WRE #349
Technical Memorandum

STORMWATER RUNOFF AND POLLUTANT MODEL (SRPM)

MODEL DOCUMENTATION

Version 1.3

by

Richard Z. Xue, P.E.

Resource Assessment Division
Water Resource Evaluation Department
South Florida Water Management District
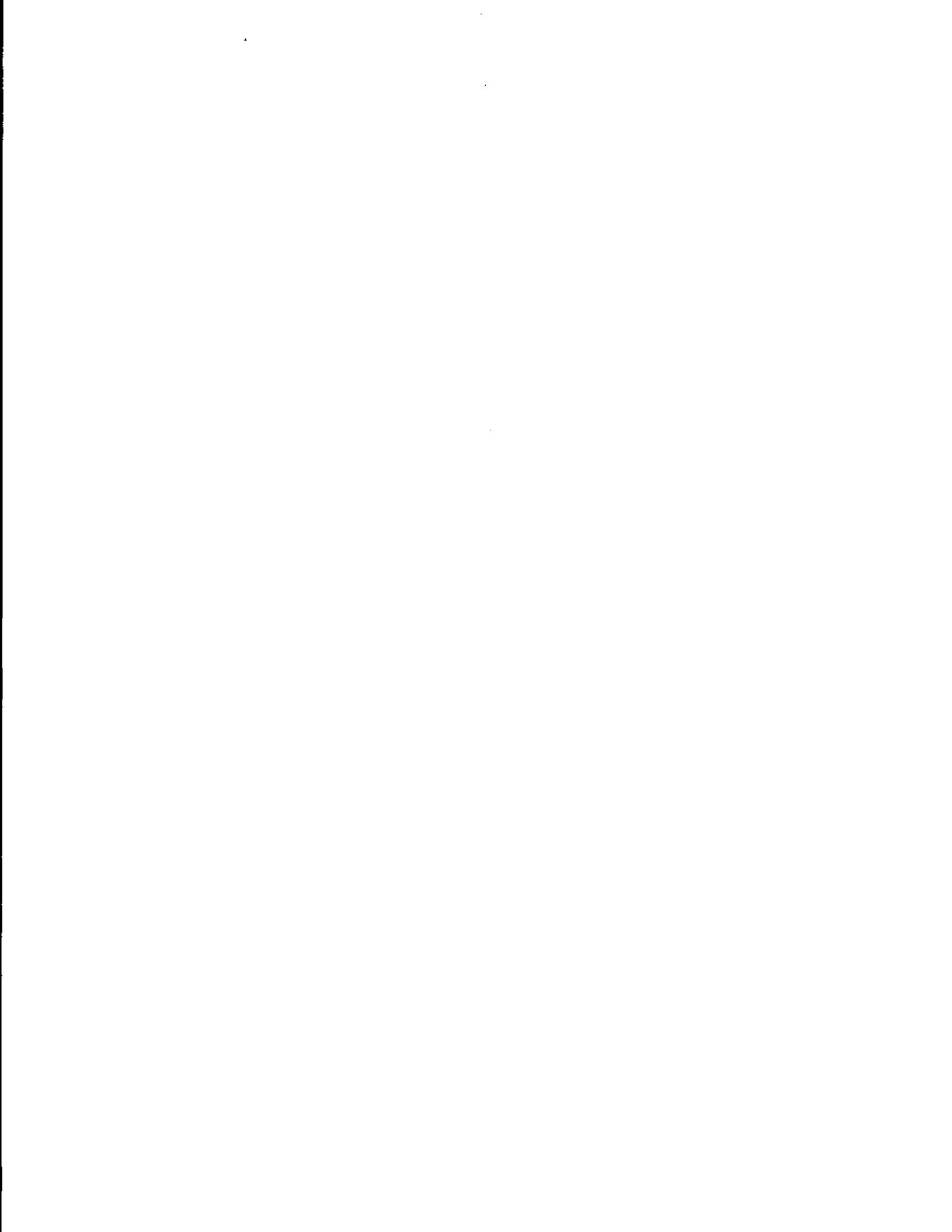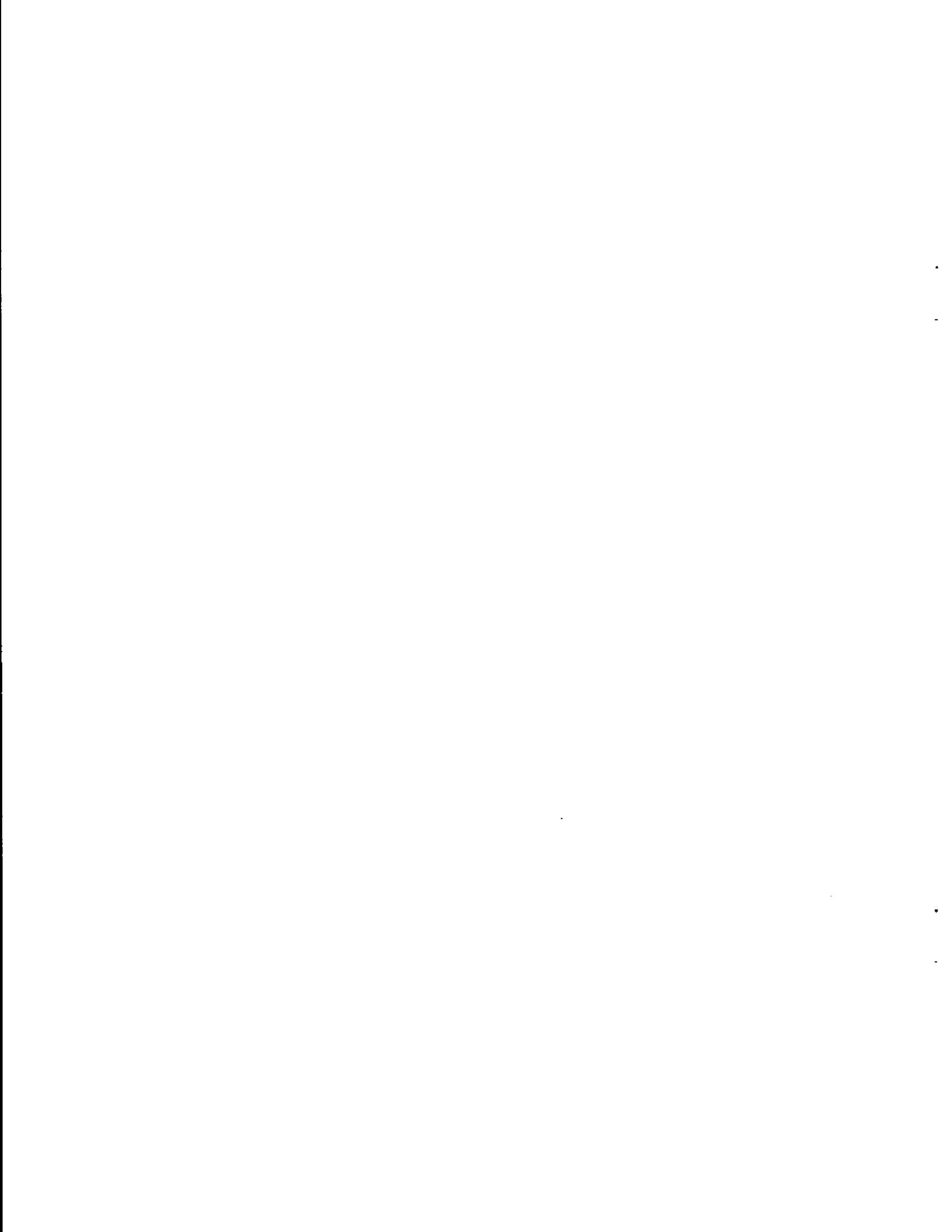West Palm Beach, FL 33406

December 1996

TABLE OF CONTENTS

i

APPENDIX B – FORTRAN PROGRAMS

APPENDIX C – SRPM OUTPUT

LIST OF TABLES

1. INTRODUCTION

Stormwater runoff and the associated pollutant loads have gained great attention in urban planning and design. Evaluation of alternative scenarios in urban development is needed to assess the environmental impacts on existing watersheds due to changes in land use. A watershed model is needed for this evaluation and can be used as a tool to predict future water quality impacts on receiving water and to assess urban stormwater management alternatives (Greene and Cruise, 1995). Watershed managers and planners need such a tool to estimate the relative water quality impact of subbasin discharges on downstream locations, which in turn helps to select appropriate watershed-wide stormwater management control alternatives (Shamsi, 1996).

Modeling the quantity and quality of stormwater runoff is difficult due to variation of such factors as land use, human activities, and meteorological conditions (Haster and James, 1994). A few existing watershed models are available to simulate stormwater runoff and its pollutant loads for different applications. The U.S. EPA (1992) defined three classes of watershed-scale models: (1) simple methods; (2) mid-range models; and (3) detailed models. Simple methods apply simplistic, statistical, and/or empirical equations to simulate annual averages of runoff and pollutant loads. These methods require historical monitoring data and their applications are usually limited to the areas for which the models were developed and to similar watersheds (U.S. EPA, 1992). Mid-range models describe the relationship of pollutant loadings to hydrologic and erosion processes on a monthly or seasonal basis. These models consider neither adsorption, degradation and transformation processes of pollutants, nor pollutant transport within and from the watershed (U.S. EPA, 1992). They can be applied for relative comparison analysis for watershed planning decisions. Detailed models simulate the physical hydrologic and pollutant transport and transformation processes in watershed areas at a small time step to account for effects of storm events, such as Areal Nonpoint Source
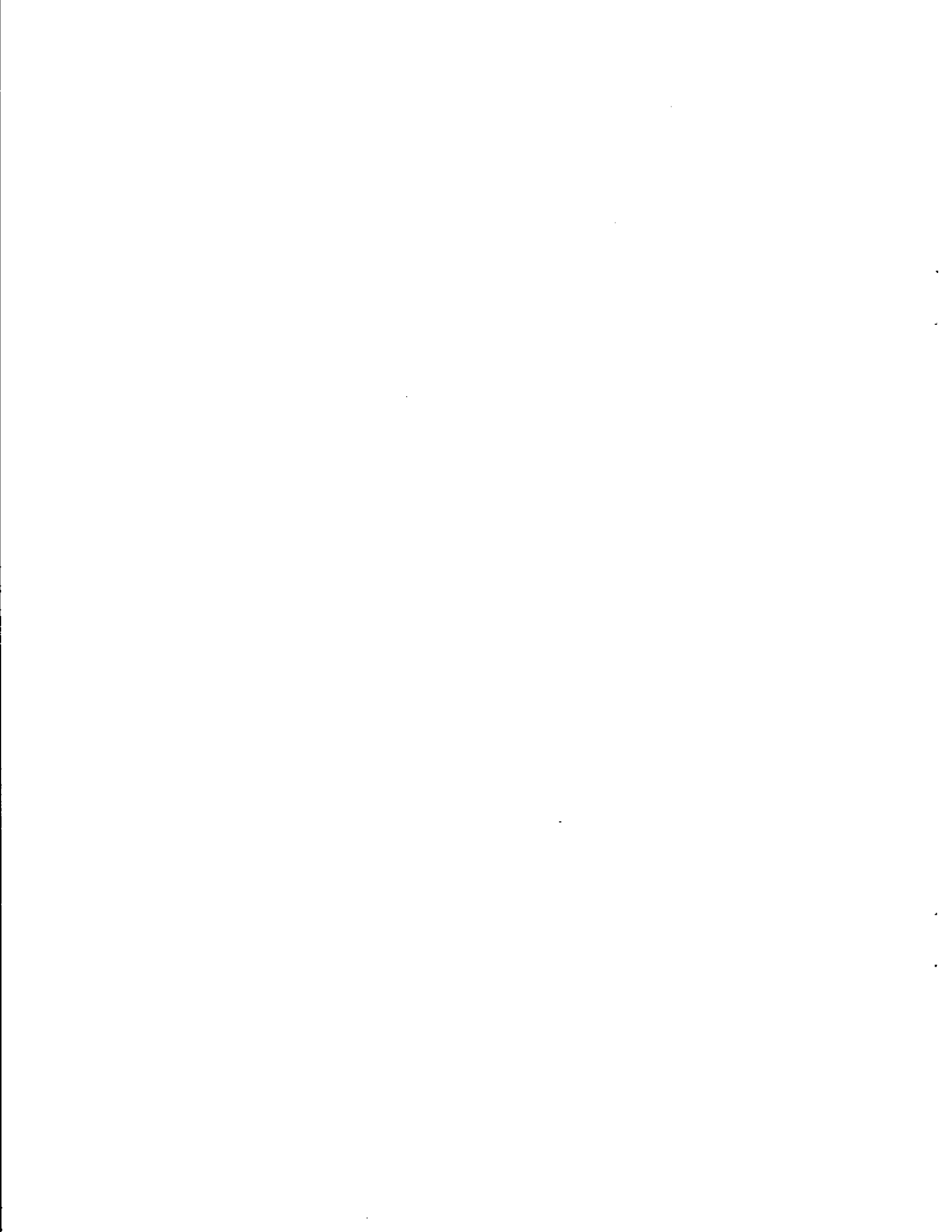
Watershed Environment Response Simulation (ANSWERS) (Beasley and Huggins, 1981), Distributed Routing Rainfall Runoff Model – Quality (DR3M-QUAL) (Alley and Smith, 1982), Hydrological Simulation Program – FORTRAN (HSPF) (U.S. EPA, 1993), Storage, Treatment, Overflow, Runoff Model (STORM) (U.S. Army Corps of Engineers, 1977), Storm Water Management Model (SWMM) (Huber et al., 1987), and Simulation for Water Resources in Rural Basins (SWRRB) (Arnold et al., 1989). Among these detailed models, ANSWERS and SWRRB were developed for agricultural areas; DR3M-QUALM, STORM, and SWMM were designed for urban areas; HSPF, on the other hand, can be applied to most complex watershed areas.

The HSPF model simulates hydrolysis, oxidation, photolysis, biodegradation, volatilization, and sorption processes to describe pollutant generation, transformation and transport from watersheds to, and within, receiving water bodies (U.S. EPA, 1993). Three distinct categories such as pervious lands, impervious lands, and stream channels are considered in HSPF. The model requires extensive input data, and highly trained personnel and team efforts, so that it is not suitable for the kind of evaluations being considered here.

DR3M-QUAL, supported by the U.S. Geologic Survey, and STORM, developed by the U.S. Army Corps of Engineers, are the detailed urban watershed models. Both models were designed to simulate limited pollutants, which do not meet the requirement of this study to allow users to define water quality constituents to be simulated. On the other hand, the SWMM model developed by the U.S. EPA (Huber et al., 1987) does allow users to specify up to ten pollutants of interest for simulation. However, SWMM also requires extensive input data and modeling effort.

As a part of the *Data Analysis and Modeling of Urban Stormwater Treatment Systems for Water Quality Compliance – Phase Two* project, a Stormwater Runoff and Pollutant Model (SRPM) was developed to simulate urban watershed runoff and the associated pollutant loads. The SRPM model is a simplified version of SWMM, requires minimum input data, and is easier to be
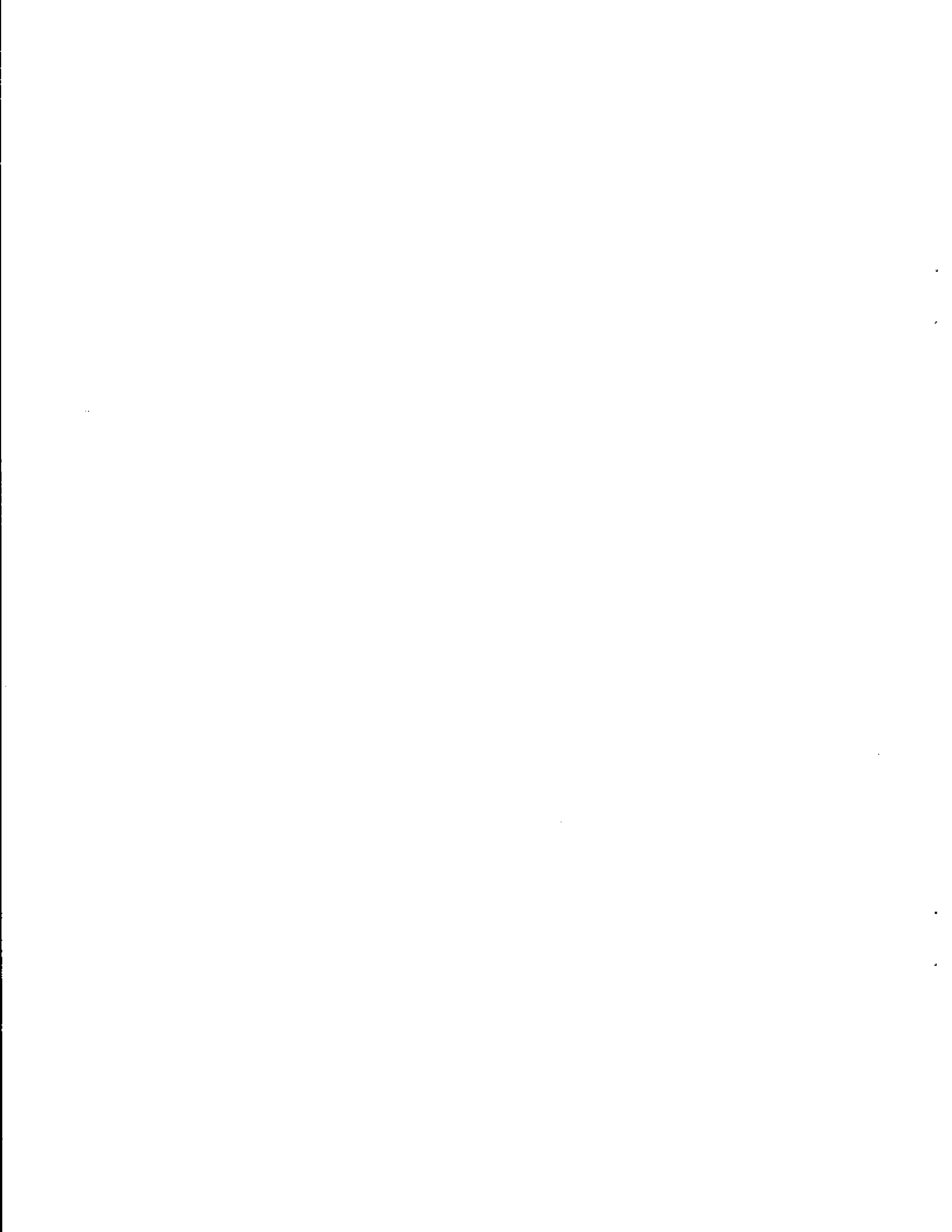
developed for a user-friendly interface with pre- and post- processors. SRPM was designed to link with a stand alone Best Management Practices Assessment Model (BMPAM) (Xue, 1996) and to integrate with a geographic information system (GIS) platform. Most hydrology and water quality simulation algorithms used in SRPM were adapted from the SWMM model. A reservoir flow routing method (Linsley and Franzini, 1964) was used in SRPM to speed up simulation time, instead of using the Newton-Raphson technique, to solve a nonlinear equation for hydrology simulation in SWMM (Nix, 1994). The SRPM model can run under either PC DOS or UNIX environments and provides reasonable simulation results with limited input data.

The objectives of the project " _Data Analysis and Modeling of Urban Stormwater Treatment Systems for Water Quality Compliance - Phase Two_ are: (1) to quantify the probabilities with which category of source and treatment system type will exceed applicable water quality standards as a function of season; and (2) to identify changes in design, operation, or maintenance parameters for each category that will reduce the frequency of occurrence of exceedences to acceptable levels as a function of season. In order to meet these objectives, three sub-projects were proposed: (1) correction and analysis of the SFWMD Stormwater Discharge Permit Database; (2) evaluation of performances of existing stormwater treatment systems; and (3) identification of changes in design, operation, or maintenance parameters to improve stormwater treatment systems.

Modeling tools will be used in the second sub-project to evaluate the performance of existing stormwater treatment systems and to provide necessary information for the following sub-project. The third sub-project will use statistical analysis results and apply calibrated and verified watershed model and BMP model in selected stormwater treatment facilities to identify the changes in design, operation, or maintenance parameters for improving pollutant removal efficiencies of selected stormwater treatment facilities. Recommendations and suggestions based on simulation results will be developed for future stormwater discharge monitoring programs for the Regulation Department.

3

With the BMP model developed for this project, SRPM can also be used by the Planning Department staff in watershed analysis to assess runoff and water quality impacts on receiving water bodies or downstream watersheds. The model with a GIS interface is a powerful tool to compare various stormwater management alternatives that occur as a result of new development of land uses and/or changes of human activities in a watershed or basin of interest.

2. DESCRIPTION OF SRPM MODEL

SRPM is a basin-scale hydrologic and water quality model which simulates storm-related surface runoff and the associated pollutant loads in a catchment or watershed. It was developed for urban watershed analysis, but can also be applied to other areas such as agricultural areas. The model was written in FORTRAN and can run under both PC DOS and UNIX operating systems.

SRPM is a continuous simulation model with an hourly time step. It can be used for a single storm event simulation or a long term (such as 10 years) continuous simulation. The outputs of simulated runoff, pollutant loads and concentrations are in standard time series ASCII formats that can be directly read by the BMPAM model described above.

An integrated GIS stormwater modeling tool was proposed to fulfill the stormwater modeling project. Due to the further development of linking SRPM and SBMPM with GIS, pre- and post-processors as well as channel/stream flow routines will be developed in the integrated GIS platform.

3. MODEL ALGORITHMS

3.1 Hydrology Simulation

The SRPM model allows users to simulate up to ten (10) sub-catchments in each

4

application run. Each sub-catchment represents a different land use type or percentage of pervious and impervious areas. The algorithm used in hydrologic simulation is similar to that used in the RUNOFF block in a U.S. EPA supported watershed model, the Storm Water Management Model (SWMM) (Huber et al., 1987). A sub-catchment is treated as a nonlinear reservoir with consideration of the processes of precipitation, evaporation, infiltration, depression, storage and surface runoff. Outflow (i.e. surface runoff) occurs only when water depth in the hypothetical reservoir exceeds the reservoir capacity which is defined by the maximum depression storage (Nix, 1994).

3.1.1 Overland flow

The rational method, Soil Conservation Service (SCS) curve number method, and Manning's equation are three most widely used methods of simulating stormwater runoff volume and peak discharges from watersheds. The rational method is an approximate deterministic model which uses a ratio of runoff to rainfall (runoff coefficient), rainfall intensity, and drainage basin area to estimate the peak flows in a watershed. This method does not consider temporary storage of runoff nor temporal and spatial variation of rainfall (Pilgrim and Cordery, 1993).

With the SCS curve number method, no runoff occurs until rainfall exceeds a specified initial abstraction. This method estimates runoff by utilizing a relationship between rainfall and a curve number. The curve number represents the soil type, land use coverage, hydrologic condition, and management practices of the land surface. The SCS curve number method does not provide accurate simulation results for small storm events, especially when runoff is less than 0.5 inch (Rawls et al., 1993).

Manning's equation is used for the hydrologic simulation in SRPM. The equation calculates overland flow velocity by using the parameters of hydraulic radius, slope, and the Manning roughness constant. The Manning roughness constant represents the land surface

condition and the land use type of a specific sub-catchment. The hydraulic radius is the ratio of the cross-sectional area of flow to the length of the wetted perimeter. The Manning's equation is defined for English units (Lindeburg, 1992) as:

$$v = \frac{1.49}{n} R^{2/3} S^{1/2}$$ (1)

where   v   = flow velocity (ft/s)

            n   = Manning roughness constant

            R   = hydraulic radius (ft)

            S   = slope of overland flow (ft/ft)

Because the depth of water flow is very small in overland flow from watersheds, the wetted perimeter can be approximated by the width of overland flow (Nix, 1994). Thus,

$$R = A_c / W = [W(d - d_p)] / W = d - d_p$$ (2)

where A_c = cross-sectional area of flow (ft^2)

            W   = width of overland flow (ft)

            d   = depth of water on the watershed (ft)

            d_p = depth of maximum depression storage (ft)

The Manning's equation can be rewritten as:

$$Q = A_c v = W(d - d_p) * \frac{1.49}{n} (d - d_p)^{2/3} S^{1/2} = W * \frac{1.49}{n} (d - d_p)^{5/3} S^{1/2}$$ (3)

where Q is runoff flow rate from a catchment (ft^3/s).

3.1.2 Evaporation

Observed pan evaporation records are used for the calculation of water depletion by the process of evaporation in watersheds. Actual evaporation is calculated based on the pan evaporation values by applying an evaporation coefficient. SRPM allows users to provide monthly evaporation coefficients to account for seasonal variations of the evaporation in a watershed. The calculated evaporation is subtracted from precipitation and/or the water stored in the watershed prior to calculating infiltration.

3.1.3 Infiltration

Horton Model

A three-parameter empirical infiltration model, the Horton Model, has been widely used to calculate the infiltration capacity into soil. The Horton model expresses that the infiltration capacity is equal to the maximum infiltration rate at the beginning of a storm event and then is reduced to a low constant rate as the soil becomes saturated (Rawls et al., 1993):

$$f_p = f_\infty + (f_0 - f_\infty) e^{-\alpha t} \tag{4}$$

where

t	= time from beginning of storm (sec)
t_p	= time at the end of simulation step (sec)
f_p	= infiltration capacity into soil at t= t_p (ft/s)
f_∞	= minimum or ultimative infiltration rate (ft/s)
f_0	= maximum or initial infiltration rate (ft/s)
α	= decay coefficient (1/sec)

The infiltration capacity calculated by Equation (4) is often less than the actual infiltration capacity because typical values for infiltration parameters are often greater than

typical rainfall intensities. The integrated form of Horton's equation (Huber et al., 1987) was selected in SRPM to solve this problem:

$$F(t_p) = \int_0^{t_p} f_p dt = f_\infty t_p + \frac{(f_0 - f_\infty)}{\alpha}(1 - e^{-\alpha t_p}) \qquad (5)$$

where $F(t_p)$ is cumulative infiltration at $t = t_p$ (ft).

The regeneration or recovery of infiltration capacity during dry weather is calculated for continuous simulation by the following equation (Huber et al., 1987):

$$f_p = f_0 - (f_o - f_\infty) e^{-\alpha_d (t - t_w)} \qquad (6)$$

where α_d = decay coefficient for the regeneration curve (1/sec)

            t_w = hypothetical projected time at which $f_p = f_\infty$ on the recovery curve (sec)

Due to the difficulty of determining the projected time t_w, Equation (6) can not be used directly. However, a combined equation was developed by Huber et al. (1987):

$$t_{p1} = t_p + \Delta t = -\frac{1}{\alpha} \ln[1 - e^{\alpha_d \Delta t}(1 - e^{\alpha t_{pr}})] \qquad (7)$$

where t_{p1} = new value of t_p for next time step (sec)

            t_{pr} = value of t_p at beginning of regeneration (sec)

            Δt = time step (sec)

Thus, the integrated form of Horton's equation can still be used by applying the calculated t_{p1} for the consideration of regeneration of infiltration. For the continuous simulation, t_{p1} will be substituted for t_{pr} and t_{p2} will be substituted for t_{p1}, etc. (Huber et al., 1987).

Green-Ampt Model

A more approximate physical theory utilizing Darcy's law, the Green-Ampt Model, was selected as another option for infiltration simulation in SRPM. The original model was developed for infiltration into a homogeneous soil with excess water at the surface at all time (Rawls et al., 1993). Mein and Larson (1973) modified the model for application of steady rainfall. The Mein-Larson formulation for infiltration rate for steady rainfall is a two-stage model (Huber et al., 1987):

For $F < F_s$:

$$f = R \text{ and}$$

$$F_s = \frac{S*IMD}{\frac{R}{K_s} - 1} \; for R > K_s \tag{8}$$

For $F \geq F_s$:

$$f = f_p \text{ and}$$

$$f_p = K_s (1 + \frac{S*IMD}{F}) \tag{9}$$

where
f	= infiltration rate (ft/s)
f_p	= infiltration capacity (ft/s)
R	= rainfall intensity (ft/s)
F	= cumulative infiltration volume for a storm event (ft)
F_s	= cumulative infiltration volume required to cause surface saturation (ft)
S	= average capillary suction at the wetting front (ft)
IMD	= initial moisture deficit for the storm event (ft/ft)
K_s	= saturated hydraulic conductivity of soil (ft/s)

3.1.4 Flow routing

Based on the principle of mass conservation, the difference between the inflow and outflow is equal to the rate of storage of water in a reservoir; that is,

$$\frac{dS}{dt} = I(t) - Q(t) \qquad (10)$$

where
    S   = storage volume of water (ft^3)

         I(t)   = inflow rate (ft^3/s)

         Q(t)   = outflow rate (ft^3/s)

Equation (10) is an ordinary differential equation that is not easily solvable. A simple hydrologic method of routing was presented by Chow (1959) and by Linsley and Franzini (1964):

$$\frac{\Delta S}{\Delta t} = I - O \qquad (11)$$

or

$$\frac{S_2 - S_1}{\Delta t} = \frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} \qquad (12)$$

where
    ΔS = change in storage of water during routing period (ft^3)

         S_2 = storage in the reservoir at the end of routing period (ft^3)

         S_1 = storage in the reservoir at the beginning of routing period (ft^3)

         Δt = routing period (sec)

         I   = average inflow during routing period (ft^3/s)

         I_1 = instantaneous inflow at the beginning of routing period (ft^3/s)

         I_2 = instantaneous inflow at the end of routing period (ft^3/s)

         O   = average outflow during routing period (ft^3/s)

O_1 = instantaneous outflow at the beginning of routing period (ft^3/s)

O_2 = instantaneous outflow at the end of routing period (ft^3/s)

Equation (12) can be rewritten as the following equation after grouping the unknowns and knowns on the each side of the equation:

$$\frac{1}{2} O_2 \Delta t + S_2 = \frac{1}{2} (I_1 + I_2) \Delta t + (S_1 - \frac{1}{2} O_1 \Delta t) \tag{13}$$

The variables on the right side of Equation (13) are known for a given time step while the two unknowns O_2 and S_2 on the left side of the equation can be solved after the relationship between O_2 and S_2 is determined. In a reservoir or a storage system, the geometric dimensions of the reservoir and the outflow structure rating data are usually given. Therefore, the relationship of O_2 with S_2, each of which is a function of storage depth, can be determined (Huber et al., 1987). This reservoir routing method was applied in the storage/treatment simulation routines of the SWMM model and is also used in SRPM for the simulation of flow routing.

3.2 Water Quality Simulation

Water quality simulation in watershed areas is difficult due to the different physical and chemical processes governing the fate and transport of pollutants, the effects of rainfall and watershed characteristics, and the land use practices (Haster and James, 1994). Both regression equations and deterministic models have been used for the simulation of pollutant loads. For SRPM, a deterministic model that includes build-up and washoff components was selected for the simulation of stormwater pollutant loads. The SRPM model can simulate up to nine water quality constituents: (1) biological oxygen demand (BOD); (2) total suspended solids (TSS); (3) total nitrogen (TN); (4) total phosphorus (TP); (5) zinc (Zn); (6) pesticide; (7) tracer; (8) lead (Pb); and (9) copper (Cu).

11
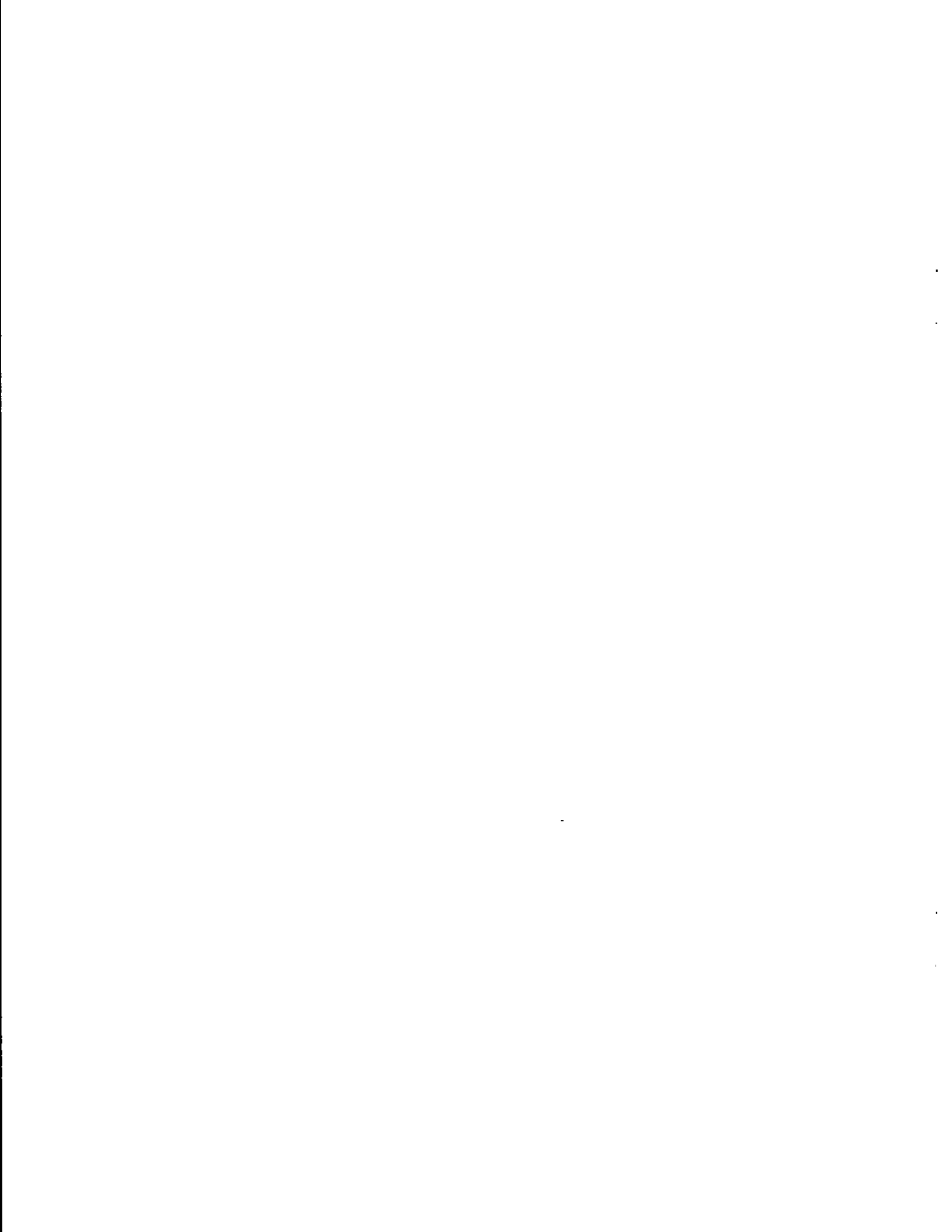
3.2.1 Buildup

The concept of "Buildup" was first used to model the accumulation of dust and dirt and associated pollutants on urban street surfaces in 1969 (ASCE and WEF, 1992). Thereafter, the buildup concept (as well as the washoff concept) has been included in several watershed models such as SWMM, HSPF, STORM, USGS, and SLAMM. Buildup is defined as the pollutant accumulation during the dry-weather periods between storms. The buildup process is affected by atmosphere deposition, wind erosion, street cleaning, or other human activities. An exponential equation (Huber et al., 1987) used in the SWMM model was selected for the simulation of the buildup of water quality constituents in SRPM:

$$P_{buildup} = P_{limit}(1 - e^{-\alpha t}) \tag{14}$$

where $P_{buildup}$ = amount of pollutant accumulation (lbs)

              P_{limit} = maximum value of pollutant buildup (lbs)

              α = pollutant buildup rate (1/sec)

              t = time (sec)

During the continuous simulation, buildup will not occur during the wet-weather time steps unless runoff is less than 0.0005 in/hr (Huber et al., 1987).

3.2.2 Washoff

Washoff is defined as the pollutant removal process associated with runoff during the wet-weather periods of storm events. Similar to the exponential buildup equation, the exponential washoff equation describes the relationship between the initial amount and the cumulative amount washed off during storm events:
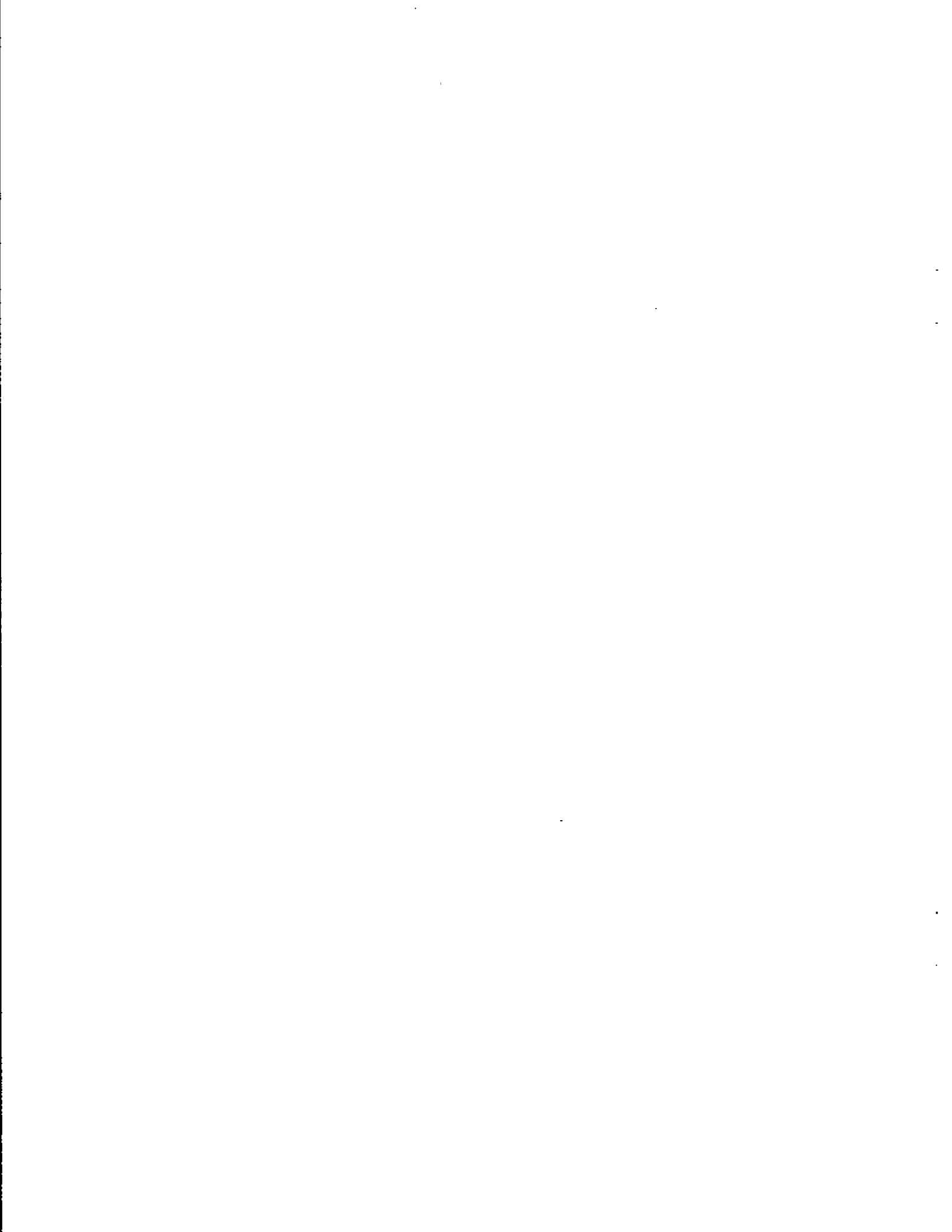
$$P_{washoff} = P_{initial}(1 - e^{-kt}) \qquad\qquad (15)$$

where $P_{washoff}$ = cumulative amount of pollutant which is washed off at time t (lbs)

                $P_{initial}$ = initial amount of pollutant on surface at t = 0 (lbs)

                k   = coefficient (1/sec)

Since the amount of pollutant remaining in a watershed (P_{remain}) is equal to the difference between the initial amount and the cumulative washoff amount of pollutant, Equation (15) can be rewritten as:

$$P_{remain} = P_{initial} - P_{washoff} = P_{initial} e^{-kt} \qquad\qquad (16)$$

Because the coefficient k is a function of runoff rate and particle size, it is very difficult to use a single value to represent the pollutant removal mechanism in the real world. By using the average power of runoff over the simulation time step, a modified washoff equation can be derived to overcome this problem (Huber et al., 1987):

$$P_{remain}(t+\Delta t) = P_{remain}(t) e^{-\beta \frac{1}{2}[r(t)^n + r(t+\Delta t)^n]\Delta t} \qquad\qquad (17)$$

where β = washoff coefficient

                Δt = simulation time step (sec)

                r(t)   = runoff rate at time t (in/hr)

                $r(t+\Delta t)$ = runoff rate at time $t+\Delta t$ (in/hr)

                n   = washoff power factor

Equation (17) is used in SRPM for the simulation of water quality washoff.

3.2.3 Phosphorus Transport in Agricultural Areas

In order to better describe phosphorus transport mechanisms in agricultural activities,

a phosphorus movement mechanism used in FHANTM was selected in phosphorus simulation with agricultural areas in SRPM (Tremwel, 1992) :

$$P_{water}(t+\Delta t) = P_{water}(t) + P_{land}(t)\Delta t(\alpha I_{rain} + \beta I_{runoff}) + CP_{rain}\Delta t I_{rain} \quad \text{(18)}$$

$$P_{land}(t+\Delta t) = P_{land}(t) - P_{land}(t)\Delta t(\alpha I_{rain} + \beta I_{runoff}) \quad \text{(19)}$$

where

P_{water} = mass of phosphorus contained in surface water (kg/ha)

P_{land} = mass of phosphorus contained in surface land (kg/ha)

P_{rain} = phosphorus concentration contained in rainfall (mg/L)

α = effectiveness of rain in removing phosphorus from P_{land} (1/cm)

β = effectiveness of runoff in removing phosphorus from P_{land} (1/cm)

I_{rain} = rainfall intensity (cm/hr)

I_{runoff} = runoff intensity (cm/hr)

C = converting factor (0.254)

Δt = time step (hour)

t = time (hour)

Phosphorus deposition comes from two sources: land and air. In general, animal wastes, fertilizers, or other nutrients introduced by human activities are considered to be land phosphorus deposition, whereas phosphorus in raindrops is considered air deposition. Equation (18) states that phosphorus mass in surface water P_{water} will cumulate with addition of phosphorus mass from raindrops P_{rain} and solubilized portion of phosphorus on surface land. The unsolubilized portions of phosphorus will remain on surface land until next the rainfall or runoff occurs (Equation (19)). Daily phosphorus mass created by animal wastes or fertilizers is added to the phosphorus mass on surface land P_{land} each day (Tremwel, 1992). Equations (18) and (19) were used for phosphorus simulation in agricultural areas. For other water quality constituents, the buildup and washoff equations were still applied for pollutant load calculations.
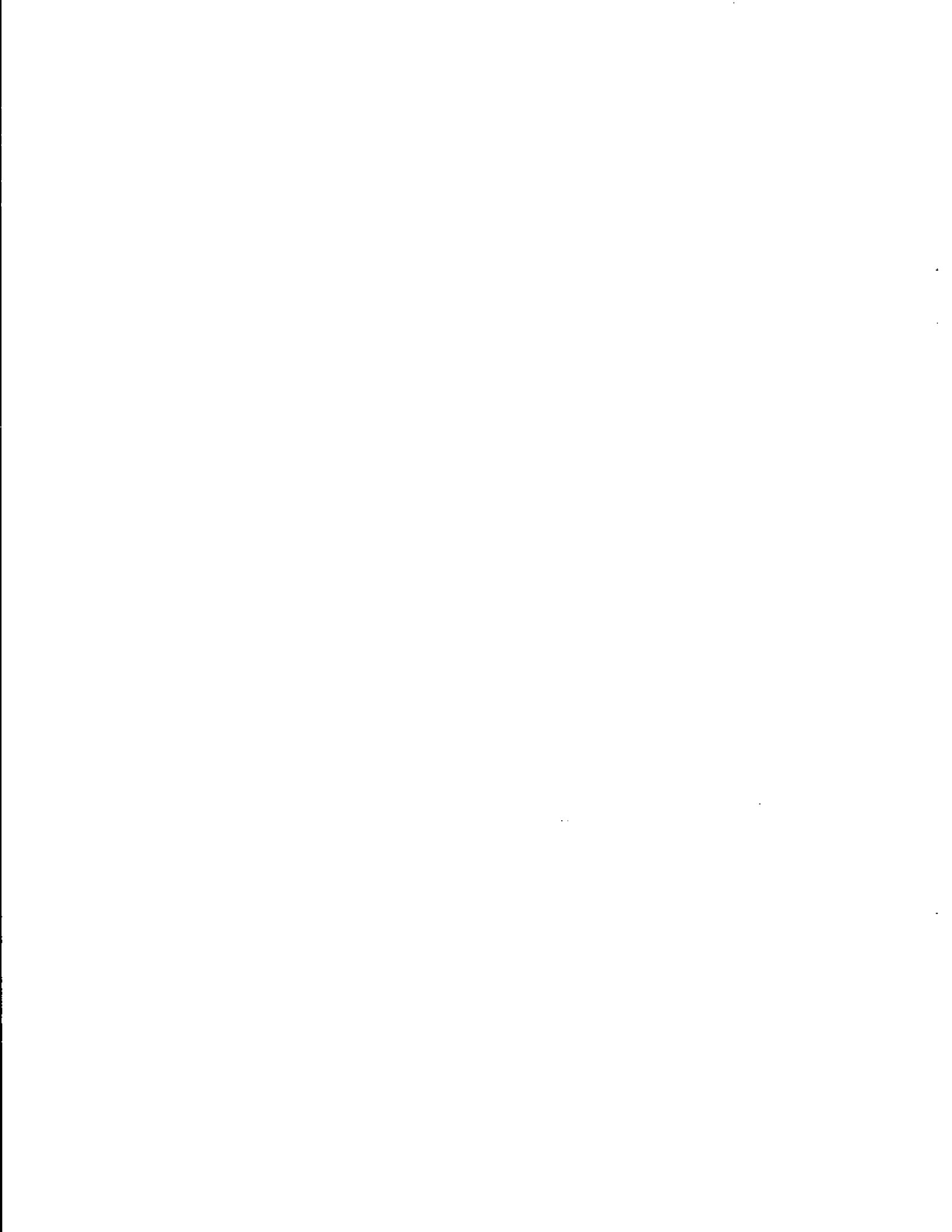
4. INPUT DATA DESCRIPTION

4.1 Meteorological Data

Observed hourly precipitation and hourly pan evaporation records are required for SRPM. Input data formats from these records are illustrated in Appendix A. Units for precipitation and evaporation input data are inches. If the observed hourly pan evaporation data are not available, the daily pan evaporation data can be converted to the hourly evaporation data by using a stand- alone FORTRAN program developed in HSPF model (U.S. EPA, 1993). The source code of the conversion program is provided in the model package (Appendix B).

4.2 Watershed Data

The SRPM model can simulate up to ten (10) subcatchments for each simulation run. The physical characteristics of each subcatchment should be provided to represent each individual basin within a simulated watershed. The required basin characteristic data includes surface area (acres), average width (feet) of overland flow, slope (feet/feet), and infiltration parameters related to soil type of the subcatchment. The infiltration parameters used in the model are the maximum infiltration rate (mm/hour), minimum infiltration rate (mm/hour), decay parameter (1/min), and infiltration regeneration ratio. Infiltration tests are usually required for obtaining these parameters at sites of interest. Users may find these parameters of different soil types in *Handbook of Hydrology* (Rawls et al., 1993) as a starting point of simulation runs. The infiltration parameters may be estimated through calibration. The format of the input watershed data is provided in Appendix A.

Three monthly variation parameters in the model for evaporation coefficient, Manning's roughness, and depression depth (inches) account for the seasonal changes of watershed characteristics. Monthly Manning's roughness and depression depth data can be specified for
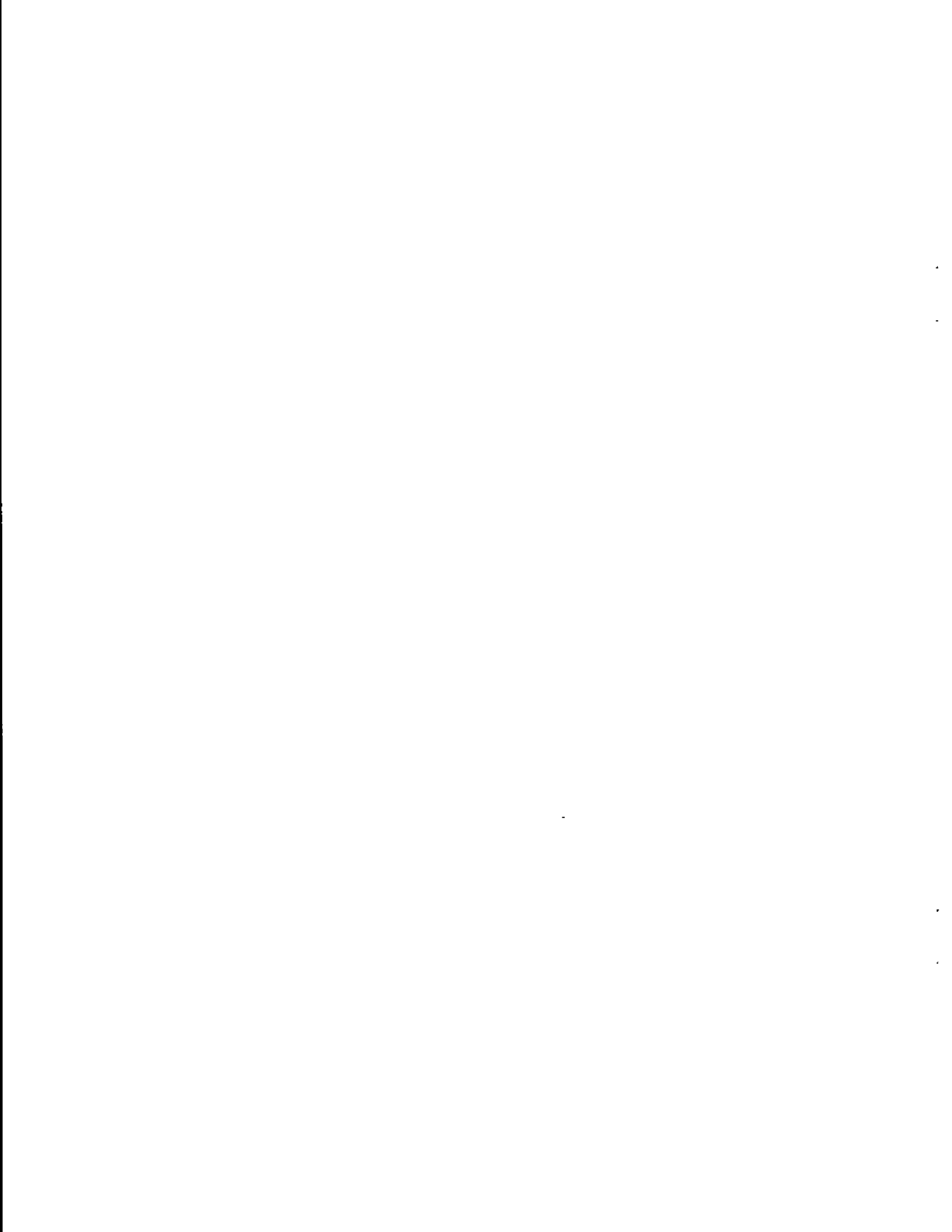
each subcatchment. However, monthly evaporation coefficients can be only specified in the entire simulation area due to the assumed small changes of evaporation rates between each subcatchment.

4.3 Pollutant Buildup/Washoff Data

As described above, the generalized pollutant buildup and washoff equations are used for the water quality simulation in SRPM. Monthly values of the maximum buildup value (lbs-ac-day), buildup rate (1/day), washoff coefficient (1/inch), and washoff exponent are the input data for the water quality simulation. Both pollutant buildup and washoff input parameters are often used as the model calibration parameters. The input format of the pollutant build up and washoff data is shown in Appendix A.

5. MODEL OUTPUT

5.1 Time Series Output

Four time-series output files are generated from SRPM: hourly, daily, monthly and annual simulation results. All output files provide runoff (in) and pollutant concentrations (Appendix C). The output files are in ASCII time-series format which is easy to use for further data analysis and graphical display and can be directly linked into a GIS platform.

5.2 Other Simulation Outputs

Besides time-series simulation results, the model also provides an hourly time step mass balance file. The mass balance file is created for checking the water budget in a time step or at the end of the simulation period. It consists of eight components: (1) PREC – amount of rainfall; (2) INFI – water infiltrated into groundwater; (3) EVAP – water loss due to evaporation;

16

(4) RUNO – runoff from watershed; (5) WREM – water remaining in watershed at the end of simulation time; (6) CUMI – cumulative water amount of precipitation; (7) CUMO – cumulative water loss, including infiltration, evaporation, and runoff; and (8) ERRO – percentage error of cumulative rainfall versus cumulative water loss (Appendix C).

Another simulation output is the geometric and hydraulic data used for the simulation of hydrologic flow routing. At each simulation run, the model will generate one geometric and hydraulic data file for each subcatchment. The format of the output file is provided in Appendix C. Huber et al (1987) described more information about the reservoir hydrologic routing method and the parameters used for the method.

6. MODEL PACKAGE

6.1 Programs and Input/Output Files

FORTRAN programs, input files, and output files which come with the SRPM model package are shown in Table 1.

Table 1. Components of SRPM Model Package

Component	File Name	Description
Programs	srpm1_3.f	FORTRAN source code of main program, Version 1.3
	srpm	executable file of the SRPM model
	convert.f	FORTRAN source code for converting daily to hourly evaporation data
	convert	executable file of the conversion program
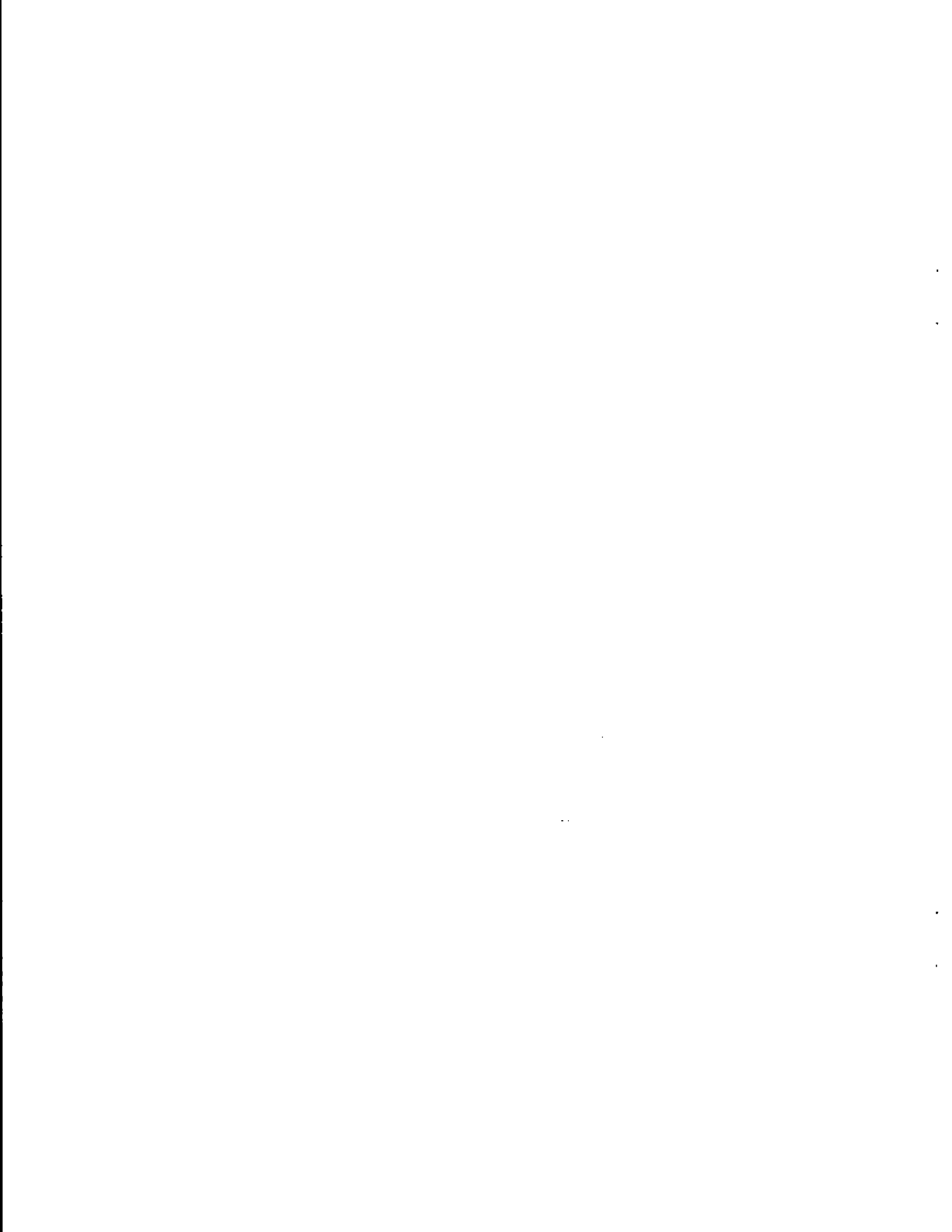
Input Files	precipi.inp	hourly precipitation data (in)
	evapora.hor	hourly pan evaporation data (in)
	watershe.inp	watershed and pollutant buildup/washoff data
Output Files	srpm_hrc.out	hourly runoff (in) and pollutant concentrations (mg/l)
	srpm_day.out	daily runoff (in) and pollutant concentrations (mg/l)
	srpm_mon.out	monthly runoff (in) and pollutant concentrations (mg/l)
	srpm_ann.out	annual runoff (in) and pollutant concentrations (mg/l)
	massbala.out	hourly water budget balance data (in)
	wat_flw1.dat " wat_flw9.dat wat_fl10.dat	geometric and hydraulic data for subcatchment 1 " geometric and hydraulic data for subcatchment 9 geometric and hydraulic data for subcatchment 10

6.2 Computer Requirements

The programs that come with SRPM were written in standard FORTRAN language. A workstation which has a FORTRAN compiler that is compatible with the operating system is needed. The model was developed and tested under the UNIX operating system on a SUN SPARC

18
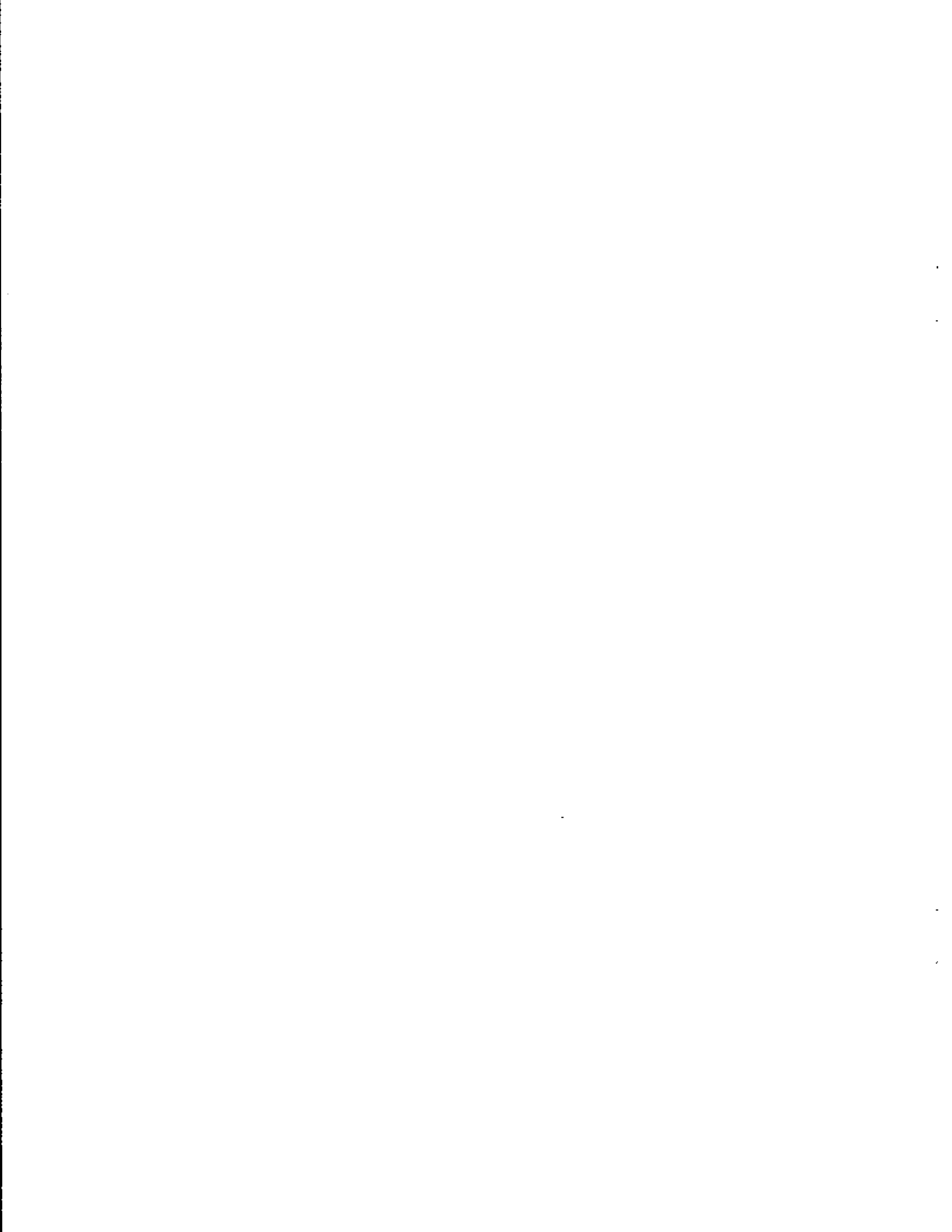
workstation.

The minimum configuration for a PC is an 80386 IBM compatible with a math coprocessor. A FORTRAN compiler for the PC is needed to compile SRPM. Two megabytes of memory or greater are required. The free hard disk space required depends on the simulation period. A minimum of 15 Mb is recommended for a 3-year simulation.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the comments of Douglas Shaw, Tim Bechtel and Garth Redfield on an earlier version of this documentation. Appreciation is also extended to Ginger Brooks, Zhenquan Chen, Steve Lin, Todd Tisdale and Joyce Zhang for their comments for this documentation. In addition, the author would like to thank other District staff for their helpful suggestions to improve the model.

REFERENCES

Alley, W. M. and Smith, P. E. (1982). "Distributed routing rainfall-runoff model - version II". *Open file report 82-344* U.S. Geological Survey, Reston, Va.

Arnold, J. G., Williams, J. R., Nicks, A. D. and Sammons, N. B. (1989). "*SWRRB, a basin scale simulation model for soil and water resources management*". Texas A&M Press.

ASCE and WEF. (1992). *Design and construction of urban stormwater management systems*. ASCE Manuals and Reports of Engineering Practice No.77 and WEF Manual of Practice FD-20. American Society of Civil Engineers, New York, N.Y.
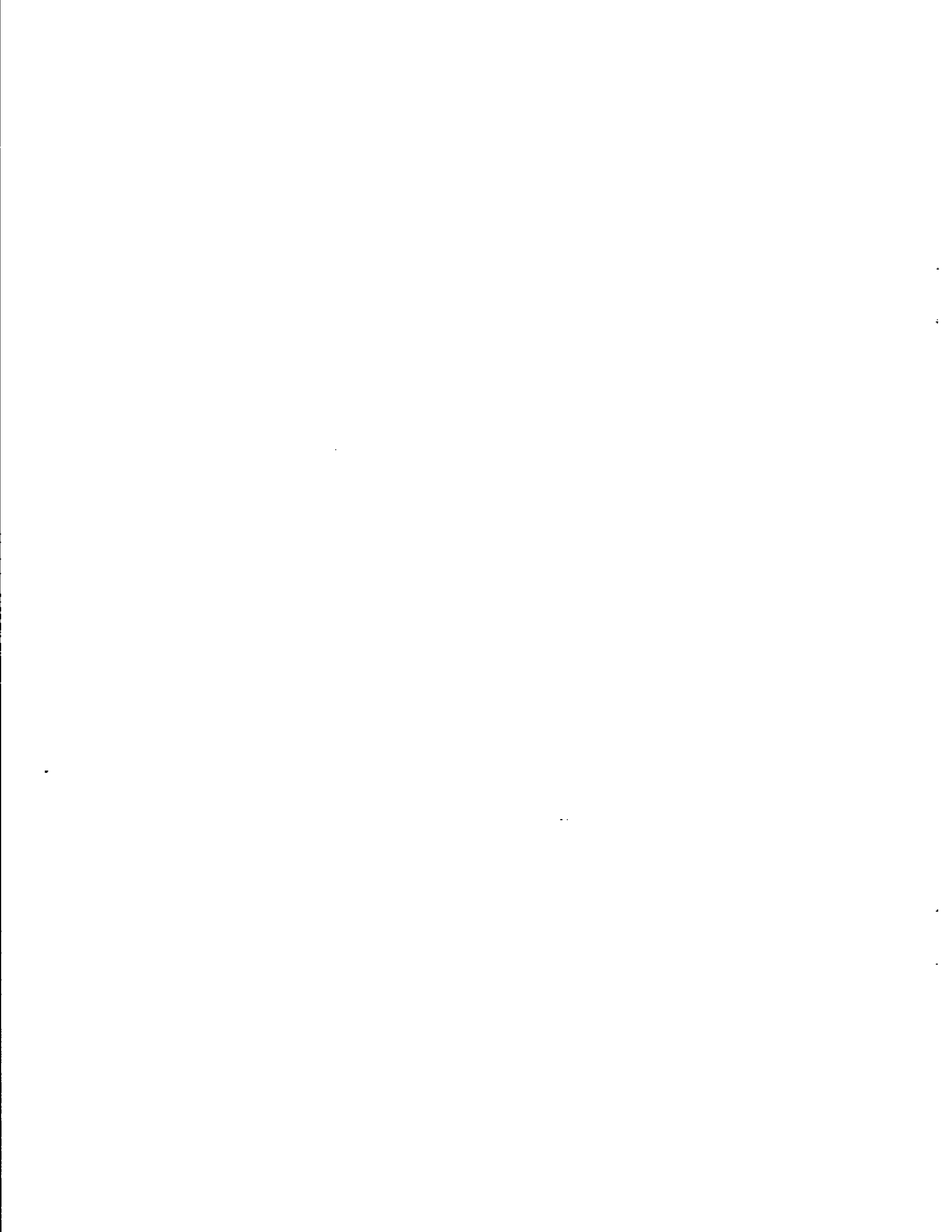
Beasley, D. B. and Huggins, L. F. (1981). "ANSWER user's manual". _EPA 905/9-82-001_ U.S. Environmental Protection Agency. Region V, Chicago, Il.

Chow V. T. (1959). _Open-channel hydraulics_ McGraw-Hill Book Company, Inc. New York, N.Y.

Greene, R. G. and Cruise, J. F. (1995). "Urban watershed modeling using geographic information system". _J. Water Resour. Plng. and Mgmt_, 121(4), 318–325.

Haster, T. W. and James, W. P. (1994). "Predicting sediment yield in storm-water runoff from urban areas." _J. Water Resour. Plng. and Mgmt_, 120(5), 630–650.

Huber, W. C., Heaney, J. P., Nix, S. J., Dickinson, R. E., and Polmann, D. J. (1987). "Storm water management model – User's manual". _EPA 600/2-84-109a_ U.S. Environmental Protection Agency. Cincinnati, Oh.

Lindeburg, M. R. (1992). _Civil engineering reference manual_ Professional Publications, Inc. Belmont, Ca.

Linsley, R. K. and Franzini, J. B. (1964). "Water-resources engineering". McGraw-Hill Book Company. New York, N.Y.

Mein, R. G. and Larson, C. L. (1973). "Modeling infiltration during a steady rain". _Water Resour. Res._ 9, 384–393.

Nix, S. J. (1994). _Urban stormwater modeling and simulation._ Lewis Publishers, Boca Raton, Fl.
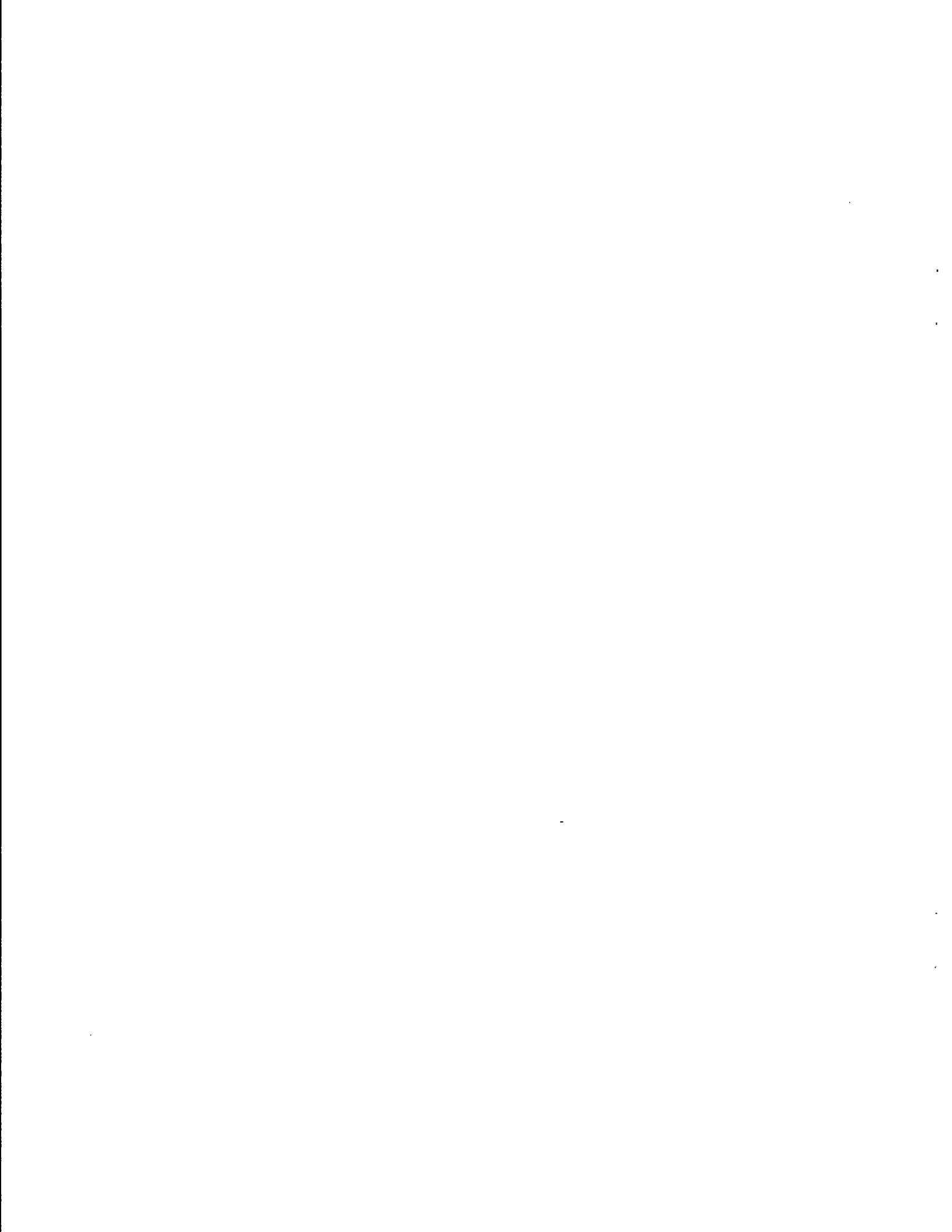
Pilgrim, D. and Cordery, I. (1993). "Flood runoff". *Handbook of hydrology.* D. R. Maidment, ed., McGraw-Hill, Inc. New York, N.Y., 9.1-9.40.

Rawls, W. J., Ahuja, L. R., Brakensiek, D. L., and Shirmohammadi, A. (1993). "Infiltration and soil water movement". *Handbook of hydrology.* D. R. Maidment, ed., McGraw-Hill, Inc. New York, N.Y., 5.1-5.51.

Shamsi, U. M. (1996). "Storm-water management implementation through modeling and GIS. *J. Water Resour. Plng. and Mgmt.,* 122(2), 114-127.

Tremwel, T. K. (1992). "*Field hydrologic and nutrient transport model - FHANTM.* Ph.D. dissertation, University of Florida, Gainesville, Fl.

U.S. Army Corps of Engineers. (1977). " Storage, treatment, overflow, runoff model, STORM, user's manual". *Generalized Computer Program 723-S8-L7520.* Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, Ca.

U.S. EPA. (1992). "Compendium of watershed-scale models for TMDL development". *EPA 841-R-92-002* U.S. Environmental Protection Agency. Washington, D.C.

U.S. EPA. (1993). "Hydrological simulation program -- FORTRAN: user's manual for release 10". *EPA/600/R-93/174.* U.S. Environmental Protection Agency. Washington, D.C.

Xue, R. Z. (1996). "Best management practices assessment model - BMPAM model documentation, version 1.1". South Florida Water Management District. West Palm Beach, Fl.
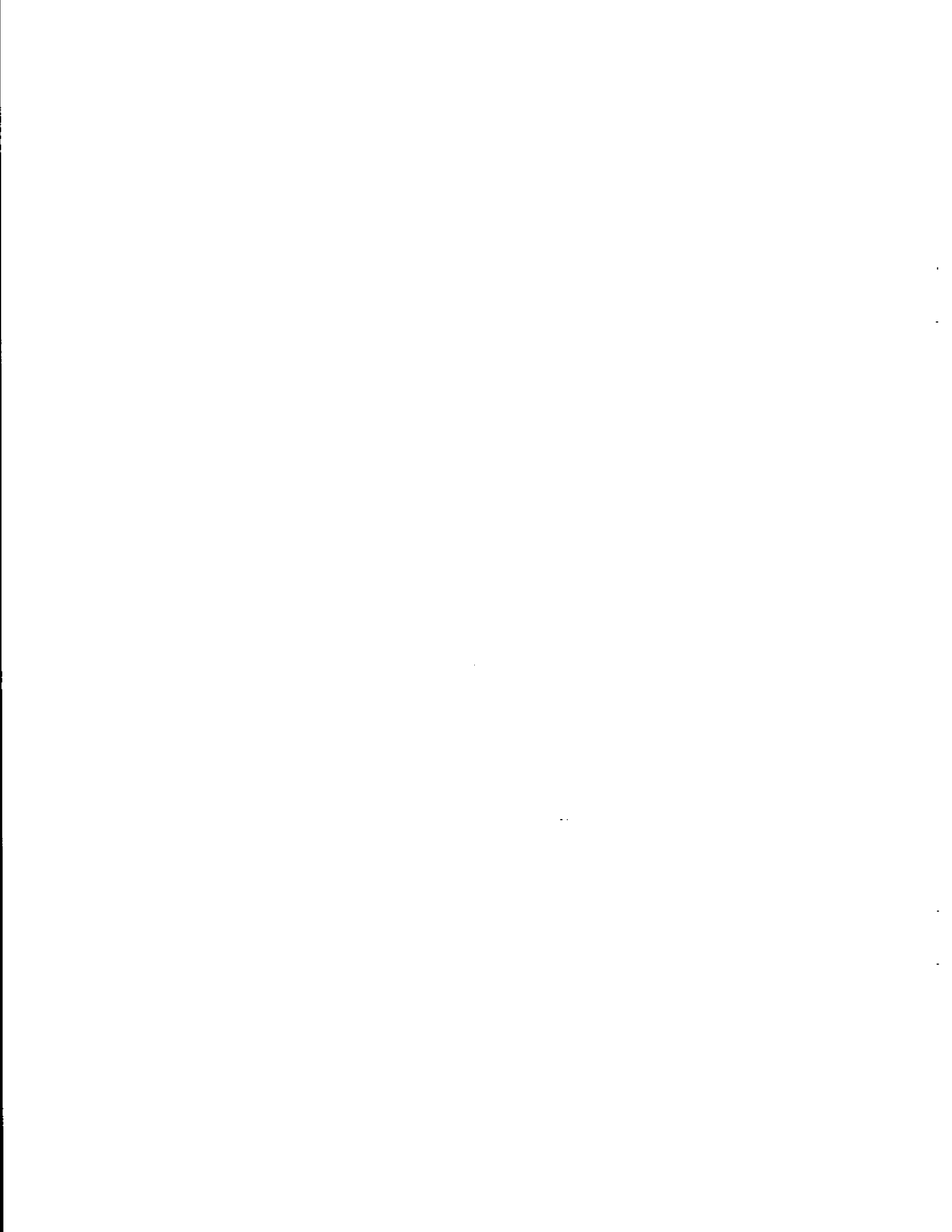
APPENDIX A

SRPM INPUT

APPENDIX A-1

Hourly Precipitation Data

```
WET   1991   7 12    7   0    0.000000000
WET   1991   7 12    8   0    0.000000000
WET   1991   7 12    9   0    0.000000000
WET   1991   7 12   10   0    0.000000000
WET   1991   7 12   11   0    0.000000000
WET   1991   7 12   12   0    0.110000000
WET   1991   7 12   13   0    0.050000000
WET   1991   7 12   14   0    0.000000000
WET   1991   7 12   15   0    0.390000000
WET   1991   7 12   16   0    0.220000000
WET   1991   7 12   17   0    0.140000000
WET   1991   7 12   18   0    0.010000000
WET   1991   7 12   19   0    0.000000000
WET   1991   7 12   20   0    0.010000000
WET   1991   7 12   21   0    0.000000000
WET   1991   7 12   22   0    0.000000000
WET   1991   7 12   23   0    0.000000000
WET   1991   7 12   24   0    0.000000000
WET   1991   7 13    1   0    0.000000000
WET   1991   7 13    2   0    0.000000000
WET   1991   7 13    3   0    0.000000000
WET   1991   7 13    4   0    0.000000000
WET   1991   7 13    5   0    0.000000000
WET   1991   7 13    6   0    0.000000000
WET   1991   7 13    7   0    0.000000000
WET   1991   7 13    8   0    0.000000000
WET   1991   7 13    9   0    0.000000000
WET   1991   7 13   10   0    0.010000000
WET   1991   7 13   11   0    1.310000000
WET   1991   7 13   12   0    0.410000000
WET   1991   7 13   13   0    0.230000000
WET   1991   7 13   14   0    0.130000000
WET   1991   7 13   15   0    0.000000000
WET   1991   7 13   16   0    0.010000000
WET   1991   7 13   17   0    0.000000000
WET   1991   7 13   18   0    0.000000000
WET   1991   7 13   19   0    0.000000000
WET   1991   7 13   20   0    0.000000000
WET   1991   7 13   21   0    0.000000000
WET   1991   7 13   22   0    0.000000000
WET   1991   7 13   23   0    0.000000000
WET   1991   7 13   24   0    0.000000000
WET   1991   7 14    1   0    0.000000000
WET   1991   7 14    2   0    0.000000000
WET   1991   7 14    3   0    0.000000000
WET   1991   7 14    4   0    0.000000000
WET   1991   7 14    5   0    0.000000000
WET   1991   7 14    6   0    0.000000000
WET   1991   7 14    7   0    0.000000000
WET   1991   7 14    8   0    0.000000000
WET   1991   7 14    9   0    0.040000000
WET   1991   7 14   10   0    0.460000000
WET   1991   7 14   11   0    0.030000000
WET   1991   7 14   12   0    0.010000000
WET   1991   7 14   13   0    0.000000000
WET   1991   7 14   14   0    0.000000000
WET   1991   7 14   15   0    0.110000000
WET   1991   7 14   16   0    0.050000000
WET   1991   7 14   17   0    0.000000000
WET   1991   7 14   18   0    0.000000000
WET   1991   7 14   19   0    0.000000000
WET   1991   7 14   20   0    0.000000000
WET   1991   7 14   21   0    0.000000000
WET   1991   7 14   22   0    0.000000000
WET   1991   7 14   23   0    0.000000000
```

APPENDIX A-2

Hourly Pan Evaporation Data

```
EVA   1991   5   1   1   0   0.000000000
EVA   1991   5   1   2   0   0.000000000
EVA   1991   5   1   3   0   0.000000000
EVA   1991   5   1   4   0   0.000000000
EVA   1991   5   1   5   0   0.000000000
EVA   1991   5   1   6   0   0.002694790
EVA   1991   5   1   7   0   0.007532608
EVA   1991   5   1   8   0   0.012370427
EVA   1991   5   1   9   0   0.015860850
EVA   1991   5   1  10   0   0.015860850
EVA   1991   5   1  11   0   0.015860850
EVA   1991   5   1  12   0   0.015860850
EVA   1991   5   1  13   0   0.015860850
EVA   1991   5   1  14   0   0.015860850
EVA   1991   5   1  15   0   0.015860850
EVA   1991   5   1  16   0   0.012370426
EVA   1991   5   1  17   0   0.007532608
EVA   1991   5   1  18   0   0.002694789
EVA   1991   5   1  19   0   0.000000000
EVA   1991   5   1  20   0   0.000000000
EVA   1991   5   1  21   0   0.000000000
EVA   1991   5   1  22   0   0.000000000
EVA   1991   5   1  23   0   0.000000000
EVA   1991   5   1  24   0   0.000000000
EVA   1991   5   2   1   0   0.000000000
EVA   1991   5   2   2   0   0.000000000
EVA   1991   5   2   3   0   0.000000000
EVA   1991   5   2   4   0   0.000000000
EVA   1991   5   2   5   0   0.000000000
EVA   1991   5   2   6   0   0.002743248
EVA   1991   5   2   7   0   0.007563240
EVA   1991   5   2   8   0   0.012383234
EVA   1991   5   2   9   0   0.015831603
EVA   1991   5   2  10   0   0.015831603
EVA   1991   5   2  11   0   0.015831603
EVA   1991   5   2  12   0   0.015831603
EVA   1991   5   2  13   0   0.015831603
EVA   1991   5   2  14   0   0.015831603
EVA   1991   5   2  15   0   0.015831603
EVA   1991   5   2  16   0   0.012383234
EVA   1991   5   2  17   0   0.007563240
EVA   1991   5   2  18   0   0.002743248
EVA   1991   5   2  19   0   0.000000000
EVA   1991   5   2  20   0   0.000000000
EVA   1991   5   2  21   0   0.000000000
EVA   1991   5   2  22   0   0.000000000
EVA   1991   5   2  23   0   0.000000000
EVA   1991   5   2  24   0   0.000000000
EVA   1991   5   3   1   0   0.000000000
EVA   1991   5   3   2   0   0.000000000
EVA   1991   5   3   3   0   0.000000000
EVA   1991   5   3   4   0   0.000000000
EVA   1991   5   3   5   0   0.000000000
EVA   1991   5   3   6   0   0.002790787
EVA   1991   5   3   7   0   0.007593253
EVA   1991   5   3   8   0   0.012395720
EVA   1991   5   3   9   0   0.015802793
EVA   1991   5   3  10   0   0.015802793
EVA   1991   5   3  11   0   0.015802793
EVA   1991   5   3  12   0   0.015802793
EVA   1991   5   3  13   0   0.015802793
EVA   1991   5   3  14   0   0.015802793
EVA   1991   5   3  15   0   0.015802793
EVA   1991   5   3  16   0   0.012395721
EVA   1991   5   3  17   0   0.007593255
EVA   1991   5   3  18   0   0.002790787
EVA   1991   5   3  19   0   0.000000000
EVA   1991   5   3  20   0   0.000000000
EVA   1991   5   3  21   0   0.000000000
EVA   1991   5   3  22   0   0.000000000
EVA   1991   5   3  23   0   0.000000000
```

APPENDIX A-3

Watershed Data and Pollutant Buildup/Washoff Data

Input Data for SRPM – Version 1.3

Subcatchment #	1	2	3	4	5	6
Land Use Type	COMME					
Area (acres)	15.32					
Width (ft)	817.					
Slope (ft/ft)	0.001					
Max Inf. Rate (mm/h)	2.0					
Min Inf. Rate (mm/h)	0.5					
Decay Param. (1/min)	0.9					
Infil. Regen. Ratio	0.01					
Hortn-1/Green-Ampt-2	1					
Capill. Suction (ft)	0.70					
Moi. Deficit (ft/ft)	0.26					
Sat Hyd. Cond.(ft/h)	0.0038					
P Added (kg/ha/day)	0.120					
P in S. Water-kg/ha	0.00					
P on Top Soil-kg/ha	10.00					

Phosphorus Coeff.	PCRAIN-mg/L	EFFPRAIN-1/cm	EFFPRUNO-1/cm
	0.1	0.0700	0.1200

Evaporation Coeff.	J	F	M	A	M	J	J	A	S	O	N	D
	.70	.70	.70	.75	.80	.95	.95	.95	.75	.75	.75	.75

Manning's roughness	J	F	M	A	M	J	J	A	S	O	N	D
1st subcatchment	.015	.020	.020	.013	.025	.015	.020	.010	.005	.010	.010	.020

Depression depth	J	F	M	A	M	J	J	A	S	O	N	D
1st subcatchment-in	.01	.01	.01	.01	.01	.010	.01	.020	.001	.010	.01	.01

Maximum Buildup	J	F	M	A	M	J	J	A	S	O	N	D
BOD5 (lb/ac-day)	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
TSS	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
TN	.05	.05	.05	.05	.10	.05	.05	.15	.12	.13	.05	.05
TP	.01	.01	.01	.01	.08	.01	.01	.11	.08	.10	.01	.01
ZN	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
PEST	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
TRAC	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
PB	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
CU	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

Buildup Coeff. (1/day)	J	F	M	A	M	J	J	A	S	O	N	D
BOD5	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
TSS	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TN	.20	.20	.20	.20	.30	.20	.20	.40	.30	.40	.20	.20
TP	.10	.10	.10	.10	.20	.10	.10	.35	.25	.20	.10	.10
ZN	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
PEST	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
TRAC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PB	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
CU	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10

Washoff Coefficient	J	F	M	A	M	J	J	A	S	O	N	D
BOD5 (1/in)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TSS	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TN	2.0	2.0	2.0	2.0	2.2	2.0	2.0	2.5	1.3	1.5	2.0	2.0
TP	2.0	2.0	2.0	2.0	2.2	2.0	2.0	2.5	1.3	1.5	2.0	2.0
ZN	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PEST	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TRAC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PB	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
CU	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Washoff Exponent	J	F	M	A	M	J	J	A	S	O	N	D
BOD5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TSS	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TN	2.0	2.0	2.0	2.0	2.2	2.0	2.0	1.8	1.8	1.6	2.0	2.0
TP	2.0	2.0	2.0	2.0	2.2	2.0	2.0	1.8	1.8	1.6	2.0	2.0
ZN	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PEST	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TRAC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PB	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
CU	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

APPENDIX B

FORTRAN PROGRAMS

APPENDIX B-1

Program to Convert Daily to Hourly Evaporation Data

```
C This program is intended to convert daily evaporation data (in) to the
C hourly format for the SWRPLM model input by using a HSPF subroutine.
C File: 'convert_daily_hourly.f' (01/25/95).
C
      REAL DRD,JDAY,RDIST(24),ALAT
      INTEGER YEAR, MON, DAY, I
      OPEN (1, FILE='evapora.inp')
      OPEN (2, FILE='evapora.hor')

      JDAY = 90.0
* 2*3.14159/360 = 0.0174582
      ALAT = 27.5
      ALAT = ALAT * 0.0174582
    5 READ (1, 20, END = 1000) YEAR, MON, DAY, DRD
   20 FORMAT (6X,I4,1X,2(I2,1X),3X,F13.0)
   30 FORMAT (1X,A3,2X,I4,1X,4(I2,1X),F13.9)

      IF (JDAY .GE. 365 ) JDAY = 0.0
      JDAY = JDAY + 1.0

      CALL RAD (ALAT,JDAY,DRD,RDIST)

      DO I =1, 24
         WRITE (2, 30) 'EVA', YEAR, MON, DAY, I, 0, RDIST(I)
      ENDDO
      GOTO 5

 1000 CLOSE (1)
      CLOSE (2)
      STOP
      END


      SUBROUTINE RAD(ALAT,JDAY,DRD,RDIST)
C     COMPUTES HSP QUALITY HOURLY RADIATION DISTRIBUTION GIVEN
C     LATITUDE, ALAT(IN RADIANS), JDAY(JULIAN DAY OF YEAR) AND
C     DAILY RADIATION.
C     ARGUMENTS
      REAL ALAT,DRD,JDAY,RDIST(24)
      REAL PHI,AD,SS,CS,X2,DELT,SUNR,SUNS,DTR2,DTR4,CRAD,SL,TRISE
      REAL TR2,TR4,RK
      INTEGER IK
      PHI=ALAT
      AD= 0.40928*COS(0.0172141*(172.-JDAY))
      SS= SIN(PHI)*SIN(AD)
      CS=COS(PHI)*COS(AD)
      X2=-SS/CS
      DELT=7.6394*(1.5708-ATAN(X2/SQRT(1.-X2**2)))
      SUNR=12.-DELT/2.
      SUNS=12.+DELT/2.
C     DEVELOP HOURLY DISTRIBUTION GIVEN SUNRISE, SUNSET AND LENGTH
C     OF DAY (DELT)
      DTR2= DELT/2.
      DTR4= DELT/4.
      CRAD= .66666667/DTR2
      SL= CRAD/DTR4
      TRISE= SUNR
      TR2= TRISE+DTR4
      TR3= TR2+DTR2
      TR4= TR3+DTR4
        DO 100 IK=1,24
        RK=REAL(IK)
        IF(RK.LE.TRISE) GO TO 90
          IF(RK.LE.TR2) GO TO 80
            IF(RK.LE.TR3) GO TO 70
              IF(RK.LE.TR4) GO TO 60
                RDIST(IK)=0.0
                GO TO 65
   60         CONTINUE
                RDIST(IK)=(CRAD-(RK-TR3)*SL)*DRD
   65         CONTINUE
                GO TO 75
   70       CONTINUE
                RDIST(IK)=CRAD*DRD
   75       CONTINUE
                GO TO 85
   80     CONTINUE
              RDIST(IK)=(RK-TRISE)*SL*DRD
   85     CONTINUE
              GO TO 95
   90     CONTINUE
```

```
          RDIST(IK)=0.0
 95       CONTINUE
100       CONTINUE
          RETURN
          END
```

APPENDIX B-2

Main Program of the SRPM Model

```
++  ********************************************************
++
++                          SRPM
++
++             Stormwater Runoff & Pollutant Model
++
++                       Version 1.3
++                      December, 1996
++
++              Developed by: Richard T. Roe
++
++            South Florida Water Management District
++            Phone:(561) 686-8800, Fax:(561) 687-6442
++                 E-mail:richard.roe@sfwmd.gov
++
++  ********************************************************

     Version 1.0, Created by Richard Roe in March, 1995
     Version 1.1, Modified by Richard Roe in June, 1995 by changing
                  the output format to hourly, daily, monthly and
                  annual runoff and concentrations for an ArcView
                  post-processor
     Version 1.2, Modified by Richard Roe in May, 1996 by adding the
                  Phosphorus Movement routine in Agricultural area
     Version 1.3, Modified by Richard Roe in December, 1996 by adding
                  the Green-Ampt Infiltration Option.

  ***************************************************************************
  *  THIS PROGRAM SIMULATES HYDROLOGIC AND WATER QUALITY IN A WATERSHED.    *
  * DELT_T   = Time step (hour)                                             *
  * TS_SEC   = Time step (sec)                                             *
  * PREC1/2  = Input precipitation at beg/end of time step (in)            *
  * PRE1/2() = Input rain at beg. and end of time for subcatchment (in)    *
  * EVAP()   = Input evaporation coefficient at time step  (in)            *
  * EVAP_C(,)=Input monthly evaporation coefficient for subcatchment       *
  * EVACT/2()= Actual evaporation data of each subcatchment (in)           *
  * A_EVP1/2()=Actual evaporation data of each subcat. at beg. & end. (in) *
  * AREA()   = Surface area of land use (acre)                             *
  * AREAF()  = Surface area of land use (ft2)                              *
  * IMPER()  = Imperviousness of land use                                  *
  * SLOPE()  = Curve number for each land use                              *
  * DEPSS(,) = Monthly depth of maximum depression storage of subcatchment *
  * DEPSS1/2()=Depth of actual depression storage at beg & end time step(ft)*
  * MANN()   = Manning's R coefficient                                     *
  * MANNH(,) = Monthly Manning's R coefficient                            *
  * RUNR1/2()= Runoff rate at beg. and end of time step-land use (in)     *
  * TAREA    = Total surface runoff from watershed (acre)                  *
  * TFLOW1/2 = Simulated total flows from watershed (acre)                 *
  * K_RET()  = Backlog coefficient                                         *
  * WREM1/2()= Water retained in subcatchment at beg/end of time step (in) *
  * WLOST()  = Water loss in subcatchment at each time step (in)           *
  * WATLES1/2()=Water loss in watershed at beg/end time step (in)          *
  * RUNOFF1/2()=Simulated total runoff from watershed (in)                 *
  * RUNOFF   = Total surface runoff of watershed (acre)                    *
  * RUNR12()= Monthly Manning's R coefficient                             *
  * K_BUILD()= Monthly maximum buildup of pollutant (kg)                   *
  * K_BUILD()= Maximum buildup of pollutant (kg)                           *
  * K_RET()  = Washoff rate of pollutant (1/in)                            *
  * A_WASH() = Monthly Washoff coefficient (1/in)                          *
  * R_WASH() = Washoff power factor                                        *
  * R_WASH(,)= Monthly Washoff power factor                                *
  * POLL1/2(,)=Pollutant for each land use at beg./end of time step (mg)   *
  * T_POLL1/2()=Total pollutant loads at beg. and end of time step (mg)    *
  * D_POLL1/2()=Total pollutant buildup at beg. and end of time step (mg)  *
  * C_POLL1/2()=Total pollutant conc. at beg. and end of time step (mg/l)  *
  * L_POLL   = Daily total pollutant loads (kg)                            *
  * D_POLL   = Daily total pollutant concentration (mg/l)                  *
  * M_RUNOFF = Monthly runoff (in)                                         *
  * M_POLL   = Monthly total pollutant concentration (mg/l)                *
  * A_POLL   = Annual total pollutant concentration (mg/l)                 *
  * A_RUNOFF = Annual runoff (in)                                          *
  * CCONC1   = Pollutant concentration (mg/l) in inflows                   *
  * CCONC2   = Pollutant concentration (mg/l) in outflows                  *
  * LBS111   = Pollutant loads in inflow (lbs)                             *
  * LBS222   = Pollutant loads in outflow (lbs)                            *
  * K_LOSS   = Pollutant net loss (grms)                                   *
  * K_D      = Pollutant 1st order decay rate (1/day - 1/sec)              *
  * POLLANN  = Annual pollutant loads in outflows (lbs)                    *
  * POLLMEN  = Mean annual pollutant loads in outflows (lbs)               *
  * POLLMTH  = Monthly pollutant loads in outflows (lbs)                   *
  * POLLMMN  = Mean monthly pollutant loads in outflows (lbs)              *
```

```
**** Read monthly maximum buildup (gm) for each pollutant ****

      READ (1, 22)
      DO I = 1, M_w
        READ (1, 25) (K_PUDP(I,J), J=1,12)
      ENDDO

**** Read monthly buildup coefficient for each pollutant ****

      READ (1, 22)
      DO I = 1, M_w
        READ (1, 25) (K_BUDP(I,J), J=1,12)
      ENDDO

**** Read monthly washoff coefficient for each pollutant ****

      READ (1, 22)
      DO I = 1, M_w
        READ (1, 25) (A_WASH(I,J), J=1,12)
      ENDDO

**** Read monthly washoff exponent for each pollutant ****

      READ (1, 22)
      DO I = 1, M_w
        READ (1, 25) (B_WASH(I,J), J=1,12)
      ENDDO

      CLOSE (1)

**** Input format ****

11  FORMAT (20X,F20-0.2/5X,F10.0))
19  FORMAT (20X,1C15X,A5))
15  FORMAT (20X,1C19X,A11)
20  FORMAT (//)
21  FORMAT (/)
22  FORMAT (20X,1CF30.6)
23  FORMAT (///)
24  FORMAT (20X,1C510))
25  FORMAT (20X,12F5.0))
26  FORMAT (25X,1CF5.0))

30  FORMAT (5F10.2)
35  FORMAT (A700)
40  FORMAT (10X,A65)
41  FORMAT (A5,',',A4,',',A3,',',A5,',',3)A6,',',1,A5,',',3)A6,',',')
43  FORMAT (113X,A4,5X,3C)8X,A4))
44  FORMAT (113X,A4,5X,3C)9CX,A4))
45  FORMAT (F10.2)
46  FORMAT (A5,',',A4,',',A3,',',A5,',',3)A6,',',1,A5,',',3)A6,',',')
           2(A6,',',A4,',',A4)
47  FORMAT (A5,',',A4,',',A3,',',3)A6,',',1,A5,',',3)A4,',',1,
           2(A6,',',A4,',',A4)
48  FORMAT (A5,',',A4,',',A3,',',3)A4,',',1,A5,',',3)A4,',',1,
           2(A6,',',A4,',',A4)

100 FORMAT (8X,4C12.1X,1C12F11.6)
102 FORMAT (8X,3C12.1X,3X,F11.6)
150 FORMAT (1X,A2,5X,14,1X,4(12.1X,10)F11.6,1X))
151 FORMAT (15,',',14,',',3)13,',',9)F13.4,',',1,F13.6)
152 FORMAT (1X,A2,2X,14,1X,4(12.1X,10)F13-6,1X))
153 FORMAT (15,',',14,',',3)12,',',9)F13.4,',',1,F13.6)
154 FORMAT (15,',',14,',',1C,',',3)F13.4,',',F13.6)
155 FORMAT (15,',',14,',',1C,',',3)F13.4,',',F13.6)
180 FORMAT (A46)

*****************************************************************
**                    Task 2: Program Initialization
**
*****************************************************************

      WRITE (*,*)
      WRITE (*,*)  ' ***      The SSPM Model is running!      ***'
      WRITE (*,*)

**** Model initialization ****

      TFLOAT = 0.0
```

```
      REW_A = 1

**** Output files for reservoir rating curves ****

      FICNFILE(2)(3) = 'out_flw1.dat'
      FICNFILE(2)(3) = 'out_flw2.dat'
      FICNFILE(5)(3) = 'out_flw3.dat'
      FICNFILE(8)(3) = 'out_flw4.dat'
      FICNFILE(5)(3) = 'out_flw5.dat'
      FICNFILE(2)(3) = 'out_flw6.dat'
      FICNFILE(7)(3) = 'out_flw7.dat'
      FICNFILE(8)(3) = 'out_flw8.dat'
      FICNFILE(9)(3) = 'out_flw9.dat'
      FICNFILE(10)(3) = 'out_f10.dat'

**** Read Watershed Input data ****

      OPEN (1, FILE='waters1e.inp')

      READ (1, 21)
      READ (1, 19) (JCTYPE(I), I=1,RUN)
      READ (1, 18) (JCTYPE(I), I=1,RUN)
      READ (1, 22) (AREAS(I), I=1,RUN)

**** Determine the number of subcatchments to be simulated ****

      TAREAS = 0.0
      M_LAND = 0

      DO I = 1, RUN
        IF (REAS(I) .EQ. 0.01 GOTO 5
        TAREAS = TAREAS + AREAS(I)
        M_LAND = M_LAND + 1
        AREAFI(I = AREAS(I)/43560.
      ENDDO

**** Read width and slope data ****

5     READ (1, 22) (WIDTH(I), I=1,M_LAND)
      READ (1, 22) (WLN(I), I=1,M_LAND)

**** Read infiltration data ****

      READ (1, 22) (WLMAX(I), I=1,M_LAND)
      READ (1, 22) (WLMIN(I), I=1,M_LAND)
      READ (1, 22) (DECAY(I), I=1,M_LAND)
      READ (1, 22) (REGEN(I), I=1,M_LAND)
      READ (1, 14) (FILRG(I), I=1,M_LAND)
      READ (1, 22) (C_Sa(I), I=1,M_LAND)
      READ (1, 22) (C_IM(I), I=1,M_LAND)
      READ (1, 22) (C_Fs(I), I=1,M_LAND)

**** Read phosphorus movement data ****

      READ (1, 22) (FRND(I), I=1,M_LAND)
      READ (1, 22) (FFART(I), I=1,M_LAND)
      READ (1, 22) (ESURF(I), I=1,M_LAND)
      READ (1, 22) PRTHFM, EFFRAN, EFFSOR0

**** Read monthly evaporation factor for each subcatchment ****

      READ (1, 21)
      DO I = 1, M_LAND
        READ (1, 25) (EVAP_F(I,J), J=1,12)
      ENDDO

**** Read monthly Manning's N coefficient for each subcatchment ****

      READ (1, 21)
      DO I = 1, M_LAND
        READ (1, 25) (MANNIN(I,J), J=1,12)
      ENDDO

**** Read monthly depression depth (in) for each subcatchment ****

      READ (1, 21)
      DO I = 1, M_LAND
        READ (1, 25) (DEPRS(I,J), J=1,12)
      ENDDO
```

```
      DELT_T    = 1.0
      TS_SEC    = 3600.
      CINFIL    = 0.5
      CEVAPOFF  = 0.5
      D_RUNOFF  = 0.0
      M_RUNOFF  = 0.0
      A_F_DROP  = 0.0
      EVENT_T   = 0.0

      DO J = 1, NUM
         C_POOL1(J) = 0.0
         B_FULL  (J) = 0.0
         L_FULL  (J) = 0.0
         M_FULL  (J) = 0.0
         A_FULL  (J) = 0.0
      ENDDO
```

**** Input parameters for infiltration calculation (unit conversion) ****

c decay rate = 2. Smin for fine sandy clay (Darei) p.5.31 "Handbook of Hydrology"
c (mm/h) = m/3600 m * ft/0.3048 m * hr/3600 sec = 1/1097380 ft/sec

```
      DO 1 = 1, N_LAND
         WSEM(I) = 0.0
         DECAY(I) = DECAY(I) /60.
         DECAY_R(I)= DECAY(I) *DECEM(I)
         NCMAX(I) = NCMAX(I) / 1097380.
         NCMIN(I) = NCMIN(I) / 1097380.
         IF (NCMAX(I) .EQ. 0.0 .OR. NCMIN(I) .EQ. 0.0) THEN
            DRFIL(I) = 0.0
         ELSE
            DRFIL(I) = NCMAX(I)
         ENDIF
         C_Is(I) = G_Is(I)/3600.
         C_F (I) = 0.0
         C_Ps(I) = 0.0
         C_Pp(I) = 0.0
         ESCEP(I) = 0.0
         FRACT(I) = 0.5
```

****
****
****
**   Task 3: Hydrologic Simulation
**
****
****

**** Open input/output files ****

```
c     OPEN (3, FILE= 'watershe.conc.hourly')
c     OPEN (5, FILE= 'watershe.conc.daily')
c     OPEN (18, FILE= 'watershe.load.daily')
c     OPEN (9, FILE= 'watershe.load.hourly')

      OPEN (12, FILE= 'precip1.inp')
      OPEN (14, FILE= 'masschole.out')
      OPEN (7, FILE= 'evapora.hor')
      OPEN (10,FILE= 'srpm.hrs.out')
      OPEN (20,FILE= 'srpm_day.out')
      OPEN (21,FILE= 'srpm_mon.out')
      OPEN (22,FILE= 'srpm_ann.out')
```

**** Write header for output file ****

```
      WRITE (13,41)
      WRITE (20,46)
      WRITE (21,47)
```

**** Read precipitation data for the 1st data ****

```
7     READ (2,100) YEAR1,MON1,DAY1,HR1,PREC1
      write(*,*) 1, year1,mon1,day1
      IF (YEAR1.NE.YEAR_B .OR. MON1.NE.MON_B .OR. DAY1.NE.DAY_B) GOTO 7
```

**** Read evaporation data (hourly) for the 1st data ****

```
9     READ (7,100) YEAR1,MON1,DAY1,HR1,EVAP_R
      write(*,*) 2, year1,mon1,day1
      IF (YEAR1.NE.YEAR_B .OR. MON1.NE.MON_B .OR. DAY1.NE.DAY_B) GOTO 9
```

```
      DO I = 1, N_LAND
```

**** Determine the evaporation coefficient ****

```
      IF (MON1 .EQ. 1)  EVAP(I) = EVAP_C(I,1)
      IF (MON1 .EQ. 2)  EVAP(I) = EVAP_C(I,2)
      IF (MON1 .EQ. 3)  EVAP(I) = EVAP_C(I,3)
      IF (MON1 .EQ. 4)  EVAP(I) = EVAP_C(I,4)
      IF (MON1 .EQ. 5)  EVAP(I) = EVAP_C(I,5)
      IF (MON1 .EQ. 6)  EVAP(I) = EVAP_C(I,6)
      IF (MON1 .EQ. 7)  EVAP(I) = EVAP_C(I,7)
      IF (MON1 .EQ. 8)  EVAP(I) = EVAP_C(I,8)
      IF (MON1 .EQ. 9)  EVAP(I) = EVAP_C(I,9)
      IF (MON1 .EQ.10)  EVAP(I) = EVAP_C(I,10)
      IF (MON1 .EQ.11)  EVAP(I) = EVAP_C(I,11)
      IF (MON1 .EQ.12)  EVAP(I) = EVAP_C(I,12)
```

**** Determine the Manning's N coefficient ****

```
      IF (MON1 .EQ. 1)  MANN(I) = MANN1M(I,1)
      IF (MON1 .EQ. 2)  MANN(I) = MANN1M(I,2)
      IF (MON1 .EQ. 3)  MANN(I) = MANN1M(I,3)
      IF (MON1 .EQ. 4)  MANN(I) = MANN1M(I,4)
      IF (MON1 .EQ. 5)  MANN(I) = MANN1M(I,5)
      IF (MON1 .EQ. 6)  MANN(I) = MANN1M(I,6)
      IF (MON1 .EQ. 7)  MANN(I) = MANN1M(I,7)
      IF (MON1 .EQ. 8)  MANN(I) = MANN1M(I,8)
      IF (MON1 .EQ. 9)  MANN(I) = MANN1M(I,9)
      IF (MON1 .EQ.10)  MANN(I) = MANN1M(I,10)
      IF (MON1 .EQ.11)  MANN(I) = MANN1M(I,11)
      IF (MON1 .EQ.12)  MANN(I) = MANN1M(I,12)

      WRITE(*,*) MANN1M(I,J,J=1,12), MANN(I)
```

**** Determine the water loss due to the depression ****

```
      IF (MON1 .EQ. 1)  DEPRES(I) = DEPRES(I,1)/12.
      IF (MON1 .EQ. 2)  DEPRES(I) = DEPRES(I,2)/12.
      IF (MON1 .EQ. 3)  DEPRES(I) = DEPRES(I,3)/12.
      IF (MON1 .EQ. 4)  DEPRES(I) = DEPRES(I,4)/12.
      IF (MON1 .EQ. 5)  DEPRES(I) = DEPRES(I,5)/12.
      IF (MON1 .EQ. 6)  DEPRES(I) = DEPRES(I,6)/12.
      IF (MON1 .EQ. 7)  DEPRES(I) = DEPRES(I,7)/12.
      IF (MON1 .EQ. 8)  DEPRES(I) = DEPRES(I,8)/12.
      IF (MON1 .EQ. 9)  DEPRES(I) = DEPRES(I,9)/12.
      IF (MON1 .EQ.10)  DEPRES(I) = DEPRES(I,10)/12.
      IF (MON1 .EQ.11)  DEPRES(I) = DEPRES(I,11)/12.
      IF (MON1 .EQ.12)  DEPRES(I) = DEPRES(I,12)/12.

      WRITE(*,*) (DEPRES(I,J),J=1,12), DEPRES(I)

      ENDDO

      DO I = 1, NUM
```

```
**** Determine the maximum pollutant buildup (mg) ****

**** Determine the pollutant buildup coefficient ****

**** Determine the pollutant washoff coefficient ****

**** Determine the pollutant washoff exponent ****


**** Generate watershed geometric and hydraulic data (reservoir) ****

DO J = 1, N_LAND

OPEN (10+J, FILE= FLOWFILE(J))

**** Geometric and Hydraulic Data - Storage Facility*
Depth    Area    Vol-VS    Overflow    Disc-Qs
FT       FT2     FT3       CFS         CFS
```

```
      RUNOF1(I) = 0.0

      WCAS2(I) = A_EVE1(I) + A_DEF1(I) + RUNO1(I)

      TF(I/W1   = TF(OW1   / TAREAS (I)
      WAT/AS1   = WAT/AS1  * TAREAS (I)
      S_DEF1    = S_INF1   * TAREAS (I)
      S_EVP1    = S_EVP1   + A_EVP1(I)* TAREAS (I)
      S_RUN1    = S_RUN1   * TAREAS (I)
      T_INH1    = T_INH1   + WCOM1(I) * TAREAS (I)

      ENDDO

      RUNOFF1 = TF(OW1  / TAREAS
      WAT/AS1 = WAT/AS1 / TAREAS
      S_INF1  = S_INF1  / TAREAS
      S_EVP1  = S_EVP1  / TAREAS
      S_RUN1  = S_RUN1  / TAREAS

      COM1M1  = COM1M1  + IS-AC1
      COM1M1  = COM1M1 + WAT/AS1
      IF (COM1M1 .GT. 0.0) THEN
         ERROR1 = (COM1M1-COM1TM1)/COM1M1*100.
      ELSE
         ERROR1 = 0.0
      ENDIF

**** Read next time step of rainfall and hourly evaporation data ****

10    READ (2,100, END=1000) YEAR1,MON1,DAY1,HR1,PREC1
      READ (7,100, END=1000) YEAR2,MON2,DAY2,HR2,EVAP_R

**** Determine the hydrologic coefficients ****

15    DO I = 1, N_LAND

**** Determine the evaporation coefficient ****

      IF (MON2 .EQ. 1)  EVAP(I) = EVAP_C(I,1)
      IF (MON2 .EQ. 2)  EVAP(I) = EVAP_C(I,2)
      IF (MON2 .EQ. 3)  EVAP(I) = EVAP_C(I,3)
      IF (MON2 .EQ. 4)  EVAP(I) = EVAP_C(I,4)
      IF (MON2 .EQ. 5)  EVAP(I) = EVAP_C(I,5)
      IF (MON2 .EQ. 6)  EVAP(I) = EVAP_C(I,6)
      IF (MON2 .EQ. 7)  EVAP(I) = EVAP_C(I,7)
      IF (MON2 .EQ. 8)  EVAP(I) = EVAP_C(I,8)
      IF (MON2 .EQ. 9)  EVAP(I) = EVAP_C(I,9)
      IF (MON2 .EQ. 10) EVAP(I) = EVAP_C(I,10)
      IF (MON2 .EQ. 11) EVAP(I) = EVAP_C(I,11)
      IF (MON2 .EQ. 12) EVAP(I) = EVAP_C(I,12)

**** Determine the Manning's N coefficient ****

      IF (MON2 .EQ. 1)  MANH(I) = MANH1M(I,1)
      IF (MON2 .EQ. 2)  MANH(I) = MANH1M(I,2)
      IF (MON2 .EQ. 3)  MANH(I) = MANH1M(I,3)
      IF (MON2 .EQ. 4)  MANH(I) = MANH1M(I,4)
      IF (MON2 .EQ. 5)  MANH(I) = MANH1M(I,5)
      IF (MON2 .EQ. 6)  MANH(I) = MANH1M(I,6)
      IF (MON2 .EQ. 7)  MANH(I) = MANH1M(I,7)
      IF (MON2 .EQ. 8)  MANH(I) = MANH1M(I,8)
      IF (MON2 .EQ. 9)  MANH(I) = MANH1M(I,9)
      IF (MON2 .EQ. 10) MANH(I) = MANH1M(I,10)
      IF (MON2 .EQ. 11) MANH(I) = MANH1M(I,11)
      IF (MON2 .EQ. 12) MANH(I) = MANH1M(I,12)

**** Determine the water loss due to the depression ****

      IF (MON2 .EQ. 1)  DEPRS(I) = DEPRS(I,1)/12.
      IF (MON2 .EQ. 2)  DEPRS(I) = DEPRS(I,2)/12.
      IF (MON2 .EQ. 3)  DEPRS(I) = DEPRS(I,3)/12.
      IF (MON2 .EQ. 4)  DEPRS(I) = DEPRS(I,4)/12.
      IF (MON2 .EQ. 5)  DEPRS(I) = DEPRS(I,5)/12.
      IF (MON2 .EQ. 6)  DEPRS(I) = DEPRS(I,6)/12.
      IF (MON2 .EQ. 7)  DEPRS(I) = DEPRS(I,7)/12.
      IF (MON2 .EQ. 8)  DEPRS(I) = DEPRS(I,8)/12.
      IF (MON2 .EQ. 9)  DEPRS(I) = DEPRS(I,9)/12.
      IF (MON2 .EQ. 10) DEPRS(I) = DEPRS(I,10)/12.
      IF (MON2 .EQ. 11) DEPRS(I) = DEPRS(I,11)/12.
      IF (MON2 .EQ. 12) DEPRS(I) = DEPRS(I,12)/12.
```

```
      ENDDO

      DO I = 1, NUM

**** Determine the maximum pollutant buildup (mg) ****

      IF (MON1 .EQ. 1)  M_BUD(I) = M_BUDP(I,1)
      IF (MON1 .EQ. 2)  M_BUD(I) = M_BUDP(I,2)
      IF (MON1 .EQ. 3)  M_BUD(I) = M_BUDP(I,3)
      IF (MON1 .EQ. 4)  M_BUD(I) = M_BUDP(I,4)
      IF (MON1 .EQ. 5)  M_BUD(I) = M_BUDP(I,5)
      IF (MON1 .EQ. 6)  M_BUD(I) = M_BUDP(I,6)
      IF (MON1 .EQ. 7)  M_BUD(I) = M_BUDP(I,7)
      IF (MON1 .EQ. 8)  M_BUD(I) = M_BUDP(I,8)
      IF (MON1 .EQ. 9)  M_BUD(I) = M_BUDP(I,9)
      IF (MON1 .EQ. 10) M_BUD(I) = M_BUDP(I,10)
      IF (MON1 .EQ. 11) M_BUD(I) = M_BUDP(I,11)
      IF (MON1 .EQ. 12) M_BUD(I) = M_BUDP(I,12)

**** Determine the pollutant buildup coefficient ****

      IF (MON1 .EQ. 1)  K_BUD(I) = K_BUDP(I,1)
      IF (MON1 .EQ. 2)  K_BUD(I) = K_BUDP(I,2)
      IF (MON1 .EQ. 3)  K_BUD(I) = K_BUDP(I,3)
      IF (MON1 .EQ. 4)  K_BUD(I) = K_BUDP(I,4)
      IF (MON1 .EQ. 5)  K_BUD(I) = K_BUDP(I,5)
      IF (MON1 .EQ. 6)  K_BUD(I) = K_BUDP(I,6)
      IF (MON1 .EQ. 7)  K_BUD(I) = K_BUDP(I,7)
      IF (MON1 .EQ. 8)  K_BUD(I) = K_BUDP(I,8)
      IF (MON1 .EQ. 9)  K_BUD(I) = K_BUDP(I,9)
      IF (MON1 .EQ. 10) K_BUD(I) = K_BUDP(I,10)
      IF (MON1 .EQ. 11) K_BUD(I) = K_BUDP(I,11)
      IF (MON1 .EQ. 12) K_BUD(I) = K_BUDP(I,12)

**** Determine the pollutant washoff coefficient ****

      IF (MON2 .EQ. 1)  A_WASH(I) = A_WASHO(I,1)
      IF (MON2 .EQ. 2)  A_WASH(I) = A_WASHO(I,2)
      IF (MON2 .EQ. 3)  A_WASH(I) = A_WASHO(I,3)
      IF (MON2 .EQ. 4)  A_WASH(I) = A_WASHO(I,4)
      IF (MON2 .EQ. 5)  A_WASH(I) = A_WASHO(I,5)
      IF (MON2 .EQ. 6)  A_WASH(I) = A_WASHO(I,6)
      IF (MON2 .EQ. 7)  A_WASH(I) = A_WASHO(I,7)
      IF (MON2 .EQ. 8)  A_WASH(I) = A_WASHO(I,8)
      IF (MON2 .EQ. 9)  A_WASH(I) = A_WASHO(I,9)
      IF (MON2 .EQ. 10) A_WASH(I) = A_WASHO(I,10)
      IF (MON2 .EQ. 11) A_WASH(I) = A_WASHO(I,11)
      IF (MON2 .EQ. 12) A_WASH(I) = A_WASHO(I,12)

**** Determine the pollutant washoff exponent ****

      IF (MON2 .EQ. 1)  B_WASH(I) = B_WASHO(I,1)
      IF (MON2 .EQ. 2)  B_WASH(I) = B_WASHO(I,2)
      IF (MON2 .EQ. 3)  B_WASH(I) = B_WASHO(I,3)
      IF (MON2 .EQ. 4)  B_WASH(I) = B_WASHO(I,4)
      IF (MON2 .EQ. 5)  B_WASH(I) = B_WASHO(I,5)
      IF (MON2 .EQ. 6)  B_WASH(I) = B_WASHO(I,6)
      IF (MON2 .EQ. 7)  B_WASH(I) = B_WASHO(I,7)
      IF (MON2 .EQ. 8)  B_WASH(I) = B_WASHO(I,8)
      IF (MON2 .EQ. 9)  B_WASH(I) = B_WASHO(I,9)
      IF (MON2 .EQ. 10) B_WASH(I) = B_WASHO(I,10)
      IF (MON2 .EQ. 11) B_WASH(I) = B_WASHO(I,11)
      IF (MON2 .EQ. 12) B_WASH(I) = B_WASHO(I,12)

      ENDDO

**** Generate watershed geometric and hydraulic data (reservoir) ****

      DO J = 1, N_LAND

      IF (DEPRS2(J) .EQ. DEPRS1(J)) THEN

      OPEN (10+J, FILE=FILNFILE(J))
```

```
c     write(*,*) inf1(i),inf2(i)

c ***** Calculate mean infil. capacity and evap. rate during a time step *****

      M_INF(I) = 0.5*(INFIL(I) - INFIL2(I))
      M_EVP(I) = 0.5*(EVAP0(I) - EVAP02(I))

c ***** Update water remained in catchment (in) due to infiltration *****

      IF (M_MREM(I) .GT. M_INF(I)) THEN
         M_INF2(I) = M_INF(I)
         M_MREM(I) = M_MREM(I) - M_INF(I)
      ELSEIF (M_MREM(I).LT.M_INF(I) .AND. M_MREM(I).GT.0.00) THEN
         M_INF2(I) = M_MREM(I)
         M_MREM(I) = 0.0
      ELSE
         A_INF2(I) = 0.0
         M_MREM(I) = 0.0
      ENDIF
      M_INF(I) = M_INF(I) - A_INF2(I)

c ***** Update net inflow (in) due to infiltration if no water remained *****

      IF (M_MREM(I) .EQ. 0.0 .AND. M_INF(I) .GT. 0.01) THEN
         IF (N_INFM(I) .GT. M_INF(I)) THEN
            A_INF2(I) = A_INF2(I) + M_INF(I)
            N_INFM(I) = N_INFM(I) - M_INF(I)
         ELSEIF (N_INFM(I).LE.M_INF(I).AND. N_INFM2(I).GT.0.) THEN
            A_INF2(I) = A_INF2(I) + N_INFM2(I)
            N_INFM(I) = 0.0
         ELSE
            N_INFM(I) = 0.0
         ENDIF
      ENDIF

c ***** Update net inflow from precipitation (in) due to evaporation *****

      IF (M_MREM2(I) .GT. M_EVP(I)) THEN
         A_EVP2(I) = M_EVP(I)
         M_MREM2(I) = M_MREM2(I) - M_EVP(I)
      ELSEIF (M_MREM2(I).LE.M_EVP(I).AND. M_MREM2(I).GT.0.0) THEN
         A_EVP2(I) = M_MREM2(I)
         M_MREM2(I) = 0.0
      ELSE
         A_EVP2(I) = 0.0
         M_MREM2(I) = 0.0
      ENDIF
      M_EVP(I) = M_EVP(I) - A_EVP2(I)

c ***** Update water remained (in) due to evaporation if no more inflow *****

      IF (M_MREM2(I) .EQ. 0.0 .AND. M_EVP(I) .GT. 0.0) THEN
         IF (N_MREM(I) .GT. M_EVP(I)) THEN
            A_EVP2(I) = A_EVP2(I) + M_EVP(I)
            N_MREM(I) = N_MREM(I) - M_EVP(I)
         ELSEIF (N_MREM(I).LE.M_EVP(I) .AND. N_MREM(I).GT.0.) THEN
            A_EVP2(I) = A_EVP2(I) + N_MREM(I)
            N_MREM(I) = 0.0
         ELSE
            N_MREM(I) = 0.0
         ENDIF
      ENDIF

c ***** Determine outflows and water elevation at end of time step *****
c ***** by using the method applied in SWMM - Storage Treatment Block *****

      O2DT_V(I) = 0.5*(M_INFM(I)+N_INFM2(I))/TS *AREAF(I) +
     *            (N_MREM(I)-0.5*M_MR04(I))/TS *AREAF(I)

c     write (*,*) O2DT_V(I),A_INFM(I),N2AF(I),N2AF(I),RUN0(I))
      IF (O2DT_V(I) .GE. 0.0) THEN
         CALL INTERS2 (DEPTH,AREA,VOLUME,Qove,DISCH,O2DT_V(I),J)
c     RNFM2(I) = Depth*2
         RUN02(I) = Qove/AREAF(I)*12.*TS_SEC
c     write (*,*) TS_SEC,RUN02(I),a_mrem(i),a_infm(i),araf(i)
c     write (*,*) DEPTH,AREA,VOLUME,Qove,DISCH,O2DT_V(I)
      ELSE
         M_EVP(I) = 0.0
         RUN02(I) = 0.0
```

```
C     S U B R O U T I N E   I N F I L T R A T I O N

C**** THIS SUBROUTINE CALCULATES ACTUAL INFILTRATION TRENCH BY USING THE
C**** INTEGRATED HORTON'S EQUATION APPLIED IN SWMM MODEL (F.47)(
C     TP/TT1  = Initial/End of time step (sec)
C     Tw      = Time difference for regeneration (sec)
C     TFR     = Value of TP at beginning of regeneration (sec)
C     DELT    = Incremented time step (sec)
C     REGEN   = Constant ratio << 1.0 for regeneration of dry time step
C     MINMX   = Maximum/initial infiltration capacity, ft/sec
C     MINTR   = Minimum/ultimate infiltration capacity, ft/sec
C     INF(1)(2)(=Cumulative infiltration at beg. and end of time step, ft/s
C     PLOSS   = Average infiltration capacity available over next time step
C     RLOSS   = Average actual infiltration capacity over the time step
C
      SUBROUTINE INFILTRATION (W_MAXa,MINTRa,REGENa,DECAYa,DECAY_Ra,
     &                         INF1a,INF12a,Tra,TP1a,V_INL_T,DECT)

      REAL CUMINF, CUML, FF, DFF, RFF, RLOSS, RLOSS1, T1, TFR
      REAL MINMXa,MINTRa,REGENa,DECAYa,DECAY_Ra
      REAL INF1a,INF12a,DELT,TPa,TP1a,V_INL_T

C**** Calculate actual infiltration capacity during wet weather ****

      IF (V_Inl_T .GT. 1.E-7) THEN

         T1 = TPa + DELT

         CUMINF = HORTON (MINMXa,MINTRa,DECAYa,T1)
         CUMI   = HORTON (MINMXa,MINTRa,DECAYa,TPa)

         RLOSS1 = (CUMINF - CUMI)/DELT

         IF (V_Inl_T .GE. RLOSS1) RLOSS = RLOSS1
         IF (V_Inl_T .LT. RLOSS1) RLOSS = V_Inl_T

         INF12a = INF1a + RLOSS*DELT

C**** Using Newton-Raphson procedure to determine TP1a ****

C**  initial guess
         TP1a = TPa + 0.5*DELT

   30    FF = HORTON (MINMXa,MINTRa,DECAYa,TP1a) - INF12a
         DFF = MINMXa + (MINTRa-MINMXa)*EXP(-DECAYa*TP1a)
         RFF = FF/DFF

C**  convergence criterion
         IF (TP1a .LE. 1E-4/DECAYa) THEN
            IF (DFF .GE. 0.001*DELT) THEN
               TP1a = TPa - RFF
               FF = HORTON (MINMXa,MINTRa,DECAYa,TP1a) - INF12a
               DFF = MINMXa + (MINTRa-MINMXa)*EXP(-DECAYa*TP1a)
               RFF = FF/DFF
               GOTO 30
            ENDIF
         ELSE
            INF12a = MINTRa
         ENDIF

      ELSE

C**** Calculate regeneration of infiltration capacity during dry weather ****

         TFR = TPa
         TP1a = -1./DECAYa*LOG(1.-EXP(-DECAY_Ra*(DELT-
     &          (1.-EXP(-DECAYa*TFR))))
         INF12a = MINMXa - (MINMXa - MINTRa) * EXP(-DECAYa*TP1a)

      ENDIF

      RETURN
      END

C     S U B R O U T I N E   I N F I L T R A T I O N 2
```

```
      C_RUNOFF = D_RUNOFF + RUNOFF1
      M_RUNOFF = M_RUNOFF + RUNOFF2
      A_RUNOFF = A_RUNOFF + RUNOFF3

      DO J = 1, NUM
         C_POLL(J) = C_POLL(J) + C_POLL2(J)*RUNOFF1**TRANS*0.10279
         D_POLL(J) = D_POLL(J) + C_POLL2(J)*RUNOFF1
         M_POLL(J) = M_POLL(J) + C_POLL2(J)*RUNOFF1
         A_POLL(J) = A_POLL(J) + C_POLL2(J)*RUNOFF1

         IF (D_RUNOFF .GT. C.0) THEN
            D_POLL(J) = D_POLL(J)/D_RUNOFF
         ELSE
            D_POLL(J) = 0.0
         ENDIF
         IF (M_RUNOFF .GE. 0.03) THEN
            M_POLL(J) = M_POLL(J)/M_RUNOFF
         ELSE
            M_POLL(J) = 0.0
         ENDIF
         IF (A_RUNOFF .GE. 0.01) THEN
            A_POLL(J) = A_POLL(J)/A_RUNOFF
         ELSE
            A_POLL(J) = 0.0
         ENDIF
      ENDIF

C**** Print out daily simulation results for last observed data ****

      WRITE (20,153) REC_D,1900-YEAR2,MON2,DAY2,D_RUNOFF,
     &               (D_POLL(J),J=1,NUM)

C**** Print out monthly simulation results for last observed data ****

      WRITE (21,154) REC_M,1900-YEAR2,MON2,M_RUNOFF,
     &               (M_POLL(J),J=1,NUM)

C**** Print out annual simulation results for last observed data ****

      WRITE (22,155) REC_A,1900-YEAR2,A_RUNOFF,
     &               (A_POLL(J),J=1,NUM)

C**** Close all files and quit the program ****

      CLOSE (12)
      CLOSE (14)
      CLOSE (17)
      CLOSE (10)

      DO I = 10, 22
         CLOSE (I)
      ENDDO

      WRITE (*,*)
      WRITE (*,*)  '    The simulation has completed !'
      WRITE (*,*)
      WRITE (*,*)

      STOP
      END

C     F U N C T I O N   H O R T O N ' S   E Q U A T I O N

C**  THIS FUNCTION USES THE INTEGRATED HORTON'S EQUATION TO CALCULATE THE
C**  THIS CUMULATIVE INFILTRATION CAPACITY - FT/S (FROM SWMM MANUAL F.47)(

      FUNCTION HORTON (MINMX,MINTR,DECAY,T)
      REAL MINMX,MINTR,DECAY,T

      HORTON = MINTR*T + (MINMX-MINTR)/DECAY*(1.0 - EXP(-DECAY*T))

      RETURN
      END
```

```
      O2DT_Va    = 0.0

      DO I = 1, NUN

      IF (O2DT_V .GE. C2DT_Va .AND. O2DT_V .EQ. O2DT_VN(I,J)) THEN
         IF (O2DT_VN(I,J) .NE. C2DT_Va) THEN
            Area  =(O2DT_V-C2DT_Va)/(O2DT_VN(I,J)-O2DT_Va)*(AreaN(I,J)
     .            -Area)+Area
            Volume=(O2DT_V-C2DT_Va)/(O2DT_VN(I,J)-O2DT_Va)*(VolumeN(I,J)
     .            -Volume) + Volume
            Qave  =(O2DT_V-C2DT_Va)/(O2DT_VN(I,J)-O2DT_Va)*(QaveN(I,J)
     .            -Qave) + Qave
            Disch =(O2DT_V-C2DT_Va)/(O2DT_VN(I,J)-O2DT_Va)*(DischN(I,J)
     .            -Disch) + Disch
            Depth =(DepthN(I,J) - Depth) + Depth
         ELSE
            Area   = AreaN(I,J)
            Volume = VolumeN(I,J)
            Qave   = QaveN(I,J)
            Disch  = DischN(I,J)
            Depth  = DepthN(I,J)
         ENDIF
         GOTO 200

      ELSE
         O2DT_Va  = O2DT_VN(I,J)
         Area     = AreaN(I,J)
         Volume   = VolumeN(I,J)
         Qave     = QaveN(I,J)
         Disch    = DischN(I,J)
         Depth    = DepthN(I,J)
      ENDIF

      ENDDO

 100  Area   = AreaN(NUN,J)
      Volume = VolumeN(NUN,J)
      Depth  = DepthN(NUN,J)
      Qave   = QaveN(NUN,J)
      Disch  = DischN(NUN,J)

 200  RETURN
      END
```

```
* *********************************************************
* THIS SUBROUTINE CALCULATES CUMULATIVE INFILTRATION VOLUME BY USING
* GREEN-AMPT EQUATION APPLIED IN THE SWMM MODEL (P.443)
* DELT = incremented time step (sec)
* INF1(1,2)) =Infiltration rate at beg. and end of time step (ft/s)
* FRE(1,2) = Input rain at beg. and end of time for subcatchment (in)
* i    = Average rainfall intensity during the time step (ft/sec)
* F    = Cumulative infiltration volume (ft)
* Fp   = Cumulative infiltration volume required to cause saturation (ft)
* fp   = Infiltration capacity  (ft/sec)
* Su   = Average capillary suction at the wetting front (ft water)
* IMD  = Initial moisture deficit for the storm event (ft/ft)
* Ks   = Saturated hydraulic conductivity of soil (ft/sec)
* *********************************************************

      SUBROUTINE INFILTR2 (INF1a,INF12a,FRE1a,FRE2a,DELT,Su,IMD,Fp,F,f,i
     .                     Su,IMD_max,Ks,Fp,Fs,F,EVENT_T)

      DOUBLE PRECISION Ks

      REAL INF1a,INF12a,FRE1a,FRE2a,DELT,Su,IMD,Fp,F,f,i
      REAL EVENT_T, T, IMD_max, F2, DV, L, DF

      IMD = IMD_max
      IF (F .LT. Fs) THEN
      i = 0.5*(FRE1a+ FRE2a)/12./DELT
         INF1a = i
         IF (i .GT. Ks) THEN
            Fs = [Su*IMD] / [(i/Ks-1.)
         ENDIF
      ELSE
         INF1a = Fp
         IF (F .GT. 2.5) THEN
            Fp = Ks + [1.+Su*IMD/F]
         ELSE
            Fp = Fs
         ENDIF
      ENDIF
      F = F + INF1a*DELT

**** Recovery of Infiltration Capacity ****

      L = 4. * SQRT(Ks*12 *3600.)
      DV = L/300.
      FU_max = L * IMD_max
      DV = DF * F2_max * DELT/3600.
      EVENT_T = EVENT_T + DELT/3600.
      T = 6./(100.* DV)

      IF (EVENT_T .LE. T) THEN
         IF (FU .GE. 0.00) F2 = FU - DV
         IF (F .GE. 0.00)  F = F - DV
         IF (IMD .LE. IMD_max) IMD = (FU_max - FU) / L
      ELSE
         F = 0.0
         EVENT_T = 0.0
      ENDIF

c     write ('.',') Su,IMD,Ks,Fp,Fs,F,EVENT_T,T

      RETURN
      END

* *********************************************************
**        S U B R O U T I N E   I N T E R E C C A T I N G (2)    **
* *********************************************************

      SUBROUTINE INTERP2 (DEPTH,AREA,VOLUME,Qave,DISCH,O2DT_V,J)

      PARAMETER (NLN=30,NLU=10)

      INTEGER I
      REAL  DEPTH,AREA,VOLUME,Qave,DISCH,O2DT_V,DEPTH,AREA,VOLUME,
     .      Qave,DISCHa,O2DT_Va
      REAL  DEPTHN(NLN,NLU),AREAN(NLN,NLU),VOLUMEN(NLN,NLU),
     .      QAVEN(NLN,NLU),DISCHN(NLN,NLU),O2DTVN(NLN,NLU),
     .      O2DT_VN(NLN,NLU)

      COMMON /NELP_1/ DepthN,AreaN,VolumeN,QaveN,DischN,O2DTV,O2DT_VN
```

APPENDIX C

SRPM OUTPUT

APPENDIX C-1

Hourly Runoff and Pollutant Concentrations

"REC", "YEAR", "MONTH", "DAY", "HOUR", "FLOW", "BOD5", "TSS", "TN", "TP", "ZN", "PEST", "TRAC", "PB", "CU"

REC	YEAR	MONTH	DAY	HOUR	FLOW	BOD5	TSS	TN	TP	ZN	PEST	TRAC	PB	CU
445	1991	5	19	13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
446	1991	5	19	14	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
447	1991	5	19	15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
448	1991	5	19	16	0.000441	0.000011	0.000011	0.034541	0.023027	0.000011	0.000180	0.000011	0.000011	0.000011
449	1991	5	19	17	0.049220	0.001639	0.001639	4.020810	2.412424	0.001639	0.029564	0.001639	0.001639	0.001639
450	1991	5	19	18	0.124258	0.004737	0.004737	11.623936	6.374329	0.004737	0.100818	0.004737	0.004737	0.004737
451	1991	5	19	19	0.141436	0.008041	0.008041	19.731436	11.838820	0.008041	0.179044	0.008041	0.008041	0.008041
452	1991	5	19	20	0.115461	0.008951	0.008951	21.961741	13.178202	0.008951	0.200164	0.008951	0.008951	0.008951
453	1991	5	19	21	0.094481	0.007103	0.007103	17.425777	10.457846	0.007103	0.153741	0.007103	0.007103	0.007103
454	1991	5	19	22	0.077894	0.005697	0.005697	13.979064	8.387373	0.005697	0.119191	0.005697	0.005697	0.005697
455	1991	5	19	23	0.062174	0.004670	0.004670	11.458278	6.874983	0.004670	0.094215	0.004670	0.004670	0.004670
456	1991	5	19	24	0.046615	0.003756	0.003756	9.216952	5.530139	0.003756	0.072434	0.003756	0.003756	0.003756
457	1991	5	20	1	0.032391	0.002871	0.002871	7.044942	4.226997	0.002871	0.052219	0.002871	0.002871	0.002871
458	1991	5	20	2	0.019639	0.002104	0.002104	5.152311	3.097361	0.002104	0.035513	0.002104	0.002104	0.002104
459	1991	5	20	3	0.008478	0.001553	0.001553	3.809894	2.236056	0.001553	0.023754	0.001553	0.001553	0.001553
460	1991	5	20	4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
461	1991	5	20	5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
462	1991	5	20	6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
463	1991	5	20	7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
464	1991	5	20	8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
465	1991	5	20	9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
466	1991	5	20	10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
467	1991	5	20	11	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
468	1991	5	20	12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
469	1991	5	20	13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
470	1991	5	20	14	0.001871	0.000056	0.000056	0.135746	0.081448	0.000056	0.000509	0.000056	0.000056	0.000056
471	1991	5	20	15	0.005473	0.000180	0.000180	0.442600	0.265494	0.000180	0.002147	0.000180	0.000180	0.000180
472	1991	5	20	16	0.004420	0.000331	0.000331	0.810305	0.486183	0.000331	0.003951	0.000331	0.000331	0.000331
473	1991	5	20	17	0.002733	0.000291	0.000291	0.715692	0.429415	0.000291	0.003311	0.000291	0.000291	0.000291
474	1991	5	20	18	0.000602	0.000383	0.000383	0.937172	0.565680	0.000383	0.003958	0.000383	0.000383	0.000383
475	1991	5	20	19	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
476	1991	5	20	20	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

APPENDIX C-2

Daily Runoff and Pollutant Concentrations

"REC",	"YEAR",	"MONTH",	"DAY",	"RUNO",	"BOD5",	"TSS",	"TN",	"TP",	"ZN",	"PEST",	"TRAC",	"PB",	"CU"
45,	1991,	6,	14,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
46,	1991,	6,	15,	0.004223,	0.000229,	0.000229,	0.563043,	0.005414,	0.336864,	0.002519,	0.000229,	0.000229,	0.000229
47,	1991,	6,	16,	0.067518,	0.001845,	0.001845,	4.527172,	0.042909,	2.716544,	0.019808,	0.001845,	0.001845,	0.001845
48,	1991,	6,	17,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
49,	1991,	6,	18,	0.581005,	0.014186,	0.014186,	34.806637,	0.322091,	20.884035,	0.146544,	0.014186,	0.014186,	0.014186
50,	1991,	6,	19,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
51,	1991,	6,	20,	0.057444,	0.001622,	0.001622,	3.979306,	0.335773,	2.387973,	0.015984,	0.001622,	0.001622,	0.001622
52,	1991,	6,	21,	0.466126,	0.010376,	0.010376,	25.450407,	0.226312,	15.276299,	0.100381,	0.010376,	0.010376,	0.010376
53,	1991,	6,	22,	0.029075,	0.004564,	0.004564,	11.198627,	0.099540,	6.718966,	0.044153,	0.004564,	0.004564,	0.004564
54,	1991,	6,	23,	0.006530,	0.000346,	0.000346,	0.849562,	0.007415,	0.510360,	0.003240,	0.000346,	0.000346,	0.000346
55,	1991,	6,	24,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
56,	1991,	6,	25,	0.499411,	0.012438,	0.012438,	30.517471,	0.258052,	18.310507,	0.110633,	0.012438,	0.012438,	0.012438
57,	1991,	6,	26,	0.036159,	0.006802,	0.006802,	16.690149,	0.141133,	10.014033,	0.060506,	0.006802,	0.006802,	0.006802
58,	1991,	6,	27,	0.015492,	0.000876,	0.000876,	2.150113,	0.017818,	1.290068,	0.007530,	0.000876,	0.000876,	0.000876
60,	1991,	6,	29,	0.000248,	0.000020,	0.000020,	0.082053,	0.000641,	0.041027,	0.000160,	0.000020,	0.000020,	0.000020
61,	1991,	6,	30,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
62,	1991,	7,	1,	0.617900,	0.012269,	0.012269,	30.104082,	0.237302,	18.062410,	0.096464,	0.012269,	0.012269,	0.012269
63,	1991,	7,	2,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
64,	1991,	7,	3,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
65,	1991,	7,	4,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
66,	1991,	7,	5,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
67,	1991,	7,	6,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
68,	1991,	7,	7,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
69,	1991,	7,	8,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
70,	1991,	7,	9,	0.005309,	0.000338,	0.000338,	0.830788,	0.006012,	0.497707,	0.002266,	0.000338,	0.000338,	0.000338
71,	1991,	7,	10,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000
72,	1991,	7,	11,	0.153520,	0.006666,	0.006666,	16.356247,	0.116492,	9.813629,	0.043302,	0.006666,	0.006666,	0.006666

APPENDIX C-3

Monthly Runoff and Pollutant Concentrations

"REC"	"YEAR"	"MONTH"	"RUNO"	"BOD5"	"TSS"	"TN"	"TP"	"ZN"	"PEST"	"TRAC"	"PB"	"CU"
1	1991	5	1.837664	0.005091	—	—	—	—	—	12.491430	—	0.106690
2	1991	6	1.754643	0.011279	0.011279	27.675924	0.246404	0.169409	0.011279	16.605508	0.011279	0.0112
3	1991	7	1.554542	0.011022	0.011022	27.044521	0.192992	0.071873	0.011022	16.226583	0.011022	0.0110
4	1991	8	2.266662	0.027144	0.027144	56.604296	1.153332	0.593835	0.027144	39.961723	0.027144	0.0271
5	1991	9	0.157321	0.017451	0.017451	42.822231	0.444350	0.243873	0.017451	25.692757	0.017451	0.0174
6	1991	10	0.123402	0.013389	0.013389	32.853886	0.944112	0.505929	0.013389	19.711641	0.013389	0.0133
7	1991	11	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000
8	1991	12	0.03327	0.008971	0.008971	22.011503	0.250202	0.113011	0.008971	13.206902	0.008971	0.0089
9	1992	1	0.564377	0.038775	0.038775	95.143394	0.922433	0.385519	0.038775	57.087057	0.038775	0.0387
10	1992	2	0.741178	0.054531	0.054531	133.807338	1.206769	0.483593	0.054531	80.287857	0.054531	0.0545
11	1992	3	0.047694	0.005288	0.005288	12.972791	0.108766	0.041555	0.005288	7.786743	0.005288	0.0052
12	1992	4	1.087279	0.063035	0.063035	154.680006	1.186818	0.424268	0.063035	92.814476	0.063035	0.0630
13	1992	5	0.546774	0.101220	0.101220	248.385681	1.482376	0.547731	0.101220	149.043167	0.101220	0.1012
14	1992	6	4.439866	0.088075	0.088075	216.131638	1.749764	0.657681	0.088075	129.689148	0.088075	0.0880
15	1992	7	0.508957	0.008417	0.008417	20.654152	0.115804	0.029223	0.008417	12.192699	0.008417	0.0084
16	1992	8	6.501061	0.020539	0.020539	50.398941	0.595240	0.302346	0.020539	30.239498	0.020539	0.0205
17	1992	9	2.137739	0.006681	0.006681	16.392334	0.176837	0.107561	0.006681	9.335384	0.006681	0.0066
18	1992	10	0.978503	0.009863	0.009863	24.199484	0.621126	0.342683	0.009863	14.519767	0.009863	0.0098
19	1992	11	0.057587	0.003017	0.003017	7.402203	0.115582	0.059728	0.003017	4.441251	0.003017	0.0030
20	1992	12	0.127475	0.013908	0.013908	34.126553	0.396194	0.157578	0.013908	20.475615	0.013908	0.0139
21	1993	1	1.242316	0.040097	0.040097	98.387245	0.930592	0.336193	0.040097	59.031242	0.040097	0.0400
22	1993	2	0.885607	0.045690	0.045690	112.106924	0.999311	0.298769	0.045690	67.263733	0.045690	0.0456
23	1993	3	1.354144	0.067624	0.067624	165.924820	1.250391	0.388924	0.067624	99.554199	0.067624	0.0676
24	1993	4	0.877631	0.039512	0.039512	96.947250	0.645003	0.179466	0.039512	58.167522	0.039512	0.0395
25	1993	5	2.055515	0.052299	0.052299	128.323608	0.707401	0.203472	0.052299	76.992752	0.052299	0.0522

APPENDIX C-4

Annual Runoff and Pollutant Concentrations

```
"REC","YEAR","RUNO","BODS","TSS","TN","TP","ZN","PEST","TRAC","PB","CU"
  1,1991,   7.737563,   0.014554,  35.712685,   0.483337,   0.240408,   0.014554,   0.014554,  21.427322,   0.014554,
  2,1992,  17.938492,   0.041928, 102.887016,   0.915421,   0.383678,   0.041928,   0.041928,  51.735002,   0.041928,
  3,1993,  21.672411,   0.031141,  76.409767,   0.672247,   0.273983,   0.031141,   0.031141,  45.844948,   0.031141
```

APPENDIX C-5

Hourly Mass Balance Data

WATERSHED MODEL SIMULATION RESULTS- MASS BALANCE

DATE					PREC	INFI	EVAP	RUNO	WREM	CUMT	CUMO	ERRO
ERR	1991	5	19	5	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	6	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	7	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	8	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	9	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	10	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	11	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	12	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	13	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	14	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	15	0	0.000000	0.000000	0.000000	0.000000	0.000000	1.575000	1.576699	-0.107879
ERR	1991	5	19	16	0	0.120000	0.081449	0.011184	0.000441	0.013463	1.695000	1.669771	1.488295
ERR	1991	5	19	17	0	0.890000	0.080375	0.008218	0.049220	0.396288	2.585000	1.807587	30.074013
ERR	1991	5	19	18	0	0.700000	0.079563	0.004566	0.124258	0.985199	3.285000	2.015912	38.632820
ERR	1991	5	19	19	0	0.000000	0.078682	0.001370	0.141436	1.120018	3.285000	2.237399	31.890440
ERR	1991	5	19	20	0	0.005000	0.077909	0.000000	0.115461	0.916169	3.290000	2.439769	26.116434
ERR	1991	5	19	21	0	0.030000	0.077181	0.000000	0.094481	0.751508	3.320000	2.602432	21.613512
ERR	1991	5	19	22	0	0.035000	0.076492	0.000000	0.077894	0.621329	3.355000	2.756817	17.829594
ERR	1991	5	19	23	0	0.010000	0.075839	0.000000	0.062174	0.497955	3.365000	2.894830	13.972356
ERR	1991	5	19	24	0	0.005000	0.075219	0.000000	0.046615	0.375843	3.370000	3.016664	10.484750
ERR	1991	5	20	1	0	0.000000	0.074630	0.000000	0.032291	0.264210	3.370000	3.123685	7.309071
ERR	1991	5	20	2	0	0.000000	0.074068	0.000000	0.019639	0.164127	3.370000	3.217391	4.528453
ERR	1991	5	20	3	0	0.000000	0.073533	0.000000	0.008478	0.076536	3.370000	3.299402	2.094900
ERR	1991	5	20	4	0	0.000000	0.073021	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	5	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	6	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	7	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	8	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	9	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	10	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908
ERR	1991	5	20	11	0	0.000000	0.000000	0.000000	0.000000	0.000000	3.370000	3.372424	-0.071908

APPENDIX C-6

Geometric and Hydraulic Data

Geometric and Hydraulic Data - Storage Facility

Depth	Area	Vol-V2	Overflow	Disc-O	AVG_O2T	AVGO2T+V2
FT	FT2	FT3	CFS	CF	FT3	FT3
0.00E+00	0.67E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.28E-03	0.67E+06	0.19E+03	0.00E+00	0.00E+00	0.00E+00	0.19E+03
0.56E-03	0.67E+06	0.37E+03	0.00E+00	0.00E+00	0.00E+00	0.37E+03
0.83E-03	0.67E+06	0.56E+03	0.00E+00	0.00E+00	0.00E+00	0.56E+03
0.12E+00	0.67E+06	0.78E+05	0.27E+01	0.00E+00	0.49E+04	0.62E+05
0.23E+00	0.67E+06	0.15E+06	0.87E+01	0.00E+00	0.16E+05	0.17E+06
0.35E+00	0.67E+06	0.23E+06	0.17E+02	0.00E+00	0.31E+05	0.26E+06
0.46E+00	0.67E+06	0.31E+06	0.27E+02	0.00E+00	0.49E+05	0.36E+06
0.58E+00	0.67E+06	0.39E+06	0.40E+02	0.00E+00	0.72E+05	0.46E+06
0.69E+00	0.67E+06	0.46E+06	0.54E+02	0.00E+00	0.97E+05	0.56E+06
0.81E+00	0.67E+06	0.54E+06	0.70E+02	0.00E+00	0.13E+06	0.67E+06
0.92E+00	0.67E+06	0.62E+06	0.87E+02	0.00E+00	0.16E+06	0.77E+06
0.10E+01	0.67E+06	0.69E+06	0.11E+03	0.00E+00	0.19E+06	0.88E+06
0.12E+01	0.67E+06	0.77E+06	0.13E+03	0.00E+00	0.23E+06	0.10E+07
0.13E+01	0.67E+06	0.85E+06	0.15E+03	0.00E+00	0.27E+06	0.11E+07
0.14E+01	0.67E+06	0.92E+06	0.17E+03	0.00E+00	0.31E+06	0.12E+07
0.15E+01	0.67E+06	0.10E+07	0.20E+03	0.00E+00	0.35E+06	0.14E+07
0.16E+01	0.67E+06	0.11E+07	0.22E+03	0.00E+00	0.40E+06	0.15E+07
0.17E+01	0.67E+06	0.12E+07	0.25E+03	0.00E+00	0.45E+06	0.16E+07
0.18E+01	0.67E+06	0.12E+07	0.28E+03	0.00E+00	0.50E+06	0.17E+07
0.20E+01	0.67E+06	0.13E+07	0.31E+03	0.00E+00	0.55E+06	0.19E+07
0.21E+01	0.67E+06	0.14E+07	0.34E+03	0.00E+00	0.61E+06	0.20E+07
0.22E+01	0.67E+06	0.15E+07	0.37E+03	0.00E+00	0.66E+06	0.21E+07
0.23E+01	0.67E+06	0.15E+07	0.40E+03	0.00E+00	0.72E+06	0.23E+07
0.24E+01	0.67E+06	0.16E+07	0.44E+03	0.00E+00	0.78E+06	0.24E+07
0.25E+01	0.67E+06	0.17E+07	0.47E+03	0.00E+00	0.85E+06	0.25E+07
0.27E+01	0.67E+06	0.18E+07	0.51E+03	0.00E+00	0.91E+06	0.27E+07
0.28E+01	0.67E+06	0.18E+07	0.54E+03	0.00E+00	0.98E+06	0.28E+07
0.29E+01	0.67E+06	0.19E+07	0.58E+03	0.00E+00	0.10E+07	0.30E+07
0.30E+01	0.67E+06	0.20E+07	0.62E+03	0.00E+00	0.11E+07	0.31E+07