstream boundary of the urban area which are available to blend with the local urban runoff, combined sewer overflow, and wastewater treatment plant effluents. These flows may be generated by one or more major streams as illustrated on Figure 8-1. Refering to Figure 8-1, flows Q_A and Q_B are the flows of interest, and their summation defines the upstream flow array which is to be read into or simulated by the model.

Several additional important concepts are illustrated in Figure 8-1. First, the receiving stream within the limits of the urban area is considered a mixing zone. This zone accepts the upstream flows and mixes these flows with the local urban-area-induced flows, including urban runoff, combined sewer overflow, and wastewater treatment plant effluent. These local flows are added to the upstream flow in order to produce the total outflow from the urban area, represented as Q_C on Figure 8-1. The total outflow (quantity and quality) from the urban area becomes the inflow to the receiving water response portion of the simulation.

DAILY STREAMFLOW (MODULE 70)

It is suggested that a minimum of 10 years of daily streamflow record be obtained for each site. This record should then be examined to determine which 5-year sequence in the 10-year record provides the best representation of the long-term streamflow.

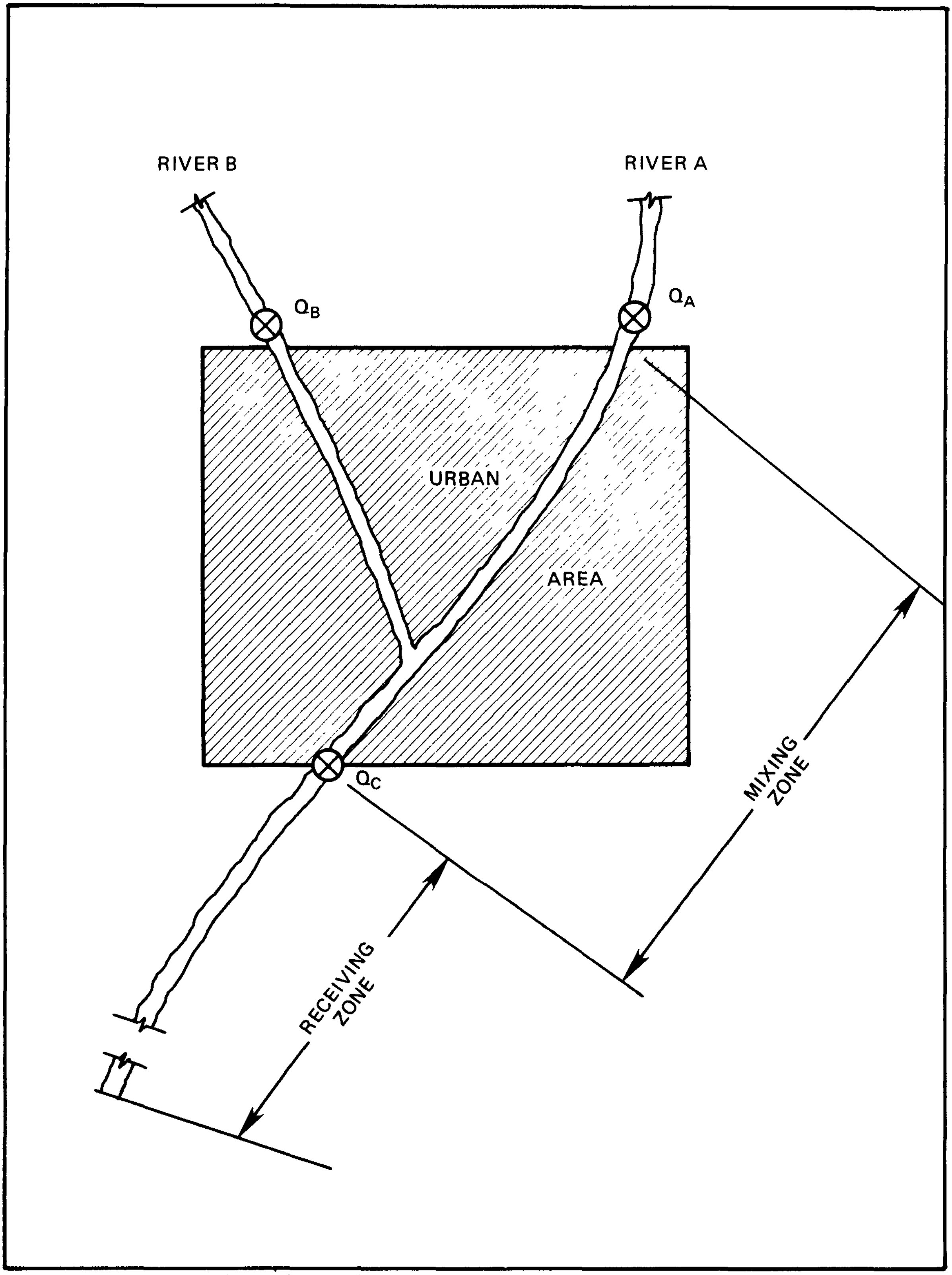

FIGURE 8-1. Definition sketch showing upstream flow, mixing zone, and receiving zone.

There are six possible 5-year sequences available in the 10 years of record, i.e., years 1 through 5, years 2 through 6, years 3 through 7, etc. The mean annual flow for each of these 5-year sequences should be compared to the long-term mean annual flow, and that sequence which yields a mean most nearly equal to the long-term mean should be selected.

The simulation assumes that a year is composed of 12 months, each 30 days long. This assumption was made to simplify internal flow control and time-step accounting procedures. However, the observed streamflow record must be modified in order to adjust for the above assumption. It is suggested that for a normal (365-day) year every 73rd value should be deleted from the data set and that for a leap year (366 days) every 60th value should be deleted. This procedure will yield a 360-day year, or 1,800 streamflow observations for the 5-year sequence.

INPUT DATA (MODULE 70)

The input data required for module 70 are discussed above. Data may be entered for 1, 2, 3, 4, or 5 years, but not for portions of a year. Thus, allowable data sets will contain 360, 720, 1,080, 1,440, or 1,800 daily streamflow values. Coding instructions are given in Appendix A.

STOCHASTIC MONTHLY STREAMFLOW SIMULATOR (MODULE 71)

Synthetic observations of monthly streamflow may be generated by application of a first-order Markov model similar to the Markov model described in Chapter 2, "Rainfall Simulator." Mathematically, these models are nearly identical. However, the parameters are defined differently.

Monthly streamflows are assumed to be defined by a log normal distribution, and the first monthly value for the first year ($Q_{(1,1)}$) is generated by Monte Carlo sampling of a log normal distribution (2).

$$Q_{(1,1)} = \mathrm{EXP}(NV \cdot \sigma_1 + QM_1) \qquad (8\text{-}1)$$

where

$Q_{(1,1)}$ = a random observation of monthly streamflow for the first month of the first year.

NV = a normally distributed random variable with a mean of zero and a standard deviation of 1,N(0,1).

σ_1 = log transformation of the standard deviation of monthly flows for month 1 (January).

QM_1 = log transformation of the mean of monthly flows for month 1 (January).

Once the monthly streamflow for the first month of the simulation has been established, then monthly flows for all subsequent months are computed by application of the first-order Markov model. This procedure is described by the following equations (2,3).

$$Y_{(i,j-1)} = \ln(Q_{(i,j-1)}) \qquad (8\text{-}2)$$

$$Y_{(i,j)} = QM_j + \rho_j \frac{\sigma_j}{\sigma_{j-1}} (Y_{(i,j-1)} - QM_{j-1}) + NV\, \sigma_j \sqrt{(1 - \rho_j^2)} \qquad (8\text{-}3)$$

$$Q_{(i,j)} = EXP(Y_{(i,j)}) \qquad (8\text{-}4)$$

where

$Y_{(i,j-1)}$ = log of monthly flow for year i and month j-1.

$Y_{(i,j)}$ = log of monthly flow for year i and month j.

QM_j = log transformation of the mean of flows for month j.

ρ_j = log transformation of correlation coefficient between flow in month j and month j-1.

σ_j = log transformation of standard deviation of flows for month j.

σ_{j-1} = log transformation of standard deviation of flows for month j-1.

QM_{j-1} = log transformation of mean of flows for month j-1.

In order to apply the above model, a sample of monthly flow data must be obtained and the mean and standard deviation of flows for each month must be computed. In addition, the correlation coefficient between adjacent monthly flows (lag 1 correlation coefficient) must be determined. Parameters for the model are then obtained by application of the transformation functions presented in Chapter 2. Thus, at total of 36 different parameters is required to define the monthly streamflow simulator.

INPUT DATA (MODULE 71)

The input data required for the stochastic monthly streamflow generator are the statistics of the raw data set as described above. The log transformations are performed internally. Specifically the data required for each month (1...12) are:

1. Mean of monthly flows.

2. Standard deviation of monthly flows.

3. Correlation coefficient between flow in current month and flow in previous month.

Coding instructions are found in Appendix A.

Chapter 9
RECEIVING WATER RESPONSE (MODULES 80, 81, AND 82)

PURPOSE AND OVERVIEW

The purpose of the receiving water response portion of the simulation is to compute the water quality of the receiving water on a continuous basis due to the combined effects of all waste sources. Water quality parameters considered are: (1) suspended solids concentrations, (2) minimum dissolved oxygen concentrations, (3) equilibrium dissolved lead concentrations, and (4) total lead concentrations. In addition, total annual discharge of all pollutants to the receiving water is determined.

The receiving water response module will generate the data required to construct a cumulative frequency distribution for each water quality parameter considered. Cumulative frequency curves may be developed for existing prototype conditions or for proposed conditions. The difference between existing condition and proposed condition curves can then be compared to quantify the receiving water quality impact of the proposed improvements.

An example of these curves for minimum dissolved oxygen is shown in Figure 9-1. In this case, simulation of the existing conditions shows that the DO standard of 5.0 mg/l will not be met 30% of the time. Simulation of a proposed condition (say an extensive storage/treatment system for CSO) shows that the DO standard of 5.0 mg/l will be exceeded only 2% of the time. Thus, this decrease in frequency of exceedance of the water quality standard is one measure of the water quality enhancement which would be obtained if the proposed improvements were constructed. Another measure of the water quality impact of the proposed improvements is given by the area between the existing conditions curve and the proposed conditions curve as shown on Figure 9-1. This area has the units of DO in mg/l and represents the average increase in minimum DO levels of the receiving water under proposed conditions. Similar curves may be constructed from the simulation results for suspended solids, total lead, and dissolved lead.

UPSTREAM FLOW QUALITY

The background upstream flow quality is specified by the user by reading in an upstream flow water quality matrix. An example of such a matrix is presented in Table 9-1. The parameters must be quantified by month and must include temperature, background DO deficit, chloride content, 5-day BOD, suspended solids, TKN, and total lead. The chloride content is important only when dealing with a river/estuary system. Where the receiving water is a freshwater stream, zero values should be entered.

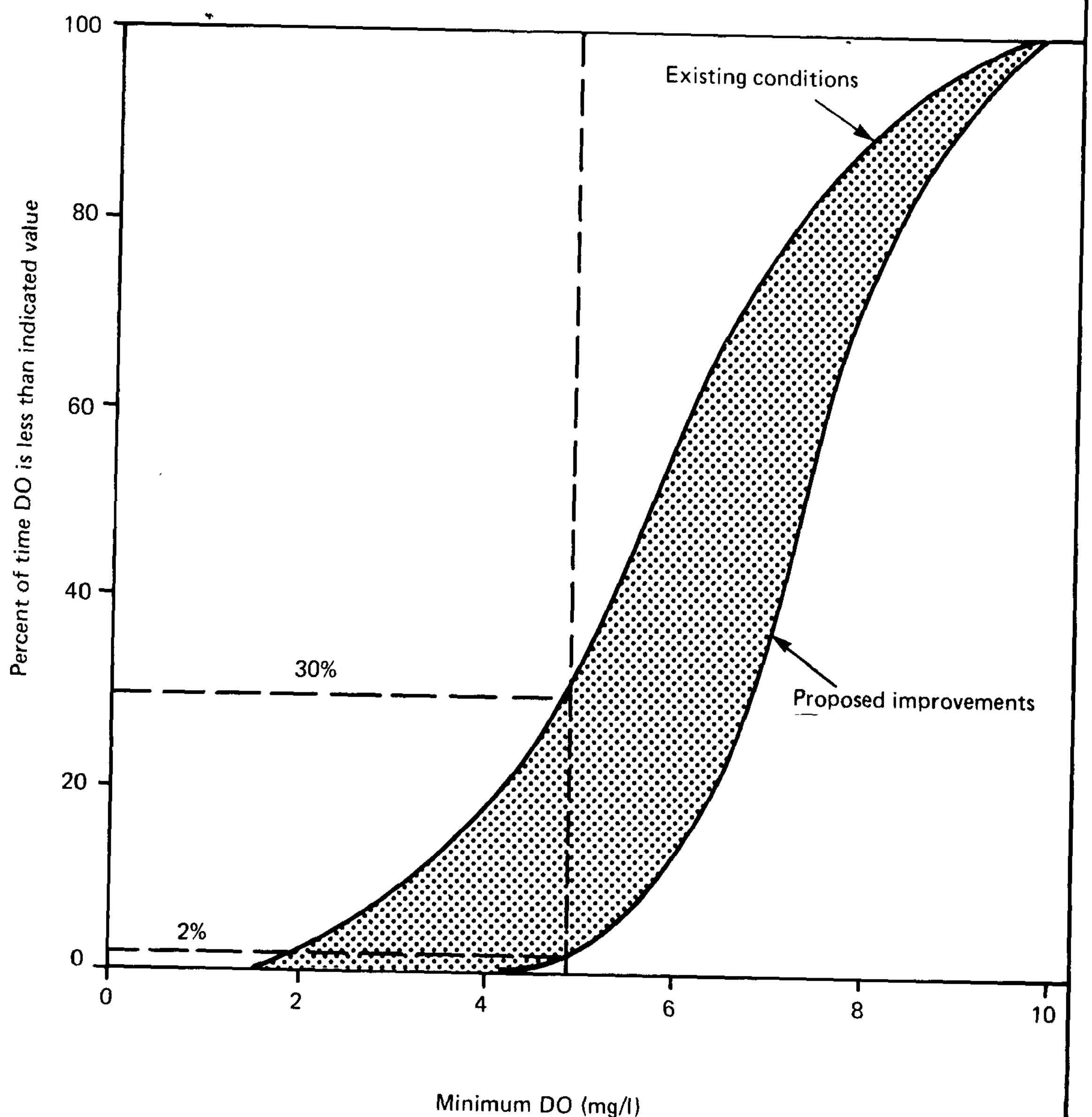

FIGURE 9-1. Example of cumulative frequency curves for minimum dissolved oxygen.

Table 9-1
Example Upstream Flow Water Quality Matrix for Des Moines, Iowa

Month	Temperature (°C)	DO Deficit (mg/l)	Chlorides (mg/l)	BOD_5 (mg/l)	SS (mg/l)	TKN (mg/l)	Pb (mg/l)
1	1.0	0.7	0.0	4.0	584	0.5	0
2	0.0	0.7	0.0	2.0	579	1.2	0
3	1.5	0.7	0.0	4.0	347	2.5	0
4	7.8	0.7	0.0	3.3	435	1.6	0.01
5	20.5	0.7	0.0	3.0	413	1.2	0
6	19.8	0.7	0.0	3.0	408	0.8	0
7	22.0	0.7	0.0	3.0	580	1.5	0
8	26.0	0.7	0.0	12.6	361	1.9	0
9	21.0	0.7	0.0	13.0	407	1.7	0.01
10	15.0	0.7	0.0	13.0	454	1.5	0
11	10.0	0.7	0.0	7.0	522	1.5	0.01
12	1.0	0.7	0.0	5.0	519	1.1	0.02

Ideally the values entered in the upstream flow water quality matrix should be monthly means determined by analysis of observed records of water quality measured upstream of the urban area. If records near the upstream boundary of the urban area are not available, then records from a nearby station which is not affected by urbanization can be used. If no water quality records are available, then reasonable values of background quality may be obtained from the literature. A good source for such information is reference 10, "Loading Functions for Assessment of Water Pollution From Nonpoint Sources."

SUSPENDED SOLIDS RESPONSE (MODULE 80)

Suspended solids is assumed to be a conservative substance during the time period required for inflows to mix. Thus, suspended solids concentration occurring in the receiving water during each time step is computed as the flow weighted average of all suspended solids entering the mixing zone (see Figure 7-1) during that time step. This computation is performed as follows.

$$SS = \frac{\sum_{i=1}^{4} Q_i \times SS_i}{\sum_{i=1}^{4} Q_i} \qquad (9\text{-}1)$$

where

SS = SS concentration for time period in mg/l.

Q_i = flow rate generated by source i (urban storm water CSO, WWTP or upstream flow) for time period in cfs.

SS_i = suspended solids concentration generated by source i for time period in mg/l.

DISSOLVED OXYGEN RESPONSE (MODULE 81)

The dissolved oxygen response model is a one-dimensional completely mixed plug flow freshwater river or river/estuary representation. Application of this model is limited to free-flowing freshwater streams and tidal river esturaries where the flow primarily occurs along one dimension. In general, if the length of the receiving water system is large compared to the width, then the model can be applied. The model cannot be applied to impounded rivers or to multidimensional estuary systems.

Parameters of the system are considered constant throughout the length of stream under consideration. Thus, the model is a lumped parameter representation rather than a distributed parameter representation.

Before the actual DO budget computations can be performed for each time step in the simulation, several system parameters must be defined. These parameters include: the mean depth of flow, the velocity of flow, the saturation value for dissolved oxygen, and the reaction coefficients such as the waste decay rate K1, the reaeration rate K2, and the sediment uptake rate SB.

<u>Receiving Water Hydraulics</u>

The relationship between depth of flow and flow rate is represented by the following equation (11).

$$H = \beta_1 Q^{\beta_2} + \beta_3 \qquad (9\text{-}2)$$

where

H = mean depth of flow in feet.

Q = total flow in the receiving water in cfs.

β_1, β_2, and β_3 = constants.

In a free flowing freshwater stream, β_3 will represent some minimum value of depth, while β_1 and β_2 define the stage discharge relationship for the reach. If open channel flow applies, then the following relationships may be used to estimate β_1 and β_2 (11).

$$\beta_1 = \left[\frac{n}{1.49\ B\ S_o^{1/2}}\right]^{0.6} \qquad (9\text{-}3)$$

$$\beta_2 = 0.6 \qquad (9\text{-}4)$$

where

n = Manning roughness coefficient for the channel.

B = the average width of the stream in the receiving reach in feet.

S_o = the average channel bottom slope of the stream in the receiving reach in feet per foot.

In general, B and S_o can be measured from USGS topographic maps, and n can be estimated from values reported in the literature. For example, see Chow, 1959 (12), pages 101 to 123.

In a deep tidal estuary where stage is relatively uneffected by changes in the freshwater flow Q, the constant β_3 may be set equal to the mean depth at mean water level, and β_1 and β_2 may be set equal to zero.

The relationship between velocity of flow and flow rate is represented in the model by the following equation (13).

$$V = \alpha_1 Q^{\alpha_2} \qquad (9\text{-}5)$$

where

V = average velocity of flow in feet per second.

α_1 and α_2 = constants.

The α_1 and α_2 values used in equation 9-5 should be based on the depth/flow relationship defined in Equation 9-2. That is, for every value of Q, there is a corresponding value of depth defined by Equation 9-2, and for every value of depth, there is a value of cross sectional area of flow computed as B x H. The average velocity of flow is then computed by dividing the flow rate Q by the cross sectional area A. Values of Q versus V may then be plotted on log-log paper to determine the proper coefficient α_1 and α_2. This procedure is illustrated in Table 9-2.

Saturation DO

Dissolved oxygen saturation is a function of temperature and chloride content and is defined in the receiving water module by the following equations.

$$DOSAT = 14.652 - 0.410222*T + 0.00799*T^2 - 0.00007777*T^3 \qquad (9\text{-}6)$$

$$DOSAT = DOSAT*(1.0 - CC/100{,}000) \qquad (9\text{-}7)$$

where

DOSAT = saturation value of dissolved oxygen in mg/l.

T = receiving water temperature in degrees centigrade.

CC = chloride concentration in mg/l.

Table 9-2
Example Computation of Hydraulic Constants
(α's and β's) for a Free Flowing Stream

Known from maps: $B = 300$ feet assume: $n = 0.03$
$S_o = 0.0005$ feet per foot

$$\beta_1 = \left(\frac{n}{1.49\ B\ S_o^{1/2}}\right)^{0.6} = \left(\frac{0.03}{1.49(300)(0.0005)^{1/2}}\right)^{0.6} = 0.0306$$

$$\beta_2 = 0.6 \qquad \beta_3 = 0.0$$

$$\underline{\underline{H = 0.0306\ Q^{0.6} + 0.0}}$$

Q (cfs)	H (ft)	Area, A (ft^2)	V (ft/sec)
100	0.48	144	0.69
500	1.27	381	1.31
1,000	1.93	579	1.73
2,000	2.93	879	2.28
5,000	5.07	1,521	3.29
10,000	7.69	2,307	4.33

from log-log plot of Q vs. V

$$\alpha_1 = 0.104$$

$$\alpha_2 = 0.407$$

$$\underline{\underline{V = 0.104\ Q^{0.407}}}$$

Equation 9-6 relates saturation dissolved oxygen to temperature for freshwater systems (14). Equation 9-7 presents an approximate relationship which defines an adjustment to the computed saturation value in systems which contains significant chlorides. Equation 9-7 was developed from analysis of dissolved oxygen solubility data reported in Reference 15.

Carbonaceous Waste Decay Rate Kl

The CBOD or carbonaceous waste decay rate is assumed to be a constant value for each type of waste source. The overall waste decay rate is computed as the weighted average of the decay rates for each source. Kl values for carbonaceous oxygen demand at 20° C are assumed as follows.

Source	Kl, day^{-1} (base e)
Upstream flow	0.16
Stormwater	0.16
Wastewater effluent	0.23
Combined sewer overflow	0.40

The above values of carbonaceous waste decay rate are default values which are built into the program. If the user does not supply specific values for Kl, then these values are assigned. The program assumes that runoff from watershed 1 is combined sewer overflow (Kl = 0.40) and that runoff from watershed 2 is separate stormwater runoff (Kl = 0.16). The user may override these assumptions by specifying a Kl value for each watershed, for the upstream flow, and for the dry-weather flow.

The ability to specify Kl values is most useful in the case where the receiving water is a shallow stream. It has been shown that for shallow flow (less than 8 feet deep), the instream carbonaceous waste decay rate is greater than the typical laboratory values which are used here as default values. The following equation can be used to estimate the effect of stream depth on Kl (16).

$$KlH = Kl*(8/H)^{.434} \qquad (9\text{-}8)$$

where

KlH = carbonaceous waste decay rate for a stream with a mean depth H less than 8 feet.

Kl = typical or laboratory value of carbonaceous waste decay rate.

H = mean depth of receiving stream in feet.

The relationship defined by Equation 9-8 is only an approximation, and considerable scatter in the data have been observed. Kl values as large as 4.0 for domestic wastes have been reported for very shallow (less than 3-foot mean depth) receiving streams. Therefore, in this case of a shallow stream, the Kl value may be used as a calibration parameter.

The Kl value for the total mixed flow is then computed by the following equation.

$$Kl = \frac{\sum_{i=1}^{4} Q_i * BOD_i * Kl_i}{\sum_{i=1}^{4} Q_i * BOD_i} \qquad (9\text{-}9)$$

where

Q_i = flow rate from source i (e.g., CSO), in cfs.

BOD_i = carbonaceous oxygen demand from source i in mg/l.

Kl_i = waste decay rate for source i as defined above in day^{-1}.

Kl is then adjusted for receiving water temperature by application of Equation 9-10 (14).

$$Kl = Kl(1.047)^{(T-20)} \qquad (9\text{-}10)$$

where all terms are as previously defined.

Nitrogenous Waste Decay Rate K3

The nitrogenous waste decay rate at 20° C is assumed to be equal to 0.10 day^{-1} base e for all sources (11). This value is adjusted for receiving water temperature as follows (11).

$$K3 = 0.10(1.017)^{(T-20)} \qquad (9\text{-}11)$$

where

K3 = nitrogenous waste decay rate in day^{-1}.

Atmospheric Reaeration Rate K2

Atmospheric reaeration of streams and estuaries has been the subject of numerous investigations. Most of these studies have resulted in the development of empirical relationships which relate the reaeration rate to the hydraulic parameters of depth of flow and velocity of flow. However, choosing the proper emprical relationship for a given case has been largely a matter of engineering judgment.

In 1976, Covar (17) reviewed many of the commonly used K2 equations and the data from which these equations were derived. From this review, specific criteria were developed by which the most appropriate equation could be selected for a given set of hydraulic conditions. The Covar criteria have been incorporated into the receiving water response module of CSPSS.

By these criteria, one of three equations is chosen based on flow hydraulics. These equations are: (1) the O'Connor-Dobbins equation, (2) the Churchill equation, and (3) the Owens equation. Each of these equations is defined below.

1. The O'Connor-Dobbins equation

$$K2 = \frac{12.9\ V^{0.5}}{H^{1.5}} \qquad (9\text{-}12)$$

2. The Churchill equation

$$K2 = \frac{11.6\ V^{0.969}}{H^{1.673}} \qquad (9\text{-}13)$$

3. The Owens equation

$$K2 = \frac{21.7\ V^{0.67}}{H^{1.85}} \qquad (9\text{-}14)$$

where

K2 = atmospheric reaeration coefficient in day^{-1} base e.

V = velocity of flow in feet per second.

H = depth of flow in feet.

The selection criteria are outlined as follows.

1. If depth is greater than 2.0 feet and velocity is less than or equal to 2.5 feet per second, the O'Connor-Dobbins equation is used.

2. If depth is greater than 2.0 feet and velocity is greater then 2.5 feet per second, the Churchill equation is used.

3. If depth is less than or equal to 2.0 feet, the Owens equation is used.

In most cases, the above procedure results in the computation of reasonable values of the reaeration coefficient for flowing streams and river/estuary systems, for each time step in the simulation. However, the user has the option of specifying a K2 value to be used in all dissolved oxygen response computations. If this option is utilized, then the Covar K2 selection criteria is bypassed, and the K2 value read in by the user is applied at each time step. This option is most useful in the case of a shallow stream where the stage-discharge and the discharge-velocity relationships are uncertain and where this uncertainly is reflected in the computation of unrealisticly large values of the reaeration rate.

The user also has the option to adjust the computed or specified K2 values, if so desired, by application of a K2 adjustment factor.

$$K2 = K2*K2ADJ \tag{9-15}$$

where

K2ADJ = a user-supplied adjustment factor.

This adjustment factor may be used to calibrate the DO budget model to prototype conditions if sufficient data exist to define the cumulative DO frequency curve in the receiving water under existing conditions. A default value of 1.0 is built into the model.

The K2 value is adjusted for receiving water temperature by the following equation (14).

$$K2 = K2(1.024)^{(T-20)} \tag{9-16}$$

where all terms are as previously defined.

All empirical equations discussed above (Equations 9-11, 9-12, and 9-13) will yield values of the reaeration coefficient which approach zero as the velocity of flow approaches zero. However, reaeration occurs even in still waters due to wind and wave action. Thus, Equations 9-11, 9-12, and 9-13 will yield unrealistically low values of K2 in cases where the velocity of flow is near zero. Therefore, a minimum value of the reaeration coefficient is computed and compared to the value obtained by application of the emperical equations. The minimum value is defined as follows.

$$K2MIN = 2.0/H \qquad (9\text{-}17)$$

where

K2MIN = minimum reaeration rate due to wind and wave action.

H = mean depth in feet.

If K2 is less than K2MIN, then K2 is replaced by K2MIN.

Sediment Uptake Rate SB

Sediment uptake rate or benthic demand at 20° C is computed as follows (14).

$$SB = SBA*3.281/H \qquad (9\text{-}18)$$

where

SB = benthic demand in mg/l/day at 20° C.

SBA = areal benthic demand in gm O_2/m^2/day.

H = depth of flow in feet.

SBA values are user-supplied and should be obtained from previous studies of the receiving water sediments, if available. Typical values as reported by Thomann (14) are given in Table 9-3.

Sediment uptake rates are then adjusted for receiving water temperature by application of Equation 9-18.

$$SB = SB(1.065)^{(T-20)} \qquad (9\text{-}19)$$

where all terms are as previously defined.

Table 9-3
Average Values of Oxygen Uptake of River Bottoms (after Thomann 1972)

Bottom Type and Location	Uptake (g $O_2/m^2/day$) at 20° C	
	Range	Approximate Average
Municipal sewage sludge--outfall vicinity	2-10.0	4
Municipal sewage sludge--"aged" downstream of outfall	1-2	1.5
Cellulosic fiber sludge[a]	4-10	7
Estuarine mud	1-2	1.5
Sandy bottom	0.2-1.0	0.5
Mineral soils	0.05-0.1	0.07

[a]Calculated from reported values of 2-5 and 3.5 at 11° C.

Dissolved Oxygen in a Stream

The dissolved oxygen deficit of a freshwater stream is represented by a plug flow model. That is, the model simulates the dissolved oxygen budget within each discrete unit of water generated by the urban system in each time step of the simulation. Mixing of waters in adjacent plugs is assumed negligible. As the discrete plug moves downstream, the oxygen resources are being depleted by waste decay, and oxygen resources are being added by reaeration. These reactions are time-dependent and thus, the equations which define the reactions are expressed as a function of time.

Oxygen demands considered are ultimate carbonaceous BOD (CBOD), nitrogenous BOD (NBOD), sediment demand (SB), and background dissolved oxygen deficit. The only oxygen source considered is atmospheric reaeration.

Ultimate carbanaceous BOD is computed as follows (13).

$$CBOD = \frac{BOD}{(1.0 - e^{-5.0*K1})} \qquad (9\text{-}20)$$

where

CBOD = ultimate carbonaceous BOD in mg/l.

BOD = 5-day BOD from all sources in mg/l.

K1 = Composite carbonaceous waste decay rate as previously defined.

Ultimate nitrogenous oxygen demand (NBOD) is computed by application of Equation 9-20 (11).

$$NBOD = 4.57*TKN \qquad (9\text{-}21)$$

where

NBOD = ultimate nitrogenous oxygen demand in mg/l.

TKN = total Kjeldahl nitrogen from all sources in mg/l.

The dissolved oxygen deficit at any time, t, is computed for each type of oxygen demand as follows.

1. For carbonaceous demand

$$D_1 = \frac{K1*CBOD}{K2 - K1} \left(e^{-K1*t} - e^{-K2*t}\right) \qquad (9\text{-}22)$$

2. For nitrogenous demand

$$D_2 = \frac{K3*NBOD}{K2 - K3} \left(e^{-K3*t} - e^{-K2*t}\right) \qquad (9\text{-}23)$$

3. For benthic demand

$$D_3 = \frac{SB}{K2} \left(1.0 - e^{-K2*t}\right) \qquad (9\text{-}24)$$

4. For initial deficit

$$D_4 = Do\ e^{-K2*t} \qquad (9\text{-}25)$$

5. For total deficit

$$DODEF = D_1 + D_2 + D_3 + D_4 \qquad (9\text{-}26)$$

where

t = travel time in the receiving reach in days.

Do = dissolved oxygen deficit in the receiving water upstream from the urban area in mg/l.

DODEF = dissolved oxygen deficit at time t, in mg/l.

All other terms are as previously defined.

The procedure used in the DO budget module for streams is to divide the receiving reach into 50 equal increments (equal travel times) and to solve the above equations for each increment. This computation yields a DO deficit array for the plug flow. This array is then searched, and the maximum value is saved. The minimum value of dissolved oxygen is then computed as follows.

$$DOMIN = DOSAT - DC \qquad (9\text{-}27)$$

where

DOMIN = minimum value of dissolved oxygen for time step in mg/l.

DOSAT = saturation value of dissolved oxygen for a given temperature and chloride concentration in mg/l.

DC = critical or maximum dissolved oxygen deficit in mg/l.

Dissolved Oxygen in an Estuary

The DO budget computations for a river/estuary are similar to the computations for a freshwater stream. However, the equations which define the reactions have been modified to account for tidal dispersion. These modifications were first proposed by O'Connor (18) and have been reported by Nemerow (19). The modified equations are:

1. For carbonaceous demand

$$D_1 = \frac{K1*CBOD}{K2 - K1} (e^{J1*X} - e^{J2*X}) \tag{9-28}$$

2. For nitrogenous demand

$$D_2 = \frac{K3*NBOD}{K2 - K3} (e^{J3*X} - e^{J2*X}) \tag{9-29}$$

3. For benthic demand

$$D_3 = \frac{SB}{K2} (1.0 - e^{J2*X}) \tag{9-30}$$

4. For initial deficit

$$D_4 = Do\ e^{J2*X} \tag{9-31}$$

where

$$J1 = \frac{VF}{2*E}\left[1.0 - \sqrt{1.0 + \frac{4*K1*E}{VF^2}}\right] \qquad (9\text{-}32)$$

$$J2 = \frac{VF}{2*E}\left[1.0 - \sqrt{1.0 + \frac{4*K2*E}{VF^2}}\right] \qquad (9\text{-}33)$$

$$J3 = \frac{VF}{2*E}\left[1.0 - \sqrt{1.0 + \frac{4*K3*E}{VF^2}}\right] \qquad (9\text{-}34)$$

VF = velocity of freshwater flow in miles per day.

E = tidal dispersion coefficient in square miles per day.

X = distance downstream from urban area in miles.

All other terms are as previously defined.

Equations 9-28 through 9-31 are applied in a manner similar to Equations 9-22 through 9-25 in order to generate the desired DO deficit array. All other computations are as described in the section on dissolved oxygen in a stream.

The tidal dispersion coefficient for the receiving water under consideration should be obtained from previous studies, if available. Typical values of the tidal dispersion coefficient as reported by Thomann are given in Table 9-4.

Computational Sequence

The DO budget computations for each time step in the simulation can be described in six steps as follows.

1. Compute the total flow from all sources entering the receiving water in cfs.

2. Compute the following parameters.

   a. Velocity of flow, V, in feet per second.

   b. Depth of flow, H, in feet.

   c. Total 5-day BOD in mg/l.

   d. Total nitrogenous oxygen demand, NBOD, in mg/l.

   e. Initial DO deficit in mg/l.

Table 9-4
Estimated Longitudinal Tidal Dispersion Coefficients (adapted from Thomann 1972)

Estuary	Mi^2/day	Tracer	Remarks
Delaware	2-7	Chlorides	Torresdale, Pennsylvania, to Reedy Island, Delaware
	7-11	Chlorides	Lower portion of estuary to Delaware Bay
Potomac	0.2-0.6	Dye	Upper 25 mi. nonsaline portion
Potomac	0.6-6.0	Chlorides	Middle 25 mi. brackish portion
Potomac	6.0-10.0	Chlorides	Lower 50 mi.-ch 3,000-10,000 mg/l
Waccasassa (Cedar Key, Florida)	2.0-2.7	Chorides	Small Gulf of Mexico estuary, brackish portion, U_{max} = 0.4 knots
	0.4-0.8	Dye	Upper nonsaline portion
New York Harbor (including upper Bay East River, North River, Newark Bay, and Kills)	10.0-24.0	Chlorides	Large saline harbor, estuary and tidal strait
James	9-11	Sulfates	Nonsaline portion
Hudson	8	Chlorides	25-50 mi. from Battery, ch-1,000-5,000 mg/l
Severn, England (summer)	1.8-4.0	Salinity	From Weston-super-Mare to Sharpness
Severn, England (winter)	4.1-17.7	Salinity	Higher river flows
Thames, England	1.8-2.8	Salinity	10-25 mi. below London Bridge, low river flow
Thames, England	11.1	Salinity	30 mi. below London Bridge, high river flow

f. Saturation DO concentration, DOSAT, in mg/l.

g. Carbonaceous waste decay rate, K1, in day^{-1}.

h. Ultimate carbonaceous oxygen demand, CBOD, in mg/l.

i. Atmospheric reareration rate, K2, in day^{-1}.

j. Nitrogenous waste decay rate, K3, in day^{-1}.

k. Benthic demand, SB, in mg/l/day.

3. If the receiving water is an estuary ($E \neq 0$), then compute the following addition parameters.

    a. Velocity of freshwater flow, VF, in miles per day.

    b. Reaction exponents, J1, J2, and J3.

4. Compute the DO deficit curve for 50 equally spaced points on the receiving stream.

5. Find the maximum DO deficit, DC, and compute the minimum DO, DOMIN, in mg/l.

6. Test for a calibration point. If DIST1 $\neq$ 0, then compute the DO at distance DIST1 (DOX1).

The above sequence is repeated for every time step in the simulation until the annual arrays are filled. These arrays, the DOMIN array and the DOX1 array, are then analyzed, and a cumulative frequency table is developed and printed for each.

DISSOLVED LEAD RESPONSE (MODULE 82)

The equilibrium dissolved lead response model for CSPSS is based on the assumption that a lead carbonate ($PbCO_3$) system governs the chemistry of lead in natural waters. In most cases, it is generally accepted that lead carbonate chemistry will control dissolved lead content for most natural waters where pH is in a reasonable range and total lead concentrations are not excessive. When the lead carbonate system governs the chemistry of aquatic lead, the solubility of lead is a function of total alkalinity, total hardness, and pH of the receiving water after mixing. The dissolved lead equilibrium model developed here is based primarily on information presented by Stumm and Morgan (20).

The purpose of the model is to compute total and dissolved lead concentrations in the receiving water for each time step of the simulation. In addition, maximum annual 96-hour and time average mean dissolved lead concentrations are also computed.

The lead carbonate model does not consider lead forming the insoluble hydroxy-carbonate solid phase, $Pb_3(CO_3)_2(OH)_2$, as well as the insoluble sulfate and phosphate phases. Also not considered is the formation of soluble organo-lead complexes with humic, fulvic, and tannic acids, which are common (and largely unquantified) constituents in natural runoff. Further, the model is based on a "closed aqueous system," that is, not open to the atmosphere.

The effects of the above limitations are, in part, offsetting. Although the consideration of the additional solid phases might serve to decrease predicted dissolved lead concentrations, the additional consideration of soluble lead complexes with organic acids would have the net effect of increasing soluble lead concentrations. Also adsorption and desorption may be important factors in determing the fate of lead, and this mechanism is not considered. Adsorption which will tend to decrease dissolved lead concentrations is associated with alkaline and neutral waters, whereas desorption which will tend to increase dissolved lead concentrations is associated with acidic waters.

Because of these uncertainties, dissolved lead concentrations found in nature may be higher or lower than values predicted by this formulation. However, the model will yield a reasonable approximation of the dissolved lead content in natural waters.

The integral chemical reaction which forms the basis of the dissolved lead response model is given by the following formula.

$$PbCO_3 \rightleftharpoons Pb^{++} + CO_3^{=} \qquad (9\text{-}35)$$

In order to solve the above chemical reaction at equilibrium conditions, several other reactions in the receiving water must be considered. These reactions are defined by the following formulas.

$$H_2CO_3 \rightleftharpoons HCO_3^{-} + H^{+} \qquad (9\text{-}36)$$

$$HCO_3^{-} \rightleftharpoons CO_3^{=} + H^{+} \qquad (9\text{-}37)$$

$$H_2O \rightleftharpoons H^{+} + OH^{-} \qquad (9\text{-}38)$$

Equilibrium constants which are used in the solution of Equations 9-35 through 9-38 are defined in Table 9-5. These constants are utilized in the mathematical solution of the equilibrium reactions defined above.

Table 9-5
Equilibrium Constants for the
Dissolved Lead Response Model

$K_{sp} = 1.5 \times 10^{-13}$ $pK_{sp} = 12.824$	Equation 9-35
$K_1 = 4.45 \times 10^{-7}$ $pK_1 = 6.35$	Equation 9-36
$K_2 = 4.69 \times 10^{-11}$ $pK_2 = 10.33$	Equation 9-37
$K_w = 10^{-14}$ $pK_w = 14.0$	Equation 9-38

Conversions and Definitions

Before proceeding with the development of the mathematical relationships which define the equilibrium dissolved lead response model, several relationships among the variables should be defined. These relationships will be useful in the forthcoming equations. It should be noted that brackets [ ] always express a concentration in moles per liter, while the absence of brackets expresses a concentration in milligrams per liter.

The relationship between the H^+ ion and pH is expressed as follows.

$$[H^+] = \frac{1}{10^{pH}} \qquad (9\text{-}39)$$

conversely;

$$pH = \text{Log}\,\frac{1}{[H^+]} \qquad (9\text{-}39a)$$

The relationship between the OH^- ion and the H^+ ion is given by the following equation.

$$[OH^-] = \frac{10^{-14}}{[H^+]} \qquad (9\text{-}40)$$

Concentration of total hardness, TH, total alkalinity, TA, and lead, Pb, may be converted from moles per liter to milligrams per liter by application of the following series of linear transformations.

$$TH = [TH] \times (1.0 \times 10^5) \qquad (9\text{-}41)$$

$$TA = [TA] \times (1.0 \times 10^5) \qquad (9\text{-}42)$$

$$Pb = [Pb](2.0719 \times 10^5) \qquad (9\text{-}43)$$

where

TH = total hardness as mg/l $CaCO_3$.

[TH] = total hardness as moles/l $CaCO_3$.

TA = total alkalinity as mg/l $CaCO_3$.

[TA] = total alkalinity as moles/l $CaCO_3$.

Pb = lead concentration as mg/l.

[Pb] = lead concentration as moles/l.

The activity of lead is defined as follows.

$$APb = [Pb]\gamma \qquad (9\text{-}44)$$

where

APb = activity of lead as moles/l.

γ = activity coefficient of lead, dimensionless.

The total carbonic species of each inflow water or of the mixed receiving water is defined by the following equation.

$$[CT] = [H_2CO_3] + [HCO_3^-] + [CO_3^=] \tag{9-45}$$

where

$$[HCO_3^-] = [CT]\alpha_{11} \tag{9-46}$$

and

$$[CO_3^=] = [CT]\alpha_{22} \tag{9-47}$$

where

α_{11} = ionization factor of HCO_3^-

$$\alpha_{11} = \left(\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]}\right)^{-1} \tag{9-48}$$

and

α_{22} = ionization factor of $CO_3^=$

$$\alpha_{22} = \left(\frac{[H^+]^2}{K_1K_2} + 1 + \frac{[H^+]^2}{K_2}\right)^{-1} \tag{9-49}$$

The activity coefficient for lead, γ, used in the solution of Equation 9-44, is determined by application of the Davies equation (20). The Davies equation defines a relationship between log γ, the ionic strength I of the solution, and the valence Z of the ion in question. It has the following form.

$$\log \gamma = -0.5Z^2\left(\frac{\sqrt{I}}{1 + \sqrt{I}} - 0.2I\right) \tag{9-50}$$

where

Z = valence of ion in question

and

$$I = 10^{-5}(4TH - TA) \tag{9-51}$$

Determination of [CT] for Each Inflow

The dissolved lead computation procedure for each time step in the computation begins with the determination of the total carbonic species [CT] for each of the four waters which make up the inflows to the receiving water. The [CT] for each inflow source is determined by application of the following equation.

$$[CT] = \frac{[TA] - [OH^-] + [H^+]}{\alpha_{11} + 2\alpha_{22}} \qquad (9\text{-}52)$$

where all terms are as previously defined.

Mixing of Inflows

The inflows are now mixed, and the concentrations TA_m, TH_m, $[CT_m]$, and $[Pb_m]$ are determined. The subscript m indicates concentrations in the receiving water after mixing, and lead is expressed in terms of total lead.

$$TA_m = \frac{\sum_{i=1}^{4} TA_i \; Q_i}{\sum_{i=1}^{4} Q_i} \qquad (9\text{-}53)$$

$$TH_m = \frac{\sum_{i=1}^{4} TH_i \; Q_i}{\sum_{i=1}^{4} Q_i} \qquad (9\text{-}54)$$

$$[CT_m] = \frac{\sum_{i=1}^{4} [CT_i] \; Q_i}{\sum_{i=1}^{4} Q_i} \qquad (9\text{-}55)$$

$$[Pb_m] = \frac{\sum_{i=1}^{4} [Pb_i] \; Q_i}{\sum_{i=1}^{4} Q_i} \qquad (9\text{-}56)$$

where

Q_i = inflow from source i in cfs and all other terms are as previously defined.

Determination of pH for Mixed Flows

In order to determine the pH of the receiving water, $[H_m^+]$ must first be determined by application of the following equation.

$$[H_m^+] = [CT_m](\alpha_{11} + 2\alpha_{22}) + [OH_m^-] - [TA_m] \quad (9\text{-}57)$$

where all terms are as previously defined.

α_{11}, α_{22}, and $[OH_m^-]$ are all functions of $[H_m^+]$. Therefore, a closed form solution to Equation 9-57 does not exist. Equation 9-57 is solved by application of the Newton-Raphson technique for the solution of nonlinear equations of the form f(x) = 0 (21). This technique appears to be free of convergence problems. However, the possibility of convergence problems always exists when numerical methods are employed. Once $[H_m^+]$ is known, then pH is determined by application of Equation 9-39a.

Precipitation Determination

Once the chemistry of the receiving water as determined in the previous three steps is known, then the occurrence or nonoccurrence of lead precipitation is determined by computing and comparing two parameters, K and K'_{sp}. The solution for parameter K is defined by the following series of equations and relationships.

$$K = \gamma[Pb_m][CT_m]\alpha_2' \quad (9\text{-}58)$$

where

$$\gamma = \frac{1}{10^d} \quad (9\text{-}59)$$

where

$$d = 2\left(\frac{\sqrt{I_m}}{1 + \sqrt{I_m}} - 0.2I_m\right) \quad (9\text{-}60)$$

where

$$I_m = 10^{-5}(4TH_m - TA_m) \tag{9-61}$$

where

$$\alpha_2' = \left(\frac{[H_m^+]^2}{K_1' K_2'} + 1 + \frac{[H_m^+]^2}{K_2'}\right)^{-1} \tag{9-62}$$

where

$$K_1' = \frac{1}{10^{pK_1'}} \tag{9-63}$$

where

$$pK_1' = pK_1 - 0.5\left(\frac{\sqrt{I_m}}{1 + \sqrt{I_m}} - 0.2I_m\right) \tag{9-64}$$

and

$$K_2' = \frac{1}{10^{pK_2'}} \tag{9-65}$$

where

$$pK_2' = pK_2 - 2\left(\frac{\sqrt{I_m}}{1 + \sqrt{I_m}} - 0.2I_m\right) \tag{9-66}$$

The solution for parameter K_{sp}' is defined by the following equations.

$$K_{sp}' = \frac{1}{10^{pK_{sp}'}} \tag{9-67}$$

where

$$pK_{sp}' = pK_{sp} - 4\left(\frac{\sqrt{I_m}}{1 + \sqrt{I_m}} - 0.2I_m\right) \tag{9-68}$$

If K is less than K'_{sp}, precipitation will not occur, and total lead will equal dissolved lead. If K is greater than K'_{sp}, then precipitation will occur, and only a portion of the total lead will be dissolved.

Dissolved Lead Determination

If precipitation does occur, then the dissolved lead fraction is determined by application of the following equations.

$$APb_{mD} = \frac{K'_{sp}}{[CT_m]\alpha'_2} \quad (9\text{-}69)$$

$$Pb_{mD} = \frac{APb_{mD}}{\gamma} 2.0219 \times 10^5 \quad (9\text{-}70)$$

where

Apb_{mD} = Actual dissolved lead activity in mixed inflows as moles/liter.

Pb_{mD} = Actual dissolved lead concentration in mixed inflows as mg/l.

The above computations are repeated for every time step in the simulation, and in this manner, a total lead array and dissolved lead array are generated for the year.

Computational Sequence

The dissolved lead computations for each time step in the simulation can be summarized in six steps as follows.

1. Compute the total flow from all sources entering the receiving water in cfs.

2. Determine the total carbonic species, [CT], of each influent water.

3. Determine the concentrations of total alkalinity, total hardness, total carbonic species, and total lead for the mixed inflow waters (i.e., receiving water).

4. Compute the pH of the receiving water using the Newton-Raphson technique.

5. Determine if lead precipitation occurs in the receiving water.

6. Determine dissolved lead concentration.

Reports generated by module 82 for each year in the simulation include: (1) cumulative frequency of total lead concentrations, (2) cumulative frequency of dissolved lead concentrations, (3) maximum annual 96-hour dissolved lead concentration, and (4) long-term average dissolved lead concentration.

INPUT DATA

The input data required for the receiving water response portion of CSPSS are considerably more extensive than are data requirements for the other modules. If module 80, suspended solids response, is run, then all that is needed is background suspended solids concentration by month for the receiving water upstream from the urban area. If module 81 is run, then the following data are required.

1. Hydraulic coefficients--α's and β's.

2. K2 of receiving water in day^{-1} base e (optional).

3. Sediment oxygen uptake rate in g $O_2/m^2/day$.

4. Adjustment factor for computed K2 (optional).

5. Distance to DO calibration point in miles (optional).

6. Length of receiving water reach in miles.

7. Tidal dispersion coefficient in mi^2/day (for river/ estuary system).

8. Waste decay rates (K1 values) for watershed 1, watershed 2, upstream flow, and dry-weather flow in day^{-1} base e (optional).

9. Background water quality matrix for receiving water. The following water quality parameters must be defined by month.

    a. Temperature, °C.

    b. DO deficit, mg/l.

    c. Chloride concentration, mg/l (for river/estuary system).

    d. BOD_5 concentration, mg/l.

    e. Suspended solids concentration, mg/l.

    f. TKN concentration, mg/l.

    If module 82 is run, then background total lead concentrations must be added to the above background water quality matrix. In addition, certain chemical parameters for each inflow source must be defined. The additional parameters required are:

a. Total alkalinity, mg/l.

b. Total hardness, mg/l.

c. pH, standard units.

Coding instructions may be found in Appendix A.

REFERENCES

1. Hillier, F. S. and Lieberman, G. J, Introduction to Operations Research, Holden-Day Inc., 1967.

2. Viessman, W, Harbaugh, T. E., and Knapp, J. W., Introduction to Hydrology, Intext, Inc. 1972.

3. Fiering, M. B. and Jackson, B. B., "Synthetic Stream Flows" Water Resources Monograph No. 1, American Geophysical Union, Washington, D.C. 1971.

4. Mockus, V. et al., "Hydrology" Section 4 SCS National Engineering Handbook Soil Conservation Service, U.S. Department of Agriculture, August 1972.

5. Donigian, A.S. and Crawford, N. H., "Modeling Nonpoint Pollution from the Land Surface" EPA-600/3-76-083, July 1976.

6. Heaney, J. P., Huber, W. C., and Nix, S. J., "Stormwater Management Model Level I - Preliminary Screening Procedures" EPA-600/2-76-275, October 1976.

7. Huber, W. C. et al., "Storm Water Management Model Users Manual Version II" EPA-670/2-75-017, March 1975, p. 139.

8. Pisano, W. C. and Queiroz, C. S. "Procedures for Estimating Dry-Weather Pollutant Deposition in Sewerage Systems" EPA-600/2-77-120, July 1977.

9. "Storage, Treatment, Overflow Runoff Model Storm" Users Manual, The Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California, July 1976.

10. McElroy, A.D. et al., "Loading Functions for Assessment of Water Pollution from Nonpoint Sources" EPA-600/ 2-76-151, May 1976.

11. Crim, R. L. and Lovelace, N. L., "Auto-Qual Modeling System" EPA-440/0-73-003, March 1973.

12. Chow, V. T., Open Channel Hydraulics, New York: McGraw Hill Book Co., 1959.

13. Heaney, J. P. et al. "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II: Cost Assessment and Impacts" EPA-600/ 2-77-064, March 1977.

14. Thomann, R. V., "Systems Analysis and Water Quality Management," Environmental Science Services Division, Environmental Research and Applications, Inc., New York: 1972.

15. Metcalf & Eddy, Inc. Wastewater Engineering, New York: McGraw Hill Book Co., 1972.

16. Hydroscience Inc., "Simplified Mathematical Modeling of Water Quality," U.S. Environmental Protection Agency, Washington, D.C., March 1971.

17. Covar, A. P., "Selecting the Proper Reaeration Coefficient for Use in Water Quality Models," Proceedings Conference on Environmental Modeling and Simulation, EPA 600/9-76-016 July 1976.

18. O'Connor, D. J., "Oxygen Balance of an Estuary," Journal of the Sanitary Engineering Division ASCE, May 1960.

19. Nemerow, N. L. Scientific Stream Pollution Analysis, McGraw Hill Book Co., 1974.

20. Stumm, W. and Morgan, J. J., "Aquatic Chemistry; An Introduction Emphasizing Chemical Equilibria in Natural Waters," Wiley-Interscience Inc., New York, 1970.

21. McCalla, T. R., "Introduction to Numerical Methods and FORTRAN Programming," John Wiley & Sons, Inc., New York, 1967.

Appendix A
CODING INSTRUCTIONS

Module--Main

Input: The following variables are inputed:

Card 1

Col 1-40	Location

Card 2

Col 1-2	Number of years to be simulated
Col 3-4	Time interval for simulation (in hours)
Col 5-6	Number of watersheds
Col 7-15	Seed number for pseudorandom number generator

Card 3

Col 1-2	First option selected
Col 3-4	Second option selected
Col 5-6	Third option selected
.	
.	
.	
Col 15-16	Eighth option selected

Output: Report on:

The location of the analysis, number of years to be simulated, time interval for the simulation, number of watersheds, seed number for the pseudorandom generator, and options selected for this simulation.

Module 10: Stochastic Rainfall Simulator

Input: The following variables are inputed:

Card 1		
	Col 1-2 . . . Col 23-24	Months in season 1, Col 1-2, 3-4, 5-6, etc., until all months in season 1 are entered (1-12 allowable)
Card 2		
	Col 1-2 . . . Col 23-24	Months in season 2, Col 1-2, 3-4, 5-6, etc., until all months in season 2 are entered (1-12 allowable)
Card 3		
	Col 1-10	Mean time between storms in hours--season 1
	Col 11-20	Mean time between storms in hours--season 2
Card 4		
	Col 1-10	Mean duration of storm in hours--season 1
	Col 11-20	Mean duration of storm in hours--season 2
Card 5		
	Col 1-10	Mean rainfall depth in inches--season 1
	Col 11-20	Standard deviation of rainfall depth in inches--season 1
	Col 21-30	Correlation coefficient of rainfall depth--season 1
Card 6		
	Col 1-10	Mean rainfall depth in inches--season 2
	Col 11-20	Standard deviation of rainfall depth in inches--season 2
	Col 21-30	Correlation coefficient of rainfall depth--season 2

Output: Report on input parameters and a summary of annual rainfall array, by season.

Module 20: Runoff by Soil Conservation Service Rainfall/Runoff Technique

Input: The following variables are inputed:

Card 1

Col 1-2	Months in dormant season, Col 1-2, 3-4, 5-6, etc., until all months in dormant season are entered (1-12 allowable)
.	
.	
.	
Col 23-24	

Card 2

Col 1-2	Months in growing season, Col 1-2, 3-4, 5-6, etc., until all months in growing season are entered (1-12 allowable)
.	
.	
.	
Col 23-24	

Card 3

Col 1-10	CN1 for watershed i
Col 11-20	CN2 for watershed i
Col 21-30	CN3 for watershed i

Card 4

Col 1-10	Drainage area in acres for watershed i
Col 11-20	Time of concentration in hours for watershed i
Col 21-30	Washoff coefficient for watershed i

Note: There is a set of Card 3 and Card 4 for each watershed. The first set of cards contains data for watershed 1, and the second set of cards contains data for watershed 2.

Output: Report on input parameters and summary of annual runoff, by watershed.

Module 30: Watershed Pollution Accumulation/Washoff

Input: The following variables are inputed:

Card 1

Col 1-10	Accumulation rate for biochemical oxygen demand in lb/ac/day
Col 11-20	Decay rate for biochemical oxygen demand in fraction removed/day

Card 2

Col 1-10	Accumulation rate for total Kjeldahl nitrogen in lb/ac/day
Col 11-20	Decay rate for total Kjeldahl nitrogen in fraction removed/day

Card 3

Col 1-10	Accumulation rate for suspended solids in lb/ac/day
Col 11-20	Decay rate for suspended solids in fraction removed/day

Card 4

Col 1-10	Accumulation rate for lead in lb/ac/day
Col 11-20	Decay rate for lead in fraction removed/day

Note: A set of Cards 1 to 4 is required for each watershed. Data for each watershed must be grouped together and watershed 1 data must precede watershed 2 data.

Output: Report on input parameters. Summary of annual runoff quality arrays and total annual washoff for each pollutant by watershed.

Module 40: Excess Sewer System Infiltration

Input: The following variables are inputed:

Card 1 (for watershed 1)

Col 1	Watershed code (1 infiltration computed, 0 infiltration not computed)
Col 2-11	Average pipe diameter, in inches
Col 12-21	Pipe length, in miles
Col 22-31	Average daily dry-weather flow, in cfs
Col 32-41	Capacity ratio for wastewater treatment plant
Col 42-51	Infiltration adjustment factor

Card 2 (Same as Card 1) (Required for the other watershed)

Output: Report on input parameters by watershed. Summary of excess infiltration results and a summary of the resultant excess infiltration plus direct runoff quality array.

Note: If a 0 is entered in Col 1, the remaining fields for that watershed may be left blank.

Module 50: Storage/Treatment

Input: The following variables are inputed:

Card 1

Col 1-10	Maximum storage capacity watershed i, in ft^3
Col 11-20	Maximum treatment rate watershed i, in cfs
Col 21-25	BOD removal efficiency watershed i
Col 26-30	Suspended solids removal efficiency watershed i
Col 31-35	TKN removal efficiency watershed i
Col 36-40	Lead removal efficiency watershed i

Card 2

Col 1-10	Initial storage watershed i, in ft^3
Col 11-20	Initial BOD concentration watershed i, in mg/l
Col 21-30	Initial suspended solids concentration watershed i, in mg/l
Col 31-40	Initial TKN concentration watershed i, in mg/l
Col 41-50	Initial lead concentration watershed i, in mg/l

Note: A set of Cards 1 and 2 is required for each watershed. Data for each watershed must be grouped together, and watershed 1 data must precede watershed 2 data.

Output: Report on input parameters and summary statistics on operation of treatment plant, the quality of the water discharged to the receiving stream, the number of overflow events, the number of days with overflow, and the annual volume of overflow in inches.

Module 60: Dry-weather Wastewater Treatment Plant Flow

Input: The following variables are inputed:

Card 1

Col 1-10	Mean daily dry-weather flow for wastewater treatment plant in cfs
Col 11-20	Mean 5-day biochemical oxygen demand concentration of dry-weather flow in mg/l
Col 21-30	Mean suspended solids concentration of dry-weather flow in mg/l
Col 31-40	Mean total Kjeldahl nitrogen concentration of dry-weather flow in mg/l
Col 41-50	Mean total lead concentration of dry-weather flow in mg/l
Col 51-60	Mean dissolved oxygen deficit of dry-weather flow in mg/l

Output: Report on input parameters.

Module 70: Daily Streamflow

Input:	The following variables are inputed on dataset FT08F001:

Card 1

Col 2	Number of years of streamflow on data set (1-5 allowable)

Cards 2 to 1,801

Col 1-6	Daily streamflow in cfs

Note:	One to five years of streamflow data may be contained on this data set. Thus, allowable number of cards read are 361, 721, 1,081, 1,441, and 1,801.
Output:	If improper amount of data is entered, then message is written and the job aborted; otherwise, output generated by this module includes the number of years of streamflow read and the first 10 values of daily streamflow on the data set.

Module 71: Stochastic Monthly Streamflow Simulator

Input: The following variables are inputed:

Cards 1 to 12	Monthly data (months 1 to 12)
Col 1-10	Monthly mean streamflow in cfs
Col 11-20	Standard deviation of monthly streamflow in cfs
Col 21-30	Correlation coefficient of monthly streamflow

Output: Report on input parameters and summary statistics for generated streamflow array.

Module 80: Suspended Solids Response

Input: The following variables are inputed:

Cards 1 to 12

Col 41-50	Suspended solids concentration in upstream flow (mg/l)

Output: Report on input parameters and on cumulative frequency of suspended solids concentration in the receiving water.

Module 81: Suspended Solids and Dissolved Oxygen Response

Input: The following variables are inputed:

Card 1

Col 1-10	α_1
Col 11-20	α_2

Card 2

Col 1-10	β_1
Col 11-20	β_2
Col 21-30	β_3
Col 31-40	K2 for receiving stream day^{-1} base e (optional)

Card 3

Col 1-10	Areal benthic uptake rate (gm O_2/m^2/day)
Col 11-20	Calibration for K_2 (K2ADJ, optional)
Col 21-30	Distance from urban area to calibration point, in miles
Col 31-40	Length of receiving water reach, in miles
Col 41-50	Tidal dispersion coefficient, in $miles^2$/day
Col 51-55	Kl for watershed 1 in day^{-1} base e (default = 0.40)
Col 56-60	Kl for watershed 2 in day^{-1} base e (default = 0.16)
Col 61-65	Kl for upstream flow in day^{-1} base e (default = 0.16)
Col 66-70	Kl for dry-weather flow in day^{-1} base e (default = 0.23)

Cards 4 to 15	(data for months 1 to 12)
Col 1-10	Water temperature (month i) (°C)
Col 11-20	Dissolved oxygen deficit (month i) (mg/l)
Col 21-30	Chloride concentration (month i) (mg/l)
Col 31-40	Biochemical oxygen demand concentration (BOD_5) in upstream flow (month i) (mg/l)
Col 41-50	Suspended solids concentration in upstream flow (month i) (mg/l)
Col 51-60	Total Kjeldahl nitrogen concentration in upstream flow (month i) (mg/l)
Col 61-70	Lead concentration in upstream flow (month i) (mg/l) (necessary only if Module 82 is run)

Output: Report on input parameters and cumulative distributions of minimum dissolved oxygen, dissolved oxygen at calibration point, portion of receiving water affected by low DO, and cumulative distribution of suspended solids.

Module 82: Suspended Solids, Dissolved Oxygen, and Dissolved Lead Response.

Input: The following variables are inputed:

Cards 1 to 15 Same as Module 81

Card 16

Col 1-10	Alkalinity--(CSO)
Col 11-20	Alkalinity--(SW)
Col 21-30	Alkalinity--(SF)
Col 31-40	Alkalinity--(DW)

Card 17

Col 1-10	Hardness--combined sewer overflow (CSO)
Col 11-20	Hardness--storm water (SW)
Col 21-30	Hardness--streamflow (SF)
Col 31-40	Hardness--dry-weather flow (DW)

Card 18

Col 1-10	pH--(CSO)
Col 11-20	pH--(SW)
Col 21-30	pH--(SF)
Col 31-40	pH--(DW)

Output: Report on input parameters, amount of lead in water column and sediment, cumulative frequency of total lead and dissolved lead concentrations, maximum annual 96-hour dissolved lead concentration, and long-term average dissolved lead concentration.

Appendix B
FORTRAN LISTING OF CONTINUOUS
STORMWATER POLLUTION SIMULATION
SYSTEM (CSPSS)

This appendix contains a listing of all subprograms which constitute CSPSS. The subprogram name and a brief description of its purpose are given below in the order in which it appears.

CSPSS

This is the main module. It controls the processing of the simulation.

AWP

This function calculates the annual washoff in pounds.

BODRD

This module reads input for DO budget model (modules 80-82).

BODRW

This is the DO budget model.

CCT

This function calculates the CT (total carbonic species) for the dissolved lead model.

CFDO

This module accumulates the frequency of minimum dissolved oxygen concentration on the ranges specified.

CFPB

This module accumulates the frequency of maximum lead concentrations on the ranges specified.

CFSS

This module accumulates the frequency of maximum suspended solids concentrations on the ranges specified.

CKSEL

This module validates the options that the user has selected.

DFN

This module is the first derivative of the function used in the Newton-Raphson method to calculate the hydrogen ion concentration in the lead model.

DOE

This module calculates the dissolved oxygen level in an estuary.

DOS

This module calculates the dissolved oxygen level in a stream.

DRYWEA

This module reads the input for the dry-weather flow simulation and calculates the value of dry-weather flow by time interval and by day of the week.

DSRD

This module reads daily streamflow records.

EXXPON

This module generates a random observation from a exponential distribution.

FN

This module is the function used in the Newton-Raphson method to calculate the hydrogen ion concentration in the lead model.

GMSF

This module simulates monthly streamflow for the number of years to be simulated.

INFL

This module simulates excess infiltration.

INFLRD

This module read input for the excess infiltration simulation.

ISTR

This module reads monthly streamflow statistics and uses GMSF to generate monthly streamflows.

LOGNOR

This module generates a random observation from a log normal distribution.

MARKOV

This module generates a lag one Markov process with a log normal distribution.

MONTH

This module determines the month of the current time step.

NWTRAF

This module uses the Newton-Raphson method to calculate the hydrogen ion concentration in the lead model.

OAF

This module is the excess infiltration equation fitted for Baltimore, Maryland. See SWMM User's Manual, vers. 2, p. 139.

PBRW

This module is the dissolved lead simulation.

PER

This function calculates percent.

PUTDOS

This module calculates and writes the time average percent of affected streamflow reach for specified levels of dissolved oxygen concentrations.

PUTFDO

This module writes the cumulative minimum dissolved oxygen frequency curve.

PUTFPB

This module writes the cumulative lead concentration frequency curves (total and dissolved).

PUTFSS

This module writes the cumulative suspended solids concentration frequency curve.

RAINFL

This module is the rainfall simulation (module 10).

RAINRD

This module reads rainfall statistics for the rainfall simulation model.

RANDOM

This module generates a random number on the !0,11 internal with a uniform distribution.

RECWAT

This module is the receiving water response simulation.

RUNOFF

This module simulates direct runoff using the SCS method.

RUNQLR

This subroutine reads input data for the runoff quality model.

RUNQLT

This module simulates pollution accumulation and washoff on the watershed.

RUNRD

This subroutine reads input data for runoff model.

SEASON

This module determines which season the time step is in.

SSRW

This module calculates suspended solids concentrations in the receiving water.

STOR

This module simulates storage/treatment of runoff.

STORRD

This module reads input for the storage/treatment model.

TRANS

This module transforms input rainfall and streamflow statistics to log form.

XL2

This function calculates the load on the watershed per time interval.

XMIX

This module calculates the average concentration resulting from the mixing of four different inputs.

XM2

This function calculates the washoff on the watershed per time interval.

```
C
C    DEVELOPED BY:    CH2M HILL INC.
C                     7201 N.W. 11TH PLACE
C                     GAINESVILLE FLORIDA 32602
C
C              FOR:   FACILITIES REQUIREMENTS DIVISION
C                     U.S. ENVIRONMENTAL PROTECTION
C                     AGENCY
C                     WASHINGTON D.C.
C
C
C
C
C******************** BLOCK DATA ******************************************
C
      BLOCK DATA
      COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
     1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
     2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
     3 K1W1,K1W2,K1USF,K1DWF
      COMMON /STR2/QDUS(360,5),QMUS(12,5),QMSF(12),SDMSF(12),CCMSF(12)
      COMMON /IO/IIN,IRIV,IOUT
      DATA IIN/5/,IRIV/8/,IOUT/6/
C
C-HERE IS WHERE YOU INITIALIZE ANY VARIABLES IN COMMON
C
      REAL QDUS/1800*0.0/
      REAL QMUS/60*0.0/,QMSF/12*0.0/,SDMSF/12*0.0/
      REAL QDW/42*0.0/
      END
C
C******************** MAIN *********************************
C
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /IO/IIN,IRIV,IOUT
      DIMENSION ISEL(8)
C
C THIS MODULE CONTROLS PROCESSING IN ALL OTHER MODULES
C
C OPTIONS SELECTABLE ARE :
C
C   OPTIONS        DESCRIPTION
C   -------        ----------------
C     10            RAINFALL SIMULATION
C     20            RUNOFF BY SCS EQUATION
C     21            RUNOFF BY COEFFICIENT METHOD
C     30            POLLUTANT WASHOFF
C     40            EXCESS INFILTRATION
C     50            STORAGE / TREATMENT
C     60            DRY WEATHER FLOW
C     70            DAILY STREAMFLOW
C     71            MONTHLY STREAMFLOW SIMULATION
C     80            SUSPENDED SOLIDS RESPONSE
C     81            SUSPENDED SOLIDS AND DISSOLVED OXYGEN RESPONSE
C     82            SUSPENDED SOLIDS,DISSOLVED OXYGEN AND
C                   LEAD RESPONSES
C
C
1000  FORMAT(3I2,I9)
1001  FORMAT(10A4)
1002  FORMAT(8I2)
```

```
1003   FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',
     1/,T30,'FEBRUARY,1979',///,
     1 T2,'GENERAL SIMULATION CONTROL DATA',20('-')//,
     2T22,'LOCATION: ',T32,10A4)
1004   FORMAT(1X,T3,'NUMBER OF YEARS TO SIMULATE:',T32,I2,
     2/,T8,'TIME INTERVAL IN HOURS:',T32,I2,/
     3T10,'NUMBER OF WATERSHEDS:',T32,I2,/
     11X,T5,'SEED FOR RANDOM GENERATOR:',T32,I9)
C
C THERE ARE 8640 HOURS IN ONE YEAR -ASSUMED 360 DAYS OF 24 HRS
C
C
C - FOR TIME INTERVAL =4 THERE ARE 2160 EVENTS PER YEAR
C
C   **************
C   *            *
C   *   STEP 1   *
C   *            *
C   **************
C
C - READ LOCATION
C
       READ (IIN,1001) LOC
       WRITE(IOUT,1003)LOC
C
C   **************
C   *            *
C   *   STEP 2   *
C   *            *
C   **************
C
C - READ NUMBER OF YEARS TO SIMULATE
C     TIME INTERVAL OF SIMULATION
C     NUMBER OF WATER SHEDS
C     SEED NUMBER FOR RANDOM NUMBER GENERATOR
C
       READ (IIN,1000) NYR,IDT,IWSD,IRN1
       WRITE(IOUT,1004)NYR,IDT,IWSD,IRN1
C
C
C   **************
C   *            *
C   *   STEP 3   *
C   *            *
C   **************
C
C - READ OPTIONS SELECTED
C
       READ (IIN,1002) ISEL
C
C   **************
C   *            *
C   *   STEP 4   *
C   *            *
C   **************
C
C VALIDATE THE OPTIONS SELECTED
C
       CALL CKSEL(ISEL,&402)
C
```

```
C    **************
C    *            *
C    *   STEP 5   *
C    *            *
C    **************
C
C INITIALIZE FIRST SIMULATION YEAR
C
      NYEAR=1
C    **************
C    *            *
C    *   STEP 6   *
C    *            *
C    **************
C
C DO OPTIONS SELECTED
C
6     CONTINUE
      DO 7 I=1,8
C
C  DO THE FOLLOWING ONLY FOR THE FIRST YEAR OF SIMULATION
C
      IF(ISEL(I).EQ.0)GOTO 10
      IF(ISEL(I).EQ.10) CALL RAINRD
      IF(ISEL(I).EQ.20) CALL RUNRD
      IF(ISEL(I).EQ.30) CALL RUNQLR
      IF(ISEL(I).EQ.40) CALL INFLRD
      IF(ISEL(I).EQ.50) CALL STORRD
      IF(ISEL(I).EQ.60) CALL DRYWEA
      IF(ISEL(I).EQ.70) CALL DSRD (NYSTRM,&403)
      IF(ISEL(I).EQ.71) CALL ISTR
      IF(ISEL(I).EQ.80) CALL BODRD(ISEL(I))
      IF(ISEL(I).EQ.81) CALL BODRD(ISEL(I))
      IF(ISEL(I).EQ.82) CALL BODRD(ISEL(I))
7     CONTINUE
10    DO 30 I=1,8
C THE FOLLOWING OPTIONS ARE EXERCISABLE EACH YEAR
      IF(ISEL(I).EQ.0)GOTO 35
      IF(ISEL(I).EQ.10) CALL RAINFL(NYEAR)
      IF(ISEL(I).EQ.20) CALL RUNOFF(NYEAR)
      IF(ISEL(I).EQ.30) CALL RUNQLT(NYEAR)
      IF(ISEL(I).EQ.40) CALL INFL
      IF(ISEL(I).EQ.50) CALL STOR(NYEAR)
      IF(ISEL(I).EQ.80) CALL RECWAT(NYEAR,ISEL(I),NYSTRM)
      IF(ISEL(I).EQ.81) CALL RECWAT(NYEAR,ISEL(I),NYSTRM)
      IF(ISEL(I).EQ.82) CALL RECWAT(NYEAR,ISEL(I),NYSTRM)
30     CONTINUE
C    **************
C    *            *
C    *   STEP 7   *
C    *            *
C    **************
C INCREMENT SIMULATION YEAR
35    NYEAR=NYEAR+1
C    **************
C    *            *
C    *   STEP 8   *
C    *            *
C    **************
C
C  IS SIMULATION FINISHED ? ? ?
```

```
C
      IF (NYEAR.LE.NYR)GO TO 10
50    CONTINUE
599   STOP
402   STOP 300
403   STOP 305
      END

C
C********************* AWP ***********************
C
      FUNCTION AWP(R,IDT,CP)
       T1=R*62.4
      T2=T1*3600
      T3=T2*IDT
      T4=T3*CP
      AWP=T4/1000000
      RETURN
      END
C
C*******************  BODRD  ************************
C
      SUBROUTINE BODRD (OPT)
      COMMON /IO/IIN,IRIV,IOUT
      COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
     1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
     2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
     3 K1W1,K1W2,K1USF,K1DWF
      COMMON /PB1/TA(4),TH(4),PH(4)
     REAL K2ADJ,K2SPEC
      REAL K1W1,K1W2,K1USF,K1DWF
      INTEGER OPT
C
C  THIS MODULE READS BOD INPUT FOR DO BUDGET MODEL
C
1000  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',
     1 /,T30,'FEBRUARY,1979',///
     2 ,T2,'INPUT TO DO BUDGET MODEL',20('-')//
     3 T10,'ALPHA VALUES :',T30,F12.8,T44,F12.8)
1001  FORMAT(1X,T11,'BETA VALUES :',T28,3(2X,F12.8)/,
     1 T11,'SPECIFIED K2 :',T28,F10.2,' 1/DAY')
1002  FORMAT(1X,T19,'SBA :',T30,F10.2,' GM O2/M**2/DAY',/,
     1   T17,'K2ADJ :',T30,F10.2
     2 /T17,'DIST1 :',T30,F10.2,' MILES',/,
     1 T17,'DIST2 :',T30,F10.2,' MILES',/T21,'E1:',T30,F10.2,
     1 ' MILES**2/DAY'/,
     1 T10,'K1 WATERSHED 1 ',T30,F5.2,' 1/DAY'/
     1 T10,'K1 WATERSHED 2',T30,F5.2,' 1/DAY'/
     1 T10,'K1 STREAMFLOW',T30,F5.2,' 1/DAY'/
     1 T10,'K1 DRY WEATHER FLOW',T30,F5.2,' 1/DAY')
1003  FORMAT(1X,' TEMP',T10,'DUS',T32,'CC')
1004  FORMAT(7F10.2)
1005  FORMAT(1X,I2,3X,6(2X,F8.2),2X,F8.4)
1006  FORMAT(3(/),T2,'UPSTREAM QUALITY ARRAY',20('-'),//,
     1 T2,'MONTH',T12,'TEMP',T24,'DO',T28,'CHLORIDE',T41
     1 ,'BOD',
     1 T48,'SUSPENDED',T62,'TKN',T71,'LEAD'/,T20,'DEFICIT',T31,'CONC',
     2 T41,'CONC',T49,'SOLIDS',T62,'CONC',T71,'CONC',
     1 /T12,'DEGREES C',T25,15('-'),'MG/L',15('-'))
1007  FORMAT(4F10.2)
```

```
1008   FORMAT(3(/),T2,'INPUT DATA FOR LEAD SUBMODEL',20('-'),//,
     1 T24,'CSO',T40,'SWR',T54,'USF',T69,'WWTP',//,
     2 T2,'ALKALINITY (MG/L)',T19,F10.2,T34,F10.2,T49,F10.2,T64,F10.2//,
     3 T2,'HARDNESS (MG/L)',T19,F10.2,T34,F10.2,T49,F10.2,T64,F10.2//,
     4 T2,'PH',T19,F10.2,T34,F10.2,T49,F10.2,T64,F10.2)
1009   FORMAT(5F10.2,4F5.2)
C DO SUSPENDED SOLIDS ONLY
       IF(OPT.EQ.80)GOTO 10
C    **************
C    *            *
C    *   STEP 1   *
C    *            *
C    **************
C
C  READ ALPHA PARAMETERS
       READ (IIN,1004) ALF1,ALF2
      WRITE(IOUT,1000) ALF1,ALF2
C
C    **************
C    *            *
C    *   STEP 2   *
C    *            *
C    **************
C
C  READ BETA PARAMETERSAND K2 AT 20 DEGREES C
C
       READ (IIN,1004) BETA1,BETA2,BETA3,K2SPEC
       WRITE(IOUT,1001) BETA1,BETA2,BETA3,K2SPEC
C
C    **************
C    *            *
C    *   STEP 3   *
C    *            *
C    **************
C
C  READ SBA-AREAL BENTHIC UPTAKE RATE (GM O2/M2/DAY)
C        K2ADJ -FOR CALIBRATION OF K2
C        DIST1-DISTANCE URBAN AREA TO CALIBRATION PT
C        DIST2-DISTANCE OF REACH
C        E - TIDAL DISPERSION COEFF
C
       READ (IIN,1009) SBA,K2ADJ,DIST1,DIST2,E,K1W1,K1W2,K1USF,K1DWF
       IF(K2ADJ.EQ.0.0)K2ADJ=1.0
       IF(K1W1.EQ.0.0)K1W1=0.40
       IF(K1W2.EQ.0.0)K1W2=0.16
       IF(K1USF.EQ.0.0)K1USF=0.16
       IF(K1DWF.EQ.0.0)K1DWF=0.23
      WRITE(IOUT,1002) SBA,K2ADJ,DIST1,DIST2,E ,K1W1,K1W2,K1USF,K1DWF
C
C    **************
C    *            *
C    *   STEP 4   *
C    *            *
C    **************
C
C READ FOR EACH MONTH  T   WATER TEMPERATURE
C                      DUS DO DEFICIT (MONTH I,I=1,12)
C                      CC  CHLORIDE CONC
C                     BOD
C                      TKN
C                      SS
```

```
C                       PB
10     WRITE(IOUT,1006)
        DO 20 I=1,12
        READ(IIN,1004) T(I),DUS(I),CC(I),BODUSF(I),SSUSF(I),TKNUSF(I),
      1 PBUSF(I)
20      WRITE(IOUT,1005) I,T(I),DUS(I),CC(I),BODUSF(I),SSUSF(I),
      1 TKNUSF(I),PBUSF(I)
        IF(OPT.NE.82)GOTO 40
        READ (IIN,1007)(TA(I),I=1,4)
        READ (IIN,1007)(TH(I),I=1,4)
        READ (IIN,1007)(FH(I),I=1,4)
        WRITE(IOUT,1008)(TA(I),I=1,4),(TH(I),I=1,4),(PH(I),I=1,4)
40      CONTINUE
C
C    **************
C    *            *
C    *   STEP 5   *
C    *            *
C    **************
C
C RETURN TO CALLING MODULE
C
        RETURN
        END
C
C************************ BODRW ***************************
C
        SUBROUTINE BODRW(QST,BST,QCS,BCS,QSF,QDR,MTH,
      1 FDO,FDOX1,TST,TCS,BODTC,BODTN,I,MTI,MO,ULOC,ULON,CDO,DOMIN)
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
        COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
      1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
      2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
      3 K1W1,K1W2,K1USF,K1DWF
        DIMENSION FDO(16)  ,FDOX1(16) ,CDO(7)
        DIMENSION TEMD1(50)
C
C THIS IS THE DO BUDGET MODEL
C
        REAL K1,K2,K2ADJ,K2MIN,J1,J2
        REAL LO,LON,K2SPEC
        REAL K1W1,K1W2,K1USF,K1DWF
        REAL K11,K12,K13,K14
        REAL J11,J12,J13,J14,J15,J16,J17
        REAL J21,K22,J23,J24,J25
        REAL LO1,LO2,LO3,LO4
        REAL K3,J3,MIC,M2,MIN,LON1,LON2,LON3,LON4
        NTP=24/IDT
C STEP 1
C
C COMPUTE QT TOTAL FLOW (IN CFS)
C
        QT=QST+QCS+QSF+QDR
        IF(QT.NE.0.0)GOTO 13
C IF NO FLOW THEN SKIP THIS ROUTINE
        BODTC=0.0
        BODTN=0.0
        GOTO 150
C STEP 2

C COMPUTE V VELOCITY OF FLOW (IN FPS)
```

```
C
13     V=ALF1*QT**ALF2
C IF V IS ZERO THEN INVALID DATA-ABORT JOB
       IF(V.EQ.0.0)STOP 100
C STEP 3
C
C COMPUTE H DEPTH OF FLOW (IN FEET)
C
       H=BETA1*QT**BETA2+BETA3
C IF H IS ZERO THEN INVALID DATA-ABORT JOB
       IF(H.EQ.0.0)STOP 110
C STEP 4
C
C COMPUTE LO - INITIAL BOD LOAD (MG/L)
C         BODT-TOTAL BOD (# PER DT)

       LO1=QST*BST
       LO2=QCS*BCS
       LO3=QSF*BODUSF(MTH)
       ULOC=AWP(QSF,IDT,BODUSF(MTH))
       LO4=QDR*BODDW
       LO=(LO1+LO2+LO3+LO4)/QT
       BODTC=AWP(QT,IDT,LO)
C
C STEP 5
C
C COMPUTE LON -INITIAL NBOD LOAD (MG/L)
C          BODTN-TOTAL NBOD (# PER DT)
C
       LON1=QST*TST*4.57
       LON2=QCS*TCS*4.57
       LON3=QSF*TKNUSF(MTH)*4.57
       T1=TKNUSF(MTH)*4.57
       ULON=AWP(QSF,IDT,T1)
       LON4=QDR*TKNDW*4.57
       LON=(LON1+LON2+LON3+LON4)/QT
       BODTN=AWP(QT,IDT,LON)
C STEP 6
C
C COMPUTE DO-INITIAL DO DEFICIT (MG/L)
C
       DO=(DUS(MTH)*QSF+DDW*QDR)/QT
C STEP 7
C
C CALCULATE TEMPERATURES
C ASSUMES TEMPERATUR READ IS FOR 15TH OF THE MONTH
C FOR BEGINNING OF NEW MONTH
       IF(MTH.NE.MO)MTI=1
       IF(MTH.NE.MO)MO=MTH
C
       IF(MTH.NE.1)GOTO 1
       TEMP=T(1)
       GOTO 10
1      IF(MTH.NE.12)GOTO 2
       TEMP=T(12)
       GOTO 10
C FOR MONTHS 2 TO 11 CALC BEGINNING OF MONTH TEMPERATURE
2      CONTINUE
       IF(T(MTH).GT.T(MTH-1))GOTO 3
C FOR T(MTH).LE.T(MTH-1)
       TEMPB=T(MTH)+.5*(T(MTH)-T(MTH-1))
```

```
      GOTO 4
3     CONTINUE
C FOR T(MTH).GT.T(MTH-1)
      TEMPB=T(MTH)-.5*(T(MTH)-T(MTH-1))
4     CONTINUE
C FOR MONTHS 2 TO 11 CALCULATE END OF MONTH TEMPERATURE
      IF(T(MTH).LE.T(MTH+1))GOTO 5
C FOR T(MTH).GT.T(MTH+1)
      TEMPE=T(MTH)-.5*(T(MTH)-T(MTH+1))
      GOTO 6
5     CONTINUE
C FOR T(MTH).LE.T(MTH+1)
      TEMPE=T(MTH)+.5*(T(MTH)-T(MTH+1))
6     CONTINUE
       DELTAT=(TEMPE-TEMPB)/(30.0*NTP)
C COUNT FROM BEGINNING OF MONTH FOR 30*NTP EVENTS
     TEMP=TEMPB+MTI*DELTAT
      MTI=MTI+1
10    CONTINUE
C COMPUTE DOSAT -SATURATION VALUE OF DO (MG/L)
C CORRECT FOR TEMP (DEGREES CELSIUS)
C
      DOSAT=14.652-0.410222*TEMP+0.00799*TEMP**2
     1 -0.00007777*TEMP**3
C CORRECT FOR CHLORIDE CONC (MG/L)
      CHL=CC(MTH)
      DOSAT=DOSAT*(1.0-CHL/100000)
C STEP 8
C
C COMPUTE K1 -WASTE DECAY COEFF
C

      K11=LO1*K1W2
      K12=LO2*K1W1
      K13=LO3*K1USF
      K14=LO4*K1DWF
      K1=(K11+K12+K13+K14)/(LO1+LO2+LO3+LO4)
C     WRITE(6,1021)TEMP
1021  FORMAT(1X,E10.5)
      K1=K1*1.047**(TEMP-20.0)
C     WRITE(6,1021)K1
C
C STEP 9
C
COMPUTE ULTIMATE BOD DEMAND FACTOR
      XF=1.0-EXP(-5.0*K1)
      FACTOR=1.0/XF
      LO=LO*FACTOR
C STEP 10
C
C COMPUTE K2-STREAM REARATION RATE (1/DAY)
C
C THE K2 VALUE IS COMPUTED FROM ONE OF THREE
C        OR IS GIVEN BY K2SPEC
C EMPIRICAL EQUATIONS AND ADJUSTED FOR
C TEMP AND MINIMUM VALUES AS FOLLOWS:
C
      IF(K2SPEC.GT.0.0)GOTO 46
      IF(H.GT.2.0.AND.V.LE.2.5) GO TO 20
      IF(H.GT.2.0.AND.V.GT.2.5) GO TO 30
      GO TO 40
```

```
20      K2=12.9*V**0.5/H**1.5
        GO TO 45
30      K2=11.6*V**0.969/H**1.673
        GO TO 45
40      K2=21.74*V**0.67/H**1.85
45      GOTO 48
46      K2=K2SPEC
C IF NO VALUE ENTERED MAKE K2ADJ=1
48      IF(K2ADJ.EQ.0.0) K2ADJ=1.0
C ADJUST K2
        K2=K2ADJ*K2
C CORRECT FOR TEMP
        K2=K2*1.024**(TEMP-20.0)
C CALCULATE MINIMUM VALUE OXYGEN EXCHANGE
        K2MIN=2.0/H
        IF(K2MIN.GT.2.0)K2MIN=2.0
C USE LARGER K2 VALUE K2=MAX(K2,K2MIN)
        IF(K2MIN.GT.K2)K2=K2MIN
C MAKE SURE K2 NOTEQUAL K1 - MAKES D UNDEFINED
        IF(K2.EQ.K1) K2=0.99*K2
C
C STEP 11
C
C COMPUTE K3 ASSUMING K3=0.10 AT 20 DEGREES C
C
        K3=0.10*1.017**(TEMP-20.0)
        IF(K3.EQ.K2)K3=0.99*K3
C STEP 12

C COMPUTE SB -BOTTOM SEDIMENT UPTAKE RATE (MG/L/DAY)
C
C CONVERT SBA TO (MG/MSQ/DAY) TO (MG/L/DAY)
        SB=SBA*3.281/H
C CORRECT UPTAKE FOR TEMP
        SB=SB*1.065**(TEMP-20.0)
C STEP 10
C
C CHECK FOR AN ESTUARY
C
C IF AN ESTUARY GO TO STEP 13-A
        IF(E.GT.0.0) GO TO 47
C OTHERWISE GO TO STEP 13-B
        GO TO 75
47      CONTINUE
C STEP 13-A
C
C COMPUTE MIC,M2,MIN,J1,J2,J3
C
C VF VELOCITY (MILES/DAY)
        VF=V*86400/5280
        VF2=VF*VF
        E4=4.0*E
        E2=2.0*E
        TK1=E4*K1
        TEM1=1.0+(TK1/VF2)
        MIC=SQRT(TEM1)
        TK2=E4*K2
        TEM2=1.0+(TK2/VF2)
        M2=SQRT(TEM2)
        TK3=E4*K3
        TEM3=1.0+(TK3/VF2)
```

```
      MIN=SQRT(TEM3)
      J1=VF*(1.0-MIC)/E2
      J2=VF*(1.0-M2)/E2
      J3=VF*(1.0-MIN)/E2
      DELTAX=DIST2/50.0
      X=0.0
      DC=0.0
      DO 50 J=1,50
      CALL DOE(X,MIC,M2,MIN,J1,J2,J3,K1,K2,K3,LO,LON,SB,DO,D1)
C ACCUMULATE TIME AVERAGED DO SUMMARY
      DOXY=DOSAT-D1
      IF(DOXY.LE.0.0)CDO(1)=CDO(1)+1.0
      IF(DOXY.LT.1.0)CDO(2)=CDO(2)+1.0
      IF(DOXY.LT.2.0)CDO(3)=CDO(3)+1.0
      IF(DOXY.LT.3.0)CDO(4)=CDO(4)+1.0
      IF(DOXY.LT.4.0)CDO(5)=CDO(5)+1.0
      IF(DOXY.LT.5.0)CDO(6)=CDO(6)+1.0
      IF(DOXY.LT.6.0)CDO(7)=CDO(7)+1.0
      IF(D1.GT.DC)DC=D1
      X=X+DELTAX
      TEMD1(J)=D1
50    CONTINUE
      GO TO 80
C STEP 13-B
C COMPUTE DC FOR A STREAM (E=0)
75    VF=V*86400/5280
      TMAX=DIST2/VF
      DELTAT=TMAX/50.0
      TIM=0.0
      DC=0.0
      DO 80 J=1,50
      CALL DOS(TIM,K1,K2,K3,LO,LON,SB,DO,D1)
C ACCUMULATE TIME AVERAGED DO SUMMARY
      DOXY=DOSAT-D1
      IF(DOXY.LE.0.0)CDO(1)=CDO(1)+1.0
      IF(DOXY.LT.1.0)CDO(2)=CDO(2)+1.0
      IF(DOXY.LT.2.0)CDO(3)=CDO(3)+1.0
      IF(DOXY.LT.3.0)CDO(4)=CDO(4)+1.0
      IF(DOXY.LT.4.0)CDO(5)=CDO(5)+1.0
      IF(DOXY.LT.5.0)CDO(6)=CDO(6)+1.0
      IF(DOXY.LT.6.0)CDO(7)=CDO(7)+1.0
      IF(D1.GT.DC)DC=D1
      TIM=TIM+DELTAT
80    CONTINUE
C
C COMPUTE MINIMUM DO
C
      DOMIN=DOSAT-DC
C STEP 14
C
C COMPUTATION OF DO AT A CALIBRATION POINT NECESSARY ?
C
      IF(DIST1.EQ.0.0) GO TO 100
C OTHERWISE CALIBRATE WITH STEP 15
C STEP 15
C
C  COMPUTE DOX1-DO AT DISTANCE,DIST1,DOWNSTREAM FROM URBAN AREA
C
C FOR NONTIDAL STREAM
      IF(E.NE.0.0) GO TO 85
      TX1=DIST1/VF
```

```
      CALL DOS(TX1,K1,K2,K3,LO,LON,SB,DO,D1)
      DOX1=DOSAT-D1
      GO TO 100
85    CONTINUE
C FOR ESTUARY (E =0)
      X=DIST1
      CALL DOE(X,MIC,M2,MIN,J1,J2,J3,K1,K2,K3,LO,LON,SB,DO,D1)
      DOX1=DOSAT-D1
100   CONTINUE
C STEP 16
C
C CUMULATIVE FREQUENCY DO
C
      CALL CFDO (DOMIN,FDO)
C
C CUMULATIVE FREQUENCY DOX1
C
      IF(DIST1.NE.0.0)CALL CFDO(DOX1,FDOX1)
C STEP 17
C
C RETURN TO CALLING MODULE
C
150   RETURN
      END
C
C******************** CCT ********************
C
      FUNCTION CCT(PH,A)
      REAL K1,K2
      K1=4.45E-7
      K2=4.69E-11
      HP=1.0/(10.0**PH)
      OH=1.0E-14/HP
      ALF10=(HP/K1)+(K2/HP)+1.0
      ALF1=1.0/ALF10
      ALF20=(HP*HP)/(K1*K2)+(HP/K2)+1.0
      ALF2=1.0/ALF20
      CT1=A-OH+HP
      CT2=(ALF1+2*ALF2)
      CCT=CT1/CT2
10    RETURN
      END
C
C*****************  CFDO  ***********************************
C
      SUBROUTINE CFDO (DO,FDO)
      DIMENSION FDO(16)
C
C  CUMULATIVE FREQUENCY DO
C
C
C ACCUM FREQ OF DO ON RANGES SPECIFIED
C
      IF (DO.LE.1.0) GOTO 10
      IF (DO.LE.2.0) GO TO 20
      IF (DO.LE.3.0) GO TO 30
      IF (DO.LE.4.0) GO TO 40
      IF (DO.LE.5.0) GO TO 50
      IF (DO.LE.6.0) GO TO 60
      IF (DO.LE.7.0) GO TO 70
      IF (DO.LE.8.0) GO TO 80
```

```
      IF (DO.LE.9.0) GO TO 90
      IF (DO.LE.10.0) GO TO 100
      IF (DO.LE.11.0) GO TO 110
      IF (DO.LE.12.0) GO TO 120
      IF (DO.LE.13.0) GO TO 130
      IF (DO.LE.14.0) GO TO 140
      IF (DO.LE.15.0) GO TO 150
      FDO(16)=FDO(16)+1.0
      GO TO 200
10    FDO(1)=FDO(1)+1.0
      GO TO 200
20    FDO(2)=FDO(2)+1.0
      GO TO 200
30    FDO(3)=FDO(3)+1.0
      GO TO 200
40    FDO(4)=FDO(4)+1.0
      GO TO 200
50    FDO(5)=FDO(5)+1.0
      GO TO 200
60    FDO(6)=FDO(6)+1.0
      GO TO 200
70    FDO(7)=FDO(7)+1.0
      GO TO 200
80    FDO(8)=FDO(8)+1.0
      GO TO 200
90    FDO(9)=FDO(9)+1.0
      GO TO 200
100   FDO(10)=FDO(10)+1.0
      GO TO 200
110   FDO(11)=FDO(11)+1.0
      GO TO 200
120   FDO(12)=FDO(12)+1.0
      GO TO 200
130   FDO(13)=FDO(13)+1.0
      GO TO 200
140   FDO(14)=FDO(14)+1.0
      GO TO 200
150   FDO(15)=FDO(15)+1.0
200   RETURN
      END
C
C***************** CFPB ***********************
C
      SUBROUTINE CFPB(PB,F)
      DIMENSION F(20)
      IF(PB.GE.0.0.AND.PB.LT.0.005)GOTO 10
      IF(PB.LT.0.010)GOTO 20
      IF(PB.LT.0.015)GOTO 30
      IF(PB.LT.0.020)GOTO 40
      IF(PB.LT.0.025)GOTO 50
      IF(PB.LT.0.030)GOTO 60
      IF(PB.LT.0.035)GOTO 70
      IF(PB.LT.0.040)GOTO 80
      IF(PB.LT.0.045)GOTO 90
      IF(PB.LT.0.050)GOTO 100
      IF(PB.LT.0.06)GOTO 110
      IF(PB.LT.0.07)GOTO 120
      IF(PB.LT.0.08)GOTO 130
      IF(PB.LT.0.09)GOTO 140
      IF(PB.LT.0.1)GOTO 150
      IF(PB.LT.0.2)GOTO 160
```

```
      IF(PB.LT.0.3)GOTO 170
      IF(PB.LT.0.4)GOTO 180
      IF(PB.LT.0.5)GOTO 190
      GOTO 200
10    F(1)=F(1)+1
      GOTO 250
20    F(2)=F(2)+1
      GOTO 250
30    F(3)=F(3)+1
      GOTO 250
40    F(4)=F(4)+1
      GOTO 250
50    F(5)=F(5)+1
      GOTO 250
60    F(6)=F(6)+1
      GOTO 250
70    F(7)=F(7)+1
      GOTO 250
80    F(8)=F(8)+1
      GOTO 250
90    F(9)=F(9)+1
      GOTO 250
100   F(10)=F(10)+1
      GOTO 250
110    F(11)=F(11)+1
      GOTO 250
120   F(12)=F(12)+1
      GOTO 250
130   F(13)=F(13)+1
      GOTO 250
140   F(14)=F(14)+1
      GOTO 250
150   F(15)=F(15)+1
      GOTO 250
160   F(16)=F(16)+1
      GOTO 250
170   F(17)=F(17)+1
      GOTO 250
180   F(18)=F(18)+1
      GOTO 250
190   F(19)=F(19)+1
      GOTO 250
200   F(20)=F(20)+1
250   CONTINUE
      RETURN
      END
C
C******************** CFSS ******************************************
C
     SUBROUTINE CFSS (SST,FSS)
C
C CUMULATIVE FREQUENCY OF SUSPENDED SOLIDS
      DIMENSION FSS(21)
C DEFAULT IS SST>500
      IF (SST.LE.25.0) GO TO 10
      IF (SST.LE.50.0) GO TO 20
      IF (SST.LE.75.0) GO TO 30
      IF (SST.LE.100.0) GO TO 40
      IF (SST.LE.125.0) GO TO 50
      IF (SST.LE.150.0) GO TO 60
      IF (SST.LE.175.0) GO TO 70
```

```
      IF (SST.LE.200.0) GO TO 80
      IF (SST.LE.225.0) GO TO 90
      IF (SST.LE.250.0) GO TO 100
      IF (SST.LE.275.0) GO TO 110
      IF (SST.LE.300.0) GO TO 120
      IF (SST.LE.325.0) GO TO 130
      IF (SST.LE.350.0) GO TO 140
      IF (SST.LE.375.0) GO TO 150
      IF (SST.LE.400.0) GO TO 160
      IF (SST.LE.425.0) GO TO 170
      IF (SST.LE.450.0) GO TO 180
      IF (SST.LE.475.0) GO TO 190
      IF (SST.LE.500.0) GO TO 200
      FSS(21)=FSS(21)+1.0
      GO TO 300
10    FSS(1)=FSS(1)+1.0
      GO TO 300
20    FSS(2)=FSS(2)+1.0
      GO TO 300
30    FSS(3)=FSS(3)+1.0
      GO TO 300
40    FSS(4)=FSS(4)+1.0
      GO TO 300
50    FSS(5)=FSS(5)+1.0
      GO TO 300
60    FSS(6)=FSS(6)+1.0
      GO TO 300
70    FSS(7)=FSS(7)+1.0
      GO TO 300
80    FSS(8)=FSS(8)+1.0
      GO TO 300
90    FSS(9)=FSS(9)+1.0
      GO TO 300
100    FSS(10)=FSS(10)+1.0
      GO TO 300
110    FSS(11)=FSS(11)+1.0
      GO TO 300
120    FSS(12)=FSS(12)+1.0
      GO TO 300
130    FSS(13)=FSS(13)+1.0
      GO TO 300
140    FSS(14)=FSS(14)+1.0
      GO TO 300
150    FSS(15)=FSS(15)+1.0
      GO TO 300
160    FSS(16)=FSS(16)+1.0
      GO TO 300
170    FSS(17)=FSS(17)+1.0
      GO TO 300
180    FSS(18)=FSS(18)+1.0
      GO TO 300
190    FSS(19)=FSS(19)+1.0
      GO TO 300
200    FSS(20)=FSS(20)+1.0
      GO TO 300
300   RETURN
      END
C
C******************** CKSEL ******************************
C
      SUBROUTINE CKSEL (SEL,*)
```

```
      COMMON /IO/IIN,IRIV,IOUT
      INTEGER  SEL(8)
C
C THIS MODULE VALIDATES THE OPTIONS SELECTED
C  IF AN ERROR THIS MODULE PRINTS MESSAGE AND ABORTS JOB
C
C
C EXAMPLES OF COMPLETE RUNS ARE:
C 1020304050607082
C 1020304050607182
C
1001    FORMAT(1X,//,T10,'INVALID OPTIONS SELECTED',8(3X,I2))
1009   FORMAT(//T2,'OPTIONS SELECTED :')
1010   FORMAT(T2,'10  RAINFALL SIMULATOR')
1020   FORMAT(T2,'20  RUNOFF BY SCS EQUATION')
1030   FORMAT(T2,'30  POLLUTANT WASHOFF')
1040   FORMAT(T2,'40  EXCESS INFILTRATION')
1050   FORMAT(T2,'50  STORAGE TREATMENT')
1060   FORMAT(T2,'60  DRY WEATHER FLOW')
1070   FORMAT(T2,'70  DAILY STREAMFLOW')
1071   FORMAT(T2,'71  MONTHLY STREAMFLOW SIMULATION')
1080   FORMAT(T2,'80  SUSPENDED SOLIDS RESPONSE')
1081   FORMAT(T2,'81  SUSPENDED SOLIDS AND DISSOLVED OXYGEN RESPONSE')
1082   FORMAT(T2,'82  SUSPENDED SOLIDS,DISSOLVED OXYGEN, AND LEAD RESPON
     1SE')
      IF(SEL(1).EQ.10)GO TO 5
      IF(SEL(1).EQ.60)GO TO 5
      IF(SEL(1).EQ.70)GO TO 5
      IF(SEL(1).EQ.71)GO TO 5
      GOTO 900
5     CONTINUE
      DO 8 I=2,8
      IF(SEL(I).EQ.0)GO TO 8
      IF(SEL(I).EQ.10)GO TO 7
      IF(SEL(I).EQ.20)GO TO 7
      IF(SEL(I).EQ.30)GO TO 7
      IF(SEL(I).EQ.40)GO TO 7
      IF(SEL(I).EQ.50)GOTO 7
      IF(SEL(I).EQ.60)GOTO 7
      IF(SEL(I).EQ.70)GOTO 7
      IF(SEL(I).EQ.71)GOTO 7
      IF(SEL(I).EQ.80)GOTO 7
      IF(SEL(I).EQ.81)GOTO 7
      IF(SEL(I).EQ.82)GOTO 7
      GOTO 900
7     CONTINUE
      IF(SEL(I-1).LT.SEL(I))GO TO 8
      GOTO 900
8     CONTINUE
      WRITE(IOUT,1009)
      DO 100 I=1,8
      IF(SEL(I).EQ.10)GO TO 10
      IF(SEL(I).EQ.20)GO TO 20
      IF(SEL(I).EQ.30)GO TO 30
      IF(SEL(I).EQ.40)GO TO 40
      IF(SEL(I).EQ.50)GO TO 50
      IF(SEL(I).EQ.60)GO TO 60
      IF(SEL(I).EQ.70)GO TO 70
      IF(SEL(I).EQ.71)GO TO 71
      IF(SEL(I).EQ.80)GO TO 80
      IF(SEL(I).EQ.81)GO TO 81
```

```
      IF(SEL(I).EQ.82)GO TO 82
      GO TO 100
10    WRITE(IOUT,1010)
      GOTO 100
20    WRITE(IOUT,1020)
      GOTO 100
30    WRITE(IOUT,1030)
      GOTO 100
40    WRITE(IOUT,1040)
      GOTO 100
50    WRITE(IOUT,1050)
      GOTO 100
60     WRITE(IOUT,1060)
      GOTO 100
70    WRITE(IOUT,1070)
      GOTO 100
71    WRITE(IOUT,1071)
      GOTO 100
80    WRITE(IOUT,1080)
      GOTO 100
81    WRITE(IOUT,1081)
      GOTO 100
82    WRITE(IOUT,1082)
100   CONTINUE
800     RETURN
900     WRITE(IOUT,1001)SEL
        RETURN 1
      END
C ERROR CODES
C 300      INVALID OPTIONS
C  305     NOT ENOUGH DATA FOR STREAMFLOW
C 100      INVALID ALPHA VALUES FOR STREAMFLOW VELOCITY
C 110      INVALID BETA VALUES FOR STREAMFLOW DEPTH
C
C************************* DFN *************************
C
      FUNCTION DFN(TA,CT,C1,C2,U)
      O1=1E-14
      T1=(U/C1)+1.0+(C2/U)
      T2=((U*U)/(C1*C2))+1.0+(U/C2)
      T3=1/(T1*T1)
      T4=-1.0*CT*T3
      T5=(1/C1)-(C2/(U*U))
      T6=T4*T5
      T7=1/(T2*T2)
      T8=-2.0*CT*T7
      T9=((2*U)/(C1*C2))+(1/C2)
      T10=T8*T9
      T11=O1/(U*U)
      DFN=T6+T10-T11-1.0
      RETURN
      END
C
C************************ DOE ************************************
C
      SUBROUTINE DOE(X1,MIC1,M21,MIN1,J11,J21,J31,K11,K21,K31,LO1,
     1 LON1,SB1,DO1,D11)
      REAL MIC1,M21,MIN1,J11,J21,J31,K11,K21,K31,LO1,LON1
C COMPUTE DEFICIT DUE TO CBOD
      A=(K11*LO1)/(K21-K11)
      B=EXP(J11*X1)
```

```
      C=EXP(J21*X1)
      DEF1=A*(B-C)
C COMPUTE DEFICIT DUE TO NBOD
      D=(K31*LON1)/(K21-K31)
      E=EXP(J31*X1)
      DEF2=D*(E-C)
C COMPUTE DEFICIT DUE TO SEDIMENT DEMAND
      F=SB1/K21
      G=1.0-EXP(J21*X1)
      DEF3=F*G
C COMPUTE DEFICIT DUE TO INITIAL DEFICIT (DO)
      DEF4=DO1*EXP(J21*X1)
C COMPUTE TOTAL DEFICIT D1
      D11=DEF1+DEF2+DEF3+DEF4
      RETURN
      END
C
C************************** DOS ***********************************
C
      SUBROUTINE DOS(T1,K11,K21,K31,LO1,LON1,SB1,DO1,D11)
      REAL K11,K21,K31,LO1,LON1
C COMPUTE DEFICIT DUE TO CBOD
      A=(K11*LO1)/(K21-K11)
      B=EXP(-1.0*K11*T1)
      C=EXP(-1.0*K21*T1)
      DEF1=A*(B-C)
C COMPUTE DEFICIT DUE TO NBOD
      D=(K31*LON1)/(K21-K31)
      E=EXP(-1.0*K31*T1)
      DEF2=D*(E-C)
C COMPUTE DEFICIT DUE TO SEDIMENT DEMAND
      F=SB1/K21
      G=1.0-C
      DEF3=F*G
C COMPUTE DEFICIT DUE TO INITIAL DEFICIT (DO)
      DEF4=DO1*C
C COMPUTE TOTAL DEFICIT
      D11=DEF1+DEF2+DEF3+DEF4
      RETURN
      END
C
C******************** DRY ***********************************
C
      SUBROUTINE DRYWEA
C     THE DRY-WEATHER FLOW SIMULATOR WILL GENERATE RANDOM OBSERVATIONS
C     OF DRY-WEATHER FLOW, THE MEAN DAILY DRY-WEATHER FLOW DERIVED FROM
C     OBSERVED DATA.
C
C     INPUT DATA WILL BE
C
C     THE SPECIFIC RANDOM VARIABLE TO BE GENERATED IS:
C        1. THE DRY-WEATHER FLOW RATE PER UNIT OF TIME
C
C     AUTHOR - MIKE MARA
C
C     DATE     DECEMBER 1977
C
      CONTINUE
C
C     INPUT VARIABLES -----------------------------------------------
C
```

```
C      NAME      DESCRIPTION/DIMENSION
C      ------    -------------------------------------------------------
C
C      IDT       LENGTH OF 1 TIME UNIT (HOURS)
C      BQDW      MEAN DAILY DRY WEATHER FLOW (CFS)
C      BODDW     BOD                DRY-WEATHER CONCENTRATION (MG/L)
C      SSDW      SUSPENDED SOLIDS DRY-WEATHER CONCENTRATION (MG/L)
C      TKNDW     TKN                DRY-WEATHER CONCENTRATION (MG/L)
C      PBDW      LEAD               DRY-WEATHER CONCENTRATION (MG/L)
C
C
C      OUTPUT VARIABLES ------------------------------------------------
C
C      NAME      DESCRIPTION/DIMENSION
C      ------    -------------------------------------------------------
C
C      QDW       DRY-WEATHER FLOW PER UNIT OF TIME (42) (CFS)
C      BODDW     BOD                DRY-WEATHER CONCENTRATION (MG/L)
C      SSDW      SUSPENDED SOLIDS DRY-WEATHER CONCENTRATION (MG/L)
C      TKNDW     TKN                DRY-WEATHER CONCENTRATION (MG/L)
C      PBDW      LEAD               DRY-WEATHER CONCENTRATION (MG/L)
C
C
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
       COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
     1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
     2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
     3 K1W1,K1W2,K1USF,K1DWF
       COMMON /IO/IIN,IRIV,IOUT
       DIMENSION FDT(6),DFR(7),HRFR(24)
       REAL DFR/1.08,1.04,0.92,1.03,1.00,0.96,0.95/
       REAL HRFR/0.6,0.5,0.5,0.5,0.5,0.8,0.8,1.4,1.5,1.5,
     11.4,1.4,1.3,1.3,1.3,1.2,1.2,1.1,1.1,1.0,1.0,0.8,0.7,0.6/
1000   FORMAT(6F10.2)
1001   FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',/,
     1 T30,'FEBRUARY,1979',//
     2 ,T2,' INPUT TO DRY WEATHER SUBMODEL',20('-'),//,
     1T25,'  QDW = ',F10.2,'  CFS'/,
     2T24,' BODDW = ',F10.2,' MG/L'/,
     3T25,' SSDW = ',F10.2,' MG/L'/,
     4T24,' TKNDW = ',F10.2,' MG/L'/,
     5T25,' PBDW = ',F10.2,' MG/L'/,
     6T25,'DDW = ',F10.2,' MG/L')
C STEP 1
C
C- READ BQDW,BODDW,SSDW,TKNDW,PBDW,DDW
C
       READ(IIN,1000) BQDW,BODDW,SSDW,TKNDW,PBDW,DDW
       WRITE (IOUT,1001) BQDW,BODDW,SSDW,TKNDW,PBDW,DDW
C ECHO THE INPUT
C STEP 2
C
C - COMPUTE NUMBER OF PERIODS IN DAY
C
       NP=24/IDT
20     CONTINUE
C STEP 3
C
C CALCULATE ADJUSTMENT RATIOS
C
```

```
      I=1
      DO 30 J=1,NP
      FDT(J)=0.0
      DO 30 J1=1,IDT
      FDT(J)=FDT(J)+HRFR(I)
      I=I+1
30     CONTINUE
      DO 35 J=1,NP
      FDT(J)=FDT(J)/IDT
35     CONTINUE
C STEP 4
C
C - CALC THE DRYWWEATHER FLOW PER UNIT OF TIME
C
      I=1
      DO 40 IDA=1,7
      DO 40 IHR=1,NP
      QDW(I)=BQDW*DFR(IDA)*FDT(IHR)
      I=I+1
40     CONTINUE
C STEP 5
C
C RETURN TO CALLING MODULE
C
      RETURN
      END
C
C********************** DSRD ********************************
C
      SUBROUTINE DSRD (NYRSTR,*)
      COMMON /IO/IIN,IRIV,IOUT
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /STR2/QDUS(360,5),QMUS(12,5),QMSF(12),SDMSF(12),CCMSF(12)
C
C READ DAILY STREAMFLOW RECORDS
C
1000  FORMAT(F6.0)
1001  FORMAT(1X,'NOT ENOUGH DAILY STREAMFLOW DATA',/,
     1' JOB ABORTED')
1002  FORMAT(I2)
1003  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',
     1/,T30,'FEBRUARY,1979',///,
     1/T2,'INPUT FOR DAILY STREAMFLOW',20('-')/,
     1//T2,'NUMBER OF YEARS OF STREAMFLOW READ  ',I2)
1004  FORMAT(//T2,'THE FIRST TEN VALUES ARE :'/)
1005  FORMAT(T10,F6.0,' CFS')
C GET THE NUMBER OF YEARS OF STREAMFLOW TO BE READ IN
      READ(IRIV,1002)NYRSTR
      IF(NYR.LT.NYRSTR)NYRSTR=NYR
      WRITE(IOUT,1003)NYRSTR
      DO 10 J=1,NYRSTR
      DO 10 I=1,360
10    READ(IRIV,1000,END=99)QDUS(I,J)
      WRITE(IOUT,1004)
      DO 20 I=1,10
      WRITE(IOUT,1005)QDUS(I,1)
20    CONTINUE
      RETURN
99    WRITE(IOUT,1001)
      RETURN 1
```

```
      END
C
C****************************** EXXPON ******************************
C
      SUBROUTINE EXXPON(XMEAN,R)
C
C-GENERATE A RANDOM OBSERVATION
C-FROM AN EXPONENTIAL DISTRIBUTION
C
C    **************
C    *            *
C    *   STEP 1   *
C    *            *
C    **************
C
C GET RANDOM NUMBER
C
      CALL RANDOM(X)
C
C    **************
C    *            *
C    *   STEP 2   *
C    *            *
C    **************
C
C CALC RANDOM VARIATE
C
      R=-1.0*(ALOG(X))*XMEAN
C
C    **************
C    *            *
C    *   STEP 3   *
C    *            *
C    **************
C
C RETURN TO CALLING MODULE
C
      RETURN
      END
C
C******************* FN ****************************
C
       FUNCTION FN(TA,CT,C1,C2,U)
       D1=1E-14
       T1=(U/C1)+1.0+(C2/U)
       T2=1.0/T1
       T3=((U*U)/(C1*C2))+1.0+(U/C2)
       T4=2/T3
       T5=D1/U
       FN=CT*(T2+T4)+T5-U-TA
       RETURN
       END
C
C********************** GMSF ****************************************
C
      SUBROUTINE GMSF
       COMMON /IO/IIN,IRIV,IOUT
        COMMON/GLOBAL/IDT,NYR,LOC(10)   ,IRN1,IWSD
       COMMON /STR2/QDUS(360,5),QMUS(12,5),QMSF(12),SDMSF(12),CCMSF(12)
1000   FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',/T30,
```

```
     1 'FEBRUARY,1979',//,T26,'MONTHLY STREAMFLOW GENERATOR',//
     2 T2,'MONTH',T11,'YEAR',T21,'QUANTITY')
1001    FORMAT(1X,//,T3,I2,T12,I2,T21,F10.2)
1002    FORMAT(1X,//,T5,'AVERAGE ANNUAL FLOW',F10.2)
C
C      THIS MODULE GENERATES MONTHLY STREAMFLOWS
C
C STEP 1
C
C GENERATE FIRST OBSERVATION IN FIRST YEAR OF SIMULATION
C
        ASUM=0.0
        IYEAR=1
        IMO=1
        QNMO=QMSF(1)
        SIG=SDMSF(1)
        CALL LOGNOR (QNMO,SIG,VAL)
        QMUS(IMO,IYEAR)=VAL
        ASUM=ASUM+VAL
C STEP 2
C
C GENERATE MONTHLY VALUES FOR MONTHS 2 TO 12
C
10      DO 20 IMO=2,12
        RATIO=SDMSF(IMO)/SDMSF(IMO-1)
        R=CCMSF(IMO)
        SIG=SDMSF(IMO)
        QNMO=QMSF(IMO)
        QNMOL1=QMSF(IMO-1)
        QMUSL1= QMUS(IMO-1,IYEAR)
15      CALL MARKOV(QNMO,SIG,RATIO,QMUSL1,QNMOL1,VAL,R)
        ASUM=ASUM+VAL
20      QMUS(IMO,IYEAR)=VAL
21      CONTINUE
       WRITE(IOUT,1000)
       DO 25 I=1,12
25      WRITE(IOUT,1001)I,IYEAR,QMUS(I,IYEAR)
        AVMUS=ASUM/12.0
        WRITE(IOUT,1002)AVMUS
        ASUM=0.0
C
C STEP 3
C
C INCREMENT SIMULATION YEAR BY 1
C
        IYEAR=IYEAR+1
C STEP 4
C
C CHECK FOR END OF SIMULATION
C
        IF (IYEAR.GT.NYR) GO TO 99
C STEP 5
C
C COMPUTE FIRST MONTH FLOW FOR NEXT YEAR
C
        IMO=1
        RATIO=SDMSF(1)/SDMSF(12)
        R=CCMSF(1)
        SIG=SDMSF(1)
        QNMO=QMSF(1)
        QNMOL1=QMSF(12)
```

```
      QMUSL1=QMUS(12,IYEAR-1)
      CALL MARKOV(QNMO,SIG,RATIO,QMUSL1,QNMOL1,VAL,R)
      QMUS(1,IYEAR)=VAL
      ASUM=ASUM+VAL
C STEP 6
C
C GO TO STEP 2
C
      GO TO 10
99    RETURN
      END
C
C********************** INFL *************************************
C
      SUBROUTINE INFL
      COMMON /IO/IIN,IRIV,IOUT
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /INFIL/WSCOD(2),ADIA(2),ALENG(2),ADWF(2),RDWF(2),
     1 IAF(2)
      COMMON /IRO/IDORM(12),IGROW(12),CN1(2),CN2(2),CN3(2),DA(2),
     1 TC(2),CWO(2)
      INTEGER WSCOD
      REAL IAF
      COMMON /RAIN/ISEAS1(12),ISEAS2(12),TBSA(2),DSA(2),RDA(2),
     1 RDSA(2),CCA(2),RDY(2160)
      COMMON /RUNQL/BOD(2,2160),TKN(2,2160),SS(2,2160),PB(2,2160)
      COMMON /RUNOF/RUN(2,2160)
      DIMENSION RF(360)
      REAL IOSS(360),IOBOD(360),IOTKN(360),IOPB(360),IOA(360)
      REAL IOSST,IOBODT,IOTKNT,IOPBT,MSS,MPB,MTKN,MBOD
      REAL IOT,MAXFLO
      INTEGER TDEI
      REAL MXIR
      REAL MXCBOD,MXCTKN,MXCSS,MXCPB
1000  FORMAT('1','EXCESS INFILTRATION RESULTS FOR WATERSHED ',I2,/
     1 T2,'TOTAL DURATION EXCESS INFILTRATION  ',I6,' HOURS',/
     1 T2,'TOTAL AMOUNT OF EXCESS INFILTRATION ',F10.2,' INCHES',/
     1 T2,'MAXIMUM EXCESS INFILTRATION RATE ',F10.2,' CFS')
1001  FORMAT(//,'1   EXCESS INFILTRATION PLUS RUNOFF QUALITY-STATISTICS
     1 FOR'
     1,5X,'WATERSHED NO. ',I3,/,
     1        T42,'BOD',T53,'TKN',T64,'SS',T75,'PB'/,
     1       1X,'MAXIMUM CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/
     1        1X,'MEAN CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/
     1        1X,'TOTAL ANNUAL WASHOFF(LBS)',T32,4(1X,F11.0),/)
C CALCULATE THE NUMBER OF TIME PERIODS PER DAY
      NTP=24/IDT
C CALCULATE THE NUMBER OF TIME PERIODS PER YEAR
      NSTEPS=8640/IDT
C DEVELOP DAILY RAINFALL ARRAY
      K=1
      L=0
29    CONTINUE
C INITIALIZE THE AMOUNT OF RAINFALL THIS DAY--DR
      DR=0
      DO 30 I=1,NTP
C ACCUMULATE DAILY RAINFALL
      DR=DR+RDY(K)
      K=K+1
30    CONTINUE
      L=L+1
```

```
C PUT AMOUNT OF DAILY RAINFALL IN DAILY RAINFALL ARRAY
      RF(L)=DR
      IF(L.GE.360)GO TO 35
      GO TO 29
35    CONTINUE
C
C NOW THE RAINFALL ARRAY (DAILY) HAS BEEN BUILT  --RF(360)
C
C
C DO ANALYSIS FOR EACH WATERSHED
      DO 999 NWS=1,IWSD
C
C IF WATERSHED HAS NO INFILTRATION THEN GO TO END OF THIS MODULE
C
      IF(WSCOD(NWS).EQ.0) GOTO 999
C
C TOTAL DURATION EXCESS INFILTRATION
      TDEI=0
C MAXIMUM INFILTRATION RATE
      MXIR=0.0
C COMPUTE TOTAL INFILTRATION ARRAY
C     ASSUME NO RAINFALL IN LAST 9 DAYS OF PREVIOUS YEAR
C
C SOME CONSTANTS FOR COMPUTING INFILTRATION OVERFLOW ARRAY
C
      C1=ADIA(NWS)
      C2=ALENG(NWS)
      C3=IAF(NWS)
      IOA(1)=OAF(RF(1),0,0,0,0,0,0,0,0,0,C1,C2,C3)
      IOA(2)=OAF(RF(2),RF(1),0,0,0,0,0,0,0,0,C1,C2,C3)
      IOA(3)=OAF(RF(3),RF(2),RF(1),0,0,0,0,0,0,0,C1,C2,C3)
      IOA(4)=OAF(RF(4),RF(3),RF(2),RF(1),0,0,0,0,0,0,C1,C2,C3)
      IOA(5)=OAF(RF(5),RF(4),RF(3),RF(2),RF(1),0,0,0,0,0,C1,C2,C3 )
      IOA(6)=OAF(RF(6),RF(5),RF(4),RF(3),RF(2),RF(1),0,0,0,0,C1,C2,C3)
      IOA(7)=OAF(RF(7),RF(6),RF(5),RF(4),RF(3),RF(2),RF(1),0,0,0,C1,
     1 C2,C3)
      IOA(8)=OAF(RF(8),RF(7),RF(6),RF(5),RF(4),RF(3),RF(2),RF(1),
     1 0,0,C1,C2,C3)
      IOA(9)=OAF(RF(9),RF(8),RF(7),RF(6),RF(5),RF(4),RF(3),RF(2),
     1 RF(1),0,C1,C2,C3)
C
      DO 200 J=10,360
      IOA(J)=OAF(RF(J),RF(J-1),RF(J-2),RF(J-3),RF(J-4),RF(J-5),
     1 RF(J-6),RF(J-7),RF(J-8),RF(J-9),C1,C2,C3)
200   CONTINUE
C
C COMPUTE INFILTRATION OVERFLOW ARRAY
      MAXFLO=ADWF(NWS)*(RDWF(NWS)-1.0)
C MAXFLO -IS THE EXCESS CAPACITY OF THE WWTP
      DO 250 J=1,360
C CALC AMOUNT OF OVERFLOW
      IOA(J)=IOA(J)-MAXFLO
C IF INFILTRATION AMOUNT LESS THAN EXCESS CAPACITY THEN NO OVERFLOW
      IF(IOA(J).LT.0.0)IOA(J)=0.0
      IF(IOA(J).NE.0.0)TDEI=TDEI+1
      IF(MXIR.LE.IOA(J))MXIR=IOA(J)
250   CONTINUE
C CONVERT TOTAL DURATION EXCESS INFILTRATION TO HOURS
      TDEI=TDEI*24
260   CONTINUE
C
```

```
C STEP 2
C
C COMPUTE INFILTRATION OVERFLOW QUALITY ARRAY
C
C   INFILTRATION OVERFLOW QUALITY IS BASED ON THE FOLLOWING
C   RAW WASTEWATER STRENGTHS
C      BOD5=200 MG/L
C      SS  =200 MG/L
C      TKN = 40 MG/L
C      PB    = 0.04 MG/L
C
C  COMPUTE SS BOD TKN AND PB QUALITY
C
       DO 300 J=1,360
C
       IF(IOA(J).NE.0.0)GO TO 275
       IOSS(J)=0.0
       IOBOD(J)=0.0
       IOTKN(J)=0.0
       IOPB(J)=0.0
       GO TO 300
275    CONTINUE
C CALC DILUTION FACTOR = RATIO OF TOTAL FLOW TO DRY WEATHER FLOW
       DILFAC=(IOA(J)+ADWF(NWS)*RDWF(NWS))/ADWF(NWS)
       IOSS(J)=200/DILFAC
       IOBOD(J)=200/DILFAC
       IOTKN(J)=40/DILFAC
       IOPB(J)=0.04/DILFAC
300    CONTINUE
C
C STEP 3
C
C OUTPUT INFILTRATION OVERFLOW SUMMARY
C
C INITIALIZE VARIABLES
       IOT=0.0
       IOSST=0.0
       IOBODT=0.0
       IOTKNT=0.0
       IOPBT=0.0
       DO 400 J=1,360
C COMPUTE TOTALS
       IOT=IOT+IOA(J)
       IOSST=IOSST+IOA(J)*IOSS(J)
       IOBODT=IOBODT+IOA(J)*IOBOD(J)
       IOTKNT=IOTKNT+IOA(J)*IOTKN(J)
       IOPBT=IOPBT+IOA(J)*IOPB(J)
400    CONTINUE
C CONVERT TOTAL EXCESS INFILTRATION TO INCHES
       IOT=IOT*3600*24
C (ACRE-FEET)
       IOT=IOT/43560.0
C (INCHES)
       IOT=IOT*12.0/DA(NWS)
       WRITE(IOUT,1000)NWS,TDEI,IOT,MXIR
C
C STEP 4
C
C COMBINE INFILTRATION OVERFLOW ARRAY WITH RUNOFF ARRAY FOR
C    WATERSHED
C
```

```
C
      MXCBOD=0.0
      MXCTKN=0.C
      MXCSS=0.0
      MXCPB=0.0
      TOSS=0.0
      TOTKN=0.0
      TOPB=0.0
      TOBOD=C.0
      TOR=0.0
      DO 500 J=1,NSTEPS
      K=J/NTP
      K=K+1
      QT=RUN(NWS,J)+IOA(K)
      IF(QT.GE.0.0001)GOTO 450
      SS(NWS,J)=0.0
      BOD(NWS,J)=0.0
      TKN(NWS,J)=0.0
      PB(NWS,J)=0.0
      RUN(NWS,J)=0.0
      GOTO 500
450   CONTINUE
      QULSS=(RUN(NWS,J)*SS(NWS,J)+IOA(K)*IOSS(K))/QT
      SS(NWS,J)=QULSS
      QULBOD=(RUN(NWS,J)*BOD(NWS,J)+IOA(K)*IOBOD(K))/QT
      BOD(NWS,J)=QULBOD
      QULTKN=(RUN(NWS,J)*TKN(NWS,J)+IOA(K)*IOTKN(K))/QT
      TKN(NWS,J)=QULTKN
      QULPB=(RUN(NWS,J)*PB(NWS,J)+IOA(K)*IOPB(K))/QT
      PB(NWS,J)=QULPB
      RUN(NWS,J)=QT
      IF(MXCBOD.LT.QULBOD)MXCBOD=QULBOD
      IF(MXCTKN.LT.QULTKN)MXCTKN=QULTKN
      IF(MXCSS.LT.QULSS)MXCSS=QULSS
      IF(MXCPB.LT.QULPB)MXCPB=QULPB
      TOSS=TOSS+(QULSS*QT)
      TOPB=TOPB+(QULPB*QT)
      TOTKN=TOTKN+(QULTKN*QT)
      TOBOD=TOBOD+(QULBOD*QT)
      TOR=TOR+QT
500   CONTINUE
      AVSS=TOSS/TOR
      AVPB=TOPB/TOR
      AVTKN=TOTKN/TOR
      AVBOD=TOBOD/TOR
      WOBOD=AWP(TOR,IDT,AVBOD)
      WOTKN=AWP(TOR,IDT,AVTKN)
      WOSS=AWP(TOR,IDT,AVSS)
      WOPB=AWP(TOR,IDT,AVPB)
      WRITE(IOUT,1001)NWS,MXCBOD,MXCTKN,MXCSS,MXCPB,AVBOD,AVTKN,
     1 AVSS,AVPB,WOBOD,WOTKN,WOSS,WOPB
999   CONTINUE
909   CONTINUE
C STEP 5
C
C RETURN TO CALLING MODULE
C
      RETURN
      END
C
C******************* INFLRD ***************************************
```

```
C
      SUBROUTINE INFLRD
      COMMON /IO/IIN,IRIV,IOUT
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /INFIL/WSCOD(2),ADIA(2),ALENG(2),ADWF(2),RDWF(2),
     1 IAF(2)
      INTEGER WSCD ,WSCOD
      REAL LENGTH,IAF ,INFAF
1000  FORMAT(I1,5F10.2)
1002  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION  SYSTEM
     1',
     1/,T30,'FEBRUARY,1979',///,
     1 T2,'EXCESS INFILTRATION INPUT DATA',20('-')/)
1001  FORMAT(
     1 //T2,'WATERSHED: ',I2,T24,'CODE: ',I2/
     1 T2,'AVERAGE PIPE DIAMETER:  ',F10.2,' INCHES'/
     1 T2,'TOTAL SYSTEM LENGTH: ',F10.2,' MILES'/
     1 T2,'DRY WEATHER FLOW: ',F10.2,' CFS'/
     1 T2,'DRY WEATHER FLOW RATIO: ',F10.2,/
     1 T2,'INFILTRATION ADJUSTMENT FACTOR: ',F10.2)
      WRITE(IOUT,1002)
      DO 20 I=1,IWSD
      READ(IIN,1000)WSCD,DIA,LENGTH,DWF,DWFR,INFAF
      IF(INFAF.EQ.0.0)INFAF=1.0
      WRITE(IOUT,1001)I,WSCD,DIA,LENGTH,DWF,DWFR,INFAF
      WSCOD(I)=WSCD
      ALENG(I)=LENGTH
      ADIA(I)=DIA
      ADWF(I)=DWF
      RDWF(I)=DWFR
      IAF(I)=INFAF
20    CONTINUE
      RETURN
      END
C
C************************* ISTR ****************************************
C
     SUBROUTINE ISTR
C
C    THE INDEPENDENT STREAMFLOW SIMULATOR WILL GENERATE RANDOM
C    OBSERVATIONS OF STREAMFLOW, GIVEN STATISTICS FROM OBSERVED DATA.
C
C    INPUT DATA WILL BE
C
C    THE SPECIFIC RANDOM VARIABLES(S) TO BE GENERATED IS(ARE):
C
C    1.
C
C    AUTHOR - MIKE MARA
C
C    DATE     DECEMBER 1977
C
     CONTINUE
C    INPUT VARIABLES -----------------------------------------------------
C
C    NAME     DESCRIPTION/DIMENSION
C    ------   ------------------------------------------------------------
C
C    QMSF     MEAN MONTHLY FLOW (12)
C    SDMSF    STANDARD DEV OF MEAN MONTHLY FLOW (12)
C    CCMSF    LAG 1 CORR COEFF OF ADJACENT MONTHLY FLOWS (12)
```

```
C      BODSF     BOD                 STREAMFLOW CONC (MG/L)
C      SSSF      SUSPENDED SOLIDS STREAMFLOW CONC (MG/L)
C      TKNSF     TKN                 STREAMFLOW CONC (MG/L)
C      PBSF      LEAD                STREAMFLOW CONC (MG/L)
C      NYR       NUMBER OF YEARS OF SIMULATION
C
C
       CONTINUE
C
C      OUTPUT VARIABLES -------------------------------------------------
C
C      NAME      DESCRIPTION/DIMENSION
C      ------    ---------------------------------------------------------
C
C      BODSF     BOD                 STREAMFLOW CONC (MG/L)
C      SSSF      SUSPENDED SOLIDS STREAMFLOW CONC (MG/L)
C      TKNSF     TKN                 STREAMFLOW CONC (MG/L)
C      PBSF      LEAD                STREAMFLOW CONC (MG/L)
C
C
        COMMON /GLOBAL/ICT,NYR,LOC(10),IRN1,IWSD
        COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
      1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
      2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
      3 K1W1,K1W2,K1USF,K1DWF
        COMMON /STR2/QDUS(360,5),QMUS(12,5),QMSF(12),SDMSF(12),CCMSF(12)
        COMMON /IO/IIN,IRIV,IOUT
1000   FORMAT(I2)
1001   FORMAT(5F10.2)
1003    FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
      1',/,
      1 T30,'FEBRUARY,1979',/
      2 //T25,'INPUT TO INDEPENDENT STREAMFLOW'/
      3 ///,T2,'MONTH',T16,'MEAN',T31,'SD',
      1 T46,'CORR COEFF')
1005   FORMAT(1X,/,T3,I2,T11,F10.2,T26,F10.2,T41,F10.2)
C STEP 1
C
C-READ MONTHLY STREAMFLOW STATISTICS
C
       WRITE(IOUT,1003)
       DO 10 I=1,12
       READ (IIN,1001) XQ,XSD,XCC
       WRITE(IOUT,1005) I,XQ,XSD,XCC
9      CONTINUE
10     CALL TRANS (XQ,XSD,XCC,QMSF(I),SDMSF(I),CCMSF(I))
15     CONTINUE
C STEP 2
C-GENERATE MONTHLY FLOWS FOR NYR FLOWS
C
       CALL GMSF
C STEP 3
C
C RETURN TO CALLING MODULE
C
40     RETURN
       END
C
C********************* LOGNOR ******************************
C
        SUBROUTINE LOGNOR(MEAN,SD,R)
```

```
      REAL MEAN,NV
C
C GENERATING A RANDOM NUMBER FROM A LOG NORMAL 0,1
C
C   **************
C   *            *
C   *   STEP 1   *
C   *            *
C   **************
C
C GENERATE 12 RANDOM NUMBERS ON UNIFORM 0,1 INTERVAL
C
      SUMRN=0.0
      DO 10 I=1,12
      CALL RANDOM (X)
10    SUMRN=SUMRN+X
C
C   **************
C   *            *
C   *   STEP 2   *
C   *            *
C   **************
C
C CALCULATE NORMAL VARIATE
C
      NV=SUMRN-6.0
      P1=SD
      P2=MEAN
C
C   **************
C   *            *
C   *   STEP 3   *
C   *            *
C   **************
C
C CALCULATE THE RANDOM VARIATE
C
      R=EXP(NV*SD+MEAN)
      P3=R
C
C   **************
C   *            *
C   *   STEP 4   *
C   *            *
C   **************
C
C RETURN TO CALLING MODULE
C
20    RETURN
      END
C
C********************* ***** MARKOV ****************************
C
      SUBROUTINE MARKOV (MEAN,SD,RATIO,QL1,ML1,RD,CC)
      REAL NV,ML1,MEAN
C
C GENERATE A LAG ONE MARKOV SERIES <LOG NORMAL DISTRIBUTION>
C
C   **************
C   *            *
C   *   STEP 1   *
```

```
C    *              *
C    **************
C
C GENERATE 12 RANDOM NUMBERS ON UNIFORM 0,1 INTERVAL
C
      SUMRN=0.0
5     DO 10 I=1,12
      CALL RANDOM (X)
10    SUMRN=SUMRN+X
C
C    **************
C    *              *
C    *   STEP 2     *
C    *              *
C    **************
C
C CALCULATE NORMAL VARIATE
C
      NV=SUMRN-6.0
20    AQL1=ALOG(QL1)
C
C    **************
C    *              *
C    *   STEP 3     *
C    *              *
C    **************
C
C CALC COEFF AND CORRECT IF GT 1
C
      COEFF=RATIO*CC
      IF (COEFF.GT.1.0)COEFF=1.0
C
C    **************
C    *              *
C    *   STEP 4     *
C    *              *
C    **************
C
C CALCULATE VARIATE
C
      YI=MEAN+COEFF*(AQL1-ML1)+NV*SD*SQRT(1-CC*CC)
30    RD=EXP(YI)
      T6=RD
40    IF (RD.LT.0.01) RD=0.01
C
C    **************
C    *              *
C    *   STEP 5     *
C    *              *
C    **************
C
C RETURN TO CALLING MODULE
C
      RETURN
      END
C
C***************************** MONTH *****************************
C
      SUBROUTINE MONTH(IUNITS,IUNIT,MTH)
C
C-SUBROUTINE MONTH WILL DETERMINE THE CURRENT MONTH(MTH)
```

```
C-GIVEN THE NUMBER OF TIME UNITS PER YEAR(IUNITS=
C-360*24/IDT), AND THE CURRENT TIME UNIT (IUNIT)
C
C
C     NAME      DESCRIPTION
C     ------    ----------------------------------------------------
C
C     INPUT VARIABLES:
C
C     IUNITS    NO.OF TIME PERIODS/YEAR,EACH OF DURATION IDT
C     IUNIT     CURRENT TIME PERIOD
C
C
C     OUTPUT VARIABLES:
C
C     MTH       CURRENT MONTH
C     IMTH      NO OF TIME PERIODS PER MONTH
C
      IMTH=IUNITS/12
      IF(IUNIT.LE.(01*IMTH))GO TO 10
      IF(IUNIT.LE.(02*IMTH))GOTO 20
      IF(IUNIT.LE.(03*IMTH))GOTO 30
      IF(IUNIT.LE.(04*IMTH))GOTO 40
      IF(IUNIT.LE.(05*IMTH))GOTO 50
      IF(IUNIT.LE.(06*IMTH))GOTO 60
      IF(IUNIT.LE.(07*IMTH))GOTO 70
      IF(IUNIT.LE.(08*IMTH))GOTO 80
      IF(IUNIT.LE.(09*IMTH))GOTO 90
      IF(IUNIT.LE.(10*IMTH))GOTO 100
      IF(IUNIT.LE.(11*IMTH))GOTO 110
      IF(IUNIT.LE.(12*IMTH))GOTO 120
      GO TO 150
10     MTH=1
       GOTO 150
20     MTH=2
       GOTO 150
30     MTH=3
       GOTO 150
40     MTH=4
       GOTO 150
50     MTH=5
       GOTO 150
60     MTH=6
       GOTO 150
70     MTH=7
       GOTO 150
80     MTH=8
       GOTO 150
90     MTH=9
       GOTO 150
100    MTH=10
       GOTO 150
110    MTH=11
       GOTO 150
120    MTH=12
150    CONTINUE
      RETURN
      END
C
C**************** NWTRAF ****************************
C
```

```
      SUBROUTINE NWTRAF(TA1,CT1,X1,J)
      COMMON /IO/IIN,IRIV,IOUT
      C1=4.45E-7
      C2=4.69E-11
      REAL*8 FDF,TOL,F,DF
C
C THIS MODULE SOLVES THE LEAD EQN FOR  H+
C USING NEWTON-RAPHSON METHOD
C
1000  FORMAT(T2,'MAX EXCEEDED IN NWTRAF  X=',E9.2,' F=',E9.2,
     1 ' DF=',E9.2,' FDF=',E9.2)
      DATA MAX,TOL/15,1.0E-11/
      NCT=0
1     NCT=NCT+1
2     F=FN(TA1,CT1,C1,C2,X1)
      DF=DFN(TA1,CT1,C1,C2,X1)
4     FDF=F/DF
      X1=X1-FDF
5     IF(DABS(FDF).LT.TOL)RETURN
      IF(NCT.LT.MAX)GOTO 1
      WRITE(IOUT,1000)X1,F,DF,FDF
      RETURN
      END
C
C******************** DAF ***********************
C
      FUNCTION DAF(XL0,XL1,XL2,XL3,XL4,XL5,XL6.XL7,XL8,XL9,D,XL,XIA)
C
C INFILTRATION EQN FITTED FOR BALTIMORE,MD
C SEE SWMM,USERS MANUAL,VERS 2,P.139
C
      T1=2.4
      T2=T1+11.3*XL0
      T3=T2+11.6*XL1
      T4=T3+5.5*XL2
      T5=T4+6.4*XL3
      T6=T5+4.8*XL4
      T7=T6+3.6*XL5
      T8=T7+1.0*XL6
      T9=T8+1.5*XL7
      T10=T9+1.4*XL8
      T11=T10+1.8*XL9
      T12=T11*D*XL*XIA
      DAF=T12*0.002228
      RETURN
      END
C
C******************** PBRW **************************
C
      SUBROUTINE PBRW (QCSO,QSW,QSF,QDW,PBCSO,PBSW,PBSF,PBDW,SPBWC,
     1 FPBI,FPBD,J1,PBWC,UPBWO,CPBM,IDT)
      COMMON /PB1/TA(4),TH(4),PH(4)
      DIMENSION FPBI(20),FPBD(20)
C
C CONSTANTS
C
       REAL*8 XK,PKSP,APBMD
      REAL KSP,K1,K2
      KSP=1.5E-13
      PKSP=12.824
      K1=4.45E-7
```

```
      PK1=6.35
      K2=4.69E-11
      PK2=10.33
C
C STEP 1
C
C CALC MIXES FOR ALKALINITY,HARDNESS,LEAD
C
      TACSO=TA(1)
      TASW=TA(2)
      TASF=TA(3)
      TADW=TA(4)
      TAM=XMIX(TACSO,QCSO,TASW,QSW,TASF,QSF,TADW,QDW)
      THCSO=TH(1)
      THSW=TH(2)
      THSF=TH(3)
      THDW=TH(4)
      THM=XMIX(THCSO,QCSO,THSW,QSW,THSF,QSF,THDW,QDW)
C PBM DISSOLVED LEAD IN WATER COLUMN
C CONVERT PB TO  PB   PB= PB *2.0719E+5
      SPCSO=PBCSO/(2.0719E+5)
      SPSW=PBSW/(2.0719E+5)
      SPSF=PBSF/(2.0719E+5)
      SPDW=PBDW/(2.0719E+5)
      BPBM=XMIX(SPCSO,QCSO,SPSW,QSW,SPSF,QSF,SPDW,QDW)
C
C  STEP 2
C
C CALC CTS
      PHCSO=PH(1)
      PHSW=PH(2)
      PHSF=PH(3)
      PHDW=PH(4)
      BTACSO=TACSO*1.0E-5
      BTASW=TASW*1.0E-5
      BTASF=TASF*1.0E-5
      BTADW=TADW*1.0E-5
      CTCSO=CCT(PHCSO,BTACSO)
      CTSW=CCT(PHSW,BTASW)
      CTSF=CCT(PHSF,BTASF)
      CTDW=CCT(PHDW,BTADW)
C
C STEP 3
C
C COMPUTE CTMIX
      CTM=XMIX(CTCSO,QCSO,CTSW,QSW,CTSF,QSF,CTDW,QDW)
C
C STEP 3 B
C
C SOLVE FOR  H+  MIXED
C
C USE NEWTON-RAPHSON METHOD
C
C STARTING VALUE FOR  H+   HPM
      HPM=1.0E-9
      BTAM=TAM*1.0E-5
      CALL NWTRAF(BTAM,CTM,HPM,J1)
C CONVERT  H+  MIXED TO PH MIXED
7     PHM=ALOG10(1.0/HPM)
8     CONTINUE
C PRECIPITATION DETERMINATION
```

```
      XIM=(4.0*THM-TAM)   *1.0E-5
      SXIM=SQRT(XIM)
      D1=((SXIM/(1.0+SXIM))-0.2*XIM)
       D=2*D1
       G=1.0/(10**D)
      PPK1=PK1-0.5*D1
      PK1=1.0/(10**PPK1)
      PPK2=PK2-2.0*D1
       PK2=1.0/(10**PPK2)
      PALF21=((HPM*HPM)/(PK1*PK2))+1.0+(HPM/PK2)
      PALF2=1.0/PALF21
      XK=G*BPBM*CTM*PALF2
      PPKSP=PKSP-4*D1
      PKSP=1.0/(10**PPKSP)
C NO PRECIPITATION THEN DISSOLVED PB = PBM
      PBM=BPBM*2.0719E+5
      IF(XK.LT.PKSP)GOTO 20
C PRECIPITATION
      APBMD=PKSP/(CTM*PALF2)
      03=2.0719E+5
      PBMD=(APBMD/G)*03
C ACTUAL DISSOLVED LEAD IN THE MIXED FLOWS
      CPBM=PBMD
C SEDIMENT LEAD AMOUNT
      SPBM=PBM-CPBM
      GOTO 40
20    CPBM=PBM
      SPBM=0.0
40     CONTINUE
      CPBM=CPBM
      SPBM=SPBM
      SSPBM=SPBM
41     CONTINUE
C CALCULATE THE AMOUNT OF SEDIMENT  =INFLOW-DISSOLVED
C FREQUENCY DISTRIBUTIONS OF DISSOLVED LEAD
      CALL CFPB(CPBM,FPBD)
C FREQUENCY DISTRIBUTION OF INFLOWING LEAD
      CALL CFPB(PBM,FPBI)
C CALC TOTAL FLOW
      QT=QCSD+QSW+QSF+QDW
C CALC WASHOFF OF LEAD IN POUNDS PER YEAR
      SPBWO=AWP(QT,IDT,SPBM)
      PBWO=AWP(QT,IDT,CPBM)
      UPBWO=AWP(QSF,IDT,PBSF)
      RETURN
      END
C
C**************** PER ***********************
C
      FUNCTION PER(R)
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      PER=(R*IDT*100.0)/8640
      RETURN
      END
C
C************* PUTDOS ***********************
C
      SUBROUTINE PUTDOS(DIST2,CDO,IDT)
      COMMON /IO/IIN,IRIV,IOUT
      DIMENSION CDO(7)
1000  FORMAT(///,T2,'TIME AVERAGED PERCENT OF STREAM REACH TO ',F6.2,
```

```
     1 ' MILES DOWNSTREAM AT OR BELOW GIVEN DO CONCENTRATION.',//
     1 T2,'DO',T20,'PERCENT OF'/
     1 T2,'CONCENTRATION',T20,'STREAM REACH'/
     1 T2,'0.0', T20,F7.4/
     1 T2,'LESS THAN 1.0',T20,F7.4/
     1 T2,'LESS THAN 2.0',T20,F7.4/
     1 T2,'LESS THAN 3.0',T20,F7.4/
     1 T2,'LESS THAN 4.0',T20,F7.4/
     1 T2,'LESS THAN 5.0',T20,F7.4/
     1 T2,'LESS THAN 6.0',T20,F7.4/
     1 )
C
C COMPUTE AVERAGE  PERCENT OF AFFECTED STREAM REACH
C
      NCOMP=432000/IDT
      DO 10 I=1,7
      CDO(I)=CDO(I)*100.0/NCOMP
10    CONTINUE
      WRITE(IOUT,1000)DIST2,CDO
      RETURN
      END
C
C********************* PUT FDO ********************************
C
     SUBROUTINE PUTFDO (FDO,DIST,IND)
      COMMON /IO/IIN,IRIV,IOUT
      DIMENSION AL(2)
      DATA AL/'TO','AT'/
     DIMENSION FDO(16)
1000  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',/,
     1 T30,'FEBRUARY,1979',/
     2 T2,'CUMULATIVE FREQUENCY-MINIMUM DISSOLVED OXYGEN',3X,A2,3X,F8.2,
     23X,'MILES DOWNSTREAM'//
     3 T7,'DO MIN',T22,'NUMBER OF',T36,'PERCENT OF',
     3T50,'CUMULATIVE',/
     4 T2,'CONCENTRATION',T21,'OCCURRENCES',T39,'TIME',
     4T50,'PERCENT')
1001  FORMAT(1X,'1.0 OR LESS',T24,F5.0,T38,F6.2,T50,F6.2)
1002  FORMAT(1X,'1.0 TO 2.0',T24,F5.0,T38,F6.2,T50,F6.2)
1003  FORMAT(1X,'2.0 TO 3.0',T24,F5.0,T38,F6.2,T50,F6.2)
1004  FORMAT(1X,'3.0 TO 4.0',T24,F5.0,T38,F6.2,T50,F6.2)
1005  FORMAT(1X,'4.0 TO 5.0',T24,F5.0,T38,F6.2,T50,F6.2)
1006  FORMAT(1X,'5.0 TO 6.0',T24,F5.0,T38,F6.2,T50,F6.2)
1007  FORMAT(1X,'6.0 TO 7.0',T24,F5.0,T38,F6.2,T50,F6.2)
1008  FORMAT(1X,'7.0 TO 8.0',T24,F5.0,T38,F6.2,T50,F6.2)
1009  FORMAT(1X,'8.0 TO 9.0',T24,F5.0,T38,F6.2,T50,F6.2)
1010  FORMAT(1X,'9.0 TO 10.0',T24,F5.0,T38,F6.2,T50,F6.2)
1011  FORMAT(1X,'10.0 TO 11.0',T24,F5.0,T38,F6.2,T50,F6.2)
1012  FORMAT(1X,'11.0 TO 12.0',T24,F5.0,T38,F6.2,T50,F6.2)
1013  FORMAT(1X,'12.0 TO 13.0',T24,F5.0,T38,F6.2,T50,F6.2)
1014  FORMAT(1X,'13.0 TO 14.0',T24,F5.0,T38,F6.2,T50,F6.2)
1015  FORMAT(1X,'14.0 TO 15.0',T24,F5.0,T38,F6.2,T50,F6.2)
1016  FORMAT(1X,'GREATER THAN 15.0',T24,F5.0,T38,F6.2,T50,F6.2)
1017  FORMAT(/T10,'TOTAL=',T24,F5.0)
     WRITE(IOUT,1000)AL(IND),DIST
C INITIALIZE TOTAL DO OCCURRENCES
      TOCC=0.0
C INITIALIZE CUMULATIVE PERCENTAGE
      CPT=0.0
     TOCC=TOCC+FDO(1)
```

```
      PT=PER(FDO(1))
       CPT=CPT+PT
      WRITE(IOUT,1001) FDO(1),PT,CPT
C
       TOCC=TOCC+FDO(2)
       PT=PER(FDO(2))
       CPT=CPT+PT
       WRITE(IOUT,1002) FDO(2),PT,CPT
C
       TOCC=TOCC+FDO(3)
       PT=PER(FDO(3))
       CPT=CPT+PT
       WRITE(IOUT,1003) FDO(3),PT,CPT
C
       TOCC=TOCC+FDO(4)
       PT=PER(FDO(4))
       CPT=CPT+PT
       WRITE(IOUT,1004) FDO(4),PT,CPT
C
       TOCC=TOCC+FDO(5)
       PT=PER(FDO(5))
       CPT=CPT+PT
       WRITE(IOUT,1005) FDO(5),PT,CPT
C
       TOCC=TOCC+FDO(6)
       PT=PER(FDO(6))
       CPT=CPT+PT
       WRITE(IOUT,1006) FDO(6),PT,CPT
C
       TOCC=TOCC+FDO(7)
       PT=PER(FDO(7))
       CPT=CPT+PT
       WRITE(IOUT,1007) FDO(7),PT,CPT
C
       TOCC=TOCC+FDO(8)
       PT=PER(FDO(8))
       CPT=CPT+PT
       WRITE(IOUT,1008) FDO(8),PT,CPT
C
       TOCC=TOCC+FDO(9)
       PT=PER(FDO(9))
       CPT=CPT+PT
       WRITE(IOUT,1009) FDO(9),PT,CPT
C
      TOCC=TOCC+FDO(10)
      PT=PER(FDO(10))
       CPT=CPT+PT
      WRITE(IOUT,1010) FDO(10),PT,CPT
C
      TOCC=TOCC+FDO(11)
      PT=PER(FDO(11))
       CPT=CPT+PT
      WRITE(IOUT,1011) FDO(11),PT,CPT
C
      TOCC=TOCC+FDO(12)
      PT=PER(FDO(12))
       CPT=CPT+PT
      WRITE(IOUT,1012) FDO(12),PT,CPT
C
      TOCC=TOCC+FDO(13)
      PT=PER(FDO(13))
```

```
      CPT=CPT+PT
     WRITE(IOUT,1013) FDO(13),PT,CPT
C
     TOCC=TOCC+FDO(14)
     PT=PER(FDO(14))
      CPT=CPT+PT
     WRITE(IOUT,1014) FDO(14),PT,CPT
C
     TOCC=TOCC+FDO(15)
     PT=PER(FDO(15))
      CPT=CPT+PT
     WRITE(IOUT,1015) FDO(15),PT,CPT
C
     TOCC=TOCC+FDO(16)
     PT=PER(FDO(16))
      CPT=CPT+PT
     WRITE(IOUT,1016) FDO(16),PT,CPT
     WRITE(IOUT,1017) TOCC
      RETURN
      END
C
C**************** PUTFPB ***************************
C
      SUBROUTINE PUTFPB (FPB,IND,DIST)
      COMMON /IO/IIN,IRIV,IOUT
      DIMENSION AL(3,2)
      DATA AL/'TOTA','L   ','    ','DISS','OLVE','D   '/
     DIMENSION FPB(20)
1000  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
    1',/,
    1 T30,'FEBRUARY,1979',//
    2 T2,'CUMULATIVE FREQUENCY- ',3A4,' LEAD',3X,'TO',F8.2,3X,
    2 'MILES DOWNSTREAM',//,
    3 T7,'PB',T22,'NUMBER OF',T36,'PERCENT OF',T50,'CUMULATIVE'/
    4 T2,'CONCENTRATION',T21,'OCCURRENCES',T39,'TIME',T50,'PERCENT'/)
1001  FORMAT(1X,'0.005 OR LESS',T24,F5.0,T38,F6.2,T50,F6.2)
1002  FORMAT(1X,'0.005 TO 0.010',T24,F5.0,T38,F6.2,T50,F6.2)
1003  FORMAT(1X,'0.010 TO 0.015',T24,F5.0,T38,F6.2,T50,F6.2)
1004    FORMAT(1X,'0.015 TO 0.020',T24,F5.0,T38,F6.2,T50,F6.2)
1005    FORMAT(1X,'0.020 TO 0.025',T24,F5.0,T38,F6.2,T50,F6.2)
1006  FORMAT(1X,'0.025 TO 0.030',T24,F5.0,T38,F6.2,T50,F6.2)
1007  FORMAT(1X,'0.030 TO 0.035',T24,F5.0,T38,F6.2,T50,F6.2)
1008  FORMAT(1X,'0.035 TO 0.040',T24,F5.0,T38,F6.2,T50,F6.2)
1009  FORMAT(1X,'0.040 TO 0.045',T24,F5.0,T38,F6.2,T50,F6.2)
1010  FORMAT(1X,'0.045 TO 0.05',T24,F5.0,T38,F6.2,T50,F6.2)
1011  FORMAT(1X,'0.05 TO 0.06',T24,F5.0,T38,F6.2,T50,F6.2)
1012  FORMAT(1X,'0.06 TO 0.07',T24,F5.0,T38,F6.2,T50,F6.2)
1013  FORMAT(1X,'0.07 TO 0.08',T24,F5.0,T38,F6.2,T50,F6.2)
1014  FORMAT(1X,'0.08 TO 0.09',T24,F5.0,T38,F6.2,T50,F6.2)
1015  FORMAT(1X,'0.09 TO 0.1',T24,F5.0,T38,F6.2,T50,F6.2)
1016  FORMAT(1X,'0.1 TO 0.2',T24,F5.0,T38,F6.2,T50,F6.2)
1017  FORMAT(1X,'0.2 TO 0.3',T24,F5.0,T38,F6.2,T50,F6.2)
1018  FORMAT(1X,'0.3 TO 0.4',T24,F5.C,T38,F6.2,T50,F6.2)
1019  FORMAT(1X,'0.4 TO 0.5',T24,F5.0,T38,F6.2,T50,F6.2)
1020  FORMAT(1X,'GREATER THAN 0.5',T24,F5.0,T38,F6.2,T50,F6.2)
1021  FORMAT(1X,'GREATER THAN 0.5',T24,F5.0,T38,F6.2,T50,F6.2)
1022  FORMAT(/,T10,'TOTAL=',T24,F5.0)
      WRITE(IOUT,1000) (AL(J,IND),J=1,3) ,DIST
C INITIALIZE TOTAL PB OCCURRENCES
      TOCC=0.0
C INITIALIZE CUMULATIVE PERCENTAGE
```

```
      CPT=0.0
      TOCC=TOCC+FPB(1)
      PT=PER(FPB(1))
      CPT=CPT+PT
      WRITE(IOUT,1001) FPB(1),PT,CPT
C
      TOCC=TOCC+FPB(2)
      PT=PER(FPB(2))
      CPT=CPT+PT
      WRITE(IOUT,1002) FPB(2),PT,CPT
C
      TOCC=TOCC+FPB(3)
      PT=PER(FPB(3))
      CPT=CPT+PT
      WRITE(IOUT,1003) FPB(3),PT,CPT
C
      TOCC=TOCC+FPB(4)
      PT=PER(FPB(4))
      CPT=CPT+PT
      WRITE(IOUT,1004) FPB(4),PT,CPT
C
      TOCC=TOCC+FPB(5)
      PT=PER(FPB(5))
      CPT=CPT+PT
      WRITE(IOUT,1005) FPB(5),PT,CPT
C
      TOCC=TOCC+FPB(6)
      PT=PER(FPB(6))
      CPT=CPT+PT
      WRITE(IOUT,1006) FPB(6),PT,CPT
C
      TOCC=TOCC+FPB(7)
      PT=PER(FPB(7))
      CPT=CPT+PT
      WRITE(IOUT,1007) FPB(7),PT,CPT
C
      TOCC=TOCC+FPB(8)
      PT=PER(FPB(8))
      CPT=CPT+PT
      WRITE(IOUT,1008) FPB(8),PT,CPT
C
      TOCC=TOCC+FPB(9)
      PT=PER(FPB(9))
      CPT=CPT+PT
      WRITE(IOUT,1009) FPB(9),PT,CPT
C
      TOCC=TOCC+FPB(10)
      PT=PER(FPB(10))
      CPT=CPT+PT
      WRITE(IOUT,1010) FPB(10),PT,CPT
C
      TOCC=TOCC+FPB(11)
      PT=PER(FPB(11))
      CPT=CPT+PT
      WRITE(IOUT,1011) FPB(11),PT,CPT
C
      TOCC=TOCC+FPB(12)
      PT=PER(FPB(12))
      CPT=CPT+PT
      WRITE(IOUT,1012) FPB(12),PT,CPT
C
```

```
      TOCC=TOCC+FPB(13)
      PT=PER(FPB(13))
       CPT=CPT+PT
      WRITE(IOUT,1013) FPB(13),PT,CPT
C
      TOCC=TOCC+FPB(14)
      PT=PER(FPB(14))
       CPT=CPT+PT
      WRITE(IOUT,1014) FPB(14),PT,CPT
C
      TOCC=TOCC+FPB(15)
      PT=PER(FPB(15))
       CPT=CPT+PT
      WRITE(IOUT,1015) FPB(15),PT,CPT
C
      TOCC=TOCC+FPB(16)
      PT=PER(FPB(16))
       CPT=CPT+PT
      WRITE(IOUT,1016) FPB(16),PT,CPT
C
      TOCC=TOCC+FPB(17)
      PT=PER(FPB(17))
       CPT=CPT+PT
      WRITE(IOUT,1017) FPB(17),PT,CPT
C
      TOCC=TOCC+FPB(18)
      PT=PER(FPB(18))
       CPT=CPT+PT
      WRITE(IOUT,1018) FPB(18),PT,CPT
C
      TOCC=TOCC+FPB(19)
      PT=PER(FPB(19))
       CPT=CPT+PT
      WRITE(IOUT,1019) FPB(19),PT,CPT
C
      TOCC=TOCC+FPB(20)
      PT=PER(FPB(20))
       CPT=CPT+PT
      WRITE(IOUT,1020) FPB(20),PT,CPT
      WRITE(IOUT,1022) TOCC
       RETURN
       END
C
C********************** PUT FSS *********************************
C
      SUBROUTINE PUTFSS (FSS,DIST)
       COMMON /IO/IIN,IRIV,IOUT
      DIMENSION FSS(21)
1000   FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',/,
     1 T30,'FEBRUARY,1979',/
     2 T2,'CUMULATIVE FREQUENCY--SUSPENDED SOLIDS',3X,'TO',F8.2,3X,
     2 'MILES DOWNSTREAM',//,
     3 T7,'SS',T22,'NUMBER OF',T36,'PERCENT OF',T50,'CUMULATIVE'/
     4 T2,'CONCENTRATION',T21,'OCCURRENCES',T39,'TIME',T50,'PERCENT'/)
1001   FORMAT(1X,'25 OR LESS',T24,F5.0,T38,F6.2,T50,F6.2)
1002   FORMAT(1X,'25 TO 50',T24,F5.0,T38,F6.2,T50,F6.2)
1003   FORMAT(1X,'50 TO 75',T24,F5.0,T38,F6.2,T50,F6.2)
1004   FORMAT(1X,'75 TO 100',T24,F5.0,T38,F6.2,T50,F6.2)
1005   FORMAT(1X,'100 TO 125',T24,F5.0,T38,F6.2,T50,F6.2)
1006   FORMAT(1X,'125 TO 150',T24,F5.0,T38,F6.2,T50,F6.2)
```

```
1007   FORMAT(1X,'150 TO 175',T24,F5.0,T38,F6.2,T50,F6.2)
1008   FORMAT(1X,'175 TO 200',T24,F5.0,T38,F6.2,T50,F6.2)
1009   FORMAT(1X,'200 TO 225',T24,F5.0,T38,F6.2,T50,F6.2)
1010   FORMAT(1X,'225 TO 250',T24,F5.0,T38,F6.2,T50,F6.2)
1011   FORMAT(1X,'250 TO 275',T24,F5.0,T38,F6.2,T50,F6.2)
1012   FORMAT(1X,'275 TO 300',T24,F5.0,T38,F6.2,T50,F6.2)
1013   FORMAT(1X,'300 TO 325',T24,F5.0,T38,F6.2,T50,F6.2)
1014   FORMAT(1X,'325 TO 350',T24,F5.0,T38,F6.2,T50,F6.2)
1015   FORMAT(1X,'350 TO 375',T24,F5.0,T38,F6.2,T50,F6.2)
1016   FORMAT(1X,'375 TO 400',T24,F5.0,T38,F6.2,T50,F6.2)
1017   FORMAT(1X,'400 TO 425',T24,F5.0,T38,F6.2,T50,F6.2)
1018   FORMAT(1X,'425 TO 450',T24,F5.0,T38,F6.2,T50,F6.2)
1019   FORMAT(1X,'450 TO 475',T24,F5.0,T38,F6.2,T50,F6.2)
1020   FORMAT(1X,'475 TO 500',T24,F5.0,T38,F6.2,T50,F6.2)
1021   FORMAT(1X,'GREATER THAN 500',T24,F5.0,T38,F6.2,T50,F6.2)
1022   FORMAT(/,T10,'TOTAL=',T24,F5.0)
      WRITE(IOUT,1000)DIST
C INITIALIZE TOTAL SS OCCURRENCES
       TOCC=0.0
C INITIALIZE CUMULATIVE PERCENTAGE
       CPT=0.0
      TOCC=TOCC+FSS(1)
      PT=PER(FSS(1))
       CPT=CPT+PT
      WRITE(IOUT,1001) FSS(1),PT,CPT
C
       TOCC=TOCC+FSS(2)
       PT=PER(FSS(2))
       CPT=CPT+PT
       WRITE(IOUT,1002) FSS(2),PT,CPT
C
       TOCC=TOCC+FSS(3)
       PT=PER(FSS(3))
       CPT=CPT+PT
       WRITE(IOUT,1003) FSS(3),PT,CPT
C
       TOCC=TOCC+FSS(4)
       PT=PER(FSS(4))
       CPT=CPT+PT
       WRITE(IOUT,1004) FSS(4),PT,CPT
C
       TOCC=TOCC+FSS(5)
       PT=PER(FSS(5))
       CPT=CPT+PT
       WRITE(IOUT,1005) FSS(5),PT,CPT
C
       TOCC=TOCC+FSS(6)
       PT=PER(FSS(6))
       CPT=CPT+PT
       WRITE(IOUT,1006) FSS(6),PT,CPT
C
       TOCC=TOCC+FSS(7)
       PT=PER(FSS(7))
       CPT=CPT+PT
       WRITE(IOUT,1007) FSS(7),PT,CPT
C
       TOCC=TOCC+FSS(8)
       PT=PER(FSS(8))
       CPT=CPT+PT
       WRITE(IOUT,1008) FSS(8),PT,CPT
C
```

```
       TOCC=TOCC+FSS(9)
       PT=PER(FSS(9))
       CPT=CPT+PT
       WRITE(IOUT,1009) FSS(9),PT,CPT
C
      TOCC=TOCC+FSS(10)
      PT=PER(FSS(10))
       CPT=CPT+PT
      WRITE(IOUT,1010) FSS(10),PT,CPT
C
      TOCC=TOCC+FSS(11)
      PT=PER(FSS(11))
       CPT=CPT+PT
      WRITE(IOUT,1011) FSS(11),PT,CPT
C
      TOCC=TOCC+FSS(12)
      PT=PER(FSS(12))
       CPT=CPT+PT
      WRITE(IOUT,1012) FSS(12),PT,CPT
C
      TOCC=TOCC+FSS(13)
      PT=PER(FSS(13))
       CPT=CPT+PT
      WRITE(IOUT,1013) FSS(13),PT,CPT
C
      TOCC=TOCC+FSS(14)
      PT=PER(FSS(14))
       CPT=CPT+PT
      WRITE(IOUT,1014) FSS(14),PT,CPT
C
      TOCC=TOCC+FSS(15)
      PT=PER(FSS(15))
       CPT=CPT+PT
      WRITE(IOUT,1015) FSS(15),PT,CPT
C
      TOCC=TOCC+FSS(16)
      PT=PER(FSS(16))
       CPT=CPT+PT
      WRITE(IOUT,1016) FSS(16),PT,CPT
C
      TOCC=TOCC+FSS(17)
      PT=PER(FSS(17))
       CPT=CPT+PT
      WRITE(IOUT,1017) FSS(17),PT,CPT
C
      TOCC=TOCC+FSS(18)
      PT=PER(FSS(18))
       CPT=CPT+PT
      WRITE(IOUT,1018) FSS(18),PT,CPT
C
      TOCC=TOCC+FSS(19)
      PT=PER(FSS(19))
       CPT=CPT+PT
      WRITE(IOUT,1019) FSS(19),PT,CPT
C
      TOCC=TOCC+FSS(20)
      PT=PER(FSS(20))
       CPT=CPT+PT
      WRITE(IOUT,1020) FSS(20),PT,CPT
C
      TOCC=TOCC+FSS(21)
```

```
      PT=PER(FSS(21))
       CPT=CPT+PT
      WRITE(IOUT,1021) FSS(21),PT,CPT
      WRITE(IOUT,1022) TDCC
       RETURN
       END
C
C****************************** RAINFL *****************************
C
      SUBROUTINE RAINFL(NYEAR)
       COMMON /IO/IIN,IRIV,IOUT
       DIMENSION IEVNT(2),TRAIN(2),NDPDS(2)
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /RAIN/ISEAS1(12),ISEAS2(12),TBSA(2),DSA(2),RDA(2),RDSA(2)
     1 ,CCA(2),RDY(2160)
C
C     THE RAINFALL SIMULATOR WILL GENERATE RANDOM OBSERVATIONS OF
C     RAINFALL, GIVEN RAINFALL STATISTICS DERIVED FROM OBSERVED DATA.
C     INPUT DATA WILL BE SELECTED RAINFALL STATISTICS AND NOT LARGE
C     QUANTITIES OF OBSERVED RECORDS.
C     THE SPECIFIC RANDOM VARIABLES TO BE GENERATED ARE:
C
C         1. TIME BETWEEN STORMS.
C
C         2. DURATION OF STORM.
C
C         3. MAGNITUDE OF STORM.
C
C     AUTHOR - STAN CARPENTER
C
C     DATE - NOVEMBER, 1977
C
      CONTINUE
C     INPUT VARIABLE NAMES--------------------------------------------------
C
C     NAME     DESCRIPTION/DIMENSION
C     ------   -------------------------------------------------------------
C     ISEAS1   MONTHS IN SEASON 1 - (12)
C     ISEAS2   MONTHS IN SEASON 2 - (12)
C     TBSA     MEAN TIME BETWEEN STORMS (HOURS) SEASON 1 AND 2-(2)
C     DSA      MEAN DURATION OF STORMS  (HOURS) SEASON 1 AND 2-(2)
C     RDA      MEAN RAINFALL DEPTH (IN) 1 TIME UNIT SEAS-1 AND 2-(2)
C     RDSA     SIGMA RAINFALL DEPTH (IN) SEASON 1 AND 2-(2)
C     CCA      LAG ONE CORR.COEFF1 TIME UNIT RAINFALL DEPTHS 1 AND 2(2)
C     NYRS     NO.OF YEARS IN THE SIMULATION
C     IDT      LENGTH OF 1 TIME UNIT (HOURS)
C
C
      CONTINUE
C     OUTPUT VARIABLES------------------------------------------------------
C
C     NAME     DESCRIPTION/DIMENSION
C     ------   -------------------------------------------------------------
C     IUNITS   NO.OF TIME INCREMENTS (IDT) PER YEAR
C     MTH      CURRENT MONTH (01 TO 12)
C     NYEAR    CURRENT YEAR
C     ISEAS    CURRENT SEASON (01 OR 02)
C     RDY      RAINFALL DEPTH ARRAY  (UNITS/YEAR)
C     TBS      GENERATED TIME BETWEEN STORMS(HOURS)
C     ITBS     GENERATED TIME UNITS BETWEEN STORMS
C     DS       GENERATED DURATION OF STORM
```

```
C      IDS       GENERATED TIME UNITS DURATION OF STORM
C      ITME      TIME COUNTER (HOURS)
C      RD        GENERATED RAINFALL DEPTH CURRENT TIME UNIT (IN)
C      TRAIN     YEARLY TOTAL RAINFALL BY SEASON (2)
C      NOPDS     NO.OF TIME PERIODS WITH RAIN BY SEASON (2)-YEARLY
C      TRDMAX    MAXIMUM RAIN FALL EVENT  TOTAL DEPTH -YEARLY
C      IDSMAX    MAXIMUM RAIN FALL EVENT  DURATION -YEARLY
C      SRDMAX    MAXIMUM RAIN FALL DEPTH  IN A SINGLE TIME PERIOD -YEARLY
C      TRD       TOTAL RAINFALL DEPTH CURRENT RAINFALL EVENT
C      IUNIT     CURRENT TIME UNIT
C      IEVNT     NO.OF RAINFALL EVENTS BY SEASON(2)
C
C
100   FORMAT(//,'1     RAINFALL STATISTICS FOR YEAR NO.',I3,//)
110   FORMAT(10X,'TOTAL RAINFALL SEASON NO.',I2,' = ',F6.2,' INCHES',/)
122   FORMAT(10X,'NO.OF PERIODS WITH RAIN SEASON NO.',I2,' = ',I4,/,
     1       10X,'NO.OF RAINFALL EVENTS   SEASON NO.',I2,' = ',I4,/)
130   FORMAT(10X,'MAXIMUM RAINFALL EVENT TOTAL DEPTH =',F6.2,' INCHES',
     1       /,10X,'MAXIMUM RAINFALL EVENT DURATION = ',I5,' HOURS',/,
     1       10X,'MAXIMUM DEPTH IN ONE',I3,' HR.PERIOD=',F5.2,' INCHES')
C
C-START A NEW YEAR- INITIALIZE YEARLY VARIABLES -(STEP 2)
C
      IUNITS=360*24/IDT
10    DO 12  I=1,IUNITS
12    RDY(I)=0.0
      DO 14  I=1,2
      TRAIN(I)=0.0
      IEVNT(I)=0
14    NOPDS(I)=0
      TRDMAX=0.0
      IDSMAX=0
      SRDMAX=0.0
      ITME=IDT
      IUNIT=1
C
C-DETERMINE TIME TO NEXT STORM-(STEP 1)
C
20    CALL MONTH(IUNITS,IUNIT,MTH)
      CALL SEASON(MTH,ISEAS1,ISEAS2,ISEAS)
      CALL EXXPON(TBSA(ISEAS),TBS)
      TBS=TBS/IDT
      TBS=TBS+0.5
      ITBS=TBS
      ITME=ITME+ITBS*IDT
      IUNIT=ITME/IDT
C
C-GENERATE DURATION OF STORM-(STEP 4,5 AND 6)
C
      CALL MONTH(IUNITS,IUNIT,MTH)
      CALL SEASON(MTH,ISEAS1,ISEAS2,ISEAS)
      CALL EXXPON(DSA(ISEAS),DS)
      DS=DS/IDT
      DS=DS+0.5
      IDS=DS
      IF(IDS.EQ.0)IDS=1
C
C-TEST FOR END OF YEAR-(STEP 3)
C
      IF(ITME.GT.(360*24))GO TO 40
      IEVNT(ISEAS)=IEVNT(ISEAS)+1
```

```
      IF((IDS*IDT).GT.IDSMAX)IDSMAX=IDS*IDT
C
C-GENERATE RAINFALL DEPTH FOR FIRST TIME UNIT-(STEP 7 AND 8)
C
      CALL LOGNOR(RDA(ISEAS),RDSA(ISEAS),RD)
      RDY(IUNIT)=RD
      NOPDS(ISEAS)=NOPDS(ISEAS)+1
      IF(RD.GT.SRDMAX)SRDMAX=RD
      TRD=RD
      RLAST=RD
      IF(IDS.EQ.1)GO TO 32
C
C-GENERATE RAINFALL DEPTHS FOR THE REST OF THE RAINFALL EVENT
C
      DO 30 I=2,IDS
      ITME=ITME+IDT
      IUNIT=ITME/IDT
      IF(ITME.GT.(360*24))GO TO 32
      RATIO=1.0
      XML1=RDA(ISEAS)
      XM=RDA(ISEAS)
      CALL MARKOV(XM,RDSA(ISEAS),RATIO,RLAST,XML1,RD,CCA(ISEAS))
      RDY(IUNIT)=RD
      RLAST=RD
      NOPDS(ISEAS)=NOPDS(ISEAS)+1
      IF(RD.GT.SRDMAX)SRDMAX=RD
      TRD=TRD+RD
30    CONTINUE
32    IF(TRD.GT.TRDMAX)TRDMAX=TRD
      TRAIN(ISEAS)=TRAIN(ISEAS)+TRD
      IF(ITME.GT.(360*24))GO TO 40
C
C-UPDATE TIME COUNTER AND GO TO STEP- 1(STEP 9 AND 10)
C
      ITME=ITME+IDT
      IUNIT=ITME/IDT
      IF(ITME.GT.(360*24))GO TO 40
      GO TO 20
C
C-OUTPUT RESULTS OF RAINFALL SIMULATION FOR CURRENT YEAR-(STEP 11)
C
40    WRITE(IOUT,100)NYEAR
      DO 42 I=1,2
42    WRITE(IOUT,110)I,TRAIN(I)
      DO  44 I=1,2
      WRITE(IOUT,122)I,NOPDS(I),I,IEVNT(I)
44     CONTINUE
      WRITE(IOUT,130)TRDMAX ,IDSMAX,IDT,SRDMAX
       RETURN
      END
C
C***************************** RAINRD ****************************
C
      SUBROUTINE RAINRD
       COMMON /IO/IIN,IRIV,IOUT
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /RAIN/ISEAS1(12),ISEAS2(12),TBSA(2),DSA(2),RDA(2),RDSA(2)
     1 ,CCA(2),RDY(2160)
C
C-SUBROUTINE RAINRD WILL READ THE INPUT DATA FOR THE
C-RAINFALL SIMULATOR AND LIST THE INPUT DATA ENTERED.
```

```
C
C
C-INPUT FORMAT STATEMENTS
C
100   FORMAT(12I2)
110   FORMAT(2F10.2)
120   FORMAT(3F10.4)
500   FORMAT('1',16X,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM'
     1,/,
     125X,'FEBRUARY,1979',//
     2,1X,'RAINFALL SIMULATOR INPUT DATA',20('-'),//
     1        /,1X,' MONTHS IN SEASON NO. 1:')
506   FORMAT(24X,I2)
510   FORMAT(/,1X,' MONTHS IN SEASON NO. 2:')
514   FORMAT(24X,I2)
518   FORMAT(//,36X,'SEASON NO. 1',10X,'SEASON NO. 2',
     1        /,1X,'MEAN TIME BETWEEN STORMS',11X,F12.2
     1,' HOURS    ',F12.2,' HOURS',
     1        /,1X,'MEAN DURATION OF STORMS',12X
     1,F12.2,' HOURS    ',F12.2,' HOURS',//
     1          T10,'INPUT RAINFALL DEPTH STATISTICS:',/
     1            T2,'SEASON ',T15,'MEAN',T31,'S.D.',T46,'CORR COEFF ')
1003  FORMAT(/T4,I2,T15,F10.4,T31,F10.4,T46,F10.4)
C
C-READ THE INPUT DATA FOR THE RAINFALL SIMULATOR
C
      WRITE(IOUT,500)
      READ(IIN,100)(ISEAS1(I),I=1,12)
      DO 504 I=1,12
      IF(ISEAS1(I).EQ.0)GO TO 508
504   WRITE(IOUT,506)ISEAS1(I)
508    CONTINUE
      WRITE(IOUT,510)
      READ(IIN,100)(ISEAS2(I),I=1,12)
      DO 512 I=1,12
      IF(ISEAS2(I).EQ.0)GO TO 516
512   WRITE(IOUT,514)ISEAS2(I)
516    CONTINUE
       READ(IIN,110)(TBSA(I),I=1,2)
      READ(IIN,110)(DSA(I),I=1,2)
       WRITE(IOUT,518)TBSA,DSA
      DO 10 I=1,2
      READ (IIN,120)XM,XSD,XP
      WRITE(IOUT,1003) I,XM,XSD,XP
      CALL TRANS(XM,XSD,XP,RDA(I),RDSA(I),CCA(I))
10    CONTINUE
11    CONTINUE
C
C-WRITE THE TITLE AND LIST THE INPUT DATA TO THE RAINFALL SIMULATOR
C
      RETURN
      END
C
C********************** RANDOM ***************************
C
       SUBROUTINE RANDOM (RN)
       COMMON /GLOBAL/IOT,NYR,LOC(10),IRN1,IWSD
C
C GENERATE A UNIFORMLY DISTRIBUTED 0,1 RANDOM VARIATE
C
       M=2147483647
```

```
10      CONTINUE
        IRN1=IRN1*131075
        R1=IRN1
20      DENOM=M
        RN=ABS(R1/DENOM)
        R2=RN
        IF (RN.EQ.0.0) RN=0.00001
30      RETURN
        END
C
C********************** RECWAT ******************************
C
        SUBROUTINE RECWAT (NYEAR,OPT,NYS)
C
C RECEIVING WATER SIMULATOR
C
        COMMON /IO/IIN,IFIV,IOUT
        COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
        COMMON /GLOBL1/ALF1,ALF2,BETA1,BETA2,BETA3,SBA,K2ADJ,DIST1,
     1 DIST2,E,T(12),DUS(12),CC(12),QDW(42),BODDW,SSDW,TKNDW,PBDW,
     2 BODUSF(12),TKNUSF(12),SSUSF(12),PBUSF(12),K2SPEC,DDW,
     3 K1W1,K1W2,K1USF,K1DWF
      COMMON /RUNOF/RUN(2,2160)
      COMMON /RUNQL/BOD(2,2160),TKN(2,2160),SS(2,2160),PB(2,2160)
        COMMON /STR2/QDUS(360,5),QMUS(12,5),QMSF(12),SDMSF(12),CCMSF(12)
        COMMON /PB1/TA(4),TH(4),PH(4)
      REAL K2ADJ
      INTEGER OPT
        DIMENSION DOMEM(18)
        DIMENSION FSS(21),FDO(16),FDOX1(16) ,CDO(7)
        DIMENSION FIPB(20),FDPB(20) ,PBMEM(24)
        DIMENSION TDOMN(2160)
1000     FORMAT(///T5,'RECEIVING WATER LOADS FOR YEAR ',I2/
     1 T2,'NBOD ',F12.0,' #/YR'/
     1 T2,'CBOD ',F12.0,' #/YR'/
     1 T2,'SUSPENDED SOLIDS ',F14.0,' #/YR'/
     1 T2,'DISSOLVED LEAD ',F12.0,' #/YR'/
     1 T2,'SEDIMENT LEAD ',F12.0,' #/YR'/
     1 T2,'NOTE: ',T8,'NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57*TKN
     1)'//
     1 T8,'CBOD=ULTIMATE CARBONACOUS OXYGEN DEMAND')
1001    FORMAT(//T5,'UPSTREAM FLOW WATER QUALITY SUMMARY FOR YEAR ',
     1 I2/
     1 T2,'BOD =',F12.0,' #/YR'/
     1 T2,'NBOD= ',F12.0,' #/YR'/
     1 T2,'SS = ',F14.0,' #/YR'/
     1 T2,'PB = ',F12.0,' #/YR'/
     1 T2,'NOTE: ',T8,'BOD = 5 DAY BOD '/
     1 T8,'NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57 * TKN) ')
1002    FORMAT(//T2,'MAXIMUM 96 HOUR DISSOLVED LEAD = ',F7.4,' MG/L'/
     1 T2,'MEAN DISSOLVED LEAD = ',F7.4,' MG/L')
1003    FORMAT(//T2,'MINIMUM 3 DAY DISSOLVED OXYGEN = ',F8.3,' MG/L'//)
C
C    **************
C    *            *
C    *   STEP 1   *
C    *            *
C    **************
C
C INITIALIZE CUMULATIVE FREQ DIST  DO
C INITIALIZE PB MEMORY
```

```
      DO 3 I=1,24
      PBMEM(I)=0.0
3     CONTINUE
C
C INITIALIZE TIME AVERAGED DO SUMMARY
      DO 4 I=1,7
      CDO(I)=0.0
4     CONTINUE
      DO 5 I=1,20
      FIPB(I)=0.0
      FDPB(I)=0.0
5     CONTINUE
      DO 10 I=1,16
      FDOX1(I)=0.0
10    FDO(I)=0.0
       DO 11 J=1,21
11    FSS(J)=0.0
      DO 510 I=1,16
      DOMEM(I)=0.0
510   CONTINUE
C   *****************
C   *               *
C   *   INITIALIZE  *
C   *               *
C   *****************
C MONTHLY TIME INTERVAL
      MTI=1
C PREVIOUS MONTH
      MO=1
C TOTAL SEDIMENT LEAD
      TSPB=0.0
      TDPB=0.0
      TUPB=0.0
      TUSS=0.0
      TULOC=0.0
      TULON=0.0
C TOTAL SUSPENDED SOLIDS
     TSS=0.0
C TOTAL BOD
      TNBOD=0.0
      TCBOD=0.0
      PB96=0.0
      PB96MX=0.0
      SUMPB=0.0
      DO3MN=10.0
C   *************
C   *           *
C   *   STEP 2  *
C   *           *
C   *************
C
C CALCULATE NUMBER OF TIME PERIODS
C
      NSTEPS=8640/IDT
      NTS96=96/IDT
      NTP=24/IDT
      NDWP=NTP*7
C NUMBER OF TIME STEPS IN 3 DAYS
      NTS3=72/IDT
      NTS3L1=NTS3-1
C   **************
```

```
C    *               *
C    *   STEP  3     *
C    *               *
C    ****************
C
C DO RECEIVING WATER ANALYSIS FOR EACH TIME PERIOD
C
       DO 20 I=1,NSTEPS
C DETERMINE VALUE OF DRY WEATHER FLOW TO BE USED
      IDW=MOD(I,NDWP)
      IF(IDW.EQ.0)IDW=NDWP
      VDW=QDW(IDW)
C DETERMINE VALUE OF MONTHLY STREAMFLOW TO BE USED
       CALL MONTH(NSTEPS,I,IMO)
      IYR=MOD(NYEAR,5)
      IF(IYR.EQ.0)IYR=5
      VSF=QMUS(IMO,IYR)
       SVSF=VSF
C WAS STREAMFLOW SIMULATOR USED
       IF(VSF.NE.0.0) GO TO 200
C DETERMINE VALUE OF DAILY STREAMFLOW USED
       J=I-1
       IDAY=J/NTP
       IDAY=IDAY+1
C GET YEAR OF STREAMFLOW BASED ON NUMBER OF YEARS READ IN
       IF(NYS.EQ.0) STOP 155
       JYR=MOD(NYEAR,NYS)
       IF(JYR.EQ.0)JYR=NYS
      VSF=QDUS(IDAY,JYR)
200   CONTINUE
      VSW=RUN(2,I)
      VCSO=RUN(1,I)
       IF(OPT.EQ.80)GO TO 202
       IF(OPT.EQ.81)GOTO 201
C    *********************
C    *                   *
C    *   LEAD ANALYSIS   *
C    *                   *
C    *********************
       PCSO=PB(1,I)
       PSW=PB(2,I)
       PSF=PBUSF(IMO)
       CALL PBRW(VCSO,VSW,VSF,VDW,PCSO,PSW,PSF,PBDW,SPB,FIPB,FDPB,I,
     1 CPBWO,UPBWO,CPB,IDT)
       TSPB=TSPB+SPB
       TUPB=TUPB+UPBWO
       TDPB=TDPB+CPBWO
       SUMPB=SUMPB+CPB
       PBMEM(1)=CPB
       IF(I.LT.NTS96-1)GOTO 2311
       PB96=0.0
       DO 2320 IT=1,NTS96
       PB96=PB96+PBMEM(IT)
2320    CONTINUE
       APB96=PB96/NTS96
       IF(APB96.GT.PB96MX)PB96MX=APB96
2311    CONTINUE
C LAG THE MEMORY OF LEAD CONCENTRATIONS FOR THE NEXT TIME STEP
       LINTS=NTS96-1
       DO 2322 IT=1,LINTS
       IT1=IT-1
```

```
      PBMEM(NTS96-IT1)=PBMEM(NTS96-IT)
2322  CONTINUE
201   CONTINUE
C    ********************************
C    *                              *
C    *   DISSOLVED OXYGEN ANALYSIS  *
C    *                              *
C    ********************************
      BODSW=BOD(2,I)
      BODCSO=BOD(1,I)
      TST=TKN(2,I)
      TCS=TKN(1,I)
19    CALL BODRW (VSW,BODSW,VCSO,BODCSO,VSF,VDW,IMO,
     1 FDO,FDOX1,TST,TCS,BODTC,BODTN,I,MTI,MO,ULOC,ULON,CDO,DOMIN)
      TNBOD=TNBOD+BODTN
      TCBOD=TCBOD+BODTC
      TULOC=TULOC+ULOC
      TULON=TULON+ULON
      IF(DOMIN.LT.0.0)DOMIN=0.0
      DOMEM(1)=DOMIN
      TDOMN(I)=DOMIN
      DOS3=0.0
      IF(I.LT.NTS3L1)GOTO 1120
      DO 1110 I1=1,NTS3
      DOS3=DOS3+DOMEM(I1)
1110  CONTINUE
      ADO3=DOS3/NTS3
      IF(ADO3.GT.DO3MN)GOTO 1120
      DO3MN=ADO3
1120  CONTINUE
      DO 1130 I2=1,NTS3L1
      I4=I2-1
      DOMEM(NTS3-I4)=DOMEM(NTS3-I2)
1130  CONTINUE
202   CONTINUE
C    ********************************
C    *                              *
C    *   SUSPENDED SOLIDS ANALYSIS  *
C    *                              *
C    ********************************
      SSSW=SS(2,I)
      SSCSO=SS(1,I)
      SSF=SSUSF(IMO)
      CALL SSRW (VSW,SSSW,VCSO,SSCSO,VSF,SSF,VDW,SSDW,SST,FSS,I,USSWO)
     TSS=TSS+SST
      TUSS=TUSS+USSWO
20    CONTINUE
C    *************
C    *           *
C    *   STEP 4  *
C    *           *
C    *************
C PUT REPORT ON UPSTREAM WATER QUALITY
      WRITE(IOUT,1001)NYEAR,TULOC,TULON,TUSS,TUPB
C PRINT CFDO
      IND=1
     IF(OPT.NE.80)CALL PUTFDO(FDO,DIST2,IND)
      IF(OPT.NE.80)WRITE(IOUT,1003)DO3MN
      IF(OPT.NE.80)CALL PUTDOS(DIST2,CDO,IDT)
C PRINT FDOX1
      IND=2
```

```
      IF(DIST1.GT.0.0)CALL PUTFDO(FDOX1,DIST1,IND)
      IND=1
      IF(OPT.EQ.82)CALL PUTFPB(FIPB,IND,DIST2)
      IND=2
      IF(OPT.EQ.82)CALL PUTFPB(FDPB,IND,DIST2)
C CALC MEAN LEAD CONC
      PBMEAN=SUMPB/NSTEPS
      IF(OPT.EQ.82)WRITE(IOUT,1002)PB96MX,PBMEAN
C PRINT CFSS
      CALL PUTFSS(FSS,DIST2)
      WRITE(IOUT,1000)NYEAR,TNBOD,TCBOD,TSS,TDPB,TSPB
C
C   **************
C   *            *
C   *   STEP 5   *
C   *            *
C   **************
C
C RETURN TO CALLING MODULE
C     CALL ARRAY(1,TDOMN)
C
      RETURN
      END
C
C**************************** RUNOFF ****************************
C
      SUBROUTINE RUNOFF(NYEAR)
      COMMON /IO/IIN,IRIV,IOUT
      DIMENSION CRI(2160),CRUN(2160),TRUN(2),TDUR(2),RUNMAX(2)
      DIMENSION XRUN(2160)
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /RAIN/ISEAS1(12),ISEAS2(12),TBSA(2),DSA(2),RDA(2),RDSA(2)
     1 ,CCA(2),RDY(2160)
      COMMON /RUNOF/RUN(2,2160)
      COMMON /IRO/IDORM(12),IGROW(12),CN1(2),CN2(2),CN3(2),DA(2),TC(2)
      DIMENSION SEA(4)
      DATA SEA/'DORM','ANT','GROW','ING'/
C     SUBROUTINE RUNOFF WILL TRANSFORM THE ANNUAL RAINFALL ARRAY
C     INTO AN ANNUAL RUNOFF ARRAY. THE METHOD USED IS BASED ON
C     A RAINFALL RUNOFF RELATIONSHIP DEVELOPED BY THE SCS. RUNOFF
C     PRODUCED BY ANY GIVEN RAINSTORM WILL BE A FUNCTION OF THE
C     TOTAL RAINFALL AMOUNT AND THE ANTECEDENT MOISTURE CONDITION.
C     THE AMC IS A FUNCTION OF THE TOTAL DEPTH OF RAINFALL OCCURRING
C     IN THE 5-DAY PERIOD IMMEDIATELY PRECEDING THE STORM.
C
C     ONCE THE RUNOFF ARRAY IS GENERATED, A SIMPLE HYDROLOGIC ROUTING
C     (TIME-AREA) WILL BE APPLIED TO ACCOUNT FOR WATERSHED STORAGE
C     (LAG OR K FACTOR).
C
C     AUTHOR - STAN CARPENTER
C
C     DATE - DECEMBER 1977
C
      CONTINUE
C
C
C
C
C     INPUT VARIABLE NAMES------------------------------------------------
C
C     NAME     DESCRIPTION
```

```
C      ------    ------------------------------------------------------
C      RDY       RAINFALL DEPTH ARRAY (2160)
C      IDORM     MONTHS IN THE DORMANT SEASON (12)
C      IGROW     MONTHS IN THE GROWING SEASON (12)
C      CN1       CN VALUE 1
C      CN2       CN VALUE 2
C      CN3       CN VALUE 3
C      DA        DRAINAGE AREA
C      TC        TIME OF CONCENTRATION
C      IDT       TIME UNIT LENGTH (HOURS)
C
       CONTINUE
C
C      OUTPUT VARIABLE NAMES-------------------------------------------
C
C      NAME      DESCRIPTION
C      ------    ------------------------------------------------------
C      SUMRD     TOTAL RAINFALL DEPTH PER STORM
C      IFIRST    TIME UNIT AT START OF STORM
C      ILAST     TIME UNIT AT END OF STORM
C      IUNIT     TIME UNIT COUNTER
C      ARF       SUMMATION OF RAINFALL DEPTHS IN THE PRECEDING 5 DAYS
C      XLI       INITIAL LOSS AMOUNT
C      CRI       CUMULATIVE RAINFALL SUMMATION ARRAY (2160)
C      CRUN      CUMULATIVE RUNOFF ARRAY (2160)
C      RUN       OUTPUT RUNOFF ARRAY
C      S         MAXIMUM SOIL STORAGE
C      XLF       LAG FACTOR
C      ILF       LAG FACTOR ROUNDED AND TRUNCATED
C
C
600    FORMAT(//,'1     RUNOFF STATISTICS FOR YEAR NO. ',I3,5X
     1,'WATERSHED NO. ',I3,//)
604    FORMAT(10X,'TOTAL RUNOFF ',2A4,' SEASON =',F6.2,' INCHES',/)
608    FORMAT(10X,'TOTAL DURATION OF RUNOFF ',2A4,' SEASON =',
     1F6.0,' HOURS',/)
614    FORMAT(10X,'MAXIMUM ',I2,' HOUR RUNOFF RATE, ',2A4,' SEASON ',
     1' = ',F8.2,' CFS ',/)
C
        DO 900 IWS=1,IWSD
C-INITIALIZE YEARLY VARIABLES
C
5      ISTOP=360*24/IDT
       DO 10 I=1,ISTOP
       RUN(IWS,I)=0.0
       XRUN(I)=0.0
       CRI(I)=0.0
10     CRUN(I)=0.0
       DO 15 I=1,2
       TRUN(I)=0.0
       TDUR(I)=0.0
       RUNMAX(I)=0.0
15     CONTINUE
       IUNIT=0
C
C-SEARCH THE RAINFALL ARRAY FOR A DEPTH GREATER THAN ZERO
C
20     IUNIT=IUNIT+1
       IF(IUNIT.GT.ISTOP)GO TO 100
       IF(RDY(IUNIT).EQ.0.0)GO TO 20
       IFIRST=IUNIT
```

```
      SUMRD=RDY(IUNIT)
C
C-SUM THE RAINFALL DEPTHS FOR THIS STORM
C
30    IUNIT=IUNIT+1
      IF(IUNIT.GT.ISTOP)GO TO 32
      SUMRD=SUMRD+RDY(IUNIT)
      IF(RDY(IUNIT).NE.0.0)GO TO 30
      IUNIT=IUNIT+1
      IF(IUNIT.GT.ISTOP)GO TO 32
      SUMRD=SUMRD+RDY(IUNIT)
      IF(RDY(IUNIT).NE.0.0)GO TO 30
      ILAST=IUNIT-2
      GO TO 35
32    ILAST=ISTOP
C
C-SUM THE RAINFALL DEPTH IN THE PRECEDING 5-DAY TIME PERIOD
C
35    IF(IFIRST.GE.(120/IDT+1))IFST=IFIRST-(120/IDT)
      IF(IFIRST.LT.(120/IDT+1))IFST=1
      IL=IFIRST-1
      IF(IL.EQ.0)IL=1
      ARF=0.0
      DO 40 I1=IFST,IL
40    ARF=ARF+RDY(I1)
C
C-ASSIGN A CN VALUE
C
      CALL MONTH(ISTOP,IFIRST,MTH)
      CALL SEASON(MTH,IDORM,IGROW,ISEAS)
      IF(ISEAS.EQ.2)GO TO 45
      IF(ARF.EQ.0.0)CN=CN1(IWS)
C     IF(ARF.GE.0.0.AND.ARF.LT..08)CN=CN1(IWS)
      IF(ARF.GT.0.0.AND.ARF.LT.0.3)CN=CN2(IWS)
CC    IF(ARF.GE..08.AND.ARF.LE.0.8)CN=CN2(IWS)
      IF(ARF.GE.0.3)CN=CN3(IWS)
C     IF (ARF.GT.0.8)CN=CN3(IWS)
      GO TO 48
45    IF(ARF.LT.0.02)CN=CN1(IWS)
CC    IF(ARF.GE.0.0.AND.ARF.LT..08)CN=CN1(IWS)
      IF(ARF.GT..02.AND.ARF.LT.0.8)CN=CN2(IWS)
C     IF(ARF.GE..08.AND.ARF.LE.0.8)CN=CN2(IWS)
      IF(ARF.GE.0.8)CN=CN3(IWS)
C     IF(ARF.GT.0.8)CN=CN3(IWS)
48    CONTINUE
C
C-DETERMINE IF THE RAINFALL EVENT PRODUCES RUNOFF
C
      S=1000./CN-10.
      XLI=0.2*S
      IF(XLI.GE.SUMRD)GO TO 20
C
C-DEVELOP CUMULATIVE RAINFALL SUMMATIONS
C
      CRI(IFIRST)=RDY(IFIRST)
      IF(IFIRST.EQ.ILAST)GO TO 55
      I1=IFIRST+1
      DO 50 I2=I1,ILAST
      I3=I2-1
      CRI(I2)=RDY(I2)+CRI(I3)
50    CONTINUE
```

```
C
C-COMPUTE THE CUMULATIVE RUNOFF BY TIME PERIOD
C
55    DO 75 I1=IFIRST,ILAST
      IF(CRI(I1).LE.XLI)GO TO 75
      XNUM=(CRI(I1)-XLI)**2.0
      XDEN=CRI(I1)+4.0*XLI
      CRUN(I1)=XNUM/XDEN
75    CONTINUE
C
C-COMPUTE THE RUNOFF DEPTH FOR EACH TIME PERIOD
C
      XRUN(IFIRST)=CRUN(IFIRST)
      IF(IFIRST.EQ.ILAST)GO TO 20
      I1=IFIRST+1
      DO 95 I2=I1,ILAST
      I3=I2-1
      XRUN(I2)=CRUN(I2)-CRUN(I3)
95    CONTINUE
      GO TO 20
C
C-ROUTE THE RUNOFF BY THE TIME AREA METHOD
C
100   XLF=TC(IWS)/IDT+0.5
      ILF=XLF
C
C-DETERMINE IF ROUTING IS REQUIRED
C
      IF(ILF.GE.2)GO TO 200
C
C-CONVERT THE RUNOFF DEPTHS TO RATE IN CFS IF NO ROUTING
C
105   DO 110 I=1,ISTOP
      IF(XRUN(I).EQ.0.00)GO TO 110
      CALL MONTH(ISTOP,I,MTH)
      CALL SEASON(MTH,IDORM,IGROW,ISEAS)
      TRUN(ISEAS)=TRUN(ISEAS)+XRUN(I)
      RUN(IWS,I)=1.00833*DA(IWS)*XRUN(I)/IDT
      TDUR(ISEAS)=TDUR(ISEAS)+IDT
      IF(ISEAS.EQ.1.AND.RUN(IWS,I).GT.RUNMAX(1))RUNMAX(1)=RUN(IWS,I)
      IF(ISEAS.EQ.2.AND.RUN(IWS,I).GT.RUNMAX(2))RUNMAX(2)=RUN(IWS,I)
110   CONTINUE
      GO TO 400
C
C-ROUTE AND CONVERT THE RUNOFF RATE TO CFS
C
200   CONTINUE
      DO 300 J=1,ISTOP
      K=J-ILF+1
      L=J
      IF(K.LE.0)K=1
      SUMRT=0.0
      DO 255 JJ=K,L
      SUMRT=SUMRT+XRUN(JJ)
255   CONTINUE
      QT=SUMRT/ILF
      IF(QT.EQ.0.00)GO TO 300
      CALL MONTH(ISTOP,J,MTH)
      CALL SEASON(MTH,IDORM,IGROW,ISEAS)
      TRUN(ISEAS)=TRUN(ISEAS)+QT
      RUN(IWS,J)=1.00833*DA(IWS)*QT/IDT
```

```
      TDUR(ISEAS)=TDUR(ISEAS)+IDT
      IF(ISEAS.EQ.1.AND.RUN(IWS,J).GT.RUNMAX(1))RUNMAX(1)=RUN(IWS,J)
      IF(ISEAS.EQ.2.AND.RUN(IWS,J).GT.RUNMAX(2))RUNMAX(2)=RUN(IWS,J)
300   CONTINUE
C
C-OUTPUT THE RUNOFF STATISTICS FOR THE CURRENT YEAR
C
400   WRITE(IOUT,600)NYEAR,IWS
      DO 602 I=1,2
       I1=I-1
       I2=2*I1+1
602   WRITE(IOUT,604)SEA(I2),SEA(I2+1),TRUN(I)
      DO 606 I=1,2
       I1=I-1
       I2=2*I1+1
606   WRITE(IOUT,608)SEA(I2),SEA(I2+1),TDUR(I)
      DO 612 I=1,2
       I1=I-1
       I2=2*I1+1
612   WRITE(IOUT,614)IDT,SEA(I2),SEA(I2+1),RUNMAX(I)
900    CONTINUE
      RETURN
      END
C
C****************** RUNQLR ********************************:
C
      SUBROUTINE RUNQLR
       COMMON /IO/IIN,IRIV,IOUT
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /RUNQR/YBOD(2),RBOD(2),YTKN(2),RTKN(2),YSS(2),RSS(2)
     1,YPB(2),RPB(2)
C
C-    SUBROUTINE RUNQLR WILL READ THE INPUT DATA FOR THE RUNOFF
C-    QUALITY MODULE AND LIST THE INPUT DATA ENTERED.
C
C-INPUT FORMAT STATEMENTS
C
100   FORMAT(2F10.4)
600   FORMAT('1',16X,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM'
     1,/
     1,25X,'FEBRUARY,1979',//
     2,1X,'RUNOFF QUALITY INPUT DATA',20('-'),//)
610    FORMAT(1X,'INPUT DATA FOR WATERSHED NO.',I3,/,
     1         4X,'BOD ACC. RATE =',F10.4,' #/AC/DAY'
     1,5X,'BOD REMOVAL RATE =',F10.4,' FRACT/DAY',/,
     1         4X,'TKN ACC. RATE =',F10.4,' #/AC/DAY'
     1,5X,'TKN REMOVAL RATE =',F10.4,' FRACT/DAY',/,
     1         4X,'SS ACC. RATE = ',F10.4,' #/AC/DAY',
     I5X,'SS REMOVAL RATE = ',F10.4,' FRACT/DAY',/,
     1         4X,'PB ACC. RATE = ',F10.4,' #/AC/DAY'
     1,5X,'PB REMOVAL RATE = ',F10.4,' FRACT/DAY',/)
C
C-READ THE INPUT DATA FOR THE RUNOFF SIMULATOR
C
      DO 200 I=1,IWSD
      READ(IIN,100)YBOD(I),RBOD(I)
      READ(IIN,100)YTKN(I),RTKN(I)
      READ(IIN,100)YSS(I),RSS(I)
      READ(IIN,100)YPB(I),RPB(I)
200   CONTINUE
C
```

```
C-LIST THE INPUT DATA TO THE RUNOFF QUALITY SIMULATOR
C
      WRITE(IOUT,600)
      DO 800 I=1,IWSD
      WRITE(IOUT,610)I,YBOD(I),RBOD(I),YTKN(I),RTKN(I),YSS(I),RSS(I),
     1 YPB(I),RPB(I)
800   CONTINUE
      RETURN
      END
C
C-************************* RUNQLT ****************************
C
      SUBROUTINE RUNQLT(NYEAR)
       COMMON /IO/IIN,IRIV,IOUT
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /RUNQL/BOD(2,2160),TKN(2,2160),SS(2,2160),PB(2,2160)
      COMMON /RUNOF/RUN(2,2160)
      COMMON /RUNQR/YBOD(2),RBOD(2),YTKN(2),RTKN(2),YSS(2),RSS(2)
     1,YPB(2),RPB(2)
      COMMON /IRO/IDORM(12),IGROW(12),CN1(2),CN2(2),CN3(2),DA(2),TC(2),
     1 CWO(2)
        COMMON /SAVE1/SI(2),BODSI(2),SSSI(2),TKNSI(2),PBSI(2),SXBOD(2),
     1 SXSS(2),SXTKN(2),SXPB(2)
C     AWP(R,IDT,CP)=R*62.4*3600*IDT*CP/1000000.
      X(Y1,IDT)=Y1*IDT/24.0
      Z(Z1,IDT)=7.5*Z1*24.0/IDT
C     XL2(XL1,R,Y,XRUN)=(XL1*(1-R)+Y)-(XL1*(1-EXP(-4.6*XRUN*C1)))
C     XM2(XL1,XRUN)=(XL1*(1-EXP(-4.6*XRUN*C1)))*C2/XRUN
C
C     SUBROUTINE RUNQLT WILL DETERMINE THE BOD ,TKN, SS AND PB
C     QUAILTY ARRAYS BY WATERSHED FROM THE INPUT RUNOFF ARRAYS BY
C     WATERSHED AND FROM THE ACCUMULATION AND RUNOFF RATES BY
C     WATERSHED AND BY POLLUTANT. OUTPUT WILL INCLUDE MAXIMUM
C     POLLUTANT CONCENTRATIONS, MEAN POLLUTANT CONCENTRATIONS,
C     TOTAL ANNUAL POLLUTANT WASHOFF, AND THE QUALITY ARRAYS FOR
C     EACH WATERSHED AND EACH POLLUTANT.
C
C-    INPUT VARIABLES:
      CONTINUE
C
C     NAME    DESCRIPTION
C     ------  ---------------------------------------------------------
C     YBOD    ACCUMULATION RATE FOR BOD FOR THE CURRENT WATERSHED
C     RBOD    WASHOFF        "    "  BOD  "   "     "          "
C     YTKN    ACCUMULATION   "       TKN  "   "     "          "
C     RTKN    WASHOFF        "    "  TKN  "   "     "          "
C     YSS     ACCUMULATION   "    "  SS   "   "     "          "
C     RSS     WASHOFF        "    "  SS   "   "     "          "
C     YPB     ACCUMULATION   "    "  PB   "   "     "          "
C     RPB     WASHOFF        "    "  PB   "   "     "          "
C     IWS     NO. OF WATERSHEDS
C     RUN     RUNOFF ARRAY FOR THE CURRENT WATERSHED
C     DA(IWS)       DRAINAGE AREA FOR THE CURRENT WATERSHED
C
C     OUTPUT VARIABLES:
      CONTINUE
C
C     BOD     BOD QUALITY ARRAY (2,2160)
C     TKN     TKN    "       "       "
C     SS      SS     "       "       "
C     PB      PB     "       "       "
```

```
C       C1        CONSTANT NO. 1
C       C2        CONSTANT NO. 2
C       XBOD      WASHOFF OF BOD BY TIME PERIOD
C       XTKN         "     "  TKN  "    "    "
C       XTKN         "     "  TKN  "    "    "
C       XSS          "     "  SS   "    "    "
C       XPB          "     "  PB   "    "    "
        CONTINUE
C       BODSUM   TOTAL BOD CONCENTRATION
C       TKNSUM     "    TKN        "
C       SSSUM      "    SS         "
C       PBSUM      "    PB         "
C       RUNSUM   TOTAL RUNOFF
C       BODMPC   MEAN BOD CONCENTRATION (MG/L)
C       TKNMPC     "    TKN        "
C       SSMPC      "    SS         "
C       PBMPC      "    PB         "
C       AWBOD    TOTAL ANNUAL WASHOFF BOD (LBS)
C       AWTKN      "      "       "    TKN
C       AWSS       "      "       "    SS
C       AWPB       "      "       "    PB
C       BODMAX   MAXIMUM CONCENTRATION BOD (MG/L)
C       TKNMAX      "            "        TKN
C       SSMAX       "            "        SS
C       PB          "            "        PB
C
C
200     FORMAT(//,'1    RUNOFF QUALITY - STATISTICS FOR YEAR NO.',
     1I3,5X,'WATERSHED NO. ',I3,/,
     1          T42,'BOD',T53,'TKN',T64,'SS',T75,'PB'/,
     1         1X,'MAXIMUM CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/
     1          1X,'MEAN CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/
     1          1X,'TOTAL ANNUAL WASHOFF(LBS)',T32,4(1X,F11.0),/)
         DO 900 IWS=1,IWSD
C-INITIALIZE ARRAYS - VARIABLES AND CONSTANTS
C
C
        ISTOP=360*24/IDT
        C1=IDT/(1.0083*DA(IWS))
        C2=DA(IWS)*4.4516/IDT
        DO 10 J=1,ISTOP
        BOD(IWS,J)=0.0
        TKN(IWS,J)=0.0
        SS(IWS,J)=0.0
        PB(IWS,J)=0.0
10      CONTINUE
C IF NO WASHOFF COEFF ENTERED THEN DEFAULT IS 4.6
         IF(CWO(IWS).EQ.0.0)CWO(IWS)=4.6
        BODMAX=0.0
        TKNMAX=0.0
        SSMAX=0.0
        PBMAX=0.0
        BODSUM=0.0
        TKNSUM=0.0
        SSSUM=0.0
        PBSUM=0.0
        RUNSUM=0.0
        CYBOD=X(YBOD(IWS),IDT)
        CRBOD=X(RBOD(IWS),IDT)
        CYTKN=X(YTKN(IWS),IDT)
        CRTKN=X(RTKN(IWS),IDT)
```

```
      CYSS=X(YSS(IWS),IDT)
      CRSS=X(RSS(IWS),IDT)
      CYPB=X(YPB(IWS),IDT)
      CRPB=X(RPB(IWS),IDT)
      IF (NYEAR.NE.1)GO TO 15
C
C-INITIALIZE WATERSHED POLLUTANT LOADS
C
      XBOD=Z(CYBOD,IDT)
      XTKN=Z(CYTKN,IDT)
      XSS=Z(CYSS,IDT)
      XPB=Z(CYPB,IDT)
      GO TO 20
15    CONTINUE
C
C INITIALIZE WATERSHED POLLUTANT LOADS FOR YEARS 2 TO N
C
       XBOD=SXBOD(IWS)
       XTKN=SXTKN(IWS)
       XSS=SXSS(IWS)
       XPB=SXPB(IWS)
C
C-LOOP FOR RUNOFF QUALITY COMPUTATIONS
C
20    DO 100 I=1,ISTOP
      IF(RUN(IWS,I).EQ.0.0)GO TO 90
C
C-CALCULATE THE CONCENTRATIONS IN MG/L
C
      BOD(IWS,I)=XM2(XBOD,RUN(IWS,I),C1,C2,CWO(IWS))
      TKN(IWS,I)=XM2(XTKN,RUN(IWS,I),C1,C2,CWO(IWS))
      SS(IWS,I)=XM2(XSS,RUN(IWS,I),C1,C2,CWO(IWS))
      PB(IWS,I)=XM2(XPB,RUN(IWS,I),C1,C2,CWO(IWS))
C
C-CALCULATE SUMMATIONS FOR MEAN DA(IWS)TA
C
      BODSUM=BODSUM+RUN(IWS,I)*BOD(IWS,I)
      TKNSUM=TKNSUM+RUN(IWS,I)*TKN(IWS,I)
      SSSUM=SSSUM+RUN(IWS,I)*SS(IWS,I)
      PBSUM=PBSUM+RUN(IWS,I)*PB(IWS,I)
      RUNSUM=RUNSUM+RUN(IWS,I)
C
C-SAVE MAXIMUM CONCENTRATIONS
C
      IF(BOD(IWS,I).GT.BODMAX)BODMAX=BOD(IWS,I)
      IF(TKN(IWS,I).GT.TKNMAX)TKNMAX=TKN(IWS,I)
      IF(SS(IWS,I).GT.SSMAX)SSMAX=SS(IWS,I)
      IF(PB(IWS,I).GT.PBMAX)PBMAX=PB(IWS,I)
80    CONTINUE
C
C-CALCULATE LOADINGS FOR THE CURRENT TIME INTERVAL
C
90    XBOD=XL2(XBOD,CRBOD,CYBOD,RUN(IWS,I),C1,CWO(IWS))
      XTKN=XL2(XTKN,CRTKN,CYTKN,RUN(IWS,I),C1,CWO(IWS))
      XSS=XL2(XSS,CRSS,CYSS,RUN(IWS,I),C1,CWO(IWS))
      XPB=XL2(XPB,CRPB,CYPB,RUN(IWS,I),C1,CWO(IWS))
100   CONTINUE
C
C SAVE ENDOF YEAR QUALITY FOR NEXT YEAR
C
       SXBOD(IWS)=XBOD
```

```
      SXSS(IWS)=XSS
      SXTKN(IWS)=XTKN
      SXPB(IWS)=XPB
C
C-CALCULATE THE MEAN POLLUTANT CONCENTRATIONS & AWP
C
      BODMPC=BODSUM/RUNSUM
      TKNMPC=TKNSUM/RUNSUM
      SSMPC=SSSUM/RUNSUM
      PBMPC=PBSUM/RUNSUM
      AWBOD=AWP(RUNSUM,IDT,BODMPC)
      AWTKN=AWP(RUNSUM,IDT,TKNMPC)
      AWSS=AWP(RUNSUM,IDT,SSMPC)
      AWPB=AWP(RUNSUM,IDT,PBMPC)
C
C-OUTPUT THE RESULTS OF THE RUNOFF QUALITY MODULE
C
      WRITE(IOUT,200)NYEAR,IWS ,BODMAX,TKNMAX,SSMAX,PBMAX,BODMPC,
     1 TKNMPC,SSMPC,PBMPC,AWBOD,AWTKN,AWSS,AWPB
900    CONTINUE
      RETURN
      END
C
C****************************** RUNRD  ******************************
C
      SUBROUTINE RUNRD
       COMMON /IO/IIN,IRIV,IOUT
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /IRO/IDORM(12),IGROW(12),CN1(2),CN2(2),CN3(2),DA(2),TC(2),
     1 CWO(2)
C
C-SUBROUTINE RUNRD WILL READ THE INPUT DATA FOR THE RUNOFF SIMULATOR
C-AND LIST THE INPUT DATA ENTERED.
C
C
C-INPUT FORMAT STATEMENTS
C
100   FORMAT(12I2)
110   FORMAT(3F10.2)
600   FORMAT('1',16X,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM'
     1,/
     1,25X,'FEBRUARY,1979',//
     2,1X,'RUNOFF   SIMULATOR INPUT DATA',20('-'),//,
     1        /,1X,'MONTHS IN DORMANT SEASON:')
606   FORMAT(24X,I2)
608   FORMAT(/,1X,'MONTHS IN GROWING SEASON:')
614   FORMAT(/,1X,'WATERSHED NO. ',I2,' DATA:',
     1        /,5X,' CN1 = ',F8.2,2X,' CN2 = ',F8.2,2X,' CN3 = '
     1,F8.2,
     1        /,5X,'DRAINAGE AREA  = ',F10.2,' ACRES',
     1        /,5X,'TIME OF CONCENTRATION = ',F10.2,' HOURS',
     1 /,T10,'WASHOFF COEFFICIENT = ',F10.2)
C
C-READ THE INPUT DATA FOR THE RUNOFF SIMULATOR
C
      READ(IIN,100)(IDORM(I),I=1,12)
      READ(IIN,100)(IGROW(I),I=1,12)
      DO 550 I=1,IWSD
      READ(IIN,110)CN1(I),CN2(I),CN3(I)
      READ(IIN,110)DA(I),TC(I),CWO(I)
       IF(CWO(I).EQ.0.0)CWO(I)=4.6
```

```
550   CONTINUE
C
C-LIST THE INPUT DATA TO THE RUNOFF SIMULATOR
C
      WRITE(IOUT,600)
      DO 604 I=1,12
      IF(IDORM(I).EQ.0)GO TO 607
604   WRITE(IOUT,606)IDORM(I)
607   CONTINUE
      WRITE(IOUT,608)
      DO 610 I=1,12
      IF(IGROW(I).EQ.0)GO TO 612
610   WRITE(IOUT,606)IGROW(I)
612   CONTINUE
      DO 650 I=1,IWSD
      WRITE(IOUT,614)I,CN1(I),CN2(I),CN3(I),DA(I),TC(I),CWO(I)
650   CONTINUE
      RETURN
      END
C
C***************************** SEASON ****************************
C
      SUBROUTINE SEASON(MTH,ISEAS1,ISEAS2,ISEAS)
C
C-SUBROUTINE SEASON WILL DETERMINE THE CURRENT SEASON (ISEAS)
C-GIVEN THE CURRENT MONTH (MTH), AND TWO ARRAYS, ISEAS1= THE
C-MONTHS IN SEASON 1, AND ISEAS2= THE MONTHS IN SEASON 2.
C
      DIMENSION ISEAS1(12),ISEAS2(12)
      DO 10 I=1,12
      IF(MTH.EQ.ISEAS1(I))ISEAS=01
      IF(MTH.EQ.ISEAS2(I))ISEAS=02
10    CONTINUE
      RETURN
      END
C
C******************** SSRW ************************
C
       SUBROUTINE SSRW (QSW,SSSW,QCSO,SSCSO,QUS,SSUS,QDW,SSDW,
     1 SST1,FSS,I,SSWOU)
       COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
       DIMENSION FSS(21)
C
C THIS MODULE ANALYZES SUSPENDED SOLIDS IN THE RECEIVING WATER
C
C   **************
C   *            *
C   *   STEP 1   *
C   *            *
C   **************
C
C COMPUTE TOTAL FLOW (IN CFS)
C
       QT=QSW+QCSO+QUS+QDW
       IF(QT.NE.0.0)GOTO 20
       SSMAX=0.0
       SST1=0.0
       GOTO 30
C   **************
C   *            *
C   *   STEP 2   *
```

```
C   *             *
C   **************
C
C COMPUTE MAXIMUM SS CONC (MG/L)
CC
20      CONTINUE
        SS1=QSW*SSSW
        SS2=QCSO*SSCSO
        SS3=QUS*SSUS
        SS4=QDW*SSDW
        SSMAX=(SS1+SS2+SS3+SS4)/QT
C   **************
C   *            *
C   *   STEP 3   *
C   *            *
C   **************
C
CC COMPUTE TOTAL SS (#/DT)
        SST1=AWP(QT,IDT,SSMAX)
        SSWOU=AWP(QUS,IDT,SSUS)
C   **************
C   *            *
C   *   STEP 4   *
C   *            *
C   **************
C
C CUMULATIVE DISTR OF SUSPENDED SOLIDS
30      CALL CFSS(SSMAX,FSS)
C   **************
C   *            *
C   *   STEP 5   *
C   *            *
C   **************
C
C RETURN TO CALLING MODULE
C
10      RETURN
        END
C
C*********************** STOR *****************************
C
        SUBROUTINE STOR (NYEAR)
C
C STORAGE / TREATMENT SIMULATOR
C
        COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
       COMMON /IRO/IDORM(12),IGROW(12),CN1(2),CN2(2),CN3(2),DA(2),TC(2)
         COMMON /RUNOF/ RUN(2,2160)
         COMMON /RUNQL/BOD(2,2160),TKN(2,2160),SS(2,2160),PB(2,2160)
         COMMON /STOR1/ETBOD(2),ETSS(2),ETTKN(2),ETPB(2),SMAX(2),TMAX(2)
         COMMON /SAVE1/SI(2),BODSI(2),SSSI(2),TKNSI(2),PBSI(2),SXBOD(2),
     1 SXSS(2),SXTKN(2),SXPB(2)
        COMMON /IO/IIN,IRIV,IOUT
        REAL LIBOD,LISS,LITKN,LIPB,LSBOD,LSSS,LSTKN,LSPB
1000    FORMAT(//T20,'RESULTS FOR STORAGE TREATMENT ',
     1 T50,'YEAR',T56,I2,T65,'WATERSHED :',T74,I2/,
     1 /T2,'NUMBER OF HOURS STORAGE IS EMPTY:',T40,I4,
     2 T50,'PERCENT OF TOTAL TIME:',T72,F6.2,
     2 /T2,'NUMBER OF HOURS WWTP OPERATING  :',T40,I4,
     3 T50,'PERCENT OF TOTAL TIME:',T72,F6.2,
     3 /T2,'NUMBER OF OVERFLOW HOURS :',T40,I4,
```

```
     4 /T2,'ANNUAL OVERFLOW VOLUME IN INCHES :',T39,F6.2,
     5 /T2,'NUMBER OF OVERFLOW EVENTS :',T40,I4,
     6 /T2,'NUMBER OF DAYS WITH OVERFLOW',T40,I4)
1001  FORMAT('1','S/T AND OVERFLOW SUMMARY FOR YEAR NO. ',I2,3X,
     1 'WATERSHED NO. ',I2//,T42,'BOD',T53,'TKN',T64,'SS',T75,
     2 'PB'//,
     1 1X,'MAXIMUM CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/,
     1 1X,'MEAN CONCENTRATIONS(MG/L)',T32,4(1X,F11.2),/,
     1 1X,'RESIDUAL ANNUAL WASHOFF(LBS)',T32,4(1X,F11.0),/)
10    CONTINUE
      DT3600=IDT*3600
      NSTEPS=8640/IDT
      IDUNIT=24/IDT
C
C
C
C
C RUN STORAGE-TREATMENT FOR ALL WATERSHEDS FOR ONE YEAR
C
      DO 21 I=1,IWSD
C INITIALIZE CONDITIONS FOR  --THIS YEAR --THIS WATERSHED
C
C INITIALIZE NUMBER HOURS STORAGE IS ZERO
       NHSO=0
C INITIALIZE NUMBER HOURS TREATMENT NOT ZERO
      NHTNO=0
C INITIALIZE NUMBER OF HOURS OF OVERFLOW
      NOH=0
C OVERFLOW VOLUME -ANNUAL
      OFLV=0.0
C INITIALIZE PREVIOUS PERIOD OVERFLOW
      POVRFL=0.0
C INITIALIZE NUMBER OF OVERFLOW EVENTS
       NOE=0
C INITIALIZE MAXIMUM CONCENTRATIONS
      BODMAX=0.0
      TKNMAX=0.0
      SSMAX=0.0
      PBMAX=0.0
C INITIALIZE SUMS
      SBOD=0.0
      STKN=0.0
      SSS=0.0
      SPB=0.0
      RUNSUM=0.0
C INITIALIZE DAY COUNT
      IDCT=0
C INITIALIZE NO. OF DAYS WITH OVERFLOW
      NDO=0
C INITIALIZE COUNTER FOR DAILY OVERFLOW EVENTS
      INDO=0
C
C
C
C
C
C
C DO ANNUAL ANALYSIS FOR A WATERSHED
      DO 20 J=1,NSTEPS
C FLOW INTO SYSTEM
      AINF=RUN(I,J)*DT3600
```

```
C SUM STORAGE PLUS INFLOW
      STOR=SI(I)+AINF
C OUTFL - FLOW RATE OUT OF STORAGE & INTO TREATMENT FOR TIME PERIOD
C          (FT**3/SEC)
2000  OUTFL=STOR/DT3600
C IS OUTFLOW RATE GREATER THAN MAX OUTFLOW RATE ?
      IF(OUTFL.GT.TMAX(I))OUTFL=TMAX(I)
C CALCULATE AMT IN STORAGE
      STOR=STOR-(OUTFL*DT3600)
C MIN VALUE FOR STORAGE
       SMIN=.0001*SMAX(I)
       IF(STOR.LE.SMIN)STOR=0.0
2001  CONTINUE
C
C CHECK FOR OVERFLOW
C
C OVERFL - AMT OF RUNOFF IN EXCESS OF STORAGE VOLUME (FT**3/SEC)
C           THIS IS UNTREATED BYPASS
      SAVE=STOR
     IF(STOR.GT.SMAX(I))STOR=SMAX(I)
     IF(STOR.EQ.SMAX(I))OVERFL=SAVE-SMAX(I)
     IF(STOR.LT.SMAX(I))OVERFL=0.0
C KEEP TRACK OF OVERFLOW VOLUME FOR ANNUAL STATISTICS
      OFLV=OFLV+OVERFL
     OVERFL=OVERFL/DT3600
C KEEP TRACK OF NUMBER HOURS OF OVERFLOW
      IF(OVERFL.NE.0.0)NOH=NOH+IDT
2002  CONTINUE
C OVERFLO QUALITY
      QOBOD=BOD(I,J)
      QOSS=SS(I,J)
      QOTKN=TKN(I,J)
      QOPB=PB(I,J)
2009   CONTINUE
C
C XINF - INFLOW TO STORAGE FOR THIS TIME PERIOD
     XINF=RUN(I,J)-OVERFL
C INPUT QUALITY FOR MIXING
      LIBOD=XINF*BOD(I,J)*DT3600
      LISS=XINF*SS(I,J)*DT3600
      LITKN=XINF*TKN(I,J)*DT3600
      LIPB=XINF*PB(I,J)*DT3600
2010  CONTINUE
C
C STORAGE QUALITY BEFORE MIXING
      LSBOD=SI(I)*BODSI (I)
      LSTKN=SI(I)*TKNSI(I)
      LSSS=SI(I)*SSSI(I)
      LSPB=SI(I)*PBSI(I)
C
C QS QUALITY OF STORAGE AFTER MIXING
2003  CONTINUE
C CALCULATE VOLUME OF STORAGE AFTER MIXING
      XINFSI=XINF*DT3600+SI(I)
      IF(XINFSI.GT.SMIN) GO TO 15
      QSBOD=0.0
      QSTKN=0.0
      QSPB=0.0
      QSSS=0.0
      BODSI(I)=0.0
      SSSI(I)=0.0
```

```
      TKNSI(I)=0.0
      PBSI(I)=0.0
C INCREMENT NUMBER HOURS STORAGE IS ZERO
      NHSO=NHSO+IDT
      GO TO 16
15    CONTINUE
      QSBOD=(LIBOD+LSBOD)/XINFSI
      BODSI(I)=QSBOD
      QSSS=(LISS+LSSS)/(XINFSI)
      SSSI(I)=QSSS
      QSTKN=(LITKN+LSTKN)/(XINFSI)
      TKNSI(I)=QSTKN
      QSPB=(LIPB+LSPB)/(XINFSI)
      PBSI(I)=QSPB
2012  CONTINUE
C
C TREATMENT OCCURS HERE
16    CONTINUE
C KEEP TRACK NUMBER OF HOURS TREATMENT NOT EQUAL ZERO
      IF(OUTFL.NE.0.0)NHTNO=NHTNO+IDT
      QOTBOD=QSBOD*(1-ETBOD(I))
      QOTSS=QSSS*(1-ETSS(I))
      QOTTKN=QSTKN*(1-ETTKN(I))
      QOTPB=QSPB*(1-ETPB(I))
2013  CONTINUE
C
C QUALITY SEND TO RECEIVING WATER
      OVEROT=OVERFL+OUTFL
      IF(OVEROT.GT.0.0)GO TO 17
      BOD(I,J)=0.0
      TKN(I,J)=0.0
      SS(I,J)=0.0
      PB(I,J)=0.0
      GO TO 19
17    CONTINUE
      BOD(I,J)=(QOBOD*OVERFL+QOTBOD*OUTFL)/OVEROT
      SS(I,J)=(QOSS*OVERFL+QOTSS*OUTFL)/OVEROT
      TKN(I,J)=(QOTKN*OVERFL+QOTTKN*OUTFL)/OVEROT
      PB(I,J)=(QOPB*OVERFL+QOTPB*OUTFL)/OVEROT
19    CONTINUE
      PBOD=BOD(I,J)
      PSS=SS(I,J)
      PTKN=TKN(I,J)
      PPB=PB(I,J)
C CHECK FOR NUMBER OF OVERFLOW EVENTS
      IF(OVERFL.NE.0.0.AND.POVRFL.EQ.0.0)NOE=NOE+1
C INITIALIZE LAG OVERFLOW FOR NEXT TIME PERIOD
      POVRFL=OVERFL
C
C SI - VOLUME IN STORAGE AT END OF TIME PERIOD (FT**3)
       SI(I)=STOR
C SAVE MAXIMUM CONCENTRATIONS
       IF(PBOD.GT.BODMAX)BODMAX=PBOD
       IF(PTKN.GT.TKNMAX)TKNMAX=PTKN
       IF(PPB.GT.PBMAX)PBMAX=PPB
       IF(PSS.GT.SSMAX)SSMAX=PSS
C CALCULATE SUMMATION FOR MEAN CONCENTRATIONS AND RUNOFF
       SBOD=SBOD+PBOD  *OVEROT
       STKN=STKN+PTKN *OVEROT
       SSS=SSS+PSS *OVEROT
       SPB=SPB+PPB     *OVEROT
```

```
C QUANTITY OF RUNOFF TO RECEIVING WATER
         RUN(I,J)=OVEROT
         RUNSUM=RUNSUM+OVEROT
C INCREMENT DAY
      IDCT=IDCT+1
      IF(IDCT.GE.IDUNIT)GO TO 100
      GO TO 120
C IF ANY OVERFLOW PERIODS THEN ACCUM ANOTHER DAY WITH OVERFLOW
100      CONTINUE
      IF(OVERFL.GT.0.0)INDO=INDO+1
      IF(INDO.GT.0)NDO=NDO+1
C  REINITIALIZE DAY COUNT AND NO. OF OVERFLOW PERIODS IN DAY
110   CONTINUE
      IDCT=0
      INDO=0
      GO TO 20
C IF THIS TIME PERIOD HAD OVERFLOW KEEP COUNT NO. OF OVERFLOWS THIS DAY
120   IF(OVERFL.GT.0.0)INDO=INDO+1
20    CONTINUE
C CONVERT ANNUAL OVERFLOW TO INCHES
      OFLV=OFLV/(43560*DA(I))
      OFLV=OFLV*12.0
C PERCENT HOURS STORAGE EMPTY
      PHSO=NHSO*100.0/8640.0
C PERCENT TIME WWTP OPERATING
      PHTNO=NHTNO*100.0/8640.0
C WRITE REPORT FOR THIS WATERSHED FOR THIS YEAR
      WRITE(IOUT,1000)NYEAR,I,NHSO,PHSO,NHTNO,PHTNO,NOH,OFLV,NOE,NDO
C CALC MEAN CONCENTRATIONS
      ABOD=SBOD/RUNSUM
      ATKN=STKN/RUNSUM
      ASS=SSS/RUNSUM
      APB=SPB/RUNSUM
C CALC ANNUAL WASHOFF
      AWOBOD=AWP(RUNSUM,IDT,ABOD)
      AWOTKN=AWP(RUNSUM,IDT,ATKN)
      AWOPB=AWP(RUNSUM,IDT,APB)
      AWOSS=AWP(RUNSUM,IDT,ASS)
      WRITE(IOUT,1001)NYEAR,I,BODMAX,TKNMAX,SSMAX,PBMAX,
     1 ABOD,ATKN,ASS,APB,AWOBOD,AWOTKN,AWOSS,AWOPB
21    CONTINUE
      RETURN
      END
C
C*********************** STORRD ******************************
C
      SUBROUTINE STORRD
      COMMON /IO/IIN,IRIV,IOUT
C
C THIS MODULE READS INPUT FOR STORAGE TREATMENT
C
      COMMON /GLOBAL/IDT,NYR,LOC(10),IRN1,IWSD
      COMMON /STOR1/ETBOD(2),ETSS(2),ETPB(2),ETTKN(2),SMAX(2),TMAX(2)
       COMMON /SAVE1/SI(2),BODSI(2),SSSI(2),TKNSI(2),PBSI(2),SXBOD(2),
     1 SXSS(2),SXTKN(2),SXPB(2)
C
1000  FORMAT(2F10.0,4F5.4)
1001  FORMAT(5F10.2)
1002  FORMAT(//,
     1 T60,'WATERSHED :',T72,I2/,
     1 T7,'MAXIMUM STORAGE VOLUME :',T40,F15.2,' FT**3'/,
```

```
     2 T7,'MAXIMUM TREATMENT RATE :',T40,F10.2,' CFS'/,
     3 T25,'TREATMENT PLANT EFFICIENCIES :',/,
     4 T26,'BOD :',T40,F9.4/,
     5 T13,'SUSPENDED SOLIDS :',T40,F9.4/,
     6 T26,'TKN :',T40,F9.4/,
     7 T25,'LEAD :',T40,F9.4)
1003  FORMAT(//,T25,'INITIAL CONDITIONS FOR STORAGE :',
     1 T60,'WATERSHED :',T72,I2/,
     1 T23,'VOLUME :',T40,F10.2,' FT**3'/,
     2 T21,'BOD CONC :',T40,F10.2,' MG/L'/,
     3 T22,'SS CONC :',T40,F10.2,' MG/L'/,
     4 T21,'TKN CONC :',T40,F10.2,' MG/L'/,
     5 T20,'LEAD CONC :',T40,F10.2,' MG/L')
1004  FORMAT('1',T26,'CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
     1',
     1/,T30,'FEBRUARY,1979',///,
     1 T26,'INPUT FOR STORAGE/TREATMENT',20('-'),//)
C READ INPUT
C TMAX -MAX TREATMENT RATE (CFS)
C SMAX -MAX STORAGE VOLUME (FT**3)
C SI   -STORAGE VOLUME AT T=0 (FT**3) (INITIAL)
C BODSI  -QUALITY OF INITIAL RUNOFF IN STORGE (MG/L)
C SSSI
C TKNSI
C PBSI
C ETBOD -TREATMENT PLANT EFFICIENCIES
C ETSS
C ETTKN
C ETPB
C
      WRITE(IOUT,1004)
      DO 5 I=1,IWSD
      READ(IIN,1000)SMAX(I),TMAX(I),ETBOD(I),ETSS(I),ETTKN(I),ETPB(I)
      WRITE(IOUT,1002)I,SMAX(I),TMAX(I),ETBOD(I),ETSS(I),ETTKN(I),
    1 ETPB(I)
      READ(IIN,1001)SI(I),BODSI(I),SSSI(I),TKNSI(I),PBSI(I)
      WRITE(IOUT,1003)I,SI(I),BODSI(I),SSSI(I),TKNSI(I),PBSI(I)
5     CONTINUE
20    RETURN
      END
C
C************************* TRANS *********************
C
      SUBROUTINE TRANS (XM,XSD,XR,TM,TSD,TR)
C
C THIS MODULE TRANSFORMS DATA TO LOG FORM
C
C TRANSFORM EQUATIONS
C
C TV=LOG((XV/(XM*XM))+1)
C
C TM=LOG(XM)-(TV/2.0)
C
C TR=LOG(XR*EXP(TV)-XR+1)/TV
C
C  CONVERT SD TO VARIANCE
      XV=XSD*XSD
120   T1=XM*XM
20    T2=XV/T1
30    T3=T2+1.0
40    TV=ALOG(T3)
```

```
50      T4=ALOG(XM)
60      T5=TV/2.0
        TM=T4-T5
80      T6=EXP(TV)
90      T7=XR*T6
100     T8=T7-XR+1.0
110     T9=ALOG(T8)
        TR=T9/TV
        TSD=SQRT(TV)
140     RETURN
        END
C
C****************** XL2 **********************
C
        FUNCTION XL2(XL1,R,Y,XRUN,C1,WDC)
        T1=XL1*(1.0-R)+Y
        T2=-WDC*XRUN*C1
        T3=EXP(T2)
        T4=XL1*(1.0-T3)
        IF(XRUN.EQ.0.0)T4=0.0
        XL2=T1-T4
        RETURN
       END
C
C************** XMIX ******************
C
        FUNCTION XMIX(A1,Q1,A2,Q2,A3,Q3,A4,Q4)
        T1=A1*Q1
        T2=A2*Q2
        T3=A3*Q3
        T4=A4*Q4
        T5=Q1+Q2+Q3+Q4
        XMIX=(T1+T2+T3+T4)/T5
        RETURN
        END
C
C**************** XM2 *********************
C
        FUNCTION XM2(XL1,XRUN,C1,C2,WDC)
        T1=-WDC*XRUN*C1
        T2=EXP(T1)
        T3=XL1*(1.0-T2)
        T4=T3*C2/XRUN
        XM2=T4
        RETURN
        END
```

Appendix C
EXAMPLE PROBLEMS

Two example problems are presented in this appendix to demonstrate the use of the program. The results presented are computer-generated and include a listing of all input variables. Input data are generally taken from the Philadelphia, Pennsylvania, site study. However, the purpose of these examples is to illustrate the use of the simulation and not necessarily to represent actual urban area/receiving water conditions at Philadelphia.

The first example problem is a 1-year simulation utilizing all modules except the storage/treatment module. This problem illustrates the use of the simulation in establishing existing or baseline water quality conditions.

The second example problem is identical to the first except for the addition of the storage/treatment module. A storage capacity of 0.5 inch and treatment rate of 0.005 inches per hour are simulated for both the combined sewer watershed and the urban stormwater runoff watershed. The receiving water impact of these facilities may be determined by comparison of the quality frequency curves developed in problem 1 to the quality frequency curves developed in problem 2.

INPUT DATA PROBLEM 1

```
PHILADELPHIA, PENNSYLVANIA (PROB 1)
0124 21234567
10203040607082
 1 2 9101112
 3 4 5 6 7 8
92.178343981.3405405
42.415094339.5217391
0.295881590.406493880.0
0.320573860.485167310.14559
 1 2 3 4101112
 5 6 7 8 9
     89.00      96.00      99.00
  50000.00       5.42        4.6
     78.00      90.00      96.00
  60000.00      12.53        1.9
    2.0260     0.0667
    0.2309     0.0667
    1.7700       0.00
   0.00320       0.00
    1.4940     0.0667
    0.4030     0.0667
    1.3800       0.00
   00.0032       0.00
1     40.00    1600.00     578.15       1.50       0.16
0
   1025.33      30.00      30.00      12.17       0.04
0.00000702       1.00
      0.00       0.00      20.65
      1.50       1.00      10.00      41.00       6.00
      2.60       0.70      20.00       1.80     108.00       0.79      0.0
      3.30       0.60      16.00       2.40      22.00       0.56      0.0
      6.00       0.60      16.00       1.90      45.00       0.62      0.00
     10.60       0.80      13.00       2.30      26.00       0.44      0.01
     18.20       1.40      11.00       2.50      23.00       0.76      0.01
     23.80       3.40      14.00       2.80      28.00       1.19      0.01
     27.10       3.60      15.00       2.60      38.00       0.63      0.013
     26.00       3.80      15.00       2.50      32.00       0.57      0.015
     21.90       2.70      22.00       1.80      10.00       0.52      0.016
     16.80       2.60      16.00       1.80      18.00       0.45      0.012
     10.40       1.80      20.00       2.10      21.00       0.51      0.020
      5.00       1.00      17.00       2.10      32.00       0.56      0.019
     10.00      10.00      37.00     100.00
     10.00      10.00     116.00      10.00
      7.00       6.30       7.00       7.00
```

Upstream Flow Array

Card 1	Card 62	Card 123	Card 184	Card 245	Card 306
65	6524.	15605.	11920.	4822.	5994.
10527.	5650.	14590.	10855.	6276.	6259.
10098.	6881.	14915.	9211.	7531.	7851.
8902.	6057.	13475.	7967.	6639.	11180.
9275.	5585.	12262.	8363.	5060.	12502.
9805.	5674.	11318.	7847.	5803.	11135.
9160.	6193.	10190.	7457.	13918.	10029.
9615.	6731.	10900.	7017.	17355.	9670.
8615.	8219.	16015.	6940.	12723.	10253.
7440.	18160.	23445.	7036.	9030.	14725.
7750.	14310.	20225.	6893.	6900.	26305.
7455.	11673.	17945.	6613.	5956.	38525.
7247.	10327.	17400.	6892.	5334.	33210.
9340.	16808.	15830.	7529.	5387.	24170.
16020.	49300.	14700.	7504.	5052.	19440.
13300.	60480.	14620.	7501.	4916.	16495.
11655.	48725.	15480.	6230.	4845.	14640.
10865.	45235.	17230.	5810.	4864.	13130.
11210.	40615.	15905.	6943.	4603.	13285.
11210.	41640.	16075.	7153.	5178.	12337.
11200.	44555.	18210.	6250.	5404.	11128.
11280.	48620.	17970.	5157.	5197.	12607.
11050.	41985.	15400.	4778.	4211.	12807.
10125.	34935.	15450.	4968.	3747.	13065.
9332.	30015.	44070.	4689.	4414.	13065.
9466.	26250.	91985.	4522.	4645.	17027.
9524.	23595.	81335.	5256.	5010.	25960.
8953.	21765.	60835.	7050.	4977.	24635.
9795.	20535.	54230.	7000.	4736.	21490.
13260.	20470.	46125.	6389.	5728.	17470.
17055.	19620.	38995.	5950.	6282.	15305.
18955.	17990.	32540.	5580.	6399.	12926.
35180.	16975.	27400.	6652.	6107.	11652.
30345.	16420.	23405.	6540.	6791.	9643.
26870.	15040.	20325.	6173.	6076.	9506.
24140.	13960.	17220.	5711.	5780.	10476.
22750.	13490.	15970.	5694.	5174.	18290.
20095.	12838.	32250.	5492.	4589.	15435.
18565.	12153.	36435.	4682.	4356.	14970.
16405.	11418.	23995.	4443.	4307.	13545.
14390.	10688.	21385.	4297.	4244.	13435.
12135.	9797.	19980.	4662.	4989.	12841.
11100.	9137.	19775.	4526.	5674.	12281.
10838.	8624.	20785.	4863.	6657.	12141.
11108.	8518.	19825.	4859.	5820.	14195.
10530.	8197.	20800.	4798.	4434.	12097.
9833.	7769.	19710.	5357.	4099.	9331.
8478.	7391.	17125.	5708.	5648.	13710.
8101.	6950.	15430.	6460.	8049.	13120.
8339.	6583.	13301.	6904.	7871.	11289.
7911.	6457.	16130.	6086.	7313.	12937.
7337.	7226.	14365.	4879.	7259.	11819.
8003.	22555.	17685.	4574.	5672.	13655.
7581.	44145.	21935.	4073.	5555.	8725.
6762.	38040.	30035.	3962.	5064.	8822.
6244.	29755.	30670.	4225.	4870.	9336.
6549.	24785.	25175.	4157.	5017.	
7206.	21315.	21100.	4130.	4727.	
7424.	19260.	18305.	4324.	4977.	
7274.	18290.	16155.	4721.	5043.	
7559.	17170.	14360.	4878.	5388.	

```
                              CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
                                  FEBRUARY,1979


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

                       LOCATION: PHILADELPHIA, PENNSYLVANIA (PROB 1)
 NUMBER OF YEARS TO SIMULATE:  1
      TIME INTERVAL IN HOURS: 24
        NUMBER OF WATERSHEDS:  2
   SEED FOR RANDOM GENERATOR: 123456700


OPTIONS SELECTED :
10  RAINFALL SIMULATOR
20  RUNOFF BY SCS EQUATION
30  POLLUTANT WASHOFF
40  EXCESS INFILTRATION
60  DRY WEATHER FLOW
70  DAILY STREAMFLOW
82  SUSPENDED SOLIDS,DISSOLVED OXYGEN, AND LEAD RESPONSE
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

RAINFALL SIMULATOR INPUT DATA-------------------

MONTHS IN SEASON NO. 1:
1
2
9
10
11
12

MONTHS IN SEASON NO. 2:
3
4
5
6
7
8

	SEASON NO. 1	SEASON NO. 2
MEAN TIME BETWEEN STORMS	92.18 HOURS	81.34 HOURS
MEAN DURATION OF STORMS	42.42 HOURS	39.52 HOURS

INPUT RAINFALL DEPTH STATISTICS:

SEASON	MEAN	S.D.	CORR COEFF
1	0.2959	0.4065	0.0
2	0.3206	0.4852	0.1456

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

RUNOFF SIMULATOR INPUT DATA--------------------

```
MONTHS IN DORMANT SEASON:
                        1
                        2
                        3
                        4
                       10
                       11
                       12

MONTHS IN GROWING SEASON:
                        5
                        6
                        7
                        8
                        9

WATERSHED NO.  1 DATA:
     CN1 =    89.00   CN2 =    96.00   CN3 =    99.00
    DRAINAGE AREA  =   50000.00 ACRES
    TIME OF CONCENTRATION =       5.42 HOURS
        WASHOFF COEFFICIENT =       4.60

WATERSHED NO.  2 DATA:
     CN1 =    78.00   CN2 =    90.00   CN3 =    96.00
    DRAINAGE AREA  =   60000.00 ACRES
    TIME OF CONCENTRATION =      12.53 HOURS
        WASHOFF COEFFICIENT =       1.90
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

RUNOFF QUALITY INPUT DATA--------------------

INPUT DATA FOR WATERSHED NO. 1

BOD ACC. RATE =	2.0260 #/AC/DAY	BOD REMOVAL RATE =	0.0667 FRACT/DAY
TKN ACC. RATE =	0.2309 #/AC/DAY	TKN REMOVAL RATE =	0.0667 FRACT/DAY
SS ACC. RATE =	1.7700 #/AC/DAY	SS REMOVAL RATE =	0.0 FRACT/DAY
PB ACC. RATE =	0.0032 #/AC/DAY	PB REMOVAL RATE =	0.0 FRACT/DAY

INPUT DATA FOR WATERSHED NO. 2

BOD ACC. RATE =	1.4940 #/AC/DAY	BOD REMOVAL RATE =	0.0667 FRACT/DAY
TKN ACC. RATE =	0.4030 #/AC/DAY	TKN REMOVAL RATE =	0.0667 FRACT/DAY
SS ACC. RATE =	1.3800 #/AC/DAY	SS REMOVAL RATE =	0.0 FRACT/DAY
PB ACC. RATE =	0.0032 #/AC/DAY	PB REMOVAL RATE =	0.0 FRACT/DAY

EXCESS INFILTRATION INPUT DATA-------------------

WATERSHED: 1 CODE: 1
AVERAGE PIPE DIAMETER: 40.00 INCHES
TOTAL SYSTEM LENGTH: 1600.00 MILES
DRY WEATHER FLOW: 578.15 CFS
DRY WEATHER FLOW RATIO: 1.50
INFILTRATION ADJUSTMENT FACTOR: 0.16

WATERSHED: 2 CODE: 0
AVERAGE PIPE DIAMETER: 0.0 INCHES
TOTAL SYSTEM LENGTH: 0.0 MILES
DRY WEATHER FLOW: 0.0 CFS
DRY WEATHER FLOW RATIO: 0.0
INFILTRATION ADJUSTMENT FACTOR: 1.00

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

INPUT TO DRY WEATHER SUBMODEL--------------------

QDW	=	1025.33	CFS
BODDW	=	30.00	MG/L
SSDW	=	30.00	MG/L
TKNDW	=	12.17	MG/L
PBDW	=	0.04	MG/L
DDW	=	0.0	MG/L

INPUT FOR DAILY STREAMFLOW--------------------

NUMBER OF YEARS OF STREAMFLOW READ   1

THE FIRST TEN VALUES ARE :

```
10527. CFS
10098. CFS
 8902. CFS
 9275. CFS
 9805. CFS
 9160. CFS
 9615. CFS
 8615. CFS
 7440. CFS
 7750. CFS
```

INPUT TO DO BUDGET MODEL-------------------

ALPHA VALUES :	0.00000702	1.00000000	
BETA VALUES :	0.0	0.0	20.64999390
SPECIFIED K2 :	0.0 1/DAY		
SBA :	1.50 GM O2/M**2/DAY		
K2ADJ :	1.00		
DIST1 :	10.00 MILES		
DIST2 :	41.00 MILES		
E1:	6.00 MILES**2/DAY		
K1 WATERSHED 1	0.40 1/DAY		
K1 WATERSHED 2	0.16 1/DAY		
K1 STREAMFLOW	0.16 1/DAY		
K1 DRY WEATHER FLOW	0.23 1/DAY		

UPSTREAM QUALITY ARRAY-------------------

MONTH	TEMP DEGREES C	DO DEFICIT	CHLORIDE CONC	BOD CONC	SUSPENDED SOLIDS	TKN CONC	LEAD CONC
		----------------	---------------MG/L	---------------			
1	2.60	0.70	20.00	1.80	108.00	0.79	0.0150
2	3.30	0.60	16.00	2.40	22.00	0.56	0.0150
3	6.00	0.60	16.00	1.90	45.00	0.62	0.0090
4	10.60	0.80	13.00	2.30	26.00	0.44	0.0110
5	18.20	1.40	11.00	2.50	23.00	0.76	0.0120
6	23.80	3.40	14.00	2.80	28.00	1.19	0.0130
7	27.10	3.60	15.00	2.60	38.00	0.63	0.0130
8	26.00	3.80	15.00	2.50	32.00	0.57	0.0150
9	21.90	2.70	22.00	1.80	10.00	0.52	0.0160
10	16.80	2.60	16.00	1.80	18.00	0.45	0.0120
11	10.40	1.80	20.00	2.10	21.00	0.51	0.0200
12	5.00	1.00	17.00	2.10	32.00	0.56	0.0190

INPUT DATA FOR LEAD SUBMODEL-------------------

	CSO	SWR	USF	WWTP
ALKALINITY (MG/L)	10.00	10.00	37.00	100.00
HARDNESS (MG/L)	10.00	10.00	116.00	10.00
PH	7.00	6.30	7.00	7.00

RAINFALL STATISTICS FOR YEAR NO. 1

TOTAL RAINFALL SEASON NO. 1 = 22.11 INCHES

TOTAL RAINFALL SEASON NO. 2 = 18.13 INCHES

NO.OF PERIODS WITH RAIN SEASON NO. 1 = 62
NO.OF RAINFALL EVENTS SEASON NO. 1 = 31

NO.OF PERIODS WITH RAIN SEASON NO. 2 = 61
NO.OF RAINFALL EVENTS SEASON NO. 2 = 30

MAXIMUM RAINFALL EVENT TOTAL DEPTH = 6.38 INCHES
MAXIMUM RAINFALL EVENT DURATION = 168 HOURS
MAXIMUM DEPTH IN ONE 24 HR.PERIOD= 6.07 INCHES

RUNOFF STATISTICS FOR YEAR NO. 1 WATERSHED NO. 1

TOTAL RUNOFF DORMANT SEASON = 21.89 INCHES

TOTAL RUNOFF GROWING SEASON = 5.00 INCHES

TOTAL DURATION OF RUNOFF DORMANT SEASON = 1728. HOURS

TOTAL DURATION OF RUNOFF GROWING SEASON = 768. HOURS

MAXIMUM 24 HOUR RUNOFF RATE, DORMANT SEASON = 11760.48 CFS

MAXIMUM 24 HOUR RUNOFF RATE, GROWING SEASON = 1296.79 CFS

RUNOFF STATISTICS FOR YEAR NO. 1 WATERSHED NO. 2

TOTAL RUNOFF DORMANT SEASON = 17.13 INCHES

TOTAL RUNOFF GROWING SEASON = 2.85 INCHES

TOTAL DURATION OF RUNOFF DORMANT SEASON = 1440. HOURS

TOTAL DURATION OF RUNOFF GROWING SEASON = 552. HOURS

MAXIMUM 24 HOUR RUNOFF RATE, DORMANT SEASON = 12390.71 CFS

MAXIMUM 24 HOUR RUNOFF RATE, GROWING SEASON = 1229.30 CFS

RUNOFF QUALITY - STATISTICS FOR YEAR NO. 1 WATERSHED NO. 1

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	528.77	60.26	1343.81	2.43
MEAN CONCENTRATIONS(MG/L)	64.72	7.38	106.31	0.19
TOTAL ANNUAL WASHOFF(LBS)	19714400.	2246834.	32382000.	58544.

RUNOFF QUALITY - STATISTICS FOR YEAR NO. 1 WATERSHED NO. 2

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	182.93	49.34	703.55	1.63
MEAN CONCENTRATIONS(MG/L)	45.07	12.16	111.38	0.26
TOTAL ANNUAL WASHOFF(LBS)	12237439.	3301025.	30244624.	70133.

EXCESS INFILTRATION RESULTS FOR WATERSHED 1
TOTAL DURATION EXCESS INFILTRATION 1272 HOURS
TOTAL AMOUNT OF EXCESS INFILTRATION 3.95 INCHES
MAXIMUM EXCESS INFILTRATION RATE 1412.76 CFS

EXCESS INFILTRATION PLUS RUNOFF QUALITY-STATISTICS FOR WATERSHED NO. 1

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	528.77	60.26	1343.81	2.43
MEAN CONCENTRATIONS(MG/L)	67.82	8.71	104.07	0.17
TOTAL ANNUAL WASHOFF(LBS)	23692640.	3042490.	36360240.	59339.

UPSTREAM FLOW WATER QUALITY SUMMARY FOR YEAR 1
BOD = 59788256. #/YR
NBOD= 82601856. #/YR
SS = 882851072. #/YR
PB = 358386. #/YR
NOTE: BOD = 5 DAY BOD
NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57 * TKN)

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979
CUMULATIVE FREQUENCY-MINIMUM DISSOLVED OXYGEN TO 41.00 MILES DOWNSTREAM

DO MIN CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
1.0 OR LESS	139.	38.61	38.61
1.0 TO 2.0	10.	2.78	41.39
2.0 TO 3.0	22.	6.11	47.50
3.0 TO 4.0	33.	9.17	56.67
4.0 TO 5.0	19.	5.28	61.94
5.0 TO 6.0	44.	12.22	74.17
6.0 TO 7.0	48.	13.33	87.50
7.0 TO 8.0	30.	8.33	95.83
8.0 TO 9.0	13.	3.61	99.44
9.0 TO 10.0	2.	0.56	100.00
10.0 TO 11.0	0.	0.0	100.00
11.0 TO 12.0	0.	0.0	100.00
12.0 TO 13.0	0.	0.0	100.00
13.0 TO 14.0	0.	0.0	100.00
14.0 TO 15.0	0.	0.0	100.00
GREATER THAN 15.0	0.	0.0	100.00
TOTAL=	360.		

MINIMUM 3 DAY DISSOLVED OXYGEN = 0.0 MG/L

TIME AVERAGED PERCENT OF STREAM REACH TO 41.00 MILES DOWNSTREAM AT OR BELOW GIVEN DO CONCENTRATION.

DO CONCENTRATION	PERCENT OF STREAM REACH
0.0	13.0889
LESS THAN 1.0	21.3611
LESS THAN 2.0	27.6778
LESS THAN 3.0	34.5611
LESS THAN 4.0	43.8167
LESS THAN 5.0	51.1500
LESS THAN 6.0	59.9944

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979
CUMULATIVE FREQUENCY-MINIMUM DISSOLVED OXYGEN AT 10.00 MILES DOWNSTREAM

DO MIN CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
1.0 OR LESS	115.	31.94	31.94
1.0 TO 2.0	23.	6.39	38.33
2.0 TO 3.0	21.	5.83	44.17
3.0 TO 4.0	18.	5.00	49.17
4.0 TO 5.0	26.	7.22	56.39
5.0 TO 6.0	21.	5.83	62.22
6.0 TO 7.0	47.	13.06	75.28
7.0 TO 8.0	45.	12.50	87.78
8.0 TO 9.0	16.	4.44	92.22
9.0 TO 10.0	13.	3.61	95.83
10.0 TO 11.0	11.	3.06	98.89
11.0 TO 12.0	4.	1.11	100.00
12.0 TO 13.0	0.	0.0	100.00
13.0 TO 14.0	0.	0.0	100.00
14.0 TO 15.0	0.	0.0	100.00
GREATER THAN 15.0	0.	0.0	100.00
TOTAL=	360.		

CUMULATIVE FREQUENCY- TOTAL LEAD TO 41.00 MILES DOWNSTREAM

PB CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
0.005 OR LESS	0.	0.0	0.0
0.005 TO 0.010	5.	1.39	1.39
0.010 TO 0.015	96.	26.67	28.06
0.015 TO 0.020	137.	38.06	66.11
0.020 TO 0.025	71.	19.72	85.83
0.025 TO 0.030	13.	3.61	89.44
0.030 TO 0.035	6.	1.67	91.11
0.035 TO 0.040	6.	1.67	92.78
0.040 TO 0.045	5.	1.39	94.17
0.045 TO 0.05	6.	1.67	95.83
0.05 TO 0.06	4.	1.11	96.94
0.06 TO 0.07	4.	1.11	98.06
0.07 TO 0.08	1.	0.28	98.33
0.08 TO 0.09	0.	0.0	98.33
0.09 TO 0.1	3.	0.83	99.17
0.1 TO 0.2	3.	0.83	100.00
0.2 TO 0.3	0.	0.0	100.00
0.3 TO 0.4	0.	0.0	100.00
0.4 TO 0.5	0.	0.0	100.00
GREATER THAN 0.5	0.	0.0	100.00
TOTAL=	360.		

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

CUMULATIVE FREQUENCY- DISSOLVED LEAD TO 41.00 MILES DOWNSTREAM

PB CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
0.005 OR LESS	0.	0.0	0.0
0.005 TO 0.010	5.	1.39	1.39
0.010 TO 0.015	96.	26.67	28.06
0.015 TO 0.020	137.	38.06	66.11
0.020 TO 0.025	71.	19.72	85.83
0.025 TO 0.030	13.	3.61	89.44
0.030 TO 0.035	6.	1.67	91.11
0.035 TO 0.040	6.	1.67	92.78
0.040 TO 0.045	5.	1.39	94.17
0.045 TO 0.05	6.	1.67	95.83
0.05 TO 0.06	4.	1.11	96.94
0.06 TO 0.07	4.	1.11	98.06
0.07 TO 0.08	1.	0.28	98.33
0.08 TO 0.09	0.	0.0	98.33
0.09 TO 0.1	3.	0.83	99.17
0.1 TO 0.2	3.	0.83	100.00
0.2 TO 0.3	0.	0.0	100.00
0.3 TO 0.4	0.	0.0	100.00
0.4 TO 0.5	0.	0.0	100.00
GREATER THAN 0.5	0.	0.0	100.00
TOTAL=	360.		

MAXIMUM 96 HOUR DISSOLVED LEAD = 0.1173 MG/L
MEAN DISSOLVED LEAD = 0.0217 MG/L

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979
CUMULATIVE FREQUENCY--SLSPENDED SOLIDS TO 41.00 MILES DOWNSTREAM

SS CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
25 OR LESS	135.	37.50	37.50
25 TO 50	181.	50.28	87.78
50 TO 75	11.	3.06	90.83
75 TO 100	9.	2.50	93.33
100 TO 125	24.	6.67	100.00
125 TO 150	0.	0.0	100.00
150 TO 175	0.	0.0	100.00
175 TO 200	0.	0.0	100.00
200 TO 225	0.	0.0	100.00
225 TO 250	0.	0.0	100.00
250 TO 275	0.	0.0	100.00
275 TO 300	0.	0.0	100.00
300 TO 325	0.	0.0	100.00
325 TO 350	0.	0.0	100.00
350 TO 375	0.	0.0	100.00
375 TO 400	0.	0.0	100.00
400 TO 425	0.	0.0	100.00
425 TO 450	0.	0.0	100.00
450 TO 475	0.	0.0	100.00
475 TO 500	0.	0.0	100.00
GREATER THAN 500	0.	0.0	100.00
TOTAL=	360.		

RECEIVING WATER LOADS FOR YEAR 1
NBOD 221970112. #/YR
CBOD 155256784. #/YR
SUSPENDED SOLIDS 1008990464. #/YR
DISSOLVED LEAD 567242. #/YR
SEDIMENT LEAD 0. #/YR
NOTE: NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57*TKN)

CBOD=ULTIMATE CARBONACOUS OXYGEN DEMAND

INPUT DATA PROBLEM 2

```
PHILADELPHIA, PENNSYLVANIA (PROB 2)
0124 21234567
1020304050607082
 1 2 9101112
 3 4 5 6 7 8
92.178343981.3405405
42.415094339.5217391
0.295881590.406493880.0
0.320573860.485167310.14559
 1 2 3 4101112
 5 6 7 8 9
     89.00      96.00      99.00
  50000.00       5.42        4.6
     78.00      90.00      96.00
  60000.00      12.53        1.9
    2.0260     0.0667
    0.2309     0.0667
    1.7700       0.00
   0.00320       0.00
    1.4940     0.0667
    0.4030     0.0667
    1.3800       0.00
   00.0032       0.00
1     40.00   1600.00     578.15       1.50       0.16
0
090750000.       252.0 0.96 0.99 0.81 0.99

108900000.0      302.4 0.96 0.99 0.81 0.99

   1025.33      30.00      30.00      12.17       0.04
0.00000702       1.00
      0.00       0.00      20.65
      1.50       1.00      10.00      41.00       6.00
      2.60       0.70      20.00       1.80     108.00       0.79       0.015
      3.30       0.60      16.00       2.40      22.00       0.56       0.015
      6.00       0.60      16.00       1.90      45.00       0.62       0.009
     10.60       0.80      13.00       2.30      26.00       0.44       0.011
     18.20       1.40      11.00       2.50      23.00       0.76       0.012
     23.80       3.40      14.00       2.80      28.00       1.19       0.013
     27.10       3.60      15.00       2.60      38.00       0.63       0.013
     26.00       3.80      15.00       2.50      32.00       0.57       0.015
     21.90       2.70      22.00       1.80      10.00       0.52       0.016
     16.80       2.60      16.00       1.80      18.00       0.45       0.012
     10.40       1.80      20.00       2.10      21.00       0.51       0.020
      5.00       1.00      17.00       2.10      32.00       0.56       0.019
     10.00      10.00      37.00     100.00
     10.00      10.00     116.00      10.00
      7.00       6.30       7.00       7.00
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

```
GENERAL SIMULATION CONTROL DATA-------------------

                      LOCATION: PHILADELPHIA, PENNSYLVANIA (PROB 2)
 NUMBER OF YEARS TO SIMULATE:  1
       TIME INTERVAL IN HOURS: 24
         NUMBER OF WATERSHEDS:  2
   SEED FOR RANDOM GENERATOR: 123456700


OPTIONS SELECTED :
10  RAINFALL SIMULATOR
20  RUNOFF BY SCS EQUATION
30  POLLUTANT WASHOFF
40  EXCESS INFILTRATION
50  STORAGE TREATMENT
60  DRY WEATHER FLOW
70  DAILY STREAMFLOW
82  SUSPENDED SOLIDS,DISSOLVED OXYGEN, AND LEAD RESPONSE
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

RAINFALL SIMULATOR INPUT DATA--------------------

MONTHS IN SEASON NO. 1:
1
2
9
10
11
12

MONTHS IN SEASON NO. 2:
3
4
5
6
7
8

	SEASON NO. 1	SEASON NO. 2
MEAN TIME BETWEEN STORMS	92.18 HOURS	81.34 HOURS
MEAN DURATION OF STORMS	42.42 HOURS	39.52 HOURS

INPUT RAINFALL DEPTH STATISTICS:

SEASON	MEAN	S.D.	CORR COEFF
1	0.2959	0.4065	0.0
2	0.3206	0.4852	0.1456

```
RUNOFF    SIMULATOR INPUT DATA--------------------


MONTHS IN DORMANT SEASON:
                         1
                         2
                         3
                         4
                        10
                        11
                        12

MONTHS IN GROWING SEASON:
                         5
                         6
                         7
                         8
                         9

WATERSHED NO.  1 DATA:
     CN1 =     89.00    CN2 =     96.00    CN3 =     99.00
    DRAINAGE AREA  =   50000.00 ACRES
    TIME OF CONCENTRATION =        5.42 HOURS
        WASHOFF COEFFICIENT =        4.60

WATERSHED NO.  2 DATA:
     CN1 =     78.00    CN2 =     90.00    CN3 =     96.00
    DRAINAGE AREA  =   60000.00 ACRES
    TIME OF CONCENTRATION =       12.53 HOURS
        WASHOFF COEFFICIENT =        1.90
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

RUNOFF QUALITY INPUT DATA----------------------

INPUT DATA FOR WATERSHED NO. 1

BOD ACC. RATE =	2.0260 #/AC/DAY	BOD REMOVAL RATE =	0.0667	FRACT/DAY
TKN ACC. RATE =	0.2309 #/AC/DAY	TKN REMOVAL RATE =	0.0667	FRACT/DAY
SS ACC. RATE =	1.7700 #/AC/DAY	SS REMOVAL RATE =	0.0	FRACT/DAY
PB ACC. RATE =	0.0032 #/AC/DAY	PB REMOVAL RATE =	0.0	FRACT/DAY

INPUT DATA FOR WATERSHED NO. 2

BOD ACC. RATE =	1.4940 #/AC/DAY	BOD REMOVAL RATE =	0.0667	FRACT/DAY
TKN ACC. RATE =	0.4030 #/AC/DAY	TKN REMOVAL RATE =	0.0667	FRACT/DAY
SS ACC. RATE =	1.3800 #/AC/DAY	SS REMOVAL RATE =	0.0	FRACT/DAY
PB ACC. RATE =	0.0032 #/AC/DAY	PB REMOVAL RATE =	0.0	FRACT/DAY

EXCESS INFILTRATION INPUT DATA-------------------

```
WATERSHED:  1          CODE:  1
AVERAGE PIPE DIAMETER:        40.00 INCHES
TOTAL SYSTEM LENGTH:    1600.00 MILES
DRY WEATHER FLOW:     578.15 CFS
DRY WEATHER FLOW RATIO:       1.50
INFILTRATION ADJUSTMENT FACTOR:       0.16

WATERSHED:  2          CODE:  0
AVERAGE PIPE DIAMETER:        0.0  INCHES
TOTAL SYSTEM LENGTH:       0.0  MILES
DRY WEATHER FLOW:      0.0  CFS
DRY WEATHER FLOW RATIO:       0.0
INFILTRATION ADJUSTMENT FACTOR:       1.00
```

```
                    CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
                        FEBRUARY,1979

                    INPUT FOR STORAGE/TREATMENT-------------------



                                                               WATERSHED :   1
MAXIMUM STORAGE VOLUME :                   90750000.00 FT**3
MAXIMUM TREATMENT RATE :                   252.00 CFS
                   TREATMENT PLANT EFFICIENCIES :
                        BOD :             0.9600
      SUSPENDED SOLIDS :                  0.9900
                        TKN :             0.8100
                       LEAD :             0.9900


                   INITIAL CONDITIONS FOR STORAGE :   WATERSHED :   1
                     VOLUME :                0.0   FT**3
                   BOD CONC :                0.0   MG/L
                    SS CONC :                0.0   MG/L
                   TKN CONC :                0.0   MG/L
                  LEAD CONC :                0.0   MG/L


                                                               WATERSHED :   2
MAXIMUM STORAGE VOLUME :                  108900000.00 FT**3
MAXIMUM TREATMENT RATE :                   302.40 CFS
                   TREATMENT PLANT EFFICIENCIES :
                        BOD :             0.9600
      SUSPENDED SOLIDS :                  0.9900
                        TKN :             0.8100
                       LEAD :             0.9900


                   INITIAL CONDITIONS FOR STORAGE :   WATERSHED :   2
                     VOLUME :                0.0   FT**3
                   BOD CONC :                0.0   MG/L
                    SS CONC :                0.0   MG/L
                   TKN CONC :                0.0   MG/L
                  LEAD CONC :                0.0   MG/L
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

INPUT TO DRY WEATHER SUBMODEL--------------------

```
  QDW =     1025.33  CFS
BODDW =       30.00 MG/L
 SSDW =       30.00 MG/L
TKNDW =       12.17 MG/L
 PBDW =        0.04 MG/L
CDW =        0.0  MG/L
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

INPUT FOR DAILY STREAMFLOW--------------------

NUMBER OF YEARS OF STREAMFLOW READ 1

THE FIRST TEN VALUES ARE :

```
10527. CFS
10098. CFS
 8902. CFS
 9275. CFS
 9605. CFS
 9160. CFS
 9015. CFS
 8615. CFS
 7440. CFS
 7750. CFS
```

INPUT TO DO BUDGET MODEL--------------------

ALPHA VALUES :	0.00000702	1.00000000	
BETA VALUES :	0.0	0.0	20.64999390
SPECIFIED K2 :	0.0 1/DAY		
SBA :	1.50 GM O2/M**2/DAY		
K2ADJ :	1.00		
DIST1 :	10.00 MILES		
DIST2 :	41.00 MILES		
E1:	6.00 MILES**2/DAY		
K1 WATERSHED 1	0.40 1/DAY		
K1 WATERSHED 2	0.16 1/DAY		
K1 STREAMFLOW	0.16 1/DAY		
K1 DRY WEATHER FLOW	0.23 1/DAY		

UPSTREAM QUALITY ARRAY--------------------

MONTH	TEMP DEGREES C	DO DEFICIT (MG/L)	CHLORIDE CONC (MG/L)	BOD CONC (MG/L)	SUSPENDED SOLIDS (MG/L)	TKN CONC	LEAD CONC
1	2.00	0.70	20.00	1.80	108.00	0.79	0.0150
2	3.30	0.60	16.00	2.40	22.00	0.56	0.0150
3	6.00	0.60	16.00	1.90	45.00	0.62	0.0090
4	10.00	0.80	13.00	2.30	26.00	0.44	0.0110
5	18.20	1.40	11.00	2.50	23.00	0.76	0.0120
6	23.80	3.40	14.00	2.80	28.00	1.19	0.0130
7	27.10	3.60	15.00	2.60	38.00	0.63	0.0130
8	26.00	3.80	15.00	2.50	32.00	0.57	0.0150
9	21.90	2.70	22.00	1.80	10.00	0.52	0.0160
10	16.80	2.60	16.00	1.80	18.00	0.45	0.0120
11	10.40	1.80	20.00	2.10	21.00	0.51	0.0200
12	5.00	1.00	17.00	2.10	32.00	0.56	0.0190

INPUT DATA FOR LEAD SUBMODEL--------------------

	CSO	SWR	USF	WWTP
ALKALINITY (MG/L)	10.00	10.00	37.00	100.00
HARDNESS (MG/L)	10.00	10.00	116.00	10.00
PH	7.00	6.30	7.00	7.00

RAINFALL STATISTICS FOR YEAR NO. 1

TOTAL RAINFALL SEASON NO. 1 = 22.11 INCHES

TOTAL RAINFALL SEASON NO. 2 = 18.13 INCHES

NO.OF PERIODS WITH RAIN SEASON NO. 1 = 62
NO.OF RAINFALL EVENTS SEASON NO. 1 = 31

NO.OF PERIODS WITH RAIN SEASON NO. 2 = 61
NO.OF RAINFALL EVENTS SEASON NO. 2 = 30

MAXIMUM RAINFALL EVENT TOTAL DEPTH = 6.38 INCHES
MAXIMUM RAINFALL EVENT DURATION = 168 HOURS
MAXIMUM DEPTH IN ONE 24 HR.PERIOD= 6.07 INCHES

RUNOFF STATISTICS FOR YEAR NO. 1 WATERSHED NO. 1

TOTAL RUNOFF DORMANT SEASON = 21.89 INCHES

TOTAL RUNOFF GROWING SEASON = 5.00 INCHES

TOTAL DURATION OF RUNOFF DORMANT SEASON = 1728. HOURS

TOTAL DURATION OF RUNOFF GROWING SEASON = 768. HOURS

MAXIMUM 24 HOUR RUNOFF RATE, DORMANT SEASON = 11760.48 CFS

MAXIMUM 24 HOUR RUNOFF RATE, GROWING SEASON = 1296.79 CFS

RUNOFF STATISTICS FOR YEAR NO. 1 WATERSHED NO. 2

TOTAL RUNOFF DORMANT SEASON = 17.13 INCHES

TOTAL RUNOFF GROWING SEASON = 2.85 INCHES

TOTAL DURATION OF RUNOFF DORMANT SEASON = 1440. HOURS

TOTAL DURATION OF RUNOFF GROWING SEASON = 552. HOURS

MAXIMUM 24 HOUR RUNOFF RATE, DORMANT SEASON = 12390.71 CFS

MAXIMUM 24 HOUR RUNOFF RATE, GROWING SEASON = 1229.30 CFS

RUNOFF QUALITY - STATISTICS FOR YEAR NO. 1 WATERSHED NO. 1

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	528.77	60.26	1343.81	2.43
MEAN CONCENTRATIONS(MG/L)	64.72	7.38	106.31	0.19
TOTAL ANNUAL WASHOFF(LBS)	19714400.	2246834.	32382000.	58544.

RUNOFF QUALITY - STATISTICS FOR YEAR NO. 1 WATERSHED NO. 2

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	182.93	49.34	703.55	1.63
MEAN CONCENTRATIONS(MG/L)	45.07	12.16	111.38	0.26
TOTAL ANNUAL WASHOFF(LBS)	12237439.	3301025.	30244624.	70133.

EXCESS INFILTRATION RESULTS FOR WATERSHED 1
TOTAL DURATION EXCESS INFILTRATION 1272 HOURS
TOTAL AMOUNT OF EXCESS INFILTRATION 3.95 INCHES
MAXIMUM EXCESS INFILTRATION RATE 1412.76 CFS

EXCESS INFILTRATION PLUS RUNOFF QUALITY-STATISTICS FOR WATERSHED NO. 1

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	528.77	60.26	1343.81	2.43
MEAN CONCENTRATIONS(MG/L)	67.82	8.71	104.07	0.17
TOTAL ANNUAL WASHOFF(LBS)	23692640.	3042490.	36360240.	59339.

RESULTS FOR STORAGE TREATMENT YEAR 1 WATERSHED 1

NUMBER OF HOURS STORAGE IS EMPTY:	4704	PERCENT OF TOTAL TIME: 54.44
NUMBER OF HOURS WWTF OPERATING :	3960	PERCENT OF TOTAL TIME: 45.83
NUMBER OF OVERFLOW HOURS :	768	
ANNUAL OVERFLOW VOLUME IN INCHES :	14.74	
NUMBER OF OVERFLOW EVENTS :	17	
NUMBER OF DAYS WITH OVERFLOW	32	

S/T AND OVERFLOW SUMMARY FOR YEAR NO. 1 WATERSHED NO. 1

	BOD	TKN	SS	PB
MAXIMUM CONCENTRATIONS(MG/L)	71.61	8.55	167.80	0.46
MEAN CONCENTRATIONS(MG/L)	16.47	2.09	18.82	0.05
RESIDUAL ANNUAL WASHOFF(LBS)	5661962.	719812.	6469031.	18222.

```
                  RESULTS FOR STORAGE TREATMENT YEAR   1        WATERSHED 2

NUMBER OF HOURS STORAGE IS EMPTY:       5616       PERCENT OF TOTAL TIME: 65.00
NUMBER OF HOURS WHTF OPERATING  :       3024       PERCENT OF TOTAL TIME: 35.00
NUMBER OF OVERFLOW HOURS :               360
ANNUAL OVERFLOW VOLUME IN INCHES :      8.12
NUMBER OF OVERFLOW EVENTS :               10
NUMBER OF DAYS WITH OVERFLOW              15



S/T AND OVERFLOW SUMMARY FOR YEAR NO.  1   WATERSHED NO.  2

                                          BOD        TKN         SS         PB

MAXIMUM CONCENTRATIONS(MG/L)            45.21      12.13     144.39       0.37
MEAN CONCENTRATIONS(MG/L)               10.04       2.41      19.31       0.08
RESIDUAL ANNUAL WASHOFF(LBS)         2657197.    636736.   5111924.     22393.


   UPSTREAM FLOW WATER QUALITY SUMMARY FOR YEAR  1
BOD =    59768256. #/YR
NBOD=     62601856. #/YR
SS =      662851072. #/YR
PB =        356386. #/YR
NOTE: BOD = 5 DAY BOD
      NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57 * TKN)
```

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979
CUMULATIVE FREQUENCY-MINIMUM DISSOLVED OXYGEN TO 41.00 MILES DOWNSTREAM

DO MIN CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
1.0 OR LESS	119.	33.06	33.06
1.0 TO 2.0	13.	3.61	36.67
2.0 TO 3.0	24.	6.67	43.33
3.0 TO 4.0	29.	8.06	51.39
4.0 TO 5.0	12.	3.33	54.72
5.0 TO 6.0	46.	12.78	67.50
6.0 TO 7.0	58.	16.11	83.61
7.0 TO 8.0	42.	11.67	95.28
8.0 TO 9.0	13.	3.61	98.89
9.0 TO 10.0	4.	1.11	100.00
10.0 TO 11.0	0.	0.0	100.00
11.0 TO 12.0	0.	0.0	100.00
12.0 TO 13.0	0.	0.0	100.00
13.0 TO 14.0	0.	0.0	100.00
14.0 TO 15.0	0.	0.0	100.00
GREATER THAN 15.0	0.	0.0	100.00
TOTAL=	360.		

MINIMUM 3 DAY DISSOLVED OXYGEN = 0.0 MG/L

TIME AVERAGED PERCENT OF STREAM REACH TO 41.00 MILES DOWNSTREAM AT OR BELOW GIVEN DO CONCENTRATION.

DO CONCENTRATION	PERCENT OF STREAM REACH
0.0	7.6167
LESS THAN 1.0	16.4722
LESS THAN 2.0	23.0944
LESS THAN 3.0	30.3833
LESS THAN 4.0	39.1167
LESS THAN 5.0	45.6889
LESS THAN 6.0	54.0778

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979
CUMULATIVE FREQUENCY-MINIMUM DISSOLVED OXYGEN AT 10.00 MILES DOWNSTREAM

DO MIN CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
1.0 OR LESS	95.	26.39	26.39
1.0 TO 2.0	26.	7.22	33.61
2.0 TO 3.0	27.	7.50	41.11
3.0 TO 4.0	12.	3.33	44.44
4.0 TO 5.0	26.	7.22	51.67
5.0 TO 6.0	20.	5.56	57.22
6.0 TO 7.0	43.	11.94	69.17
7.0 TO 8.0	55.	15.28	84.44
8.0 TO 9.0	26.	7.22	91.67
9.0 TO 10.0	14.	3.89	95.56
10.0 TO 11.0	10.	2.78	98.33
11.0 TO 12.0	6.	1.67	100.00
12.0 TO 13.0	0.	0.0	100.00
13.0 TO 14.0	0.	0.0	100.00
14.0 TO 15.0	0.	0.0	100.00
GREATER THAN 15.0	0.	0.0	100.00
TOTAL=	360.		

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

CUMULATIVE FREQUENCY- TOTAL LEAD TO 41.00 MILES DOWNSTREAM

PB CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
0.005 OR LESS	0.	0.0	0.0
0.005 TO 0.010	8.	2.22	2.22
0.010 TO 0.015	94.	26.11	28.33
0.015 TO 0.020	153.	42.50	70.83
0.020 TO 0.025	93.	25.83	96.67
0.025 TO 0.030	6.	1.67	98.33
0.030 TO 0.035	2.	0.56	98.89
0.035 TO 0.040	3.	0.83	99.72
0.040 TO 0.045	0.	0.0	99.72
0.045 TO 0.05	0.	0.0	99.72
0.05 TO 0.06	1.	0.28	100.00
0.06 TO 0.07	0.	0.0	100.00
0.07 TO 0.08	0.	0.0	100.00
0.08 TO 0.09	0.	0.0	100.00
0.09 TO 0.1	0.	0.0	100.00
0.1 TO 0.2	0.	0.0	100.00
0.2 TO 0.3	0.	0.0	100.00
0.3 TO 0.4	0.	0.0	100.00
0.4 TO 0.5	0.	0.0	100.00
GREATER THAN 0.5	0.	0.0	100.00
TOTAL=	360.		

CUMULATIVE FREQUENCY- DISSOLVED LEAD TO 41.00 MILES DOWNSTREAM

PB CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
0.005 OR LESS	0.	0.0	0.0
0.005 TO 0.010	8.	2.22	2.22
0.010 TO 0.015	94.	26.11	28.33
0.015 TO 0.020	153.	42.50	70.83
0.020 TO 0.025	93.	25.83	96.67
0.025 TO 0.030	6.	1.67	98.33
0.030 TO 0.035	2.	0.56	98.89
0.035 TO 0.040	3.	0.83	99.72
0.040 TO 0.045	0.	0.0	99.72
0.045 TO 0.05	0.	0.0	99.72
0.05 TO 0.06	1.	0.28	100.00
0.06 TO 0.07	0.	0.0	100.00
0.07 TO 0.08	0.	0.0	100.00
0.08 TO 0.09	0.	0.0	100.00
0.09 TO 0.1	0.	0.0	100.00
0.1 TO 0.2	0.	0.0	100.00
0.2 TO 0.3	0.	0.0	100.00
0.3 TO 0.4	0.	0.0	100.00
0.4 TO 0.5	0.	0.0	100.00
GREATER THAN 0.5	0.	0.0	100.00
TOTAL=	360.		

MAXIMUM 96 HOUR DISSOLVED LEAD = 0.0308 MG/L
MEAN DISSOLVED LEAD = 0.0179 MG/L

CONTINUOUS STORMWATER POLLUTION SIMULATION SYSTEM
FEBRUARY,1979

CUMULATIVE FREQUENCY--SUSPENDED SOLIDS TO 41.00 MILES DOWNSTREAM

SS CONCENTRATION	NUMBER OF OCCURRENCES	PERCENT OF TIME	CUMULATIVE PERCENT
25 OR LESS	152.	42.22	42.22
25 TO 50	178.	49.44	91.67
50 TO 75	0.	0.0	91.67
75 TO 100	14.	3.89	95.56
100 TO 125	16.	4.44	100.00
125 TO 150	0.	0.0	100.00
150 TO 175	0.	0.0	100.00
175 TO 200	0.	0.0	100.00
200 TO 225	0.	0.0	100.00
225 TO 250	0.	0.0	100.00
250 TO 275	0.	0.0	100.00
275 TO 300	0.	0.0	100.00
300 TO 325	0.	0.0	100.00
325 TO 350	0.	0.0	100.00
350 TO 375	0.	0.0	100.00
375 TO 400	0.	0.0	100.00
400 TO 425	0.	0.0	100.00
425 TO 450	0.	0.0	100.00
450 TO 475	0.	0.0	100.00
475 TO 500	0.	0.0	100.00
GREATER THAN 500	0.	0.0	100.00
TOTAL=	360.		

RECEIVING WATER LOADS FOR YEAR 1

NBOD 199179664. #/YR
CBOD 127645712. #/YR
SUSPENDED SOLIDS 953967360. #/YR
DISSOLVED LEAD 478385. #/YR
SEDIMENT LEAD 0. #/YR
NOTE: NBOD=ULTIMATE NITROGENOUS OXYGEN DEMAND (4.57*TKN)

CBOD=ULTIMATE CARBONACOUS OXYGEN DEMAND

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 430/9-79-004	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE 1978 Needs Survey--Continuous Stormwater Pollution Simulation System-- Users Manual		5. REPORT DATE 10 February 1979
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Ronald L. Wycoff and Michael J. Mara		8. PERFORMING ORGANIZATION REPORT NO. FRD-4
9. PERFORMING ORGANIZATION NAME AND ADDRESS CH2M HILL SOUTHEAST, INC. (formerly Black, Crow and Eidsness, Inc.) 7201 N.W. 11th Place Gainesville, FL 32601		10. PROGRAM ELEMENT NO. 2BG647
		11. CONTRACT/GRANT NO. 68-01-3993
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Municipal Construction Division Office of Water Program Operations Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE 700/02

15. SUPPLEMENTARY NOTES

Project Officer: Philip H. Graham, see also EPA 430/9-79-003 (FRD-3) 1978 Needs Survey--Cost Methodology for Control of CSO and Stormwater Discharges

16. ABSTRACT

A simplified continuous rainfall/runoff/receiving water quality response simulation model is presented. The purpose of this model is to simulate all major urban pollution sources in a simple yet rational manner. Application of the model provides long-term simulation of the total urban system at moderate cost. Processes simulated include rainfall, direct runoff, watershed pollution accumulation and washoff, sewer system infiltration, storage/treatment systems for wet-weather flow, dry-weather WWTP effluent, upstream flow, and receiving water quality response to the combined effects of all the above pollution sources. Pollutants considered are biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), suspended solids (SS), and lead (Pb). Receiving water responses simulated included suspended solids concentrations, minimum dissolved oxygen concentrations, and total and dissolved lead concentrations. The simulation provides a planning tool which may be used to evaluate the long-term water quality impacts of various water quality management alternatives including control of combined sewer overflow and/or urban stormwater runoff.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Simulation Models Rainfall Runoff Stormwater Combined Sewers	Water Quality Water Pollution Control Construction Grants	Drainage Systems Storm Runoff Urban Hydrology Combined Sewer Overflow	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 211
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

INSTRUCTIONS

1. **REPORT NUMBER**
Insert the EPA report number as it appears on the cover of the publication.

2. **LEAVE BLANK**

3. **RECIPIENTS ACCESSION NUMBER**
Reserved for use by each report recipient.

4. **TITLE AND SUBTITLE**
Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific title.

5. **REPORT DATE**
Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected *(e.g., date of issue, date of approval, date of preparation, etc.)*.

6. **PERFORMING ORGANIZATION CODE**
Leave blank.

7. **AUTHOR(S)**
Give name(s) in conventional order *(John R. Doe, J. Robert Doe, etc.)*. List author's affiliation if it differs from the performing organization.

8. **PERFORMING ORGANIZATION REPORT NUMBER**
Insert if performing organization wishes to assign this number.

9. **PERFORMING ORGANIZATION NAME AND ADDRESS**
Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hirearchy.

10. **PROGRAM ELEMENT NUMBER**
Use the program element number under which the report was prepared. Subordinate numbers may be included in parentheses.

11. **CONTRACT/GRANT NUMBER**
Insert contract or grant number under which report was prepared.

12. **SPONSORING AGENCY NAME AND ADDRESS**
Include ZIP code.

13. **TYPE OF REPORT AND PERIOD COVERED**
Indicate interim final, etc., and if applicable, dates covered.

14. **SPONSORING AGENCY CODE**
Insert appropriate code.

15. **SUPPLEMENTARY NOTES**
Enter information not included elsewhere but useful, such as: Prepared in cooperation with, Translation of, Presented at conference of, To be published in, Supersedes, Supplements, etc.

16. **ABSTRACT**
Include a brief *(200 words or less)* factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **KEY WORDS AND DOCUMENT ANALYSIS**
(a) DESCRIPTORS - Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

(b) IDENTIFIERS AND OPEN-ENDED TERMS - Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.

(c) COSATI FIELD GROUP - Field and group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the Primary Field/Group assignment(s) will be specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s)

18. **DISTRIBUTION STATEMENT**
Denote releasability to the public or limitation for reasons other than security for example "Release Unlimited." Cite any availability to the public, with address and price.

19. & 20. **SECURITY CLASSIFICATION**
DO NOT submit classified reports to the National Technical Information service.

21. **NUMBER OF PAGES**
Insert the total number of pages, including this one and unnumbered pages, but exclude distribution list, if any.

22. **PRICE**
Insert the price set by the National Technical Information Service or the Government Printing Office, if known.

☆ U S GOVERNMENT PRINTING OFFICE 1979 -281-147/20