EVALUATION OF THE EFFECTIVENESS OF BMP'S FOR URBAN STORMWATER MANAGEMENT: SINGLE-EVENT SIMULATION

by

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(ABSTRACT)

A desk top model has been developed for "user-friendly" application in personal computers to simulate watershed response to a rainfall event in terms of runoff generation and to estimate nonpoint source pollutant loadings associated with the storm event. The algorithms utilize the SCS TR - 55 method for calculating runoff hydrographs for a single storm event. A methodology has been adapted to generate pollutographs which combines the SCS Type II rainfall distribution with the standard pollutant washoff equations. In addition, this model allows for the design, evaluation, and cost effectiveness analysis of various best management practice (BMP) measures as tools to manage stormwater quantity and quality.

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CHAPTER 1: INTRODUCTION

The environment today is subject to an increasing number of pressures due to rapid development of land. This rapid urbanization has reduced the capacity of the environment to absorb such development by-products as increased air and water pollution. In addition, increased land development has created other pressures on the environment in the form of increased storm runoff, which leads to flooding and channel erosion further downstream. Over a period of years, as grasslands and forests are changed to urbanized areas, peak flood flows produced by storms of a given magnitude may double or even triple (Whipple, et al., 1983).

Urbanization has also led to decreasing water quality of streams and other bodies of water which receive urban stormwater runoff. It has been shown that the increased runoff associated with urbanization also contains increased pollutant loadings (Whipple, et al., 1983). The pollutants present, and their concentrations, are a function of the degree of urbanization, the type of land use, the densities of automobile traffic and animal populations, and the degree of air pollution just prior to a storm event (Whipple, et al., 1983).

Efforts to control the effects of urbanization on the quantity and quality of urban stormwater have centered around best management practices (BMP's). These management strategies range from controlling peak flows during storm events with structural devices such as detention ponds to land use zoning and ordinances which control stormwater discharge at a desirable level.

The primary objective of this study is to develop a methodology to compare various stormwater management strategies on the basis of their impact on runoff and pollutant load at the outlet of a watershed and on the total costs involved. Different management approaches include local placement of different types of BMP facilities as well as combining individual facilities into effective regional programs. In an effort to fulfill this objective, the following sub-objectives were realized:

- Development of methodology to generate runoff hydrographs by the SCS TR - 55 method using personal computers

- Incorporation of pollution washoff processes in conjunction with hydrograph generation to produce pollutographs

- Development of methodology for prediction of hydrographs and pollutographs for pre- and post-development conditions for a watershed and all sub-drainage basins within the watershed using personal computers; these graphs also reflect impact of BMP's on stormwater quantity and quality

- Completion of software package for preliminary design and analysis of BMP's within a watershed in conjunction with a user's manual which includes an example problem

- Application of computer model to a watershed in northern Virginia; model results are compared with monitored data.

A review of literature is presented in Chapter 2. The SCS method for runoff hydrograph generation is presented in Chapter 3. Chapter 4 presents methods for design and analysis of three basic types of BMP structures: detention ponds (dry ponds, wet ponds, and extended wet ponds), porous pavement, and infiltration trenches. Chapter 5 details procedures to calculate pollutographs for the pollutants total N, total PO_4, BOD_5, and total suspended solids. Chapter 6 presents cost relationships developed to facilitate comparison of different stormwater management strategies. Software development is discussed in Chapter 7. Model verification results are presented in Chapter 8. Chapter 9 discusses applications of the software and Chapter 10 summarizes the study and presents conclusions. Appendixes A and B present a user's manual and program listings for the software package developed for use on personal computers to facilitate this analysis.

CHAPTER 2: LITERATURE REVIEW

Efforts to control the effects of urbanization on the quantity and quality of urban stormwater have centered around best management practices (BMP's). These practices can be grouped into at least three categories: structural, non-structural, and regulatory (Wanielista, 1979). Structural BMP's include detention ponds, infiltration devices, grassed swales, and rooftop detention. Structural devices have been found effective in reducing peak storm flows, runoff volumes, and in controlling pollution loads from urban stormwater. Non-structural controls attempt to treat urban pollution at its origin and include street sweeping and catch basin flushing (Wanielista, 1979), land use zoning, and other ordinances. Regulatory activities control and manage urban pollution by allowing discharge only in designated areas. This study focuses on the use of structural BMP's for stormwater management; a treatment of institutional stormwater management issues in Virginia can be found in Cox (1986). Non-structural approaches such as street sweeping were found to be relatively ineffective in controlling stormwater quality (Wanielista, 1979) and were thus not considered in this study.

Impoundment of storm flows has long been a popular stormwater management strategy. These impoundments, referred to as detention ponds, are typically designed to control short, high-intensity local storms which typically cause the most frequent flooding (Whipple, et al., 1983). Detention ponds release stormwater gradually, which greatly reduces the peak flow of hydrographs for points just below the structure; the peak-shaving effect diminishes as the flow travels downstream. Thus, the larger the storage capacity of the pond the greater the effect downstream (Whipple, et al., 1983). The continuity equation is used to route an inflow hydrograph through the detention facility; this procedure is treated in most standard texts (Chow, 1964; Viessman, 1977).

Infiltration structures for stormwater management are relatively new undertakings. These management strategies do not have as great an impact on peak flow reduction as other controls such as detention ponds and therefore have not gained wide recognition (Maryland Dept. of Nat. Resources, 1984). Infiltration practices focus on controlling total runoff volume and are particularly useful for controlling runoff quantity from highly impervious areas such as parking lots and streets. The infiltration practices examined in this study, i. e. infiltration trenches and porous pavement, control runoff quantity by temporarily storing precipitation excess in small underground reservoirs from which it is allowed to infiltrate into the surrounding soil media. Thus, infiltration devices also enhance the water supply because they allow precipitation to percolate back into the soil. There exists, however, widespread concern that the use of infiltration practices for stormwater management may result in widespread contamination of the soil and groundwater (Maryland Dept. of Nat. Res., 1984). The Environmental Protection Agency (1980) has developed criteria for onsite wastewater treatment that specify a minimum distance between the bottom of the infiltration practice and the seasonal high water table; adoption of these criteria in infiltration facility design helps ensure that the benefits derived from these stormwater management practices exceed potential disadvantages (Maryland

Dept. of Nat. Res., 1984). The Maryland Department of Natural Resources published in 1984 the most comprehensive treatment of infiltration practices to date.

Increased urbanization has led to serious degradation of waters receiving urban runoff; this problem has received much attention in recent stormwater management literature (Biggers, et al., 1980; Whipple, et al., 1983; Wanielista, 1979). Transition from stormwater management strategies which control only runoff quantity to dual purpose strategies to manage stormwater quality and quantity has gained attention as a method to control some of the problems caused by increased urbanization (Biggers, et al., 1980; Whipple, et al., 1983). Biggers and others have shown that increasing runoff retention time in conventional detention ponds significantly increases the pollutant trap efficiency of the facility. Increased storage time allows more particulates to settle out; many other types of pollutants are often attached to sediment in storm runoff. The pollutant removal capacity of detention ponds also depends on the type of pond, land uses upstream, and type of pollutant. Pollutant removal efficiencies of different types of BMP facilities for various types of pollutants can be found in studies done by Schueler, et al., (1985), and the Northern Virginia Planning District Commission (1979).

Volume control stormwater management strategies such as the infiltration practices examined in this study typically provide high pollutant removal from stormwater. Many types of pollutants, such as organic and biological pollutants, are removed from stormwater by natural, physical, chemical, and biological processes as it filters through the soil profile beneath the structure (Biggers, et al., 1980). The degree of pollutant removal achieved by infiltration practices thus depends on the type of pollutants and properties of the soil beneath the facility.

Thus, prediction of peak flows during storm events is an aspect of hydrology critical to effective stormwater management. A widely used tool for the analysis of watershed response to rainfall is the hydrograph. A hydrograph is defined as a graphical representation of the magnitude and time distribution of streamflows (Viessman, 1977). Hydrographs include the integrated contributions from surface runoff, interflow, groundwater flow, and channel precipitation. Climatic factors and topographic and geologic features influence the shape of hydrographs (Gray, 1970). Hydrographs are generally empirically separated into at least two components; base flow and direct runoff are most common. Base flow hydrographs represent the normal day-to-day flow and result primarily from the groundwater contributions to streamflow (Viessman, 1977). Direct runoff results from precipitation excess after abstractions of rainfall have been deducted. Storage of rain in small depressions on the ground surface and infiltration of rain into the soil constitute some of the continuous abstractions that reduce the amount of precipitation available for runoff. Hydrographs, therefore, represent with a single curve the extremely complex processes by which precipitation contributes to streamflow. Hydrograph methods for modelling this process are considered "black box" techniques and do not depend on physical laws but on observed response functions (Raudkivi, 1979).

Many methods exist for predicting peak flow using hydrograph techniques. These methods are divided into two categories based on watershed size: those for large watershed analysis and those for small watershed analysis. A small watershed is defined by Gray, et al., (1970) as an area in which time involved in overland flow is significant and therefore cannot be neglected; a large watershed is defined as an area in which time of travel by surface runoff in channel flow predominates, being much greater than the travel time in overland flow. The smaller the watershed, the more accurate the runoff prediction (Whipple, et al., 1983). In addition, the ideal case for small basin analysis is a uniform rainfall falling on a flat plate (Whipple, et al., 1983). Since this situation rarely occurs in nature, techniques were developed for hydrographs from multiperiod rainfall. The Rational Method is one of the most widely used techniques for small watershed analysis; synthethic unit hydrograph techniques are popular for large watersheds. Most of these techniques are treated in standard hydrology texts (Viessman, 1977; Chow, 1964; Wanielista, 1979). The methods developed by the U. S. Soil Conservation Service (SCS) were originally for use on small urban watersheds (SCS TR - 55,1975) but can be applied to both types of watersheds. Their applicability to large catchments is based on a summation of smaller sub-basin hydrographs (Whipple, et al., 1983). The SCS tabular method, discussed in the SCS Technical Release 55 (1975), is presented in this study.

Pollutographs, similar to hydrographs, represent dynamic pollutant loadings during storm events and are therefore useful tools for evaluating alternate stormwater management strategies. Pollutographs are especially useful for analysis of small watersheds where first flush effects are evident. The first flush effect concentrates pollutant loads in the first part of runoff waters (Whipple, et al., 1983) and results because there are often large quantities of loosely attached materials on impervious surfaces; these materials are easily washed off and transported during the early part of a storm event. In larger basins, the interactions and time delays of subbasins produce somewhat random concentrations (Whipple, et al., 1983). Wanielista, 1979, published procedures for pollutograph calculation which assume that the amount of pollutants washed off the ground surface in any time interval is proportional to the amount of pollutants remaining on that surface.

CHAPTER 3: HYDROGRAPH GENERATION

INTRODUCTION

The SCS methods for estimation of hydraulic and hydrologic parameters used in the development of runoff volumes and peak rates of discharge in small urban and urbanizing areas has gained widespread popularity because of their easy-to-apply approach (McCuen, 1982). In addition, these methods are far more comprehensive and cover a far wider range of conditions than the Rational Method. Differences in land uses, soil types, and vegetative cover are reflected in the runoff quantity calculated by these methods, which produce a complete hydrograph as well as giving peak flow and runoff volume.

RAINFALL

The SCS methods are based on regional rainfall distributions for a given frequency storm. These dimensionless distributions are for a 24-hour time period because of the general availability of daily rainfall data which can be used to estimate 24-hour rainfall amounts (SCS TR-55, 1975). The National Weather Service publishes the most current 24-hour rainfall data; Figure 1 shows a typical map prepared by this agency which can be used to estimate total precipitation in inches in 24 hours for a 10-year storm. The SCS rainfall distributions were developed using incremental rainfall depths based on the generalized rainfall-depth-duration-frequency relationships given in publications by the Weather Bureau. Because all of the critical storm depths are contained within the storm distributions, these methods are applicable to both small and large watersheds (McCuen, 1982). In addition, since a total rainfall amount in 24 hours is used for design, the hydrographs produced by the SCS method are composite hydrographs reflecting rainfall amounts of varying intensity within the 24 hour period.

The SCS developed two regional distributions: Type I, intended for Hawaii, Alaska, and the coastal side of the Sierra Nevada and Cascade Mountains; Type II, intended for the remainder of the United States, Puerto Rico, and the Virgin Islands. Table 1 presents the type II rainfall distribution used in this study.

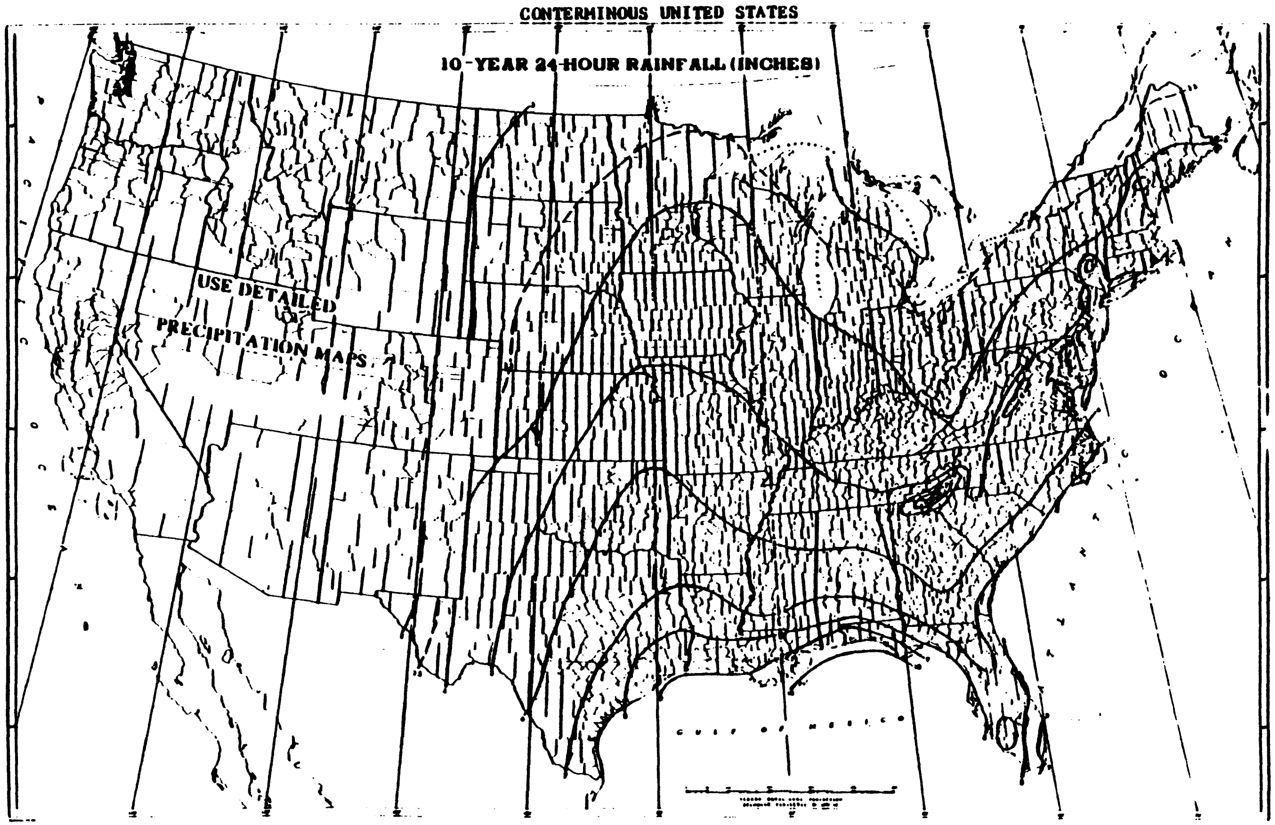

Figure 1. 10-Year 24-Hour Rainfall (SCS TR - 55, 1975; prepared by U. S. Weather Bureau)

Table 1. SCS Type II 24-hour Rainfall Distribution

STORM TIME (HOURS)	CUMULATIVE PRECIPITATION RATIO	STORM TIME (HOURS)	CUMULATIVE PRECIPITATION RATIO
0.0	0.0000	12.5	0.7351
0.5	0.0053	13.0	0.7724
1.0	0.0108	13.5	0.7989
1.5	0.0164	14.0	0.8197
2.0	0.0223	14.5	0.8380
2.5	0.0284	15.0	0.8538
3.0	0.0347	15.5	0.8676
3.5	0.0414	16.0	0.8801
4.0	0.0483	16.5	0.8914
4.5	0.0555	17.0	0.0919
5.0	0.0632	17.5	0.9115
5.5	0.0712	18.0	0.9206
6.0	0.0797	18.5	0.9291
6.5	0.0887	19.0	0.9371
7.0	0.0984	19.5	0.9446
7.5	0.1089	20.0	0.9519
8.0	0.1203	20.5	0.9588
8.5	0.1328	21.0	0.9653
9.0	0.1467	21.5	0.9717
9.5	0.1625	22.0	0.9777
10.0	0.1808	22.5	0.9836
10.5	0.2042	23.0	0.9892
11.0	0.2351	23.5	0.9947
11.5	0.2833	24.0	1.0000
12.0	0.6632		

Source: McCuen, 1982.

RAINFALL-RUNOFF RELATIONSHIP

The relationship between rainfall and runoff, shown in Figure 2, is given by :

$$F/S = Q/(P - I_a) \quad (1)$$

where:

F = volume of water in retention

S = potential maximum retention

Q = total volume of runoff (inches)

P = total storm rainfall in 24 hours (inches)

I_a = initial abstraction

The actual retention, defined as the difference between precipitation volume and the initial abstraction, combined with Equation (1) yields the SCS equation for predicting runoff volume, given by Equation (2).

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad (2)$$

The initial abstraction, I_a, which accounts for all precipitation losses before runoff begins, is related to the maximum potential retention, S, through the following relationship for a Type II storm distribution:

$$I_a = 0.2\ S \tag{3}$$

The SCS found that the potential maximum retention, S, can be estimated empirically by the relationship:

$$S = 1000/CN - 10 \tag{4}$$

The curve number (CN) represents the hydrologic soil groups, land uses, and soil treatment and hydrologic condition of the soil for a given area. Soils are grouped into four hydrologic soil types (A, B, C, and D) by their minimum infiltration rate. Hydrologic soil type A corresponds to soils with high rates of water transmission which allows for low runoff potential. Similarly, soils classified as hydrologic soil type D have very slow rates of water transmission and therefore have a high runoff potential. Land use possibilities reflected by the curve number range from highly urban areas such as industrial areas to highly pervious areas such as forests and meadows. This study used the expanded curve number table incorporating 78 land use possibilities given in the as yet unpublished revision to the 1975 version of SCS TR - 55. Land uses possibilities are further divided by soil treatment, ground cover, and hydrologic condition of the soil. These criteria reflect the water infiltration capacity of the soil. The curve number also reflects the antecedent moisture condition of the soil, which has significant effect on both the volume and rate of runoff (McCuen, 1982).

For watersheds which contain more than one land use type, this study proposes calculation of a weighted curve number for use in Equation (4).

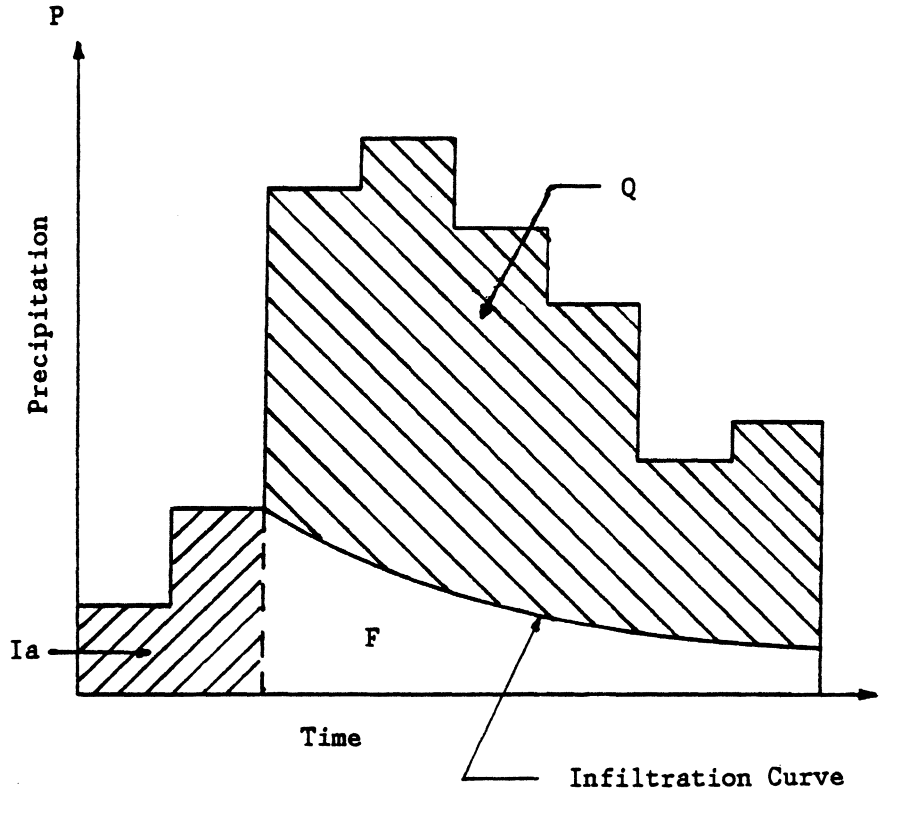

Figure 2. Relationship Between Precipitation, Runoff, and Retention (SCS TR - 55, 1975)

Weighting is based on soil types within each land use and on the percentage of total area taken up by each land use type. Equation (5) presents the relationship used to calculate a weighted curve number.

$$RCN = \sum_{i=1}^{N} CN_i \times area_i \Big/ \sum_{i=1}^{N} area_i \tag{5}$$

where:

- RCN = weighted runoff curve number
- CN_i = curve number for land use type i
- $area_i$ = area corresponding to land use type i
- Σ area = total area in watershed or sub-drainage basin

TIME OF CONCENTRATION

The time of concentration is defined as the time for a particle of water to travel from the hydrologically most distant point in the watershed to the point of interest. This parameter is important in hydrograph analysis because it has been shown to have significant impact on the shape and peak of the hydrograph (Lazaro, 1979). The time of concentration is computed by calculating the travel time of a particle of water through the various methods of runoff transport in the watershed. This study used the upland method (McCuen, 1982) to calculate these travelling times; this method is expressed by Equation (6).

$$T = l / V \qquad (6)$$

where:

l = hydraulic flow length

V = velocity

T = travel time for flow transport element

Velocity is estimated based on land use and slope for overland flow; Figure 3 presents the widely used SCS relationships for overland flow which were followed in this study. Manning's equation, given by Equation (7), is used for sewer, gutter, and channel flow.

$$V = (1.49\, r^{2/3}\, s^{1/2}) / n \qquad (7)$$

where:

V = average velocity (ft/s)

r = hydraulic radius (ft)

s = slope of the hydraulic gradient (feet/foot)

n = Manning's "n" value, a roughness coefficient

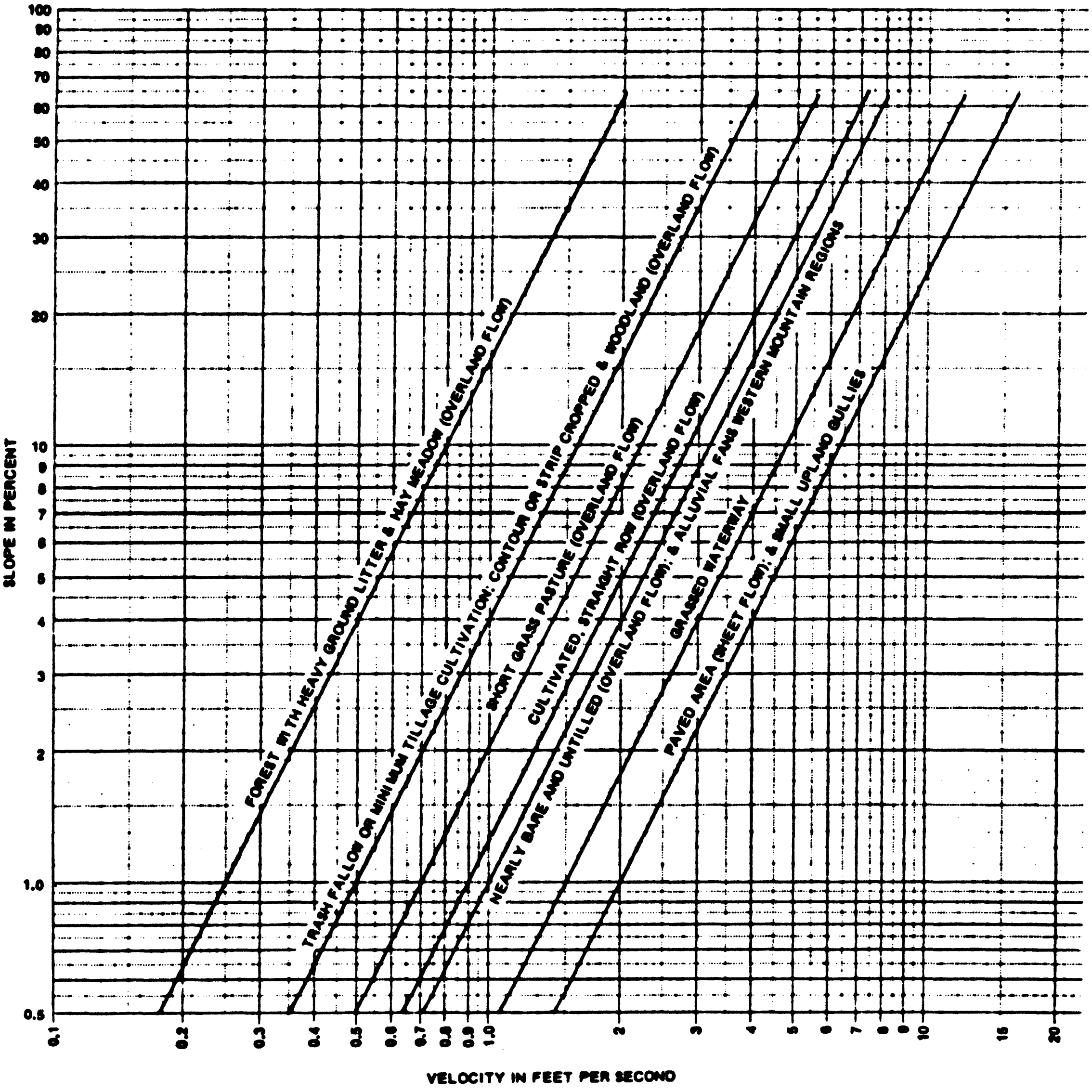

Figure 3. SCS Overland Flow Velocities (SCS TR - 55, 1975)

TIME OF TRAVEL

The time of travel is a parameter used when developing composite hydrographs for a watershed containing several sub-drainage basins. Travel time is defined as the time it takes a water particle to travel from the outlet of the sub-drainage basin to the outlet of the watershed. The time of travel is calculated using the relationships given in Equations (6), (7) and Figure 3. The travel times for the various transport elements are summed to find a total time of travel for the sub-basin.

CALCULATION OF HYDROGRAPHS

The SCS tabular method used in this study facilitates calculation of partial composite hydrographs for points of interest in a watershed. This flexibility makes this method extremely useful for analyzing the effects of best management practices (BMPs) such as land use management through zoning and detention facilities on the quantity and quality of stormwater at different points in a watershed. SCS TR-55 provides computer generated tables of hydrograph ordinates for a variety of combinations of times of concentration and travel. These ordinates are given in units of cfs/square mile/inch of runoff for hydrograph times ranging from 11.0 hours to 20.0 hours in different time increments. Thus, runoff hydrographs for points of interest within a watershed may be calculated using the following relationship:

$$q_t = q\ A\ Q \tag{8}$$

where:

q_t = hydrograph ordinate (cfs) at hydrograph time t

q = tabular hydrograph ordinate (cfs/square mile/inch of runoff)

A = drainage area of individual sub-drainage basin (square mile)

Q = total runoff volume or rainfall excess (inches)

Composite watershed hydrographs are computed by linearly combining the hydrograph ordinates from each sub-drainage area at the outlet of the watershed as follows:

$$q_{c,t} = \sum_{i=1}^{N} q_{i,t} \tag{9}$$

where:

$q_{c,t}$ = composite hydrograph ordinate at time t

$q_{i,t}$ = hydrograph ordinate at time t for sub-drainage area i

Linear combination of hydrographs generated for different sub-drainage areas at a point of interest using the relationship given by Equation (9) is a feature unique to the SCS tabular method. A common time base for linear combination at a single point is inherent in this method since all hydrograph ordinates are calculated using the computer generated tabular hydrograph ordinates given by the term "q" in Equation (8).

These ordinates have been tabulated by taking into consideration times of concentration and travel times.

CHAPTER 4: BMP DESIGN AND ANALYSIS

DETENTION PONDS

The detention basins examined in this study can be classified by the length of time water is retained. It has been shown that the length of stormwater retention time greatly affects the quality of the stormwater as it leaves the facility (Biggers, et al., 1980; Whipple, et al., 1983). Dry ponds and wet ponds are primarily peak shaving devices which retain stormwater for a short period of time. Dry ponds eventually completely release all stormwater; wet ponds, however, retain a permanent pool of water below elevations used for peak flow control. Extended wet ponds are larger facilities that impound water for a time sufficient to achieve high pollutant removal from the stormwater. The design procedure used for all three types of detention ponds, however, is the same and is presented below.

DESIGN AND EVALUATION

The first step in detention basin design is the calculation of a hydrograph for the flow into the pond. The methods described in Chapter 3 are used to calculate a runoff hydrograph for the area within a sub-drainage basin which contributes flow to the proposed pond site. The inflow hydrograph is routed through the detention pond using the storage indication working curve method, which assumes that the outflow from the pond is directly proportional to the storage in the basin. Figure 4 depicts the basic assumptions used in the derivation of this method, expressed mathematically by Equation (10).

$$I_1 + I_2 + 2S_1 / \Delta t - O_1 = 2S_2 / \Delta t + O_2 \qquad (10)$$

where:

I_1, I_2 = inflow rates at times 1 and 2, respectively

O_1, O_2 = outflow rates and times 1 and 2, respectively

S_1, S_2 = storage volume at times 1 and 2, respectively

Δt = time interval

The unknowns storage volume and outflow, S_2 and O_2, respectively, in Equation (10) are determined by Equation (10) and another equation which relates the outflow rating curve and storage versus elevation data; this data is supplied by the designer.

The hydrograph for outflow from the detention basin must be lagged with respect to time before combination with hydrographs calculated for other areas contributing flow to the sub-basin outlet to form revised sub-basin and composite watershed hydrographs. Lagging is necessary to accurately reflect the effect ponding has on the runoff hydrograph because hydrographs generated by the SCS method are extremely sensitive to time for their shape. The simple relationship used to lag the outflow hydrograph from detention facilities is given by:

$$\text{Lag time} = T_{p\ out} - T_{p\ in} + T_{travel} \tag{11}$$

where:

$T_{p\ out}$ = time to peak of outflow hydrograph

$T_{p\ in}$ = time to peak of inflow hydrograph

T_{travel} = time of travel

The time of travel, T_{travel}, in Equation (11) is measured from the outlet of the detention pond to the outlet of the sub-basin for calculation of sub-basin hydrographs; for composite watershed hydrographs, travel time is measured from the outlet of the detention pond to the outlet of the entire watershed. The lagged outflow hydrograph is then linearly combined with the previously calculated hydrograph for the sub-drainage area or for the composite watershed as follows:

$$q_{r,t} = q_t - q_{prebmp,t} + q_{out,t} \tag{12}$$

where:

$q_{r,t}$ = revised hydrograph ordinate at time t

q_t = pre-BMP hydrograph ordinate for sub-basin at time t

$q_{prebmp,t}$ = pre-BMP hydrograph ordinate for detention pond drainage area at time t

$q_{out,t}$ = lagged outflow hydrograph ordinate for detention pond at time t

The revised sub-basin hydrographs calculated by Equation (12) can then be linearly combined using the relationship given in Equation (9) to produce a composite hydrograph for the watershed which reflects the presence of detention ponds.

INFILTRATION STRUCTURES

Two types of infiltration structures used for stormwater management are examined in this study: infiltration trenches and porous pavement. An infiltration trench is defined as a subsurface trench that is used to temporarily store runoff in a stone-filled reservoir; runoff then exfiltrates through the surrounding soil media. The surface of the trench consists of either a stone covered area or a grass covered area with an inlet (See Figure 5) (Maryland Dept. of Nat. Resources, 1984). Porous pavement, depicted in Figure 6, is defined as a low density, permeable asphalt surface in which water is rapidly transmitted to an aggregate reservoir subbase for storage. Water then infiltrates into the surrounding soil media (Maryland Dept. of Natural Resources, 1984). Thus, infiltration structures control runoff volume and quality and augment groundwater supplies and do not focus as much on peak flow reduction.

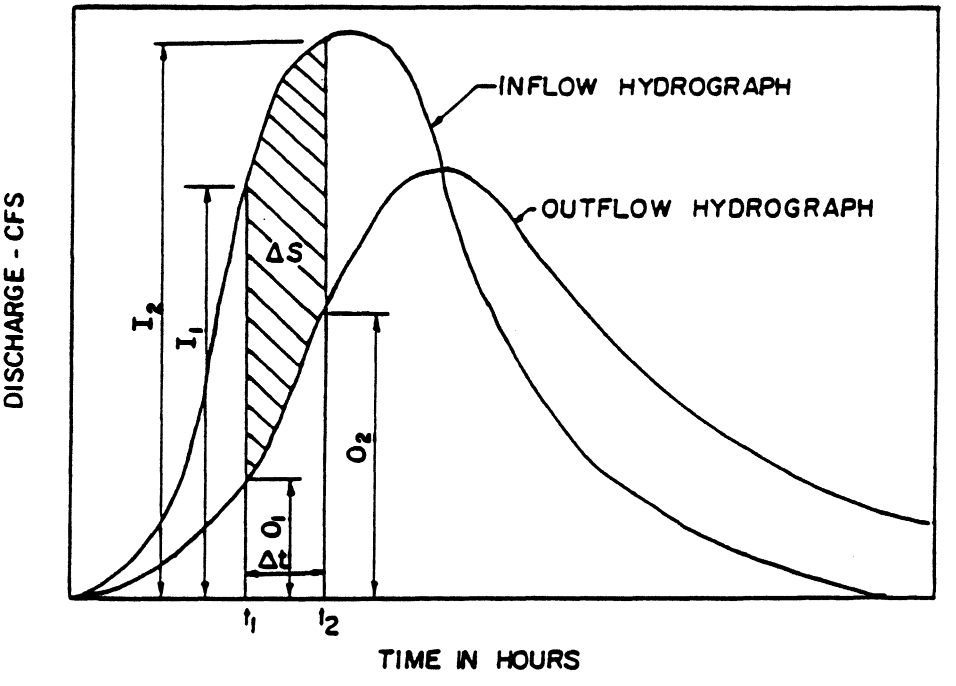

Figure 4. Derivation of Storage for Storage - Indication Working Curve Method

FEASIBILITY CRITERIA

The applicability of infiltration devices for stormwater management depends on subsurface conditions at the proposed site. To design an infiltration device effectively, the following information is required (Maryland Dept. of Nat. Resources, 1984):

- Textural character of the soil media in the subsoil profile
- Location of seasonal high groundwater table
- Depth to bedrock

The methods presented in this study are based on two hydrological soil properties: the effective water capacity and the minimum infiltration rate of the soil surrounding the infiltration structure. The effective water capacity of a soil is the fraction of the void spaces available for water storage. The minimum infiltration rate is the final rate that water flows through soil during saturated conditions (Maryland Dept. of Nat. Resources, 1984). Table 2 shows the criteria used in this study. It has been found that soils with minimum infiltration rates of 0.17 inches per hour or less are not suitable for infiltration structures (Maryland Dept. Nat. Resources, 1984).

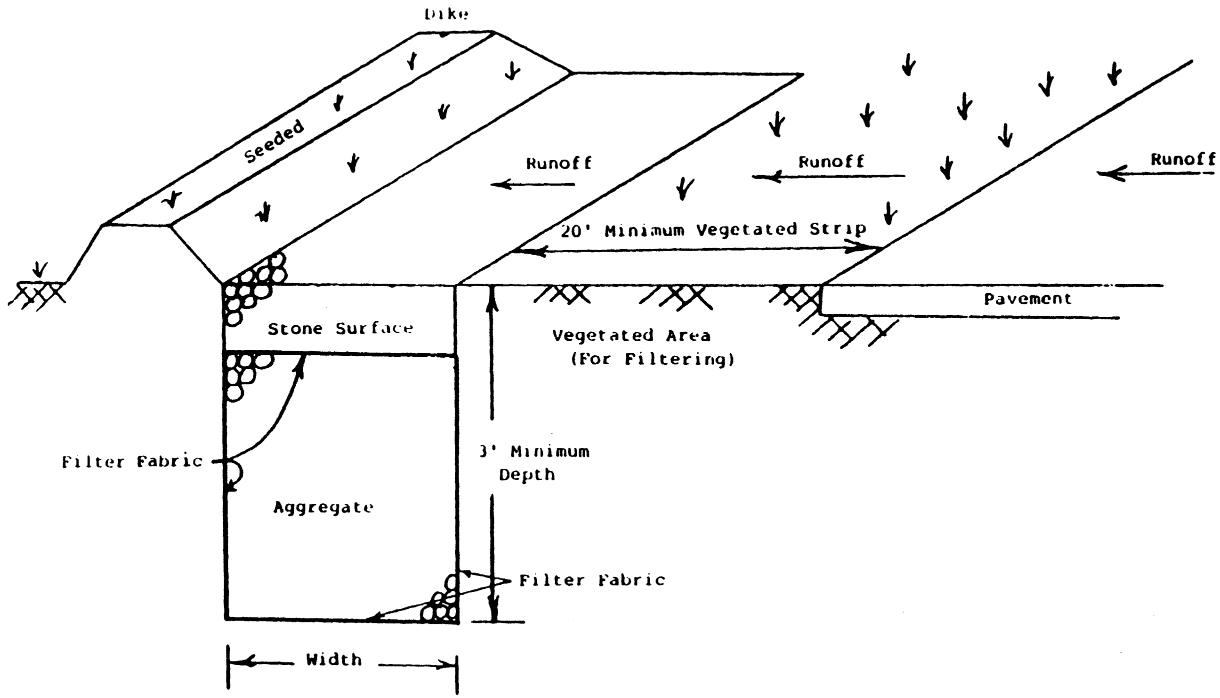

Figure 5. Typical Infiltration Trench (Maryland Department of Natural Resources, 1984)

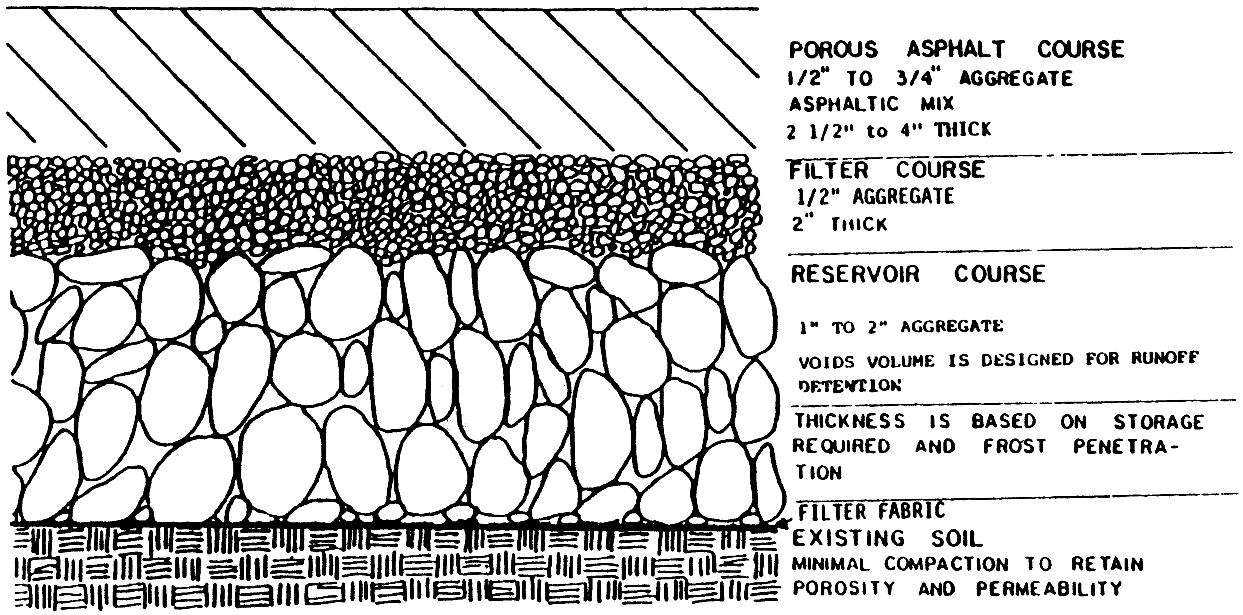

Figure 6. Typical Porous Pavement (Maryland Department of Natural Resources, 1984)

Table 2. Hydrologic Soil Properties

TEXTURE CLASS	EFFECTIVE WATER CAPACITY (IN/IN)	MINIMUM INFILTRATION RATE (IN/HR)	HYDROLOGIC SOIL GROUPING
Sand	0.35	8.27	A
Loamy Sand	0.31	2.41	A
Sandy Loam	0.25	1.02	B
Loam	0.19	0.52	B
Silt Loam	0.17	0.27	C
Sandy Clay Loam	0.14	0.17	C
Clay Loam	0.14	0.09	D
Silty Clay Loam	0.11	0.06	D
Sandy Clay	0.09	0.05	D
Silty Clay	0.09	0.04	D
Clay	0.08	0.02	D

Source: Maryland Department of Natural Resources, 1984.

Another design criterion for the effectiveness of infiltration stormwater control measures is determining the safe distance between the bottom of the structure and the location of the seasonal high water table (Maryland Dept. Nat. Resources, 1984). This distance is necessary to prevent flooding of the infiltration structure during periods of water table rise. In addition, soil between the bottom of an infiltration structure and the top of the water table traps pollutants present in stormwater; stormwater filtration through a layer of soil eliminates part of the risk of groundwater contamination. The distance limitation used in this study follows the Environmental Protection Agency's (EPA) limitations for onsite wastewater treatment and disposal systems. Their standard specifies that a 2 to 4 foot distance be maintained between the bottom of the system and the water table or bedrock (EPA, 1980). Thus, this study used a minimum 2 foot distance between the bottom of the structure and the watertable or bedrock in the design procedures presented.

A further criterion for installation of infiltration devices for stormwater management is a maximum allowable storage time within the stone subsurface reservoir (Maryland Dept. of Nat. Res., 1984). The Maryland Department of Natural Resources in their Standards and Specifications for Infiltration Practices limits this time to 3 days or 72 hours; their criterion was used in this study. The maximum design depth of the infiltration trench or porous pavement stone reservoir is given by:

$$d_s = f\, T_s / V_r \qquad (13)$$

where:

d_s = maximum depth of stone reservoir

f = minimum infiltration rate of soil surrounding aggregate reservoir

T_s = maximum allowable storage time (72 hours)

V_r = void ratio of stone aggregate reservoir

DESIGN AND EVALUATION

Once a suitable site has been selected based on the criteria given in the previous section, the amount of runoff volume to be handled by the infiltration device can be estimated using Equation (14) (Maryland Dept. of Nat. Res., 1984); this relationship is depicted in Figure 7.

$$V_w = \Delta Q_u A_u + PA_s - fTA_s \tag{14}$$

where:

V_w = volume of water that must be stored in the stone reservoir (cubic feet)

ΔQ_u = rainfall excess draining into BMP facility (inches)

A_u = area which drains into BMP facility site

P = precipitation

A_s = surface area of the structure

f = infiltration rate (in/hr) of soil surrounding stone reservoir

T = stone reservoir filling time (value of 2 hours found for designs based on SCS type II rainfall distribution)

The first term on the right hand side of Equation (14) represents the runoff volume from the area draining into the infiltration control site; the second term represents the volume of water that falls on the surface area of the structure. The third term in Equation (14) represents the runoff volume that exfiltrates from the bottom of the aggregate reservoir of the control structure. The SCS method outlined in Chapter 3 is used to estimate runoff to the BMP site. Data such as land uses, soil types, and traveling times must be collected for the area draining into each infiltration site.

Equation (15) relates the structure geometry to the amount of rainfall and runoff entering the infiltration structure (Maryland Dept. of Nat. Resources, 1984):

$$V_s = V_w / V_r = d_s A_s \tag{15}$$

where:

V_s = gross volume of the infiltration structure

V_r = void ratio of aggregate reservoir

d_s = depth of aggregate reservoir

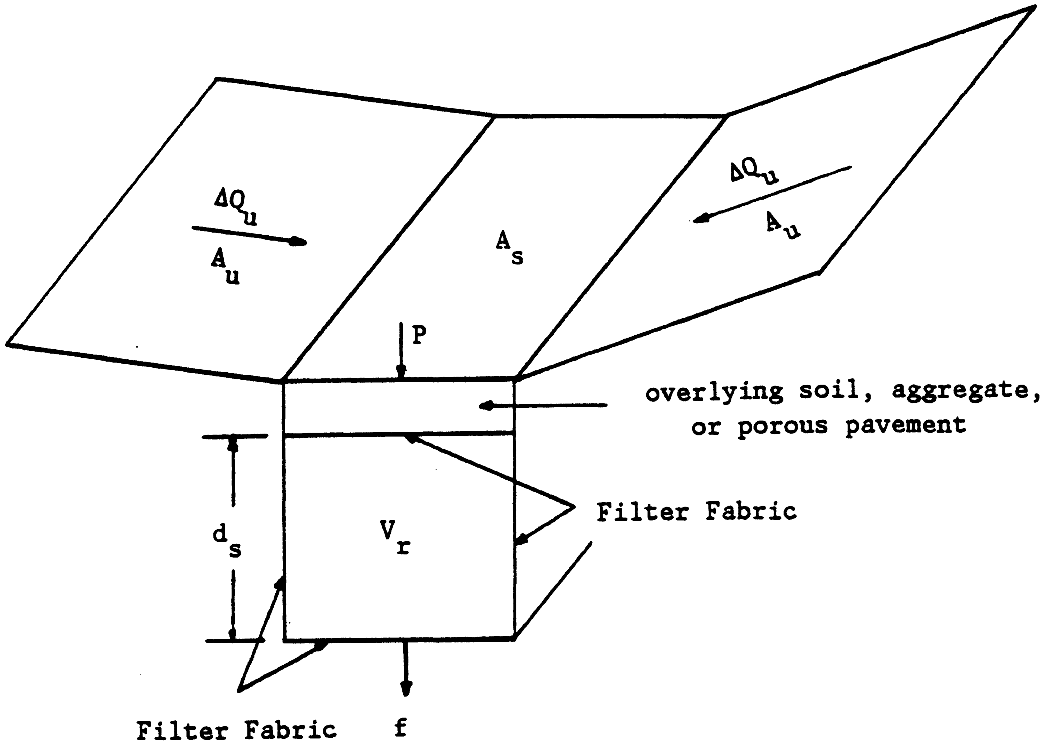

Figure 7. Schematic of Infiltration Practices (Maryland Department of Natural Resources, 1984)

Combining Equations (14) and (15) yields the equation used for design of infiltration structures:

$$d_s A_s V_r = \Delta Q_u A_s + P A_s - f T A_s \tag{16}$$

Equation (16) may be solved based on feasibility criteria and geometric limitations as specified by the designer.

The performance of infiltration controls such as porous pavement and infiltration trenches can be derived by revising runoff hydrographs. Prior to BMP installation, the runoff volume from the sub-basin is estimated using the SCS method. After the structure design has been finalized, a runoff hydrograph is calculated based on the amount of runoff removed by the infiltration structure. This hydrograph is then combined with the pre-BMP hydrograph for the sub-basin to produce a revised sub-basin hydrograph which reflects the presence of the BMP facility using the relationship given by Equation (17):

$$q_{r,t} = q_t - q_{BMP,t} \tag{17}$$

where:

$q_{r,t}$ = revised sub-basin hydrograph ordinate at time t

q_t = sub-basin hydgrograph ordinate prior to BMP installation at time t

$q_{BMP,t}$ = runoff hydrograph ordinate based on runoff removed by structure at time t

The revised sub-drainage hydrographs can then be linearly combined using the relationship given in Equation (9) to produce a composite hydrograph for the watershed which reflects the presence of infiltration stormwater control facilities. The relationships given by Equations (9) and (17) are valid for hydrographs calculated with a common time base.

CHAPTER 5: POLLUTOGRAPH GENERATION

INTRODUCTION

Water quality impacts from stormwater must also be considered when planning stormwater management strategies. Pollutographs, which represent dynamic pollutant loadings during storm events, aid in evaluating stormwater management alternatives. A methodology for pollutograph generation is given in the following discussion.

METHODOLOGY

This study uses a methodology for pollutograph generation that combines the SCS rainfall distributions with the standard pollutant washoff equations. Pollutant accumulation and subsequent washoff are simulated separately for the watershed's pervious and impervious areas. Pollutant washoff is estimated by assuming that the amount of pollutants washed off in any time interval is proportional to the amount of pollutants remaining:

$$\frac{dP}{dt} = -kP \qquad (18)$$

which integrates to

$$P_o - P = P_o(1 - e^{-kt}) \qquad (19)$$

where:

P_o = initial pollutant loading (pounds)

P = mass remaining after time t

k = constant

t = time

$P_o - P$ = mass washed away in time t

Initial pollutant loadings are functions of population densities, precipitation, land uses, and other variables. Several methods such as the popular SWMM level I analysis (Wanielista, 1980) exist for estimation of initial pollutant loadings. This study assumes that the total mass of pollutants which has accumulated on the ground surface during dry days is a weighted value resulting from different loading rates for different land use types within a watershed. This relationship is given in Equation (20):

$$P_i = \Sigma (p_j \times \%area_j) \qquad (20)$$

where:

P_i = initial pollutant loading per day

p_j = mass loading rate for land use type j

$\%area_j$ = percentage of area of land use type j which is either pervious or impervious

Equation (20) is applied to both impervious and pervious areas in each sub-basin within the watershed to obtain separate pollutant accumulations. Table 3 and Table 4 , adapted from a study done by Biggers, et al., (1980), show typical pollutant accumulation rates for the Northern Virginia area in pounds/acre/day. Table 5 shows the fraction of impervious area in each land use used in this study.

The constant, k, in Equation (19) is a function of runoff and was determined by assuming that a uniform runoff of 0.5 in/hr will wash off 90% of the initial pollutant load in one hour (originally discussed in the EPA's SWMM model and cited by Wanielista (1980)). Thus, Equation (19) becomes

$$P_o - P = P_o(1 - e^{-4.6rt}) \quad \text{for impervious areas} \qquad (21)$$

$$P_o - P = P_o(1 - e^{-1.4rt}) \quad \text{for pervious areas} \qquad (22)$$

where:

r = rainfall excess (in/hr)

Table 3. Typical Pollutant Loading Rates--Urban Land Uses

LAND USE	POLLUTANT LOADING RATE (LBS/ACRE/DAY)							
	TSS		BOD		N		P	
	PRV	IMPV	PRV	IMPV	PRV	IMPV	PRV	IMPV
Single Family Residential:								
Estate (.05-0.2 DU/Ac)	1.2	2.2	.07	.13	.011	.04	.0014	.004
Large Lot (.5-2 DU/Ac)	1.0	5.5	.13	.20	.02	.08	.0035	.01
Medium Density (3-6DU/Ac)	1.0	5.5	.13	.20	.02	.08	.0035	.01
Townhouses & Apartments	2.0	5.5	.26	.20	.04	.08	.007	.01
High Rise Residential	0.7	3.5	.07	.63	.011	.05	.0017	.006
Institutional	0.7	2.5	.07	.35	.011	.05	. 0017	.006
Industrial	0.7	2.5	.07	.63	.011	.09	.0017	.01
Suburban Shopping Center	0.7	2.5	.07	.63	.011	.05	.0017	.006
Central Business District	0.7	2.5	.07	.76	.011	.09	.0017	.01

Adapted from Biggers, et al., 1980.

Table 4. Typical Pollutant Loading Rates--Agricultural Land Uses

LAND USE	POLLUTANT LOADING RATE (LBS/ACRE/DAY)							
	TSS		BOD		N		P	
	PRV	IMPV	PRV	IMPV	PRV	IMPV	PRV	IMPV
Idle land	1.0	0.5	.034	.09	.008	.015	.0005	.0013
Pasture	1.5	0.5	.35	.09	.047	.015	.047	.0013
Forest (Jan - Sept)	1.0	0.5	.036	.09	.006	.015	.0004	.0013
Forest (Oct - Dec)	2.0	0.5	.048	.09	.0084	.015	.0005	.0013

Adapted from Biggers, et al., 1980.

where: TSS = total suspended solids; BOD = biological oxygen demand

N = total nitrogen ; P = total phosphorus

PRV = pervious area loading rate

IMPV = impervious area loading rate

Table 5. Impervious Area by Land Use

LAND USE	PERCENT IMPERVIOUS AREA
Streets and Roads: Gravel or dirt	50
Commercial and Business Areas	85
Industrial Districts	72
Townhouses/Apartments	65
Residential:	
1/4 acre lot size	38
1/3 acre lot size	30
1/2 acre lot size	25
1 acre lot size	20
2+ acre lot size	12
Paved areas, etc.	100
All others (e.g. agricultural, forest, etc.)	1

Adapted from SCS TR - 55, 1975.

To account for the fact that the runoff rate is usually not constant for a storm event, the rainfall excess term, r, in Equations (21) and (22) is calculated over each time interval to obtain an average value as follows:

$$r = \Delta Q / \Delta t \qquad (23)$$

Rainfall excess is calculated for pervious and impervious areas separately. The runoff term in Equation (23), ΔQ, is computed using the SCS runoff equations (Equations (2) and (3)). The curve number in Equation (3) is assigned for each of the two area types in the following manner:

- impervious areas: curve number of 98 is read from CN tables in SCS TR - 55

- pervious areas: curve number of 65.6 computed as the average of all land use types in 1984 SCS TR - 55 revised curve number tables EXCEPT urban and urbanizing areas.

For consistency with relationships given in Equation (19), a weighted curve number (See Equation (5)) should be calculated for the pervious and impervious areas within each sub-basin.

A type II rainfall distribution in 24 hours, given in Table 1, was adopted to find the value of rainfall excess for each time increment in Equation (23) as follows:

$$\Delta Q = Q_{\Delta t+t} - Q_t \tag{24}$$

where:

$$Q_{\Delta t+t} = (P_{\Delta t+t} - 0.2S)^2 / (P_{\Delta t+t} + 0.8S) \tag{25}$$

$$Q_t = (P_t - 0.2S)^2 / (P_t + 0.8S) \tag{26}$$

P_t, $P_{\Delta t+t}$ is the amount of rain accumulated at times t and Δt+t obtained from the SCS type II 24-hour storm distribution.

Equations (21) and (22), applied with rainfall excess computed by Equation (23) to both pervious and impervious areas, yield a total amount of pollutants washed off during a given time period. Concentration as a function of time is then obtained using the following relationship:

$$\text{Conc (mg/}\ell\text{)} = \text{Mass washed} / \Delta\text{Vol} \quad \text{for each } \Delta t \tag{27}$$

where:

ΔVol = runoff volume calculated from hydrograph

Pollutographs can be calculated for individual sub-basins in a watershed; linear combination of these pollutographs using the relationship expressed by Equation (28) yields composite pollutographs for the entire watershed.

$$C_t = \sum_{i=1}^{N} c_{i,t} \tag{28}$$

where:

C_t = composite pollutograph ordinate at time t

$c_{i,t}$ = pollutograph ordinate at time t for sub-drainage area i

BMP PERFORMANCE

The methodology proposed in the preceeding discussion may also be applied to areas containing BMP structures to evaluate the performance of various stormwater management alternatives. Weighted initial pollutant loadings are calculated for the area that drains into the BMP facility using the relationship given in Equation (20). The pollutant washoff equations (Equations (21) and (22)) are then applied to the BMP drainage area; the mass washed from the pervious and impervious areas in each time interval is summed to find a total mass of pollutant entering the BMP facility. Mean pollutant concentration entering the facility is computed using Equation (29):

$$Conc_{in} = \Delta Mass \,/\, (\Delta Q_i + \Delta Q_p) \quad \text{for each } \Delta t \tag{29}$$

where:

$Conc_{in}$ = pollutant concentration entering the BMP facility

$\Delta Mass$ = total mass removed from pervious and impervious area in BMP drainage site; calculated from Equations (21) and (22)

ΔQ_i = runoff from impervious area in BMP drainage site

ΔQ_p = runoff from pervious area in BMP drainage site

Δt = time interval

The pollutant removal efficiency of the BMP facility is a function of the stormwater detention time in the facility, the type of pollutant, and the land uses within the area draining into the facility. Table 6 shows the BMP pollutant removal efficiencies used in this study. The values given for removal efficiencies of extended wet ponds are average values for all land use types.

The amount of pollutant trapped in the BMP facility can be estimated by Equation (30):

$$Mass_t = Conc_{in} \times \Delta Stvol \times \eta \quad \text{for each } \Delta t \tag{30}$$

where:

$Mass_t$ = pollutant mass trapped in structure during time increment

$\Delta Stvol$ = stormwater volume stored in structure during time increment

η = BMP pollutant removal efficiency

Table 6. Averaged BMP Pollutant Removal Rates

BMP TYPE	PERCENT POLLUTANT REMOVAL			
	TSS	BOD	N	P
Dry Pond	14	0	20	10
Wet Pond	55	22	66	28
Extended Wet Pond	91	42	42	27
Infiltration Trench	96	84	61	41
Porous Pavement	96	84	61	41

Source:

Dry ponds and Wet Ponds: EPA Washington, D.C. NURP Executive Summary, 1983

Extended Wet Pond and Infiltration Devices: Biggers, et al., 1980

where:

TSS = total suspended solids

BOD = biological oxygen demand

N = total nitrogen

P = total phosphorus

For detention ponds, the incremental storage volume, $\Delta Stvol$, in Equation (30) is calculated as the difference between inflow and outflow for each time increment (See Figure 4). For infiltration facilities, the incremental storage volume is computed using Equation (31).

$$\Delta Stvol = (q_{BMP,t+1} - q_{BMP,t}) \times \Delta t \qquad (31)$$

where:

$(q_{BMP,t+1} - q_{BMP,t})$ = runoff removed from BMP facility during time increment

Δt = time increment

The mass of pollutant released by the structure to travel downstream is thus the difference between the mass washed off the ground and the mass trapped by the BMP facility, expressed as:

$$Mass_{out} = \Delta Mass - Mass_t \quad \text{in each } \Delta t \qquad (32)$$

where:

$Mass_{out}$ = mass released from BMP facility during time increment

The pollutant mass released by the BMP structure is added to the mass washed off from area in the sub-basin which does not drain into the BMP facility using the relationship in Equation (33).

$$\Delta Mass_{sub} = Mass_{out} + Mass_r \tag{33}$$

where:

$\Delta Mass_{sub}$ = total pollutant mass at outlet of subarea

$Mass_r$ = mass washed off remaining area of subarea

It is assumed that there is no pollutant deposition/decay in the channel as it travels downstream; therefore, concentration at the outlet of a sub-basin can be computed as follows:

$$Conc_{r,t}\ (mg/\ell) = \Delta Mass_{sub} / \Delta Vol \quad \text{for each } \Delta t \tag{34}$$

where:

$Conc_{r,t}$ = concentration reflecting BMP performance at time t

ΔVol = runoff volume calculated as area under revised sub-basin hydrograph during time increment

Composite pollutographs which reflect the performance of all BMP structures within a watershed are then computed using Equation (28).

The hydrographs used to calculate runoff volumes in Equations (27), (30), (31), and (34) are generated by the SCS tabular method, which produces hydrograph ordinates for times between the 11th and 20th hours of a 24 hour period. Because the first flush phenomenon is an important element of the pollutant washoff process, pollutographs are generated for times between 0 and 24 hours. Therefore, a linear interpolation of hydrograph ordinates between times 0 and 11 hours is necessary to estimate runoff volumes for those time intervals.

CHAPTER 6: COST ANALYSIS

In order to provide a basis for evaluating alternative urban stormwater management investments, a cost analysis for Best Management Practices (BMPs) needs to be developed. After extensive research in the current literature, a cost analysis has been derived by Allison (1985) primarily from studies completed in 1983 by the Metropolitan Washington Council of Governments (MWCOG) and in 1979 by the Northern Virginia Planning District Commission (NVPDC). This analysis focuses on the BMP structures examined in this study which include dry ponds, wet ponds, extended wet ponds, infiltration trenches, and porous pavement. All costs are presented in fourth quarter 1980 dollars.

Three cost factors are needed to consider the overall investment necessary for implementation of BMP alternatives:

- BASE CONSTRUCTION COSTS: the direct costs of implementing the construction of the project (exclusive of land costs)

- CONTINGENCY COSTS: costs that arise from administering, overseeing, and engineering a project

- OPERATION AND MAINTENANCE COSTS: costs associated with maintaining and operating stormwater management projects. These include both routine and non-routine maintenance.

Costs associated with long-term financing vary widely with the size of the facility and with current interest rates. Capital costs for a small project may well fit into the budget of the implementing agency or developer such that no long-term financing is necessary. At the other extreme the project may require extensive long-term financing, but costs will depend heavily on the long-term rates prevailing at the time of construction.

DETENTION PONDS

In the 1983 MWCOG study, construction costs for 31 detention ponds (dry and wet) in the Metropolitan Washington area were analyzed. A summary of the type, size, and land use characteristics of the ponds studied is shown in Table 7. The costs were calculated from unit construction costs obtained from 12 area organizations involved in designing, constructing and maintaining detention ponds. The organizations included 3 private land developers, 3 consulting engineering firms, and 6 public utility agencies. The unit costs were used to calculate 12 separate construction cost estimates for each of the 31 ponds. A statistical analysis of the 372 construction cost estimates found a nonlinear relationship between the volume of storage and the construction cost as follows:

$$MWCC = 77.4 \times V^{0.51} \tag{35}$$

Table 7. Charactersitics of Ponds Used in Derivation of Cost Equations

ON-SITE DRAINAGE AREA (ACRES)	TOTAL NUMBER OF PONDS	LAND	ON-SITE USE	NUMBER OF PONDS	VOLUME STORAGE CREST EMERGENCY SPILLWAY (CU. FT.)	OF AT OF	NUMBER OF PONDS
0-5	8	Large Lot		3	2,000-10,000		5
		Single Family			10,001-20,000		4
6-10	5	Medium Density		6	20,001-30,000		1
		Single Family			30,001-40,000		4
11-15	2						
16-20	2						
21-30	1	Townhouse/			40,001-50,000		3
		Garden Apt.		9	50,001-70,000		3
31-50	4						
51-75	4						
76-100	1	High Rise			70,001-100,000		2
		Apt.		1	100,001-150,000		5
101-150	3						
51-200	-	Commercial/			150,001-200,000		1
		Industrial		12	200,001-400,000		1
201-350	1				400,001-800,000		2
TOTALS	31			31			31

Source: Metropolitan Washington Council of Governments, 1983.

where:

MWCC = MWCOG Construction Cost

V = Volume of Storage

Equation (35) compares favorably with the results of a storm water management study done in 1977 by Montgomery County, Maryland for the Soil Conservation Service (SCS); 34 detention ponds were studied in Montgomery County, Maryland. Montgomery County officials also found a nonlinear relationship between the volume of storage and construction costs. After conversion to fourth quarter 1980 dollars, the updated SCS cost equation is given by:

$$SCSCC = 113.4 \times V^{0.483} \qquad (36)$$

where:

SCSCC = SCS Construction Cost

V = Volume of Storage

A plot of the Equations (35) and (36) is shown in Figure 8. As seen in Figure 8, the SCS equation tends to result in values approximately 10% higher than the MWCOG equation. Since costs are a function of the volume, the larger the pond storage capacity the higher the cost of construction . The MWCOG study encompassed a larger study area and was based on more recent data than the SCS study; therefore, this study

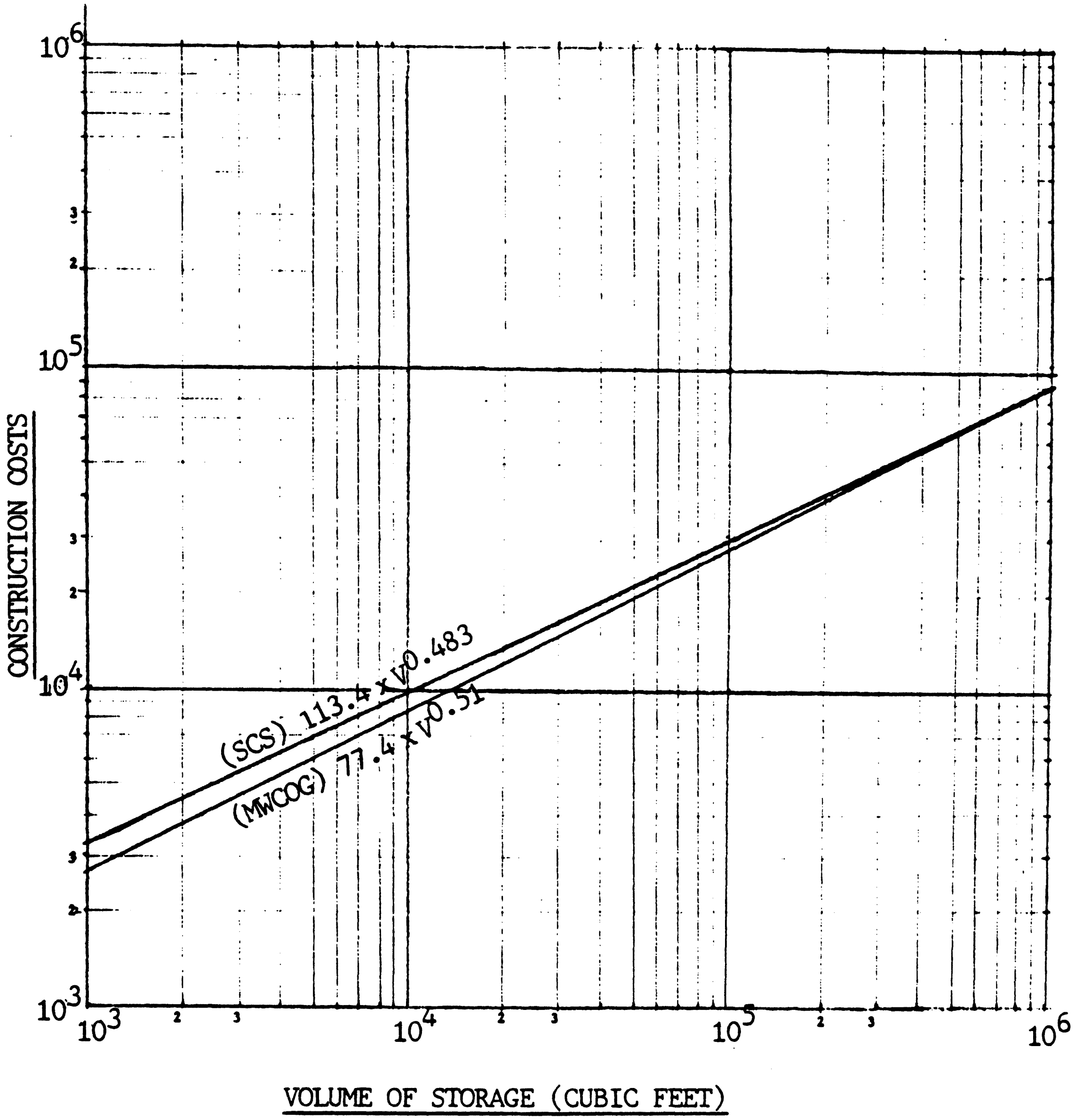

Figure 8. Relationship Between Detention Pond Construction Cost and Storage Volume (MWCOG 12-82)

uses the MWCOG equation for detention basins construction cost estimation.

Operation and maintenance (O & M) costs fall into two main catagories: "Routine" and "Non-Routine" maintenance. Routine maintenance includes those tasks performed on a regular basis. Included in this category are site inspections, grass maintenance and mowing, debris and litter removal, bank stabilization, weed control, pest insect control, and fence repair. Non-Routine maintenance includes tasks which require major maintenance over a long period of time. Those tasks which are considered non-routine maintenance include structural repairs which may include pipe replacement and major repairs to the dam, and major sediment and debris removal which is intended to maintain storage volume at the design level.

O & M cost data was collected in the MWCOG study for a total of 198 detention ponds involving approximately 680 maintained acres. Maintained acres are defined as the surface area of the pond (wet and dry) plus the acreage immediately adjacent to the pond that is maintained. Analysis of this data resulted in average annual O & M costs (exclusive of sediment removal) of $286 per maintained acre or $982 per pond.

Annual O & M costs are most commonly estimated as a percentage of construction cost. Therefore, determine the relationship between O & M and construction costs, the MWCOG study related the calculated O & M costs to a representative sampling of 16 of the 31 ponds studied. A value of 2% to 3% of the construction cost was found to be an acceptable approximation of O & M costs exclusive of sediment removal. Sediment removal was estimated to be approximately 1% to 3% of construction costs. MWCOG concluded that a total O & M cost (maintenance plus sediment removal) of

3% to 5% of construction costs is a good approximation for projecting annual O & M costs.

These results compare favorably with the results of the 1979 NVPDC study. In this study, O & M costs were found to average 5% of construction costs. The costs ranged from a high of 8.2% for low density (high permability) watersheds to a low of 3.7% for shopping center drainage areas. In general, the O & M costs tend to decrease as a percentage of construction costs with volume of storage increase.

Based on the results of these two studies, a value of 5% of the construction cost was used in this study for estimation of the annual O & M costs associated with dry and wet detention ponds. The NVPDC study found that the O & M costs for extended wet detention ponds will be greater than those for dry and wet ponds; this increase results from higher pollutant removal effeciencies and resultant increased sediment accumulation and removal costs for extended wet ponds. A value of 6.25% was recommended for estimating the annual O & M costs associated with extended wet detention ponds.

Contingency costs arise from planning, overseeing and administering a project. The MWCOG study found that these costs averaged about 25% of the base construction costs for all three types of ponds.

The total cost of a detention pond is the sum of its construction, contingency, and O & M costs. The total cost for each of the 3 types of detention ponds is summarized below:

$$DWPTC = \$100.6 \times V^{0.51} \tag{37}$$

$$EWPTC = \$101.6 \times V^{0.51} \quad (38)$$

where:

DWPTC = Dry and Wet Pond Total Cost

EWPTC = Extended Wet Pond Total Cost

Total costs for wet ponds tend to be higher than those of dry ponds. Assuming a runoff storage volume of 0.50 inches per acre of drainage area for the permanent pool storage volume, the MWCOG study found that wet pond costs tend to be between 26% and 40% higher than dry pond costs. When the permanent pool storage volume is assumed to be the same as the peak shaving control storage volume for dry ponds, the wet pond costs may be assumed to be greater than 40% dry pond costs. However, there are several advantages of wet ponds over dry ponds. First, the initial excavation costs of wet ponds may be offset by reduced O & M costs resulting from less frequent sediment removal. Second, the value of land adjoining the permanent pond is quite often increased. Allison (1985), in an attempt to determine some approximate costs for land value increase, tabulated responses from real estate agents and developers of both commercial and residential property. Allison reports the percent increases varied widely (from 0 to 100 percent), but the land value increase should be a factor in the decision-making process. Third, aquatic and terrestrial life is much more abundant where a permanent pool exists. Fourth, often site topography such as natural depressions enable wet pond construction without extensive excavation.

INFILTRATION TRENCHES AND POROUS PAVEMENTS

The cost relationships developed in this study for infiltration trenches and porous pavements are based on the standard designs recommended in the Maryland Department of Natural Resources "Standards and Specifications for Infiltration Practices" (1984). Cost relationships are based on the unit costs of the individual components of each structure.

Unit costs for infiltration trenches were provided by the Maryland Water Resources Administration (1985) and the Virginia Division of Soil and Water Conservation (1985). Information concerning porous pavement was obtained from various governmental agencies and contractors in Virginia, Maryland, and Washington D.C. The capital costs were derived from itemized costs. These expenditures came from the Maryland Water Resources Administration, the Virginia Division of Soil and Water Conservation, and Atler B. Stanley and Sons Contractors. The unit cost obtained for the individual items are shown in Table 8.

Table 8. Unit Costs for Infiltration Structures

ITEM	COST
Excavation	$0.11/CF
Filter Fabric	$0.14/SF
Crushed Stone	$0.57/CF
Seeding & Mulching	$0.04/SF
Porous Asphalt (4" thickness)	$1.75/SF
Observation Well (4" diameter perforated PVC)	$2.50/FT

Adapted from various sources.

The design width, depth, and length of the infiltration facility dictate the amount of each item presented in Table 8 that is required and thus the cost of construction. Therefore, the construction costs for infiltration trenches and porous pavements are a function of their geometry.

Annual O & M costs for infiltration trenches were determined to be approximately 3% of the base construction cost. This figure was obtained from the 1983 MWCOG study and a 1985 study by Thomas Schueler, et al. This value reflects only routine maintenance costs. Contingency costs are estimated to be 25% of the base contruction cost. This was the general consensus of all the organizations mentioned above as well as the NVPDC.

Annual O & M costs for porous pavements was found to be approximately $5 to $8/CY of storage volume in the 1979 NVPDC study. These expenditures included vacuum street sweeping of 3 to 5 passes per week. Using a mean value of $6.50/CY yields $0.24/CF of storage volume for the O & M costs. Contingency costs for porous pavement facilities were found to be higher than the other types of BMP's examined int this study, as reported by Schueler (1985). This cost increase results from the extra costs for site surveys, soil inspection and testing, and observation wells necessary for pavement facilities. The contingency costs are thus estimated at 35% of construction costs.

The total costs associated with the installation of infiltration practices for stormwater management are thus given by the structure geometry, O & M costs, and contingency costs. The following relationships have been developed for the total cost of infiltration structures:

$$IT = 1.28\{0.68[W \times L \times (D+1)] + 0.28[(W \times L) + (W \times D) + (L \times D)] + 2.5(D+1) + 0.04[(40 + W) \times (40 + L) - (W \times L)]\} \quad (39)$$

$$PP = 1.35\{0.68[W \times L \times (D+2/12)] + 0.14[(W \times L) + 2(W \times D) + 2(L \times D)] + 1.75[W \times L]\} + 0.096(W \times L \times D) \quad (40)$$

where:

IT = Infiltration Trench Total Cost

PP = Porous Pavement Total Cost

W = width of the structure (ft)

L = length of the structure (ft)

D = depth of the structure (ft)

The cost relationships given by Equations (39) and (40) vary from area to area and depend heavily on the proximity of the material. This is especially true for the crushed stone. Costs given in this study for the BMP structures are extremely site specific. In addition, the findings in the various studies examined were averaged to yield average BMP costs. Therefore, care should be taken when using the cost relationships presented in this study.

CHAPTER 7: SOFTWARE DEVELOPMENT

DESCRIPTION

Appendixes A and B contain a user's manual and program listings for the software package BMPSOFT developed to facilitate the planning and design of urban BMP's for stormwater management. All programming was done in "user-friendly" BASIC; therefore, the software package is meant to be used on a personal computer. All input data is entered by the user in response to the computer prompts. Figure 9 shows a flow chart for the execution of the software package. Some of the algorithms vary depending on whether a present condition or a future condition watershed analysis is desired.

The program module SCS calculates runoff hydrographs for the sub-basins of a watershed as well as a composite watershed using the SCS tabular method outlined in Chapter 3. Data requirements include design storm rainfall and frequency, land uses, soil types, and overland and channel flow information for the watershed. Subroutines in the program BMP allow the user to evaluate existing BMP structures or design new ones. Chapter 4 outlines theories used in the design procedures for the BMP facilities. For detention pond design, required input data include both an outflow rating curve and storage versus elevation data for the proposed detention facility. The user must provide the rating curve for the flexibility of choosing different types of outlet structures. Rating curves determined internally by the computer instead of by the user would

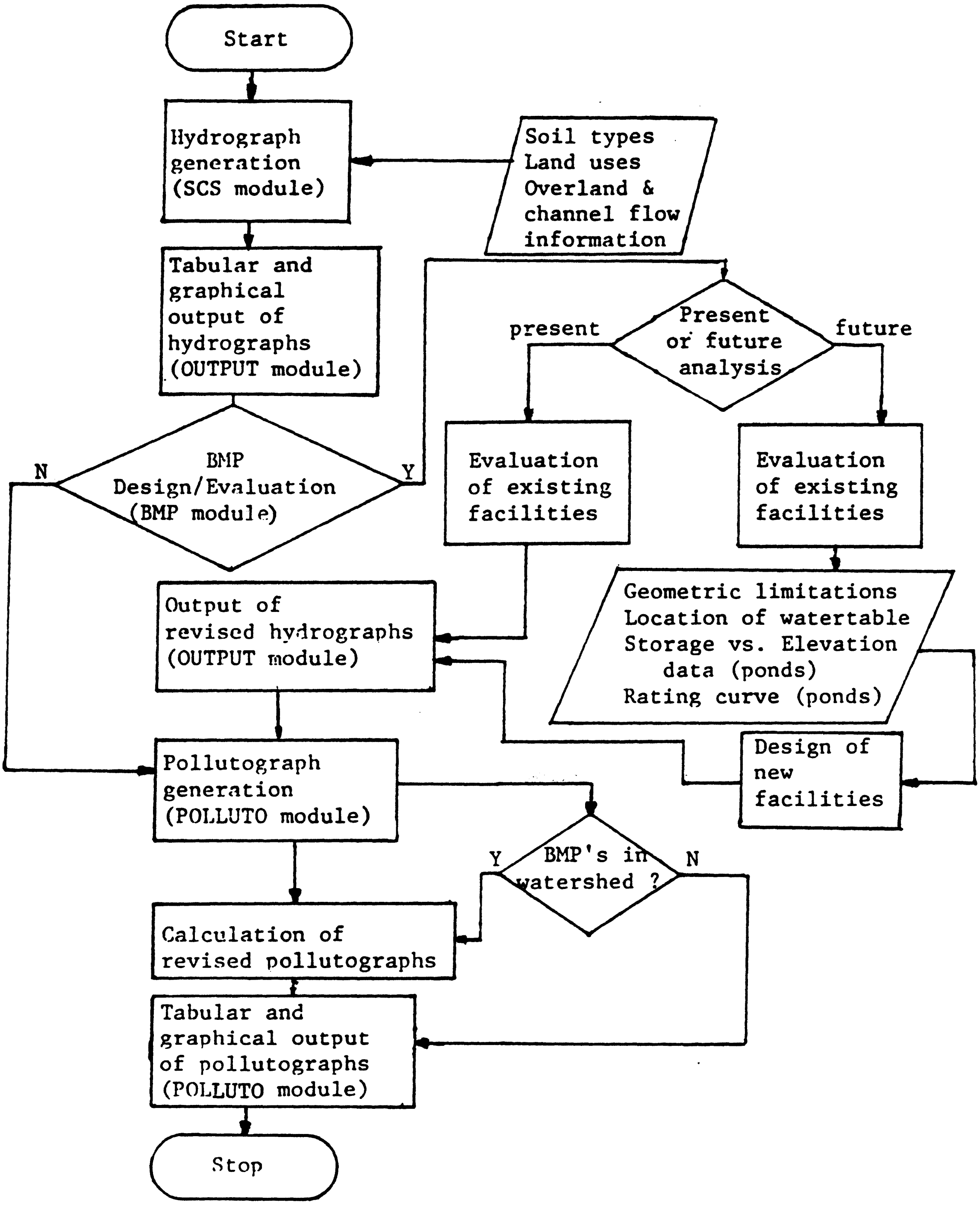

Figure 9. Flow Chart for Software Package "BMPSOFT"

require different algorithms for every type of outlet structure and would thus limit the designer to outlet structures included in the software (without modification of the program). Thus, the routing procedure is performed on a trial and error basis; the outflow structure and storage versus elevation data can be changed for a particular site until the designer is satisfied and the structure meets peak shaving requirements. Infiltration structures are designed in a similar manner. Based on input data such as amount of runoff to be handled by the facility and geometric limitations, the algorithm given by Equation (16) is repeated until the structure satisfies design criteria for a given area. Revised hydrographs which reflect the performance of the BMP's are calculated by the SCS method.

The program POLLUTO calculates pollutographs for each sub-basin in the watershed as well as composite pollutographs. The relationships given in Chapter 5 for pollutant loadings and subsequent washoff are used in this analysis. Four water quality parameters are examined: total suspended solids, BOD_5, total N, and total PO_4. The relationships outlined in Chapter 5 for pollutograph generation may also be used to model other types of pollutants, such as the heavy metals found in high concentrations in urban areas, with a minimum of programming changes (See Appendix B). Input data includes pollutant loadings for each land use type witin the watershed and the number of days since the last storm event. A time increment of one hour is used in the pollutant washoff equations (Equations (21) and (22)).

Select input data and relevant intermediate calculations are presented as output. In addition, the generated hydrographs and pollutographs are presented in both tabular and graphical forms.

DISCUSSION AND LIMITATIONS

This model is at a medium level of sophistication, meant to be used as a management tool for estimation of the location and type of control measures needed to attain a given level of runoff and pollutant control at the outlet of the watershed. In other words, detailed simulation of pollutant source and buildup, washoff and transport/deposition is not performed. Thus, this software package yields order of magnitude pollutant loadings to facilitate the planning process.

The programs in the software package are set up in "modular" form and run from a batch file execution. This programming style was chosen to facilitate modification by subsequent users; such modifications may include analysis of different pollutants or capability for design of additional or different BMP structures. The version of BASIC used in programming limits computer memory usage to 64K; thus, this software package would be more powerful and able to design larger numbers of BMP structures, for example, if it were translated into a new version of BASIC or into FORTRAN.

Recommended improvements to the model presented in this report are summarized below:

1. The version of BASIC used in programming the software package recognizes only 64K of computer memory. This restriction limits the number of sub-basins and BMP structures that can be analyzed within a given watershed. Translation of the software into a better version of BASIC or into another computer language such as FORTRAN will make the package more powerful.

2. The present status of the software package has several programming inefficiencies. At present, data is generated in one program module and must be reduced by subsequent program modules (See Appendixes A and B). Creation of program modules to handle these intermediate calculations will make available more computer memory within each program module; the software package will thus be made more powerful.

3. Due to computer memory limitations discussed above, several assumptions and approximations were made in programming the software package. For pollutograph generation, incremental runoff volumes from pervious and impervious areas are calculated using the SCS runoff equations and Type II rainfall distribution. At present, the runoff equations are applied based on runoff curve numbers assigned to the two area types. For more accuracy, a weighted curve number should be calculated for both pervious and impervious areas in the watershed.

   In addition, the time increment used in the pollutant removal algorithms was limited to one hour. In an effort to determine the impact of the time increment size on the stormwater pollutant concentrations predicted by the model, a sensitivity analysis was performed for this parameter. The software package was applied to the hypothetical watershed described in Chapter 9 and in Appendix B and pollutant concentrations were computed for a modelling time increment of 15 minutes, 30 minutes, and 1 hour. Pollutographs predicted by the model for the four types of pollutants examined are shown in Figure 10 - Figure 13. A smaller time increment more clearly illustrates the dynamic aspect of pollutant loadings during a storm event, as can be seen in the figures. In addition, as the modelling time increment becomes shorter, the pollutant concentrations also decrease for the same time period. Thus, decreasing the time increment should yield better estimates of stormwater pollutant concentrations.

4. Should more memory become available through the previously discussed programming improvements, greater flexibility may be available to the user of the software package. For example, at present the pollutant removal efficiencies of the BMP structures are assigned internally by the computer. Memory made available for programming could allow the user to enter their desired removal rates or another algorithm could be written which computes removal efficiencies based on total pollutant mass entering the facility. Another possible programming improvement would allow the user to choose default values for certain parameters such as the runoff curve number or allow the user to enter values of his choice.

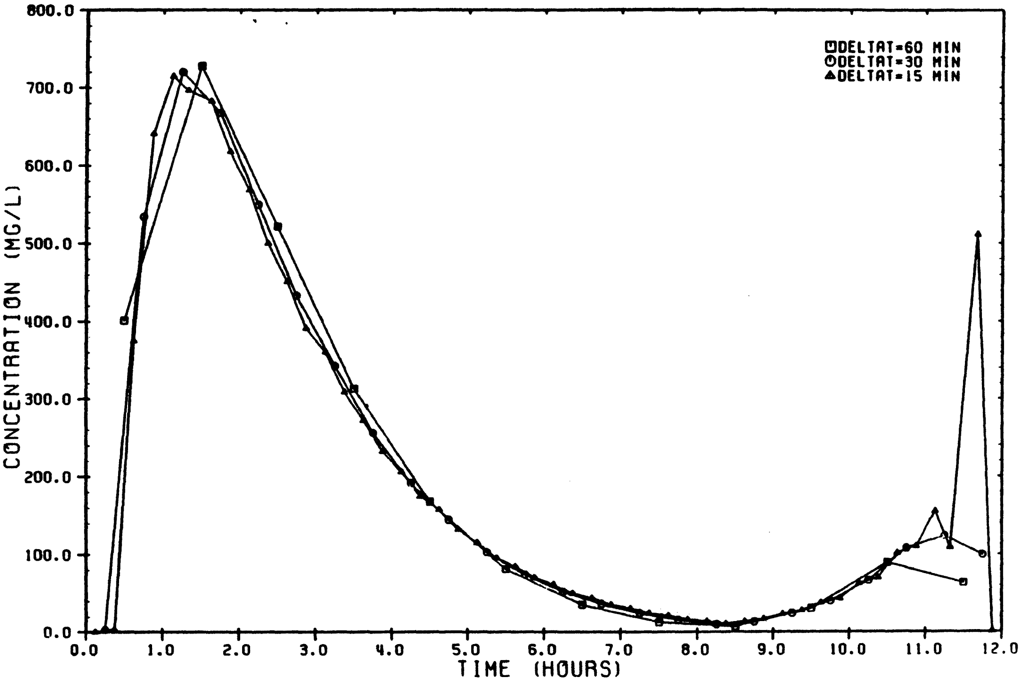

Figure 10. Pollutograph Time Increment Sensitivity--Total Suspended Solids

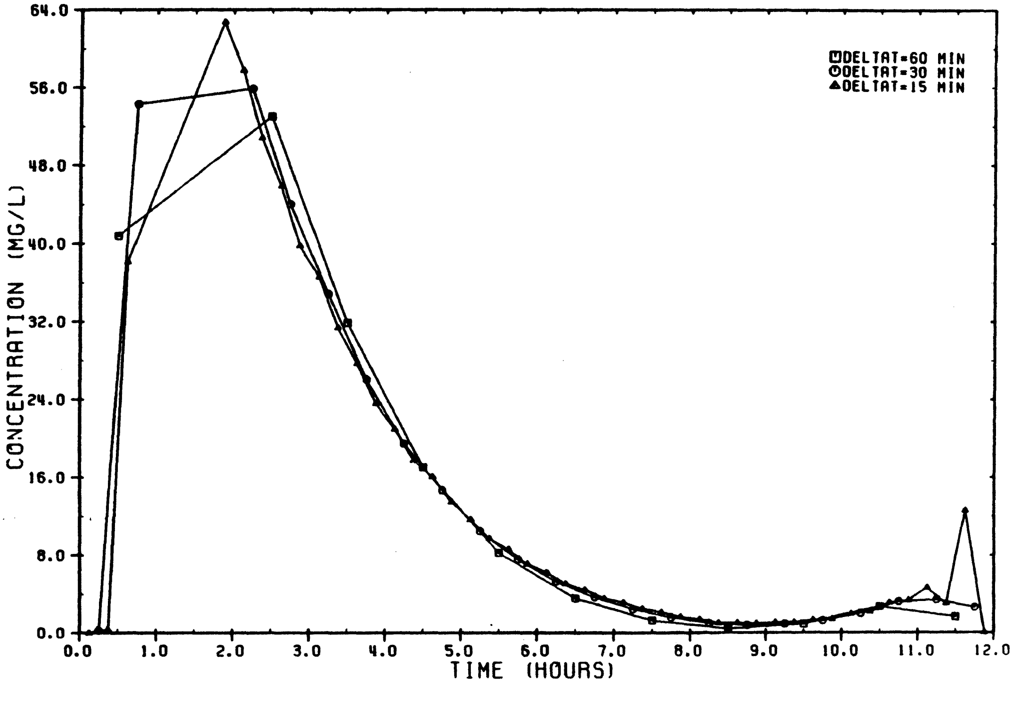

Figure 11. Pollutograph Time Increment Sensitivity--BOD

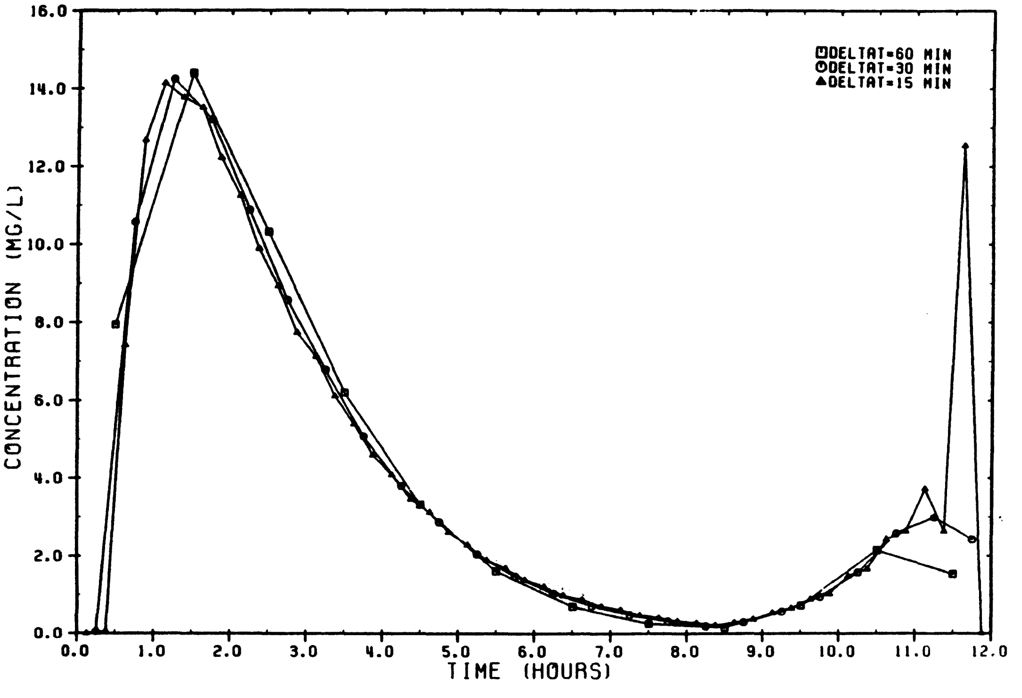

Figure 12. Pollutograph Time Increment Sensitivity--Total Nitrogen

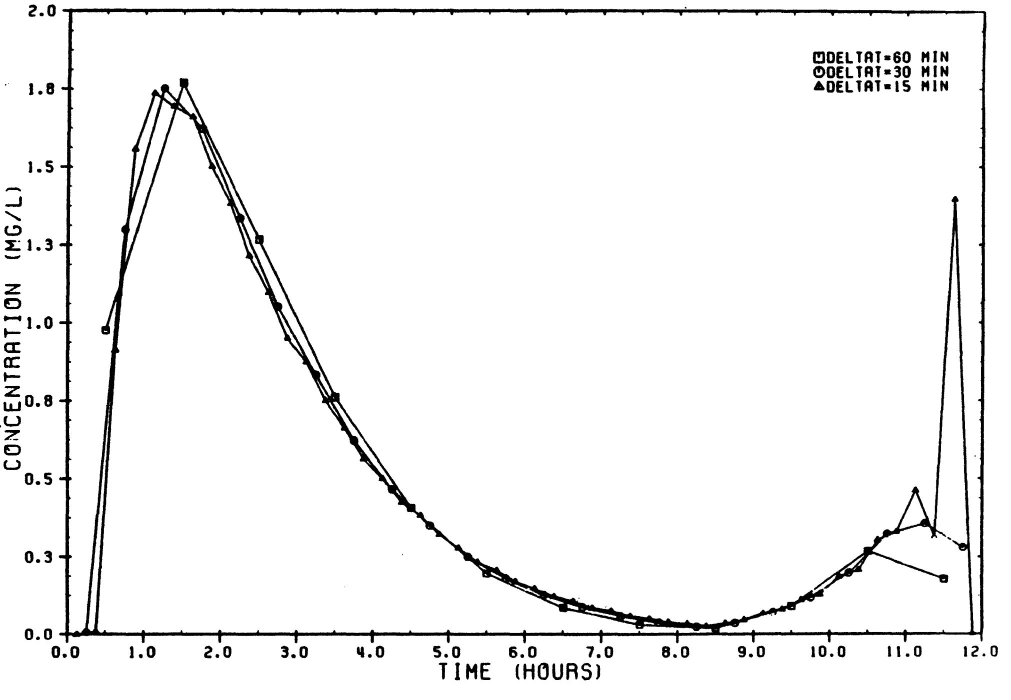

Figure 13. Pollutograph Time Increment Sensitivity--Phosphorus

CHAPTER 8: MODEL VERIFICATION

WATERSHED DESCRIPTION

In an effort to verify the model, the software package BMPSOFT was applied to the Cub Run watershed located in northern Virginia. This 32,000-acre watershed consists of parts of Loudoun and Fairfax counties and is part of the larger Occoquan watershed, as depicted in Figure 14. The watershed is composed primarily of soils of hydrologic soil group classification C (see Table 10). Fourteen different land use types have been defined within the watershed; however, forest and agricultural lands dominate the land use scheme presented in Table 9.

To meet the limitations inherent in the SCS tabular method, the watershed was divided into nineteen (19) sub-drainage basins such that the area of each was not greater than 2000 acres. The SCS tabular method also requires that the time of concentration for each sub-basin be less than or equal to 2 hours; this requirement was infeasible for the heavily forested and agricultural Cub Run watershed due to slow overland flow. The time of concentration for sub-basins which did not meet this requirement was thus set to be 2 hours. Table 11 lists parameters associated with each sub-basin in the watershed.

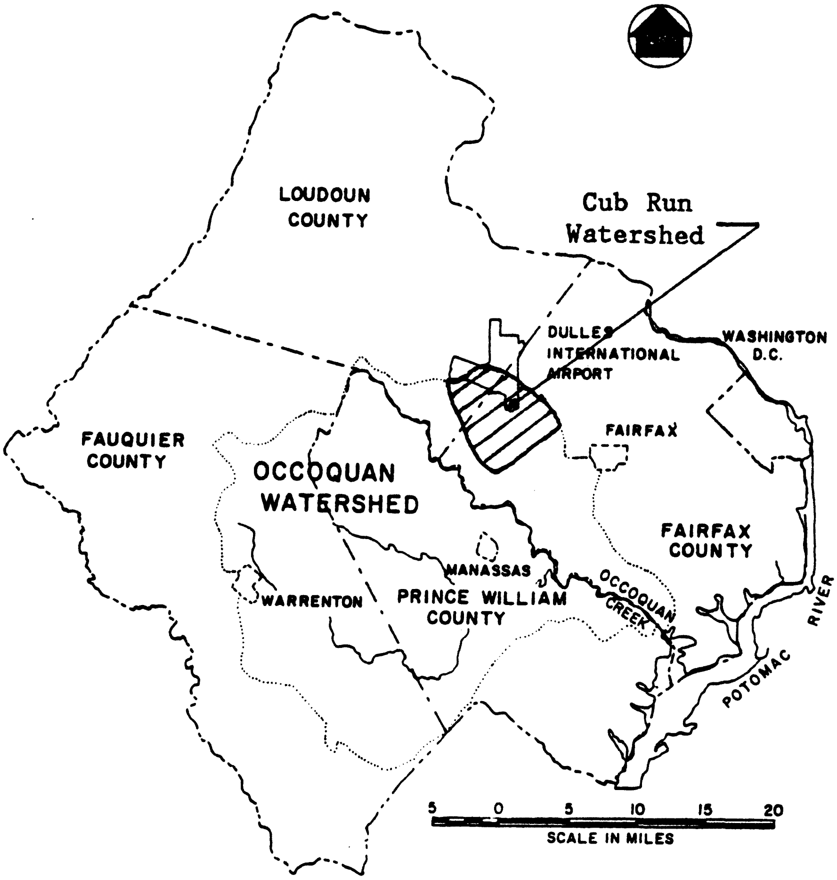

Figure 14. Cub Run Watershed Location Map (Randall, et al., 1978)

Table 9. Cub Run Watershed Land Use Percentages

LAND USE	PERCENTAGE OF WATERSHED AREA
Estate Residential	0.2
Low Density Residential (0-2 DU/Ac)	3.3
Medium Density Residential (2-8 Du/Ac)	4.1
Townhouses, Garden Apartments	0.3
Commercial	0.3
Industrial	5.7
Institutional	0.4
Golf Course	1.4
Livestock and Pasture	11.5
Conventional Tillage Grain	1.7
Mixed-Conventional Tillage Grain and Livestock	2.6
Minimum Tillage Grain	13.1
Mixed-Minimum Tillage Grain and Livestock	0.7
Forest and Idle Land	54.7

Table 10. Cub Run Watershed Soil Type Percentages

HYDROLOGIC SOIL TYPE	PERCENTAGE OF WATERSHED AREA
A	0
B	18.6
C	52.2
D	29.2

Table 11. Characteristics of Cub Run Watershed

SUB-BASIN	AREA (ACRES)	WEIGHTED RUNOFF CURVE NUMBER	TIME OF CONCENTRATION (HOURS)	TIME OF TRAVEL (HOURS)
1	1626	81.24	1.21	1.99
2	2113	80.83	2.00	1.74
3	1611	81.21	1.29	1.35
4	2001	84.73	1.73	1.10
5	2196	87.69	2.00	2.06
6	1774	83.97	1.45	1.90
7	1170	82.98	2.00	1.55
8	1586	79.09	2.00	1.52
9	1259	80.72	2.00	1.42
10	1325	80.41	2.00	0.94
11	1724	76.51	1.35	1.95
12	1463	79.15	0.88	1.71
13	2039	78.65	1.69	0.69
14	904	85.45	1.83	0.20
15	904	79.21	2.00	1.58
16	1990	74.69	0.73	1.08
17	2015	82.71	1.70	0.63
18	1973	79.03	1.07	0.12
19	1366	84.98	1.62	0.00

Flow and pollutant concentration data used in the verification process was obtained from the Occoquan Watershed Monitoring Laboratory (OWML) (Grizzard, 1985) for the period 1977-1980. This time frame most closely matched the Cub Run land use, soil type, and topographic maps used in this study. Grab sampling techniques were used by OWML at their Cub Run monitoring station, located at the outlet of this watershed. Samples were taken during base flow and storm conditions; a single, flow-weighted concentration was given for each pollutant during a storm event. Similarly, the flow rate given for a storm event was an average of the measurements taken during the event. Both the number of samples taken and the sampling time frame varied from storm to storm. Output from the software package, given in hydrograph and pollutograph form, for similar storms thus could thus not be compared directly with the OWML data. However, an attempt has been made to gain some insights into the OWML data and the software output. The historical rainfall record for a gaging station near the watershed was analyzed. The station at Washington National airport was chosen because of its historic record length and for its proximity to the watershed. Storms of 18-30 hour duration were included in the rainfall frequency analysis; these durations approximately correspond with the 24-hour duration rainfall base used in the SCS tabular method and in the methodology used for pollutograph generation. Results of the frequency analysis for the 38-year rainfall record are presented in Table 12. Monitored data from OWML for these "24-hour" storms was available for 5 storms in the period 1977-1980.

Table 12. Cub Run Watershed LP-III Precipitation Distribution: 1977-1980

EXCEEDANCE PROBABILITY	K	Y	X
95	-1.4877	-0.1025	0.79
90	-1.2144	-0.0319	0.929
80	-0.8561	0.0606	1.2
50	-0.0846	0.2598	1.8
20	0.8072	0.49	3.1
10	1.3235	0.623	4.2
4	1.9129	0.7755	5.9
2	2.3158	0.8796	7.6
1	2.6929	0.977	9.5

where:

X = precipitation in inches

Y = log (X)

N = sample size = 33 years

S_Y = standard deviation = 0.26

G_Y = skew coefficient = 0.51

YMEAN = 0.28

RESULTS AND DISCUSSION

Comparison of model results and monitored data for four select 24-hour storms is presented in Table 13 - Table 16 . The model was applied to the Cub Run watershed for design storm conditions similar to conditions which produced the monitored data from OWML. A 28-hour hydrograph time base was used in the model to compute the average flow for each design storm. In addition, the simulated average pollutant concentrations at the watershed outlet are flow-weighted averages computed from a 28-hour time base which takes into consideration the pollutant removed during the 24th hour and an average 4 hour basin time of concentration.

There are many difficulties associated with the verification of a model with observed data. Good data is in itself scarce and often unsuitable to specific model needs. More important, the conditions under which the data were obtained are often unknown or not reproducable by the model. Many problems of model verification stem from the inherent modelling assumptions, which can only approximate the real world. The following discussion presents some difficulties encountered with the verification of this model.

1. One small sub-basin encompassing part of Dulles International Airport (Fairfax County) which contributes to the headwaters of Cub Run was eliminated from the watershed analysis. The flow travel time over the flat paved surfaces associated with this facility was many times greater than the 2 hour limitation imposed by the SCS tabular method. In addition, the time of concentration for seven sub-basins within

the watershed was computed to be just over 2 hours; these times were reduced to 2 hours for verification purposes. These reductions, coupled with the elimination of one sub-basin, alter both the shape and magnitude of the resulting composite hydrograph computed at the outlet of the watershed. Thus, these assumptions influence both the average flow magnitude and the flow-weighted average pollutant concentrations computed from model output for a given storm.

2. Geometric data for the channels in the watershed was obtained from a 25-year flood plain analysis. The return periods of the storms used in the verification process, however, were all less than 3 years. In addition, other watershed parameters such as Manning's roughness coefficient and the headwater dimensions of many streams were estimated. These factors influence the time of travel and the time of concentration of each of the sub-basins within the watershed and ultimately influence the shape and magnitude of the composite watershed hydrograph computed by the model.

3. The historical precipitation data corresponding to the monitored Cub Run data was obtained from the weather station at Washington National Airport, approximately 25 miles east of the center of the Cub Run watershed. This data agrees reasonably well with data from a station in Fauquier county, located approximately equidistant west of Cub Run. However, "since storm cells are dynamic, stationary rain data is unreasonable in urban runoff studies" (Shivalingaiah, 1984).

Thus, the 24 hour rainfall used in the model may not agree with the actual precipitation which produced the monitored data.

4. The local storm pattern for the Cub Run watershed may not be exactly reproduced by the SCS type II rainfall distribution assumed in the model. The SCS type II distribution was developed from rainfall depths averaged over the area in the U. S. designated type II (i. e. most of the country). Calibration of the model for the Cub Run watershed storm pattern was not possible due to lack of data.

5. The number of samples and the sampling time frame used by OWML to generate the data used for model verification varied widely from storm to storm. The sampling time frame varied from 20 hours to 97 hours for the four storms compared in Table 13 - Table 16 . The time frame used for computation of flow-weighted pollutant concentrations from the model was 28 hours, based on 24-hour precipitation. This time base discrepancy could have a large impact on the flow-weighted values computed by both OWML and the computer model. OWML samples taken during base flow conditions would produce an average pollutant concentration significantly different from a storm related average. Similar reasoning can be applied to the average flow rates reported for Cub Run.

6. The 24-hour storms of record corresponding to the OWML monitored data reported in Table 13 - Table 16 occured during winter months. Wu (1978) reports "in stream concentrations of pollutants vary greatly

with flow rate and season". There are several possible explanations for this variance. Firstly, snow and icemelt from precipitation prior to the design storm may contribute significantly to streamflow. In addition, the pollutant loadings on the watershed differ in type and magnitude from the average pollutant loading rates used by the model. For example, de-icing chemicals used in urban areas contribute to water quality degradation only during the winter months. Fertilizers, a major constituent in agricultural runoff during the growing season, is virtually absent during the winter months. Decaying vegetation also contributes to runoff quantity and quality during the winter season. Thus, correction for seasonal variations is a suggested improvement to the present version of the computer model.

7. The computer model does not allow for street sweeping activities during dry days between storms; such activities reduce the amount of pollutants available for washoff during a storm event. In addition, this model does not account for artificial washoff of pollutants during dry days by irrigation and similar activities on non-urban land uses within the watershed. Removal of pollutants from the ground surface by wind and vehicle eddies and biological decomposition is also not estimated by this model.

8. Pollutant loading rates for pollutant buildup during dry days are estimated from average values for the Northern Virginia area compiled by the Northern Virginia Planning District Commission (NVPDC) (1979).

The actual pollutant loading rates for the Cub Run watershed may differ from these average values. For example, if the hydrologic condition of an area is better than the condition of a similar area tested to determine the NVPDC values, the average loading rate would be different than that in the watershed. Actual pollutant loading rates lower than the average values used in the model may account for the high pollutant concentrations predicted by the model.

In addition, the NVPDC reports pollutant loading rates primarily for urban land uses; their report estimates pollutant loadings for only three rural land uses. The Cub Run watershed, however, is principally undeveloped from an urban viewpoint (see Table 9). The loadings for several of the land uses within this watershed were thus interpolated from the NVPDC report; such interpolation reduces the accuracy of the pollutant buildup during dry days estimated by the computer model and thus reduces the accuracy of the calculated pollutant concentrations over time.

9. The model assumes that pollutants buildup on the ground surface during dry days at a constant rate, given by the NVPDC average loading rates previously discussed. Researchers have discovered, however, that pollutant buildup rates decrease over a dry day period and eventually go to zero; that is, a steady state is achieved whereby pollution addition is equal to pollutant removal for a time period (Shivalingaiah, 1984). In addition, Kibler, et al., (1982) report that "rate of accumulation is most rapid during the first two or three days after a significant rainstorm. The rate of accumulation de-

creases subsequent to that time." Thus, the amount of pollutants estimated to be available for washoff by the model at the start of a storm event is higher than real conditions. The resulting pollutant concentrations during the storm event are subsequently higher than the actual values.

10. Complete streamflows such as hydrographs were not available for the Cub Run watershed during the 1977-1980 verification period. Wu, et al., (1978) report that "it is important to consider high flow pollutant loadings as a phenomenon separate from low flow pollutant loadings". The pollutant concentrations reported by OWML are flow-weighted averages; high flow conditions will produce significantly different concentrations from values computed from low flow conditions for the same pollutant mass in the stream. In addition, because the sampling time base used by OWML varies so widely (in some cases) from the time base used in the model, this consideration could have significant bearing on this verification attempt.

11. The accuracy of modelling the pollutant washoff process is dependant on the time increment used. It was shown in the sensitivity analysis presented in Chapter 7 that the magnitude of stormwater pollutant concentrations decreased with the shortening of the modelling time increment. In addition, Shivalingaiah (1984) reports "the longer the timestep, the greater the error". The computer model SWWM, for example, uses a time increment of one minute for single event simulation (Shivalingaiah, 1984). A small time increment, however, is costly

in computer time and in computer memory. Memory limitations of the micro-computer used in this study restricted the time increment to one hour for analysis of a watershed as large as Cub Run. However, Shivalingaiah (1984) also reports that "for lower rainfall intensities, time steps may not influence the runoff quality results, but for high rain intensity, the computed pollutographs are sensitive to timestep, particularly during the initial period of washoff". The first flush effect, discussed in Chapter 2, is particularly important for modelling highly impervious areas. First flush effects, therefore, probably do not play a large role in the washoff processes in Cub Run watershed due to the relatively small amount of impervious area. The use of a smaller time increment in the pollutant washoff equations, however, would probably yield lower flow-weighted pollutant concentrations.

Table 13. Comparison of Actual and Computed Values--Average Flow

STORM	RAINFALL (INCH)	STORM RETURN PERIOD (YEARS)	DRY DAYS PRECEDING STORM	COMPUTED AVERAGE VALUE (CFS)	OBSERVED AVERAGE VALUE (CFS)
A	1.45	1.6	5	346	13
B	1.95	2.27	7	672	96
D	1.83	2.125	5	588	473
E	1.26	1.36	4	243	491

Table 14. Comparison of Actual and Computed Values--Total Suspended Solids

STORM	RAINFALL (INCH)	STORM RETURN PERIOD (YEARS)	DRY DAYS PRECEDING STORM	COMPUTED AVERAGE VALUE (MG/ℓ)	OBSERVED AVERAGE VALUE (MG/ℓ)
A	1.45	1.6	5	798	11
B	1.95	2.27	7	789	86
D	1.83	2.125	5	590	143
E	1.26	1.36	4	869	30

Table 15. Comparison of Actual and Computed Values--Total Nitrogen

STORM	RAINFALL (INCH)	STORM RETURN PERIOD (YEARS)	DRY DAYS PRECEDING STORM	COMPUTED AVERAGE VALUE (MG/ℓ)	OBSERVED AVERAGE VALUE (MG/ℓ)
A	1.45	1.6	5	13.5	5.9
B	1.95	2.27	7	12.6	3.3
D	1.83	2.125	5	9.5	2.4
E	1.26	1.36	4	14.9	1.6

Table 16. Comparison of Actual and Computed Values--Phosphorus

STORM	RAINFALL (INCH)	STORM RETURN PERIOD (YEARS)	DRY DAYS PRECEDING STORM	COMPUTED AVERAGE VALUE (MG/ℓ)	OBSERVED AVERAGE VALUE (MG/ℓ)
A	1.45	1.6	5	1.6	0.34
B	1.95	2.27	7	1.4	0.39
D	1.83	2.125	5	1.1	0.1
E	1.26	1.36	4	1.8	0.08

CHAPTER 9: APPLICATIONS

INTRODUCTION

For purposes of illustration, the software package described in Chapter 7 has been applied to a hypothetical 1000-acre watershed. (For details see also Appendix B). This demonstration area has been developed from some previous condition to the land use scheme depicted in Figure 15. The watershed contains three land use types: an agricultural area consisting of row crops, a commercial area, and a residential area of one-third acre dwelling unit density. Analysis was performed for a 5-year design storm with 24-hour rainfall depth of 8 inches with the hydrologic condition of the soil described by antecedent moisture condition number 2. Several stormwater management alternatives are evaluated on the basis of peak reduction, pollutant removal, and total cost as strategies to control the increased runoff due to development.

Two different stormwater management approaches are considered: local controls versus regional controls. Local controls are installed within individual sub-basins to control runoff from a particular area. Regional management strategies use centrally located facilities to control runoff from a variety of developments. A thirty-five percent (35%) reduction in post-development peak flow at the watershed outlet was chosen, for demonstration purposes, as the peak shaving criterion to be met by the various management alternatives. No standards exist for post-development water quality. Table 17 and Table 18 present the performance of each stormwater management strategy described below. To provide a basis of comparison, the performance of different stormwater management alternatives is analyzed at the outlet of the entire watershed. Table 19 presents the storage capacities and total costs of the detention facilities used in this study.

DISCUSSION OF RESULTS

Figure 16 illustrates the alternative described as "Local Approach #1". Extended detention ponds are placed at the outlet of the two upstream sub-basins, labelled sub-basins 1 and 2. Figure 19, Figure 20, and Figure 21 illustrate the impact of the detention ponds on the outflow hydrographs at the outlets of sub-basin 1, sub-basin 2, and the entire watershed, repectively. The peak shaving effects are greatest just below the outlet of the structures and decrease as the hydrograph moves down the watershed. A peak reduction of approximately 35% is achieved by this alternative.

The regional approach labelled "Regional Approach #1" in Figure 17 has a larger extended detention pond located at the stream confluence in the middle of the watershed. The watershed therefore is broken into 2 sub-basins and the detention facility placed at the outlet of the upper sub-basin. Figure 22 and Figure 23 illustrate the peak shaving performance of this regional approach at the outlet of the structure and at the outlet of of the watershed, respectively. A 40% peak reduction is achieved at the watershed outlet.

A second regional management stategy is illustrated in Figure 15 and referenced as "Regional Approach #2". A master extended detention facility is placed at the outlet of the entire watershed. The hydrographs generated for the pre- and post-BMP conditions are presented in Figure 24 This strategy provides approximately 40% reduction in peak flow.

All of the management strategies described above meet the peak shaving criterion for post-development peak flow reduction (See Table 17). Local approach #1, however, provides the least peak flow reduction for the greatest total cost. Evaluation of these management strategies from the aspect of water quality improvement is not as simple, as can be seen from Table 18. Regional approach #2 provides the greatest reduction of pollutants transported for all four pollutants examined (i.e. total suspended solids, BOD, total nitrogen, and total phosphorus). This strategy, located at the outlet of the entire watershed, is the largest detention pond designed in this study and therefore costs more than regional approach #1. Because water is retained longer in this facility, the pollutants (especially solids and those attached to solids) have more time to settle out of suspension which probably accounts for the marked difference in pollutant reduction.

A second local management approach provides comparison between the cost and pollution removal performance of infiltration facilities and conventional detention ponds for a given peak flow reduction. Local Approach #2, depicted in Figure 18, compares a cluster of five infiltration trenches located near the outlet of sub-basin 2 with an extended detention pond located at the outlet of sub-basin 2. Each of these alternatives provides approximately 25% peak reduction at the outlet of sub-basin 2 and approximately 10% peak reduction at the outlet of the entire watershed (See Figure 25through Figure 28). These two management alternatives, however, show marked differences in water quality improvement and in total costs as can be seen from Table 18. The cluster arrangement of infiltration trenches costs four times as much as a single extended detention facility for the same peak flow reduction, but provides greater removal of the pollutants total N and total P. The extended detention pond traps considerably more of the suspended solids than the trench strategy but both facilities provide the same BOD reduction.

Thus, the location and type of stormwater management strategies significantly influences the amount of stormwater quantity and quality control they provide. The costs associated with a given level of stormwater management also vary widely with BMP location, size and type. These factors must be examined in conjunction with an institutional feasibility analysis before an optimum stormwater management strategy can be recommended for an urbanizing area.

Table 17. Comparison of Alternate Management Strategies

ALTERNATIVE	PERCENT PEAK FLOW REDUCTION	TOTAL COST
Local Approach #1	approx. 35	$ 140,142
Regional Approach #1	approx. 40	$ 97,430
Regional Approach #2	approx. 40	$ 128,801
Local Approach #2 (Trenches)	approx. 10	$ 400,000
Local Approach #2 (Pond)	approx. 12	$ 100,763

Table 18. Pollutant Removal Performance of Alternate Management Strategies

ALTERNATIVE	PERCENT POLLUTANT REMOVAL				TOTAL COST
	TSS	BOD	N	P	
Local Approach #1	20	16	15	15	$ 140,142
Regional Approach #1	15	12	11	10	$ 97,430
Regional Approach #2	90	42	42	28	$ 128,801
Local Approach #2 (Trenches)	28	25	22	27	$ 400,000
Local Approach #2 (Pond)	62	25	10	15	$ 100,763

where:

TSS = total suspended solids

BOD = biological oxygen demand

N = total nitrogen

P = total phosphorus

Table 19. Volumes of Detention Pond Alternatives

ALTERNATIVE	VOLUME (CUBIC FEET)	TOTAL COST
Local Approach #1 (Subarea 1)	370,000	$ 69,793
Local Approach #1-Subarea 2	380,000	$ 70,349
Regional Approach #1	720,000	$ 97,430
Regional Approach #2	1,260,000	$ 128,801
Local Approach #2 (Pond)	765,000	$ 100,763

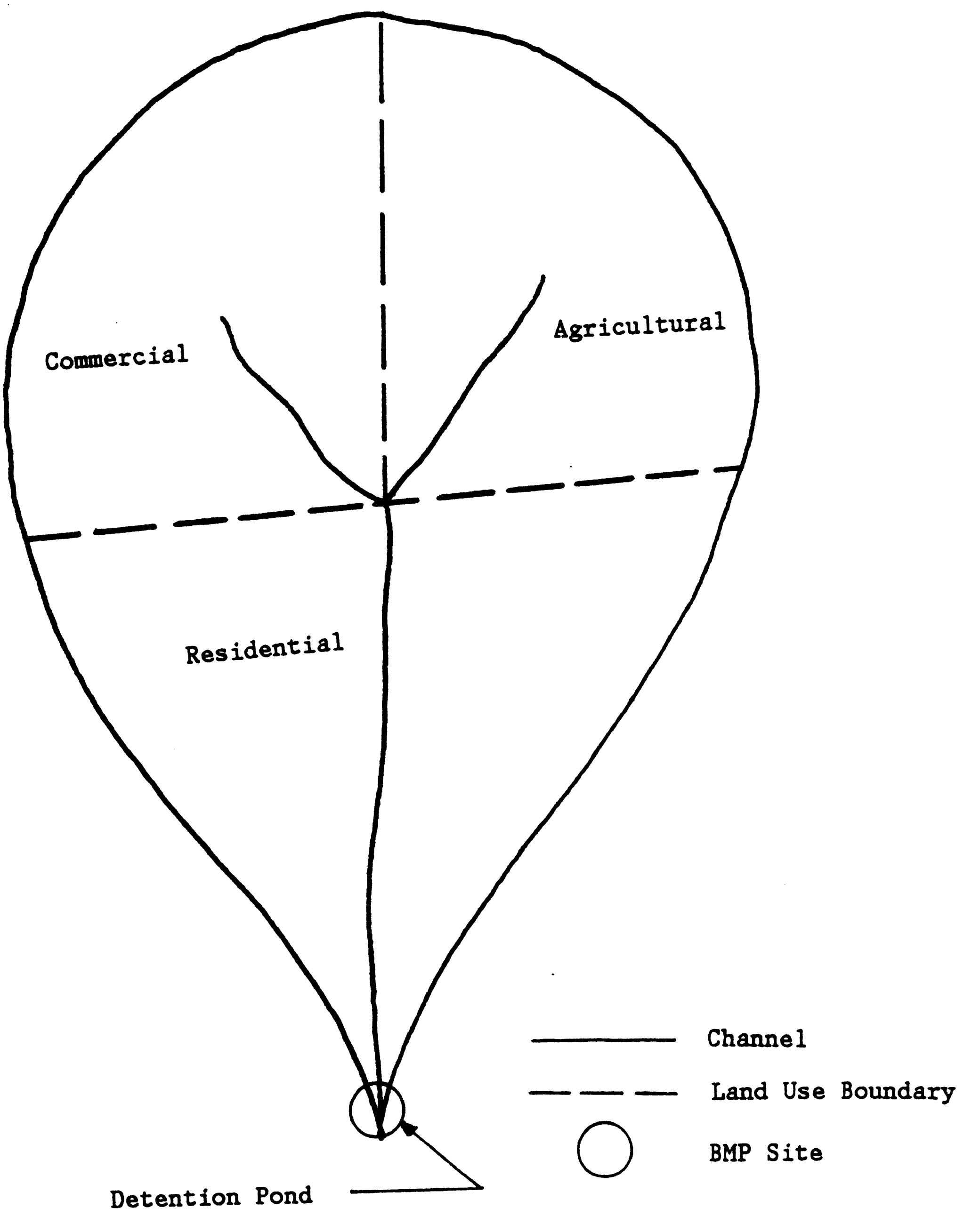

Figure 15. Watershed Map for Regional Approach #2

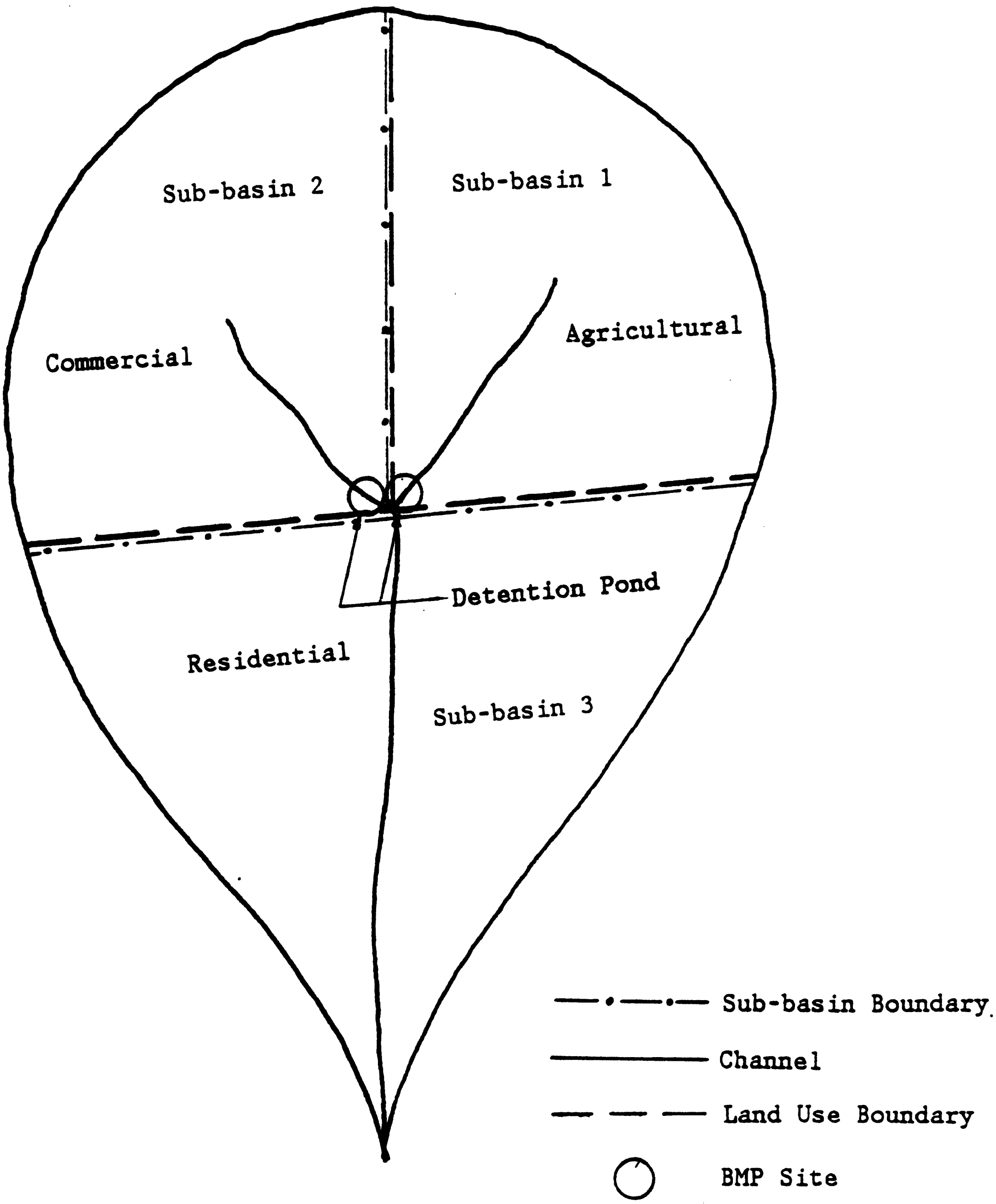

Figure 16. Watershed Map for Local Approach #1

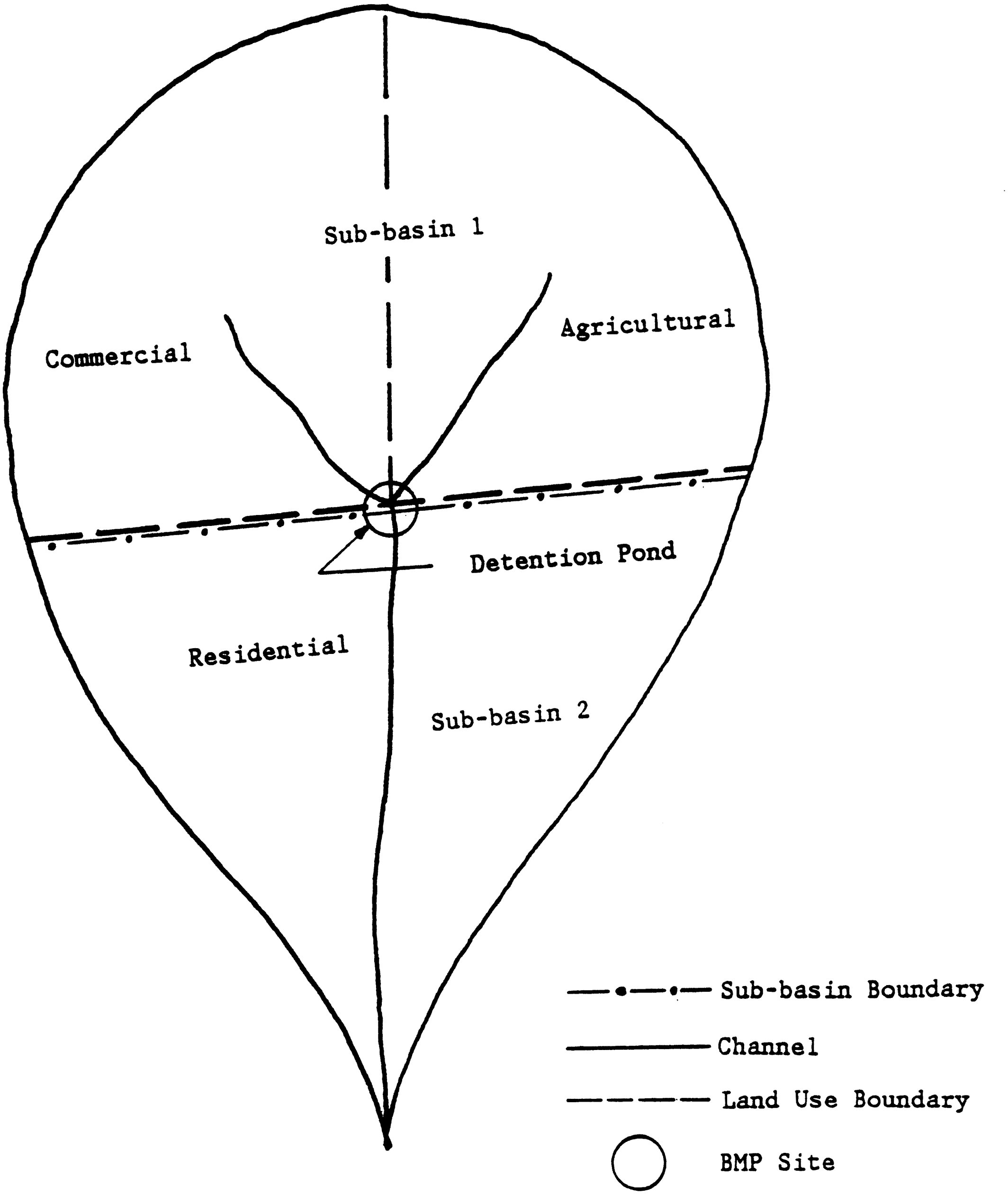

Figure 17. Watershed Map for Regional Approach #1

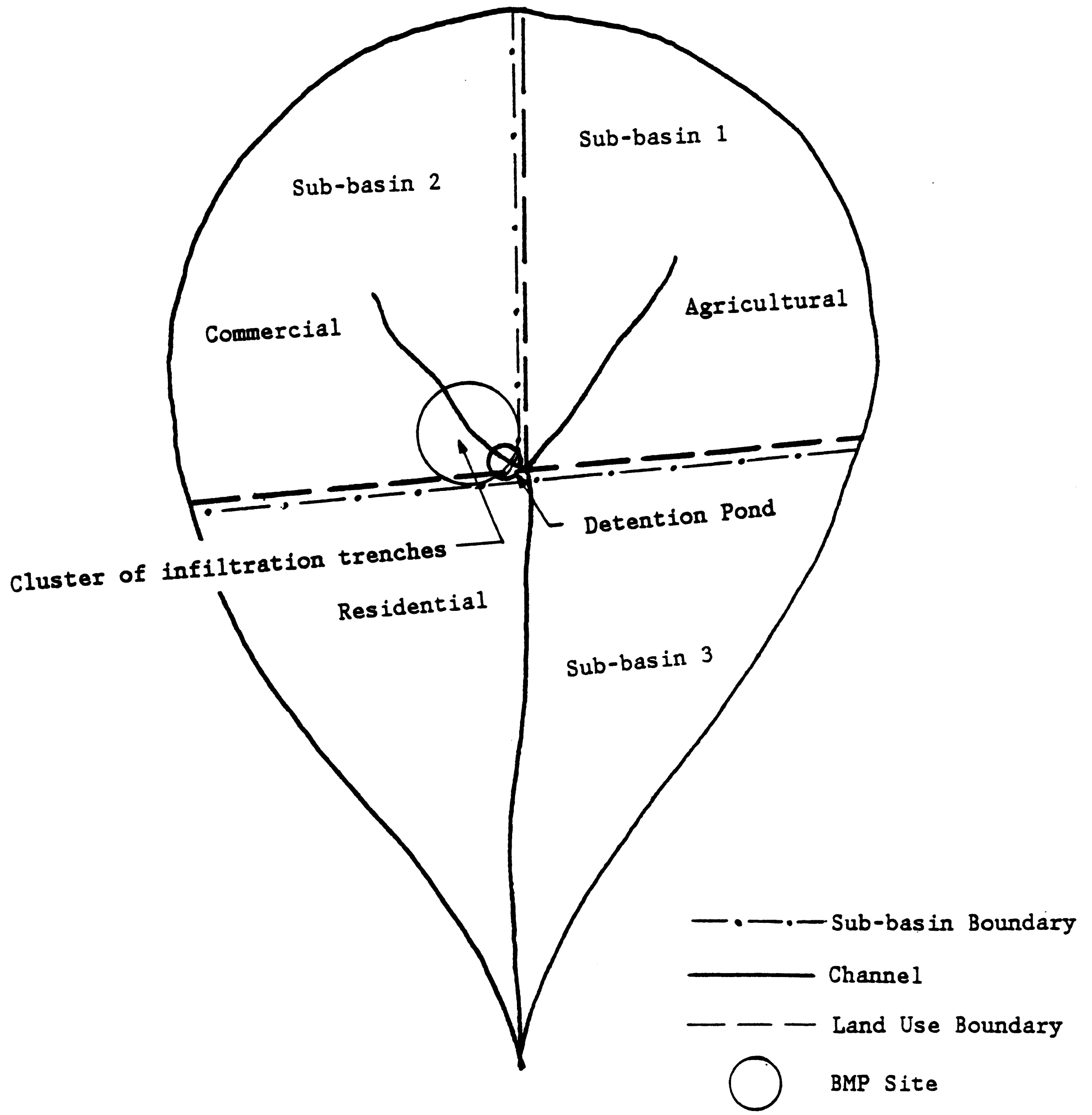

Figure 18. Watershed Map for Local Approach #2

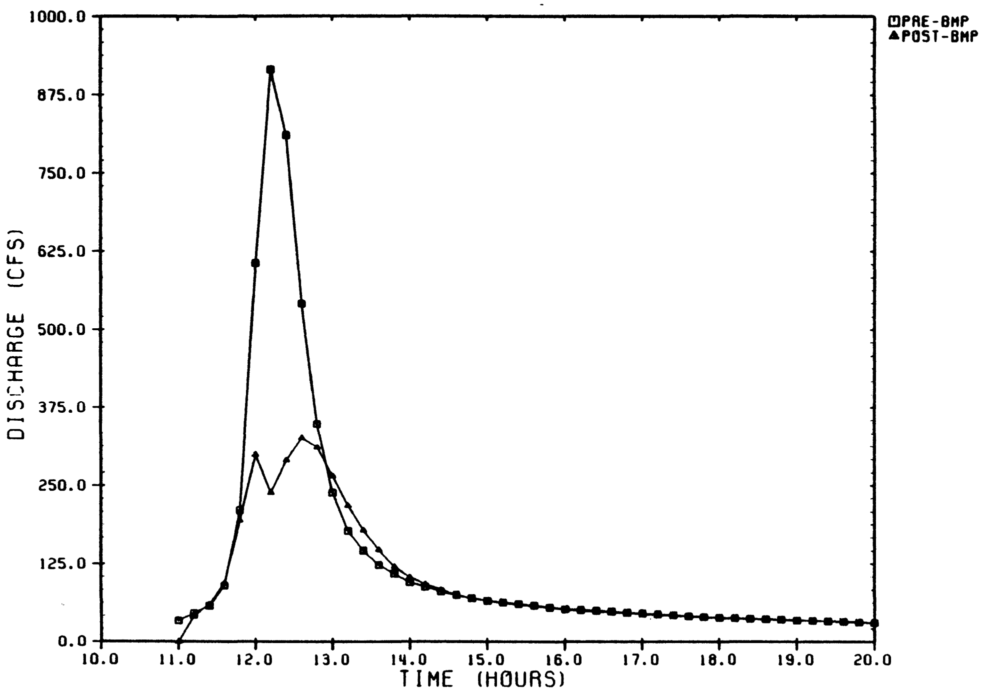

Figure 19. Future Sub-Basin 1 Hydrographs - Local Approach #1

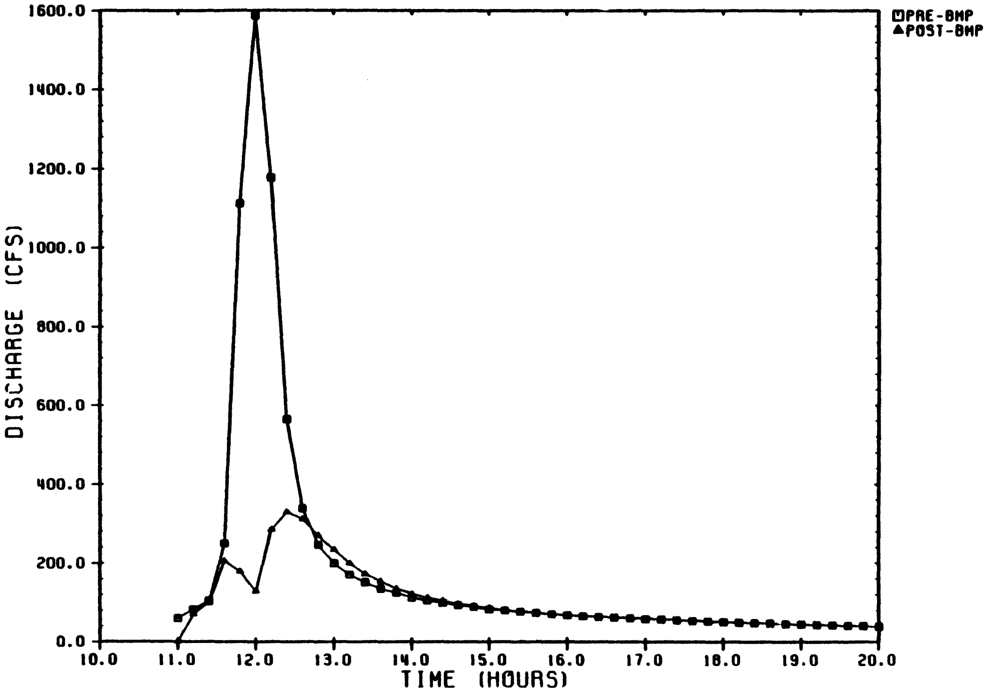

Figure 20. Future Sub-Basin 2 Hydrographs - Local Approach #1

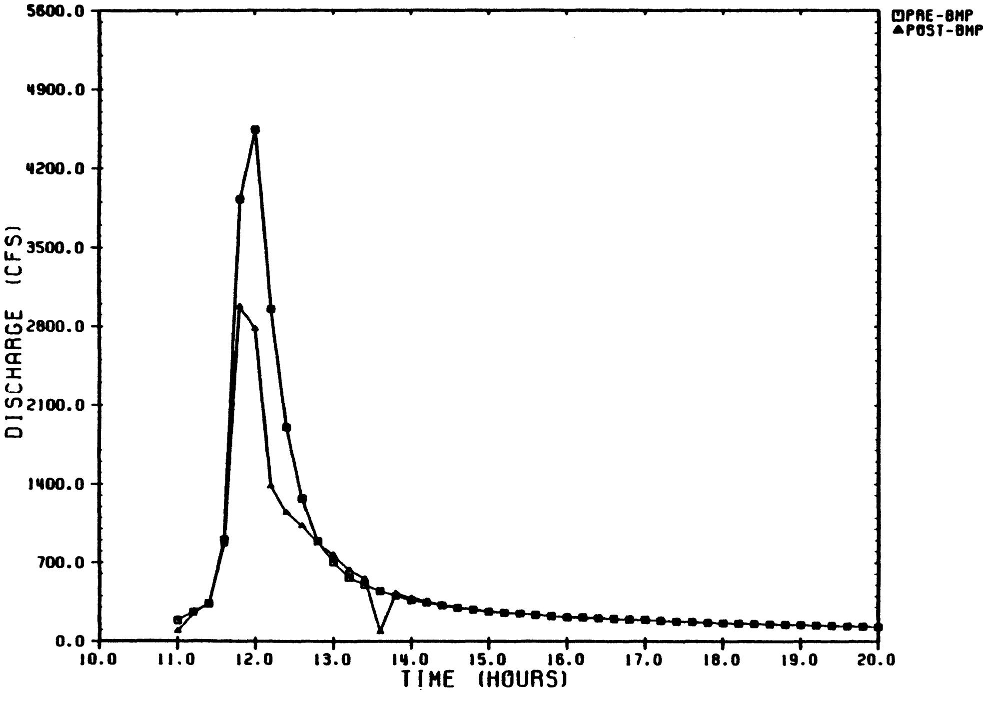

Figure 21. Future Composite Watershed Hydrographs - Local Approach #1

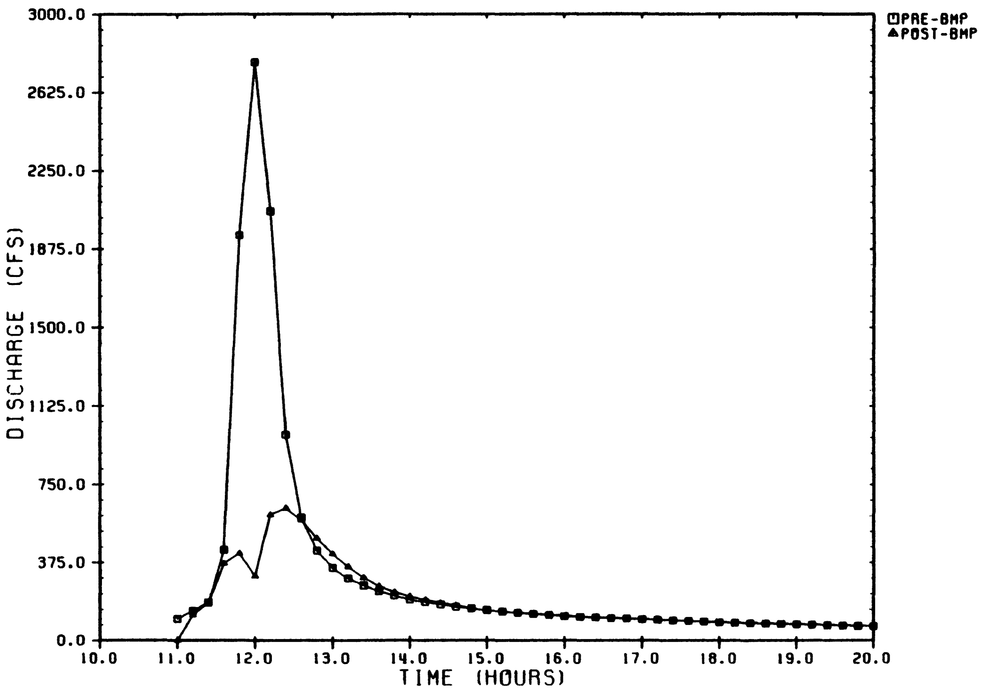

Figure 22. Future Sub-Basin 1 Hydrographs - Regional Approach #1

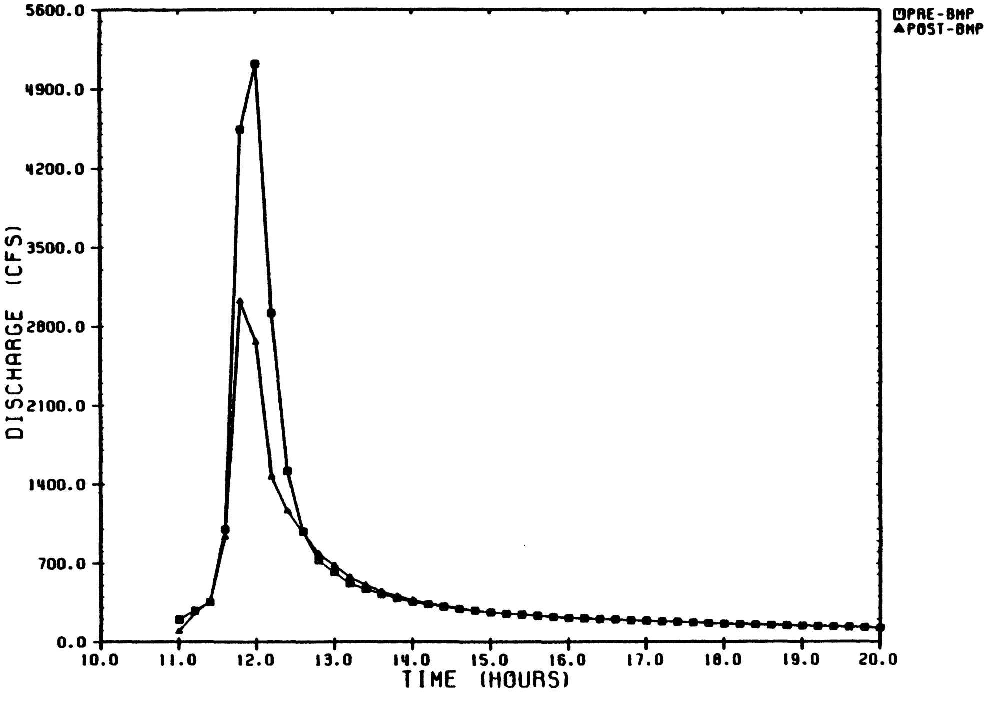

Figure 23. Future Composite Watershed Hydrographs - Regional Approach #1

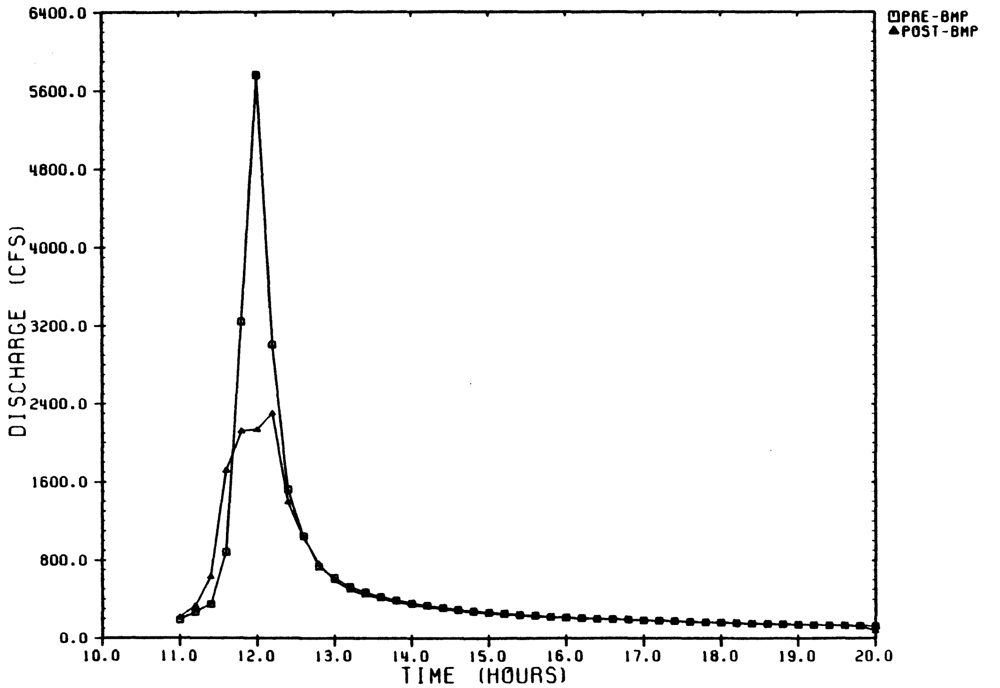

Figure 24. Future Composite Watershed Hydrographs - Regional Approach #2

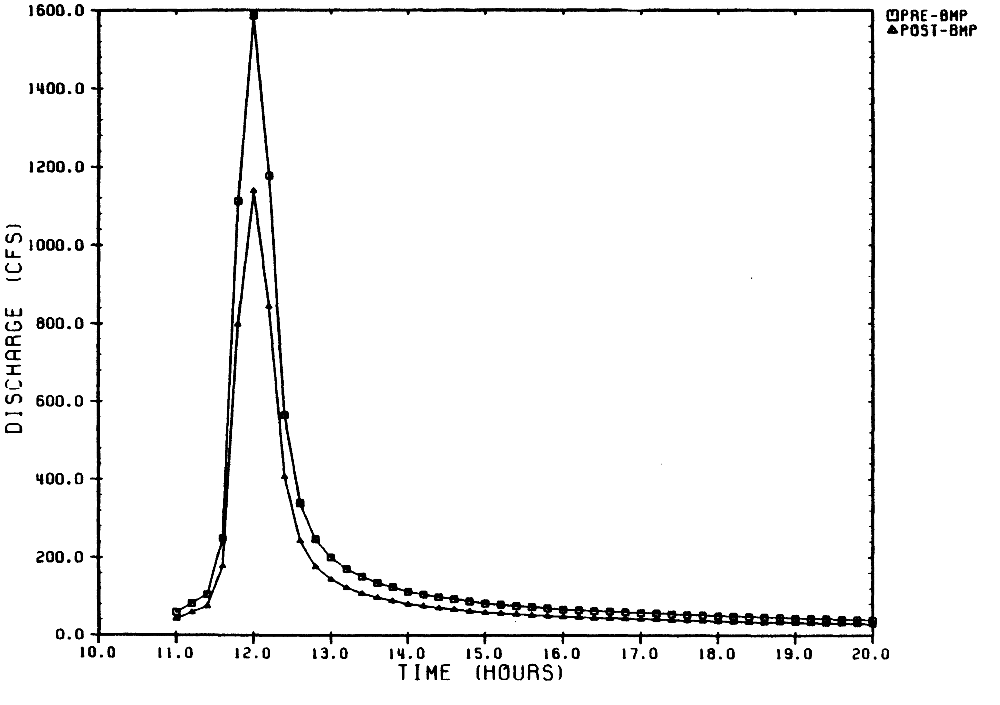

Figure 25. Future Sub-Basin 2 Hydrographs - Local Approach #2 (Trenches)

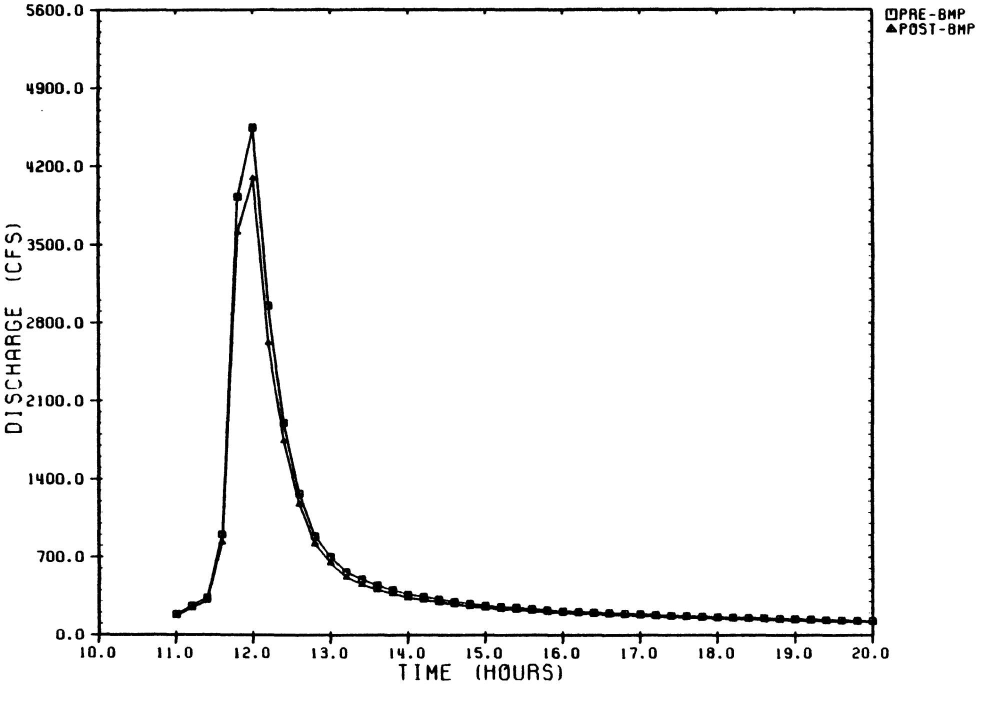

Figure 26. Future Composite Watershed Hydrographs - Local Approach #2 (Trenches)

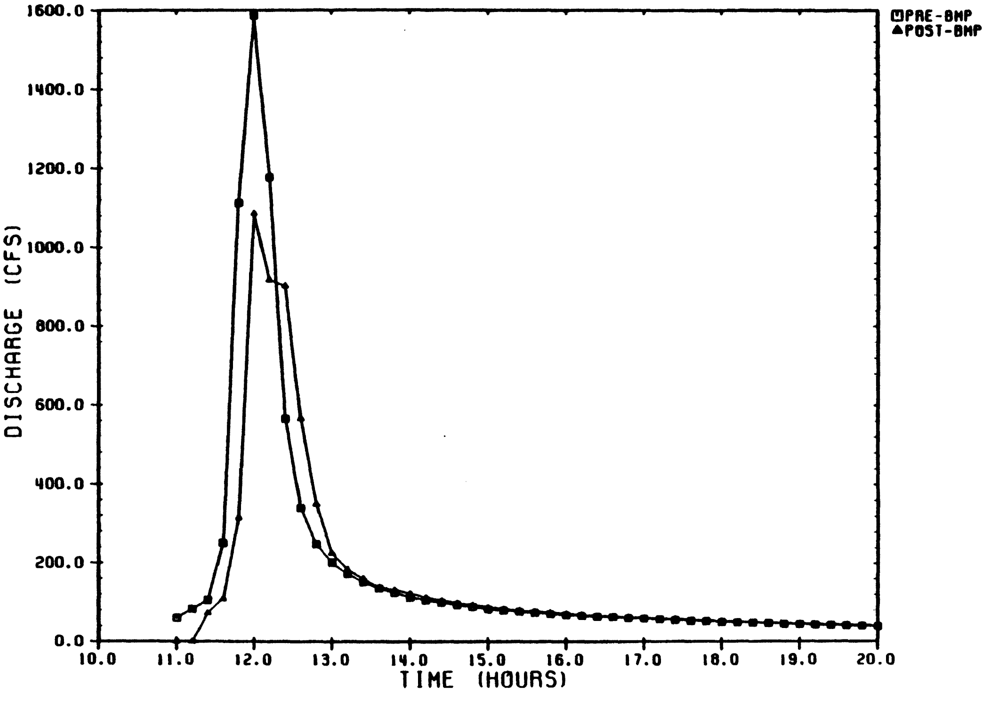

Figure 27. Future Sub-Basin 2 Hydrographs - Local Approach #2 (Pond)

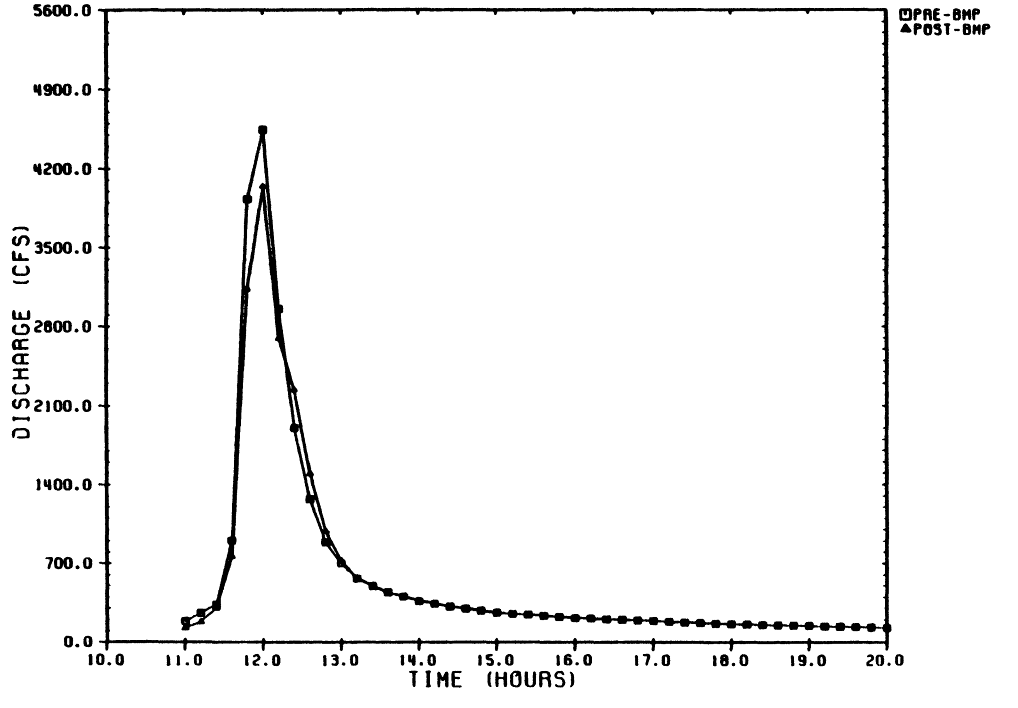

Figure 28. Future Composite Watershed Hydrographs - Local Approach #2 (Pond)

CHAPTER 10: SUMMARY AND CONCLUSIONS

In summary, the primary objective of this report is to present a methodology to compare various stormwater management strategies on the basis of their impact on runoff and pollutant load at the outlet of a watershed and on the total costs involved. Software was developed for "user-friendly" application to personal computers to facilitate such an analysis. This software includes algorithms developed to generate hydrographs using the SCS tabular method as outlined in TR - 55. In addition, pollution washoff processes were incorporated in conjunction with hydrograph generation to produce pollutographs. Prediction of hydrographs and pollutographs for pre- and post-development conditions for a watershed and all sub-drainage basins within the watershed is possible. In addition, five types of best management practice (BMP) structures (i. e. wet ponds, dry ponds, extended wet ponds, infiltration trenches, and porous pavement) can be designed and compared in terms of cost effectiveness in managing stormwater quantity and quality. To provide a basis for comparison of these BMP facilities, a cost analysis was developed from the current literature. Applications of the software to a hypothetical watershed are presented for purposes of illustration. Model results are compared with monitored data from the Cub Run watershed in northern Virginia.

Based on the findings of this research, the following conclusions can be presented:

1. The purpose of the model presented in this study is to provide the user with an easy-to-use, desk top model for use on the personal computer. Since the model is at a medium level of sophistication, it is meant to be used as a management tool for estimation of the location and type of control measures needed to attain a given level of runoff and pollutant control at the outlet of the watershed. In addition, the procedures used to estimate size and location of different BMP structures yield good preliminary design estimates of these structures. These design estimates can then be compared on an order of magnitude scale for their impact on runoff and pollutant load at the outlet of the watershed and on the total costs involved. BMP designs predicted by the model are meant to be used as a preliminary estimate for the final design of these facilities. Thus, this model is meant to be used primarily as a planning tool; its use for complex hydrologic analysis is not recommended.

   In addition, it is strongly recommended that the user of the model be familiar with the tabular hydrograph computation methods outlined in SCS TR - 55 (1975). The user should be aware of the limitations of these methods and of the conditions under which they should be applied.

2. Chapter 7 presents technical limitations and recommended improvements to the software package.

3. Results of a preliminary verification of the model are presented in Chapter 8. For the watershed examined in this process, the model

yielded flow and pollutant concentrations an order of magnitude greater than the monitored values. This discrepancy may be explained in part by the discussion presented in Chapter 8. Better verification results may be achieved with the application of the model to a smaller, more urbanized watershed.

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APPENDIX A. SOFTWARE PROGRAM LISTINGS

```
10 '*****************************************************************************
20 '**                        SCS PROGRAM MODULE                                **
30 '**                      WRITTEN BY: K. A. CAVE                              **
40 '**                           VERSION 2.2                                    **
50 '**                           MARCH, 1986                                    **
60 '*****************************************************************************
70 COLOR 7,9,0:KEY OFF:WIDTH 80
80 DIM CN(4,78),AMCF(10,3)
90 OPEN "B:PREP.DAT" FOR INPUT AS #1
100 FOR I=1 TO 78:INPUT #1, CN(1,I),CN(2,I),CN(3,I),CN(4,I):NEXT I
110 FOR II=1 TO 10:INPUT #1, AMCF(II,1),AMCF(II,3):NEXT II
120 CLOSE:CLS:LOCATE 3,18:PRINT "********RUNOFF HYDROGRAPH GENERATION**
    ******"
130 PRINT:PRINT:PRINT "     The following program module uses the SCS
    Method to develop an inflow"
140 PRINT "     hydrograph for a given watershed.  The watershed can be
    divided
150 PRINT "     into sub-drainage areas and hydrographs developed for
    each area;"
160 PRINT "     a composite hydrograph is computed for the entire
    watershed.  You"
170 PRINT "     will be prompted for information during program
    execution."
180 OPEN "B:prePOL1.DAT" FOR OUTPUT AS #3   'data to POLNEW
190 PRINT:PRINT "     First, information about the watershed
    characteristics and the design conditions must be provided.":PRINT
200 INPUT"     What is the name of the watershed";N$
210 WRITE #3, N$  ' N$ is the name of the watershed.
220 PRINT:INPUT "     What is the drainage area (in acres)";DRA
230 WRITE #3, DRA   'DRA REPRESENTS THE TOTAL DRAINAGE AREA OF THE BASIN.
240 PRINT:INPUT "     What is the expected rainfall (in inches over
    the basin) for the design        storm";P
250 REM P represents the expected rainfall (in inches) for a storm
    with a frequency of FREQ years.
260 WRITE #3, P
270 PRINT:INPUT "     What is the return period of the design storm
    (in years)";FREQ
280 CLS:LOCATE 6,6:PRINT"Which of the following best describes the
    antecedent moisture conditions?":PRINT
290 PRINT"                        5-DAY ANTECEDENT RAINFALL "
300 PRINT"                       _______(in inches)_______"
310 PRINT"     General Description:      Dormant Season  Growing Season"
320 PRINT"1.   Soils are dry but not to       <0.5            <1.4    "
330 PRINT"     the wilting point.  "
340 PRINT"     (Enter 1.)"
```

```
350 PRINT"2.    Avg value for annual           0.5-1.1          1.4-2.1"
360 PRINT"      floods.  (Enter 2.)"
370 PRINT"3.    Heavy rainfall or light         >1.1             >2.1"
380 PRINT"      rainfall and low temp"
390 PRINT"      within 5 days prior to"
400 PRINT"      design storm.  (Enter 3.)"
410 INPUT "                                                      ";AMC
420 REM AMC represents the Antecedent Moisture Condition of
    the soil when the design storm occurs.
430 CLS:OPEN "B:runcond" FOR INPUT AS #1
440 INPUT #1, TIM$:CLOSE #1
450 IF TIM$="future" THEN WHEN$="future "
460 IF TIM$="present" THEN WHEN$="present "
470 PRINT "     Provide the following information regarding the ";WHEN$
480 PRINT "     condition of the watershed:":PRINT
490 PRINT "     How many different sub-drainage areas are located
    within this"
500 INPUT "       drainage area";N
510 WRITE #3, N
520 DIM DA(N),DASM(N),RCN(N),AREA(N,10),SP(N),QP(N),TCONC(N),TTIME(N)
530 FOR J=1 TO N
540 WRCN=0:ASUM=0!:KDP=1:CLS
550 PRINT "For ";WHEN$;" subarea ";J
560 PRINT:INPUT "   What is the area (in acres)";DA(J):PRINT
570 PRINT:INPUT "   Is this number correct (Y|N) ";CORR$
580 IF CORR$="n" OR CORR$="N" THEN GOTO 560
590 FOR K=1 TO N:DASM(K)=DA(K)/640!:NEXT K
600 CLS:GOSUB 620
610 GOTO 970
620 PRINT:PRINT:PRINT:PRINT:PRINT "     Information now needs to be
    provided to allow calculation of the "
630 PRINT "  runoff curve numbers for the ";WHEN$;" condition subareas."
640 PRINT:PRINT "     For each subarea,"
650 PRINT "  enter each land use type and the amount of land (in acres)
    for
660 PRINT "  each type successively.  Note the order of entry of these
    land
670 PRINT "  use types; you will be asked further questions concerning
    land
680 PRINT "  uses in another segment of the program.":PRINT
690 PRINT "  How many land use types exist in ";WHEN$;"subarea ";J;
700 INPUT " ";LUT
710 IF LUT><0 THEN GOTO 730
720 BEEP:PRINT:PRINT"     YOU MUST ENTER A POSITIVE VALUE.":PRINT:
    GOTO 690
730 WRITE #3,LUT
740 CLS:PRINT:PRINT:PRINT "     Which of the following best describes
    the GENERAL land use:"
750 PRINT:PRINT "        A.   Fully developed urban area (vegetation
    established)"
760 PRINT:PRINT "        B.   Developing urban area (no vegetation
```

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established)"
770 PRINT:PRINT "       C.   Cultivated agricultural land      "
780 PRINT:PRINT "       D.   Non-cultivated agricultural land"
790 PRINT:PRINT "       E.   Forest-Range"
800 PRINT:INPUT"      Type the appropriate letter ";TYPE$
810 IF TYPE$="a" OR TYPE$="A" OR TYPE$="b" OR TYPE$="B" OR TYPE$="c"
    OR TYPE$="C" OR TYPE$="d" OR TYPE$="D" OR TYPE$="e" OR TYPE$="E"
    THEN GOTO 830
820 BEEP:PRINT:PRINT "      YOU DID NOT ENTER A POSSIBLE CHOICE.":
    GOTO 800
830 CLS TYPE$="a" OR TYPE$="A" THEN GOSUB 3930
840 IF TYPE$="b" OR TYPE$="B" THEN GOSUB 4210
850 IF TYPE$="c" OR TYPE$="C" THEN GOSUB 4310
860 IF TYPE$="d" OR TYPE$="D" THEN GOSUB 4820
870 IF TYPE$="e" OR TYPE$="E" THEN GOSUB 5090
880 CLS:GOSUB 2920
890 ATOTAL=HSGA+HSGB+HSGC+HSGD ATOTAL=AREA(J,KDP) THEN GOTO 920
900 BEEP:PRINT:PRINT "   The total of the soil group areas does not
    equal the land use area.":PRINT:PRINT "    Please re-enter these
    numbers.":PRINT
910 PRINT:INPUT "   Press RETURN to continue ",GO:ATOTAL=0:GOTO 880
920 TCN=HSGA*CN(1,LUD%)+HSGB*CN(2,LUD%)+HSGC*CN(3,LUD%)+HSGD*CN(4,LUD%)
930 WRCN=WRCN+TCN:ASUM=ASUM+AREA(J,KDP)
940 IF KDP=LUT THEN GOTO 960
950 KDP=KDP+1:GOTO 740
960 RETURN
970 CLS ASUM=DA(J) THEN GOTO 1010
980 BEEP:PRINT:PRINT "  The total of the land use type areas does not
    equal the area of the subbasin.":PRINT:PRINT "   Please re-enter
    these numbers."
990 PRINT:INPUT "   Press RETURN to continue ",GO
1000 WRCN=0:ASUM=0!:KDP=1:GOTO 600
1010 RCN(J)=WRCN/ASUM
1020 IF AMC=1 OR AMC=3 THEN GOSUB 3370
1030 NEXT J
1040 ASUM=0:FOR J=1 TO N:ASUM=ASUM + DA(J):NEXT J
1050 IF ASUM=DRA THEN GOTO 1090
1060 CLS:BEEP:LOCATE 5,5:PRINT"The total of the areas entered for the
     subareas does not equal"
1070 LOCATE 6,5:PRINT"the total watershed area.  Please re-enter these
     numbers.
1080 LOCATE 8,5:INPUT"Press RETURN to continue  ",GO:GOTO 530
1090 FOR KAC=1 TO N:WRITE #3, DA(KAC):NEXT KAC
1100 FOR K=1 TO N
1110 SP(K)=(1000/RCN(K))-10 'SP represents a watershed storage parameter.
1120 REM This method assumes an initial abstraction of 0.2*SP
1130 QP(K)=(P-.2*SP(K))*(P-.2*SP(K))/(P+.8*SP(K))
1140 IF (P-.2*SP(K)) > 0 THEN GOTO 1200
1150 QP(K)=0:CLS:LOCATE 5,5:PRINT"Calculations indicate that the
     expected precipitation is less than "
1160 LOCATE 6,5:PRINT"the initial abstraction for subarea ";K;" --
```

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    thus the runoff "
1170 LOCATE 7,5:PRINT"for this subarea is zero.  Type  yes' if you
    wish to continue "
1180 LOCATE 8,5:INPUT"or  no' if you wish to return to the beginning
    for data revision ",GOO$
1190 IF GOO$="no" OR GOO$="NO" THEN CLEAR:GOTO 40
1200 REM QP represents the direct runoff (in inches) for each subarea.
1210 NEXT K
1220 ERASE AREA,SP,AMCF,CN
1230 REM ***TRAVEL TIMES & TIME OF CONCENTRATION CALCULATIONS ******
1240 CLS:LOCATE 5:PRINT "     It is now necessary to provide
    information which will allow the calculation of times of
    concentration and times of travel."
1250 PRINT "     Necessary data includes:  descriptions of the basin
    regarding                   overland flow and surface runoff."
1260 PRINT:PRINT:PRINT:PRINT:INPUT "      Press RETURN to continue ",
    PETE:CLS
1270 FOR KAC=1 TO N
1280 TOTALT=0:DRP=1
1290 PRINT:PRINT "                 TIME OF CONCENTRATION CALCULATIONS:"
    :PRINT
1300 PRINT "     Determine which of the following best describes the "
    ;WHEN$;" condition"
1310 PRINT "     of the runoff flow from the farthest point in the
    subarea to the outlet"
1320 PRINT "     of the subarea.  If several conditions exist, enter
    each successively."
1330 PRINT:PRINT "     For ";WHEN$;"subarea ";KAC
1340 PRINT:PRINT "          POSSIBLE CONDITIONS:  "
1350 PRINT "     1.  Forest with heavy ground litter and meadow ":
    PRINT "     2.  Fallow or minimum tillage cultivation          "
1360 PRINT "     3.  Short grass and lawns":PRINT "     4.  Nearly
    bare ground                        "
1370 PRINT "     5.  Grassed waterway ":PRINT "     6.  Paved area
    (sheet flow) & shallow gutter flow "
1380 PRINT "     7.  Gutter flow":PRINT "     8.  Channel flow ":PRINT "
    9.  Sewer flow  ":PRINT
1390 INPUT "     How many conditions describe this type of runoff flow "
    ;NTIME
1400 IF NTIME><0 THEN CLS:GOTO 1420
1410 BEEP:PRINT:PRINT"     YOU MUST ENTER A POSITIVE VALUE.":PRINT:
    GOTO 1390
1420 GOSUB 1440
1430 GOTO 1680
1440 PRINT:PRINT "          POSSIBLE CONDITIONS:  "
1450 PRINT "     1.  Forest with heavy ground litter and meadow
    (Enter 1)"
1460 PRINT "     2.  Fallow or minimum tillage cultivation
    (Enter 2)"
1470 PRINT "     3.  Short grass and lawns
```

```
    (Enter 3)"
1480 PRINT "     4.  Nearly bare ground
    (Enter 4)"
1490 PRINT "     5.  Grassed waterway
    (Enter 5)"
1500 PRINT "     6.  Paved area (sheet flow) & shallow gutter flow
    (Enter 6)"
1510 PRINT "     7.  Gutter flow
    (Enter 7)"
1520 PRINT "     8.  Channel flow
    (Enter 8)"
1530 PRINT "     9.  Sewer flow
    (Enter 9)":PRINT
1540 INPUT "     What is the condition";COND
1550 IF COND=1 OR COND=2 OR COND=3 OR COND=4 OR COND=5 OR COND=6 OR
    COND=7 OR COND=8 OR COND=9 THEN GOTO 1570
1560 BEEP:PRINT:PRINT "     YOU DID NOT ENTER A POSSIBLE CONDITION
    NUMBER.":PRINT:GOTO 1540
1570 INPUT "     What is the length of flow for this condition (in
    feet)";LENG
1580 INPUT "     What is the slope of the flow for this condition (in
    percent)";SLOPE
1590 IF COND=7 THEN GOSUB 3590:GOTO 1650
1600 IF COND=8 THEN GOSUB 3700:GOTO 1650
1610 IF COND=9 THEN GOSUB 3840:GOTO 1650
1620 GOSUB 3470
1630 TIME=LENG/VEL
1640 TOTALT=TOTALT+TIME:CLS
1650 IF DRP=NTIME THEN GOTO 1670
1660 DRP=DRP+1:GOTO 1440
1670 RETURN
1680 TCONC(KAC)=TOTALT/3600!
1690 CLS:TOTALT=0!:DRP=1:PRINT
1700 PRINT:PRINT "                    TRAVEL TIME CALCULATION:    "
1710 PRINT "     Determine which of the following best describes the "
    ;WHEN$;" condition"
1720 PRINT "     of the runoff flow once it exits the subarea and
    travels to the outlet "
1730 PRINT "     of the watershed.  If several conditions exist, enter
    each successively."
1740 PRINT:PRINT "     Note: If the runoff flow of a subarea exits
    where the watershed exits, "
1750 PRINT "     enter  0' for the number of conditions."
1760 PRINT:PRINT "     For ";WHEN$;"subarea ";KAC
1770 PRINT:PRINT "        POSSIBLE CONDITIONS:  "
1780 PRINT "     1.  Forest with heavy ground litter and meadow "
    :PRINT "     2.  Fallow or minimum tillage cultivation            "
1790 PRINT "     3.  Short grass and lawns":PRINT "     4.  Nearly
    bare ground                                  "
1800 PRINT "     5.  Grassed waterway ":PRINT "     6.  Paved area
```

```
     (sheet flow) & shallow gutter flow "
1810 PRINT "     7.  Gutter flow":PRINT "     8.  Channel flow ":
     PRINT "     9.  Sewer flow  ":PRINT
1820 INPUT "     How many conditions describe this type of runoff flow"
     ;NTIME
1830 IF NTIME=0 THEN TOTALT=0!
1840 IF NTIME=0 THEN GOTO 1860
1850 CLS:GOSUB 1440
1860 CLS:TTIME(KAC)=TOTALT/3600!
1870 NEXT KAC
1880 CLS:Y$="#########.##"
1890 PRINT:PRINT "     The following is a partial listing of data for
     the ";N$;" watershed.":PRINT
1900 IF WHEN$="future " THEN GOTO 1930
1910 PRINT "                    DATA FOR THE PRESENT CONDITION:":PRINT
1920 IF WHEN$="present " THEN GOTO 1940
1930 PRINT "                    DATA FOR THE FUTURE CONDITION:":PRINT
1940 PRINT "     Subarea  Area(acres)    RCN      TC(hrs)    TT(hrs)
     Runoff(in)     "
1950 FOR M=1 TO N
1960 PRINT USING Y$; M; DA(M); RCN(M); TCONC(M); TTIME(M); QP(M)
1970 NEXT M
1980 PRINT:PRINT:INPUT "     Press RETURN to continue  ",MICK:CLS
1990 LOCATE 5,5:PRINT " Hydrograph calculations. . . .":PRINT
2000 DIM OFL(11,24),OFH(11,24),OFLP(24),OFHP(24),OTP(24),QS(N,24),
     QSC(N,24),QTOT(24),FLOW(46)
2010 REM OFL(1 to 11,1 to 24) are the tabular values (as given in
     TR-55) for any condition inflow hydrograph for a time of
     concentration = TCL.
2020 REM OFH(1 to 11,1 to 24) are the tabular values (as given in
     TR-55) for any condition inflow hydrograph for a time of
     concentration = TCH.
2030 REM OFLp(1 to 24) are the tabular values (as given in
     TR-55) of any condition inflow hydrograph (for subarea K)
     for a time of concentration = TCL and travel time = TTIME(K).
2040 REM OFHp(1 to 24) are the tabular values (as given in
     TR-55) of any condition inflow hydrograph (for subarea K)
     for a time of concentration = TCH and travel time = TTIME(K)
2050 REM OTp(1 to N,1 to 24) are the tabular values (as given in
     TR-55) for any condition inflow hydrograph of subarea K for
2060 REM QS(1 to n,1 to 24) are the discharge values of the hydrograph
     of subarea K for any condition.
2070 REM QSC(1 to n,1 to 24) are the discharge values of the hydrograph
     of subarea K which contribute to the composite hydrograph for
     any condition.
2080 REM ****************** Hydrograph calculation**********
2090 FOR KKK=1 TO 24:QTOT(KKK)=0:NEXT KKK
2100 FOR MM=1 TO N
2110 GOSUB 2990
2120 IF TCONC(MM)>=.1 AND TCONC(MM)=<2! THEN GOTO 2140
2130 CLEAR:GOTO 40
```

```
2140 FOR JJJ=1 TO 24
2150 OFLP(JJJ)=OFL(TTL,JJJ)+(OFL(TTH,JJJ)-OFL(TTL,JJJ))*(TTIME(MM)-TT1)
     /(TT2-TT1)
2160 OFHP(JJJ)=OFH(TTL,JJJ)+(OFH(TTH,JJJ)-OFH(TTL,JJJ))*(TTIME(MM)-TT1)
     /(TT2-TT1)
2170 OTP(JJJ)=OFLP(JJJ)+(OFHP(JJJ)-OFLP(JJJ))*(TCONC(MM)-TCL)/(TCH-TCL)
2180 QSC(MM,JJJ)=OTP(JJJ)*DASM(MM)*QP(MM)
2190 QTOT(JJJ)=QTOT(JJJ)+QSC(MM,JJJ)
2200 NEXT JJJ
2210 FOR JJJ=1 TO 24
2220 TTL=1:TTH=1:TT1=0:TT2=1   'SETS TTIME = 0
2230 OFLP(JJJ)=OFL(TTL,JJJ):OFHP(JJJ)=OFH(TTL,JJJ) 'this sets ttime=0
2240 OTP(JJJ)=OFLP(JJJ)+(OFHP(JJJ)-OFLP(JJJ))*(TCONC(MM)-TCL)/(TCH-TCL)
2250 QS(MM,JJJ)=OTP(JJJ)*DASM(MM)*QP(MM)
2260 NEXT JJJ
2270 NEXT MM
2280 OPEN "b:preBMP1.dat" FOR OUTPUT AS #1   'data to BMP
2290 WRITE #1, N$:WRITE #1, N:WRITE #1, P:WRITE #1, AMC
2300 FOR LAND=1 TO N
2310   FOR JJ=1 TO 24:WRITE #1, QS(LAND,JJ):NEXT JJ
2320 NEXT LAND
2330 FOR LAND=1 TO N
2340   FOR JJ=1 TO 24:WRITE #1, QSC(LAND,JJ):NEXT JJ
2350 NEXT LAND
2360 FOR NSUB=1 TO N:WRITE #1, TTIME(NSUB):NEXT NSUB
2370 OPEN "b:preBMP2.dat" FOR OUTPUT AS #2   'data to BMP
2380 FOR LAND=1 TO N
2390 WRITE #2, DA(LAND):WRITE #2, RCN(LAND):WRITE #2, TCONC(LAND):
     WRITE #2, QP(LAND)
2400 NEXT LAND
2410 CLOSE #1,#2
2420 CLS:BMP$="no"
2430 LOCATE 4,10:PRINT " Hydrographs have been calculated for each
     subarea and for the "
2440 LOCATE 6,10:PRINT " entire watershed.  Please choose which form
     you wish to view them:"
2450 LOCATE 8,25:PRINT " A.  Tabular form"
2460 LOCATE 9,25:PRINT " B.  Graphical form"
2470 LOCATE 10,25:PRINT " C.  Tabular and graphical form"
2480 LOCATE 12,10:INPUT " Enter the letter of your choice ",FORM$
2490 IF FORM$="a" OR FORM$="A" OR FORM$="c" OR FORM$ ="C" OR FORM$="b"
     OR FORM$="B" THEN GOTO 2510
2500 BEEP:CLS:LOCATE 14,20:PRINT "YOU DID NOT ENTER A POSSIBLE CHOICE"
     :GOTO 2430
2510 PRINT:PRINT "          The program will now call the output module
     to output"
2520 PRINT "          the hydrographs."
2530 PRINT "          This will take a few minutes . . . please be
     patient."
2540 PRINT:INPUT "          Press RETURN to continue ",GO
2550 OPEN "b:hyd.ord" FOR OUTPUT AS #2   'data to OUTPUT
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2560 OPEN "b:prePOL2.dat" FOR OUTPUT AS #1   'data to POLNEW
2570 WRITE #2, BMP$:WRITE #2, N$:WRITE #2, N:WRITE #2, WHEN$:WRITE
     #2, FORM$
2580 FOR LAND=1 TO N
2590 GOSUB 5300
2600   FOR NUMB=1 TO 46
2610   WRITE #2, FLOW(NUMB)
2620   WRITE #1, FLOW(NUMB)
2630   NEXT NUMB
2640 NEXT LAND
2650 LAND=1
2660 FOR OOP=1 TO 24:QS(LAND,OOP)=QTOT(OOP):NEXT OOP
2670 GOSUB 5300
2680 FOR KK=1 TO 46:WRITE #2, FLOW(KK):NEXT KK
2690 CLOSE #2
2700 FOR LAND=1 TO N
2710 FOR OOP=1 TO 24:QS(LAND,OOP)=QSC(LAND,OOP):NEXT OOP
2720 GOSUB 5300
2730 FOR KK=1 TO 46:WRITE #1, FLOW(KK):NEXT KK
2740 NEXT LAND
2750 CLS:PRINT:PRINT:PRINT:PRINT:PRINT
2760 PRINT " The data you have supplied concerning the ";WHEN$;
     " condition of"
2770 PRINT " the ";N$;" watershed and the hydrographs generated by this"
2780 PRINT " program segment have been stored in data files on the B:
     drive"
2790 PRINT " as follows: ":PRINT
2800 PRINT "      hyd.ord'          contains the computed hydrographs"
2810 PRINT "                        for each subarea and the  composite"
2820 PRINT "                        basin hydrograph"
2830 PRINT "      preBMP1.da'       contain data such as types and
     amounts      preBMP2.da'       of land uses, design criteria, and"
2840 PRINT "      prePOL1.da'       of soils and land uses within the
     basin "
2850 PRINT "      prePOL2.dat'      and the generated hydrographs for
     the "
2860 PRINT "                        for the ";WHEN$;" design conditions"
2870 PRINT:PRINT"     These files are used in other program segments."
2880 PRINT:INPUT "     Press RETURN to continue",BBD
2890 CLOSE:CLS
2900 SYSTEM
2910 REM!!!!!!!!!!!!!!!!!!!!!SUBROUTINES FOLLOW !!!!!!!!!!!!!!!!!!!!!
2920 REM *********Subroutine to input soil types*********
2930 PRINT:INPUT "   How much of this area (in acres) consists
     of hydrologic soil group A";HSGA
2940 INPUT "   How much of this area (in acres) consists of hydrologic
     soil group B";HSGB
2950 INPUT "   How much of this area (in acres) consists of hydrologic
     soil group C";HSGC
2960 INPUT "   How much of this area (in acres) consists of hydrologic
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     soil group D";HSGD
2970 REM HSG* REPRESENTS THE AMOUNT OF THE LAND USE TYPE WHICH CONSISTS
     OF SOIL IN HYDROLOGIC SOIL GROUP (A, B, C, OR D).
2980 CLS:RETURN
2990 REM ¢¢¢¢¢¢¢Travel time & time of concentration tables¢¢¢¢¢¢¢¢
3000 IF TCONC(MM)<.1 THEN BEEP:PRINT TAB(2) "The time of concentration
     for subarea ";MM;" for the ";WHEN$;" condition is less than the
     minimum tabular value given in TR-55.":PRINT
3010 IF TCONC(MM)<.1 THEN PRINT TAB(2) "Recommend that this subarea be
     combined with other small subareas"
3020 IF TCONC(MM)<.1 THEN PRINT TAB(2) "in the watershed and the
     program rerun.  The program will return  "
3030 IF TCONC(MM)<.1 THEN PRINT TAB(2) "to the beginning for data
     revision.":PRINT
3040 IF TCONC(MM)<.1 THEN INPUT " Press RETURN to continue";GO:GOTO 3360
3050 IF TCONC(MM)>=.1 AND TCONC(MM)<.2 THEN OPEN "B:DATA1" FOR INPUT
     AS #1:OPEN "B:DATA2" FOR INPUT AS #2:TCL=.1:TCH=.2
3060 IF TCONC(MM)>=.2 AND TCONC(MM)<.3 THEN OPEN "B:DATA2" FOR INPUT
     AS #1:OPEN "B:DATA3" FOR INPUT AS #2:TCL=.2:TCH=.3
3070 IF TCONC(MM)>=.3 AND TCONC(MM)<.4 THEN OPEN "B:DATA3" FOR INPUT
     AS #1:OPEN "B:DATA4" FOR INPUT AS #2:TCL=.3:TCH=.4
3080 IF TCONC(MM)>=.4 AND TCONC(MM)<.5 THEN OPEN "B:DATA4" FOR INPUT
     AS #1:OPEN "B:DATA5" FOR INPUT AS #2:TCL=.4:TCH=.5
3090 IF TCONC(MM)>=.5 AND TCONC(MM)<.75 THEN OPEN "B:DATA5" FOR INPUT
     AS #1:OPEN "B:DATA6" FOR INPUT AS #2:TCL=.5:TCH=.75
3100 IF TCONC(MM)>=.75 AND TCONC(MM)<1! THEN OPEN "B:DATA6" FOR INPUT
     AS #1:OPEN "B:DATA7" FOR INPUT AS #2:TCL=.75:TCH=1!
3110 IF TCONC(MM)>=1! AND TCONC(MM)<1.25 THEN OPEN "B:DATA7" FOR INPUT
     AS #1:OPEN "B:DATA8" FOR INPUT AS #2:TCL=1!:TCH=1.25
3120 IF TCONC(MM)>=1.25 AND TCONC(MM)<1.5 THEN OPEN "B:DATA8" FOR INPUT
     AS #1:OPEN "B:DATA9" FOR INPUT AS #2:TCL=1.25:TCH=1.5
3130 IF TCONC(MM)>=1.5 AND TCONC(MM)<=2! THEN OPEN "B:DATA9" FOR INPUT
     AS #1:OPEN "B:DATA10" FOR INPUT AS #2:TCL=1.5:TCH=2!
3140 IF TCONC(MM)>2! THEN BEEP:PRINT TAB(2) "THE TIME OF CONCENTRATION
     FOR SUBAREA ";MM;" FOR THE ";WHEN$;" CONDITION EXCEEDS THE TABULAR
     VALUES GIVEN IN TR-55.":PRINT
3150 IF TCONC(MM)>2! THEN PRINT TAB(2) "RECOMMEND THAT THIS SUBAREA BE
     BROKEN INTO SEVERAL SMALLER SUBAREAS"
3160 IF TCONC(MM)>2! THEN PRINT TAB(2) "AND THE PROGRAM RERUN.  THE
     PROGRAM WILL RETURN TO THE BEGINNING "
3170 IF TCONC(MM)>2! THEN PRINT TAB(2) "FOR DATA REVISION.":PRINT
3180 IF TCONC(MM)>2! THEN  INPUT " PRESS RETURN TO CONTINUE",GO
3190 IF TCONC(MM)>2! THEN GOTO 3360
3200 FOR J=1 TO 11
3210    FOR JJ=1 TO 24:INPUT #1, OFL(J,JJ):INPUT #2, OFH(J,JJ):NEXT JJ
3220 NEXT J
3230 CLOSE #1, #2
3240 IF TTIME(MM)=0 THEN TTL=1:TTH=1:TT1=TTIME(MM):TT2=1
3250 IF TTIME(MM)>0 AND TTIME(MM)<=.25 THEN TTL=1:TTH=2:TT1=0:TT2=.25
3260 IF TTIME(MM)>.25 AND TTIME(MM)<=.5 THEN TTL=2:TTH=3:TT1=.25:TT2=.5
3270 IF TTIME(MM)>.5 AND TTIME(MM)<=.75 THEN TTL=3:TTH=4:TT1=.5:TT2=.75
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3280 IF TTIME(MM)>.75 AND TTIME(MM)<=1! THEN TTL=4:TTH=5:TT1=.75:TT2=1!
3290 IF TTIME(MM)>1! AND TTIME(MM)<=1.5 THEN TTL=5:TTH=6:TT1=1!:TT2=1.5
3300 IF TTIME(MM)>1.5 AND TTIME(MM)<=2! THEN TTL=6:TTH=7:TT1=1.5:TT2=2!
3310 IF TTIME(MM)>2! AND TTIME(MM)<=2.5 THEN TTL=7:TTH=8:TT1=2!:TT2=2.5
3320 IF TTIME(MM)>2.5 AND TTIME(MM)<=3! THEN TTL=8:TTH=9:TT1=2.5:TT2=3!
3330 IF TTIME(MM)>3! AND TTIME(MM)<=3.5 THEN TTL=9:TTH=10:TT1=3!:TT2=3.5
3340 IF TTIME(MM)>3.5 AND TTIME(MM)<=4! THEN TTL=10:TTH=11:TT1=3.5:TT2=4!
3350 IF TTIME(MM)>4! THEN PRINT "The travel time exceeds the tabular
     values given in TR-55."
3360 RETURN
3370 REM ***** The following nine lines correct the runoff curve number
     for the appropriate antecendent moisture conditions.
3380 IRCN=INT(RCN(J)/10)
3390 DIFF=RCN(J)-IRCN*10
3400 LFAC=AMCF(IRCN,AMC)
3410 IF IRCN=10 THEN 3430
3420 IRCN=IRCN+1
3430 HFAC=AMCF(IRCN,AMC)
3440 DIFAC=HFAC-LFAC
3450 RCN(J)=RCN(J)*(LFAC+DIFF*DIFAC/10)
3460 RETURN
3470 REM ######   SUBROUTINE  OVERLAND FLOW VELOCITY  #######
3480 IF COND=1 THEN B=1.2    'FOREST
3490 IF COND=2 THEN B=.656   'CULTIVATION
3500 IF COND=3 THEN B=.3     'GRASS
3510 IF COND=4 THEN B=.0133 'GRASSED WW
3520 IF COND=5 THEN B=-.354  'PAVED
3530 IF COND=6 THEN B=-.602
3540 Y=LOG(SLOPE)*.4342945
3550 M=2!
3560 X=((Y-B)/M)*2.302585
3570 VEL=EXP(X)
3580 RETURN
3590 REM*********************GUTTER FLOW***************
3600 INPUT "     What is the depth of flow in the gutter";GUTDEP
3610 INPUT "     What is the cross slope for the gutter (in
     ft/ft)";CRSLOPE
3620 INPUT "     What is the value for Manning's N for the gutter";MAN.N
3630 REM CALCULATE GUTTER FLOW VELOCITY
3640 FLOWG=(.56)*(1/CRSLOPE)*(1/MAN.N)*((SLOPE/100)¢.5)*(GUTDEP¢2.6667)
3650 AREAG=.5*(1/CRSLOPE)*GUTDEP*GUTDEP
3660 VELG=FLOWG/AREAG
3670 TIME=LENG/VELG
3680 TOTALT=TOTALT+TIME
3690 CLS:RETURN
3700 REM **************  CHANNEL FLOW  **************
3710 INPUT "     What is the channel depth (in feet)";CHANDEP
3720 INPUT "     What is the channel width (in feet)";CHANWID
3730 INPUT "     What is the average side slope for the channel (in
     ft/ft)";SIDESL
3740 INPUT "     What is the average value of Manning's N for the
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     channel";MAN.N
3750 REM  CALCULATE CHANNEL FLOW VELOCITY
3760 AREA=CHANWID*CHANDEP+SIDESL*CHANDEP*CHANDEP
3770 WETPM=CHANWID+2*((((SIDESL*CHANDEP)¢2)+CHANDEP*CHANDEP)¢.5)
3780 PERIM=SQR(WETPM)
3790 HYDR=AREA/WETPM
3800 VELCH=(1.486/MAN.N)*(HYDR¢.6666)*((SLOPE/100)¢.5)
3810 TIME=LENG/VELCH
3820 TOTALT=TOTALT+TIME
3830 CLS:RETURN
3840 REM ****************  SEWER FLOW ******************
3850 INPUT "     What is the sewer's diameter (in feet)";SEWDIA
3860 INPUT "     What is the value for Manning's N for the sewer";MAN.N
3870 REM   CALCULATE SEWER FLOW VELOCITY
3880 HYDR=SEWDIA/4
3890 VELS=(1.486/MAN.N)*(HYDR¢.6666)*((SLOPE/100)¢.5)
3900 TIME=LENG/VELS
3910 TOTALT=TOTALT+TIME
3920 CLS:RETURN
3930 REM FULLY DEVELOPED URBAN AREAS CHART FOLLOWS
3940 PRINT:PRINT "      Open Spaces, lawns, parks, golf courses, etc."
3950 PRINT "        good condition:  grass cover on 75% or more of the
     area.    (Enter 1)"
3960 PRINT "        fair condition:  grass cover on 50% to 75% of the
     area.     (Enter 2)"
3970 PRINT "        poor condition:  grass cover on 50% or less of the
     area     (Enter 3)"
3980 PRINT "     Paved parking lots, roofs, driveways, etc.
     (Enter 4)"
3990 PRINT "     Streets and roads:  paved with curbs and storm sewers
     (Enter 5)"
4000 PRINT "                         gravel.
     (Enter 6)"
4010 PRINT "                         dirt.
     (Enter 7)"
4020 PRINT "                         paved with open ditches
     (Enter 8)"
4030 PRINT "                                      Average % impervious"
4040 PRINT "     Commercial and business areas              85
     (Enter 9)"
4050 PRINT "     Industrial districts,                      72
     (Enter 10)"
4060 PRINT "     Row houses,town houses, and residential     "
4070 PRINT "        with lot sizes 1/8 acre or less         65
     (Enter 11)"
4080 PRINT "     Residential area:"
4090 PRINT "       Average lot size    "
4100 PRINT "            1/4 acre                            38
     (Enter 12)"
4110 PRINT "            1/3 acre                            30
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     (Enter 13)"
4120 PRINT "          1/2 acre                              25
     (Enter 14)"
4130 PRINT "          1   acre                              20
     (Enter 15)"
4140 PRINT "          2   acre                              12
     (Enter 16)":PRINT
4150 INPUT " Enter appropriate number";LUD%
4160 WRITE #3, LUD%:PRINT
4170 PRINT" Enter amount of land (in acres) in ";WHEN$;"subarea ";J
4180 INPUT"  corresponding to the above land use type ";AREA(J,KDP)
4190 WRITE #3, AREA(J,KDP)
4200 RETURN
4210 REM  Developing urban area chart follows
4220 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
4230 PRINT "        Newly graded area                 (Enter 17)"
4240 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
4250 INPUT " Enter appropriate number";LUD%
4260 WRITE #3, LUD%:PRINT
4270 PRINT" Enter amount of land (in acres) in ";WHEN$;"subarea ";J
4280 INPUT"  corresponding to the above land use type ";AREA(J,KDP)
4290 WRITE #3, AREA(J,KDP)
4300 RETURN
4310 REM  Cultivated agricultural land chart follows
4320 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT
4330 PRINT "        Land Use      Treatment/Practice    Hydrologic
     Condition":PRINT
4340 PRINT "        Fallow        Straight row
     (Enter 18)"
4350 PRINT "                      Conservation tillage         poor
     (Enter 19)"
4360 PRINT "                      Conservation tillage         good
     (Enter 20)"
4370 PRINT "        Row Crops     Straight row                 poor
     (Enter 21)"
4380 PRINT "                      Straight row                 good
     (Enter 22)"
4390 PRINT "                      Conservation tillage         poor
     (Enter 23)"
4400 PRINT "                      Conservation tillage         good
     (Enter 24)"
4410 PRINT "                      Contoured                    poor
     (Enter 25)"
4420 PRINT "                      Contoured                    good
     (Enter 26)"
4430 PRINT "                      Contoured + conservation"
4440 PRINT "                                  tillage          poor
     (Enter 27)"
4450 PRINT "                      Contoured + conservation
4460 PRINT "                                  tillage          good
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     (Enter 28)"
4470 PRINT "                         Contoured + terraces          poor
     (Enter 29)"
4480 PRINT "                         Contoured + terraces          good
     (Enter 30)"
4490 PRINT "                         Contoured + terraces          "
4500 PRINT "                           + conservation tillage      poor
     (Enter 31)"
4510 PRINT "                         Contoured + terraces          "
4520 PRINT "                           + conservation tillage      good
     (Enter 32)":PRINT
4530 INPUT" Press RETURN to view rest of cultivated agricultural
     chart ";IHT:CLS
4540 PRINT "        Small grain      Straight row                  poor
     (Enter 33)"
4550 PRINT "                         Straight row                  good
     (Enter 34)"
4560 PRINT "                         Conservation tillage          poor
     (Enter 35)"
4570 PRINT "                         Conservation tillage          good
     (Enter 36)"
4580 PRINT "                         Contoured                     poor
     (Enter 37)"
4590 PRINT "                         Contoured                     good
     (Enter 38)"
4600 PRINT "                         Contoured + conservation"
4610 PRINT "                                     tillage           poor
     (Enter 39)"
4620 PRINT "                         Contoured + conservation
4630 PRINT "                                     tillage           good
     (Enter 40)"
4640 PRINT "                         Contoured + terraces          poor
     (Enter 41)"
4650 PRINT "                         Contoured + terraces          good
     (Enter 42)"
4660 PRINT "                         Contoured + terraces          "
4670 PRINT "                           + conservation tillage      poor
     (Enter 43)"
4680 PRINT "                         Contoured + terraces          "
4690 PRINT "                           + conservation tillage      good
     (Enter 44)"
4700 PRINT "        Close-seeded     Straight row                  poor
     (Enter 45)"
4710 PRINT "        Legumes or       Straight row                  good
     (Enter 46)"
4720 PRINT "        Rotation         Contoured                     poor
     (Enter 47)"
4730 PRINT "        Meadow           Contoured                     good
     (Enter 48)"
4740 PRINT "                         Contoured & terraces          poor
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     (Enter 49)"
4750 PRINT "                         Contoured & terraces        good
     (Enter 50)":PRINT
4760 INPUT " Enter appropriate number";LUD%
4770 WRITE #3, LUD%:PRINT
4780 PRINT" Enter amount of land (in acres) in ";WHEN$;"subarea ";J
4790 INPUT"  corresponding to the above land use type ";AREA(J,KDP)
4800 WRITE #3, AREA(J,KDP)
4810 RETURN
4820 REM Non-cultivated agricultural land chart follows
4830 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT
4840 PRINT "        Land Use      Treatment/Practice    Hydrologic
     Condition":PRINT
4850 PRINT "        Pasture       No mechanical treatment      poor
     (Enter 51)"
4860 PRINT "          or range    No mechanical treatment      fair
     (Enter 52)"
4870 PRINT "                      No mechanical treatment      good
     (Enter 53)"
4880 PRINT "                      Contoured                    poor
     (Enter 54)"
4890 PRINT "                      Contoured                    fair
     (Enter 55)"
4900 PRINT "                      Contoured                    good
     (Enter 56)"
4910 PRINT "        Meadow                                     ----
     (Enter 57)"
4920 PRINT "        Forestland--
4930 PRINT "         grass or
4940 PRINT "         orchards--                                poor
     (Enter 58)"
4950 PRINT "         evergreen or                              fair
     (Enter 59)"
4960 PRINT "         deciduous                                 good
     (Enter 60)"
4970 PRINT "        Brush                                      poor
     (Enter 61)"
4980 PRINT "                                                   good
     (Enter 62)"
4990 PRINT "        Woods                                      poor
     (Enter 63)"
5000 PRINT "                                                   fair
     (Enter 64)"
5010 PRINT "                                                   good
     (Enter 65)"
5020 PRINT "        Farmsteads                                 ----
     (Enter 66)":PRINT
5030 INPUT " Enter appropriate number";LUD%
5040 WRITE #3, LUD%:PRINT
5050 PRINT" Enter amount of land (in acres) in ";WHEN$;"subarea ";J
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5060 INPUT"  corresponding to the above land use type ";AREA(J,KDP)
5070 WRITE #3, AREA(J,KDP)
5080 RETURN
5090 REM  Forest-range chart follows
5100 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT
5110 PRINT "        Land Use                         Hydrologic
     Condition":PRINT
5120 PRINT "        Herbaceous                                poor
     (Enter 67)"
5130 PRINT "                                                  fair
     (Enter 68)"
5140 PRINT "                                                  good
     (Enter 69)"
5150 PRINT "        Oak-Aspen                                 poor
     (Enter 70)"
5160 PRINT "                                                  fair
     (Enter 71)"
5170 PRINT "                                                  good
     (Enter 72)"
5180 PRINT "        Juniper-grass                             poor
     (Enter 73)"
5190 PRINT "                                                  fair
     (Enter 74)"
5200 PRINT "                                                  good
     (Enter 75)"
5210 PRINT "        Sage-grass                                poor
     (Enter 76)"
5220 PRINT "                                                  fair
     (Enter 77)"
5230 PRINT "                                                  good
     (Enter 78)":PRINT
5240 INPUT " Enter appropriate number";LUD%
5250 WRITE #3, LUD%:PRINT
5260 PRINT" Enter amount of land (in acres) in ";WHEN$;"subarea ";J
5270 INPUT"  corresponding to the above land use type ";AREA(J,KDP)
5280 WRITE #3, AREA(J,KDP)
5290 RETURN
5300 ' CONVERSION OF INFLOW HYDROGRAPH ORDINATES TO CONSTANT TIME SCALE
5310 FLOW(1)=QS(LAND,1)
5320 INC=(QS(LAND,2)-QS(LAND,1))/5
5330 FLOW(2)=QS(LAND,1)+2*INC
5340 FLOW(3)=QS(LAND,1)+4*INC
5350 FLOW(4)=(QS(LAND,3)+QS(LAND,2))/2
5360 JJ=4: FOR J=5 TO 11
5370 FLOW(J)=QS(LAND,JJ)
5380 JJ=JJ+2: NEXT J
5390 FLOW(12)=QS(LAND,17)
5400 INC=(QS(LAND,18)-QS(LAND,17))/3
5410 FLOW(13)=QS(LAND,17)+2*INC
5420 INC=(QS(LAND,19)-QS(LAND,18))/5
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5430 FLOW(14)=QS(LAND,18)+INC
5440 FLOW(15)=QS(LAND,18)+3*INC
5450 FLOW(16)=QS(LAND,19)
5460 INC=(QS(LAND,20)-QS(LAND,19))/5
5470 FLOW(17)=QS(LAND,19)+2*INC
5480 FLOW(18)=QS(LAND,19)+4*INC
5490 INC=(QS(LAND,21)-QS(LAND,20))/5
5500 FLOW(19)=QS(LAND,20)+INC
5510 FLOW(20)=QS(LAND,20)+3*INC
5520 FLOW(21)=QS(LAND,21)
5530 INC=(QS(LAND,22)-QS(LAND,21))/5:KK=1
5540 FOR NM=22 TO 26:FLOW(NM)=QS(LAND,21)+KK*INC:KK=KK+1:NEXT NM
5550 INC=(QS(LAND,23)-QS(LAND,22))/10:KK=1
5560 FOR NN=27 TO 36:FLOW(NN)=QS(LAND,22)+KK*INC:KK=KK+1:NEXT NN
5570 INC=(QS(LAND,24)-QS(LAND,23))/10:KK=1
5580 FOR MN=37 TO 46:FLOW(MN)=QS(LAND,23)+KK*INC:KK=KK+1:NEXT MN
5590 RETURN
```

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10 '*****************************************************************
20 '**                     BMP PROGRAM MODULE                      **
30 '**                   WRITTEN BY: K. A. CAVE                    **
40 '**                        VERSION 2.2                          **
50 '**                        MARCH, 1986                          **
60 '*****************************************************************
70 COLOR 7,9,0:KEY OFF:WIDTH 80:BMP$="yes"
80 DIM CN(4,78),AMCF(10,3)
90 OPEN "B:PREP.DAT" FOR INPUT AS #1
100 FOR I=1 TO 78:INPUT #1, CN(1,I),CN(2,I),CN(3,I),CN(4,I):NEXT I
110 FOR II=1 TO 10:INPUT #1, AMCF(II,1),AMCF(II,3):NEXT II
120 CLS:OPEN "B:RUNCOND" FOR INPUT AS #2:INPUT #2,TIM$:CLOSE
130 REM ********** BMP DESIGN/ANALYSIS
140 GOSUB 4520
150 OPEN "B:BMPpoll.DAT" FOR OUTPUT AS #3
160 IF TIM$="future" THEN WHEN$="future "
170 IF TIM$="present" THEN WHEN$="present "
180 PRINT:PRINT "              Do you wish to design/evaluate BMP
    structures in the watershed?"
190 INPUT "             Type  y' or  n' as appropriate ",ANS$:PRINT
200 IF ANS$="n" OR ANS$="N" THEN ANS$="no":GOTO 2940
210 PRINT:PRINT "              Reading data from previous module . . .
    please be patient"
220 OPEN "B:preBMP1.DAT" FOR INPUT AS #2
230 INPUT #2, N$:INPUT #2, N:INPUT #2, P:INPUT #2, AMC
240 DIM EBMP(N),NBMP(N),QBMP(24),QSUB(N,46),QSUBC(N,46),FLOW(46),
    TTIME(N)
250 FOR LAND=1 TO N
260  FOR JJ=1 TO 24:INPUT #2, QBMP(JJ):NEXT JJ
270 GOSUB 8550
280 FOR KAC=1 TO 46:QSUB(LAND,KAC)=FLOW(KAC):NEXT KAC
290 NEXT LAND
300 FOR LAND=1 TO N
310  FOR JJ=1 TO 24:INPUT #2, QBMP(JJ):NEXT JJ
320 GOSUB 8550
330 FOR KAC=1 TO 46:QSUBC(LAND,KAC)=FLOW(KAC):NEXT KAC
340 NEXT LAND
350 FOR NSUB=1 TO N: INPUT #2, TTIME(NSUB):NEXT NSUB
360 CLOSE #2:CLS
370 IF WHEN$="future " THEN GOTO 480
380 INPUT "             Type  y' or  n' as appropriate ",ANS$
390 TSTRUC=0:PRINT     ' TSTRUC IS THE TOTAL NUMBER OF BMP STRUCTURES
    PRESENT IN THE WATERSHED
400 FOR LAND=1 TO N
410 PRINT " How many BMP structures are present in subarea ";LAND;
420 INPUT " ",NBMP(LAND):PRINT
430 WRITE #3, NBMP(LAND)
440 TSTRUC=TSTRUC+NBMP(LAND)
450 NEXT LAND
460 GOTO 620
470 TSTRUC=0:PRINT     ' TSTRUC IS THE TOTAL NUMBER OF BMP STRUCTURES
```

```
    TO BE INSTALLED IN THE WATERSHED
480 FOR LAND=1 TO N
490 PRINT "            How many BMP structures are existing in future
    subarea ";LAND;
500 INPUT " ";EBMP(LAND):PRINT:TSTRUC=TSTRUC+EBMP(LAND)
510 NEXT LAND
520 PRINT "  Do you wish to install BMP structures in the watershed?"
530 INPUT "     Type  y' or  n' as appropriate ",ANSN$
540  IF ANSN$="n" AND TSTRUC=0 OR ANSN$="N" AND TSTRUC=0 THEN ANS$="no":
     GOTO 2940
550 FOR LAND=1 TO N
560  IF ANSN$="no" OR ANSN$="NO" THEN GOTO 600
570 PRINT:PRINT "For subarea ";LAND;" enter the number of BMP structures"
580 INPUT "             to be designed ";NBMP(LAND):PRINT
590 TSTRUC=TSTRUC+NBMP(LAND)
600 NBMP(LAND)=NBMP(LAND)+EBMP(LAND):WRITE #3, NBMP(LAND)
610 NEXT LAND
620 WRITE #3, TSTRUC
630 ERASE EBMP:CLS:ATOTAL=0:BASINS=0:ANS$="yes"
640 DIM BRCN(N,TSTRUC),BDA(N,TSTRUC),TYPE$(N,TSTRUC),QB(N,TSTRUC),
    SB(N,TSTRUC),AREA(N,TSTRUC,10)
650 FOR KK=1 TO N
660   FOR NUMB=1 TO NBMP(KK)
670   GOSUB 4580      'Menu routine
680   IF TYPE$(KK,NUMB)="a" OR TYPE$(KK,NUMB)="A" OR TYPE$(KK,NUMB)="B"
      OR TYPE$(KK,NUMB)="b" OR TYPE$(KK,NUMB)="C" OR TYPE$(KK,NUMB)="c"
      THEN BASINS=BASINS+1
690 GOSUB 6370  'subroutine to input site drainage area
700   KDP=1:ASUM=0!:WRCN=0
710   GOSUB 7950      'Curve number routine
720     IF ASUM=BDA(KK,NUMB) THEN GOTO 760
730     BEEP:PRINT:PRINT "  The total of the land use type areas does
        not equal the area of the BMP site."
740     PRINT:PRINT "  Please re-enter these numbers."
750     PRINT:INPUT "  Press RETURN to continue ",GO:WRCN=0:ASUM=0:
        KDP=1:GOTO 690
760   BRCN(KK,NUMB)=WRCN/ASUM OR AMC=3 THEN GOSUB 3470
770   SB(KK,NUMB)=(1000/BRCN(KK,NUMB))-10
780   QB(KK,NUMB)=(P-.2*SB(KK,NUMB))*(P-.2*SB(KK,NUMB))/(P+.8*
      SB(KK,NUMB))
790 IF (P-.2*SB(KK,NUMB)) > 0 THEN GOTO 840
800 QB(KK,NUMB)=0
810 CLS:LOCATE 5,5:PRINT"Calculations indicate that the expected
    precipitation is less"
820 LOCATE 6,5:PRINT"than the initial abstraction for BMP site ";NUMB;
    " in subarea ";KK
830 LOCATE 7,5:INPUT"Thus the runoff for this site is zero.  Press
    RETURN to continue ",GO:CLS
840   NEXT NUMB
850 NEXT KK
860 ERASE SB,CN,AMCF,AREA
```

```
870 TOTAL=TSTRUC+BASINS
880 DIM TCONCB(N,TOTAL),TTIMEB(N,TOTAL),BDASM(N,TSTRUC),AU(N,TSTRUC)
890 REM  TRAVEL TIME & TIME OF CONCENTRATION CALCULATIONS
900 FOR LAND=1 TO N
910 FOR KKK=1 TO NBMP(LAND):TOTALT=0:DRP=1
920 IF WHEN$="present " THEN PRINT :PRINT"                    PRESENT
    CONDITION CALCULATIONS:":GOTO 940
930 PRINT :PRINT"                  FUTURE CONDITION CALCULATIONS:"
940 PRINT:PRINT "                TIME OF CONCENTRATION CALCULATIONS:":
    PRINT
950 PRINT "     Determine which of the following best describes the ";
    WHEN$;" condition"
960 PRINT "     of the runoff flow from the farthest point in the BMP
    site to the outlet"
970 PRINT "     of the BMP site.  If several conditions exist, enter
    each successively."
980 PRINT:PRINT "     For BMP site ";KKK;" in ";WHEN$;" subarea ";LAND
990 PRINT:PRINT "         POSSIBLE CONDITIONS:  "
1000 PRINT "     1.  Forest with heavy ground litter and meadow":PRINT
     "      2.  Fallow or minimum tillage cultivation"
1010 PRINT "     3.  Short grass and lawns":PRINT "     4.  Nearly bare
     ground"
1020 PRINT "     5.  Grassed waterway":PRINT "     6.  Paved area (sheet
     flow) & shallow gutter flow"
1030 PRINT "     7.  Gutter flow":PRINT "     8.  Channel flow":PRINT
     "      9.  Sewer flow":PRINT
1040 INPUT "     How many conditions describe this type of runoff
     flow ";NTIME
1050 IF NTIME><0 THEN CLS:GOTO 1070
1060 BEEP:PRINT:PRINT"     YOU MUST ENTER A POSITIVE VALUE.":PRINT:GOTO
     1040
1070 GOSUB 8310
1080 TCONCB(LAND,KKK)=TOTALT/3600!
1090 CLS:TOTALT=0:DRP=1:PRINT:PRINT:PRINT "                    TRAVEL
     TIME CALCULATION:    "
1100 PRINT "     Determine which of the following best describes the ";
     WHEN$;" condition"
1110 PRINT"     of the runoff flow once it exits the BMP site and
     travels to the outlet "
1120 PRINT "     of the watershed.  If several conditions exist, enter
     each successivley."
1130 PRINT:PRINT "     NOTE: If the runoff flow of a subarea exits
     where the watershed exits, "
1140 PRINT "     enter  0' for the number of conditions.":PRINT
1150 PRINT "     For BMP site ";KKK;" in ";WHEN$;" subarea ";LAND
1160 PRINT:PRINT "         POSSIBLE CONDITIONS:  "
1170 PRINT "     1.  Forest with heavy ground litter and meadow":PRINT
     "      2.  Fallow or minimum tillage cultivation"
1180 PRINT "     3.  Short grass and lawns":PRINT "     4.  Nearly bare
     ground"
1190 PRINT "     5.  Grassed waterway":PRINT "     6.  Paved area (sheet
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    flow) & shallow gutter flow"
1200 PRINT "     7.  Gutter flow":PRINT "     8.  Channel flow":PRINT
    "     9.  Sewer flow":PRINT
1210 INPUT "     How many conditions describe this type of runoff flow
    ";NTIME
1220 IF NTIME=0 THEN TOTALT=0!:GOTO 1240
1230 CLS:GOSUB 8310
1240 CLS:TTIMEB(LAND,KKK)=TOTALT/3600!
1250 NEXT KKK
1260 NEXT LAND
1270   PRINT:PRINT:PRINT:PRINT:PRINT "         Calculating. . . ":PRINT
1280 FOR KD=1 TO N
1290   FOR DK=1 TO NBMP(KD):WRITE #3, BDA(KD,DK):NEXT DK
1300 NEXT KD
1310 FOR KELL=1 TO N
1320   FOR DK=1 TO NBMP(KELL):WRITE #3, TYPE$(KELL,DK):NEXT DK
1330 NEXT KELL
1340 DIM DELTAQ(N,TSTRUC),OTB(24),QTBMP(46),QCTBMP(46),O2(46)
1350 DIM OFL(11,24),OFH(11,24),OFLP(24),OFHP(24),QTOT(46),COST(N,TSTRUC),
    STORAGE(N,TSTRUC)
1360 REM OTB are the interpolated values from the TR-55 tables for the
    unit discharges
1370 REM deltaq is the amount of runoff in inches removed by the BMP
    structure
1380 FOR K=1 TO N
1390 IF NBMP(K)=0 THEN GOTO 1800
1400   FOR NUMB=1 TO NBMP(K)
1410   BDASM(K,NUMB)=BDA(K,NUMB)/640
1420   AU(K,NUMB)=BDA(K,NUMB)*43560!   'AU is the area of the site in
       sq. feet
1430   GOSUB 3090    'tconc,ttime  tables
1440    IF TCONCB(K,NUMB)>=.1 AND TCONCB(K,NUMB)=<2! THEN GOTO 1460
1450    CLEAR:GOTO 70
1460 IF WHEN$="present " THEN GOTO 1520
1470 CLS:LOCATE 5,5:PRINT "In future subarea ";K;" is BMP site ";NUMB;
    " an existing"
1480 LOCATE 6,5:PRINT "structure or one to be designed?"
1490 LOCATE 8,5:INPUT "Enter  e' for existing or  d' for design    ",
    WHICH$
1500 IF WHICH$="e" OR WHICH$="E" OR WHICH$="d" OR WHICH$="D" THEN GOTO
    1520
1510 BEEP:LOCATE 10,5:PRINT "YOU DID NOT ENTER A POSSIBLE CHOICE":GOTO
    1490
1520 CLS:LOCATE 6,6:PRINT "Calculating . . . "
1530 IF TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="E" OR
    TYPE$(K,NUMB)="e" THEN GOTO 1550
1540 DELTAQ(K,NUMB)=QB(K,NUMB):GOTO 1640
1550   IF WHEN$="future " THEN GOTO 1590
1560   IF TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="D" THEN KIND$=
       "infiltration trench":GOSUB 5790
1570   IF TYPE$(K,NUMB)="e" OR TYPE$(K,NUMB)="E" THEN KIND$="porous
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       pavement":GOSUB 5790
1580   GOTO 1630
1590   IF TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" THEN KIND$="infiltration
       trench"
1600   IF TYPE$(K,NUMB)="e" OR TYPE$(K,NUMB)="E" THEN KIND$="porous
       pavement"
1610   IF (TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="e"
       OR TYPE$(K,NUMB)="E") AND (WHICH$="e" OR WHICH$="E") THEN
       GOSUB 5790
1620   IF (TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="E"
       OR TYPE$(K,NUMB)="e") AND (WHICH$="d" OR WHICH$="D") THEN
       GOSUB 4740
1630   PRINT:PRINT:PRINT:PRINT:PRINT "        Calculating. . . ":PRINT
1640 STORAGE(K,NUMB)=DELTAQ(K,NUMB)/12*AU(K,NUMB)
1650 REM DELTAQ(2,1)=5.3:DELTAQ(2,2)=5.58
1660   GOSUB 8780       'Calculate hydrograph based on amount REMOVED
       from area for contribution to composite
1670   GOSUB 8550       'Changes hydrograph to constant time scale
       (delta t = .2 hr)
1680 FOR JJ=1 TO 46:QCTBMP(JJ)=QCTBMP(JJ)+FLOW(JJ):NEXT JJ   'qtbmp is
     sum of hydrographs removed from subarea contributing to composite
1690 TTL=1:TTH=1:TT1=0:TT2=1:TEMPTT=TTIMEB(K,NUMB):TTIMEB(K,NUMB)=0
     'sets ttime = 0
1700   GOSUB 8780       'Calculate hydrograph based on amount REMOVED
       from area
1710   GOSUB 8550       'Changes hydrograph to constant time scale
       (delta t = .2 hr)
1720 FOR JJ=1 TO 46:QTBMP(JJ)=QTBMP(JJ)+FLOW(JJ)   'qtbmp is sum of
     hydrographs removed from subarea
1730   IF TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="e"
       OR TYPE$(K,NUMB)="E" THEN WRITE #3, FLOW(JJ)
1740 NEXT JJ
1750 TTIMEB(K,NUMB)=TEMPTT
1760   NEXT NUMB
1770 FOR JJJ=1 TO 46:QSUBC(K,JJJ)=QSUBC(K,JJJ)-QCTBMP(JJJ):NEXT JJJ
1780 FOR JJJ=1 TO 46:QSUB(K,JJJ)=QSUB(K,JJJ)-QTBMP(JJJ):NEXT JJJ
1790 FOR JJJ=1 TO 46:QCTBMP(JJJ)=0:QTBMP(JJJ)=0:NEXT JJJ
1800 NEXT K
1810 CLOSE #1, #2:ERASE QTBMP,QCTBMP:DIM QBASIN(46),QCBASIN(46),QTB(46),
     QCTB(46),STVOL(46)
1820 FOR K=1 TO N
1830   FOR NUMB=1 TO NBMP(K)
1840   IF TYPE$(K,NUMB)="D" OR TYPE$(K,NUMB)="d" OR TYPE$(K,NUMB)="e"
       OR TYPE$(K,NUMB)="E" THEN GOTO 2040
1850 TEMPT=TTIMEB(K,NUMB)
1860   TTIMEB(K,NUMB)=0
1870   GOSUB 3090       'Tconc, etc   routine
1880 TTIMEB(K,NUMB)=TEMPT
1890   GOSUB 8780       'Hydrograph calculation
1900 WRITE #3, QBMP(1)  'to interpolate 0 -11 hr storage volumes in
```

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    POLLUTO
1910   GOSUB 6420           'Basin prep routine
1920   GOSUB 6490    'Evaluate existing basin or design new one
1930   PRINT:PRINT:PRINT:PRINT:PRINT "         Calculating. . . ":PRINT
1940 FOR KK=1 TO 46
1950 IF TLAG>46 THEN GOTO 1970
1960 QBASIN(TLAG)=O2(KK)
1970 IF TLAGC>46 THEN GOTO 2000
1980 QCBASIN(TLAGC)=O2(KK)
1990 TLAG=TLAG+1:TLAGC=TLAGC+1
2000 NEXT KK
2010 FOR DRP=1 TO 46:QTB(DRP)=QTB(DRP)+QBASIN(DRP):NEXT DRP
2020 FOR UDR=1 TO 46:QCTB(UDR)=QCTB(UDR)+QCBASIN(UDR):NEXT UDR
2030 FOR KLD=1 TO 46:WRITE #3, STVOL(KLD):NEXT KLD
2040   NEXT NUMB
2050 FOR JJJ=1 TO 46:QSUB(K,JJJ)=QSUB(K,JJJ)+QTB(JJJ):NEXT JJJ
2060 FOR JJJ=1 TO 46:QSUBC(K,JJJ)=QSUBC(K,JJJ)+QCTB(JJJ):NEXT JJJ
2070 FOR JJJ=1 TO 46:QCTB(JJJ)=0:QTB(JJJ)=0:NEXT JJJ
2080 NEXT K
2090 ERASE OFL,OFH,OFLP,OFHP,OTB,QBMP,FLOW,BDASM,AU,QTB,QCTB,QBASIN,
     QCBASIN,STVOL
2100 OPEN "b:bmppol2.dat" FOR OUTPUT AS #1
2110 FOR LAND=1 TO N
2120   FOR KK=1 TO 46:WRITE #1, QSUB(LAND,KK):NEXT KK
2130 NEXT LAND
2140 FOR LAND=1 TO N
2150 FOR KAC=1 TO 46:WRITE #1, QSUBC(LAND,KAC):NEXT KAC
2160 NEXT LAND
2170 FOR KKK=1 TO 46:QTOT(KKK)=0:NEXT KKK
2180 FOR LAND=1 TO N
2190   FOR JJJ=1 TO 46
2200 IF QSUBC(LAND,JJJ)<0 THEN QSUBC(LAND,JJJ)=0!
2210   QTOT(JJJ)=QTOT(JJJ)+QSUBC(LAND,JJJ)
2220 IF QTOT(JJJ)<0 THEN QTOT(JJJ)=0!
2230   NEXT JJJ
2240 NEXT LAND
2250 CLOSE #3, #1
2260 OPEN "B:preBMP2.DAT" FOR INPUT AS #2
2270 DIM DA(N),RCN(N),QP(N),TCONC(N)
2280 FOR LAND=1 TO N
2290 INPUT #2, DA(LAND):INPUT #2, RCN(LAND):INPUT #2, TCONC(LAND):INPUT
     #2, QP(LAND)
2300 NEXT LAND
2310 CLOSE #2:CLS:Y$="#########.##"
2320 IF WHEN$="present " THEN PRINT:PRINT:PRINT:PRINT "
        DATA FOR THE PRESENT CONDITION:        ":PRINT:GOTO 2350
2330 PRINT:PRINT:PRINT:PRINT "                              DATA FOR THE
     FUTURE CONDITION:         ":PRINT
2340 PRINT "                                        Runoff or"
2350 PRINT "     Subarea    BMP Site    Area        RCN         TC
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    TT      Storage"
2360 PRINT "                              (acres)                 (hrs)
    (hrs) (in / cu.ft)"
2370 FOR J=1 TO N:DDD=0
2380 PRINT USING Y$; J; DDD; DA(J); RCN(J); TCONC(J); TTIME(J); QP(J)
2390 FOR KKK=1 TO NBMP(J)
2400 IF TYPE$(J,KKK)="d" OR TYPE$(J,KKK)="D" OR TYPE$(J,KKK)="E" OR
    TYPE$(J,KKK)="e" THEN GOTO 2430
2410 PRINT USING Y$; J; KKK; BDA(J,KKK); BRCN(J,KKK); TCONCB(J,KKK);
    TTIMEB(J,KKK);
2420 PRINT TAB(70) USING "#.##¢¢¢¢";STORAGE(J,KKK):GOTO 2440
2430 PRINT USING Y$; J; KKK; BDA(J,KKK); BRCN(J,KKK); TCONCB(J,KKK);
    TTIMEB(J,KKK); DELTAQ(J,KKK)
2440 NEXT KKK
2450 NEXT J
2460 PRINT:PRINT "     NOTE:  The values given for runoff from the BMP
    sites show "
2470 PRINT "     the amount of runoff the infiltration structure (will)
    handle(s)  "
2480 PRINT "     or the maximum storage (cubic feet) of the detention
    pond(s)."
2490 PRINT:INPUT "     Press RETURN to continue  . . . ",GO:CLS:PRINT:
    PRINT:PRINT:PRINT:PRINT
2500 IF WHEN$="present " THEN GOTO 2700
2510 PRINT "                            COST ANALYSIS":PRINT
2520 PRINT "           Subarea    BMP Site   Runoff or Storage
    Total Cost"
2530 PRINT "                                  (in / cu.ft)
    ($)":PRINT
2540 FOR J=1 TO N
2550 FOR KKK=1 TO NBMP(J)
2560 IF TYPE$(J,KKK)="d" OR TYPE$(J,KKK)="D" OR TYPE$(J,KKK)="E" OR
    TYPE$(J,KKK)="e" THEN GOTO 2600
2570 PRINT TAB(7) USING Y$; J; KKK;
2580 PRINT TAB(39) USING "#.##¢¢¢¢";STORAGE(J,KKK);
2590 PRINT TAB(54) USING Y$; COST(J,KKK):GOTO 2630
2600 PRINT TAB(7) USING Y$; J; KKK;
2610 PRINT TAB(34) USING Y$;  DELTAQ(J,KKK);
2620 PRINT TAB(54) USING Y$; COST(J,KKK)
2630 NEXT KKK
2640 NEXT J
2650 PRINT:PRINT "        Total costs for the BMP structure include
    construction costs,"
2660 PRINT "         contingency costs, and operation and maintenance
    costs.  The"
2670 PRINT "         figures quoted above are in fourth quarter 1980
    dollars and"
2680 PRINT "         do NOT reflect the cost of the land."
2690 PRINT:INPUT "        Press RETURN to continue ",GO:CLS:PRINT:
    PRINT:PRINT:PRINT:PRINT
2700 PRINT "         The data you have supplied concerning the BMP
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     structures for the               ";WHEN$;"condition of the ";N$;"
     watershed and the hydrographs "
2710 PRINT "        generated by this program segment have been stored
     in data files "
2720 PRINT "        on the B: drive as follows: ":PRINT
2730 LOCATE 11,18:PRINT " bmppol1.dat'";TAB(37) "contain data such as
     types and amounts":LOCATE 12,18:PRINT " bmppol2.dat'";TAB(37) "of
     land uses and design criteria for  ":LOCATE 13,37:PRINT "the BMP
     structures for the ";WHEN$
2740 LOCATE 14,36:PRINT " condition watershed."
2750 LOCATE 16,18:PRINT " hyd.ord'";TAB(37) "contains the adjusted
     hydrographs":LOCATE 17,37:PRINT "for the watershed.":PRINT:PRINT
     "          These files are used in other program segments."
2760 PRINT:INPUT "          Press RETURN to continue",BBD:CLOSE:CLS
2770 LOCATE 4,10:PRINT " Hydrographs have been calculated for each
     subarea and for the "
2780 LOCATE 5,10:PRINT " entire watershed which reflect the presence
2790 LOCATE 6,10:PRINT " you have designed/evaluated.  Please choose
     which form you wish":LOCATE 7,10:PRINT " to view them:"
2800 LOCATE 9,25:PRINT " A.  Tabular form":LOCATE 10,25:PRINT " B.
     Graphical form":LOCATE 11,25:PRINT " C.  Tabular and graphical
     form"
2810 LOCATE 13,10:INPUT " Enter the letter of your choice ",FORM$
2820 IF FORM$="a" OR FORM$="A" OR FORM$="c" OR FORM$ ="C" OR FORM$="b"
     OR FORM$="B" THEN GOTO 2840
2830 BEEP:CLS:LOCATE 14,20:PRINT "YOU DID NOT ENTER A POSSIBLE CHOICE":
     GOTO 2770
2840 OPEN "b:hyd.ord" FOR OUTPUT AS #2
2850 WRITE #2, BMP$:WRITE #2, N$:WRITE #2, N
2860 WRITE #2, WHEN$:WRITE #2, FORM$
2870 FOR LAND=1 TO N
2880   FOR JJ=1 TO 46:WRITE #2, QSUB(LAND,JJ):NEXT JJ
2890 NEXT LAND
2900 FOR KK=1 TO 46:WRITE #2, QTOT(KK):NEXT KK
2910 CLOSE:PRINT:PRINT "             The program will now call the output
     module to output"
2920 LOCATE 16,11:PRINT "the hydrographs.":LOCATE 17,11:PRINT "This will
     take a few minutes . . . please be patient.":LOCATE 18,11:INPUT
     "Press RETURN to continue ",GO
2930 ANS$="yes"
2940 OPEN "b:answer" FOR OUTPUT AS #2   'To tell OUTPUT.BAS whether
     to run
2950 WRITE #2, ANS$:CLOSE #2
2960 SYSTEM
2970 REM!!!!!!!!!!!!!!!!!!!!SUBROUTINES FOLLOW !!!!!!!!!!!!!!!!!!!!!
2980 REM    Subroutine to input hydrologic soil types for each land use
2990 PRINT:PRINT:INPUT "  How much of this area (in acres) consists of
     hydrologic soil group A";HSGA
3000 INPUT "  How much of this area (in acres) consists of hydrologic
     Soil group B";HSGB
3010 INPUT "  How much of this area (in acres) consists of hydrologic
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    soil group C";HSGC
3020 INPUT "  How much of this area (in acres) consists of hydrologic
    soil group D";HSGD
3030 REM HSG* REPRESENTS THE AMOUNT OF SUBAREA J WHICH CONSISTS OF SOIL
    IN HYDROLOGIC SOIL GROUP A, B, C, OR D.
3040 ATOTAL=HSGA+HSGB+HSGC+HSGD
3050 IF ATOTAL=AREA(KK,NUMB,KDP) THEN GOTO 3080
3060 BEEP:PRINT:PRINT "  The total of the soil group areas does not
    equal the land use area."
3070 PRINT:PRINT "  Please re-enter these numbers.":PRINT:GOTO 2990
3080 CLS:RETURN
3090 REM  ¢¢¢¢¢¢Travel time & time of concentration tables¢¢¢¢¢¢¢¢¢¢¢¢
3100 IF TCONCB(K,NUMB)<.1 THEN BEEP:PRINT TAB(2) "The time of
    concentration for BMP site ";NUMB;" in subarea ";K;" for the "
3110 IF TCONCB(K,NUMB) < .1 THEN PRINT TAB(2) WHEN$;" condition is less
    than the minimum tabular value given in TR-55.":PRINT
3120 IF TCONCB(K,NUMB)<.1 THEN PRINT TAB(2) "Recommend that this site
    be combined with other sites within this subarea "
3130 IF TCONCB(K,NUMB)<.1 THEN PRINT TAB(2) "and a combined analysis/
    design performed.  The program will now return "
3140 IF TCONCB(K,NUMB)<.1 THEN PRINT TAB(2) "to the beginning of the BMP
    section for data revision.":PRINT
3150 IF TCONCB(K,NUMB)<.1 THEN  INPUT " Press RETURN to continue",GO:
    GOTO 3460
3160 IF TCONCB(K,NUMB)>=.1 AND TCONCB(K,NUMB)<.2 THEN OPEN "b:data1" FOR
    INPUT AS #1:OPEN "B:DATA2" FOR INPUT AS #2:TCL=.1:TCH=.2
3170 IF TCONCB(K,NUMB)>=.2 AND TCONCB(K,NUMB)<.3 THEN OPEN "b:data2" FOR
    INPUT AS #1:OPEN "B:DATA3" FOR INPUT AS #2:TCL=.2:TCH=.3
3180 IF TCONCB(K,NUMB)>=.3 AND TCONCB(K,NUMB)<.4 THEN OPEN "b:data3" FOR
    INPUT AS #1:OPEN "B:DATA4" FOR INPUT AS #2:TCL=.3:TCH=.4
3190 IF TCONCB(K,NUMB)>=.4 AND TCONCB(K,NUMB)<.5 THEN OPEN "b:data4" FOR
    INPUT AS #1:OPEN "b:data5" FOR INPUT AS #2:TCL=.4:TCH=.5
3200 IF TCONCB(K,NUMB)>=.5 AND TCONCB(K,NUMB)<.75 THEN OPEN "b:data5"
    FOR INPUT AS #1:OPEN "b:data6" FOR INPUT AS #2:TCL=.5:TCH=.75
3210 IF TCONCB(K,NUMB)>=.75 AND TCONCB(K,NUMB)<1! THEN OPEN "b:data6"
    FOR INPUT AS #1:OPEN "b:data7" FOR INPUT AS #2:TCL=.75:TCH=1!
3220 IF TCONCB(K,NUMB)>=1! AND TCONCB(K,NUMB)<1.25 THEN OPEN "b:data7"
    FOR INPUT AS #1:OPEN "b:data8" FOR INPUT AS #2:TCL=1!:TCH=1.25
3230 IF TCONCB(K,NUMB)>=1.25 AND TCONCB(K,NUMB)<1.5 THEN OPEN "b:data8"
    FOR INPUT AS #1:OPEN "b:data9" FOR INPUT AS #2:TCL=1.25:TCH=1.5
3240 IF TCONCB(K,NUMB)>=1.5 AND TCONCB(K,NUMB)=<2! THEN OPEN "B:DATA9"
    FOR INPUT AS #1:OPEN "B:DATA10" FOR INPUT AS #2:TCL=1.5:TCH=2!
3250 IF TCONCB(K,NUMB)>2! THEN BEEP:PRINT TAB(2) "The time of
    concentration for BMP site ";NUMB;" in subarea ";K;" for the ";
    WHEN$;" condition exceeds the tabular values given in TR-55.":
    PRINT
3260 IF TCONCB(K,NUMB)>2! THEN PRINT TAB(2) "Recommend that this BMP
    site be broken into several smaller sites"
3270 IF TCONCB(K,NUMB)>2! THEN PRINT TAB(2) "and the program rerun.
    The program will return to the beginning "
3280 IF TCONCB(K,NUMB)>2! THEN PRINT TAB(2) "of the BMP section for data
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     revision.":PRINT
3290 IF TCONCB(K,NUMB)>2! THEN  INPUT " Press RETURN to continue",GO:
     GOTO 3460
3300 FOR J=1 TO 11
3310    FOR JJ=1 TO 24:INPUT #1, OFL(J,JJ):INPUT #2, OFH(J,JJ):NEXT JJ
3320 NEXT J
3330 CLOSE #1, #2
3340 IF TTIMEB(K,NUMB)=0 THEN TTL=1:TTH=1:TT1=TTIMEB(K,NUMB):TT2=1
3350 IF TTIMEB(K,NUMB)>0 AND TTIMEB(K,NUMB)<.25 THEN TTL=1:TTH=2:TT1=0:
     TT2=.25
3360 IF TTIMEB(K,NUMB)>.25 AND TTIMEB(K,NUMB)<.5 THEN TTL=2:TTH=3:
     TT1=.25:TT2=0!
3370 IF TTIMEB(K,NUMB)>.5 AND TTIMEB(K,NUMB)<.75 THEN TTL=3:TTH=4:
     TT1=.5:TT2=.7

3380 IF TTIMEB(K,NUMB)>.75 AND TTIMEB(K,NUMB)<1! THEN TTL=4:TTH=5:
     TT1=.75:TT2=1
3390 IF TTIMEB(K,NUMB)>1! AND TTIMEB(K,NUMB)<1.5 THEN TTL=5:TTH=6:
     TT1=1!:TT2=1!
3400 IF TTIMEB(K,NUMB)>1.5 AND TTIMEB(K,NUMB)<2! THEN TTL=6:TTH=7:
     TT1=1.5:TT2=2
3410 IF TTIMEB(K,NUMB)>2! AND TTIMEB(K,NUMB)<2.5 THEN TTL=7:TTH=8:
     TT1=2!:TT2=2!
3420 IF TTIMEB(K,NUMB)>2.5 AND TTIMEB(K,NUMB)<3! THEN TTL=8:TTH=9:
     TT1=2.5:TT2=3
3430 IF TTIMEB(K,NUMB)>3! AND TTIMEB(K,NUMB)<3.5 THEN TTL=9:TTH=10:
     TT1=3!:TT2=3.5
3440 IF TTIMEB(K,NUMB)>3.5 AND TTIMEB(K,NUMB)<4! THEN TTL=10:TTH=11:
     TT1=3.5:TT2=4!
3450 IF TTIMEB(K,NUMB)>4! THEN PRINT "The travel time exceeds the
     tabular values given in TR-55."
3460 RETURN
3470 REM ***** The following nine lines correct the bmp runoff curve
number for the appropriate antecendent moisture conditions.
3480 IBRCN=INT(BRCN(KK,NUMB)/10)
3490 DIFF=BRCN(KK,NUMB)-IBRCN*10
3500 LFAC=AMCF(IBRCN,AMC)
3510 IF IBRCN=10 THEN 3530
3520 IBRCN=IBRCN+1
3530 HFAC=AMCF(IBRCN,AMC)
3540 DIFAC=HFAC-LFAC
3550 BRCN(KK,NUMB)=BRCN(KK,NUMB)*(LFAC+DIFF*DIFAC/10)
3560 RETURN
3570 REM#########   SUBROUTINE  OVERLAND FLOW VELOCITY  ############
3580 IF COND=1 THEN B=1.2
3590 IF COND=2 THEN B=.656
3600 IF COND=3 THEN B=.3
3610 IF COND=4 THEN B=.0133
3620 IF COND=5 THEN B=-.354
3630 IF COND=6 THEN B=-.602
3640 Y=LOG(SLOPE)*.4342945
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3650 M=2:X=((Y-B)/M)*2.302585
3660 VEL=EXP(X)
3670 RETURN
3680 REM********************GUTTER FLOW***************
3690 INPUT "     What is the depth of flow in the gutter";GUTDEP
3700 INPUT "     What is the cross slope for the gutter (in ft/ft)";
     CRSLOPE
3710 INPUT "     What is the value for Manning's N for the gutter";
     MAN.N
3720 FLOWG=(.56)*(1/CRSLOPE)*(1/MAN.N)*((SLOPE/100)¢.5)*(GUTDEP¢2.6667)
3730 AREAG=.5*(1/CRSLOPE)*GUTDEP*GUTDEP
3740 VELG=FLOWG/AREAG       'GUTTER FLOW VELOCITY
3750 AREAG=.5*(1/CRSLOPE)*GUTDEP*GUTDEP
3760 TIME=LENG/VELG:TOTALT=TOTALT+TIME
3770 CLS:RETURN
3780 REM ***************  CHANNEL FLOW  ***************
3790 INPUT "     What is the channel depth (in feet)";CHANDEP
3800 INPUT "     What is the channel width (in feet)";CHANWID
3810 INPUT "     What is the average side slope for the channel (in
     ft/ft)";SIDESL
3820 INPUT "     What is the average value of Manning's N for the
     channel";MAN.N
3830 AREA=CHANWID*CHANDEP+SIDESL*CHANDEP*CHANDEP
3840  WETPM=CHANWID+2*((((SIDESL*CHANDEP)¢2)+CHANDEP*CHANDEP)¢.5)
3850 PERIM=SQR(WETPM)
3860 HYDR=AREA/WETPM
3870 VELCH=(1.486/MAN.N)*(HYDR¢.6666)*((SLOPE/100)¢.5)  'CHANNEL FLOW
     VELOCITY
3880 TIME=LENG/VELCH:TOTALT=TOTALT+TIME
3890 CLS:RETURN
3900 REM ****************  SEWER FLOW *****************
3910 INPUT "     What is the sewer's diameter (in feet)";SEWDIA
3920 INPUT "     What is the value for Manning's N for the sewer";MAN.N
3930 HYDR=SEWDIA/4
3940 VELS=(1.486/MAN.N)*(HYDR¢.6666)*((SLOPE/100)¢.5)  'SEWER FLOW
     VELOCITY
3950 TIME=LENG/VELS:TOTALT=TOTALT+TIME
3960 CLS:RETURN
3970 REM FULLY DEVELOPED URBAN AREAS CHART FOLLOWS
3980 PRINT:PRINT "     Open Spaces, lawns, parks, golf courses, etc.":
     LOCATE 3,8:PRINT "good condition:  grass cover on 75% or more of
     the area.";TAB(68) "(Enter 1)"
3990 PRINT "       fair condition:  grass cover on 50% to 75% of the
     area.     (Enter 2)":LOCATE 5,8:PRINT "poor condition:  grass
     cover on 50% or less of the area.";TAB(68) "(Enter 3)"
4000 PRINT "     Paved parking lots, roofs, driveways, etc.";TAB(68)
     "(Enter 4)":LOCATE 7,6:PRINT "Streets and roads:  paved with curbs
     and storm sewers";TAB(68) "(Enter 5)"
4010 LOCATE 8,26:PRINT "gravel.";TAB(68) "(Enter 6)":LOCATE 9,26:PRINT
     "dirt.";TAB(68) "(Enter 7)":LOCATE 10,26:PRINT "paved with open
     ditches.";TAB(68) "(Enter 8)":LOCATE 11,39:PRINT "Averag
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     e % impervious"
4020 PRINT "     Commercial and business areas";TAB(48) "85";TAB(68)
     "(Enter 9)":LOCATE 13,6:PRINT "Industrial districts";TAB(48) "72";
     TAB(68) "(Enter 10)"
4030 PRINT "     Row houses,town houses, and residential":LOCATE 15,9:
     PRINT "with lot sizes 1/8 acre or less";TAB(48) "65";TAB(68)
     "(Enter 11)"
4040 PRINT "     Residential area:":LOCATE 17,8:PRINT "Average Lot
     Size":LOCATE 18,13:PRINT "1/4 acre";TAB(48) "38";TAB(68) "(Enter
     12)":LOCATE 19,13:PRINT "1/3 acre";TAB(48) "30";TAB(68) "(Enter
     13)"
4050 LOCATE 20,13:PRINT "1/2 acre";TAB(48) "25";TAB(68) "(Enter 14)":
     LOCATE 21,13:PRINT "1   acre";TAB(48) "20";TAB(68) "(Enter 15)":
     LOCATE 22,13:PRINT "2   acre";TAB(48) "12";TAB(68) "(Enter 16)":
     PRINT:RETURN
4060 REM  Developing urban area chart follows
4070 LOCATE 8,10:PRINT "Newly graded area                (Enter 17)":
     PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
4080 RETURN
4090 REM  Cultivated agricultural land chart follows
4100 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT:LOCATE 4,9:PRINT "Land Use      Treatment/Practice
     Hydrologic Condition":PRINT
4110 LOCATE 6,9:PRINT "Fallow        Straight row";TAB(68) "(Enter
     18)":LOCATE 7,23:PRINT "Conservation tillage";TAB(52) "poor
     (Enter 19)":LOCATE 8,23:PRINT "Conservation tillage";TAB(52)
     "good           (Enter 20)"
4120 LOCATE 9,9:PRINT "Row Crops     Straight row";TAB(52) "poor
     (Enter 21)":LOCATE 10,23:PRINT "Straight row";TAB(52) "good
     (Enter 22)"
4130 LOCATE 11,23:PRINT "Conservation tillage         poor
     (Enter 23)":LOCATE 12,23:PRINT "Conservation tillage         good
     (Enter 24)":LOCATE 13,23:PRINT "Contoured";TAB(52) "poor
     (Enter 25)"
4140 LOCATE 14,23:PRINT "Contoured";TAB(52) "good           (Enter 26)"
     :LOCATE 15,23:PRINT "Contoured + conservation":LOCATE 16,30:PRINT
     "tillage";TAB(52) "poor           (Enter 27)"
4150 LOCATE 17,23:PRINT "Contoured + conservation":LOCATE 18,30:PRINT
     "tillage";TAB(52) "good           (Enter 28)":LOCATE 19,23:PRINT
      "Contoured + terraces";TAB(52) "poor           (Enter 29)"
4160 LOCATE 20,23:PRINT "Contoured + terraces         good
     (Enter 30)":LOCATE 21,23:PRINT "Contoured + terraces":LOCATE 22,25:
     PRINT "+ conservation tillage";TAB(52) "poor           (Enter 31)"
4170 LOCATE 23,23:PRINT "Contoured + terraces":LOCATE 24,25:PRINT "
     conservation tillage";TAB(52) "good        (Enter 32)":PRINT:
     INPUT "Press RETURN to view rest of cultivated agricultural chart
     ",IHT:CLS
4180 LOCATE 1,9:PRINT "Small grain   Straight row";TAB(52) "poor
     (Enter 33)":LOCATE 2,23:PRINT "Straight row";TAB(52) "good
     (Enter 34)"
4190 LOCATE 3,23:PRINT "Conservation tillage        poor
     (Enter 35)":LOCATE 4,23:PRINT "Conservation tillage";TAB(52) "good
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     (Enter 36)":LOCATE 5,23:PRINT "Contoured";TAB(52) "poor
     (Enter 37)"
4200 LOCATE 6,23:PRINT "Contoured";TAB(52) "good          (Enter 38)":
     LOCATE 7,23:PRINT "Contoured + conservation":LOCATE 8,30:PRINT
     "tillage";TAB(52) "poor          (Enter 39)"
4210 LOCATE 9,23:PRINT "Contoured + conservation":LOCATE 10,30:PRINT
     "tillage";TAB(52) "good          (Enter 40)":LOCATE 11,23:PRINT
     "Contoured + terraces";TAB(52) "poor          (Enter 41)"
4220 LOCATE 12,23:PRINT "Contoured + terraces          good
     (Enter 42)":LOCATE 13,23:PRINT "Contoured + terraces":LOCATE 14,25:
     PRINT "+ conservation tillage";TAB(52) "poor          (Enter 43)"
4230 LOCATE 15,23:PRINT "Contoured + terraces":LOCATE 16,25:PRINT "
     conservation tillage";TAB(52) "good          (Enter 44)"
4240 LOCATE 17,9:PRINT "Close-seeded  Straight row";TAB(52) "poor
     (Enter 45)":LOCATE 18,9:PRINT "Legumes or    Straight row";TAB(52)
     "good          (Enter 46)"
4250 LOCATE 19,9:PRINT "Rotation      Contoured";TAB(52) "poor
     (Enter 47)":LOCATE 20,9:PRINT "Meadow";TAB(23) "Contoured";TAB(52)
     "good          (Enter 48)"
4260 LOCATE 21,23:PRINT "Contoured & terraces          poor
     (Enter 49)":LOCATE 22,23:PRINT "Contoured & terraces";TAB(52)
     "good          (Enter 50)":PRINT:RETURN
4270 REM Non-cultivated agricultural land chart follows
4280 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT:LOCATE 4,9:PRINT "Land Use     Treatment/Practice
     Hydrologic Condition":PRINT
4290 PRINT "        Pasture       No mechanical treatment      poor
     (Enter 51)":LOCATE 7,10:PRINT "or range";TAB(23) "No mechanical
     treatment";TAB(52) "fair          (Enter 52)"
4300 LOCATE 8,23:PRINT "No mechanical treatment      good
     (Enter 53)":LOCATE 9,23:PRINT "Contoured";TAB(52) "poor
     (Enter 54)"
4310 LOCATE 10,23:PRINT "Contoured                    fair
     (Enter 55)":LOCATE 11,23:PRINT "Contoured";TAB(52) "good
     (Enter 56)"
4320 LOCATE 12,9:PRINT "Meadow";TAB(52) "----          (Enter 57)":
     LOCATE 13,9:PRINT "Forestland--":LOCATE 14,10:PRINT "grass or"
4330 LOCATE 15,10:PRINT "orchards--";TAB(52) "poor          (Enter
     58)":LOCATE 16,10:PRINT "evergreen or";TAB(52) "fair
     (Enter 59)"
4340 LOCATE 17,10:PRINT "deciduous";TAB(52) "good          (Enter
     60)":LOCATE 18,9:PRINT "Brush";TAB(52) "poor          (Enter
     61)":LOCATE 19,52:PRINT "good          (Enter 62)"
4350 LOCATE 20,9:PRINT "Woods";TAB(52) "poor          (Enter 63)":
     LOCATE 21,52:PRINT "fair          (Enter 64)":LOCATE 22,52:PRINT
     "good          (Enter 65)"
4360 PRINT "        Farmsteads                              ----
     (Enter 66)":PRINT:RETURN
4370 REM  Forest-range chart follows
4380 PRINT:PRINT "  Which of the following best describes the land
     use:":PRINT
4390 PRINT "        Land Use                          Hydrologic
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     Condition":PRINT
4400 PRINT "        Herbaceous                               poor
     (Enter 67)":LOCATE 7,52:PRINT "fair          (Enter 68)":LOCATE
     8,52:     PRINT "good          (Enter 69)"
4410 PRINT "        Oak-Aspen                                poor
     (Enter 70)":LOCATE 10,52:PRINT "fair          (Enter 71)":LOCATE
     11,52:PRINT "good          (Enter 72)"
4420 PRINT "        Juniper-grass                            poor
     (Enter 73)":LOCATE 13,52:PRINT "fair          (Enter 74)":LOCATE
     14,52:PRINT "good          (Enter 75)"
4430 PRINT "        Sage-grass                               poor
     (Enter 76)":LOCATE 16,52:PRINT "fair          (Enter 77)":LOCATE
     17,52:PRINT "good          (Enter 78)"
4440 RETURN
4450 REM ********* SUBROUTINE TO INPUT BRCN AND AREAS ********
4460 INPUT " Enter appropriate number";LUD%
4470 WRITE #3, LUD%:PRINT
4480 PRINT" Enter amount of land (in acres) in BMP site";NUMB;"in ";
     WHEN$;"condition subarea";KK
4490 INPUT"  corresponding to the above land use type ";AREA(KK,NUMB,
     KDP)
4500 WRITE #3, AREA(KK,NUMB,KDP)
4510 RETURN
4520 PRINT:PRINT:PRINT:PRINT "          *************** BMP STRUCTURE
     DESIGN/ANALYSIS***************
4530 PRINT:PRINT:PRINT:PRINT "          The following program module
     allows for the design and/or
4540 PRINT "          analysis of five different best management
     practice facilities.
4550 PRINT "          You must provide information when prompted to
     aid in this
4560 PRINT "          process.":PRINT
4570 RETURN
4580 REM ******BMP structure type menu
4590 PRINT "   For subarea ";KK;" in the ";N$;" watershed, for the ";
     WHEN$;" condition:":PRINT
4600 PRINT "    Choose the type of structure to be analyzed:":PRINT:
     PRINT
4610 PRINT "          A.  Detention pond: Dry basin      ":PRINT
4620 PRINT "          B.  Detention pond: Wet basin      ":PRINT
4630 PRINT "          C.  Detention pond: Extended wet basin":PRINT
4640 PRINT "          D.  Infiltration trench            ":PRINT
4650 PRINT "          E.  Porous pavement                ":PRINT:PRINT
4660 INPUT "    Enter the corresponding letter of your choice ";TYPE$
     (KK,NUMB)
4670 IF TYPE$(KK,NUMB)="A" OR TYPE$(KK,NUMB)="a" OR TYPE$(KK,NUMB)="b"
     OR TYPE$(KK,NUMB)="B" OR TYPE$(KK,NUMB)="c" OR TYPE$(KK,NUMB)="C"
     THEN GOTO 4700
4680 IF TYPE$(KK,NUMB)="D" OR TYPE$(KK,NUMB)="d" OR TYPE$(KK,NUMB)="E"
     OR TYPE$(KK,NUMB)="e" THEN GOTO 4700
4690 BEEP:PRINT:PRINT "    YOU DID NOT ENTER A POSSIBLE CHOICE.":PRINT:
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    GOTO 4660
4700 PRINT:PRINT "     Note:  This structure has been designated BMP
    site";NUMB
4710 PRINT "     in ";WHEN$;" subarea ";KK;" for your reference.":PRINT
4720 INPUT "     Press  RETURN' to continue . . . ";GO:CLS
4730 RETURN
4740 REM ###Infiltration trench/Porous pavement design routine########
4750 IF KIND$="infiltration trench" THEN CLS:PRINT:PRINT:PRINT"
     INFILTRATION TRENCH DESIGN ROUTINE":PRINT:GOTO 4770
4760 CLS:PRINT:PRINT:PRINT"                    POROUS PAVEMENT DESIGN
    ROUTINE":PRINT
4770 PRINT "       Information now needs to be provided to aid in the
    design of"
4780 PRINT "       the ";KIND$;" designated BMP site ";NUMB;" in future"
4790 PRINT "       subarea ";K:PRINT
4800 PRINT "       This site contributes ";QB(K,NUMB);" inches of runoff
    to the total "
4810 PRINT "       runoff in ";WHEN$;" subarea ";K;" for the expected ";
    P;" inch rainfall.":PRINT
4820 PRINT "       Press RETURN for BMP structure design to remove all
    of the runoff "
4830 INPUT "       from the site or enter the removal amount (in inches)
    desired";DELTAQ(K,NUMB)
4840 IF DELTAQ(K,NUMB)=0 THEN DELTAQ(K,NUMB)=QB(K,NUMB)
4850 PRINT:INPUT "       Press RETURN to continue . . . ",GO:CLS
4860 TS=72:VR=.4:T=2
4870 REM vr = void ratio of subbase material; ts = max allowable storage
    time; T = time during which trench fills with water ; P = rainfall
    depth (in)
4880 PRINT:PRINT:PRINT:INPUT " What is the estimated normal depth of the
    groundwater table in feet ";WTD
4890 IF WTD>0 THEN GOTO 4910
4900 BEEP:PRINT:PRINT "  YOU MUST ENTER A POSITIVE VALUE.":PRINT:GOTO
    4880
4910 PRINT:PRINT " Enter the desired value for the width of the ";KIND$;
    " in feet."
4920 INPUT " Press RETURN if no width limitation";WID:PRINT
4930 PRINT:PRINT " Enter the desired value for the length of the ";
    KIND$;" in feet."
4940 INPUT " Press RETURN if no length limitation";LENG:PRINT
4950 PRINT:PRINT " Enter the desired value for the depth of the ";KIND$;
    " in feet."
4960 INPUT " Press RETURN if no depth limitation";D:PRINT
4970 GOSUB 6000     'Obtain infiltration rate, F (in/hr)
4980 DMAX=F*TS/(VR*12)   'Maximum design depth in feet
4990 REM  Choose design depths
5000 IF D=0 THEN GOTO 5040
5010 IF D<DMAX THEN DMAX=D
5020 DT(1)=DMAX
5030 GOTO 5060
5040 IF WTD<DMAX THEN DMAX=WTD
5050 DT(1)=DMAX-2   'Must allow 2 feet between the bottom of the
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     structure and the top of the water table
5060 DT(2)=DT(1)/2
5070 REM  Compute allowable surface areas
5080 IF LENG><0 AND WID><0 THEN GOTO 5130
5090 FOR KK=1 TO 2
5100 AT(KK)=((DELTAQ(K,NUMB)/12!)*AU(K,NUMB))/(VR*DT(KK)+((F*T-P)/12))
5110 NEXT KK
5120 HI=1:GOTO 5160
5130 A=LENG*WID
5140 D=(DELTAQ(K,NUMB)/12!*(AU(K,NUMB)/A)+(P-F*T)/12!)/VR
5150 HI=4:GOTO 5290
5160 IF WID=0 THEN GOTO 5180
5170 W(1)=WID:W(2)=W(1)/2:GOTO 5200
5180 W(1)=50:W(2)=100   'Set structure widths
5190 IF LENG><0 THEN GOTO 5270
5200 IF LENG=0 THEN HI=3
5210 M=1:FOR KKK=1 TO 2
5220   FOR LL=1 TO 2
5230   L(M)=AT(KKK)/W(LL):M=M+1
5240   NEXT LL
5250 NEXT KKK
5260 GOTO 5290
5270 FOR KK=1 TO 2:W(KK)=AT(KK)/LENG:NEXT KK
5280 CLS:PRINT:PRINT:PRINT
5290 IF KIND$="porous pavement" THEN GOTO 5340
5300 CLS:PRINT:PRINT:PRINT
5310 PRINT "                    ***********INFILTRATION TRENCH DESIGN*****
     *****":PRINT:PRINT:PRINT
5320 PRINT "    Choice     Depth      Trench Area    Width        Length
     Total Cost"
5330 PRINT "               (ft)          (sq ft)       (ft)          (ft)
     ($)":PRINT:GOTO 5370
5340 PRINT "                      ***********POROUS PAVEMENT DESIGN******
     ****":PRINT:PRINT:PRINT
5350 PRINT "    Choice     Depth     Pavement Area   Width        Length
     Total Cost"
5360 PRINT "               (ft)          (sq ft)       (ft)          (ft)
     ($)":PRINT
5370 COUNT=1 HI><4 THEN GOTO 5400
5380 GOSUB 5560
5390 PRINT TAB(7) COUNT;TAB(15);D;TAB(27);A;TAB(41);WID;TAB(52);LENG;
     TAB(63);COSTT(COUNT):GOTO 5640
5400 IF LENG><0 THEN GOTO 5490
5410 PP=1:FOR MMM=1 TO 2
5420    FOR KK=1 TO 2
5430 WID=W(KK):LENG=L(PP):D=DT(MMM)
5440 GOSUB 5560
5450 PRINT TAB(7) COUNT;TAB(15);D;TAB(27);AT(MMM);TAB(41);WID;TAB(52);
     LENG;TAB(63);COSTT(COUNT)
5460 PP=PP+1:COUNT=COUNT+1:NEXT KK
5470 NEXT MMM
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5480 GOTO 5640
5490 FOR KAC=1 TO 2
5500 WID=W(KAC):D=DT(KAC)
5510 GOSUB 5560
5520 PRINT TAB(7) COUNT;TAB(15);D;TAB(27);AT(KAC);TAB(41);WID;TAB(52);
     LENG;TAB(63);COSTT(COUNT)
5530 COUNT=COUNT+1
5540 NEXT KAC
5550 GOTO 5640
5560 '%%%%% COST SUBROUTINE %%%%%%%
5570 IF KIND$="porous pavement" THEN GOTO 5610
5580 CONSTC= .68*(WID*LENG*(D+1))+ .28 *((WID*LENG) + (WID*D)  (LENG*D))
     + 2.5*(D+1) + .04*((40+WID)*(40+LENG)-(WID*LENG))
5590 COSTT(COUNT) = CONSTC*1.28
5600 GOTO 5630
5610 CONSTC= .68*(WID*LENG*(D+2/12)) + .14*((WID*LENG) + 2*(WID*D)
     2*(LENG*D)) + 1.75*(LENG*WID) + .096*(WID*LENG*D)
5620 COSTT(COUNT) = 1.35*CONSTC
5630 RETURN
5640 PRINT:PRINT:PRINT "          Do you wish to reconsider geometric
     limitations for"
5650 PRINT "          this structure?":PRINT
5660 PRINT "          Type  yes' or  no' as appropriate if you want to
     redesign"
5670 INPUT "          this structure for the given site conditions ";
     AGAIN$
5680 IF AGAIN$="yes" OR AGAIN$="YES"  THEN GOTO 4740
5690 PRINT:PRINT "          Please choose (by number) one of the above
     designs "
5700 INPUT "          for presentation in data table  ",CHOOSE:COST(K
     ,NUMB)=COSTT(CHOOSE):CLS
5710 PRINT:PRINT:PRINT "          The ";KIND$;" will remove ";
     DELTAQ(K,NUMB);" inches "
5720 PRINT "          of runoff from the ";QB(K,NUMB);" inches
     generated from BMP site ";NUMB
5730 PRINT "          in future subarea ";K;" for the expected ";P;
     " inch rainfall"
5740 PRINT "          for a total cost of $";
5750 PRINT USING "#.##cccc";COST(K,NUMB);
5760 PRINT "."
5770 PRINT:INPUT "          Press RETURN to continue . . .",GO:CLS
5780 RETURN
5790 REM ****Infiltration trench/Porous pavement evaluation routine***
5800 CLS:PRINT:PRINT:PRINT"     Information now needs to be provided
     for evaluation of the"
5810 PRINT"     existing ";KIND$;" designated BMP site ";NUMB
5820 PRINT"     in ";WHEN$;" subarea ";K
5830 PRINT:PRINT:PRINT "     What is the length of the ";KIND$
5840 INPUT "          in feet ";LENGTH:PRINT
5850 PRINT "     What is the width of the ";KIND$
5860 INPUT "          in feet ";WID:PRINT
5870 AREAT=WID*LENGTH
5880 PRINT "     What is the depth (in feet) of the stone sub-base"
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5890 PRINT "          underlying the ";KIND$;
5900 INPUT " ";DEPTH:PRINT
5910 GOSUB 6000  'Infiltration rate determination
5920 TS=72:VR=.4:T=2
5930 DEPTH=DEPTH*12
5940 DELTAQ(K,NUMB)=AREAT/AU(K,NUMB)*(VR*DEPTH-P+F*T)   'Runoff removed
     by structure
5950 CLS:PRINT:PRINT:PRINT:PRINT "    The existing ";KIND$;" designated
     BMP site ";NUMB
5960 PRINT "    in ";WHEN$;" subarea ";K;" theoretically removes ";
     DELTAQ(K,NUMB);" inches"
5970 PRINT "    of runoff from subasin ";K;" for the expected ";P;"
     inch rainfall."
5980 PRINT:INPUT "    Press RETURN to continue . . . ",GO:CLS
5990 RETURN
6000 REM ******Infiltration rate determination routine*******
6010 CLS:PRINT:PRINT:PRINT "                           INFILTRATION RATE
     DETERMINATION":PRINT
6020 PRINT "                          Hydrologic
     Infiltration "
6030 PRINT "          Texture Group    Soil Group        Rate
     Choice":PRINT
6040 PRINT "         Sand                  A             8.27
      A"
6050 PRINT "         Loamy Sand            A             2.41
      B"
6060 PRINT "         Sandy Loam            B             1.02
      C"
6070 PRINT "         Loam                  B             0.52
      D"
6080 PRINT "         Silt Loam             C             0.27
      E"
6090 PRINT "         Sandy Clay Loam       C             0.17
      F"
6100 PRINT "         Clay Loam             D             0.09
      G"

6110 PRINT "         Silty Clay Loam       D             0.06
      H "
6120 PRINT "         Sandy Clay            D             0.05
      I"
6130 PRINT "         Silty Clay            D             0.04
      J"
6140 PRINT "         Clay                  D             0.02
      K"
6150 PRINT:PRINT "          Soil with a known infiltration rate to
     be entered  L"
6160 PRINT:PRINT "   For the soil underlying the infiltration trench
     to be evaluated "
6170 INPUT "    or designed, enter the letter of your choice ";CHOICE$
6180 IF CHOICE$ = "A" OR CHOICE$="a" THEN F=8.270001
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6190 IF CHOICE$ = "B" OR CHOICE$="b" THEN F=2.41
6200 IF CHOICE$ = "C" OR CHOICE$="c" THEN F=1.02
6210 IF CHOICE$ = "D" OR CHOICE$="d" THEN F=.52
6220 IF CHOICE$ = "E" OR CHOICE$="e" THEN F=.27
6230 IF CHOICE$ = "L" OR CHOICE$="l" THEN GOTO 6350
6240 IF CHOICE$ = "F" OR CHOICE$="G" OR CHOICE$ ="H" OR CHOICE$ ="I" OR
     CHOICE$ ="J" OR CHOICE$ = "K" THEN 6300
6250 IF CHOICE$ = "f" OR CHOICE$="g" OR CHOICE$ ="h" OR CHOICE$ ="i" OR
     CHOICE$ ="j" OR CHOICE$ = "k" THEN 6300
6260 IF CHOICE$="A" OR CHOICE$="B" OR CHOICE$="C" OR CHOICE$="D" OR
     CHOICE$="E" OR CHOICE$="F" OR CHOICE$="G" OR CHOICE$="H" OR
     CHOICE$="I" OR CHOICE$="J" OR CHOICE$="K" OR CHOICE$="L" THEN 6290
6270 IF CHOICE$="a" OR CHOICE$="b" OR CHOICE$="c" OR CHOICE$="d" OR
     CHOICE$="e" OR CHOICE$="f" OR CHOICE$="g" OR CHOICE$="h" OR
     CHOICE$="i" OR CHOICE$="j" OR CHOICE$="k" OR CHOICE$="l" THEN 6290
6280 BEEP:PRINT"    YOU DID NOT ENTER A POSSIBLE CHOICE.":PRINT:GOTO
     6160
6290 GOTO 6360
6300 PRINT:PRINT "    Literature review indicates that soils of this
     texture class "
6310 PRINT "    are not suitable for infiltration devices.":PRINT
6320 PRINT "    Do you wish to continue and enter a suitable
     infiltration
6330 INPUT "    rate (>0.27)? Enter  yes' or  no' as appropriate ";
     ANSW$
6340 IF ANSW$ ="no" OR ANSW$ = "NO" THEN RETURN
6350 PRINT:INPUT "    Please enter an infiltration rate of your choice
     ";F
6360 CLS:RETURN
6370 REM   Subroutine--Input DA & Soil Types for BMP sites
6380 PRINT:PRINT:PRINT:PRINT "      For BMP site "; NUMB;" in ";WHEN$;
     " subarea ";KK
6390 PRINT "     enter the upland area in acres that produces runoff"
6400 INPUT "     (to be) managed by the BMP structure";BDA(KK,NUMB):
     PRINT:PRINT
6410 CLS:RETURN
6420 REM ***** Detention Basin Preparatory********
6430 DIM TIMS$(46),INFLW(46),H1(46),H2(46)          'ARRAYS TO STORE
     INFO FROM SUBROUTINES
6440 FOR KAC=1 TO 46:READ TIMS$(KAC):NEXT KAC
6450 DATA 11.0,11.2,11.4,11.6,11.8,12.0,12.2,12.4,12.6,12.8,13.0,13.2,
     13.4,13.6,13.8,14.0
6460 DATA 14.2,14.4,14.6,14.8,15.0,15.2,15.4,15.6,15.8,16.0,16.2,16.4,
     16.6,16.8,17.0
6470 DATA 17.2,17.4,17.6,17.8,18.0,18.2,18.4,18.6,18.8,19.0,19.2,19.4,
     19.6,19.8,20.0,0,0,0,0,0
6480 RETURN
6490 REM DETENTION BASIN DESIGN/EVALUATION ROUTINE
6500 '************************************************************
6510 'THIS SUBROUTINE PERFORMS HYDROLOGIC FLOOD ROUTING IN A RESERVOIR
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6520 '****************************************************************
6530 CLS:LOCATE 6,22:PRINT"DETENTION BASIN DESIGN/EVALUATION ROUTINE":
     PRINT
6540 PRINT:INPUT "                                        PRESS RETURN TO CONTINUE
     ",GO:CLS
6550 GOSUB 8550
6560 FOR J=1 TO 46:INFLW(J)=FLOW(J):NEXT J
6570 PRINT "      IT IS NOW NECESSARY TO ENTER THE RATING CURVE "
6580 PRINT "      AND STORAGE vs. ELEVATION DATA FOR BMP SITE ";NUMB;
     "IN SUBAREA ";K;" .":PRINT
6590 INPUT "      WHAT IS THE MAXIMUM ELEVATION IN THIS DATA (ft)";MAX
6600 INPUT "      IN WHAT INCREMENTS OF ELEVATION IS THIS DATA GIVEN
     (ft)";INC
6610 PRINT:INPUT "      WERE THESE VALUES ENTERED CORRECTLY? (Y/N)",
     ANS$
6620 IF ANS$="N" OR ANS$="n" THEN CLS:GOTO 6570
6630 DIM STOR(MAX+1),OTFLW(MAX+1)
6640 PRINT:PRINT "      FOR EACH POOL ELEVATION, ENTER THE CORRESPONDING
     STORAGE (CUBIC FEET) "
6650 PRINT "      AND OUTLET STRUCTURE DISCHARGE (CFS): ":PRINT
6660 PRINT "       Elevation          Storage          Outflow"
6670 YY=13
6680 FOR H=0 TO MAX STEP INC
6690 PRINT TAB(10) H
6700 LOCATE YY,25:INPUT " ",STOR(H)
6710 LOCATE YY,45:INPUT " ",OTFLW(H)
6720 YY=YY+1
6730 NEXT H
6740 YY=YY+1
6750 PRINT:INPUT "      ARE ALL THE VALUES CORRECT? (Y/N)", ANS$
6760 IF ANS$="Y" OR ANS$="y" THEN 6840
6770 INPUT "      WHAT IS THE SUBSCRIPT OF THE INCORRECT VALUE? ";H
6780 Y=13 +H
6790 LOCATE Y,25:INPUT " ", STOR (H)
6800 LOCATE Y,45:INPUT " ", OTFLW(H)
6810 LOCATE YY,6:PRINT:PRINT:PRINT
6820 LOCATE YY,6:INPUT "ANY MORE INCORRECT VALUES ? (Y/N)", ANS$
6830 IF ANS$="Y" OR ANS$="y" THEN 6770
6840 DELTAT=720:S$="hrs"   'Delta time = 12 minutes ( 720 seconds )
6850 CLS:LOCATE 5,5:PRINT "Calculating . . . "
6860 HMAX=-1:OMAX=-1:INMAX=-1:TMAX=0:H1=0:TLAG=0:TLAGC=0:KLD=1
6870 GOSUB 6910
6880 GOSUB 7320
6890 GOSUB 7370
6900 RETURN
6910 '*********BASIN DESIGN -- COMPUTE I1 +I2 *********
6920 FOR T=1 TO 46
6930 T2=T+1 T2>46 THEN T2=0
6940 H1(T)=H1
6950 TERM1=INFLW(T)+INFLW(T2)
6960 IF INFLW(T)>INMAX THEN INMAX=INFLW(T):TINMAX=T   'sorting to
```

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     find maximum inflow
6970 GOSUB 7000
6980 NEXT T
6990 RETURN
7000 '*********BASIN DESIGN -- COMPUTE (2*S/DELTA T)-O ****************
7010 INTERP=INT(H1/INC)*INC    'INTERPOLATION TO FIND H1
7020 IF INTERP=H1 THEN S=STOR(H1):O1=OTFLW(H1): GOTO 7090
7030 INTERP1=INTERP+INC
7040 HINT=INTERP1-INTERP
7050 SINT=STOR(INTERP1)-STOR(INTERP)
7060 O1INT=OTFLW(INTERP1)-OTFLW(INTERP)
7070 S=((SINT/HINT)*(H1-INTERP))+STOR(INTERP)
7080 O1=((O1INT/HINT)*(H1-INTERP))+OTFLW(INTERP)
7090 TERM2=((2*S)/(DELTAT))-O1
7100 TERM3=TERM1+TERM2
7110 GOSUB 7130
7120 RETURN
7130 '************BASIN DESIGN -- COMPUTE H2 AND O2 ********************
7140 DEF FNTERM3(X)=(((STOR(X)*2)/DELTAT)+OTFLW(X))
7150 FOR J=0 TO MAX STEP INC
7160 IF TERM3<FNTERM3(J) THEN 7190
7170 NEXT J
7180 REM _____INTERPOLATING FOR H2
7190  H2(T)=((J-(J-INC))/(FNTERM3(J)-FNTERM3(J-INC))*(TERM3-FNTERM3(J-
      INC)))+(J-INC)
7200 H2=H2(T)
7210 INTERP=INT(H2/INC)*INC    'INTERPOLATION TO FIND O2
7220 IF INTERP=H2 THEN O2(T)=OTFLW(H2): GOTO 7270
7230 INTERP2=INTERP+INC
7240 HINT=INTERP2-INTERP
7250 O2INT=OTFLW(INTERP2)-OTFLW(INTERP)
7260 O2(T)=((O2INT/HINT)*(H2-INTERP))+OTFLW(INTERP)
7270 IF H2(T)>HMAX THEN HMAX=H2(T)  'SORTING TO FIND MAXIMUM POOL
     ELEVATION
7280 IF O2(T)>OMAX THEN OMAX=O2(T):TMAX=T  'SORTING TO FIND MAXIMUM
     OUTFLOW
7290 H1=H2(T)
7300 GOSUB 8860
7310 RETURN
7320 '****************** COMPUTE STORAGE ******************************
7330 IHMAX=INT(HMAX/INC)*INC
7340 I2HMAX=IHMAX+INC
7350 STORAGE(K,NUMB)=((STOR(I2HMAX)-STOR(IHMAX))/(I2HMAX-IHMAX))*
     (HMAX-IHMAX)+STOR(IHMAX) + .5*(INFLW(1)*11*3600)     ' LAST TERM
     IS 0 - 11 HR STORAGE
7360 RETURN
7370 '***********DETENTION BASIN PRINT SUBROUTINE ******************
7380 CLS:PRINT TAB(15); "THE RESULTS OF THE ROUTING ARE AS FOLLOWS":
     PRINT
7390 COLOR 2,9,0
7400 PRINT TAB(15);"T1" TAB(22);"T2" TAB(29);"I1" TAB(36);"I2";
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```
7410 PRINT  TAB(46);"H1" TAB(53);"H2" TAB(61);"OUTFLOW"
7420 PRINT TAB(15);S$ TAB(22);S$ TAB(29);"cfs" TAB(36);"cfs";
7430 PRINT  TAB(46);"ft" TAB(53);"ft" TAB(61);"cfs":COLOR 7,9,0:PRINT
7440 Z$="#####.#":Y$="##.#":X$="#####.#"
7450 FOR T=1 TO 46
7460 T2=T+1: IF T2>46 THEN T2=0
7470 PRINT TAB(15);TIMS$(T) TAB(21); TIMS$(T2);
7480 PRINT TAB(26); USING X$; INFLW(T);
7490 PRINT TAB(33);USING X$; INFLW(T2);
7500 PRINT TAB(45);USING Y$; H1(T);
7510 IF H2(T)=HMAX THEN COLOR 20,9,0
7520 PRINT TAB(52);USING Y$;H2(T);
7530 PRINT TAB(58);USING X$;O2(T):COLOR 7,9,0
7540 IF T=15 OR T=33 THEN PRINT:INPUT "                    Press RETURN
     to view rest of chart ",GO:CLS
7550 IF T=15 OR T=33 THEN COLOR 2,9,0:PRINT TAB(15);"T1" TAB(22);"T2"
     TAB(29);"I1" TAB(36);"I2";
7560 IF T=15 OR T=33 THEN PRINT  TAB(46);"H1" TAB(53);"H2" TAB(61);
     "OUTFLOW"
7570 IF T=15 OR T=33 THEN PRINT TAB(15);S$ TAB(22);S$ TAB(29);"cfs"
     TAB(36);"cfs";
7580 IF T=15 OR T=33 THEN PRINT TAB(46);"ft" TAB(53);"ft" TAB(61);
     "cfs":PRINT:COLOR 7,9,0
7590 NEXT T
7600 PRINT:PRINT TAB(20);"FOR BMP SITE ";NUMB;"IN SUBAREA ";K
7610 PRINT:PRINT TAB(15);"MAXIMUM POOL ELEVATION -";
7620 PRINT TAB(40);USING X$;HMAX;
7630 PRINT TAB(51);"ft":PRINT
7640 PRINT TAB(22);"MAXIMUM OUTFLOW -";
7650 PRINT TAB(40);USING X$;OMAX;
7660 PRINT TAB(51);"cfs":PRINT
7670 PRINT TAB(22);"MAXIMUM STORAGE -";
7680 PRINT TAB(41);USING "##.##¢¢¢¢";STORAGE(K,NUMB);
7690 PRINT TAB(51);"cubic feet"
7700 IF WHEN$="present " THEN GOTO 7840
7710 IF TYPE$(K,NUMB)="a" OR TYPE$(K,NUMB)="A" OR TYPE$(K,NUMB)="B" OR
     TYPE$(K,NUMB)="b" THEN GOTO 7780
7720 STORAGE(K,NUMB)=STORAGE(K,NUMB)+.188*STORAGE(K,NUMB)
7730 PRINT:PRINT TAB(10) "Note: To achieve the pollutant removal rate
     for an extended wet pond,"
7740 PRINT TAB(10) "this pond size must be increased by 18.8%.
     Therefore, ":PRINT
7750 PRINT TAB(22);"MAXIMUM STORAGE -";
7760 PRINT TAB(41);USING "##.##¢¢¢¢";STORAGE(K,NUMB);
7770 PRINT TAB(51);"cubic feet "
7780 CONSTC= 77.4*STORAGE(K,NUMB)¢.51    'Construction costs
7790 CONTIGC = .25 * CONSTC
7800 IF TYPE$(K,NUMB)="a" OR TYPE$(K,NUMB)="A" OR TYPE$(K,NUMB)="B" OR
     TYPE$(K,NUMB)="b" THEN OMCOST = .05 * CONSTC:GOTO 7820
7810 OMCOST = .0625 * CONSTC
7820 COST(K,NUMB)=CONSTC + CONTIGC + OMCOST 'Detention basin total cost
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7830 PRINT:PRINT TAB(22) "TOTAL COST - $ ";COST(K,NUMB)
7840 PRINT:PRINT:INPUT "                    PRESS RETURN TO CONTINUE ",GO
7850 IF WHEN$="present " THEN CLS:GOTO 7900
7860 CLS:LOCATE 6,5:PRINT "DO YOU WISH TO REDESIGN THE BASIN USING A
     DIFFERENT "
7870 LOCATE 7,5:PRINT "STORAGE-ELEVATION RELATIONSHIP OR OUTFLOW
     STRUCTURE? "
7880 LOCATE 9,5:INPUT "ENTER (Y|N) AS APPROPRIATE  ",AGAIN$:CLS
7890 IF AGAIN$="Y" OR AGAIN$="y" THEN ERASE STOR,OTFLW:CLS:GOTO 6570
7900 REM Compute time lag in counter increments
7910 TLAGC=CINT(ABS(TINMAX-TMAX) + TTIMEB(K,NUMB)/.2)+1  'LAG TO OUTLET
     OF WATERSHED
7920 TLAG=CINT(ABS(TINMAX-TMAX) + (TTIMEB(K,NUMB) - TTIME(K)))+1  'LAG
     TO OUTLET OF SUBAREA
7930 ERASE H1,H2,STOR,OTFLW,TIMS$,INFLW:RESTORE 6450
7940 RETURN
7950 REM    CURVE NUMBER MENU
7960 LOCATE 4,6:PRINT "     Information now needs to be provided to
     allow calculation of the runoff"
7970 PRINT "     curve numbers for the ";WHEN$;"condition BMP sites."
7980 PRINT:PRINT "     For each BMP site,"
7990 PRINT "     enter each land use type and the amount of land (in
     acres) for"
8000 PRINT "     each type successively.  Note the order of entry of
     these land"
8010 PRINT "     use types; you will be asked further questions
     concerning land"
8020 PRINT "     uses in another segment of the program.":PRINT
8030 PRINT "     How many land use types exist in BMP site ";NUMB;" in "
8040 PRINT "     ";WHEN$;" condition subarea ";KK;
8050 INPUT " ";LUT
8060 IF LUT><0 THEN GOTO 8080
8070 BEEP:PRINT:PRINT"     YOU MUST ENTER A POSITIVE VALUE.":PRINT:GOTO
     8030
8080 WRITE #3,LUT
8090 CLS:PRINT:PRINT:PRINT "     Which of the following best describes
     the GENERAL land use:"
8100 PRINT:PRINT "      A.   Fully developed urban area (vegetation
     established)"
8110 PRINT:PRINT "      B.   Developing urban area (no vegetation
     established)
8120 PRINT:PRINT "      C.   Cultivated agricultural land     "
8130 PRINT:PRINT "      D.   Non-cultivated agricultural land"
8140 PRINT:PRINT "      E.   Forest-range"
8150 PRINT:INPUT"     Type the appropriate letter ";LUSE$
8160 IF LUSE$="a" OR LUSE$="A" OR LUSE$="b" OR LUSE$="B" OR LUSE$="c"
     OR LUSE$="C" OR LUSE$="d" OR LUSE$="D" OR LUSE$="e" OR LUSE$="E"
     THEN CLS:GOTO 8180
8170 BEEP:PRINT:PRINT "      YOU DID NOT ENTER A POSSIBLE CHOICE.":GOTO
     8150
8180 IF LUSE$="a" OR LUSE$="A" THEN GOSUB 3970
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8190 IF LUSE$="b" OR LUSE$="B" THEN GOSUB 4060
8200 IF LUSE$="c" OR LUSE$="C" THEN GOSUB 4090
8210 IF LUSE$="d" OR LUSE$="D" THEN GOSUB 4270
8220 IF LUSE$="e" OR LUSE$="E" THEN GOSUB 4370
8230 GOSUB 4450
8240 CLS:GOSUB 2980
8250 TCN=HSGA*CN(1,LUD%)+HSGB*CN(2,LUD%)+HSGC*CN(3,LUD%)+HSGD*CN(4,LUD%)
8260 WRCN=WRCN+TCN
8270 ASUM=ASUM+AREA(KK,NUMB,KDP)
8280 IF KDP=LUT THEN GOTO 8300
8290 KDP=KDP+1:GOTO 8090
8300 RETURN
8310 REM           TRAVEL TIME TABLES
8320 PRINT:PRINT "          POSSIBLE CONDITIONS:  "
8330 PRINT "      1.  Forest with heavy ground litter and meadow
     (ENTER 1)"
8340 PRINT "      2.  Fallow or minimum tillage cultivation
     (ENTER 2)"
8350 PRINT "      3.  Short grass and lawns
     (ENTER 3)"
8360 PRINT "      4.  Nearly bare ground
     (ENTER 4)"
8370 PRINT "      5.  Grassed waterway
     (ENTER 5)"
8380 PRINT "      6.  Paved area (sheet flow) & shallow gutter flow
     (ENTER 6)"
8390 PRINT "      7.  Gutter flow
     (ENTER 7)"
8400 PRINT "      8.  Channel flow
     (ENTER 8)"
8410 PRINT "      9.  Sewer flow
     (ENTER 9)":PRINT
8420 INPUT "      What is the condition";COND
8430 IF COND=1 OR COND=2 OR COND=3 OR COND=4 OR COND=5 OR COND=6 OR
     COND=7 OR COND=8 OR COND=9 THEN GOTO 8450
8440 BEEP:PRINT:PRINT "     YOU DID NOT ENTER A POSSIBLE CONDITION
     NUMBER.":PRINT:GOTO 8420
8450 INPUT "      What is the length of flow for this condition (in
     feet)";LENG
8460 INPUT "      What is the slope of the flow for this condition  (in
     percent)";SLOPE
8470 IF COND=7 THEN GOSUB 3680:GOTO 8520
8480 IF COND=8 THEN GOSUB 3780:GOTO 8520
8490 IF COND=9 THEN GOSUB 3900:GOTO 8520
8500 GOSUB 3570
8510 TIME=LENG/VEL:TOTALT=TOTALT+TIME
8520 IF DRP=NTIME THEN RETURN
8530 CLS:DRP=DRP+1:GOTO 8320
8540 RETURN
8550 REM   CONVERSION OF INFLOW HYDROGRAPH ORDINATES TO CONSTANT TIME
```

```
     SCALE
8560 FLOW(1)=QBMP(1)
8570 INC=(QBMP(2)-QBMP(1))/5
8580 FLOW(2)=QBMP(1)+2*INC:FLOW(3)=QBMP(1)+4*INC
8590 FLOW(4)=(QBMP(3)+QBMP(2))/2
8600 JJ=4:FOR J=5 TO 11:FLOW(J)=QBMP(JJ):JJ=JJ+2:NEXT J
8610 FLOW(12)=QBMP(17)
8620 INC=(QBMP(18)-QBMP(17))/3:FLOW(13)=QBMP(17)+2*INC
8630 INC=(QBMP(19)-QBMP(18))/5
8640 FLOW(14)=QBMP(18)+INC:FLOW(15)=QBMP(18)+3*INC
8650 FLOW(16)=QBMP(19)
8660 INC=(QBMP(20)-QBMP(19))/5
8670 FLOW(17)=QBMP(19)+2*INC:FLOW(18)=QBMP(19)+4*INC
8680 INC=(QBMP(21)-QBMP(20))/5
8690 FLOW(19)=QBMP(20)+INC:FLOW(20)=QBMP(20)+3*INC
8700 FLOW(21)=QBMP(21)
8710 INC=(QBMP(22)-QBMP(21))/5:KK=1
8720 FOR NM=22 TO 26:FLOW(NM)=QBMP(21)+KK*INC:KK=KK+1:NEXT NM
8730 INC=(QBMP(23)-QBMP(22))/10:KK=1
8740 FOR NN=27 TO 36:FLOW(NN)=QBMP(22)+KK*INC:KK=KK+1:NEXT NN
8750 INC=(QBMP(24)-QBMP(23))/10:KK=1
8760 FOR MN=37 TO 46:FLOW(MN)=QBMP(23)+KK*INC:KK=KK+1:NEXT MN
8770 RETURN
8780 REM  HYDROGRAPH CALCULATION
8790    FOR JJJ=1 TO 24
8800    OFLP(JJJ)=OFL(TTL,JJJ)+(OFL(TTH,JJJ)-OFL(TTL,JJJ))*(TTIMEB(K,
        NUMB)-TT1)/(TT2-TT1)
8810    OFHP(JJJ)=OFH(TTL,JJJ)+(OFH(TTH,JJJ)-OFH(TTL,JJJ))*(TTIMEB(K,
        NUMB)-TT1)/(TT2-TT1)
8820    OTB(JJJ)=OFLP(JJJ)+(OFHP(JJJ)-OFLP(JJJ))*(TCONCB(K,NUMB)-TCL)/
        (TCH-TCL)
8830    QBMP(JJJ)=OTB(JJJ)*BDASM(K,NUMB)*DELTAQ(K,NUMB)
8840    NEXT JJJ
8850 RETURN
8860 REM ****** ROUTINE TO CALCULATE STORAGE VOLUME FOR EACH TIME
     INTERVAL
8870 IF 02(T) < 01 THEN STVOL(KLD)=0:GOTO 8900
8880 IF INFLW(T2) < INFLW(T) THEN STVOL(KLD)=((.5*ABS(INFLW(T2) -
     INFLW(T))+ INFLW(T2))-(.5*ABS(02(T)-01)+01))*DELTAT:GOTO 8900
8890 STVOL(KLD)=((.5*ABS(INFLW(T2) - INFLW(T))+ INFLW(T))-(.5*ABS
     (02(T)-01)+01))*DELTAT
8900 KLD=KLD+1:RETURN
```

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10 '**************************************************************
20 '**                    OUTPUT PROGRAM MODULE                  **
30 '**                  WRITTEN BY:  K. A. CAVE                  **
40 '**                        VERSION 2.2                        **
50 '**                        MARCH, 1986                        **
60 '**************************************************************
70 OPEN "b:answer" FOR INPUT AS #2
80 INPUT #2, ANS$:CLOSE
90 IF ANS$="no" OR ANS$="NO"  THEN GOTO 800
100 SCREEN 0,0:WIDTH 80:KEY OFF:COLOR 7,9,0:CLS
110 LOCATE 5,5:PRINT "Calculating . . ."
120 OPEN "B:HYD.ORD" FOR INPUT AS #2
130 INPUT #2, BMP$
140 INPUT #2, N$
150 INPUT #2,N
160 INPUT #2, WHEN$
170 INPUT #2, FORM$
180 DIM X(N,46),Y(46),YMAX(N),YCIR(46),QS(N,46),QTOT(46),ORD(24)
190 FOR LAND=1 TO N
200   FOR JJ=1 TO 46:INPUT #2, QS(LAND,JJ):NEXT JJ
210 NEXT LAND
220 FOR KK=1 TO 46:INPUT #2, QTOT(KK):NEXT KK
230 FOR KAC=1 TO 24:READ ORD(KAC):NEXT KAC
240 DATA 11.0,11.2,11.4,11.6,11.8,12.0,12.2,12.4,12.6,12.8,13.0,13.2
250 DATA 13.4,13.6,13.8,14.0,14.2,14.4,14.6,14.8,15.0,16.0,18.0,20.0
260 REM Find the peak discharge
270 FOR LAND=1 TO N
280    FOR JJ=1 TO 46:X(LAND,JJ)=QS(LAND,JJ):NEXT JJ
290 NEXT LAND
300 FOR LAND=1 TO N
310   FOR JJ=1 TO 45
320    FOR KK=JJ+1 TO 46
330 IF X(LAND,JJ)>= X(LAND,KK) THEN GOTO 370
340 TEMP=X(LAND,JJ)
350 X(LAND,JJ)=X(LAND,KK)
360 X(LAND,KK)=TEMP
370 NEXT KK
380 NEXT JJ
390 YMAX(LAND)=X(LAND,1)
400 NEXT LAND
410 REM Find peak discharge for composite hydrograph
420 FOR JJ=1 TO 46
430 Y(JJ)=QTOT(JJ)
440 NEXT JJ
450   FOR JJ=1 TO 45
460    FOR KK=JJ+1 TO 46
470 IF Y(JJ)>= Y(KK) THEN GOTO 510
480 TEMP=Y(JJ)
490 Y(JJ)=Y(KK)
500 Y(KK)=TEMP
510 NEXT KK
```

```
520 NEXT JJ
530 YMAXT=Y(1)
540 IF FORM$="b" OR FORM$="B" THEN GOTO 710
550 REM OUTPUT SUBAREA AND COMPOSITE HYDROGRAPHS
560 FOR MK=1 TO N
570 CLS:PRINT "       The runoff hydrograph for the ";WHEN$;" condition
    includes:"
580 GOSUB 810
590 CLS
600 NEXT MK
610 PRINT:PRINT "       The total composite hydrograph for the ";WHEN$;
    " condition:
620 GOSUB 1050
630 IF BMP$="yes" THEN GOTO 660
640 IF BMP$="no" THEN PRINT:PRINT "       This hydrograph is for the ";
    WHEN$;"         condition watershed without the presence of BMP
    structures"
650 GOTO 680
660 PRINT:PRINT "       This hydrograph reflects the presence of BMP
    structures in  "
670 PRINT "         the ";WHEN$;" condition watershed."
680 PRINT:PRINT:INPUT "       Press RETURN to continue. . .",DRP
690 CLS
700 IF FORM$="a" OR FORM$="A" THEN GOTO 800
710 REM &&&&&Graphical output of hydrographs&&&&&&&&&
720 IF WHEN$="future " THEN WHEN$="FUTURE"
730 IF WHEN$="present " THEN WHEN$="PRESENT"
740 LOCATE 5,5:PRINT "Calculating . . . "
750 FOR LAND=1 TO N
760 GOSUB 1240   'output subarea hydrographs
770 NEXT LAND
780 TOTAL=1
790 GOSUB 1240  'output composite hydrographs
800 SYSTEM
810 REM   Format for output of subarea hydrographs
820 Z$="##############.#"
830 PRINT:PRINT "         ____________________FOR SUBAREA";MK;
    "____________________"
840 PRINT "       TIME(hours)";"   HYD ORD(cfs)";"    TIME(hours)";
    "   HYD ORD(cfs)"
850 PRINT USING Z$; ORD(1); QS(MK,1); ORD(13); QS(MK,13)
860 PRINT USING Z$; ORD(2); QS(MK,2); ORD(14); QS(MK,14)
870 PRINT USING Z$; ORD(3); QS(MK,3); ORD(15); QS(MK,15)
880 PRINT USING Z$; ORD(4); QS(MK,4); ORD(16); QS(MK,16)
890 PRINT USING Z$; ORD(5); QS(MK,5); ORD(17); QS(MK,17)
900 PRINT USING Z$; ORD(6); QS(MK,6); ORD(18); QS(MK,18)
910 PRINT USING Z$; ORD(7); QS(MK,7); ORD(19); QS(MK,19)
920 PRINT USING Z$; ORD(8); QS(MK,8); ORD(20); QS(MK,20)
930 PRINT USING Z$; ORD(9); QS(MK,9); ORD(21); QS(MK,21)
940 PRINT USING Z$; ORD(10); QS(MK,10); ORD(22); QS(MK,26)
950 PRINT USING Z$; ORD(11); QS(MK,11); ORD(23); QS(MK,36)
```

```
960 PRINT USING Z$; ORD(12); QS(MK,12); ORD(24); QS(MK,46)
970 IF BMP$="yes" THEN GOTO 1010
980 IF BMP$="no" THEN PRINT:PRINT "       This hydrograph is for the ";
    WHEN$
990 PRINT "          condition watershed without the presence of BMP
    structures."
1000 GOTO 1030
1010 PRINT:PRINT "       This hydrograph reflects the presence of BMP
     structures
1020 PRINT "          in the ";WHEN$;" condition watershed."
1030 PRINT:PRINT:INPUT "          Press RETURN to continue. . . ",KUO:CLS
1040 RETURN
1050 REM   Format for output of composite hydrographs
1060 Z$="##############.#"
1070 FOR J=1 TO 24
1080 QTOT(J)=INT(QTOT(J)*10)/10
1090 NEXT J
1100 PRINT:PRINT:PRINT "          TIME(hours)";"   HYD ORD(cfs)";
     "    TIME(hours)";"   HYD ORD(cfs)"
1110 PRINT USING Z$; ORD(1); QTOT(1); ORD(13); QTOT(13)
1120 PRINT USING Z$; ORD(2); QTOT(2); ORD(14); QTOT(14)
1130 PRINT USING Z$; ORD(3); QTOT(3); ORD(15); QTOT(15)
1140 PRINT USING Z$; ORD(4); QTOT(4); ORD(16); QTOT(16)
1150 PRINT USING Z$; ORD(5); QTOT(5); ORD(17); QTOT(17)
1160 PRINT USING Z$; ORD(6); QTOT(6); ORD(18); QTOT(18)
1170 PRINT USING Z$; ORD(7); QTOT(7); ORD(19); QTOT(19)
1180 PRINT USING Z$; ORD(8); QTOT(8); ORD(20); QTOT(20)
1190 PRINT USING Z$; ORD(9); QTOT(9); ORD(21); QTOT(21)
1200 PRINT USING Z$; ORD(10);QTOT(10); ORD(22);QTOT(26)
1210 PRINT USING Z$; ORD(11);QTOT(11); ORD(23);QTOT(36)
1220 PRINT USING Z$; ORD(12); QTOT(12); ORD(24); QTOT(46)
1230 RETURN
1240 REM *********Graphical presentation of hydrographs**********
1250 IF TOTAL=1 THEN GOTO 1300
1260 YHIGH=YMAX(LAND)+10
1270 YLOW=X(LAND,46)
1280 QPEAK=YMAX(LAND)
1290 GOTO 1330
1300 YHIGH=YMAXT+10
1310  YLOW=Y(46)
1320 QPEAK=YMAXT
1330 YRANGE=YHIGH-YLOW
1340 SCREEN 2,0:WIDTH 80:KEY OFF:CLS
1350 YAXISLEN=165
1360 LINE (60,0)-(60,165)
1370 LINE (60,165)-(600,165)
1380 FOR TIKX=90 TO 600 STEP 30
1390    LINE (TIKX,163)-(TIKX,167)
1400 NEXT TIKX
1410 FOR TICY=165 TO 0 STEP -20
1420     LINE (60,TICY)-(64,TICY)
```

```
1430 NEXT TICY
1440 LOCATE 22:PRINT "                   12.0    13.0     14.0    15.0     16.0
     17.0     18.0    19.0     20.0"
1450 LOCATE 23:PRINT "                                           TIME (hrs)"
1460 YINC=(40/YAXISLEN)*YRANGE
1470 X$="####.#"
1480 LOCATE 21,2:PRINT USING X$;YLOW
1490  LOCATE 16,2:PRINT USING X$;(YLOW+YINC)
1500 LOCATE 11,2:PRINT USING X$;(YLOW+YINC*2)
1510 LOCATE 6,2:PRINT USING X$;(YLOW+YINC*3)
1520 LOCATE 1,1:PRINT CINT(YLOW+YINC*4)
1530 LOCATE 5,1:PRINT "D"
1540 LOCATE 6,1:PRINT "I"
1550 LOCATE 7,1:PRINT "S"
1560 LOCATE 8,1:PRINT "C"
1570 LOCATE 9,1:PRINT "H"
1580 LOCATE 10,1:PRINT "A"
1590 LOCATE 11,1:PRINT "R"
1600 LOCATE 12,1:PRINT "G"
1610 LOCATE 13,1:PRINT "E"
1620 LOCATE 14,1:PRINT "(cfs)"
1630 FOR I=1 TO 46
1640 IF TOTAL=1 THEN GOTO 1670
1650   YCIR(I)=YAXISLEN-(QS(LAND,I)-YLOW)*YAXISLEN/YRANGE
1660   GOTO 1680
1670   YCIR(I)=YAXISLEN-(QTOT(I)-YLOW)*YAXISLEN/YRANGE
1680 NEXT I
1690 XCIR=60
1700 FOR KAC=1 TO 46
1710 CIRCLE (XCIR,YCIR(KAC)),2
1720 XCIR=XCIR+12
1730 NEXT KAC
1740 IF TOTAL=1 THEN GOTO 1770
1750 LOCATE 1,45:PRINT WHEN$;" SUBAREA ";LAND;" HYDROGRAPH"
1760 GOTO 1780
1770 LOCATE 1,35:PRINT "COMPOSITE HYDROGRAPH--";N$;" WATERSHED"
1780 LOCATE 3,45:PRINT "Q PEAK = ";QPEAK;" cfs"
1790 IF BMP$="no" THEN LOCATE 4,45:PRINT "No BMP structures in
     watershed"
1800 IF BMP$="yes" THEN LOCATE 4,45:PRINT "BMP structures in watershed"
1810 LOCATE 23,59:INPUT "RETURN to continue ",GO
1820 RETURN
```

```
10 '**************************************************************
20 '**                    POLLUTO PROGRAM MODULE                 **
30 '**                    WRITTEN BY: K. A. CAVE                 **
40 '**                         VERSION 2.2                       **
50 '**                         MARCH, 1986                       **
60 '**************************************************************
70 SCREEN 0,0:COLOR 7,9,0:KEY OFF:WIDTH 80:CLS
80 NPOL=4   '  NPOL is the number of types of pollutants analyzed
90 DIM CNAM$(NPOL),PDP24(49)    'PDP24 are the Type II rainfall
   distribution curve
100 FOR KKK=1 TO 4:READ CNAM$(KKK):NEXT KKK
110 DATA Total Suspended Solids,BOD,Nitrogen,Phosphorus
120 FOR KEL=0 TO 48:READ PDP24(KEL):NEXT KEL
130 DATA 0,.0053,.0108,.0164,.0223,.0284,.0347,.0414,.0483,.0555,.0632,
    .0712,.0797
140 DATA .0887,.0984,.1089,.1203,.1328,.1467,.1625,.1808,.2042,.2351,
    .2833,.6632
150 DATA .7351,.7724,.7989,.8197,.838,.8538,.8676,.8801,.8914,.9019,
    .9115,.9206
160 DATA .9291,.9371,.9446,.9519,.9588,.9653,.9717,.9777,.9836,.9892,
    .9947,1!
170 DELTIM=60!   'DELTIM is time interval chosen  to be 60 minutes****
180 DIM RAVGP(24),RAVGI(24),TOTALQ(24),QINTERP(23),VOL(29)
190 OPEN "b:bmprun" FOR INPUT AS #1
200 INPUT #1, BMPRUN$:CLOSE
210 IF BMPRUN$="no" THEN GOTO 950
220 PRINT:PRINT:PRINT "          ****************POLLUTOGRAPH
    GENERATION*****************":PRINT
230 PRINT "          This program module computes pollutographs for
    various"
240 PRINT "          pollutants.  Water quality parameters considered
    are"
250 PRINT "          total N, total PO4, BOD, and total suspended
    solids."
260 PRINT "          The user will be prompted for information during
    the"
270 PRINT "          program execution."
280 OPEN "b:runcond" FOR INPUT AS #1
290 INPUT #1, TIM$:CLOSE #1
300 OPEN "b:prebmpp.dat" FOR OUTPUT AS #1
310 PRINT:INPUT "        How many days since previous storm event";NDRY
320 WRITE #1, NDRY
330 CLS:LOCATE 5,5:PRINT "Reading data from previous modules . . .
    please be patient":PRINT
340 OPEN "b:prepoll.dat" FOR INPUT AS #3
350 INPUT #3, N$:WRITE #1, N$
360 INPUT #3, DRA   'Drainage basin area
370 INPUT #3, RAIN:WRITE #1, RAIN 'Precipitation for 24 hr design storm
380 INPUT #3, N:WRITE #1, N 'Number of subbasins within watershed
390 DIM DA(N),AREA(N,39),LUD(N,39),KDP(N):NLU=0
```

```
400 FOR KP=1 TO N
410 INPUT #3, KDP(KP) 'KDP is the number of land use types within
    subarea N
420 NLU=NLU+KDP(KP)     'nlu is the total number of land uses for the
    watershed
430   FOR KND=1 TO KDP(KP)
440   INPUT #3, LUD(KP,KND):INPUT #3, AREA(KP,KND)  'Land use type and
      corresponding area
450   NEXT KND:NEXT KP
460 FOR LP=1 TO N:INPUT #3, DA(LP):NEXT LP    'Area of subbasin
470 CLOSE #3:TAREA$="subarea"
480 DIM PLUI(N,NLU,NPOL),PLUP(N,NLU,NPOL),POI(N,NPOL,37),POP(N,NPOL,37)
490 REM****Calculate the initial pollutant loadings ****
500 GOSUB 520
510 GOTO 660
520 CLS:PRINT:PRINT:PRINT:PRINT
530 PRINT "      It is now necessary to provide pollutant loading
    information"
540 PRINT "      for the watershed.  For each land use type in each ";
    TAREA$
550 PRINT "      enter the pollutant loadings in appropriate units for
    each"
560 PRINT "      of the four pollutants.  In each ";TAREA$;" the first
    land use
570 PRINT "      type for which you will enter pollutant loadings will
    correspond "
580 PRINT "      to the land use type you entered first in the hydrograph
    generation "
590 PRINT "      program module; loadings for the second type will match
    the second "
600 PRINT "      type you entered, etc. ":PRINT
610 PRINT "      A chart of typical pollutant loadings will appear on
    the screen "
620 PRINT "      for your information. (Ref.: GUIDEBOOK FOR SCREENING
    URBAN "
630 PRINT "      NONPOINT POLLUTION MANAGEMENT STRATEGIES, No. Va.
    Planning "
640 PRINT "      District Commission, November 1979)":PRINT
650 INPUT "      Press RETURN to continue . . . ",BBD:CLS:RETURN
660 REM Pollutant loadings in lb/acre/day for subareas
670 FOR LAND=1 TO N
680    FOR LU=1 TO KDP(LAND)
690       FOR IC=1 TO NPOL:GOSUB 3020:NEXT IC
720    NEXT LU:NEXT LAND
730 CLS:PRINT:PRINT:PRINT:PRINT "  Calculating . . ."
740 REM Calculate weighted pollutant loadings for each subarea
750 FOR LAND=1 TO N
760    FOR IC=1 TO NPOL:SUMI=0:SUMP=0
770       FOR LU=1 TO KDP(LAND)
780       GOSUB 2730
790       SUMI=SUMI+ PLUI(LAND,LU,IC)*AREA(LAND,LU)*AIMPERV
```

```
800        SUMP=SUMP+ PLUP(LAND,LU,IC)*AREA(LAND,LU)*(1-AIMPERV)
810        NEXT LU
820     POI(LAND,IC,1)=SUMI*NDRY:POP(LAND,IC,1)=SUMP*NDRY
830     WRITE #1, POI(LAND,IC,1):WRITE #1, POP(LAND,IC,1)
840 NEXT IC:NEXT LAND
850 GOSUB 3670  'subroutine to calculate ravg
860 CLOSE #1:ERASE PLUP,PLUI,LUD,AREA,DA,KDP,PDP24
870 DIM DELPOL(N,NPOL,16),CONC(N,NPOL,16),TOTCON(NPOL,16),QS(N,46),
    QSC(N,46)
880 REM***Calculate pollutant removed during each DELTIM for each type
890 REM   of pollutant for watershed***
900 FOR NSUB=1 TO N
910     FOR IC=1 TO NPOL
920        FOR J=1 TO 16:GOSUB 3530:NEXT J
930 NEXT IC:NEXT NSUB
940 BMP$="no":GOTO 1990
950 OPEN "b:answer" FOR INPUT AS #2:INPUT #2, ANS$:CLOSE #2
960 IF ANS$="yes" OR ANS$="YES" THEN GOTO 980
970 BMPRUN$="none":GOTO 2630
980 LOCATE 10,10:PRINT "Analysis of BMP structure effect on the
    previously":LOCATE 11,10:PRINT "calculated pollutographs will now
    begin.":LOCATE 13,10:INPUT "Press RETURN to continue. . .",GO
990 CLS:LOCATE 6,6:PRINT "Reading data from previous modules. . .
    please be patient"
1000 OPEN "b:runcond" FOR INPUT AS #1
1010 INPUT #1, TIM$:CLOSE #1
1020 OPEN "b:prebmpp.dat" FOR INPUT AS #2
1030 INPUT #2, NDRY:INPUT #2, N$:INPUT #2, RAIN:INPUT #2, N
1040 INPUT #2, N$
1050 DIM NBMP(N), POI(N,NPOL,17), POP(N,NPOL,17)
1060 FOR LAND=1 TO N
1070   FOR PPP=1 TO NPOL
1080   INPUT #2, POI(LAND,PPP,1):INPUT #2, POP(LAND,PPP,1)
1090 NEXT PPP:NEXT LAND
1100 CLOSE:OPEN "b:bmppoll.dat" FOR INPUT AS #3
1110 FOR LAND=1 TO N:INPUT #3, NBMP(LAND):NEXT LAND   'Number of BMP
     structures in each subbasin
1120 INPUT #3, TSTRUC   'Total number of structures in the watershed
1130 DIM BDA(N,TSTRUC),TYPE$(N,TSTRUC),BNLU(N,TSTRUC),BLUD(N,TSTRUC,10),
     BAREA(N,TSTRUC,10),STORAGE(N,TSTRUC,47),QS(N,47)
1140 NLUB=0:FOR KP=1 TO N
1150 FOR NUMB=1 TO NBMP(KP)
1160 INPUT #3, BNLU(KP,NUMB)   'Number of land use types in BMP site
1170 NLUB=NLUB+BNLU(KP,NUMB)
1180   FOR KND=1 TO BNLU(KP,NUMB)
1190   INPUT #3, BLUD(KP,NUMB,KND):INPUT #3, BAREA(KP,NUMB,KND) 'Land
     use type and area
1200 NEXT KND:NEXT NUMB:NEXT KP
1210 FOR LAND=1 TO N
1220   FOR NUMB=1 TO NBMP(LAND):INPUT #3, BDA(LAND,NUMB):NEXT NUMB
```

```
     'Area of BMP site
1230 NEXT LAND
1240 FOR LAND=1 TO N
1250   FOR NUMB=1 TO NBMP(LAND)
1260   INPUT #3, TYPE$(LAND,NUMB)   'Type of BMP structure
1270 NEXT NUMB:NEXT LAND
1280 FOR LAND=1 TO N
1290    FOR NUMB=1 TO NBMP(LAND)
1300      FOR KELL=1 TO 46
1310      IF TYPE$(LAND,NUMB)="d" OR TYPE$(LAND,NUMB)="D" OR TYPE$(LAND,
     NUMB)="e" OR TYPE$(LAND,NUMB)="E" THEN INPUT #3, STORAGE(LAND,NUMB,
     KELL)
1320 NEXT KELL:NEXT NUMB:NEXT LAND
1330 FOR LAND=1 TO N
1340    FOR NUMB=1 TO NBMP(LAND)
1350      IF TYPE$(LAND,NUMB)="a" OR TYPE$(LAND,NUMB)="A" OR TYPE$(LAND,
     NUMB)="b" OR TYPE$(LAND,NUMB)="B" OR TYPE$(LAND,NUMB)="C" OR TYPE$
     (LAND,NUMB)="c" THEN INPUT #3, STORAGE(LAND,NUMB,1)
1360      FOR KELL=2 TO 47
1370      IF TYPE$(LAND,NUMB)="a" OR TYPE$(LAND,NUMB)="A" OR TYPE$(LAND,
     NUMB)="b" OR TYPE$(LAND,NUMB)="B" OR TYPE$(LAND,NUMB)="C" OR TYPE$
     (LAND,NUMB)="c" THEN INPUT #3, STORAGE(LAND,NUMB,KELL)
1380 NEXT KELL:NEXT NUMB:NEXT LAND
1390 CLOSE #3:CLS:TAREA$="BMP site":BMP$="yes"
1400 DIM PLUIB(N,TSTRUC,NLUB,NPOL),PLUPB(N,TSTRUC,NLUB,NPOL),LUD(TSTRUC,
     NLUB)
1410 DIM PIBMP(17),PPBMP(17),DELPOLB(TSTRUC,16),DELPOL(N,NPOL,16)
1420 REM Pollutant loadings in lb/acre/day for BMP sites
1430 GOSUB 520
1440 FOR LAND=1 TO N
1450  FOR NUMB=1 TO NBMP(LAND)
1460    FOR LU=1 TO BNLU(LAND,NUMB)
1470       FOR IC=1 TO NPOL:GOSUB 3020:NEXT IC
1480 NEXT LU:NEXT NUMB:NEXT LAND
1490 CLS:PRINT:PRINT:PRINT:PRINT "   Calculating . . ."
1500 GOSUB 3670  'subroutine to calculate ravg
1510 REM Calculate revised weighted pollutant loadings for each subarea
1520 LAND=1:FOR NSUB=1 TO N
1530    FOR IC=1 TO NPOL
1540     FOR NUMB=1 TO NBMP(NSUB)
1550    SUMI=0!:SUMP=0:LAND=1
1560       FOR LU=1 TO BNLU(NSUB,NUMB)
1570       LUD(LAND,LU)=BLUD(NSUB,NUMB,LU)
1580       GOSUB 2730     '% impervious of land use area
1590       GOSUB 3350     'removal rates of BMP structures
1600       SUMI=SUMI+ PLUIB(NSUB,NUMB,LU,IC)*BAREA(NSUB,NUMB,LU)*AIMPERV
1610       SUMP=SUMP+ PLUPB(NSUB,NUMB,LU,IC)*BAREA(NSUB,NUMB,LU)*(1-
           AIMPERV)
1620       NEXT LU
1630     PIBMP(1)=SUMI*NDRY:PPBMP(1)=SUMP*NDRY
1640     PTIBMP=PTIBMP+PIBMP(1):PTPBMP=PTPBMP+PPBMP(1)  'total pollutant
```

```
        load on subarea from bmp sites
1650    IF TYPE$(NSUB,NUMB)="a" OR TYPE$(NSUB,NUMB)="A" OR TYPE$(NSUB,
        NUMB)="b" OR TYPE$(NSUB,NUMB)="B" OR TYPE$(NSUB,NUMB)="C" OR
        TYPE$(NSUB,NUMB)="c" THEN GOTO 1690
1660    FOR KELL=1 TO 46:QS(LAND,KELL)=STORAGE(NSUB,NUMB,KELL):NEXT KELL
1670    GOSUB 2880
1680    JKJ=0:KKD=0:GOSUB 2920:GOTO 1730
1690    QS(LAND,1)=STORAGE(NSUB,NUMB,1)
1700    GOSUB 2880
1710    JKJ=0:KKD=0:GOSUB 2920
1720    GOSUB 3620
1730        FOR J=1 TO 16
1740        DELPP=1.4*RAVGP(J)*PPBMP(J)*DELTIM/60!
1750        DELPI=4.6*RAVGI(J)*PIBMP(J)*DELTIM/60!
1760        PIBMP(J+1)=PIBMP(J)-DELPI:PPBMP(J+1)=PPBMP(J)-DELPP
1770        IF DELPI > PIBMP(J) THEN DELPI=PIBMP(J):PIBMP(J+1)=0
1780        IF DELPP > PPBMP(J) THEN DELPP=PPBMP(J):PPBMP(J+1)=0
1790        DPOLB=DELPI+DELPP
1800        CBMP=DPOLB/(TOTALQ(J)/12*BDA(NSUB,NUMB)*43560!) 'concen-
            tration coming into structure
1810    IF TYPE$(NSUB,NUMB)="C" OR TYPE$(NSUB,NUMB)="c" THEN VOL(J)=
        VOL(J)*1.188
1820        POLTRAP=CBMP*VOL(J)*BMPEFF  'pollutant removed by structure
1830        DELPOLB(NUMB,J)=DPOLB-POLTRAP
1840        IF DELPOLB(NUMB,J)<0 THEN DELPOLB(NUMB,J)=0
1850        NEXT J
1860    LAND=LAND+1:NEXT NUMB
1870   POI(NSUB,IC,1)=POI(NSUB,IC,1)-PTIBMP:POP(NSUB,IC,1)=POP(NSUB,
       IC,1)-PTPBMP
1880   PTIBMP=0:PTPBMP=0
1890   IF POI(NSUB,IC,1) < 0 THEN POI(NSUB,IC,1) = 0
1900   IF POP(NSUB,IC,1) < 0 THEN POP(NSUB,IC,1) = 0
1910      FOR J=1 TO 16
1920      GOSUB 3530
1930        FOR KEL=1 TO NBMP(NSUB)
1940        DELPOL(NSUB,IC,J)=DELPOL(NSUB,IC,J)+DELPOLB(KEL,J)
            'pollutant load in stream
1950        NEXT KEL
1960 NEXT J:NEXT IC:NEXT NSUB
1970 ERASE PLUIB,PLUPB,BAREA,BLUD,LUD,TYPE$,BNLU,BDA,STORAGE,TOTALQ,
     PIBMP,PPBMP,DELPOLB,PDP24
1980 DIM CONC(N,NPOL,16),TOTCON(NPOL,16),QSC(N,46)
1990 ERASE RAVGP,RAVGI,POP,POI
2000 IF BMP$="no" THEN OPEN "b:polpreb.ord" FOR OUTPUT AS #3
2010 IF BMP$="yes" THEN OPEN "b:polbmp.ord" FOR OUTPUT AS #3
2020 IF BMP$="no" THEN OPEN "b:prepol2.dat" FOR INPUT AS #1
2030 IF BMP$="yes" THEN OPEN "b:bmppol2.dat" FOR INPUT AS #1
2040 FOR KAC=1 TO N
2050   FOR M=1 TO 46:INPUT #1, QS(KAC,M):NEXT M 'Inflow hydrographs for
       each subbasin
2060 NEXT KAC
```

```
2070 FOR KAC=1 TO N
2080   FOR M=1 TO 46
2090   INPUT #1, QSC(KAC,M) 'Inflow hydrographs for each subbasin
       contributing to composite
2100   NEXT M
2110 NEXT KAC:CLOSE #1
2120 REM***Calculate pollutant concentrations (mg/l) for each subarea**
2130 FOR LAND=1 TO N
2140 GOSUB 2880    'Linear interpolation for 0 - 11hr hydrograph
     ordinates
2150    JKJ=0:KKD=1
2160       GOSUB 2920 'calculate runoff volume from hydrograph ordinates
2170    FOR PP=1 TO NPOL
2180       FOR JJ=1 TO 16
2190       IF VOL(JJ)=0! THEN CONC(LAND,PP,JJ) =0!:GOTO 2210
2200       CONC(LAND,PP,JJ)=DELPOL(LAND,PP,JJ)*16019!/VOL(JJ)
2210       WRITE #3, CONC(LAND,PP,JJ)
2220 NEXT JJ:NEXT PP:NEXT LAND
2230 REM    CALCULATE COMPOSITE POLLUTOGRAPH
2240 FOR P=1 TO NPOL
2250 FOR MM=1 TO 16:TOTCON(P,MM)=0:NEXT MM
2260 NEXT P
2270 REM***Calculate pollutant concentrations (mg/l) for composite
     watershed**
2280 FOR LAND=1 TO N
2290   FOR KC=1 TO 46:QS(LAND,KC)=QSC(LAND,KC):NEXT KC
2300 GOSUB 2880    'Linear interpolation for 0 - 11hr hydrograph
     ordinates
2310    JKJ=0:KKD=1
2320       GOSUB 2920          'calculate runoff volume from hydrograph
           ordinates
2330    FOR PP=1 TO NPOL
2340       FOR JJ=1 TO 16
2350       IF VOL(JJ)=0! THEN CONCC=0:GOTO 2370
2360       CONCC=DELPOL(LAND,PP,JJ)*16019!/VOL(JJ)
2370       TOTCON(PP,JJ)=TOTCON(PP,JJ)+CONCC
2380       WRITE #3, TOTCON(PP,JJ)
2390 NEXT JJ:NEXT PP:NEXT LAND:CLOSE #3
2400 REM******Output Pollutograph*******
2410 CLS:LOCATE 4,10:PRINT " Pollutographs have been calculated for each
     subarea and"
2420 LOCATE 5,10:PRINT " and for the entire watershed for each type of
     pollutant "
2430 LOCATE 6,10:PRINT " analyzed.  Please choose which form you wish
     to view them:"
2440 LOCATE 8,25:PRINT " A. Tabular form"
2450 LOCATE 9,25:PRINT " B. Graphical form"
2460 LOCATE 10,25:PRINT " C. Tabular and graphical form"
2470 LOCATE 12,10:INPUT " Enter the letter of your choice ",FORM$
2480 IF FORM$="A" OR FORM$="a" OR FORM$="b" OR FORM$="B" OR FORM$="C"
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     OR FORM$="c" THEN GOTO 2500
2490 BEEP:CLS:LOCATE 14,20:PRINT "YOU DID NOT ENTER A POSSIBLE CHOICE":
     GOTO 2410
2500 REM   Output pollutographs in POLLOUT program module
2510 OPEN "B:poll.ord" FOR OUTPUT AS #3
2520 WRITE #3, BMP$:WRITE #3, N$:WRITE #3, N:WRITE #3, TIM$:WRITE #3,
     FORM$
2530 FOR LAND=1 TO N
2540  FOR KKK=1 TO NPOL
2550    FOR KAC=1 TO 16:WRITE #3, CONC(LAND,KKK,KAC):NEXT KAC
2560  NEXT KKK
2570 NEXT LAND
2580 FOR NNN=1 TO NPOL
2590   FOR KDL=1 TO 16:WRITE #3, TOTCON(NNN,KDL):NEXT KDL
2600 NEXT NNN:CLOSE #3
2610 IF BMP$="yes" OR BMP$="YES" THEN BMPRUN$="yes"
2620 IF BMP$="no" OR BMP$="NO" THEN BMPRUN$="no"
2630 OPEN "B:bmprun" FOR OUTPUT AS #3
2640 WRITE #3, BMPRUN$:CLOSE
2650 CLS:LOCATE 6,6:PRINT "The pollutograph ordinates for each of the
     pollutographs generated for"
2660 LOCATE 7,6:PRINT "each of the four pollutants for each subarea and
     the composite"
2670 LOCATE 8,6:PRINT "pollutographs for pre- and post-BMP conditions
     have been stored"
2680 LOCATE 9,6:PRINT "in data files on the DATA diskette labeled
      polpreb.ord'"
2690 LOCATE 10,6:PRINT "and  polbmp.ord'."
2700 LOCATE 12,6:INPUT "Press RETURN to continue ",GO
2710 SYSTEM
2720 REM !!!!!!!!!!!!!!!!!!!!!!SUBROUTINES!!!!!!!!!!!!!!!!!!!
2730 REM***Calculate the percent of impervious area based on SCS module
2740 IF LUD(LAND,LU)=4 OR LUD(LAND,LU)=5 OR LUD(LAND,LU)=6 OR LUD(LAND,
     LU)=7 OR LUD(LAND,LU)=8 OR LUD(LAND,LU)=9 THEN GOTO 2770
2750 IF LUD(LAND,LU)=10 OR LUD(LAND,LU)=11 OR LUD(LAND,LU)=12 OR LUD
     (LAND,LU)=13 OR LUD(LAND,LU)=14 OR LUD(LAND,LU)=15 OR
     LUD(LAND,LU)=16 THEN GOTO 2770
2760 AIMPERV=.01:GOTO 2870
2770 IF LUD(LAND,LU)=6 OR LUD(LAND,LU)=7 THEN AIMPERV=.5
2780 IF LUD(LAND,LU)=9 THEN AIMPERV=.85
2790 IF LUD(LAND,LU)=10 THEN AIMPERV=.72
2800 IF LUD(LAND,LU)=11 THEN AIMPERV=.65
2810 IF LUD(LAND,LU)=12 THEN AIMPERV=.38
2820 IF LUD(LAND,LU)=13 THEN AIMPERV=.3
2830 IF LUD(LAND,LU)=14 THEN AIMPERV=.25
2840 IF LUD(LAND,LU)=15 THEN AIMPERV=.2
2850 IF LUD(LAND,LU)=16 THEN AIMPERV=.12
2860 IF LUD(LAND,LU)=4 OR LUD(LAND,LU)=5 OR LUD(LAND,LU)=8 THEN AIMPERV=1
2870 RETURN
2880 REM   Routine for linear interpolation of hydrographs from SCNEW
```

```
     for 0 - 11 hours
2890 QINTERP(0)=0:INC=QS(LAND,1)/22
2900 FOR KKAC=1 TO 22:QINTERP(KKAC)=QINTERP(KKAC-1)+INC:NEXT KKAC
2910 RETURN
2920 REM Calculate runoff volumes from hydrograph ordinates
2930 FOR JJ=1 TO 16:DELTIM=60
2940 IF JJ> 11 THEN GOTO 2960
2950 VOL(JJ)=(QINTERP(JKJ) + .5*ABS(QINTERP(JKJ)-QINTERP(JKJ+2)))*DELTIM
     *60:JKJ=JKJ+2:GOTO 3000
2960 IF QS(LAND,KKD) > QS(LAND,KKD+5) THEN GOTO 2980
2970 VOL(JJ)=(QS(LAND,KKD) + .5*ABS(QS(LAND,KKD)-QS(LAND,KKD+5)))*DELTIM
     *60:GOTO 2990
2980 VOL(JJ)=(QS(LAND,KKD+5) + .5*ABS(QS(LAND,KKD)-QS(LAND,KKD+5)))*
     DELTIM*60
2990 KKD=KKD+5
3000 NEXT JJ
3010 RETURN
3020 REM     POLLUTANT LOADING TABLE
3030 PRINT " -----------------------------------------------------------
     ------------------"
3040 PRINT "|                                Pollutant Loadings (lb/
     acre/day)           |"
3050 PRINT "|       Land Use                 TSS          BOD
     N            P      |"
3060 PRINT "|                          Imperv Perv  Imperv Perv
     Imperv Perv  Imperv Perv|"
3070 PRINT "| Single Family Residential:
                     |"
3080 PRINT "|   Estate (.05-0.2 DU/Ac)    2.2    1.2     .13    .07     .04
     .011   .004 .0014 |"
3090 PRINT "|   Large Lot (.5-2 DU/Ac)    5.5    1.0     .20    .13     .08
     .02    .01 .0035 |"
3100 PRINT "|   Medium Density(3-6DU/Ac) 5.5    1.0     .20    .13     .08
     .02    .01 .0035 |"
3110 PRINT "| Townhouses/Apartments      5.5    2.0     .20    .26     .08
     .04    .01  .007 |"
3120 PRINT "| High Rise Residential      3.5    0.7     .63    .07     .05
     .011   .006 .0017 |"
3130 PRINT "| Institutional              2.5    0.7     .35    .07     .05
     .011   .006 .0017 |"
3140 PRINT "| Industrial                 2.5    0.7     .63    .07     .05
     .011   .006 .0017 |"
3150 PRINT "| Suburban Shopping Center   2.5    0.7     .63    .07     .05
     .011   .006 .0017 |"
3160 PRINT "| Central Business District  2.5    0.7     .76    .07     .09
     .011    .01 .0017 |"
3170 PRINT "| Idle land                  0.5    1.0     .09   .034    .015
     .008  .0013 .0005 |"
3180 PRINT "| Pasture                    0.5    1.5     .09    .35    .015
     .047  .0013 .0047 |"
3190 PRINT "| Forest (Jan - Sept)        0.5    1.0     .09   .036    .015
```

```
     .006  .0013 .0004 |"
3200 PRINT "| Forest (Oct - Dec)          0.5   2.0    .09  .048   .015
     .0084  .0013 .0005 |"
3210 PRINT " ----------------------------------------------------------
     --------------------"
3220 REM***Calculate initial pollutant loadings in pounds***
3230 IF TAREA$="BMP site" THEN PRINT "   For BMP site ";NUMB;" in ";TIM$
     ;" subarea ";LAND:GOTO 3250
3240 PRINT "   For ";TIM$;" subarea ";LAND;" in the watershed ";N$
3250 PRINT "   and the pollutant ";CNAM$(IC)
3260 PRINT "   Enter the pollutant loading for the impervious area "
3270 PRINT "   in Land Use # ";LU;" in lbs./acre-day";
3280 IF TAREA$="BMP site" THEN INPUT "    ",PLUIB(LAND,NUMB,LU,IC):GOTO
     3300
3290 INPUT "  ",PLUI(LAND,LU,IC)
3300 PRINT:PRINT "   Enter the pollutant loading for the pervious area "
3310 PRINT "   in Land Use # ";LU; " in lbs./acre-day";
3320 IF TAREA$="BMP site" THEN INPUT "    ",PLUPB(LAND,NUMB,LU,IC):GOTO
     3340
3330 INPUT "  ",PLUP(LAND,LU,IC)
3340 CLS:RETURN
3350 REM   SUBROUTINE TO FIND BMP STRUCTURE EFFICIENCIES
3360 IF TYPE$(NSUB,NUMB)="A" AND IC=1 OR TYPE$(NSUB,NUMB)="a" AND IC=1
     THEN BMPEFF=.14
3370 IF TYPE$(NSUB,NUMB)="A" AND IC=2 OR TYPE$(NSUB,NUMB)="a" AND IC=2
     THEN BMPEFF=0
3380 IF TYPE$(NSUB,NUMB)="A" AND IC=3 OR TYPE$(NSUB,NUMB)="a" AND IC=3
     THEN BMPEFF=.2
3390 IF TYPE$(NSUB,NUMB)="A" AND IC=4 OR TYPE$(NSUB,NUMB)="a" AND IC=4
     THEN BMPEFF=.1
3400 IF TYPE$(NSUB,NUMB)="B" AND IC=1 OR TYPE$(NSUB,NUMB)="b" AND IC=1
     THEN BMPEFF=.55
3410 IF TYPE$(NSUB,NUMB)="B" AND IC=2 OR TYPE$(NSUB,NUMB)="b" AND IC=2
     THEN BMPEFF=.22
3420 IF TYPE$(NSUB,NUMB)="B" AND IC=3 OR TYPE$(NSUB,NUMB)="b" AND IC=3
     THEN BMPEFF=.66
3430 IF TYPE$(NSUB,NUMB)="B" AND IC=4 OR TYPE$(NSUB,NUMB)="b" AND IC=4
     THEN BMPEFF=.28
3440 IF TYPE$(NSUB,NUMB)="C" AND IC=1 OR TYPE$(NSUB,NUMB)="c" AND IC=1
     THEN BMPEFF=.91
3450 IF TYPE$(NSUB,NUMB)="C" AND IC=2 OR TYPE$(NSUB,NUMB)="c" AND IC=2
     THEN BMPEFF=.42
3460 IF TYPE$(NSUB,NUMB)="C" AND IC=3 OR TYPE$(NSUB,NUMB)="c" AND IC=3
     THEN BMPEFF=.42
3470 IF TYPE$(NSUB,NUMB)="C" AND IC=4 OR TYPE$(NSUB,NUMB)="c" AND IC=4
     THEN BMPEFF=.27
3480 IF TYPE$(NSUB,NUMB)="d" AND IC=1 OR TYPE$(NSUB,NUMB)="D" AND IC=1
     OR TYPE$(NSUB,NUMB)="E" AND IC=1 OR TYPE$(NSUB,NUMB)="e" AND IC=1
     THEN BMPEFF=.96
3490 IF TYPE$(NSUB,NUMB)="d" AND IC=2 OR TYPE$(NSUB,NUMB)="D" AND IC=2
     OR TYPE$(NSUB,NUMB)="E" AND IC=2 OR TYPE$(NSUB,NUMB)="e" AND IC=2
```

```
     THEN BMPEFF=.84
3500 IF TYPE$(NSUB,NUMB)="d" AND IC=3 OR TYPE$(NSUB,NUMB)="D" AND IC=3
     OR TYPE$(NSUB,NUMB)="E" AND IC=3 OR TYPE$(NSUB,NUMB)="e" AND IC=3
     THEN BMPEFF=.61
3510 IF TYPE$(NSUB,NUMB)="d" AND IC=4 OR TYPE$(NSUB,NUMB)="D" AND IC=4
     OR TYPE$(NSUB,NUMB)="E" AND IC=4 OR TYPE$(NSUB,NUMB)="e" AND IC=4
     THEN BMPEFF=.41
3520 RETURN
3530 REM****SUBROUTINE--POLLUTANT REMOVAL EQUATIONS*********
3540       DELPP=1.4*RAVGP(J)*POP(NSUB,IC,J)*DELTIM/60!
3550       DELPI=4.6*RAVGI(J)*POI(NSUB,IC,J)*DELTIM/60!
3560       POI(NSUB,IC,J+1)=POI(NSUB,IC,J)-DELPI
3570       POP(NSUB,IC,J+1)=POP(NSUB,IC,J)-DELPP
3580       IF DELPI > POI(NSUB,IC,J) THEN DELPI=POI(NSUB,IC,J):POI(NSUB,
           IC,J+1)=0
3590       IF DELPP > POP(NSUB,IC,J) THEN DELPP=POP(NSUB,IC,J):POP(NSUB,
           IC,J+1)=0
3600       DELPOL(NSUB,IC,J)=DELPI+DELPP
3610 RETURN
3620 'ROUTINE TO CONVERT STORAGE VOLUME INCREMENTS TO INCREMENTS USED
      IN THIS PROGRAM&00&00&00&00
3630 KELC=2:FOR KKAC=12 TO 16
3640 VOL(KKAC)=STORAGE(NSUB,NUMB,KELC)+STORAGE(NSUB,NUMB,KELC+1)+STORAGE
     (NSUB,NUMB,KELC+2)+STORAGE(NSUB,NUMB,KELC+3)+STORAGE(NSUB,NUMB,
     KELC+4)
3650 KELC=KELC+5:NEXT KKAC
3660 RETURN
3670 REM***Calculate RAVG, the average runoff rate (in./hr.) for
     subareas***
3680 TOTQP=0:TOTQI=0
3690 CNI=98:CNP=65.6         'CNP determined from taking average of
     pervious CN from SCS manual
3700 SI=(1000/CNI)-10:SP=(1000/CNP)-10
3710   KKK=2:FOR KD=1 TO 24
3720   PRECIP2=RAIN*PDP24(KKK):PRECIP1=RAIN*PDP24(KKK-2)
3730   DELQI2=(PRECIP2-.2*SI)¢2/(PRECIP2 + .8*SI)
3740   DELQP2=(PRECIP2-.2*SP)¢2/(PRECIP2 + .8*SP)
3750   DELQI1=(PRECIP1-.2*SI)¢2/(PRECIP1 + .8*SI)
3760   DELQP1=(PRECIP1-.2*SP)¢2/(PRECIP1 + .8*SP)
3770   IF (PRECIP2-.2*SI) <0 THEN DELQI2 = 0
3780   IF (PRECIP2-.2*SP) <0 THEN DELQP2 = 0
3790   IF (PRECIP1-.2*SI) <0 THEN DELQI1 = 0
3800   IF (PRECIP1-.2*SP) <0 THEN DELQP1 = 0
3810   DELTAQI=DELQI2-DELQI1:DELTAQP=DELQP2-DELQP1
3820   TOTQP=TOTQP+DELTAQP:TOTQI=TOTQI+DELTAQI
3830   TOTALQ(KD)=DELTAQI+DELTAQP
3840   RAVGI(KD)=DELTAQI/(DELTIM/60):RAVGP(KD)=DELTAQP/(DELTIM/60)
3850   KKK=KKK+2:NEXT KD
3860 RETURN
```

```
10 '****************************************************************
20 '**                 POLLOUT PROGRAM MODULE                     **
30 '**                 WRITTEN BY: K. A. CAVE                     **
40 '**                      VERSION 2.2                           **
50 '**                      MARCH, 1986                           **
60 '****************************************************************
70 OPEN "b:bmprun" FOR INPUT AS #2
80 INPUT #2, BMPRUN$:CLOSE
90 IF BMPRUN$="none" THEN GOTO 670
100 SCREEN 0,0:COLOR 7,9,0:KEY OFF:WIDTH 80:CLS
110 LOCATE 5,5:PRINT "Calculating . . ."
120 NPOL=4   '  NPOL is the number of types of pollutants analyzed
130 DIM CNAM$(NPOL)
140 FOR KKK=1 TO 4:READ CNAM$(KKK):NEXT KKK
150 DATA Total Suspended Solids,BOD,Nitrogen,Phosphorus
160 OPEN "B:poll.ord" FOR INPUT AS #1
170 INPUT #1, BMP$
180 INPUT #1, N$
190 INPUT #1, N
200 INPUT #1, WHEN$
210 INPUT #1, FORM$
220 DIM TIMES$(16), YCIR(16), CONC(N,NPOL,16), TOTCON(NPOL,16)
230 DIM X(N,NPOL,16),YMAX(N,NPOL),YLOW(N,NPOL),Y(NPOL,16),YMAXT(NPOL),
    YLOWT(NPOL)
240 FOR LAND=1 TO N
250   FOR KK=1 TO NPOL
260     FOR KAC=1 TO 16:INPUT #1, CONC(LAND,KK,KAC):NEXT KAC
270   NEXT KK
280 NEXT LAND
290 FOR ILD=1 TO NPOL
300   FOR KLD=1 TO 16:INPUT #1, TOTCON(ILD,KLD):NEXT KLD
310 NEXT ILD
320 CLOSE
330 REM   Output pollutographs for each subarea for each pollutant
340 FOR KK=1 TO 16:READ TIMES$(KK):NEXT KK
350 DATA 0.0-1.0,1.0-2.0,2.0-3.0,3.0-4.0,4.0-5.0,5.0-6.0,6.0-7.0,7.0-8.0
360 DATA 8.0-9.0,9.0-10.0,10.0-11.0,11.0-12.0,12.0-13.0,13.0-14.0,
    14.0-15.0,15.0-16.0
370 CLS FORM$="B" OR FORM$="b" THEN GOTO 420
380 GOSUB 680
390 PRINT:PRINT:PRINT"          Calculating . . ."
400 GOSUB 1140  'output composite pollutographs
410 CLS FORM$="a" OR FORM$="A" THEN GOTO 670
420 REM @@@@@@@@@GRAPHICAL OUTPUT @@@@@@@@@@@@@
430 IF WHEN$="future" THEN WHEN$="FUTURE"
440 IF WHEN$="present" THEN WHEN$="PRESENT"
450 LOCATE 5,5:PRINT "Calculating . . . "
460 REM   OUTPUT SUBAREA POLLUTOGRAPHS
470 GOSUB 1570
480 FOR LAND=1 TO N
490   FOR POL=1 TO NPOL
```

```
500   YHIGH=YMAX(LAND,POL)+1
510   YLOW=YLOW(LAND,POL)
520   QPEAK=YMAX(LAND,POL)
530   GOSUB 1900
540   NEXT POL
550 NEXT LAND
560 SCREEN 0,0:COLOR 7,9,0:KEY OFF:WIDTH 80:CLS
570 LOCATE 5,5:PRINT "Calculating . . . "
580 REM       OUTPUT COMPOSITE POLLUTOGRAPHS
590 GOSUB 1760
600 FOR POL=1 TO NPOL
610   YHIGH=YMAXT(POL)+1
620   YLOW=YLOWT(POL)
630   QPEAK=YMAXT(POL)
640   TOTAL=1
650   GOSUB 1900
660 NEXT POL
670 SYSTEM
680 REM************Pollutograph Output Format************
690 W$="####.#####"
700 FOR P=1 TO NPOL
710   FOR LAND=1 TO N
720 PRINT:PRINT "                 _______________________FOR SUBAREA";
    LAND;"_______________________":PRINT
730 PRINT "             TIME(hour)";"  POLL. ORD.(mg/l)";"    TIME(hour)";
    "  POLL. ORD.(mg/l)":PRINT
740 PRINT TAB(12) TIMES$(1);
750 PRINT TAB(25);USING W$;CONC(LAND,P,1);
760 PRINT TAB(44) TIMES$(9);
770 PRINT TAB(56);USING W$;CONC(LAND,P,9)
780 PRINT TAB(12) TIMES$(2);
790 PRINT TAB(25);USING W$;CONC(LAND,P,2);
800 PRINT TAB(43) TIMES$(10);
810 PRINT TAB(56);USING W$;CONC(LAND,P,10)
820 PRINT TAB(12) TIMES$(3);
830 PRINT TAB(25);USING W$;CONC(LAND,P,3);
840 PRINT TAB(42) TIMES$(11);
850 PRINT TAB(56);USING W$;CONC(LAND,P,11)
860 PRINT TAB(12) TIMES$(4);
870 PRINT TAB(25);USING W$;CONC(LAND,P,4);
880 PRINT TAB(42) TIMES$(12);
890 PRINT TAB(56);USING W$;CONC(LAND,P,12)
900 PRINT TAB(12) TIMES$(5);
910 PRINT TAB(25);USING W$;CONC(LAND,P,5);
920 PRINT TAB(42) TIMES$(13);
930 PRINT TAB(56);USING W$;CONC(LAND,P,13)
940 PRINT TAB(12) TIMES$(6);
950 PRINT TAB(25);USING W$;CONC(LAND,P,6);
960 PRINT TAB(42) TIMES$(14);
970 PRINT TAB(56);USING W$;CONC(LAND,P,14)
980 PRINT TAB(12) TIMES$(7);
```

```
990 PRINT TAB(25);USING W$;CONC(LAND,P,7);
1000 PRINT TAB(42) TIMES$(15);
1010 PRINT TAB(56);USING W$;CONC(LAND,P,15)
1020 PRINT TAB(12) TIMES$(8);
1030 PRINT TAB(25);USING W$;CONC(LAND,P,8);
1040 PRINT TAB(42) TIMES$(16);
1050 PRINT TAB(56);USING W$;CONC(LAND,P,16)
1060 PRINT:PRINT "          This pollutograph is for the pollutant ";
     CNAM$(P)
1070 PRINT"          for ";WHEN$;" conditions"
1080 IF BMP$="yes" THEN PRINT "          and reflects the presence of
     BMP structures within the watershed"
1090 IF BMP$="no" THEN PRINT "          without the presence of BMP
     structures within the watershed"
1100 PRINT:INPUT "          Press RETURN to continue ",KELLY:CLS
1110 NEXT LAND
1120 NEXT P
1130 RETURN
1140 REM**Print composite pollutograph for entire watershed**
1150 FOR P=1 TO NPOL
1160 CLS:PRINT:PRINT"          ____________COMPOSITE POLLUTOGRAPH FOR ";N$;
     " WATERSHED____________":PRINT
1170 PRINT "          TIME(hour)";"  POLL. ORD.(mg/l)";"   TIME(hour)";
     "  POLL. ORD.(mg/l)":PRINT
1180 PRINT TAB(12) TIMES$(1);
1190 PRINT TAB(25);USING W$;TOTCON(P,1);
1200 PRINT TAB(44) TIMES$(9);
1210 PRINT TAB(56);USING W$;TOTCON(P,9)
1220 PRINT TAB(12) TIMES$(2);
1230 PRINT TAB(25);USING W$;TOTCON(P,2);
1240 PRINT TAB(43) TIMES$(10);
1250 PRINT TAB(56);USING W$;TOTCON(P,10)
1260 PRINT TAB(12) TIMES$(3);
1270 PRINT TAB(25);USING W$;TOTCON(P,3);
1280 PRINT TAB(42) TIMES$(11);
1290 PRINT TAB(56);USING W$;TOTCON(P,11)
1300 PRINT TAB(12) TIMES$(4);
1310 PRINT TAB(25);USING W$;TOTCON(P,4);
1320 PRINT TAB(42) TIMES$(12);
1330 PRINT TAB(56);USING W$;TOTCON(P,12)
1340 PRINT TAB(12) TIMES$(5);
1350 PRINT TAB(25);USING W$;TOTCON(P,5);
1360 PRINT TAB(42) TIMES$(13);
1370 PRINT TAB(56);USING W$;TOTCON(P,13)
1380 PRINT TAB(12) TIMES$(6);
1390 PRINT TAB(25);USING W$;TOTCON(P,6);
1400 PRINT TAB(42) TIMES$(14);
1410 PRINT TAB(56);USING W$;TOTCON(P,14)
1420 PRINT TAB(12) TIMES$(7);
1430 PRINT TAB(25);USING W$;TOTCON(P,7);
1440 PRINT TAB(42) TIMES$(15);
```

```
1450 PRINT TAB(56);USING W$;TOTCON(P,15)
1460 PRINT TAB(12) TIMES$(8);
1470 PRINT TAB(25);USING W$;TOTCON(P,8);
1480 PRINT TAB(42) TIMES$(16);
1490 PRINT TAB(56);USING W$;TOTCON(P,16)
1500 PRINT:PRINT "          This pollutograph is for ";WHEN$;
     " conditions"
1510 PRINT"            for the pollutant ";CNAM$(P)
1520 IF BMP$="yes" THEN PRINT "          and reflects the presence
     of BMP structures within the watershed"
1530 IF BMP$="no" THEN PRINT "          without the presence of BMP
     structures within the watershed"
1540 PRINT:INPUT "          Press RETURN to continue ",DON
1550 NEXT P
1560 RETURN
1570 REM &&&&&&& PEAK DISCHARGE CALCULATIONS &&&&&&&&
1580 REM   SUBAREA CALCULATIONS
1590 FOR LLL=1 TO N
1600  FOR POLL=1 TO NPOL
1610     FOR JJ=1 TO 16:X(LLL,POLL,JJ)=CONC(LLL,POLL,JJ):NEXT JJ
1620  NEXT POLL
1630 NEXT LLL
1640 FOR SA=1 TO N
1650  FOR P=1 TO NPOL
1660   FOR JJJ=1 TO 15
1670    FOR KKK=JJJ+1 TO 16
1680    IF X(SA,P,JJJ)>= X(SA,P,KKK) THEN GOTO 1700
1690    TEMP=X(SA,P,JJJ):X(SA,P,JJJ)=X(SA,P,KKK):X(SA,P,KKK)=TEMP
1700    NEXT KKK
1710  NEXT JJJ
1720 YMAX(SA,P)=X(SA,P,1):YLOW(SA,P)=X(SA,P,16)
1730 NEXT P
1740 NEXT SA
1750 RETURN
1760 REM    PEAK DISCHARGE FOR COMPOSITE
1770 FOR P=1 TO NPOL
1780   FOR JJ=1 TO 16:Y(P,JJ)=TOTCON(P,JJ):NEXT JJ
1790 NEXT P
1800 FOR P=1 TO NPOL
1810   FOR JJ=1 TO 15
1820     FOR KK=JJ+1 TO 16
1830     IF Y(P,JJ)>= Y(P,KK) THEN GOTO 1850
1840     TEMP=Y(P,JJ):Y(P,JJ)=Y(P,KK):Y(P,KK)=TEMP
1850     NEXT KK
1860   NEXT JJ
1870 YMAXT(P)=Y(P,1):YLOWT(P)=Y(P,16)
1880 NEXT P
1890 RETURN
1900 REM ********Graphical presentation of pollutographs**********
1910 CLS:SCREEN 2,0:WIDTH 80:KEY OFF
1920 YRANGE=YHIGH-YLOW:YAXISLEN=165
```

```
1930 LINE (50,0)-(50,165):LINE (50,165)-(610,165)
1940 FOR TIKX=50 TO 610 STEP 35:LINE (TIKX,163)-(TIKX,167):NEXT TIKX
1950 FOR TICY=165 TO 0 STEP -20:LINE (50,TICY)-(54,TICY):NEXT TICY
1960 LOCATE 22:PRINT "               2.0      4.0      6.0      8.0
     10.0    12.0    14.0    16.0"
1970 LOCATE 23:PRINT "                                   TIME (hrs)"
1980 YINC=(40/YAXISLEN)*YRANGE
1990 X$="####.#"
2000 LOCATE 21,1:PRINT USING X$;YLOW:LOCATE 16,1:PRINT USING X$;(YLOW
     +YINC)
2010 LOCATE 11,1:PRINT USING X$;(YLOW +YINC*2):LOCATE 6,1:PRINT USING
     X$;(YLOW +YINC*3):LOCATE 1,1:PRINT USING X$;(YLOW +YINC*4)
2020 LOCATE 2,1:PRINT "C":LOCATE 3,1:PRINT "O":LOCATE 4,1:PRINT "N":
     LOCATE 5,1:PRINT "C":LOCATE 6,1:PRINT "E":LOCATE 7,1:PRINT "N"
2030 LOCATE 8,1:PRINT "T":LOCATE 9,1:PRINT "R":LOCATE 10,1:PRINT "A"
2040 LOCATE 11,1:PRINT "T":LOCATE 12,1:PRINT "I":LOCATE 13,1:PRINT "O"
     :LOCATE 14,1:PRINT "N"
2050 LOCATE 15,1:PRINT "(mg/1)" THEN GOTO 2080
2060 FOR I=1 TO 16:YCIR(I)=YAXISLEN-(CONC(LAND,POL,I)-YLOW(LAND,POL))*
     YAXISLEN/YRANGE:NEXT I
2070 GOTO 2090
2080 FOR I=1 TO 16:YCIR(I)=YAXISLEN-(TOTCON(POL,I)-YLOWT(POL))*YAXISLEN
     /YRANGE:NEXT I
2090 XCIR = 68:FOR KEL=1 TO 16
2100 CIRCLE (XCIR,YCIR(KEL)),2
2110 XCIR=XCIR+35:NEXT KEL
2120 IF TOTAL=1 THEN GOTO 2170
2130 LOCATE 1,35:PRINT WHEN$;" SUBAREA ";LAND;" POLLUTOGRAPH"
2140 LOCATE 2,38:PRINT CNAM$(POL)
2150 IF BMP$="no" THEN LOCATE 3,38:PRINT "No BMP structures present in
     watershed":GOTO 2210
2160 LOCATE 3,38:PRINT "BMP structures present in watershed":GOTO 2210
2170 LOCATE 1,35:PRINT "COMPOSITE POLLUTOGRAPH--";N$;" WATERSHED"
2180 LOCATE 2,38:PRINT CNAM$(POL)
2190 IF BMP$="no" THEN LOCATE 3,38:PRINT "No BMP structures present in
     watershed":GOTO 2210
2200 LOCATE 3,38:PRINT "BMP structures present in watershed"
2210 LOCATE 4,35:PRINT "PEAK CONCENTRATION = ";QPEAK;" mg/1"
2220 LOCATE 23,59:INPUT "RETURN to continue ",GO
2230 RETURN
```

APPENDIX B. SOFTWARE USER'S MANUAL

Stormwater Management Package
User's Guide
Version 2.2

April 8, 1986

Kelly A. Cave

Hydrosystems Division
Department of Civil Engineering
Virginia Tech
Blacksburg, Virginia 24061

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INTRODUCTION

This "user-friendly" software package enables the user to evaluate watershed response to a rainfall event . Runoff hydrographs are calculated using methods outlined in the Soil Conservation Service Technical Release 55 (TR-55). It is required that the user be familiar with these methods before using the software. Hydrographs may be calculated for sub-drainage basins within a watershed as well as a composite hydrograph for the entire basin. In addition, the program will analyze the effects of existing best management practice facilities (BMPs) within the watershed and reflect their performance in the hydrographs. For planning purposes, this software package enables the user to calculate hydrographs for different proposed land use schemes for future conditions. Furthermore, five different types of BMP structures may be designed, priced, and their presence evaluated for the future condition of the watershed using this software.

In addition, the quality of the runoff produced by a single storm event may be analyzed. The software package computes a "pollutograph" for four types of pollutants: total suspended solids, BOD, total nitrogen, and phosphorus. The performance of BMP structures in the watershed is also reflected by the pollutographs.

PURPOSE

The purpose of this software package is to provide the user with an easy-to-use, desk top model for use on the personal computer. This model is at a medium level of sophistication, meant to be used as a management tool for estimation of the location and type of control measures needed to attain a given level of runoff and pollutant control at the outlet of the watershed. In other words, detailed simulation of pollutant source and buildup, washoff and transport/deposition is not performed. Thus, this software package yields order of magnitude pollutant loadings to facilitate the planning process.

In addition, the procedures followed to estimate size and location of the different BMP structures examined yield good preliminary design estimates of these structures. These design estimates can then be compared on an order of magnitude scale for their impact on runoff and pollutant load at the outlet of the watershed and on the total costs involved. These designs are meant to be a preliminary estimate for the final design of these facilities.

LIMITATIONS

Limitations of this version of the software package are listed below.

1. The version of BASIC used to program the software only recognizes 64K of computer memory. This restriction limits the number of sub-basins and BMP facilities that can be analyzed within a given watershed. Therefore, at present, the software package is applicable only to relatively small watersheds. For example, the software will analyze watersheds with a maximum of thirteen (13) sub-basins without BMP structures; this number is significantly reduced for watersheds where BMP structures exist or are to be installed. An estimate of the maximum number of sub-basins and BMP structures the software can handle is a combination of sub-basins and structures that produces a two dimensional array of thirty (30) elements. For example, you can analyze 6 sub-basins which contain a total of 5 BMP structures (i. e. 6 x 5 array) or a watershed containing 4 sub-basins and 7 BMP structures (i. e. 4 x 7 array). This estimate is not an absolute; better results may be produced by trial and error (See "Possible Errors" on page 191). Translation of the software into a better version of BASIC or into another computer language such as FORTRAN will make this package more powerful.

2. The SCS TR - 55 method for runoff hydrograph calculation limits the size of sub-basins within a watershed to 2000 acres or less. In addition, time of concentration of any of the sub-drainage basins within the watershed cannot be less than 0.1 hour or greater than 2.0 hours for hydrograph generation by the SCS tabular method.

3. This software was developed for the Soil Conservation Service in Virginia. Therefore, certain parameters such as the Type II rainfall distribution used in pollutograph generataion may need to be changed should the software be applied to areas significantly different from Virginia (See "Program Modifications" on page 202 for instructions). The pollutant loading table given for reference was developed from a study done in Northern Virginia.

4. This software was developed for use on IBM personal computers; IBM compatible computer users may need to make a few modifications to the software (See "Program Modifications" on page 202).

GETTING STARTED

The first thing that must be done is to make a backup of the two software diskettes labeled PROGRAM and DATA. The following discussion assumes your IBM computer system meets the following requirements.

REQUIREMENTS

DOS	version 2.1 or higher
BASICA	version 1.10 or higher
DISK DRIVES	One or two disk drives. Two double sided disk drives are preferred. Systems with a hard disk require a few changes in the software (See "Program Modifications" on page 202)
MEMORY	A minimum of 64K. Memory less than 64K will not support the BASICA compiler
MONITOR	Graphics capability needed
PRINTER	Graphics capability needed for hardcopy of graphs produced by software

In much of the discussion on following pages, you will be instructed to give the computer certain commands to accomplish different procedures. These instructions are printed in this manual enclosed in quotations, e. g. in the form "command". Thus, you will only type the command, not the quotations; the computer will not recognize commands enclosed in quotations.

NOTE: The words "sub-basin" and "subarea" are used interchangably throughout this manual and in the computer prompts to mean a sub-drainage area within a watershed.

SOFTWARE CONTENTS

The contents of the software diskettes PROGRAM and DATA are listed below for your reference.

DISKETTE	FILES	DESCRIPTION
PROGRAM	autoexec.bat	
	menu.bat	
	1.bat	'*.bat' files execute
	2.bat	the software
	3.bat	
	4.bat	
	5.bat	
	presrun.bas	
	futrun.bas	
	scs.bas	
	bmp.bas	'*.bas' files perform
	output.bas	computations
	polprep.bas	
	polluto.bas	
	pollout.bas	
	command.com	'*.com' are operating
	basica.com	system files
	graphics.com	
DATA	data2	
	data1	
	data3	
	data4	data1 - data10
	data5	contain SCS tabular
	data6	discharge values for
	data7	SCS type II rainfall
	data8	distribution
	data9	
	data10	
	prep.dat	contains the SCS runoff
		curve number table

BACKING UP THE SOFTWARE DISKETTES

TWO DOUBLE-SIDED DISK DRIVES

This section will be followed if your system has two double-sided disk drives. The steps outlined here are for DOS 2.1; other versions of DOS may produce different responses from the computer but the overall procedure will be the same.

1. The computer should be off.
2. Place a DOS diskette in the A: drive (i.e. left drive).
3. Turn the computer on; DOS should load (called "booting").
4. Answer the date and time prompts.
5. The DOS version number and copyright banner will appear.
6. The system prompt will appear. When the prompt appears, DOS will accept commands. Commands can be upper or lower case.
7. Type "diskcopy a: b:" after the system prompt and press RETURN.
8. Place a one of the two software diskettes in drive A: ; place a new diskette in drive B: and press RETURN.
9. When the computer is finished copying, DOS will ask if you wish to copy another. Press "Y".
10. Place the second of the two software diskettes in drive A: and a new diskette in drive B: and press RETURN.
11. Answer "N" when computer is finished copying AFTER you have placed the DOS diskette in the A: drive.
12. It is a good idea to check that all data transferred correctly during the copying process. To accomplish this, type "diskcomp a: b:" and press RETURN with DOS in the A: drive.
13. Answer the DOS prompt by placing one of the two software diskettes in drive A: and placing your copy of it in drive B:. Press RETURN.
14. Answer "Y" to DOS question; repeat previous step with second of two software diskettes.
15. Place the DOS diskette in drive A: and press "n" after comparing is complete.
16. Refer to the DOS manual for troubleshooting if you were unable to complete any of these steps.

ONE DOUBLE-SIDED DISK DRIVE

If your computer has one double-sided disk drive, you will follow the steps outlined in "Two Double-Sided Disk Drives" on page 186 with one difference. Your single disk drive acts as both drives A: and B: for your system. Therefore, when DOS tells you to place a diskette in drive A:, you will place the software diskette in the drive; you will place the new diskette in the drive when DOS asks for a diskette in drive B:.

HARD DRIVE WITH SUPPORTING DISK DRIVE

This section will be followed if your computer has a hard drive with one disk drive. It is assumed that DOS has been placed in memory on the hard drive. The steps outlined here are for DOS 2.1; other versions of DOS may produce different responses from the computer but the overall procedure will be the same.

1. The computer should be off.
2. Turn the computer on; DOS should load (called "booting"). **NOTE:** The A: drive should be empty.
3. Answer the date and time prompts.
4. The DOS version number and copyright banner will appear.
5. The system prompt will appear. When the prompt appears, DOS will accept commands. Commands can be upper or lower case.

The PROGRAM diskette has a file called "autoexec.bat" which bypasses the normal date and time prompts in DOS. This file tells the computer to run this stormwater management package automatically when the computer is turned on. Therefore, you need to rename this file before you copy it onto the hard disk in your system. The following steps accomplish this:

1. Type "a:" after the C: drive system prompt and press RETURN; drive A: will be the default drive.
2. Insert the PROGRAM diskette into the A: drive.
3. You need to choose the name you wish to call this software package. Your name must be less than 8 characters. In the following discussion this new name will be referred to as "myprog".
4. Type "rename autoexec.bat myprog.*" after the system prompt and press RETURN.
5. Type "copy a:*.* c:" after the system prompt and press RETURN.

6. To run the software package, you will type the new name assigned in step 3 (e. g. "myprog") after the DOS system prompt and press RETURN.

7. Copy the DATA diskette following steps outlined in "Two Double-Sided Disk Drives" on page 186. Your left drive will act as drives A: and B:, so you will have to replace the DATA diskette with a new diskette to which DATA is to be copied when the computer asks you for a diskette in drive B:.

NOTE: It is a good idea to copy the PROGRAM diskette onto another floppy diskette as well. To do this, follow steps outlined in "Two Double-Sided Disk Drives" on page 186. Your left drive will act as drives A: and B:, so you will have to replace the PROGRAM diskette with a new diskette when the computer asks you for a diskette in drive B:.

RUNNING THE PROGRAMS

TWO DOUBLE-SIDED DISK DRIVES

This section will be followed if your system has two double-sided disk drives. The steps outlined here are for DOS 2.1; other versions of DOS may produce different responses from the computer but the overall procedure will be the same.

1. The computer should be off.

2. Place the PROGRAM diskette in the A: drive (i.e. left drive) and the DATA diskette in the B: drive.

3. Turn the computer on and you're off! The software package was written in "user-friendly" BASIC; thus, you will be prompted for data by the computer.

4. Hardcopy of any information present on your display may be obtained by the following procedures outlined in "Software Output" on page 200.

5. Program execution may be interrupted at any point by pressing the "Crtl" key and "Break" key simultaneously. To resume program execution:

    - at that point: Type "cont" and press RETURN.

    - at the beginning of the program module you are currently in: Type "run" and press RETURN. This will restart the program module you stopped in and will use data generated in previous modules. This is useful if you have made an error in data input in the current program module.

    If you wish to exit a program module, press the "Crtl" key and "Break" key simultaneously, then type "system" and press RETURN. This will return you to DOS in the middle of a batch file execution. Therefore, you will need to repeat this step for each subsequent program module until you are returned to the main menu.

6. Refer to the DOS and BASICA manuals or this manual for explanation of procedures used in the programming.

ONE DOUBLE-SIDED DISK DRIVE

This section will be followed if your computer has one double-sided diskette drive. The steps outlined here are for DOS 2.1; other versions of DOS may produce different responses from the computer but the overall procedure will be the same.

1. The computer should be off.

2. Place the PROGRAM diskette in the A: drive (i.e. left drive).

3. Turn the computer on.

4. Your disk drive acts as both drives A: and B: for your system. Therefore, when the computer asks you for a diskette in drive B: you will insert the DATA diskette; you will insert the PROGRAM diskette in the drive when asked for a diskette in drive A:.

5. Follow steps 4 - 6 in "Two Double-Sided Disk Drives" on page 189 for additional software features.

HARD DISK WITH SUPPORTING DISK DRIVE

This section will be followed if your computer has a hard disk with a supporting diskette drive. This discussion assumes DOS has been stored on the hard drive. The steps outlined here are for DOS 2.1; other versions of DOS may produce different responses from the computer but the overall procedure will be the same.

1. Turn the computer on; DOS should boot from the hard drive.

2. Answer the date and time prompts if necessary.

3. After the C: system prompt appears, place the DATA diskette in the A: drive.

4. Type the name you have given to this software package from page 7 (e. g."myprog") and press RETURN. The software package was written in "user-friendly" BASIC; thus, you will be prompted for data by the computer.

5. The program has specified that all data will be read/written to the B: drive. Therefore, occasionally you will see a message to place a diskette in B: drive and press a key to continue. Since you have already placed the data disk in the A: drive (which functions as both A: and B: drives for a system with a hard disk), you just need to press any key to continue.

6. Hardcopy of any information present on your display may be obtained by the following procedures outlined in "Software Output" on page 200.

7. Program execution may be interrupted at any point by pressing the "Crtl" key and "Break" key simultaneously. To resume program execution:

- at that point: Type "cont" and press RETURN.

- at the beginning of the program module you are currently in: Type "run" and press RETURN. This will restart the program module you stopped in and will use data generated in previous modules. This is useful if you have made an error in data input in the current program module.

If you wish to exit a program module, press the "Crtl" key and "Break" key simultaneously, then type "system" and press RETURN. This will return you to DOS in the middle of a batch file execution. Therefore, you will need to repeat this step for each subsequent program module until you are returned to the main menu.

8. Refer to the DOS and BASICA manuals or this manual for explanation of procedures used in the programming.

POSSIBLE ERRORS

Listed below are a few of the error messages you may recieve while running the software package.

1. **Out of Memory In ******: You have specified for analysis more sub-basins and/or BMP facilities than can be stored in the computer memory. The only solution is to reduce the number of sub-basins and/or BMP facilities and try again.

2. **File Not Found In ******: Computer cannot locate a data file on the drive spedified. Check that diskettes are in the correct drive. For computing systems will only one disk drive, check that you have inserted the proper diskette when asked by the computer.

3. **Disk Full in ******: The DATA diskette is full. Transfer any stored information not used by the software package onto another diskette for future reference and clear memory space on the DATA diskette.

4. **Device Timeout**: Printer not hooked up or turned on.

5. If your personal computer is not an IBM, the software may not load correctly into your computer memory and thus will not run. Check your computer manuals to see if your computer will use the MS-DOS (Disk Operating System) and MS-BASICA software resident on the PROGRAM diskette. See "Program Modifications" on page 202 for instructions to modify the software for compatibility with your computer.

Consult your DOS, BASICA, or printer manual for further trouble-shooting.

DATA REQUIREMENTS

SOFTWARE ORGANIZATION

This software package has been organized in "module" form; different modules perform different functions. These modules run sequentially from a DOS batch file and use data generated by previous modules. Following is a list of the main modules comprising this software in the order in which they run:

MODULE	DESCRIPTION
SCS	Generates hydrographs by the SCS tabular method
BMP	Present conditions: Evaluates the presence of existing BMP structures and generates revised hydrographs reflecting their presence Future conditions: Evaluates the presence of existing BMP structures and allows for the design of new structures; generates revised hydrographs reflecting effects of BMP structures
OUTPUT	Presents hydrographs generated by SCS and BMP modules in tabular and graphical forms
POLLUTO	Generates and presents pollutographs for pre- and post-BMP conditions
POLLOUT	Presents pollutographs generated by POLLUTO module in tabular and graphical form for pre- and post-BMP conditions

All programs are written in "user-friendly" BASIC.

HYDROGRAPH GENERATION

The runoff hydrographs for a single storm event are generated by using the method developed by the U. S. Soil Conservation Service (SCS), outlined in Technical Release 55 (See "References" on page 205). This software incorporates the expanded runoff curve number table from the as yet unpublished revision to the 1975 edition. Hydrographs for sub-basins as well as a composite watershed hydrograph can be generated using the tabular SCS method.

Table 1 defines data you need to input to program module SCS to generate hydrographs for each sub-basin in the watershed. For ease in discussion the data are perceived as card images. Each "card" in Table 1 describes each input value; certain cards may be repeated as many times as necessary to fulfill the input requirements. When you run the software, the computer will prompt you for this information in the order that it is presented in Table 1.

TABLE 1 - INPUT DATA FOR SCS MODULE

CARD	DESCRIPTION
A	watershed name
B	watershed drainage area in acres
C	rainfall for design storm in inches during 24-hour period
D	return period of design storm in years
E	antecedent moisture condition of soil when design storm occurs
F	number of sub-basins located within watershed
G	area of sub-basin
H	number of specific land use types in sub-basin
I	GENERAL land use classification for each specific land use type
J	specific land use number under the GENERAL classification
K	area of sub-basin corresponding to the specific land use type in card J
L	area of specific land use type by hydrologic soil type
	Cards I through L are repeated for all specific land use types within each sub-basin as specified by card H and the entire sequence of cards G through L is repeated for each sub-basin until all are exhausted
M	total number of flow conditions that describe flow comprising **time of concentration** for each sub-basin; flow condition possibilities are listed on screen
N	type of flow condition
O	length, slope, and other information if necessary (i. e. channel width and depth) for each type of flow
	Cards N and O are repeated for each condition specified by card M

P	total number of flow conditions that describe flow comprising **time of travel** for each sub-basin; flow condition possibilities are listed on screen
Q	type of flow condition
R	length, slope, and other information if necessary (i. e. channel width and depth) for each type of runoff flow
	Cards Q and R are repeated for each condition specified by card P. The entire sequence of cards M through R is repeated until all the sub-basins are exhausted
S	choice of output format

BMP DESIGN AND EVALUATION

The design and/or evaluation of three basic types of BMP structures is possible. These structures are detention ponds (dry ponds, wet ponds, and extended wet ponds), infiltration trenches, and porous pavement.

For each BMP structure you wish to evaluate and/or design, you must enter data describing the area which drains into the BMP site to generate a hydrograph for this area. Table 2 specifies the data needed for each BMP site. For ease in discussion the data are perceived as card images; each "card" in Table 2 describes an input value. Certain cards may be repeated as many times as necessary to fulfill the input requirements. When you run the software, the computer will prompt you for this information in the order that it is presented in Table 2.

TABLE 2 - INPUT DATA FOR BMP MODULE

CARD	DESCRIPTION
A	**Present condition watersheds:** number of BMP structures existing
	Future condition watersheds: specify both number of BMP structures existing and number of BMP structures to be designed
	Card A is repeated for each sub-basin within the watershed
B	type of BMP structure to be analyzed/designed
C	drainage area that contributes runoff to BMP site in acres
D	number of specific land use types in BMP drainage area
E	GENERAL land use classification

F specific land use type for the GENERAL classification

G area of sub-basin corresponding to specific land use type

H area of specific land use type by hydrologic soil type

Cards E through H are repeated for each land use type specified by Card D within each BMP drainage area within each sub-basin and the entire sequence of cards B through H is repeated for each BMP structure specified by Card A

I total number of flow conditions that describe flow comprising **time of concentration** for each BMP drainage area; flow condition possibilities are listed on screen

J type of flow condition

K length, slope, and other information if necessary (i. e. channel width and depth) for each type of flow

Cards J and K are repeated for each condition specified by card I; card I is repeated for each BMP drainage area in each sub-basin

L total number of flow conditions that describe flow comprising **time of travel** for each BMP drainage area; flow condition possibilities are listed on screen

M type of flow condition

N length, slope, and other information if necessary (i. e. channel width and depth) for each type of runoff flow

Cards M and N are repeated for each condition specified by card L; card L is repeated for each BMP drainage area in each sub-basin

O data needed for design/evaluation of each BMP structure specified by card A

Data requirements for Card O are detailed in Tables 3 and 4

P choice of output format

Note: Computer memory limitations require that the routines for detention pond design follow the routines for infiltration device design. Thus, the computer will prompt you for Card O data for detention basin design/evaluation in each sub-basin AFTER all Card O data has been entered for ALL infiltration facilities within the watershed.

DETENTION PONDS

The three types of detention ponds examined by this software package are differentiated by the amount of pollutant removal attained. A dry pond provides the least amount of pollutant removal since by definition it is a basin which temporarily detains an amount of water that is completely released at a later time. Wet ponds function in the same manner as dry ponds except they retain a permanent pool of water. Both wet and dry ponds are primarily peak-shaving devices which control short, high intensity local storms. An extended wet pond is a larger wet pond which detains water long enough for substantial settling of pollutants in runoff to occur.

Algorithms using the storage-indication working curve method route an inflow hydrograph through the detention pond and generate the outflow hydrograph from the structure. For analysis of a present condition watershed, the software evaluates the effect of the detention pond on the hydrograph at the watershed outlet or at a point of interest. For a future condition watershed, the algorithm is repeated until the pond design provides sufficient reduction of peak flow or meets other design criteria. Once a satisfactory design has been found, the detention facility is sized depending on what type of pond has been specified. Data needed to accomplish this procedure given in Table 3 in the order you will be prompted by the computer to enter it.

TABLE 3 - INPUT DATA FOR DETENTION BASIN ROUTINES

CARD	DESCRIPTION
A	**For basins already in place:** specify both the outflow discharge rating curve and the storage vs. elevation data **For basins to be designed:** specify both the outflow discharge rating curve and the storage vs. elevation data

The routing procedure is performed by the computer and you will be asked if the structure meets your design criteria. If not, you may change data described by card A (i. e. redesign the structure) until a satisfactory design has been made.

WARNING: If your basin design is not large enough to handle the given inflow, the outflow hydrograph produced will have more than one peak. You must increase the size of the detention pond and/or its outlet works to obtain a feasible design (hydrographs generated by the SCS method have only one peak). An outflow hydrograph with multiple peaks is the **ONLY** indication by the software that your design is not feasible.

INFILTRATION STRUCTURES

Infiltration structures are volume control devices to control stormwater quantity and quality. An infiltration trench is defined as a subsurface trench that is used to temporarily store runoff in a stone filled reservoir and exfiltrate the runoff through the surrounding soil media (Maryland Dept. of Nat. Resources, 1984). The surface of the trench consists of either a stone covered area or a grass covered area with an inlet. Porous pavement is defined as a low density, permeable asphalt surface in which water is rapidly transmitted to an aggregate reservoir subbase for storage (Maryland Dept. of Nat. Resources, 1984). Water then infiltrates into the surrounding soil media.

The design for infiltration structures is based on controlling increased runoff due to urbanization for a specific frequency storm event; this depends on the volume of water stored in the stone subbase. Data needed to accomplish infiltration structure design and/or evaluation is given in Table 4 in the order you will be prompted for it.

TABLE 4 - INPUT DATA FOR INFILTRATION ROUTINES

CARD	DESCRIPTION
A	**Structures to be designed:** amount of runoff in inches the structure will handle
B	normal depth of groundwater table at site location
C	**Existing structures:** physical geometry of the infiltration structure
	Structures to be designed: any physical geometric limitations
D	type of soil underlying structure

NOTE: Physical geometric limitations include the length, depth, and width of the structure. The equations used for design allow a **maximum of two** of these variables to be fixed by the designer.

Designs of future structures may be revised by changing input data specified in Table 4 until the structure meets the design requirements.

COST ANALYSIS

A basis for evaluating alternative urban stormwater management investments was developed after extensive literature review. Three cost factors are considered in this analysis: base construction costs, contingency costs, and operation and maintenance costs. Table 5 presents equations developed to facilitate BMP evaluation (all costs in fourth quarter 1980 dollars).

TABLE 5 - BMP COST EQUATIONS

BMP Type	Total Cost
Dry Pond	$\$100.6 \times V^{0.51}$
Wet Pond	$\$100.6 \times V^{0.51}$
Extended Wet Pond	$\$101.6 \times V^{0.51}$
Infiltration Trench	$1.28\{0.68[W \times L \times (D+1)] + 0.28[(W \times L) + (W \times D) + (L \times D)] + 2.5(D+1) + 0.04[(40 + W) \times (40 + L) - (W \times L)]\}$
Porous Pavement	$1.35\{0.68[W \times L \times (D+2/12)] + 0.14[(W \times L) + 2(W \times D) + 2(L \times D)] + 1.75[W \times L]\} + 0.096(W \times L \times D)$

where:

W = width of structure (ft)
L = length of structure (ft)
D = depth of structure (ft)
V = volume of structure (cu. ft.)

The relationships given in Table 5 do not reflect the costs of grates, etc. for infiltration devices and do not reflect the the cost of the land associated with any type of BMP structure. The costs associated with all types of BMP structures are extremely site specific; the equations given in Table 5 yield order of magnitude costs for planning purposes.

POLLUTOGRAPH GENERATION

Pollutographs can be produced by the model to represent dynamic pollutant loadings during the storm event. Four water quality parameters are examined: total nitrogen, total phosphorus, BOD, and total suspended solids. Loadings are based on the total mass of pollutants which has accumulated on the ground surface and the fraction of this mass which is removed by the runoff. The total mass of accumulated pollutants prior to the storm event is a weighted value accounting for pollutant dry weather accumulation rates (pounds/acre/day) for both pervious and impervious areas for all land use types. A table of typical pollutant loadings in the Northern Virginia area is shown on the screen for your reference; you may, however, enter any loading rate you desire. Average runoff rates are calculated for the runoff from pervious and impervious areas separately based on the SCS Type II rainfall distribution; runoff rates for areas with different rainfall distributions may be calculated by making the programming changes outlined in "Program Modifications" on page 202.

Table 6 specifies input data needed to generate pollutographs for each type of pollutant for each sub-basin within the watershed. For purposes of discussion, the data are perceived as card images. Each "card" describes each input value; certain cards may need to be repeated as many times as necessary to describe design parameters. Table 6 lists data in the order you will be prompted by the computer to enter it.

TABLE 6 - INPUT DATA FOR POLLUTO MODULE

CARD	DESCRIPTION
A	number of days since last storm event
B	pollutant loadings for pervious and for impervious areas in units of pounds/acre/day **Card B is repeated for each land use type in each sub-basin in the watershed**
C	choice of output format for pre-BMP pollutographs
D	**If BMP structures are in watershed:** pollutant loadings for pervious and for impervious areas within the area which contributes runoff to the BMP site given in units of pounds/acre/day **Card D is repeated for each land use type in each BMP drainage area in each sub-basin**
E	choice of output format for pollutographs reflecting performance of BMP facility

SOFTWARE OUTPUT

Two methods are available for you to obtain hardcopy of select data or software output. One method is to print out data that is present on the computer monitor while you are running the software; the other is to copy data files created by the software and stored on the DATA diskette. The following paragraphs outline procedures to aid you is this process.

Hardcopy of Output to Screen: The program modules SCS and BMP present tables of select input data combined with results of relevant intermediate calculations on the monitor prior to presenting the generated hydrographs. The program pauses at these points until you press RETURN. In addition, the program modules OUTPUT and POLLOUT, which present the generated hydrographs and pollutographs, pause during each screen of output presentation until you press RETURN . To obtain a copy of any of this information, follow these simple steps:

- Make sure the printer is turned "ON".
- After the computer has paused to display information, press the "shift" and "PrtSc" keys simultaneously until printing begins.
- After printing has stopped, press "RETURN" as instructed on the screen to resume program execution.

Hardcopy of Output to Data Files: The software creates several data files during execution which are used as the individual program modules run sequentially (See "Software Organization" on page 192). These data files are summarized in Table 7 on page 21.

To print out the contents of any of these data files, follow these simple steps:

- You must be in DOS (See "Getting Started" on page 184).
- Make sure the printer is turned "ON".
- Type "copy filename.dat lptl:" and press RETURN. This command will work if you have a printer connected in parallel with your computer; consult your printer manual for instructions if your printer is connected in serial.

NOTE: Every time you use this software package, the program modules create **NEW** data files with the names listed in Table 7. This means that any data present in these files from previous runs will be **ERASED**. Therefore, if you want to save files you have created for future reference, you must rename each of these files to something the software will not use. To rename these files, choose new names for them that will be meaningful to you, then:

- type "rename oldname.dat newname.dat" and press RETURN while you are in DOS where "oldname.dat" is a file name listed in Table 7 and "newname" is the data file name you have chosen with the file name extension ".dat".

TABLE 7

File Name	Created By	Used By	Description
prepoll.dat	SCS	POLLUTO	Basin description, design information, land use types, etc.
prepol2.dat	SCS	POLLUTO	Pre-BMP hydgrograph ordinates
prebmpl.dat	SCS	BMP	Design criteria for watershed
prebmp2.dat	SCS	BMP	Pre-BMP watershed description
hyd.ord	SCS	OUTPUT	Pre-BMP hydrograph ordinates for presentation on screen/printer
bmppoll.dat	BMP	POLLUTO	BMP design information
bmppol2.dat	BMP	POLLUTO	Post-BMP hydrograph ordinates
hyd.ord	BMP	OUTPUT	Hydrograph ordinates reflecting presence of BMP structures for presentation on screen/printer
polpreb.ord	POLLUTO	--	Ordinates for pollutographs for pre-BMP watershed conditions
poll.ord	POLLUTO	POLLOUT	Pre-BMP pollutograph ordinates for presentation on screen/printer
prebmpp.dat	POLLUTO	POLLUTO	Pollutant loadings for pre-BMP conditions; used in calculations for post-BMP pollutographs
polbmp.ord	POLLUTO	--	Ordinates for pollutographs reflecting BMP's in watershed
poll.ord	POLLUTO	POLLOUT	Pollutograph ordinates reflecting performance of BMP facilities for presentation on screen/printer

PROGRAM MODIFICATIONS

This software package has been set up in 'module' form such that each module performs a different function. (See "Software Organization" on page 192). The main modules do very little calculation; they merely call subroutines to perform various functions. This programming style makes it easier for subsequent users to adapt the software to meet their needs with a minimum of programming changes.

NON-IBM PERSONAL COMPUTERS

If your personal computer is not an IBM, it may not recognize the MS-DOS and MS-BASICA software used to execute this software package. If your computer is IBM-compatible, you may be able to change either the disk operating system or the version of BASICA if necessary to use this software package. Your computer manuals should tell you if this is necessary to make your system IBM compatible. The following information may help you in this process:

1. If the disk operating system (DOS) needs to be changed, you need to format a new diskette following instructions given in the computer manuals; the system files **must** be copied onto the new diskette when formatting. You will then copy all files from the PROGRAM diskette onto the newly formatted diskette using a command similiar to the MS-DOS "copy" command. In addition, files similar to "command.com" and "graphics.com" resident on the PROGRAM diskette need to be copied from your version of DOS onto the new diskette; "command.com" and "graphics.com" should be erased. The files on the PROGRAM diskette with file extension ".bat" need to be modified to reflect the changes you have made.

2. If the version of MS-BASICA is not compatible with your computer, you need to copy the version of BASIC recognized by your computer onto the PROGRAM diskette and erase the file "basica.com". In addition, the files with the extension ".bat" will need to be modified to reflect the name of the version of BASICA you are using. The BASIC used by your computer must recognize the same commands used by MS-BASIC for this procedure to work. The DOS for your computer must have batch file capabilities consistent with MS-DOS for the software to execute properly.

You may need to make modifications additional to the ones listed above; your computer manuals should assist you further in this process.

Additional BMP structures

The software currently designs/evaluates five different BMP structures. If you wish to add routines to design other BMP structures, it is simply a matter of writing a subroutine to perform the necessary calculations and inserting it into the software. There are a few other programming changes necessary which are listed below:

1. The BMP module calls a "menu" subroutine which asks the user the type of BMP structure he wishes to design/evaluate (lines 4580 - 4730). This menu must be modified to your specifications. The string variable "TYPE$" in this menu controls execution of the entire program module. In addition, if you have specified choices other than "A", "B", "C", "D" or "E" you must modify the correct type check in lines 4670 and 4680 for your new choices.

2. In the program module BMP, lines 1530 - 1620, 1730, and 1840 transfer execution to the subroutine the user has chosen corresponding to the structure type. These lines need to be modified or new lines added to reflect the structure type changes you have made.

3. Line 680 in the program module BMP counts the number of detention ponds to be designed. This line should be modified to reflect changes in the main menu.

4. Lines 2320 - 2690 in the program module BMP present tables of intermediate calculations and data for each BMP facility. This routine must be modified for new BMP facility types.

5. In the program module POLLUTO, BMP pollutant removal efficiences are assigned in lines 3350 - 3520. This subroutine must be modified to reflect any new BMP facility types.

6. Lines 1310, 1350, 1370, 1650, and 1810 in the program module POLLUTO transfer execution to different program lines depending on BMP structure type; these lines must also reflect changes made to the BMP module.

7. Additional programming changes such as new format for output, etc. can be made by an experiened BASIC programmer.

Note: If you add additional structure types to the program, the size of watershed and number of BMP facilities the software package can analyze may be furthur restricted due to memory limitations.

POLLUTOGRAPH GENERATION

Additional pollutants analyzed

The program module POLLUTO currently analyzes four types of pollutants. If you wish to modify the module to analyze additional or different pollutants, there are a few steps to follow:

1. Change the value of the variable NPOL in line 80 to the number of pollutants to be analyzed (current value is 4).

2. Change the names of the types of pollutants to be analyzed in line 110 as appropriate. These names are for output of results.

3. Change line 250 as appropriate to reflect which pollutants you wish to analyze.

4. The pollutant loading table (lines 3020 - 3210) given for your reference may need modification.

5. BMP pollutant removal efficiences are assigned in lines 3350 - 3520. This subroutine must be modified to reflect your choice of pollutants for analysis.

6. In the program module POLLOUT, change the value of the variable NPOL in line 120 to the number of pollutants to be analyzed (current value is 4).

7. Change the names of the types of pollutants to be analyzed in line 150 of POLLOUT as appropriate. These names are for output of results.

8. Additional programming changes such as new format for output, etc. can be made by an experiened BASIC programmer.

Note: If you add additional pollutant types to the program, the size of watershed and number of BMP facilities the software package can analyze may be furthur restricted due to memory limitations.

Different SCS rainfall distribution

The program module POLLUTO uses the SCS Type II rainfall distribution to calculate incremental runoff rates. Lines 130-160 are DATA statements which contain cumulative rainfall ratios for this distribution. These values may be changed to reflect any other SCS rainfall distribution.

REFERENCES

Biggers, D. J., Hartigan, J. P., and Bonuccelli, H. A., "Urban Best Management Practices (BMP's): Transition from Single-Purpose to Multipurpose Stormwater Management," Proceedings of the International Symposium on Urban Storm Runoff, Lexington, Kentucky, July, 1980. Reference for stormwater management performance of BMP structures.

Schueler, T., Magill, R.,Sullivan, M., and Wiegand, C., "Comparative Pollutant Removal Capability, Economics and Physical Suitability of Urban Best Management Practices in the Washington, DC Metropolitan Area", paper presented at Nonpoint Pollution Abatement Symposium, Marquette University. Milwaukee, WI. April 23-25, 1985. Reference for cost analysis of BMP structures.

Maryland Department of Natural Resources, Water Resources Administration, Stormwater Management Division,"Maryland Standards and Specifications for Stormwater Management Infiltration Practices", February, 1984.

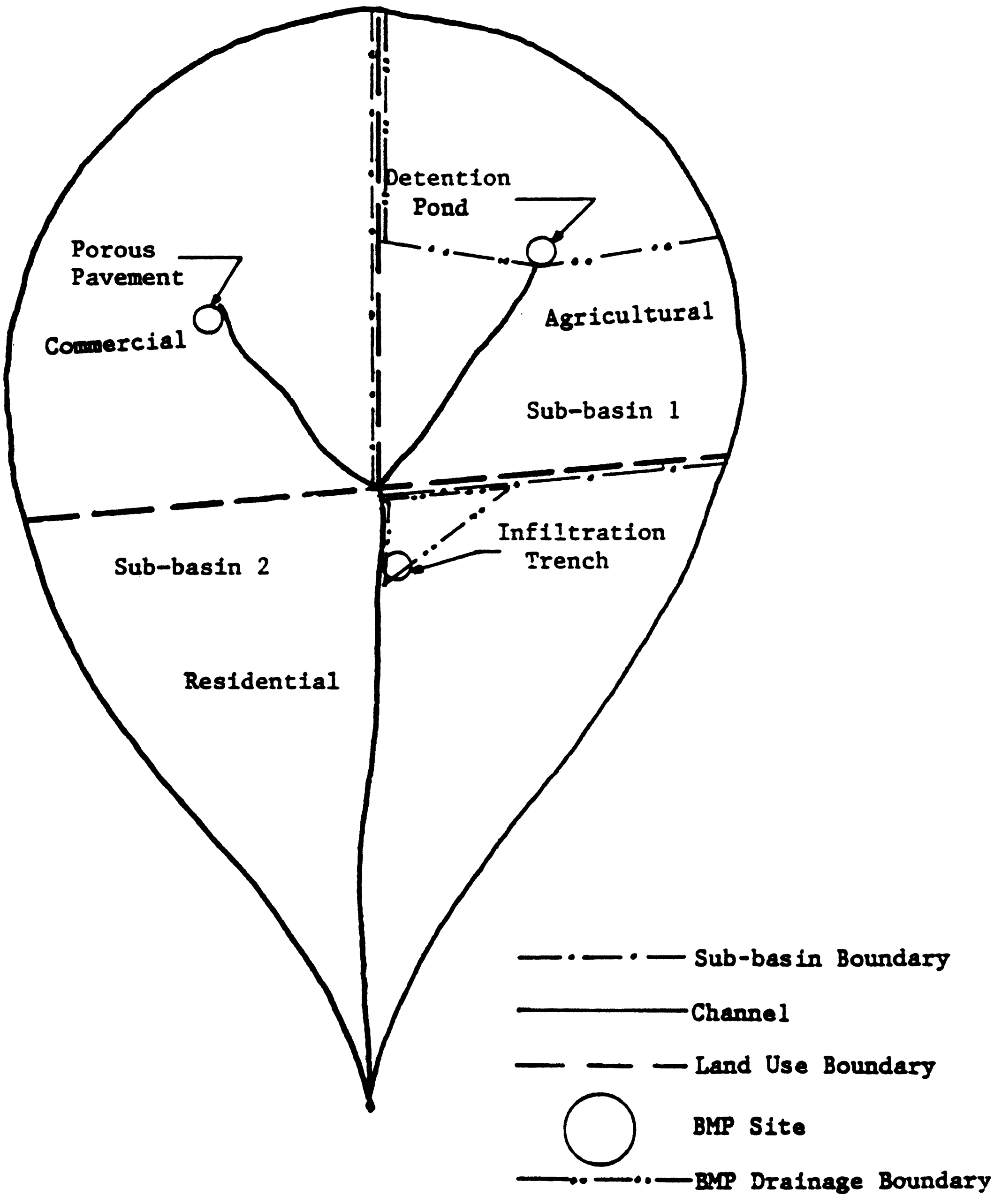
Northern Virginia Planning District Commission, "Guidebook for Screening Urban Nonpoint Pollution Management Strategies", November, 1979. Reference for pollutant loading table given for reference in program module POLLUTO.

Soil Conservation Service, "Urban Hydrology for Small Watersheds", Technical Release No. 55, January, 1975.

Wanielista, M. P., Stormwater Management: Quantity and Quality, Ann Arbor, Michigan, 1978. Information on pollutograph generation.

APPENDIX A. CASE STUDY

The following pages contain input data and example output for a hypothetical watershed. This example allows you to design and evaluate three types of BMP structures for a **FUTURE** condition watershed (enter "4" from the main menu for future condition analysis). The answers to the questions you will be asked by the computer are shown in **bold face** on the following pages; refer to "Data Requirements" on page 192 for input data explanation if you have difficulty.



DEMONSTRATION WATERSHED

DESIGN CONDITIONS:

CARD A: Watershed name: **DEMO**
CARD B: Watershed drainage area in acres: **1000**
CARD C: Expected 24-hour rainfall in inches: **8**
CARD D: Design storm return period in years: **5**
CARD E: Antecedant Moisture Condition: **2**
CARD F: Number of sub-basins: **2**

SUB-BASIN CHARACTERISITICS:

CARD G: Area of sub-basin 1 in acres: **250**
CARD H: Number of specific land use types in sub-basin 1: **1**
CARD I: General land use classification for specific land use type 1: **C** (e. g. cultivated agricultural)
CARD J: Specific land use number corresponding to card I: **22** (e. g. row crops, straight row, good hydrologic condition)
CARD K: Area of sub-basin (acres) corresponding to specific land use type: **250**
CARD L: Area (acres) of specific land use type by hydrologic soil type:
- Soil type A: **100**
- Soil type B: **50**
- Soil type C: **50**
- Soil type D: **50**

CARD G: Area of sub-basin 2 in acres: **250**
CARD H: Number of specific land use types in sub-basin 2 : **2**
CARD I: General land use classification for specific land use type 1: **A** (e. g. fully developed urban)
CARD J: Specific land use number corresponding to card I: **13** (e. g. residential, 1/3 acre lot size)
CARD K: Area of sub-basin (acres) corresponding to specific land use type: **500**
CARD L: Area (acres) of specific land use type by hydrologic soil type:
- Soil type A: **100**
- Soil type B: **100**
- Soil type C: **200**
- Soil type D: **100**

CARD I: General land use classification for specific land use type 2: **A** (e. g. fully developed urban)
CARD J: Specific land use number corresponding to card I: **9** (e. g. commercial and business)
CARD K: Area of sub-basin (acres) corresponding to specific land use type: **250**

CARD L: Area (acres) of specific land use type by hydrologic soil type:

Soil type A: 50
Soil type B: 100
Soil type C: 50
Soil type D: 50

CARD M: Sub-basin 1 time of concentration flow conditions: 2
CARD N: Type of flow condition: 2 (e. g. minimum cultivation tillage)
CARD O: Length of flow (feet): 1000
Slope (percent): 4
CARD N: Type of flow condition: 8 (e. g. channel)
CARD O: Length of flow (feet): 3000
Slope (percent): 3
Channel depth (feet): 2
Channel width (feet): 1
Channel side slope: 1
Manning's n: 0.04

CARD P: Sub-basin 1 time of travel flow conditions: 1
CARD Q: Type of flow condition: 8 (e. g. channel)
CARD R: Length of flow (feet): 7000
Slope (percent): 4
Channel depth (feet): 3
Channel width (feet): 3
Channel side slope: 1
Manning's n: 0.035

CARD M: Sub-basin 2 time of concentration flow conditions: 2
CARD N: Type of flow condition: 9 (e. g. sewer)
CARD O: Length of flow (feet): 3000
Slope (percent): 4
Sewer diameter (feet): 2
Manning's n: 0.013
CARD N: Type of flow condition: 8 (e. g. channel)
CARD O: Length of flow (feet): 9000
Slope (percent): 4
Channel depth (feet): 3
Channel width (feet): 3
Channel side slope: 1
Manning's n: 0.035

CARD P: Sub-basin 2 time of travel flow conditions: 0

The following is a partial listing of data for the DEMO watershed.

DATA FOR THE FUTURE CONDITION:

Subarea	Area(acres)	RCN	TC(hrs)	TT(hrs)	Runoff(in)
1.00	250.00	77.20	0.43	0.17	5.30
2.00	750.00	81.07	0.28	0.00	5.75

Press RETURN to continue

The runoff hydrograph for the future condition includes:

FOR SUBAREA 1			
TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	40.0	13.4	122.7
11.2	55.4	13.6	107.5
11.4	70.9	13.8	97.6
11.6	137.7	14.0	87.6
11.8	422.3	14.2	81.8
12.0	1065.8	14.4	76.0
12.2	949.7	14.6	71.1
12.4	555.2	14.8	66.9
12.6	348.5	15.0	62.8
12.8	235.1	16.0	50.4
13.0	175.5	18.0	37.2
13.2	143.0	20.0	29.7

This hydrograph is for the future
condition watershed without the presence of BMP structures.

Press RETURN to continue. . .

The runoff hydrograph for the future condition includes:

FOR SUBAREA 2			
TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	144.7	13.4	361.3
11.2	205.3	13.6	327.3
11.4	265.9	13.8	301.0
11.6	677.2	14.0	274.7
11.8	2481.5	14.2	256.4
12.0	4406.5	14.4	238.2
12.2	2301.9	14.6	223.4
12.4	1165.7	14.8	212.0
12.6	803.3	15.0	200.5
12.8	561.8	16.0	161.7
13.0	473.6	18.0	121.3
13.2	403.0	20.0	94.3

This hydrograph is for the future
condition watershed without the presence of BMP structures.

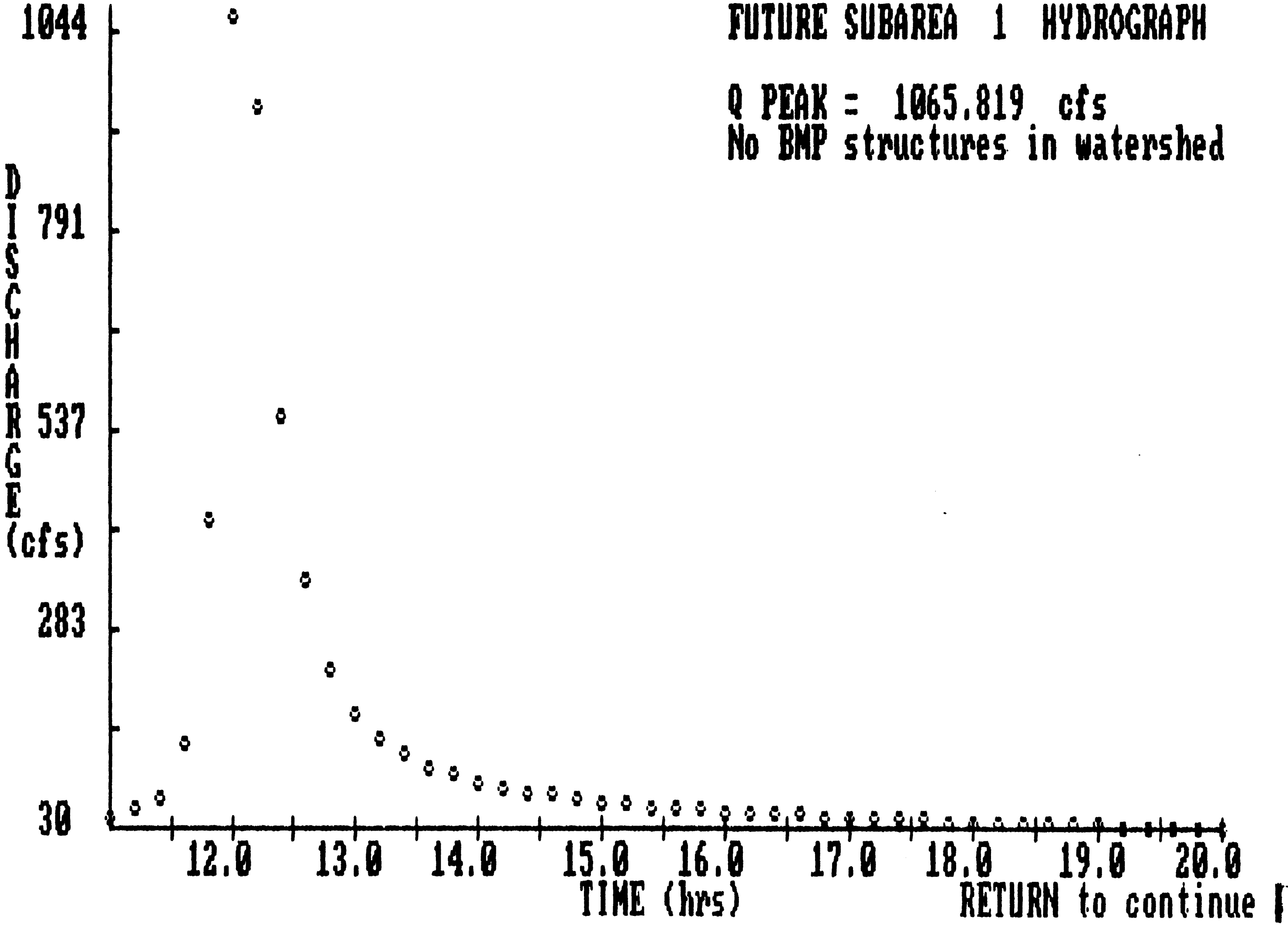
Press RETURN to continue. . .

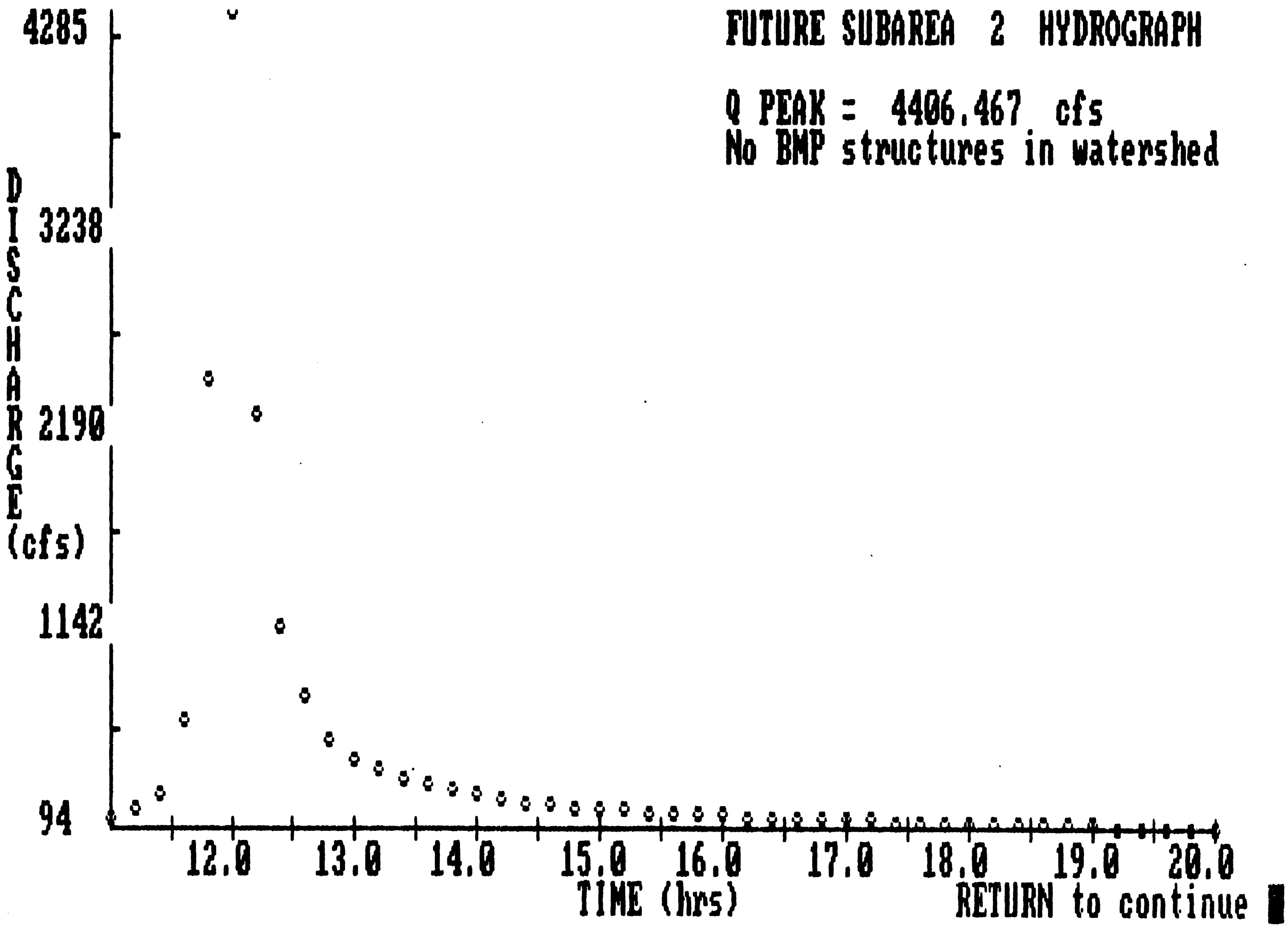
The total composite hydrograph for the future condition:

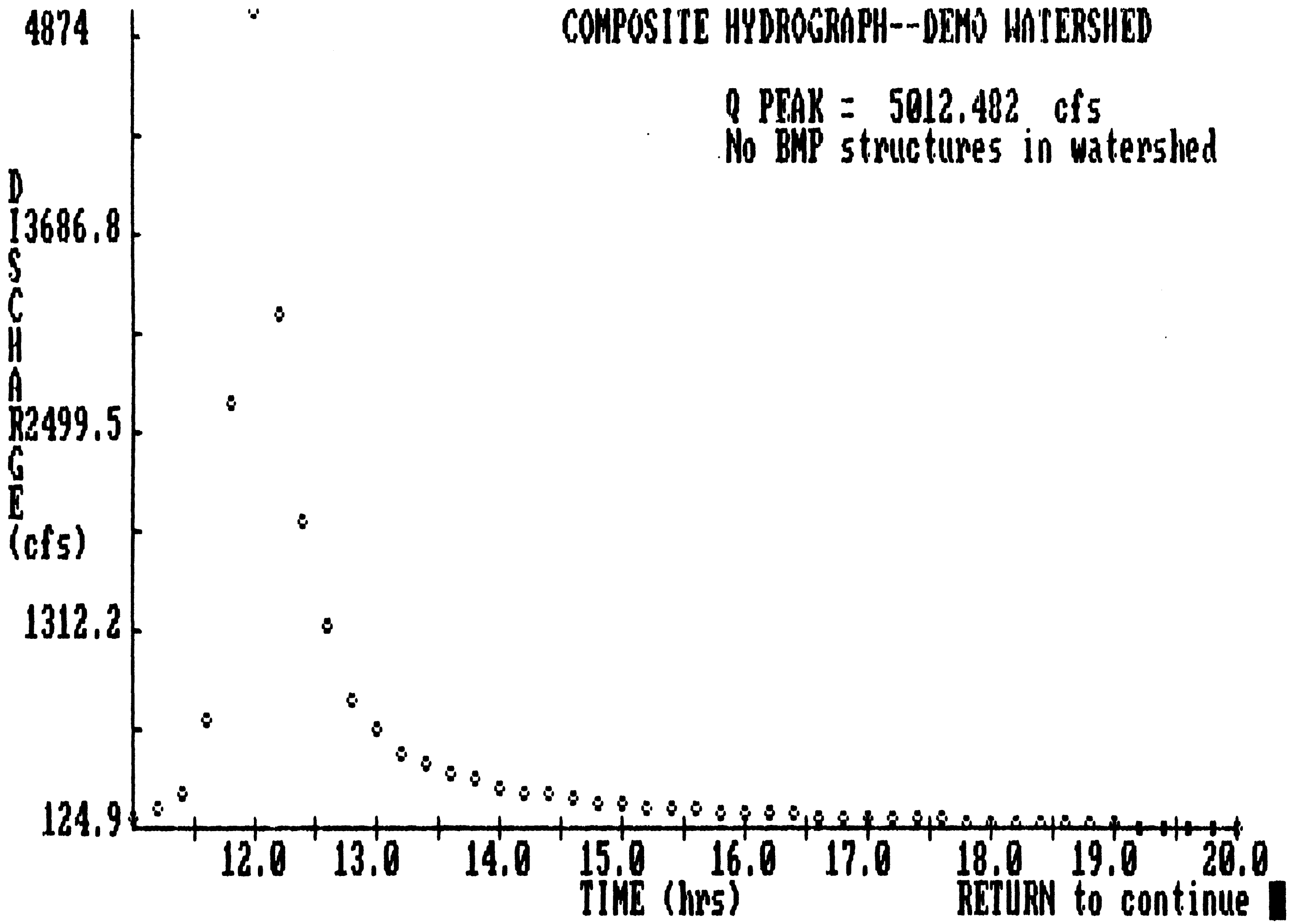
TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	178.6	13.4	507.4
11.2	251.1	13.6	450.6
11.4	323.5	13.8	410.2
11.6	767.0	14.0	369.7
11.8	2691.9	14.2	344.4
12.0	5012.4	14.4	319.1
12.2	3217.1	14.6	298.3
12.4	1976.5	14.8	282.2
12.6	1344.6	15.0	266.1
12.8	909.9	16.0	214.4
13.0	712.1	18.0	159.9
13.2	580.7	20.0	124.9

This hydrograph is for the future
condition watershed without the presence of BMP structures

Press RETURN to continue. . .


FUTURE SUBAREA 1 HYDROGRAPH
Q PEAK = 1065.819 cfs
No BMP structures in watershed
DISCHARGE (cfs)
1044
791
537
283
30
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue


FUTURE SUBAREA 2 HYDROGRAPH
Q PEAK = 4406.467 cfs
No BMP structures in watershed
DISCHARGE (cfs)
4285
3238
2190
1142
94
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue



COMPOSITE HYDROGRAPH--DEMO WATERSHED
Q PEAK = 5012.482 cfs
No BMP structures in watershed
4874
3686.8
2499.5
1312.2
124.9
DISCHARGE (cfs)
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue

BMP SITE CHARACTERISTICS:

CARD A: Number of existing structures in watershed:
Sub-basin 1: **0**
Sub-basin 2: **0**

Do you wish to design BMP structures? **Y**
Number in sub-basin 1: **1**
Number in sub-basin 2: **2**

CARD B: Subarea 1 BMP site 1 structure type: **C** (e. g. extended wet pond)

CARD C: BMP site drainage area (acres): **100**
CARD D: Number of specific land use types in sub-basin 1 BMP site 1: **1**
CARD E: General land use classification for specific land use type 1: **C** (e. g. cultivated agricultural)
CARD F: Specific land use number corresponding to card E: **22** (e. g. row crops, straight row, good hydrologic condition)
CARD G: Site drainage area (acres) corresponding to specific land use type: **100**
CARD H: Area (acres) of specific land use type by hydrologic soil type:
Soil type A: **25**
Soil type B: **25**
Soil type C: **25**
Soil type D: **25**

CARD B: Subarea 2 BMP site 1 structure type: **E** (e. g. porous pavement)

CARD C: BMP site drainage area (acres): **5**
CARD D: Number of specific land use types in sub-basin 2 BMP site 1: **1**
CARD E: General land use classification for specific land use type 1: **A** (e. g. fully developed urban)
CARD F: Specific land use number corresponding to card E: **4** (e. g. paved area)
CARD G: Site drainage area (acres) corresponding to specific land use type: **5**
CARD H: Area (acres) of specific land use type by hydrologic soil type:
Soil type A: **1**
Soil type B: **2**
Soil type C: **1**
Soil type D: **1**

CARD B: Subarea 2 BMP site 2 structure type: D
(e. g. infiltration trench)

CARD C: BMP site drainage area (acres): 20
CARD D: Number of specific land use types in sub-basin 2 BMP site 2: 1
CARD E: General land use classification for specific land use type 1: A (e. g. fully developed urban)
CARD F: Specific land use number corresponding to card E: 13
(e. g. residential, 1/3 acre lot size)
CARD G: Site drainage area (acres) corresponding to specific land use type: 20
CARD H: Area (acres) of specific land use type by hydrologic soil type:
Soil type A: 5
Soil type B: 5
Soil type C: 5
Soil type D: 5

CARD I: Sub-basin 1 BMP site 1 time of concentration flow conditions: 1
CARD J: Type of flow condition: 2 (e. g. minimum cultivation tillage)
CARD K: Length of flow (feet): 1000
Slope (percent): 4

CARD L: Sub-basin 1 BMP site 1 time of travel flow conditions: 2
CARD M: Type of flow condition: 8 (e. g. channel)
CARD N: Length of flow (feet): 3000
Slope (percent): 3
Channel depth (feet): 2
Channel width (feet): 1
Channel side slope: 1
Manning's n: 0.04
CARD M: Type of flow condition: 8 (e. g. channel)
CARD N: Length of flow (feet): 7000
Slope (percent): 4
Channel depth (feet): 3
Channel width (feet): 3
Channel side slope: 1
Manning's n: 0.035

CARD I: Sub-basin 2 BMP site 1 time of concentration flow conditions: 1
CARD J: Type of flow condition: 6 (e. g. paved)
CARD K: Length of flow (feet): 2000
Slope (percent): 4

CARD L: Sub-basin 2 BMP site 1 time of travel flow conditions: 2
CARD M: Type of flow condition: 7 (e. g. gutter)
CARD N: Length of flow (feet): 500
Slope (percent): 4
Gutter depth (feet): 1
Gutter cross slope: 1
Manning's n: 0.013

CARD M: Type of flow condition: 8 (e. g. channel)
CARD N: Length of flow (feet): 8000
Slope (percent): 4
Channel depth (feet): 3
Channel width (feet): 3
Channel side slope: 1
Manning's n: 0.035

CARD I: Sub-basin 2 BMP site 2 time of concentration flow conditions: 2
CARD J: Type of flow condition: 6 (e. g. paved)
CARD K: Length of flow (feet): 1000
Slope (percent): 2
CARD J: Type of flow condition: 7 (e. g. gutter)
CARD K: Length of flow (feet): 1000
Slope (percent): 3
Gutter depth (feet): 1
Gutter cross slope: 1
Manning's n: 0.013

CARD L: Sub-basin 2 BMP site 2 time of travel flow conditions: 1
CARD M: Type of flow condition: 8 (e. g. channel)
CARD N: Length of flow (feet): 4000
Slope (percent): 4
Channel depth (feet): 3
Channel width (feet): 3
Channel side slope: 1
Manning's n: 0.035

BMP DESIGN CRITERIA:

CARD O: All structures are to be designed!

NOTE: All card references in the following section correspond to Table 3 (page 16) for detention ponds and Table 4 (page 17) for infiltration devices.

Sub-basin 2 BMP site 1:

CARD A: Amount of runoff (inches) handled by pavement structure: **5**
CARD B: Water table depth (feet): **20**
CARD C: Width limitation (feet): **none**
Length limitation (feet): **none**
Depth limitation (feet): **8**
CARD D: Infiltration rate choice: **B**

NOTE: Choose design number 2 for your results to be consistent with those presented in this manual

Sub-basin 2 BMP site 2:

CARD A: Amount of runoff (inches) handled by trench structure: **4**
CARD B: Water table depth (feet): **20**
CARD C: Width limitation (feet): **none**
Length limitation (feet): **none**
Depth limitation (feet): **10**
CARD D: Infiltration rate choice: **B**

NOTE: Choose design number 2 for your results to be consistent with those presented in this manual

Sub-basin 1 BMP site 1:

CARD A: Storage-Indication Curve and Rating Curve Data:

Maximum elevation in this data: **5**
Elevation increments (feet): **1**

H	Storage (cu. ft.)	Outflow (cfs)
0	0	0
1	30000	60
2	80000	170
3	200000	312
4	400000	480
5	650000	671

DATA FOR THE FUTURE CONDITION:

Subarea	BMP Site	Area (acres)	RCN	TC (hrs)	TT (hrs)	Runoff or Storage (in / cu.ft)
1.00	0.00	250.00	77.20	0.43	0.17	5.30
1.00	1.00	100.00	79.75	0.30	0.31	0.77E+06
2.00	0.00	750.00	81.07	0.28	0.00	5.75
2.00	1.00	5.00	98.00	0.14	0.20	5.00
2.00	2.00	20.00	74.00	0.12	0.10	4.00

NOTE: The values given for runoff from the BMP sites show the amount of runoff the infiltration structure (will) handle(s) or the maximum storage (cubic feet) of the detention pond(s).

Press RETURN to continue . . .

COST ANALYSIS

Subarea	BMP Site	Runoff or Storage (in / cu.ft)	Total Cost ($)
1.00	1.00	0.77E+06	102021.20
2.00	1.00	5.00	343994.10
2.00	2.00	4.00	777344.40

Total costs for the BMP structure include construction costs, contingency costs, and operation and maintenance costs. The figures quoted above are in fourth quarter 1980 dollars and do NOT reflect the cost of the land.

Press RETURN to continue

The runoff hydrograph for the future condition includes:

FOR SUBAREA 1

TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	40.2	13.4	121.5
11.2	57.4	13.6	106.6
11.4	90.0	13.8	96.5
11.6	226.1	14.0	87.0
11.8	455.5	14.2	81.1
12.0	872.3	14.4	75.5
12.2	944.8	14.6	70.7
12.4	603.8	14.8	66.5
12.6	363.6	15.0	62.5
12.8	235.0	16.0	50.3
13.0	173.1	18.0	37.2
13.2	141.6	20.0	17.4

This hydrograph reflects the presence of BMP structures in the future condition watershed.

Press RETURN to continue. . .

The runoff hydrograph for the future condition includes:

FOR SUBAREA 2

TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	140.8	13.4	353.1
11.2	199.7	13.6	319.7
11.4	258.5	13.8	293.9
11.6	650.2	14.0	268.2
11.8	2336.4	14.2	250.4
12.0	4322.3	14.4	232.6
12.2	2273.6	14.6	218.1
12.4	1145.2	14.8	206.9
12.6	788.7	15.0	195.8
12.8	550.1	16.0	157.8
13.0	462.8	18.0	118.3
13.2	394.3	20.0	92.0

This hydrograph reflects the presence of BMP structures in the future condition watershed.

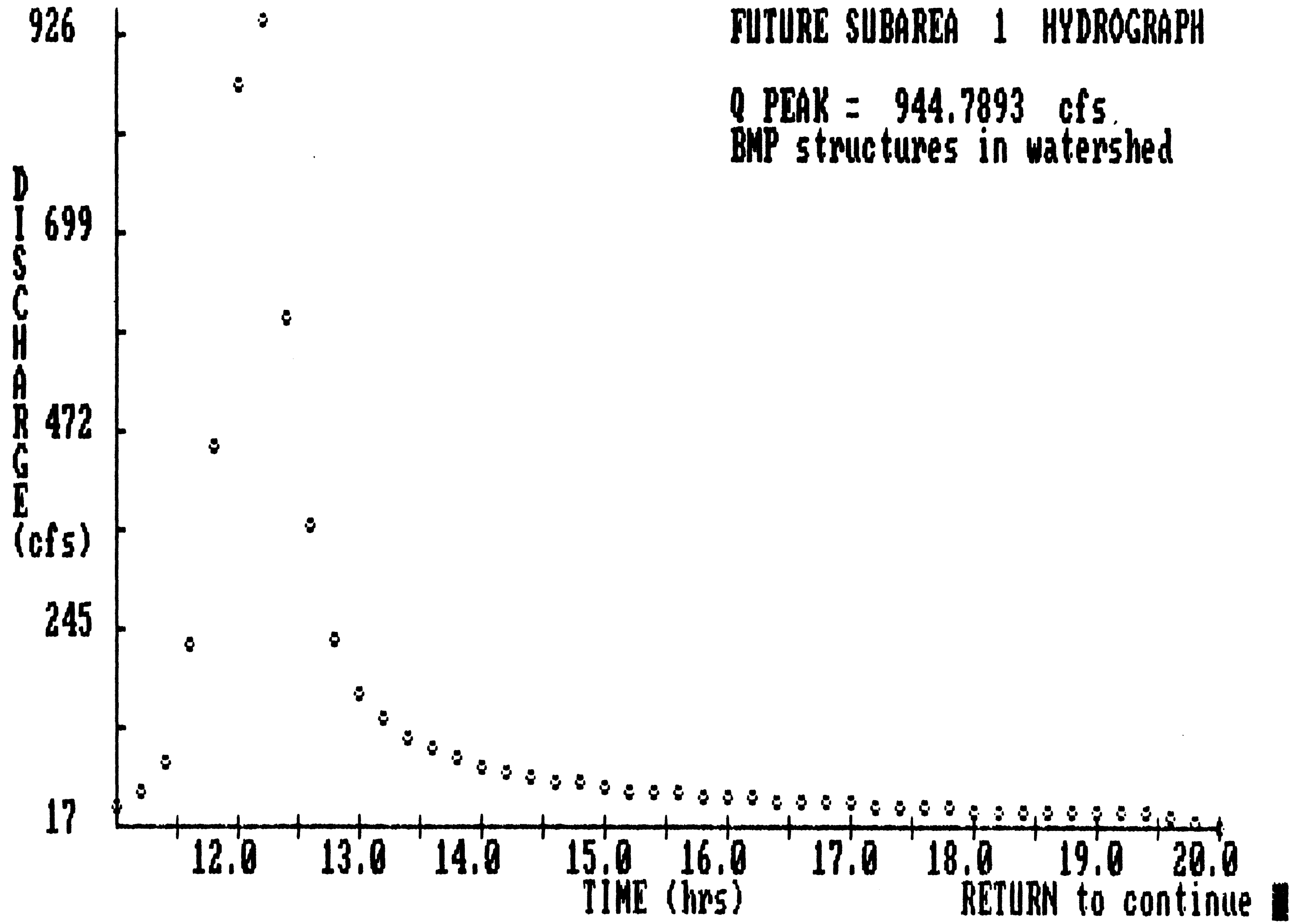
Press RETURN to continue. . .

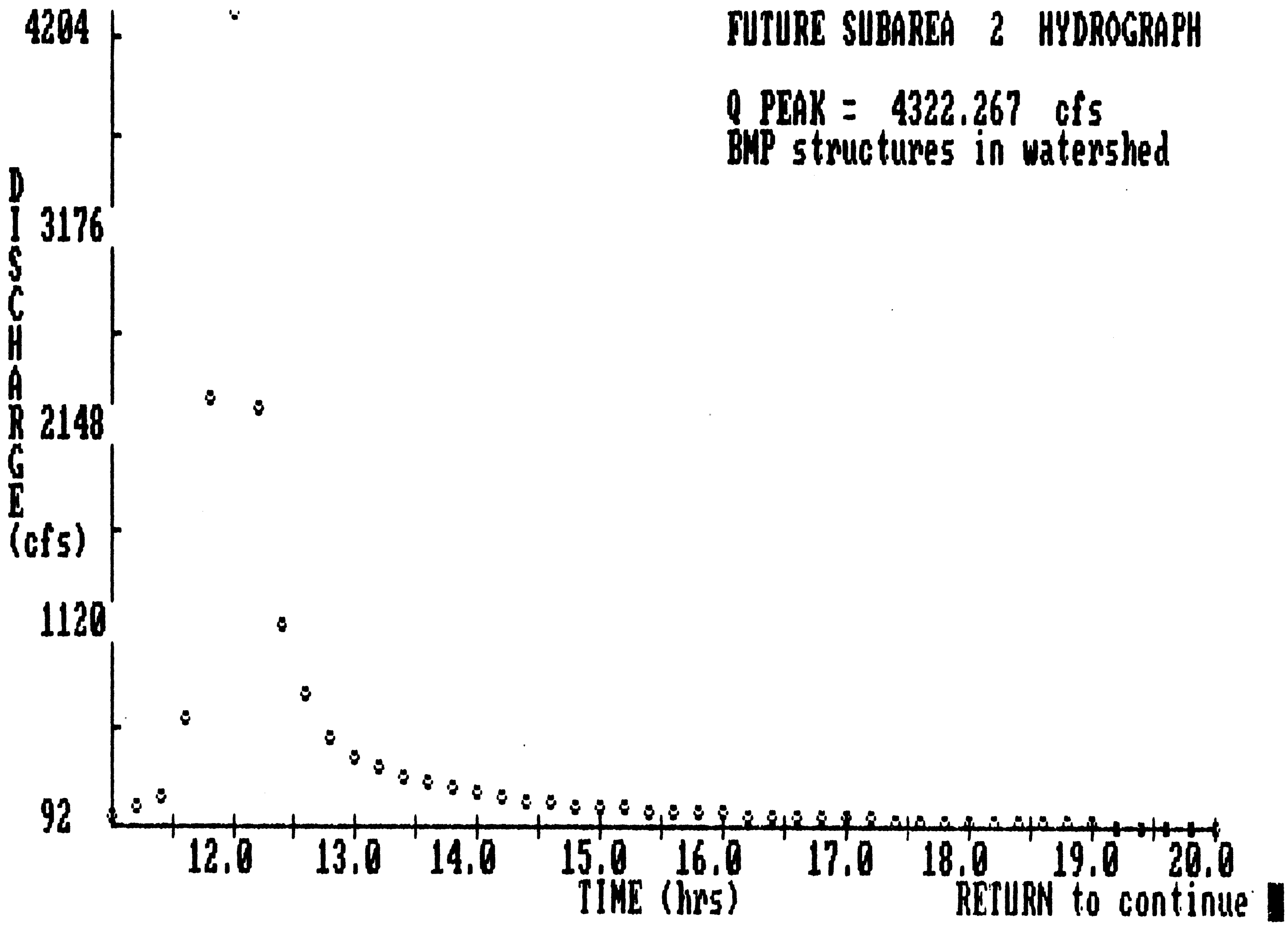
The total composite hydrograph for the future condition:

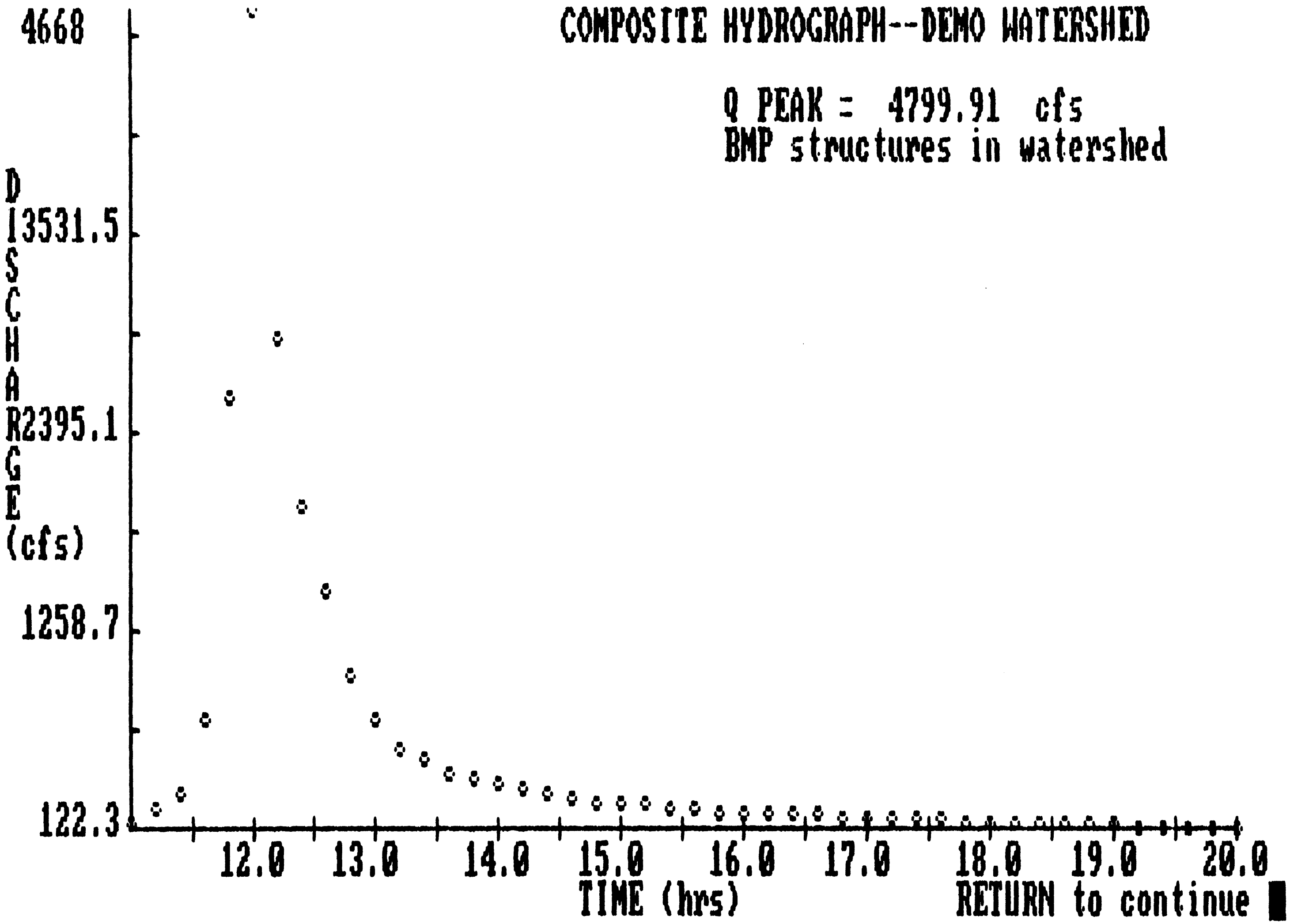
TIME(hours)	HYD ORD(cfs)	TIME(hours)	HYD ORD(cfs)
11.0	159.3	13.4	506.2
11.2	225.0	13.6	448.1
11.4	309.3	13.8	406.9
11.6	742.3	14.0	367.0
11.8	2592.7	14.2	341.0
12.0	4799.9	14.4	315.6
12.2	2924.3	14.6	294.8
12.4	1967.2	14.8	278.4
12.6	1482.4	15.0	262.4
12.8	1007.5	16.0	211.6
13.0	753.2	18.0	158.1
13.2	586.2	20.0	122.3

This hydrograph reflects the presence of BMP structures in the future condition watershed.

Press RETURN to continue. . .


FUTURE SUBAREA 1 HYDROGRAPH
Q PEAK = 944.7893 cfs.
BMP structures in watershed
DISCHARGE (cfs)
926
699
472
245
17
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue


FUTURE SUBAREA 2 HYDROGRAPH
Q PEAK = 4322.267 cfs
BMP structures in watershed
DISCHARGE (cfs)
4204
3176
2148
1120
92
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue


COMPOSITE HYDROGRAPH--DEMO WATERSHED
Q PEAK = 4799.91 cfs
BMP structures in watershed
DISCHARGE (cfs)
4668
3531.5
2395.1
1258.7
122.3
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
TIME (hrs)
RETURN to continue

POLLUTANT LOADINGS:

CARD A: Number of dry days: **10**

CARD B: SUB-BASIN LOADINGS

Sub-basin 1:	Pollutant Total Suspended Solids Impervious Loading: **0.5** Pervious Loading:` **2.0**
	Pollutant BOD Impervious Loading: **0.09** Pervious Loading: **0.04**
	Pollutant Nitrogen Impervious Loading: **0.015** Pervious Loading: **0.05**
	Pollutant Phosphorus Impervious Loading: **0.013** Pervious Loading: **0.005**
Sub-basin 2--Land Use 1:	Pollutant Total Suspended Solids Impervious Loading: **2.5** Pervious Loading: **0.7**
	Pollutant BOD Impervious Loading: **0.76** Pervious Loading: **0.07**
	Pollutant Nitrogen Impervious Loading: **0.09** Pervious Loading: **0.011**
	Pollutant Phosphorus Impervious Loading: **0.01** Pervious Loading: **0.0017**
Sub-basin 2--Land Use 2:	Pollutant Total Suspended Solids Impervious Loading: **5.5** Pervious Loading: **1.0**
	Pollutant BOD Impervious Loading: **0.2** Pervious Loading: **0.13**
	Pollutant Nitrogen Impervious Loading: **0.08** Pervious Loading: **0.02**
	Pollutant Phosphorus Impervious Loading: **0.01** Pervious Loading: **0.035**

FOR SUBAREA 1

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	1.17219	8.0-9.0	2.90662
1.0-2.0	2.12571	9.0-10.0	22.35402
2.0-3.0	1.52322	10.0-11.0	66.72811
3.0-4.0	0.91494	11.0-12.0	33.67652
4.0-5.0	0.48881	12.0-13.0	0.00000
5.0-6.0	0.23667	13.0-14.0	0.00000
6.0-7.0	0.10236	14.0-15.0	0.00000
7.0-8.0	0.03692	15.0-16.0	0.00000

This pollutograph is for the pollutant Total Suspended Solids
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

FOR SUBAREA 2

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	399.75140	8.0-9.0	3.51098
1.0-2.0	724.92700	9.0-10.0	3.68295
2.0-3.0	519.46260	10.0-11.0	10.51590
3.0-4.0	312.02210	11.0-12.0	4.66966
4.0-5.0	166.69770	12.0-13.0	0.00000
5.0-6.0	80.71088	13.0-14.0	0.00000
6.0-7.0	34.90730	14.0-15.0	0.00000
7.0-8.0	12.58938	15.0-16.0	0.00000

This pollutograph is for the pollutant Total Suspended Solids
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

________________________FOR SUBAREA 1 ________________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.21099	8.0-9.0	0.05957
1.0-2.0	0.38263	9.0-10.0	0.44716
2.0-3.0	0.27418	10.0-11.0	1.33456
3.0-4.0	0.16469	11.0-12.0	0.67353
4.0-5.0	0.08799	12.0-13.0	0.00000
5.0-6.0	0.04260	13.0-14.0	0.00000
6.0-7.0	0.01842	14.0-15.0	0.00000
7.0-8.0	0.00664	15.0-16.0	0.00000

This pollutograph is for the pollutant BOD
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

________________________FOR SUBAREA 2 ________________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	40.52541	8.0-9.0	0.35712
1.0-2.0	73.49057	9.0-10.0	0.38254
2.0-3.0	52.66131	10.0-11.0	1.09347
3.0-4.0	31.63172	11.0-12.0	0.48556
4.0-5.0	16.89923	12.0-13.0	0.00000
5.0-6.0	8.18219	13.0-14.0	0.00000
6.0-7.0	3.53878	14.0-15.0	0.00000
7.0-8.0	1.27627	15.0-16.0	0.00000

This pollutograph is for the pollutant BOD
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

FOR SUBAREA 1

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.03517	8.0-9.0	0.07271
1.0-2.0	0.06377	9.0-10.0	0.55885
2.0-3.0	0.04570	10.0-11.0	1.66820
3.0-4.0	0.02745	11.0-12.0	0.84191
4.0-5.0	0.01466	12.0-13.0	0.00000
5.0-6.0	0.00710	13.0-14.0	0.00000
6.0-7.0	0.00307	14.0-15.0	0.00000
7.0-8.0	0.00111	15.0-16.0	0.00000

This pollutograph is for the pollutant Nitrogen
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

FOR SUBAREA 2

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	7.89792	8.0-9.0	0.06778
1.0-2.0	14.32244	9.0-10.0	0.06053
2.0-3.0	10.26307	10.0-11.0	0.17123
3.0-4.0	6.16465	11.0-12.0	0.07604
4.0-5.0	3.29346	12.0-13.0	0.00000
5.0-6.0	1.59461	13.0-14.0	0.00000
6.0-7.0	0.68967	14.0-15.0	0.00000
7.0-8.0	0.24873	15.0-16.0	0.00000

This pollutograph is for the pollutant Nitrogen
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

----------------------FOR SUBAREA 1 ---------------------

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.03048	8.0-9.0	0.00748
1.0-2.0	0.05527	9.0-10.0	0.05590
2.0-3.0	0.03960	10.0-11.0	0.16682
3.0-4.0	0.02379	11.0-12.0	0.08419
4.0-5.0	0.01271	12.0-13.0	0.00000
5.0-6.0	0.00615	13.0-14.0	0.00000
6.0-7.0	0.00266	14.0-15.0	0.00000
7.0-8.0	0.00096	15.0-16.0	0.00000

This pollutograph is for the pollutant Phosphorus
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

----------------------FOR SUBAREA 2 ---------------------

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.93869	8.0-9.0	0.01026
1.0-2.0	1.70226	9.0-10.0	0.02416
2.0-3.0	1.21979	10.0-11.0	0.07101
3.0-4.0	0.73268	11.0-12.0	0.03153
4.0-5.0	0.39144	12.0-13.0	0.00000
5.0-6.0	0.18952	13.0-14.0	0.00000
6.0-7.0	0.08197	14.0-15.0	0.00000
7.0-8.0	0.02956	15.0-16.0	0.00000

This pollutograph is for the pollutant Phosphorus
for future conditions
without the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	401.13310	8.0-9.0	6.93698
1.0-2.0	727.43260	9.0-10.0	30.03139
2.0-3.0	521.25800	10.0-11.0	89.16759
3.0-4.0	313.10050	11.0-12.0	62.86268
4.0-5.0	167.27380	12.0-13.0	0.00000
5.0-6.0	80.98984	13.0-14.0	0.00000
6.0-7.0	35.02795	14.0-15.0	0.00000
7.0-8.0	12.63289	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant Total Suspended Solids
without the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	40.77411	8.0-9.0	0.42733
1.0-2.0	73.94157	9.0-10.0	0.90960
2.0-3.0	52.98448	10.0-11.0	2.66650
3.0-4.0	31.82584	11.0-12.0	1.64942
4.0-5.0	17.00294	12.0-13.0	0.00000
5.0-6.0	8.23240	13.0-14.0	0.00000
6.0-7.0	3.56050	14.0-15.0	0.00000
7.0-8.0	1.28410	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant BOD
without the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	7.93937	8.0-9.0	0.15348
1.0-2.0	14.39761	9.0-10.0	0.71924
2.0-3.0	10.31693	10.0-11.0	2.13753
3.0-4.0	6.19700	11.0-12.0	1.53086
4.0-5.0	3.31074	12.0-13.0	0.00000
5.0-6.0	1.60298	13.0-14.0	0.00000
6.0-7.0	0.69329	14.0-15.0	0.00000
7.0-8.0	0.25003	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant Nitrogen
without the presence of BMP structures within the watershed

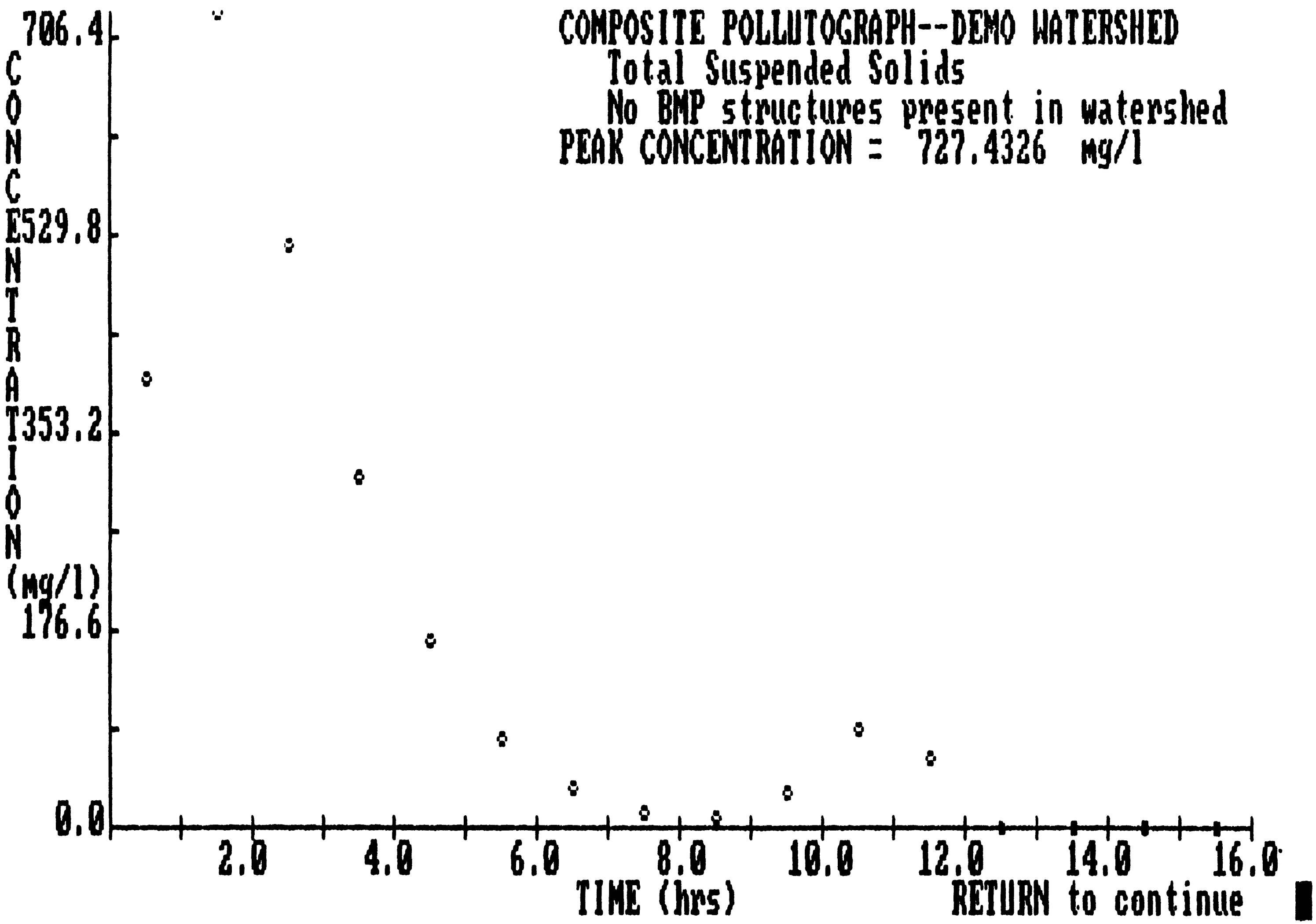
Press RETURN to continue

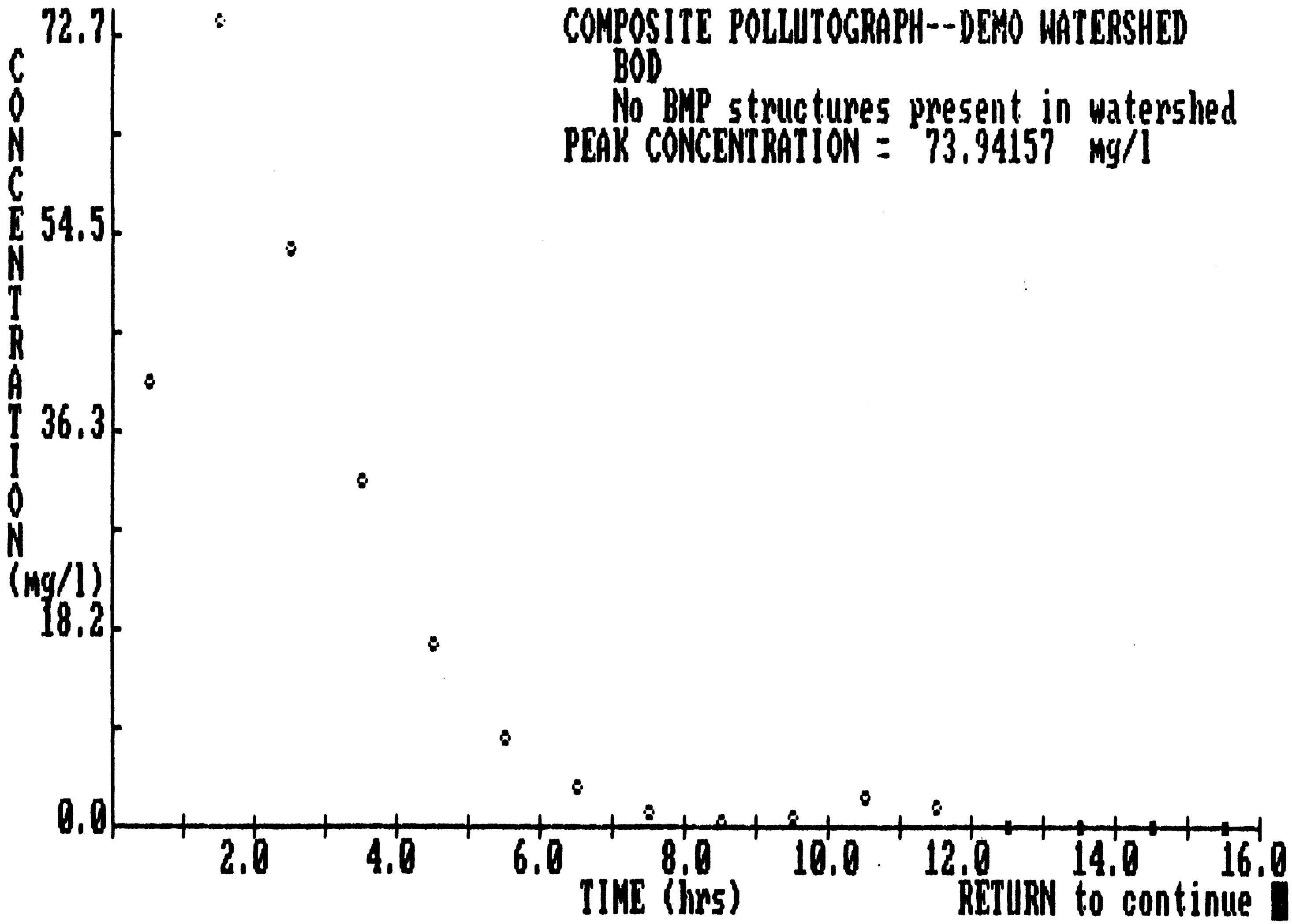
____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

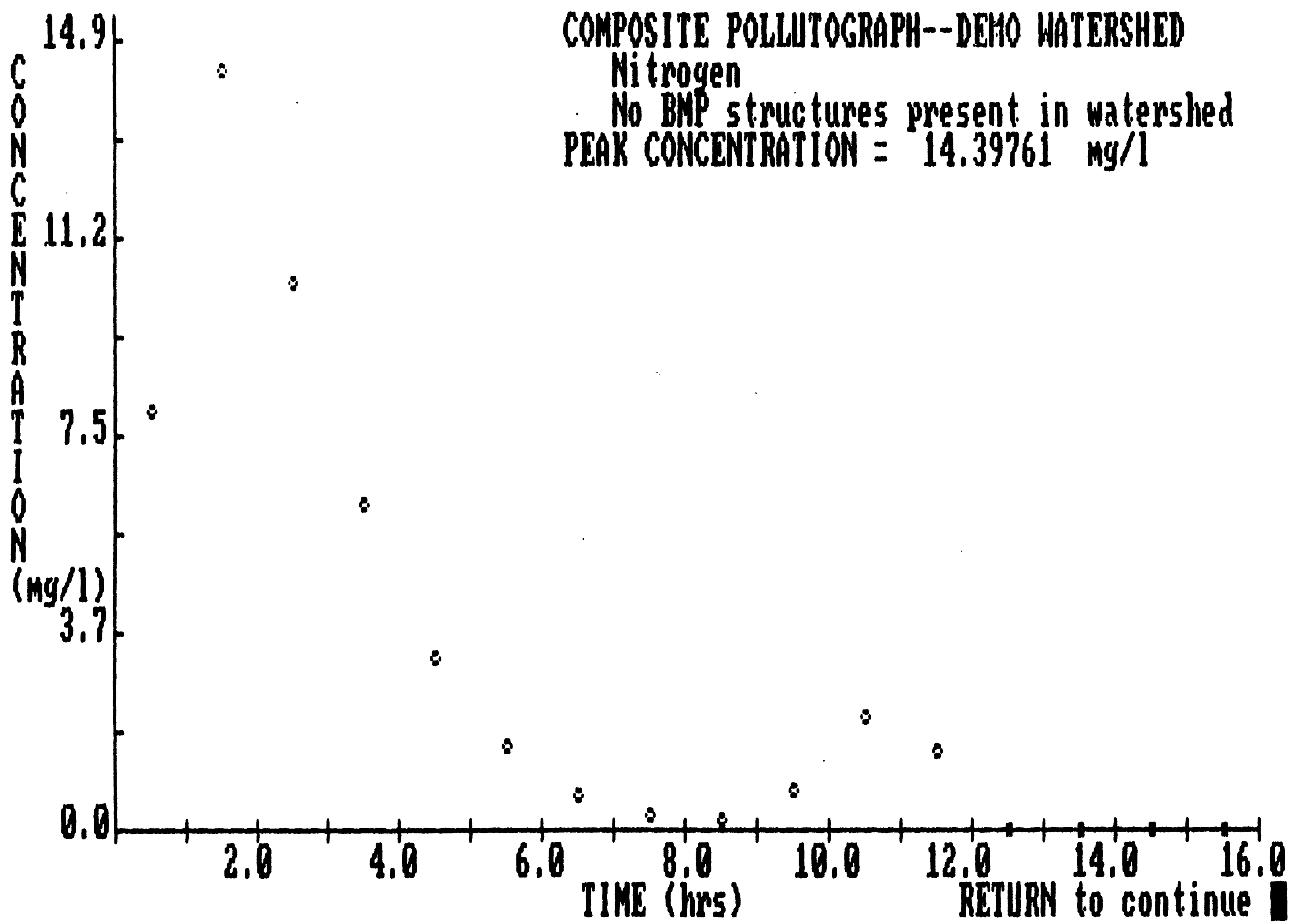
TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.97461	8.0-9.0	0.01907
1.0-2.0	1.76740	9.0-10.0	0.09005
2.0-3.0	1.26647	10.0-11.0	0.26763
3.0-4.0	0.76072	11.0-12.0	0.17701
4.0-5.0	0.40642	12.0-13.0	0.00000
5.0-6.0	0.19678	13.0-14.0	0.00000
6.0-7.0	0.08511	14.0-15.0	0.00000
7.0-8.0	0.03069	15.0-16.0	0.00000

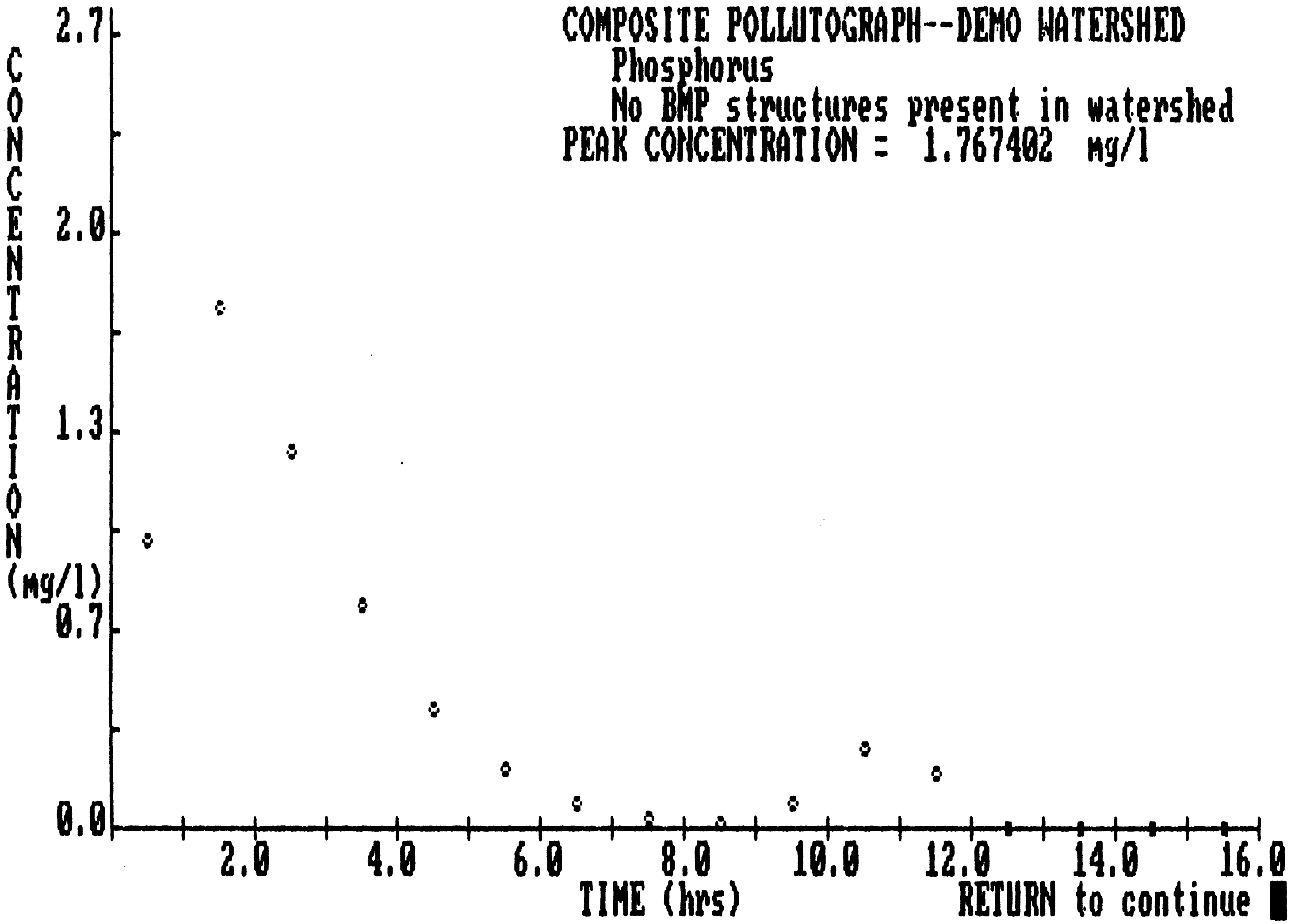
This pollutograph is for future conditions
for the pollutant Phosphorus
without the presence of BMP structures within the watershed

Press RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Total Suspended Solids
No BMP structures present in watershed
PEAK CONCENTRATION = 727.4326 mg/l
CONCENTRATION (mg/l)
706.4
529.8
353.2
176.6
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
BOD
No BMP structures present in watershed
PEAK CONCENTRATION = 73.94157 mg/l
CONCENTRATION (mg/l)
72.7
54.5
36.3
18.2
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Nitrogen
No BMP structures present in watershed
PEAK CONCENTRATION = 14.39761 mg/l
CONCENTRATION (mg/l)
14.9
11.2
7.5
3.7
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Phosphorus
No BMP structures present in watershed
PEAK CONCENTRATION = 1.767402 mg/l
CONCENTRATION (mg/l)
2.7
2.0
1.3
0.7
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue

CARD D: BMP SITE LOADINGS

Sub-basin 1 BMP site 1:

Pollutant Total Suspended Solids
Impervious Loading: 0.5
Pervious Loading: 2.0

Pollutant BOD
Impervious Loading: 0.09
Pervious Loading: 0.04

Pollutant Nitrogen
Impervious Loading: 0.015
Pervious Loading: 0.05

Pollutant Phosphorus
Impervious Loading: 0.013
Pervious Loading: 0.005

Sub-basin 2 BMP site 1:

Pollutant Total Suspended Solids
Impervious Loading: 5.5
Pervious Loading: 1.0

Pollutant BOD
Impervious Loading: 0.2
Pervious Loading: 0.13

Pollutant Nitrogen
Impervious Loading: 0.08
Pervious Loading: 0.02

Pollutant Phosphorus
Impervious Loading: 0.01
Pervious Loading: 0.035

Sub-basin 2 BMP site 2:

Pollutant Total Suspended Solids
Impervious Loading: 2.5
Pervious Loading: 0.7

Pollutant BOD
Impervious Loading: 0.76
Pervious Loading: 0.07

Pollutant Nitrogen
Impervious Loading: 0.09
Pervious Loading: 0.011

Pollutant Phosphorus
Impervious Loading: 0.01
Pervious Loading: 0.0017

FOR SUBAREA 1

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.69925	8.0-9.0	2.04196
1.0-2.0	1.62939	9.0-10.0	17.03850
2.0-3.0	1.13521	10.0-11.0	56.61578
3.0-4.0	0.65564	11.0-12.0	38.81255
4.0-5.0	0.33725	12.0-13.0	0.00000
5.0-6.0	0.15888	13.0-14.0	0.00000
6.0-7.0	0.06814	14.0-15.0	0.00000
7.0-8.0	0.02495	15.0-16.0	0.00000

This pollutograph is for the pollutant Total Suspended Solids
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

FOR SUBAREA 2

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	400.71440	8.0-9.0	3.54719
1.0-2.0	735.28510	9.0-10.0	3.73023
2.0-3.0	526.23480	10.0-11.0	10.70864
3.0-4.0	315.56300	11.0-12.0	4.67593
4.0-5.0	168.32760	12.0-13.0	0.00000
5.0-6.0	81.41153	13.0-14.0	0.00000
6.0-7.0	35.19881	14.0-15.0	0.00000
7.0-8.0	12.70204	15.0-16.0	0.00000

This pollutograph is for the pollutant Total Suspended Solids
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

______________________FOR SUBAREA 1 ______________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.16796	8.0-9.0	0.05120
1.0-2.0	0.34020	9.0-10.0	0.39669
2.0-3.0	0.24109	10.0-11.0	1.23707
3.0-4.0	0.14264	11.0-12.0	0.79776
4.0-5.0	0.07512	12.0-13.0	0.00000
5.0-6.0	0.03601	13.0-14.0	0.00000
6.0-7.0	0.01552	14.0-15.0	0.00000
7.0-8.0	0.00563	15.0-16.0	0.00000

This pollutograph is for the pollutant BOD
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

______________________FOR SUBAREA 2 ______________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	40.60233	8.0-9.0	0.36084
1.0-2.0	74.52074	9.0-10.0	0.38832
2.0-3.0	53.33226	10.0-11.0	1.11513
3.0-4.0	31.98023	11.0-12.0	0.48763
4.0-5.0	17.05835	12.0-13.0	0.00000
5.0-6.0	8.25008	13.0-14.0	0.00000
6.0-7.0	3.56695	14.0-15.0	0.00000
7.0-8.0	1.28721	15.0-16.0	0.00000

This pollutograph is for the pollutant BOD
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

-----------------------FOR SUBAREA 1 ----------------------

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.02799	8.0-9.0	0.06250
1.0-2.0	0.05670	9.0-10.0	0.49578
2.0-3.0	0.04018	10.0-11.0	1.54633
3.0-4.0	0.02377	11.0-12.0	0.99720
4.0-5.0	0.01252	12.0-13.0	0.00000
5.0-6.0	0.00600	13.0-14.0	0.00000
6.0-7.0	0.00259	14.0-15.0	0.00000
7.0-8.0	0.00094	15.0-16.0	0.00000

This pollutograph is for the pollutant Nitrogen
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

-----------------------FOR SUBAREA 2 ----------------------

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	7.98112	8.0-9.0	0.06887
1.0-2.0	14.58880	9.0-10.0	0.06165
2.0-3.0	10.44521	10.0-11.0	0.17499
3.0-4.0	6.26699	11.0-12.0	0.07668
4.0-5.0	3.34463	12.0-13.0	0.00000
5.0-6.0	1.61820	13.0-14.0	0.00000
6.0-7.0	0.69971	14.0-15.0	0.00000
7.0-8.0	0.25245	15.0-16.0	0.00000

This pollutograph is for the pollutant Nitrogen
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

_______________________FOR SUBAREA 1 _______________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.02642	8.0-9.0	0.00679
1.0-2.0	0.05122	9.0-10.0	0.05173
2.0-3.0	0.03645	10.0-11.0	0.15864
3.0-4.0	0.02169	11.0-12.0	0.10054
4.0-5.0	0.01149	12.0-13.0	0.00000
5.0-6.0	0.00553	13.0-14.0	0.00000
6.0-7.0	0.00239	14.0-15.0	0.00000
7.0-8.0	0.00086	15.0-16.0	0.00000

This pollutograph is for the pollutant Phosphorus
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

_______________________FOR SUBAREA 2 _______________________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	0.95396	8.0-9.0	0.01048
1.0-2.0	1.73909	9.0-10.0	0.02478
2.0-3.0	1.24550	10.0-11.0	0.07287
3.0-4.0	0.74756	11.0-12.0	0.03206
4.0-5.0	0.39911	12.0-13.0	0.00000
5.0-6.0	0.19314	13.0-14.0	0.00000
6.0-7.0	0.08352	14.0-15.0	0.00000
7.0-8.0	0.03013	15.0-16.0	0.00000

This pollutograph is for the pollutant Phosphorus
for future conditions
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	401.29300	8.0-9.0	8.05213
1.0-2.0	737.11210	9.0-10.0	41.38285
2.0-3.0	527.47410	10.0-11.0	135.82550
3.0-4.0	316.25060	11.0-12.0	75.48876
4.0-5.0	168.66680	12.0-13.0	0.00000
5.0-6.0	81.56624	13.0-14.0	0.00000
6.0-7.0	35.26447	14.0-15.0	0.00000
7.0-8.0	12.72654	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant Total Suspended Solids
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	40.87561	8.0-9.0	0.47314
1.0-2.0	75.09288	9.0-10.0	1.26422
2.0-3.0	53.73646	10.0-11.0	3.84684
3.0-4.0	32.21832	11.0-12.0	1.94348
4.0-5.0	17.18322	12.0-13.0	0.00000
5.0-6.0	8.30975	13.0-14.0	0.00000
6.0-7.0	3.59266	14.0-15.0	0.00000
7.0-8.0	1.29654	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant BOD
and reflects the presence of BMP structures within the watershed

Press RETURN to continue

____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	8.02373	8.0-9.0	0.20685
1.0-2.0	14.67892	9.0-10.0	1.15737
2.0-3.0	10.50882	10.0-11.0	3.59256
3.0-4.0	6.30441	11.0-12.0	1.89601
4.0-5.0	3.36423	12.0-13.0	0.00000
5.0-6.0	1.62756	13.0-14.0	0.00000
6.0-7.0	0.70374	14.0-15.0	0.00000
7.0-8.0	0.25392	15.0-16.0	0.00000

This pollutograph is for future conditions
for the pollutant Nitrogen
and reflects the presence of BMP structures within the watershed

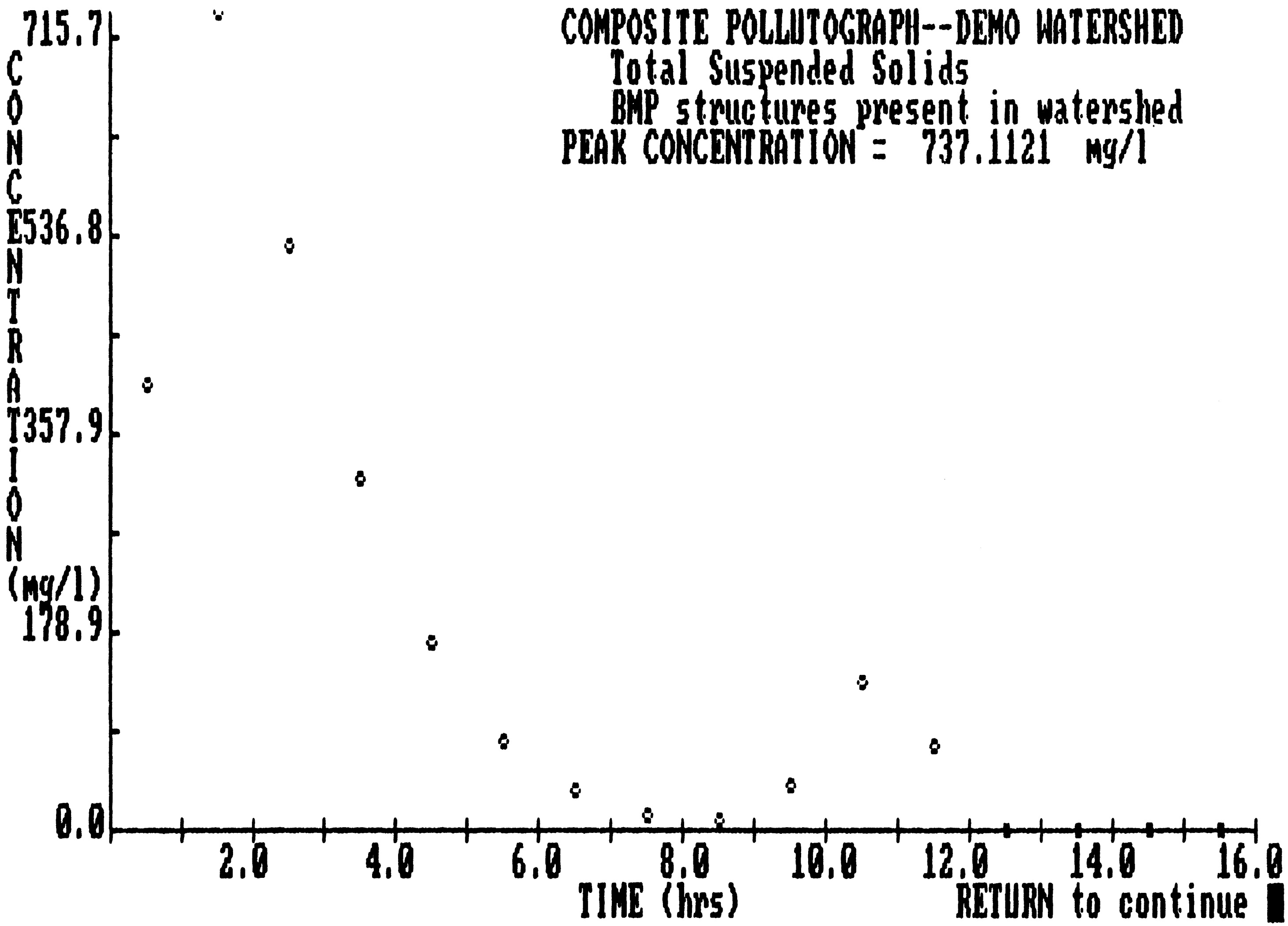
Press RETURN to continue

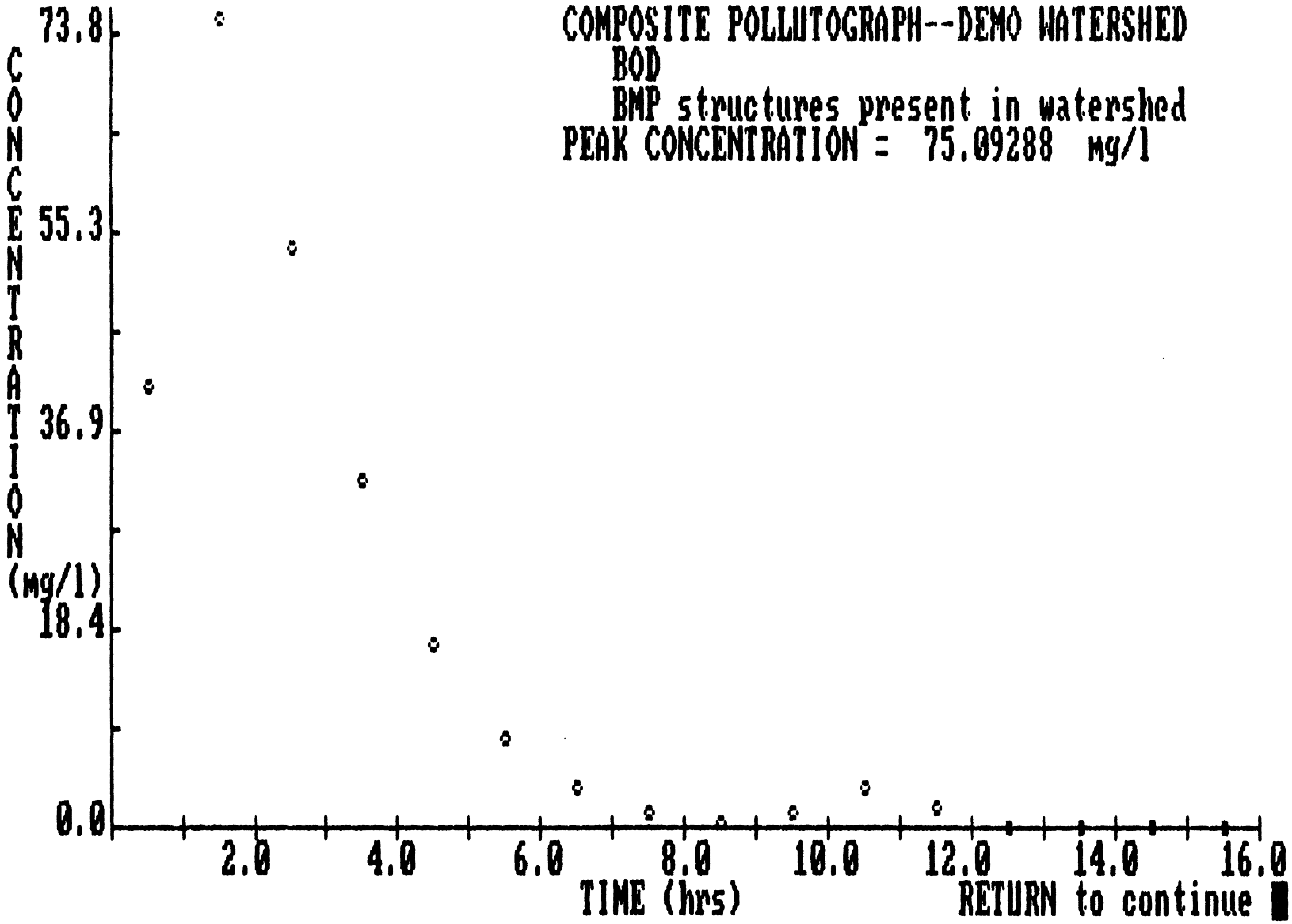
____________COMPOSITE POLLUTOGRAPH FOR DEMO WATERSHED____________

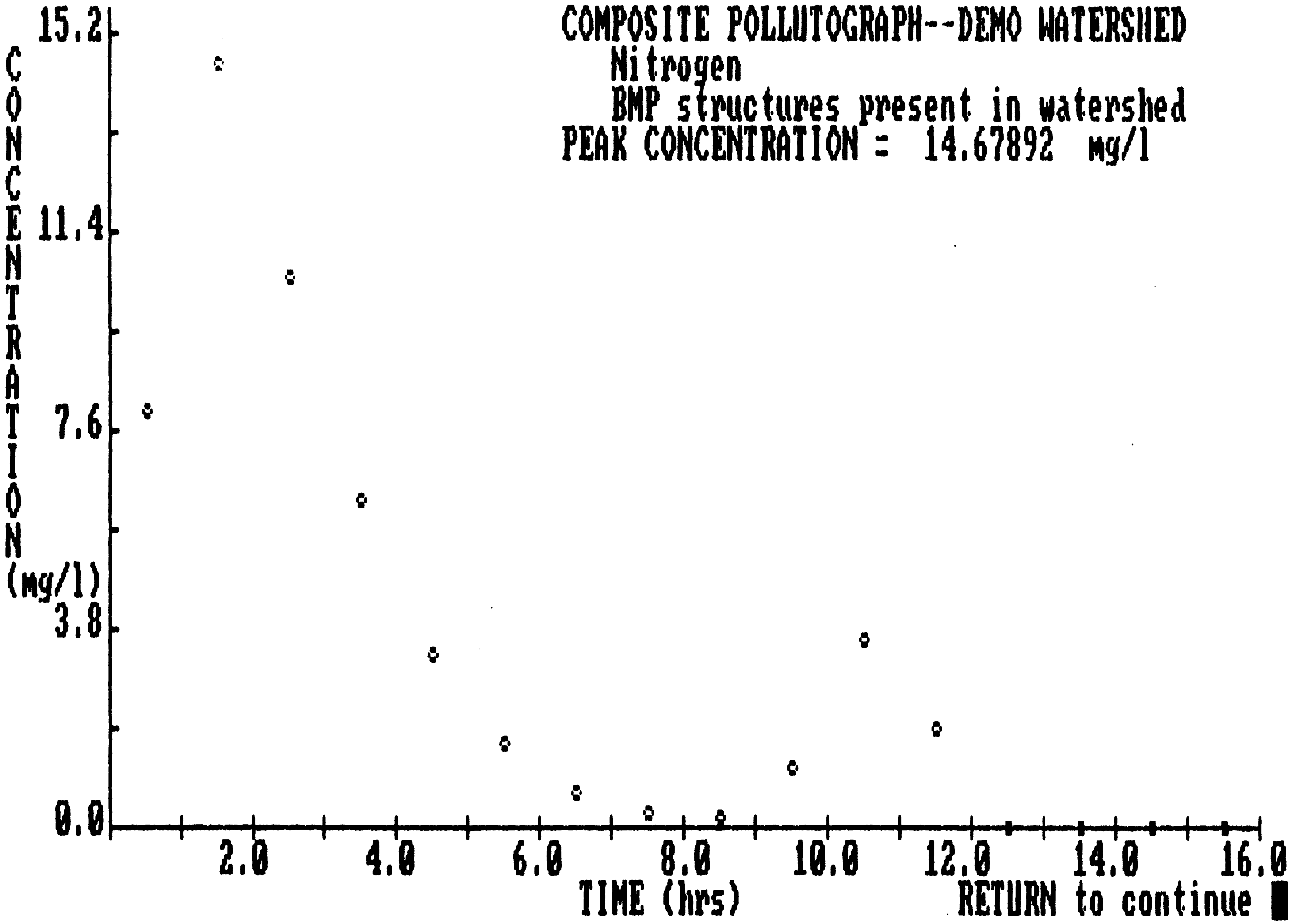
TIME(hour)	POLL. ORD.(mg/l)	TIME(hour)	POLL. ORD.(mg/l)
0.0-1.0	1.01005	8.0-9.0	0.02545
1.0-2.0	1.84810	9.0-10.0	0.13905
2.0-3.0	1.32306	10.0-11.0	0.42335
3.0-4.0	0.79371	11.0-12.0	0.21552
4.0-5.0	0.42354	12.0-13.0	0.00000
5.0-6.0	0.20490	13.0-14.0	0.00000
6.0-7.0	0.08860	14.0-15.0	0.00000
7.0-8.0	0.03197	15.0-16.0	0.00000

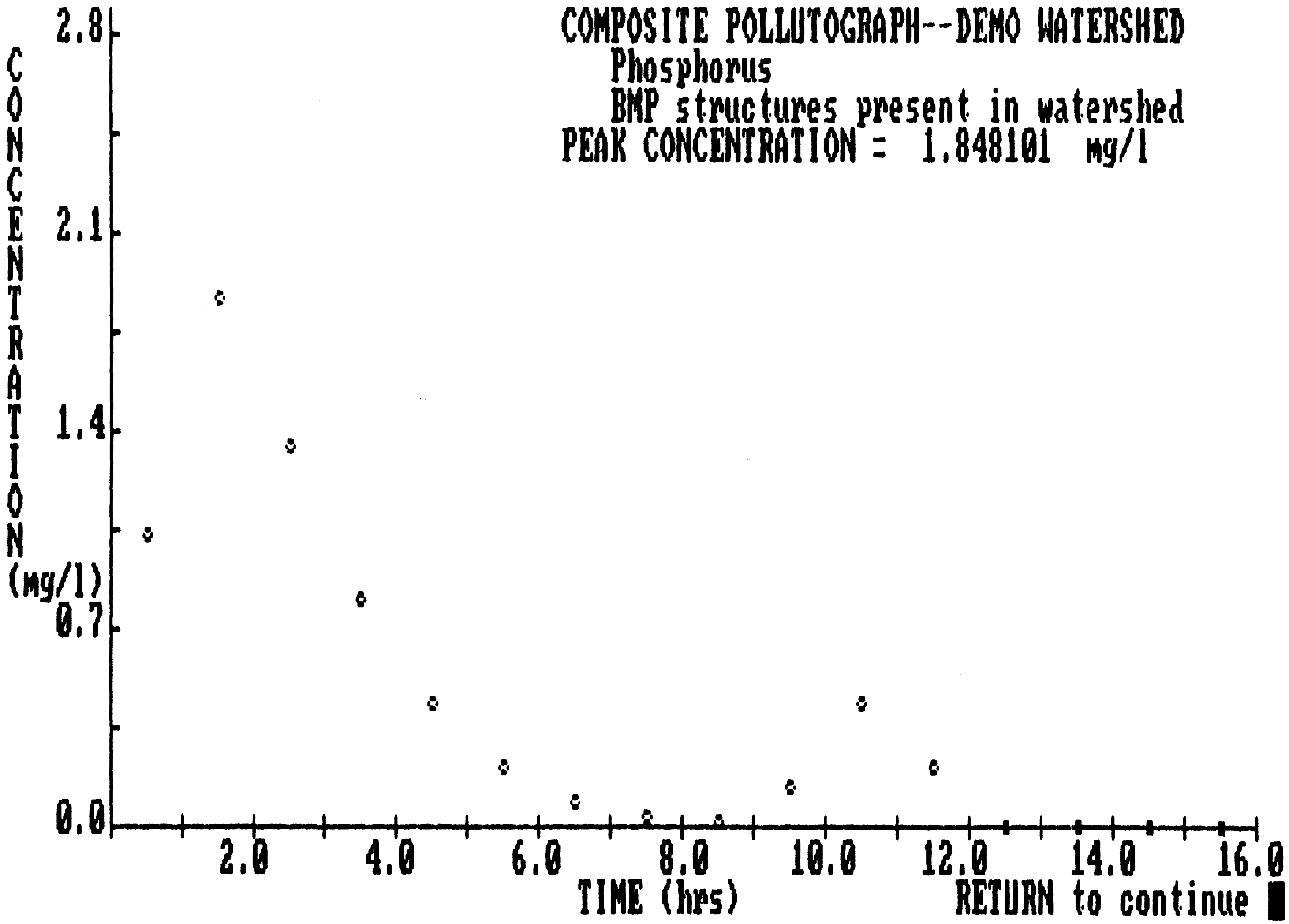
This pollutograph is for future conditions
for the pollutant Phosphorus
and reflects the presence of BMP structures within the watershed

Press RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Total Suspended Solids
BMP structures present in watershed
PEAK CONCENTRATION = 737.1121 mg/l
CONCENTRATION (mg/l)
715.7
536.8
357.9
178.9
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
BOD
BMP structures present in watershed
PEAK CONCENTRATION = 75.09288 mg/l
CONCENTRATION (mg/l)
73.8
55.3
36.9
18.4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Nitrogen
BMP structures present in watershed
PEAK CONCENTRATION = 14.67892 mg/l
CONCENTRATION (mg/l)
15.2
11.4
7.6
3.8
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue


COMPOSITE POLLUTOGRAPH--DEMO WATERSHED
Phosphorus
BMP structures present in watershed
PEAK CONCENTRATION = 1.848101 mg/l
CONCENTRATION (mg/l)
2.8
2.1
1.4
0.7
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
TIME (hrs)
RETURN to continue

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