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STORM WATER MANAGEMENT MODEL, VERSION 4:

USER'S MANUAL

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The Storm Water Management Model (SWMM) described in this manual must be used at the user's own risk. Neither the U.S. Environmental Protection Agency, the State of Florida, the University of Florida, the State of Oregon, Oregon State University, or the program authors can assume responsibility for model operation, output, interpretation or usage.

Abstract

The EPA Storm Water Management Model (SWMM) is a comprehensive mathematical model for simulation of urban runoff quantity and quality in storm and combined sewer systems. All aspects of the urban hydrologic and quality cycles are simulated, including surface and subsurface runoff, transport through the drainage network, storage and treatment. This volume represents Version 4 of SWMM as it is an update of three earlier User's Manuals issued in 1971, 1975 and 1981. It should be coupled with Addendum I in order to run the Extran Block (detailed hydraulic flow routing) developed by Camp, Dresser and McKee.

Detailed descriptions are provided herein for all blocks: Runoff, Transport, Storage/Treatment, Combine, Statistics, Rain, Temp and Graph (part of the Executive Block). The latter five blocks are "service" blocks; the first three are the principal computational blocks. In addition, extensive documentation of new procedures is provided in the text and in several appendices. Versions of the model for main-frame, minicomputers and IBM-compatible microcomputers are supported.

This report was submitted in partial fulfillment of cooperative agreement CR-811607 by the University of Florida under the sponsorship of the U.S. Environmental Protection Agency. Work was completed as of April 1987.

Preface

This version of SWMM is an update and improvement of the 1981 release of Version 3. There are several extensions and improvements to the model, mostly in the area of additional flexibility (e.g., natural channel cross sections in Extran), features (e.g., subsurface flow routing in Runoff), and conveniences (e.g., improved input and output). A list of major changes implemented in Version 4 is given in Section 1 of this manual, and Table 1-1 presents a summary of all SWMM characteristics. Effort has been taken to adapt the model for microcomputer as well as main-frame use; the same Fortran-77 code will run on either type of hardware, but the primary emphasis is on the microcomputer (DOS-based). Unfortunately, this dual personality of the model means that SWMM does not take full advantage of either medium. For example, line-printer plots are still used in lieu of bit-mapped graphics readily available on micros. However, detailed information is provided about the file structures used for hydrographs and pollutographs so that users can employ their own software for graphics, etc. (Spreadsheets are especially useful.) Development of pre- and post-processors is also encouraged.

This manual is basically an edited version of the 1981 Version 3 manual. The most significant changes deal with file management (Section 2), unformatted data input (all sections), new options for reading continuous precipitation, temperature, evaporation and wind speed records (Sections 4, 10 and 11), and a new subsurface quantity routing routine for the Runoff Block (Section 4 and Appendix X). References on some topics were current at the time of writing which may be circa 1980 for some topics, e.g., snowmelt, storage/treatment. The user should obtain familiarity with current information and alter his/her modeling practices as necessary.

An attempt has been made to provide adequate information in this manual for most users so that they can conceptualize a stormwater problem and simulate it using SWMM. As a result, some of the text is rather lengthy, approaching a hydrology textbook in style. Unfortunately, it will still be the user's responsibility to seek out the proper references for additional information on modeling, especially when dealing with water quality. The 1985 SWMM bibliography referenced in Section 1 is still a valuable source of literature citations dealing with all aspects of SWMM usage.

Due to the dynamic nature of the model improvements, no detailed examples have been included within this manual itself. However, several examples are provided on the distribution disks. These are complete with input and output files and will greatly enhance the learning process. Regarding learning about the model, the user should start with simple examples for which the answers are well known. For example, a good first case study for SWMM is to use just the Runoff Block to simulate the runoff from steady rainfall onto an impervious surface (e.g., corresponding to Figure 4-14). Inclusion of a single pipe can follow, with more detailed networks that use the Transport or Extran Blocks later.

The authors hope that the user is not "put off" by the length of this volume and the size of the SWMM program. Aside from the fact that the overlaid executable code requires a large computer random access memory (about 500 K bytes), the program may often be easily and usefully run with a minimum of input, say a dozen lines of data. For small systems in which time step requirements

are not severe, the model is very economical as well, and is within the reach of most users, especially as it may be run on a microcomputer. For complex systems with many channels and pipes, especially when running Extran, a 486 or better system is recommended.

SWMM is by no means the only engineering tool of its kind available, but it has benefited greatly from its longevity and feedback from model users. The authors hope such feedback will continue, and earnestly solicit suggestions for improvements. Although no major support for model changes is likely to be forthcoming, the EPA Storm Water and Water Quality Model Users Group (formerly the SWMM Users Group) remains a convenient forum. Announcements of corrections, changes and new options will be made through that group, managed by Mr. Robert B. Ambrose, Center for Exposure Assessment Modeling (CEAM), EPA, Athens, Georgia 30613. The program (Fortran and executable code plus examples and some documentation) is available from the same source. Contact CEAM at (706) 546-3548. As of October 1992, the most recent version is 4.2. The CEAM announces changes, corrections, and updates on its computer bulletin board: (706) 546-3402.

SPECIAL PREFACE TO OCTOBER 1992 PRINTING

This printing differs very little from the August 1988 first printing. See the subsequent **CHANGES FOR OCTOBER 1992 SECOND PRINTING** section for a list of altered pages. (Changes to the Extran User's Manual for its February 1989 second printing are more substantial.) However, a few additional program options have been included since the August 1988 release of version 4.0, mostly in the Rain Block. For the most part, these options are not documented in this User's Manual (although the Rain Block changes are). Instead, the user should refer to documentation (.DOC) files for each SWMM block included on the distribution disks. These contain annotated data input templates comparable to the data preparation tables (e.g., Table 4-31 for Runoff Block data) found in this manual. These .DOC files include modifications to identify changes in input requirements.

If a user encounters an error message during the data input process that appears to result from the need for an additional or altered input parameter, this is most likely described in the appropriate .DOC file.

Foreword

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Assessment Branch develops state-of-the-art mathematical models for use in water quality evaluation and management.

Mathematical models are an important tool for use in analysis of quantity and quality problems resulting from urban storm water runoff and combined sewer overflows. This report is an updated user's manual and documentation for one of the first of such models, the EPA Storm Water Management Model (SWMM). Detailed instructions on the use of the model are given and its use is illustrated with case studies.

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Too many individuals have contributed to specific improvements to list here. This user's manual, however, is based upon earlier versions to which the following persons contributed significant authorship while at the University of Florida: Mr. Brett A. Cunningham, Mr. Victor Gagliardo, Dr. Stephen J. Nix, Mr. Donald J. Polmann and Mr. W. Alan Peltz. In particular, Msrs. Cunningham and Gagliardo developed the new subsurface routing routine in the Runoff Block. Dr. James P. Heaney has served staunchly as colleague, critic, and pioneer of new ideas. Omission of these names from the current list of authors does not diminish our gratitude for current and past efforts in developing the model.

The Extran Block is one of the most valuable and widely-used components of SWMM. Dr. Larry A. Roesner and Mr. John A. Aldrich of Camp, Dresser and McKee, Inc., one of the three original SWMM developers, have given generously of their time to enhance Extran and to provide useful suggestions for improvements of Extran and the rest of the SWMM model.

The Fortran-77 code for Version 4 of SWMM is based on a microcomputer version prepared by Mr. Richard M. Baker and Mr. Karl J. Brazauskas of Metcalf and Eddy, Inc., another one of the original three developers. Much of the user's manual text for Version 4 has been adapted from a computerized edition of the Version 3 manuals prepared by Dr. William James of Wayne State University. We are grateful to Dr. James and to Dr. Stephen Nix of Syracuse University for their helpful comments regarding Version 4. Assistance in printing of the manuals was provided by KBN Applied Sciences and Engineering, Inc. of Gainesville.

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Changes for October 1992 Second Printing

Very little is changed in this manual from the first printing of August 1988. Altered pages are listed below:

Page	Change
-	Title page
ii	Disclaimer
iv-v	Preface
23	Typo
28-32	Corrections to interface file structure and array limits
124	Typo
220-221	Units corrections for groundwater input parameters
375-377a	Additional Rain Block options

Users are encouraged to examine RUNOFF.DOC, EXTRAN.DOC etc. documentation (template) files for each block for current list of input parameters and options.

Section 1 Introduction

Urban Runoff Analysis

Urban runoff quantity and quality constitute problems of both a historical and current nature. Cities have long assumed the responsibility of control of stormwater flooding and treatment of point sources (e.g., municipal sewage) of wastewater. Within the past two decades, the severe pollution potential of urban non-point sources, principally combined sewer overflows and stormwater discharges, has been recognized, both through field observation and federal legislation. The advent of modern, high speed computers has led to the development of new, complex, sophisticated tools for analysis of both quantity and non-point pollution problems. The EPA Storm Water Management Model, SWMM, developed in 1969-71, was one of the first of such models, it has been continually maintained and updated, and is perhaps the best known and most widely used of the available urban runoff quantity/quality models.

Many of the changes that have occurred to SWMM during the past 15 years have been poorly documented and were not readily visible to users. This volume includes documentation (of both the theory and programming details) of major changes to the model since its original development. This documentation is located primarily in the appendices whereas the text consists primarily of the User's Manual. Theory that underlies unchanged parts of the model may still be reviewed in the original documentation (Metcalf and Eddy et al., 1971a, 1971b, 1971c, 1971d) plus intermediate reports (Huber et al., 1975; Heaney et al., 1975). This volume supersedes Version 3 documentation (Huber et al., 1981b) and includes essentially all material from that manual.

Urban Runoff Models

Objectives

Models are generally used for studies of quantity and quality problems associated with urban runoff in which four broad objectives may be identified: screening, planning, design and operation. Each objective typically produces models with somewhat different characteristics, and the different models overlap to some degree.

Screening Models

Screening models are preliminary, "first-cut" ("Level I"), desktop procedures that require no computer. They are intended to provide a first estimate of the magnitude of urban runoff quantity and quality problems, prior to an investment of time and resources into more complex computer based models. Only after the screening model indicates its necessity should one of the latter models be used. Examples of screening models include SWMM Level I procedures (Heaney et al., 1976;

Heaney and Nix, 1977) and others: Howard (1976), Hydroscience (1976, 1979), Chan and Bras (1979).

Planning Models

Planning models are used for an overall assessment of the urban runoff problem as well as estimates of the effectiveness and costs of abatement procedures. They may also be used for “first-cut” analyses of the rainfall-runoff process and illustrate trade-offs among various control options. They are typified by relatively large time steps (hours) and long simulation times (months and years), i.e., continuous simulation. Data requirements are kept to a minimum and their mathematical complexity is low.

Various continuous simulation models are reviewed in Appendix I. SWMM has had this capability since 1976, following the earliest work of the Stanford Watershed Model (Crawford and Linsley, 1966) and the latter widely-used Corps of Engineers STORM model (Roesner et al., 1974; HEC, 1977a).

A planning model may also be run to identify hydrologic events that may be of special interest for design or other purposes. These storm events may then be analyzed in detail using a more sophisticated design model (Huber et al., 1986). SWMM can be used in both the planning and design mode. Planning or long-term models may also be used to generate initial conditions (i.e., antecedent conditions) for input to design models. They may occasionally be coupled to continuous receiving water models as well; for example, SWMM and STORM may be used as input to Medina’s (1979) Level III Receiving Water Model.

Design Models

Design models are oriented toward the detailed simulation of a single storm event. They provide a complete description of flow and pollutant routing from the point of rainfall through the entire urban runoff system and often into the receiving waters as well. Such models may be used for predictions of flows and concentrations anywhere in the rainfall/runoff system and can illustrate the detailed and exact manner in which abatement procedures or design options affect them. As such, these models are a highly useful tool for determining least-cost abatement procedures for both quantity and quality problems in urban areas. Design models are generally used for simulation of a single storm event and are typified by short time steps (minutes) and short simulation times (hours). Data requirements may be moderate to very extensive depending upon the particular model employed.

In its original form (Metcalf and Eddy et al., 1971a, 1971b, 1971c, 1971d), SWMM was strictly a design model. However, as described above, it may now be used in both a planning and design mode. In addition, it has acquired additional design potential through inclusion of the Extended Transport Model, Extran, developed by Camp, Dresser and McKee (formerly Water Resources Engineers). Extran is probably the most sophisticated program available in the public domain for detailed hydraulic analysis of sewer systems (Shubinski and Roesner, 1973; Roesner et al., 1981; Roesner et al., 1987).

Operational Models

Operational models are used to produce actual control decisions during a storm event. Rainfall is entered from telemetered stations and the model is used to predict system responses a

short time into the future. Various control options may then be employed, e.g., in-system storage, diversions, regulator settings.

These models are frequently developed from sophisticated design models and applied to a particular system; Schilling (1985) provides a review. Examples are operational models designed for Minneapolis-St. Paul (Bowers et al., 1968) and Seattle (Leiser, 1974).

Other Models

SWMM is by no stretch of the imagination the only urban runoff model available, or necessarily the preferred one under many circumstances. Many other urban runoff models have been described in the literature and are too numerous to list here. However, good comparative reviews are available, e.g., Brandstetter (1977), Chu and Bowers (1977), Huber and Heaney (1980, 1982), Kibler (1982), Kohlhaas (1982), EPA(1983a), Whipple et al. (1983) and Hall (1984). EPA's water quality models are reviewed by Barnwell (1984). A general review of methods available for urban quality modeling and six operational urban quality models is provided by Huber (1985, 1986). Many more models are available for purely hydrologic and hydraulic analysis.

Development of the Storm Water Management Model

Under the sponsorship of the Environmental Protection Agency, a consortium of contractors B Metcalf and Eddy, Incorporated, the University of Florida, and Water Resources Engineers, Incorporated B developed in 1969-71 the Storm Water Management Model, SWMM, capable of representing urban stormwater runoff and combined sewer overflow phenomena. Both quantity and quality problems and control options may be investigated with the model, with associated cost estimates available for storage and/or treatment controls. Effectiveness can be evaluated by inspection of hydrographs, pollutographs, pollutant loads, and modeled changes in receiving water quality.

The original project report is divided into four volumes. Volume I, the "Final Report" (Metcalf and Eddy et al., 1971a), contains the background, justifications, judgments, and assumptions used in the model development. It further includes descriptions of unsuccessful modeling techniques that were attempted and recommendations for forms of user teams to implement systems analysis techniques most effectively. Although many modifications and improvements have since been added to the SWMM, the material in Volume I still accurately describes much of the theory behind updated versions. Documentation of some of the procedures included in the 1975 Version II (Huber et al., 1975) release of SWMM is also provided by Heaney et al. (1975).

Volume II, "Verification and Testing," (Metcalf and Eddy et al., 1971b), describes the methods and results of the application of the original model to four urban catchments.

Volume III, the "User's Manual" (Metcalf and Eddy et al., 1971c) contains program descriptions, flow charts, instructions on data preparation and program usage, and test examples. This was updated in 1975 by the Version II User's Manual (Huber et al., 1971) and in 1981 by the Version 3 User's Manuals (Huber et al., 1981; Roesner et al., 1981). This present report supersedes all of these previous documents.

Volume IV, "Program Listing" (Metcalf and Eddy et al., 1971d), lists the entire original program and Job Control Language (JCL) as used in the demonstration runs. Since many routines in the updated version are similar or identical to the original, it is still a useful reference, but on the whole should be disregarded since the present coding is in most cases, completely different.

All three original contractors have continued to modify and improve the SWMM, as have numerous other users since its release. Through EPA research grants, the University of Florida has conducted extensive research on urban runoff and SWMM development, and has evolved into an unofficial “clearinghouse” for SWMM improvements. There has clearly been a large benefit from the fact that SWMM is in the public domain and non-proprietary since the present version reflects the input and critical assessments of over ten years of user experience. Of course, lingering “bugs” are the responsibility of the present report’s authors alone.

An extensive bibliography of SWMM usage is available (Huber et al., 1985) and is highly recommended for new users. Case studies mentioned in the bibliography are especially useful.

As described earlier, this report is both a SWMM Version 4 User’s Manual and also documentation of new procedures. In order to accommodate both main-frame and microcomputer versions of the Fortran code, input formats have been revised from previous versions, including Version 3. The main difference is that all input is now unformatted, eliminating the field restrictions of all previous versions. Hence, although basic data requirements remain the same, some data groups will need to be revised for input into Version 4. (Since card input is no longer routinely used for input to any computers, references to “card group” will now be “data group” or “data line.”) Hence, it must be assumed by the user that all input must be prepared anew for this SWMM version. Further details on new aspects of Version 4 are given later in this section.

Overall SWMM Description

Overview

SWMM simulates real storm events on the basis of rainfall (hyetograph) and other meteorological inputs and system (catchment, conveyance, storage/treatment) characterization to predict outcomes in the form of quantity and quality values. Since study objectives may be directed toward both complete temporal and spatial detail as well as to gross effects (such as total pounds of pollutant discharged in a given storm), it is essential to have both time series output, i.e., hydrographs and “pollutographs” (concentrations versus time) and daily, monthly, annual and total simulation summaries (for continuous simulation) available for review.

An overview of the model structure is shown in Figure 1-1. In simplest terms the program is constructed in the form of “blocks” as follows:

- 1) The input sources:
The Runoff Block generates surface and subsurface runoff based on arbitrary rainfall (and/or snowmelt) hyetographs, antecedent conditions, land use, and topography. Dry-weather flow and infiltration into the sewer system may be optionally generated using the Transport Block.
- 2) The central cores:
The Runoff, Transport and Extended Transport (Extran) Blocks route flows and pollutants through the sewer or drainage system. (Pollutant routing is not available in the Extran Block.) Very sophisticated hydraulic routing may be performed with Extran.
- 3) The correctional devices:
The Storage/Treatment Block characterizes the effects of control devices upon flow and quality. Elementary cost computations are also made.

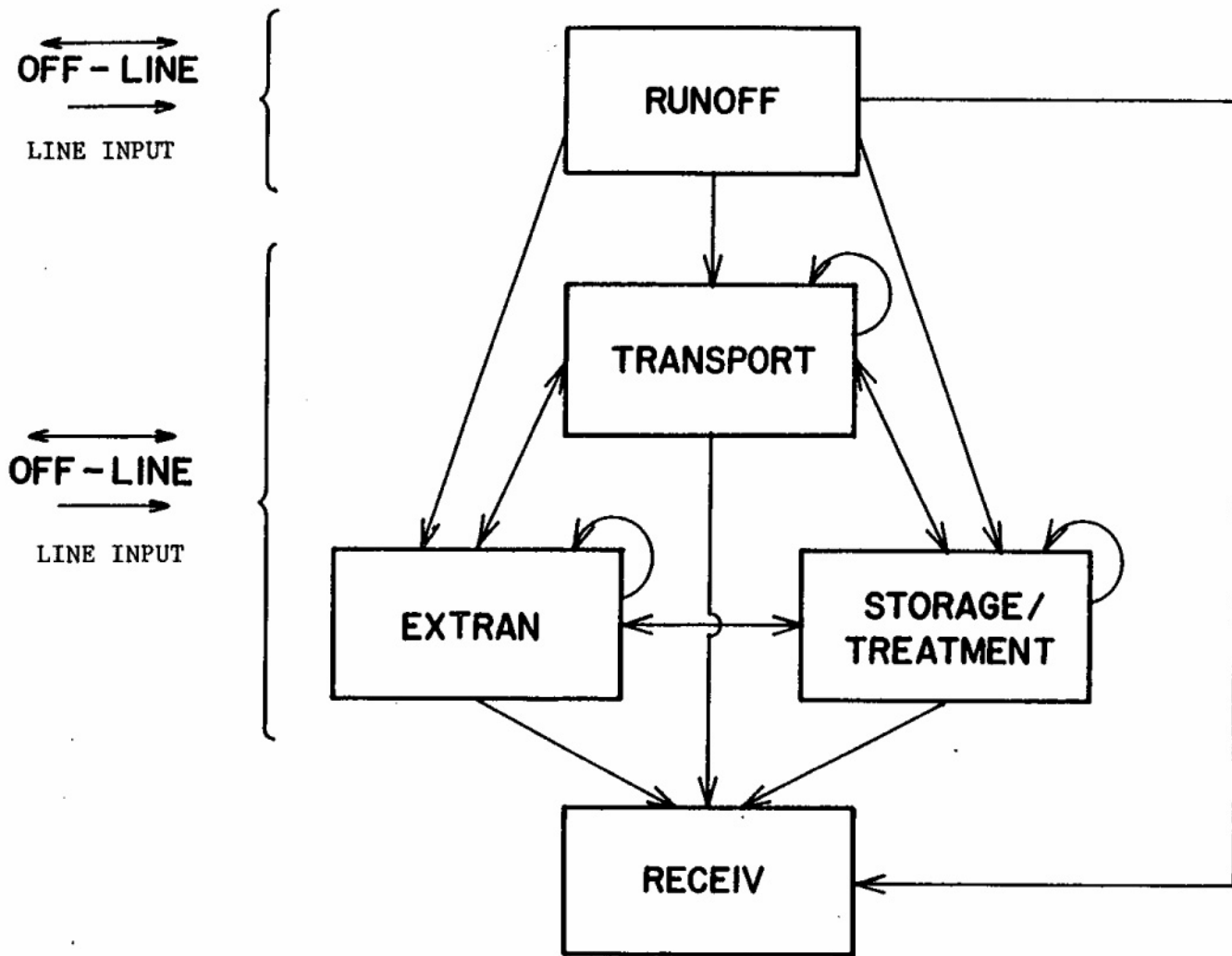


Figure 1-1. Overview of SWMM model structure, indicating linkages among the computational blocks. Receiving Water simulation is by external programs, not Receive Block. "Line input" refers to data input from terminal, etc.

- 4) The effect (receiving waters):
SWMM does not include a receiving water model. The Receiving Water Block (Receiv) is no longer included within the SWMM framework. However, a linkage is provided for the EPA WASP and DYNHYD models (Ambrose et al., 1986).

Quality constituents for simulation may be arbitrarily chosen for any of the blocks, although the different blocks have different constraints on the number and type of constituents that may be modeled. The Extran Block is the only block that does not simulate water quality.

As indicated in Figure 1-1, the Transport, Extran and Storage/Treatment Blocks may all use input and provide output to any block, including themselves. The Runoff Block uses input from no other computational block but may receive input from new Rain and Temp Blocks for meteorological input.

Service Blocks

Executive Block

In addition to the four computational blocks mentioned above, six service blocks are utilized. The Executive Block assigns logical unit numbers to off-line files (disk/tape/drum) and determines the block or sequence of blocks to be executed. All access to the computational and service blocks and transfers between them must pass through the MAIN program of the Executive Block. Transfers are accomplished on off-line devices (disk/tape/drum) that may be saved for multiple trials or permanent record using control parameters described in Section 2. Dependency on machine-dependent job control language should be minimized.

Graph Block

Line-printer plots of hydrographs, pollutographs and other time series output may be obtained using the Graph Block, which is documented along the Executive Block in Section 2. Measured as well as predicted time series may be plotted. Alternatively, the user may access the time series file (known in this manual as the "interface file") for plots by other graphics software.

Combine Block

This block allows the manipulation of multiple interface files in order to aggregate results of multiple previous runs for input into subsequent blocks. In this manner large, complex drainage systems may be partitioned for simulation in smaller segments.

Rain Block

Continuous simulation relies upon precipitation input using long-term data available on magnetic tapes from the National Weather Service (NWS) National Climatic Data Center in the United States or Atmospheric Environment Service in Canada. The Rain Block processes NWS tapes for input into the Runoff Block. A synoptic statistical analysis may also be performed on rain-fall data, similarly to the EPA SYNOP program (Hydroscience 1976, 1979).

Temp Block

In a similar manner, the Temp Block processes NWS long-term temperature data for input into the Runoff Block for snowmelt calculations.

Statistics Block

Output from continuous simulation can be enormous if results for every time step are printed. Even the monthly and annual summaries contain more information than may easily be assimilated. The Statistics Block has the capability to review the time step output from a continuous (or single event) simulation, separate output into discrete storm events, rank the events according to almost any desired criterion (e.g., peak or average runoff rate, pollutant load, etc.), assign empirical frequencies and return periods to runoff and pollutant parameters, tabulate and graph the results, and calculate statistical moments. Output from this block can thus be used to identify key events for further study and for many other screening and analytical purposes.

Total Simulation

The capability exists to run up to 25 blocks sequentially in a given run, although from a practical and sometimes necessary viewpoint (due to computer memory limitations) typical runs usually involve only one or two computational blocks together with the Executive Block. This approach may be used to avoid overlay and, moreover, allow for examination of intermediate results before continuing the computations.

This manual provides for each block a description of program operation, documentation of most algorithms used within the block (or reference to earlier documentation), and instructions on data preparation with input requirements. However, the user's manual and documentation for the Extended Transport (Extran) Block has been prepared by Camp, Dresser and McKee (Roesner et al., 1987) as an addendum to this report and is available as a separate document. Thus, Section 5 of this report merely introduces Extran.

Detailed SWMM Summary

A concise description of most features of SWMM is given in Table 1-1, adapted from similar tables prepared by Huber and Heaney (1980, 1982). An indication of almost all modeling techniques is included in the table.

Usage Requirements

Computer Facilities

SWMM may be run on both main-frame and IBM-PC compatible microcomputers. Development and testing of Version 4 has been performed using RM/Fortran on a Zenith Z-248, AT-compatible microcomputer, followed by main-frame testing using VS-Fortran on an IBM 3033 at the University of Florida. Fortran-77 standards are followed. Version 4 was developed from a base version of the Version 3 code developed for EPA by Metcalf and Eddy, Inc. (Baker and Brazauskas, 1986) for the microcomputer. Further refinements were based on an alternative microcomputer version of SWMM (James and Robinson, 1984).

VS Fortran requires at least 2500 K words of storage using virtual memory (no overlay). Mainframe and minicomputer users should not have to bother with any overlay structure. Those who still have system memory limitations can simply employ an overlay structure with each SWMM block in a single overlay. The largest combination will be the Executive Block and Runoff Block together (less than 600 K). Microcomputer users must have at least 512 K bytes of memory and an 8087 or 80287 math coprocessor and will benefit from a hard disk, although the latter is not a rigid requirement. Main-frame users will have to compile and link the Fortran code. Microcomputer users will have the option of using executable code or recompiling and linking the source code.

Table 1-1. Summary of EPA Storm Water Management Model (SWMM) Characteristics

Applicable Land Drainage Area	
(1)	Urban.
(2)	General nonurban.
Time Properties	
(1)	Single-event or continuous simulation; both modes have an unlimited number of time steps.
(2)	Precipitation: input at arbitrary time intervals for single-event simulation (typically 1-15 min) and continuous simulation (typically 1-hr); for snowmelt daily max-min temperatures required for continuous, temperatures at arbitrary intervals for single-event.
(3)	Output at time step intervals (or multiples); daily, monthly, annual, and total summaries for continuous simulation.
(4)	Time step arbitrary for single-event (typically 5 minutes) and continuous (typically one hour); variable time step available in Runoff Block; time step for Extended Transport Block (Extran) routing depends on stability criteria, may be as small as a few seconds.
Space Properties	
(1)	Small to large multiple catchments.
(2)	Surface: lumped simulation of surface flow with allowance for up to 200 subcatchments and 10 input hyetographs, up to 200 channel/pipes may be simulated by nonlinear reservoir routing.
(3)	Channel/pipes: one-dimensional network, up to 200 conduit/nonconduit elements for Transport Block, up to 200 conduits in Extran Block, up to 30 in-line storage units in Transport Block. Values easily changed using Fortran Parameter statement.
(4)	Catchment area may be disaggregated and modeled sequentially for simulation of areas too large for existing SWMM dimensions.
(5)	Storage/treatment simulated separately, receiving input from upstream routing.
(6)	Output from surface, channel/pipe, or storage/treatment simulation may serve as new input for further simulation by same or different blocks.
Physical Processes	
(1)	Flow derived from precipitation and/or snowmelt; snow accumulation and melt simulated using temperature-index methods developed by National Weather Service; snow redistribution (e.g., plowing, removal) may be simulated.
(2)	Overland flow by nonlinear reservoir using Manning's equation and lumped continuity, depression storage, integrated Horton or Green-Ampt infiltration (with optional subsurface routing), recovery of depression storage via evaporation between storms during continuous simulation, also exponential recovery of infiltration capacity.
(3)	Subsurface routing only of flows through unsaturated and saturated zones simulated using lumped storages; subsurface outflow by power equation; simulation of ET and water table fluctuation.
(4)	Channel/pipes: <ul style="list-style-type: none"> (a) nonlinear reservoir formulation for channel/pipes in Runoff Block, includes translation and attenuation effects, (b) modified kinematic wave formulation in original Transport Block assumes cascade of conduits, cannot simulate backwater over more than one conduit length, surcharging handled by storing water at surcharged junction pending available flow capacity; (c) Extended Transport Block solves complete St. Venant equations including effects of backwater, flow reversal, surcharging, looped connections, pressure flow, (d) infiltration and dry-weather flow may enter conduit of either transport simulation.
(5)	Storage routing using modified Puls method assuming horizontal water surface, outlets include pumps, weirs,

orifices.

Table 1-1. Continued

Physical Processes (continued)	
(6)	Surface quality on basis of linear or non-linear buildup of dust/dirt or other constituents during dry-weather and associated pollutant fractions, power-exponential washoff with decay parameter a power function of low rate only (rating curve); erosion by Universal Soil Loss Equation.
(7)	Dry-weather flow quantity and quality on basis of diurnal and daily variation, population density and other demographic parameters, buildup of suspended solids in conduits by dry weather deposition using Shield's criterion.
(8)	Quality routing by advection and mixing in conduits and by plug flow or complete mixing in storage units, scour and deposition of suspended solids in conduits (original Transport Block) using Shield's criterion.
(9)	Storage/treatment device simulated as series-parallel network of units, each with optional storage routing.
(10)	Treatment simulation: <ul style="list-style-type: none">(a) use of arbitrary user-supplied removal equations (e.g., removal as exponential function of residence time);(b) use of sedimentation theory coupled with particle size-specific gravity distribution for constituents.

Chemical Processes	
(1)	Ten arbitrary conservative constituents in Runoff Block, rainfall quality included, choice of concentration units is arbitrary; erosion "sediment" is optional.
(2)	Four constituents may be routed through the original transport module (with optional first order decay), three through the storage/treatment module and none through Extran (quantity only).

Biological Processes	
(1)	Coliform simulation may be included.
(2)	Biological treatment may be simulated.

Economic Analysis	
(1)	Amortized capital plus operation and maintenance costs for control units are determined.

Mathematical Properties	
(1)	Physically-based model.
(2)	Surface quantity: iterative solution of coupled continuity and Manning equations, Green-Ampt or integrated form of Horton infiltration (infiltration rate proportional to cumulative infiltration, not time).
(3)	Surface channel/pipe routing: non-linear reservoir assuming water surface parallel to invert.
(4)	Channel/pipes: <ul style="list-style-type: none">(a) original Transport: implicit finite difference solution to modified kinematic wave equation;(b) Extran transport: explicit finite difference solution of complete St. Venant equations, stability may require short time step.
(5)	Storage/detention: modified Puls method requires table look-up for calculation of outflow.
(6)	Surface quality, quality routing and treatment: algebraic equations, no iterations required once flows and conduit volumes are known.

Computational Status	
(1)	Coded in Fortran-77, approximately 25,000 statements long.

Table 1-1. Continued

Computational Status (continued)	
(2)	Has been run on IBM, UNIVAC, CDC, Amdahl, VAX, Prime, Harris, Boroughs and other main-frame and minicomputers; main-frame version must be compiled.
(3)	Microcomputer version for IBM-PC compatibles uses same Fortran code; requires 512 K bytes plus math co-processor; hard disk desirable; executable and source code available.
(4)	May be run in modular form (surface runoff, original or Extran transport, storage/treatment, plus executive and service routines, i.e., plotting, file combining, statistics, data input.
(5)	Largest block requires about 125,000 words or 500K bytes of storage.
(6)	Available on a magnetic tape or floppy disks. (7) Requires up to eight off-line storage files.
Input Data Requirements	
(1)	Historical or synthetic precipitation record; uses National Weather Service precipitation tapes for continuous simulation.
(2)	Monthly or daily evaporation rates.
(3)	For snowmelt: daily max-min (continuous) or time-step (single event) temperatures, monthly wind speeds, melt coefficients and base melt temperatures, snow distribution fractions and areal depletion curves (continuous only), other melt parameters.
(4)	Surface quantity: area, imperviousness, slope, width, depression storage and Manning's roughness for pervious and impervious areas; Horton or Green-Ampt infiltration parameters.
(5)	Subsurface quantity: porosity, field capacity, wilting point, hydraulic conductivity, initial water table elevation, ET parameters; coefficients for groundwater outflow as function of stage and tail water elevation.
(6)	Channel/pipe quantity: linkages, shape, slope, length, Manning's roughness; Extran transport also requires invert and ground elevation, storage volumes at manholes and other structures; geometric and hydraulic parameters for weirs, pumps, orifices, storages, etc.; infiltration rate into conduits.
(7)	Storage/sedimentation quantity: stage-area-volume-outflow relationship, hydraulic characteristics of outflows.
(8)	Surface quality (note: several parameters are optional, depending upon methods used): land use; total curb length; catchbasin volume and initial pollutant concentrations; street sweeping interval, efficiency and availability factor; dry days prior to initial precipitation; dust/dirt and/or pollutant fraction parameters for each land use, or pollutant rating curve coefficients; initial pollutant surface loadings; exponential and power washoff coefficients; concentrations in precipitation; erosion parameters for Universal Soil Loss Equation, if simulated.
(9)	Dry-weather flow constant or on basis of diurnal and daily quantity/quality variations, population density, other demographic parameters.
(10)	Optional particle size distribution, Shields parameter and decay coefficients for channel/pipe quality routing and scour/deposition routine.
(11)	Storage/treatment: parameters defining pollutant removal equations; parameters for individual treatment options, e.g., particle size distribution, maximum flow rates, size of unit, outflow characteristics; optional dry-weather flow data when using continuous simulation.
(12)	Storage/treatment costs: parameters for capital and operation and maintenance costs as function of flows, volumes and operating time.
(13)	Data requirements for individual blocks much less than for run of whole model; large reduction in data requirements possible by aggregating (lumping) of subcatchments and channel/pipes, especially useful for continuous simulation.
(14)	Metric units optional for all I/O.

Table 1-1. Continued

Ease of Application	
(1)	Nonproprietary model available from EPA, Athens, GA or University of Florida, Department of Environmental Engineering Sciences, Gainesville.
(2)	Updated user=s manual and thorough documentation of most routines published as EPA reports; no one report covers all model aspects.
(3)	Test cases documented in several EPA and other reports.
(4)	Short course proceedings also useful for model applications.
(5)	U.S. and Canadian users groups with newsletters and semi-annual meetings permit publication of changes.
(6)	Due to its age (originally published in 1971), availability, and documentation, examples of SWMM usage are widely available in the literature; bibliography available.
(7)	Frequent model update/corrections/improvements are often difficult to learn about; new model released approximately on a bi-annual basis.
(8)	Size of model most frequent deterrent to use, however, see item 13 above under Input Data Requirements.
(9)	Initial model setup often moderately difficult due to size.
(10)	Model supported by EPA Center for Water Quality Modeling, Athens, GA.
Output and Output Format	
(1)	Input data summary including precipitation.
(2)	Hydrographs and pollutographs (concentrations and loads versus time) at any point in system on time step or longer basis; no stages or velocities printed.
(3)	Extran transport also outputs elevation of hydraulic grade line.
(4)	Surcharge volumes and required flow capacity; original transport model will resize conduits to pass required flow (optional).
(5)	Stage, discharge and soil moisture content for subsurface routing in Runoff Block.
(6)	Removal quantities in storage/treatment units, generated sludge quantities.
(7)	Summaries of volumes and pollutant loads for simulation period, continuity check, initial and final pounds of solids in conduit elements.
(8)	Daily (optional), monthly, annual and total summaries for continuous simulation, plus ranking of 50 highest time-step precipitation runoff and pollutant values.
(9)	Line printer plots of hietographs, hydrographs, and pollutographs.
(10)	Costs of simulated storage/treatment options.
(11)	Statistical analysis of continuous (or single event) output for event separation, frequency analysis, moments and identification of critical events.
Linkages to Other Models	
(1)	Linkage provided to EPA WASP and DYNHYD receiving water quality models.
(2)	Individual blocks and the total SWMM model have been linked to the HEC STORM model, the QUAL-II model, simplified receiving water models, and others.
(3)	Individual blocks (e.g., Runoff Block) have been altered by various groups.
Personnel Requirements	
(1)	Civil/environmental engineer familiar with urban hydrological processes for data reduction and model analysis.
(2)	Computer programmer for model setup and establishment of off-line files on main-frames.

Table 1-1. Continued

Costs	
(1)	Model and documentation available at little or no charge from EPA Center for Exposure Assessment Modeling, Athens, GA, 30613; also available for nominal charge from Department of Environmental Engineering Sciences, University of Florida, Gainesville, FL, 32611.
(2)	Data assembly and preparation may require multiple man-weeks for a large catchment or urban area.
(3)	Example main-frame computer execution costs given in user's manual, on the order of \$20 for a surface runoff and transport run for a single storm event with about 50 subcatchments and channel/pipes; use of Extran transport can be more costly (> \$100 per run) due to short time step; continuous simulation (hourly time step) of one subcatchment with snowmelt for two years costs about \$20.
(4)	Microcomputer execution times depend on machine, execution times on AT-compatible approximately 50 times longer than for main-frame.
(5)	Extensive calibration may be required to duplicate measured quality results, quantity calibration relatively simple. (5) National Weather Service precipitation tapes for continuous simulation cost about \$200 for at least a 25-year hourly record for all stations in one state.
Model Accuracy	
(1)	Quantity simulation may be made quite accurate with relatively little calibration.
(2)	Quality simulation requires more extensive calibration using measured pollutant concentrations; quality results will almost certainly be very inaccurate without local measurements.
(3)	Extran transport accurately simulates backwater, flow reversal, surcharging, pressure flow; original transport routines may be used at less cost if these conditions not present.
(4)	Sensitivity to input parameters depends upon schematization, however, surface quality predictions are most sensitive to pollutant loading rates.

Distribution of both the main-frame and microcomputer versions of the program is through:
 Center for Exposure Assessment Modeling
 U.S. Environmental Protection Agency
 College Station Road
 Athens, Georgia 30613

Input Data Requirements

As will be seen from a review of following sections, the data requirements for the SWMM may be extensive. Collection of the data from various municipal and other offices within a city is possible to accomplish within a few days. However, reduction of the data for input to the model is time consuming and may take up to three man-weeks for a large area (e.g., greater than 2000 acres). On an optimistic note, however, most of the data reduction is straight forward (e.g., tabulation of slopes, lengths, diameters, etc., of the sewer system).

SWMM is flexible enough to allow different modeling approaches to the same area, and a specific, individual modeling decision upstream in the catchment will have little effect on the predicted results at the outfall. Furthermore, a lumped approach may often be used for preliminary modeling in which catchment properties are aggregated and only minimal data are needed. The user should realize that only portions of the overall model (e.g., one block) need be run at any one time.

Verification and Calibration

Calibration is the adjustment of model parameters using one set of data. Verification is the testing of this parameter selection by using an independent data set. Although the simulation of many of the urban runoff processes found in SWMM is physically based, the concept fails in practice because the input data and the numerical methods are not accurate enough for many real applications. Furthermore, many computational procedures within the model are based upon limited data themselves and highly empirical, especially surface quality predictions. As a result it is essential that local verification/calibration data be available at specific application sites to lend credibility to the predictions of any urban runoff model.

Calibration and verification data are usually in the form of measured flows and concentrations at outfalls or combined sewer overflow locations. However, it is important to note that detailed short-time-increment pollutographs during a storm are seldom needed for analysis of receiving water quality (see discussion in Section 4). Hence, total storm event loads or event mean concentrations are usually sufficient for quality calibration and verification. (Note that quality concentrations without accompanying flows are of little value.) SWMM has sufficient parameters that may be “adjusted,” particularly in the Runoff Block, such that calibrating the model against measured data is usually readily accomplished.

Quantity (hydrograph) predictions are often “within the ball park” on the first try, given decent rainfall, area and imperviousness data. However, initial quality estimates may be off by orders of magnitude (Huber, 1985). Hence, quality predictions are not credible without adequate site-specific data for calibration and verification. At best, relative effects of pollution abatement alternatives may be studied if such data are not available.

Metrification

Use of metric units for input and output of data and results is an option in all blocks as an alternative to U.S. customary units. In the Runoff and Transport Blocks, metric units are used strictly for I/O; all internal quantity calculations are still performed in units of feet and seconds. (Feet-second units also apply to program generated error messages printed during the simulation.)

However, the Storage/Treatment and Extran Blocks use metric units for internal calculations also, when used. Most quality calculations use conventional concentration units (e.g., mg/l) and loads may be given in both pounds and kilograms, depending on the particular subroutine, although pounds will not be used if metric I/O is specified.

No attempt has been made to conform to SI standards or even customary metric units for some parameters. For instance, because of output format complications, metric pipe diameters are requested and printed in meters instead of the more usual millimeters. However, all units are clearly stated for both input and output. It should be a simple task to convert to other metric alternatives.

Changes for Version 4

Not all users will require Version 4 since in most respects the computations are identical to Version 3. Significant modifications are listed below.

- 1) Input/output has been enhanced. All input is free-format with line (data group) identifiers. The line identifiers are now a requirement since the program uses them as the only means of separating one data group from another. Program-generated error messages make it easier to locate problems caused by improper entry of data. Input strings of up to 230 characters are allowed in SWMM 4. Strict column

sequencing of input data is still possible as long as at least one space separates the fields.

Comment lines are allowed in this version of SWMM. A comment line begins with an asterisk in the first column. A template for full screen editing is included as an example for each block of SWMM. The templates include brief comments about each input field.

- 2) Errors have been corrected for all blocks as best they are known.
- 3) Extran is available in a metric format and uses data group identifiers. Additional features include: a "hot start" capability (restart from end of previous run); natural channel cross sections, with cross-sections input as in HEC-2; minor improvements to surcharge and flow routing routines; and automatic adjustment of small pipe lengths.
- 4) SWMM output may be linked to the DYNHYD4 (water quantity) and WASP4 (water quality) programs for receiving water quality simulation (Ambrose et al., 1986). Runoff, Transport, Storage/Treatment, and Extran interface files can be read by both DYNHYD4 and WASP4. DYNHYD4 reads only the flows from the interface file. WASP4 reads water quality loading rates from Runoff, Transport, and Storage/Treatment. A model of an estuary therefore can include Runoff to generate surface pollutant loadings, Transport or Extran for detailed simulation of surface routing network, DYNHYD4 for simulating a link-node estuary model, and WASP4 for simulating the water quality of the estuary under the stress of the Runoff or Transport pollutant loadings.
- 5) The microcomputer version permits greater manipulation of interface files and other scratch and I/O files. The Combine Block may be used to convert any interface file to formatted (ASCII/text) files capable of being read by programs such as Lotus 1-2-3 or other software. All interface files can be permanently saved and retrieved. Users can input their own interface files.
- 6) A subsurface routing package (quantity only) has been added to the Runoff Block. A separate accounting is made for the unsaturated and saturated zones, and the water table elevation can fluctuate. Baseflow to Runoff channel/pipes may be generated from the saturated zone.
- 7) The Runoff Block (through access to the Rain Block) will read the new National Weather Service format for precipitation tapes. In general, continuous simulation is easier, with several options for input of precipitation data and other time series. User-defined input time series may also be used. Continuous simulation is capable of using up to 10 rain gages.

Instead of processing continuous meteorological data in the Runoff Block, two new blocks have been added: Rain and Temp. These include the capabilities of the former Subroutine CTRAIN in Runoff with additional statistical analysis similar to the SYNOP program of Hydrosience (1976, 1979). It is also possible to process rainfall data with the SWMM Statistics Block.

- 8) Numerical methods have been improved in the Runoff Block. A variation of the extrapolation method (Press et al., 1986) is used to couple the nonlinear reservoir equations, evaporation, infiltration, and groundwater flow. Subroutine Gutter no longer has convergence problems. There is no distinction any more between single

- event and continuous simulation, eliminating parameter ICRAIN. Runoff uses a wet, dry and intermediate (wet/dry) time step defined by the user.
- 9) This version of SWMM tries to use more Fortran primitives. There is one subroutine to read interface files, one subroutine to write interface files, one clock subroutine, one file opening routine etc. for all blocks. The common functions of all blocks are exactly the same.
 - 10) This version can be made more modular than the EPA Version 3 for the microcomputer. It is possible to run files containing only the blocks of interest, saving the interface file for use by the next block. This permits file compression for ease of distribution and much faster execution times.
 - 11) The Graph Block is no longer limited to 200 data points. An unlimited number of points for both measured and predicted graphs can be plotted. Graph plots loadographs (mass/time versus time) and pollutographs (concentration versus time).
 - 12) The user has more control over printout in this version of SWMM. Most printout can be bypassed at the user's discretion. Error messages are summarized at the end of a run instead of being printed every time step.
 - 13) Microcomputer users will see the current time or time step printed on the screen during the simulation as well as other program messages.

When Should SWMM Be Used?

SWMM is a large, relatively sophisticated hydrologic, hydraulic and water quality simulation program. It is not appropriate for all applications or for all personnel. For instance, hydrologic routing (e.g., prediction of runoff from rainfall) may be performed simply using standard techniques (e.g., units hydrographs, linear reservoirs) described in hydrology texts and suitable for programmable hand-held calculators (e.g., Croley, 1977) or microcomputers (e.g., Golding, 1981). In addition, many other, smaller Fortran programs are available for urban hydrologic simulation that may be entirely suitable for a given problem and much easier to implement on a given computer system. Notable among the hundreds of such program are the Corps of Engineers, Hydrologic Engineering Center program STORM (Roesner et al., 1974, HEC, 1977a) for continuous simulation and the Illinois State Water Survey program ILLUDAS (Terstreip and Stall, 1974) for single-event simulation and pipe sizing. Both have good documentation and user support and have been extensively tested and utilized by engineers other than the model developers. HSPF (Johanson et al., 1980) is another alternative for catchments that are primarily nonurban or that require more sophisticated simulation of pollutant interaction.

SWMM is certainly formidable both in terms of its size and capabilities. Who, then, should use SWMM and for what purposes? Some criteria for usage are given below:

- 1) The engineer must be knowledgeable of the modeling techniques (e.g., non-linear reservoirs, kinematic waves, St. Venant equations, buildup-washoff equations). An appreciation for how physical processes may be simulated in a Fortran program is a necessity. As a corollary, the engineer is assumed to be familiar with the problem to be solved and with customary techniques for handling it. A clear problem definition is a prerequisite to any solution methodology.
- 2) By virtue of the problem size (e.g., sewer system with hundreds of pipes) or complexity (e.g., hydraulic controls, backwater) a simpler technique or model will not work. It may be borne in mind, however, that if calibration/verification data are

available, SWMM may also be used as a very simple “black box” model with minimal input data, at the expense of computer overhead to manage the program size and off-line files.

- 3) Quality is to be simulated. Although there are other models that also simulate quality, SWMM is perhaps the most flexible of any. Of course, SWMM is often applied just to quantity problems.

A large body of literature on theory and case studies is available for SWMM. Since the model was originally introduced in 1971, a wealth of such information is available, including citation in hydrology texts (e.g., Viessman et al., 1977; Wanielista, 1978; Kibler, 1982). A bibliography of SWMM-related literature is available (Huber et al., 1985)

While any number of examples could be presented for when SWMM should not be used, attention is drawn to just one: the user is already familiar with an adequate alternative technique or model. It is far more important for the engineer/user to understand the methodology being utilized than it is for a model such as SWMM to be employed on the premise of a more sophisticated technique. In the final analysis, the engineer/analyst is responsible for the decisions made using any technique of analysis; the technique or model is only a tool that must be clearly understood by those using it.

Modeling Caveats

The preceding section may be summarized by a few caveats for modeling in general and use of SWMM in particular.

- 1) Have a known project and modeling objective at the outset of work. Do not let the model capabilities or lack of them dictate the objective.
- 2) Use experienced personnel. A knowledge of engineering fundamentals is essential to proper model use and interpretation.
- 3) Use the simplest model suitable for the job. Although SWMM can be run in a very simple (e.g., minimal data) manner, there may be alternative models that require less initial effort to install. Sometimes a conclusion will be apparent simply from a review of data and prior studies, with no modeling necessary.
- 4) Start simple when learning. Obtain model familiarity by simulating very simple configurations for which the result is known, e.g., runoff from a steady rainfall onto an impervious surface.
- 5) Models are poor substitutes for data collection. Do not use the model to generate “real” data.
- 6) Examine the results critically. Is continuity preserved? Are predictions physically realistic? If not, review parameter estimates and model assumptions. Perhaps the model cannot simulate a particular physical process of interest.
- 7) Use one set of data for calibration and an independent set for verification of parameter choices.
- 8) Absolute magnitudes of quality predictions by SWMM or any other model are not to be trusted without calibration and verification data. At best, relative comparisons can be made between runs with differing conditions. Urban runoff quality processes involve too many unknown physical, chemical and biological factors to be simulated accurately.

SECTION 2

Executive Block, Graph Routines and System Requirements

Block Description

Functions

The Executive Block performs six main functions:

- 1) assignment of logical units and files,
- 2) control of the sequencing of computational blocks,
- 3) graphing of data files by the line printer,
- 4) control of the simulation time clock for all blocks,
- 5) input error checking, and
- 6) control and summarization of input and computational errors.

These six functions are summarized under the subheadings Program Operation (1,2), SWMM Graphics (3), SWMM Time (4), Input Errors (5), and No-Fault Error Summary (6). This block is the operating “shell” of SWMM; no hydrologic computations as such are performed in the Executive Block. The relationship of the Executive Block to other blocks is shown in Figure 2-1.

Before diving into the world of program functionality the following discussion of data entry should be read and understood.

How to Enter Data in SWMM

The following significant changes have been made to SWMM input files relative to previous versions:

- 1) free format input,
- 2) line identifiers are required in all blocks,
- 3) comment lines are allowed in the input,
- 4) SWMM reads up to 230 columns of input, and
- 5) OPEN FILE statements are controlled by the user with the @ function.

This documentation recognizes that almost all input to SWMM will be prepared at a terminal using an editor to create an input data file. Hence, use of the word “card” to indicate an 80-column line of input has been superseded by “line” or “data group” within this manual. Of course, a few users may still prepare input on punched cards, in which case each line of input will be on one card.

In a major departure from the restrictions of fixed format 80 column input this version of SWMM has been written to accept up to 230 columns of free format input. Free format input means that data do not have to be entered in fixed columns. The only restrictions are: (1) decimal points may not be used when an integer number is expected, (2) at least one space must separate each data

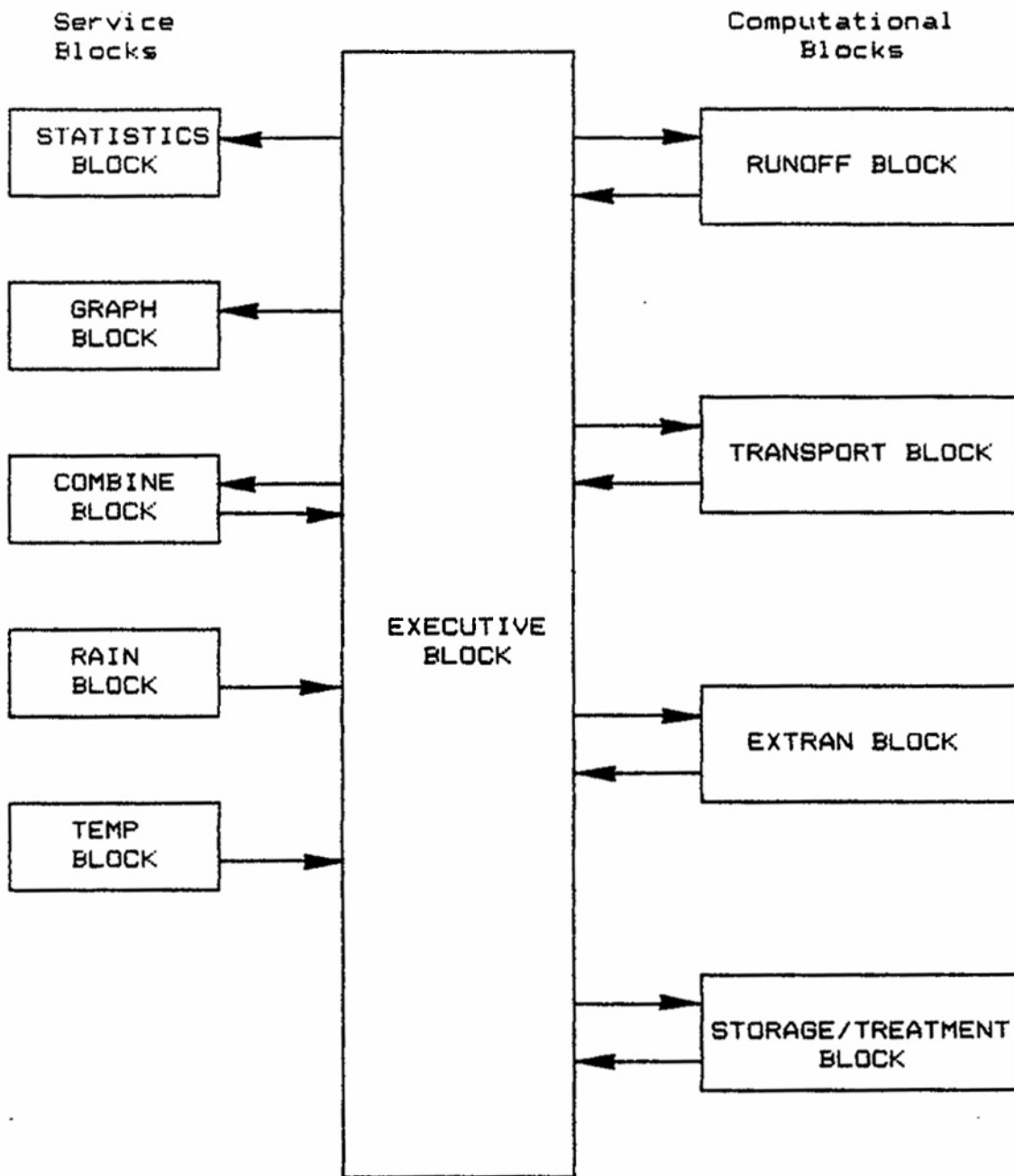


Figure 2-1. Relationship among SWMM blocks. Executive Block manipulates interface file and other off-line files. All blocks may receive off-line input (e.g., tapes, disks) and user line input (e.g., terminal, cards, etc.).

field, (3) character data must be enclosed by single quotes, and (4) a number or character must be entered for all data fields. All SWMM blocks have free format input.

An additional SWMM requirement is the line identifiers entered in columns one and two of each data line. See Table 2-1 for example line identifiers. Do not put quote marks around the line identifiers. These identifiers are necessary for the following reasons:

- 1) they control the sequence of read statements,
- 2) they are used in the error checking of data files, and
- 3) they help in understanding the input.

There are three special symbols (always entered in column 1) that signal block and file control to the program. These symbols are:

\$ --> Signals the calling of a SWMM Block, e.g. \$RUNOFF, \$RAIN.

@ --> Enables the user to permanently save an interface or scratch file (see Table 2-1 for an example, and Table 2-9 for the input format).

* --> Comment line. Enter an asterisk to place comments in SWMM input files. No closing asterisk is necessary.

These special control characters are read by subroutine STRIP, which is called by the MAIN program of SWMM. STRIP edits the input file, which has a logical unit number of 55, and creates a temporary file sans comment and @ lines that is saved on logical unit number 5. Numbers 5 (input), 6 (output) and 55 are thus restricted numbers in this version of SWMM. Interface and scratch files should not use 5, 6 or 55 as logical unit numbers.

Comment and @ function lines are never read by the simulation blocks of SWMM. Input lines beginning with * or @ can be placed anywhere in the input file, since they are acted upon only in subroutine STRIP. Listed below is an example of a set of comment and @ function lines. The example will work on both microcomputers and main-frames. (Do not be concerned that the example file name follows MS-DOS conventions.)

```
*   JIN(1) JOUT(1)   The next line lists the logical unit numbers for
*                   an example SWMM run.
SW 1  9    8
*
*   Permanently save interface file 8 under the name 'INT.OUT'
@   8 'INT.OUT'
*
*   The @ function also allows the use of an existing file
*       Use 'INT.IN' as interface file 9
@   9 'INT.IN'
```

The form of the @ function is simply @, in column 1, followed by the logical unit number of the scratch or interface file, and lastly the filename in single quotation marks. The @ line uses free format input. Just make sure there is a space between the unit number and the filename.

Subroutine STRIP opens the file with STATUS = 'UNKNOWN'. This has the following effects on filename FILE depending on the preexisting conditions:

Table 2-1. Example SWMM Input with Control Symbols (File RUNOFF2.DAT)

```

*      SPECIAL CONTROL SYMBOLS NOW CONTROL THE SWMM INPUT FILE
*      THE SPECIAL SYMBOLS ARE '*', '@', AND '$'.
*      * ---> COMMENT LINE
*      @ ---> SAVE A FILE PERMANENTLY OR USE A SAVED FILE
*      $ ---> CALL A SWMM BLOCK
*      THE FIRST LINE CONTAINS THE NUMBER OF BLOCKS TO BE RUN AND
*      THE JIN AND JOUT INTERFACE FILE UNIT NUMBERS.
*      (NOTE THAT A SECOND BLOCK IS NOT RUN IN THIS EXAMPLE.)
* NBLOCK JIN(1) JOUT(1) JIN(2) JOUT(2)
SW 2 0 10 10 0
*      THE SECOND LINE CONTAINS UP TO 6 SCRATCH FILE UNIT NUMBERS.
MM 6 11 12 13 14 15 16
*      FILE 10 (OR ANY UNIT NUMBER) COULD BE PERMANENTLY SAVED.
* @ 10 'SAVE10.OUT'
*      CALL THE RUNOFF BLOCK USING $RUNOFF
$RUNOFF
*      THERE ARE TWO A1 OR TITLE CARDS IN EVERY BLOCK.
*      ALL CHARACTER DATA MUST BE ENCLOSED IN SINGLE QUOTES.
A1 'RUNOFF EXAMPLE 2, SIMPLE CONFIGURATION, 100 % IMPERVIOUS'
A1 'SINGLE CATCHMENT PLUS SINGLE PIPE, CONST. RAIN'
*      COMMENT LINES CAN BE USED TO IDENTIFY INPUT VARIABLES.
* METRIC ISNOW NRGAG INFILM KWALTY IVAP NHR NMN NDAY MONTH IYRSTR
B1 0 0 0 1 0 0 0 0 0 3 12 88
B2 0 0 2
* 5-MIN TIME STEP, 2-HR SIMULATION
* WET WETDRY DRY LUNIT LONG
B3 300. 300. 300. 2 2.0
B4 0 0
D1 0
* KTYPE KINC KPRINT KTHIS KTIME KPREP NHISTO THISTO TZRAIN
E1 2 1 0 0 0 0 3 60.0 0.0
* STEP-FUNCTION HYETOGRAPH
* TIME=REIN(1) RAIN=REIN(2)
E3 0.0 1.0
E3 60.0 0.0
E3 120.0 0.0
* 2-FT DIAMETER CIRCULAR PIPE
* NAMEG NGTO NPG GWIDTH GLEN G3 GS1 GS2 G6 DFULL GDEPTH
G1 101 102 2 2.0 300.0 0.005 0.0 0.0 0.014 0.0 0.0
* 2-AC IMPERVIOUS CATCHMENT
* JK NAMEW NGTO WW1 WW2 WW3 WW4 WW5 WW6 WW7 WW8 WW9 WW10 WW11
H1 1 201 101 200.0 2.0 100.0 0.01 0.020 0.20 0.03 0.3 3.0 0.3 0.001
* PRINT CONTROL PARAMETERS
M1 2 1
* DEFAULT STARTING AND STOPPING PRINT TIME IS DURATION OF SIMULATION.
M2 1 0 0
* PRINT HYDROGRAPHS FOR PIPE 101 AND INLET 102.
M3 101 102
*      END THE SWMM SIMULATION BY USING $ENDPROGRAM.
*      (ANOTHER BLOCK COULD FOLLOW INSTEAD.)
$COMBIN
A1 5
$ENDPROGRAM

```

- 1) FILE does not exist • creates (opens) a file named FILE. If FILE is read by a subsequent SWMM block, the proper format must be used (e.g., an interface file must be read according to the format of the interface file). Otherwise, an error message is generated and the program stops.

- 2) FILE exists • opens FILE. If subsequently FILE has information written on it the old information on FILE is lost.

It is hoped that the above changes will make SWMM an easier model to use and facilitate the construction of input preprocessors.

Program Operation

The Executive Block assigns logical units and files, and controls the computational block(s) to be executed. These functions depend on reading in at least four data lines which must be supplied according to the needs of a given computer run. These data lines are: (1) the interface file numbers, (2) the scratch file numbers, (3) the names of the various blocks called in the simulation run, and (4) \$ENDPROGAM.

The Executive Block assigns logical unit numbers to the interface and scratch files by reading the SW and MM data groups, respectively. The first line (denoted by SW in the first two columns) may contain up to 50 integer numbers, corresponding to 25 input and 25 output units. The maximum number of files open at any one time is eight (two interface files and six scratch files). These file limits should not exceed the realistic capability of most computer systems. Usually only two to six units will be needed for any single simulation. The output file is saved (during the run) for use by a subsequent computational block and is subsequently deleted, unless the file is saved permanently by using the '@' function. The output files can be examined directly during the run by using the graphing and statistical capability of the Executive Block.

The file assignments in the second data group (denoted as MM) are for scratch files, i.e., files that are generated and used during execution of the program, and erased at the end of the run. Again, there is provision for up to six such files, but only one or two are typically needed. The unit numbers of the interface and scratch files are stored in the labeled common COMMON/TAPES/ for use by all blocks.

Scratch files are opened when a block is called and closed when control returns to the executive block. This was done to ensure that the Runoff Block does not erase valuable user data.

The Runoff Block uses NSCRAT files for precipitation, evaporation, temperature, and wind speed input. Thus, the @ lines should be clustered within the data of a block. Multiple @ functions should be used when a scratch file has a different meaning from block to block. For example, NSCRAT(1) may be the rainfall input file in Runoff and be a true scratch file in Transport. An @ line should be used anywhere before the \$TRANSPORT to open the file for Runoff. The file will be closed when Runoff finishes execution. A new file called FORT#, where # is the unit number assigned to NSCRAT(1) will then be opened when the Transport Block is called.

SWMM Line Printer Graphics

The graphing subroutines enable hydrographs and pollutographs to be plotted on the line printer for selected locations for output data files (e.g., predicted results); measured data that are input by the user may be plotted as well. The predicted and measured results may be plotted on one graph for comparison. Operation of the graph routines is described later. The subroutines include GRAPH, called from the main executive program only, in which control information, titles, and measured data (if any) are read.

Subroutine HYSTAT is called from GRAPH for computation of hydrograph volumes, durations, peak flows, and times of peaks. This is done for both predicted and measured hydrographs. Statistical comparisons between measured and predicted flows and pollutants are

printed either under the graph or a separate summary page is written. Similarly, total loads, durations, peak concentration, and time of peaks for both predicted and measured pollutographs can be printed.

Subroutine CURVE is called from GRAPH to coordinate the actual plotting. It is also called directly from the Runoff and Extran blocks. The control information, titles, etc. are supplied from those blocks, bypassing Subroutine GRAPH. Subroutine CURVE performs the following operations:

- 1) Determines maximum and minimum values of arrays to be plotted, calculates the range of values, and selects appropriate scale intervals using subroutine SCALE.
- 2) Computes vertical axis labels based upon the calculated scales.
- 3) Computes horizontal axis labels based upon the calculated scales.
- 4) Joins individual parts of the curve using Subroutine PINE.
- 5) Outputs the final plot using Subroutine PLOT.

Subroutine SCALE calculates ranges and scaling factors. Subroutine PINE joins two coordinate locations with appropriate characters in the output image array A of PLOT. Subroutine PLOT initializes the plotting array, stores individual locations, and outputs the final array A for the printer plot.

SWMM Time

The simulation clock for all blocks is controlled by the Executive Block. Previous versions of SWMM had different “clocks” in each block which often caused problems in reading interface files. The multiplicity of clocks also complicated the process of model verification. This version of SWMM uses variable time steps in runoff modeling that necessitated a restructuring of the clock time in the Runoff, Transport, Graph and Statistics Blocks in any event.

For these reasons a single “SWMM Clock” based on integer numbers was created. The basic units of time in SWMM are the second of the day and the Julian date. Julian dates are five digit numbers incorporating the year and the day of the year. The Julian dates for 1987 range from 87001 to 87365. As an example, March 20, 1987 at 10:30:00 would be the 37800th second of day 87079.

It is not necessary to have a time step smaller than one second in any block, including Extran. The two numbers necessary to define any moment during the simulation are the Julian date and the second of the day. There are 86,400 seconds in a Julian day. Thus, the largest integer number in SWMM can easily be handled by any INTEGER*4 variable in FORTRAN.

The interface and scratch files use only the Julian date and the second of day to define the flow and concentration time. Subroutine DATED in the Executive Block uses the date/second combination to return the year, month, day, hour, minute, and second. This subroutine is used extensively by the print and graph routines in SWMM. Subroutine STIME updates the Julian date and second counter at each time step based on the current time step increment DELTA.

Input Errors

Upon encountering an input error each input subroutine of SWMM calls Subroutine IERROR. IERROR prints the data group identifier of the problem line, prints the first 80 characters of the line, and stops program operation. This subroutine should eliminate mysterious operating system error messages and provide the user with at least some assistance in correcting input mistakes.

Possible input errors include: (1) decimal points in integer fields, (2) double decimals, (3) missing input fields, (4) improper character data, and (5) the wrong input order. The user should consult the data input tables for the proper input order and format.

No-Fault Error Summary

Another type of error in SWMM consists of error/warning messages about non-convergence, surcharging, etc. Subroutine IERROR also prints summary error/warning tables when a SWMM Block is finished executing. The error/warning message is printed once during the program execution and then the total number of errors/warnings are printed at the end of program execution. The first message is to inform the user of potential problems with his/her model in case a catastrophic event such as repeated division by zero occurs and the model run aborts.

Run-time errors may also be generated by the compiled Fortran program and appear on the screen when run on a microcomputer. These may be defined by reference to the Ryan-McFarland or IBM Professional Fortran users manuals. Please notify the SWMM program authors of repeated errors or bugs.

Default/Ratio Data Lines

Within the Runoff and Transport Blocks, default/ratio lines may be used to create default values and ratios for selected variables (denoted by asterisks in selected data groups). These lines are indicated by a -1 (new ratio) or -2 (new default) for the requested location ID number. Altered ratios or defaults are input for any nonzero parameter value.

The user triggers the use of the default value when 0.0 is used in the input field of a data group. Since default values included in a model can lead to lack of initiative on the part of the modeler in collection of data, the user must thus explicitly and knowingly enter all but a very few default values. The parameter ratios may be used for sensitivity analysis and global model adjustment. For instance, a ratio of 1.1 would indicate that the value of the input parameter used in the program will be 10 % higher than the value given on the input data line. A parameter value is always multiplied by the current ratio.

The new default value or ratio is only valid for the subsequent lines of the current data group. When a new data group is read the default values become 0.0 and the ratios become 1.0. Multiple default/ratio lines can be used within a data group.

Interfacing Between Blocks

Data may be transferred or interfaced from one block to another through the use of the file assignments on data group SW. The interface file header consists of:

- 1) descriptive titles,
- 2) the simulation starting date and time,
- 3) the name of the block generating the interface file,
- 4) the total catchment or service area,
- 5) the number of hydrograph locations (inlets, outfalls, elements, etc.),

- 6) the number of pollutants found on the interface file,
- 7) the location identifiers for transferred flow and pollutant data,
- 8) the user-supplied pollutant and unit names,
- 9) the type of pollutant concentration units, and
- 10) flow conversion factor (conversion to internal SWMM units of cfs).

Following the file header are the flow and pollutant data for each time step for each of the specified locations. The detailed organization of the interfacing file is shown in Table 2-2, and example FORTRAN statements that will write such a file are shown in Table 2-3. These tables may be used as guidelines for users who may wish to write or read an interfacing file with a program of their own. Further information on required pollutant identifiers, etc. may be found later in the Runoff Block input data descriptions.

The title and the values for the starting date and time from the first computational block are not altered by any subsequent block encountered by the Executive Block. All other data may (depending on the block) may be altered by subsequent blocks. The individual computational blocks also have limitations on what data they will accept from an upstream block and pass to a downstream block. These limitations are summarized in Table 2-4. Detailed discussions are presented in the manuals for each block.

Block limitations can be adjusted upwards or downwards by the user by modifying the PARAMETER statement found in the include file TAPES.INC. Follow the instructions of Table 2-5.

Computer System Requirements

FORTRAN

This version of SWMM was programmed in FORTRAN 77, specifically using the RM/FORTRAN compiler on the PC and VS/FORTRAN on an IBM 3033 main-frame. The problems of the past with FORTRAN compatibility on main-frames should be alleviated in this version of SWMM.

The likely sources of any potential incompatibility are Subroutines CHKFILE and INTCHR. CHKFILE opens and closes interface and scratch files. INTCHR converts character data to integer data in the Rain Block. This is based on the ASCII character set and intrinsic functions in RM/FORTRAN and VS/FORTRAN. However, this will only affect people who are using pre-1980 National Weather Service (NWS) precipitation tapes.

The NWS sells fixed format and variable block/length precipitation tapes. This version of SWMM is written to read both fixed format and variable block/length tapes. However, the IBM mainframe at the University of Florida cannot read variable block/length records. Hence, the variable block/length code is obviously unverified. User beware. It is recommended that the user purchase fixed format (record length of 43, blocksize of 6300), ASCII tapes from the NWS.

Sample execution times on an 8 Mhz IBM Compatible AT (Zenith Z-248) are shown in Table 2-6. Clock time refers to human waiting time. This table tries to show the gamut of possible SWMM runs. Multiply or divide for faster or slower machines.

System Memory

Main-frame users of SWMM should have no need for any overlay structure or any concern for memory limitations. The entire SWMM program compiled under VS FORTRAN is

approximately 2500 kb on an IBM main-frame. Virtual memory allows program sizes in the gigabyte range. This statement also applies to minicomputers and Macintoshes.

Table 2-2. Detailed Organization of SWMM Interface File

Note: See Subroutine INFACE for example of reading and writing this file.

	Variable Name	Description ^a
FROM FIRST COMPUTATIONAL BLOCK	TITLE(1)	First line of title from first block, maximum of 80 characters.
	TITLE(2)	Second line of title from first block, maximum of 80 characters.
	IDATEZ	Starting date; 5-digit number, 2-digit year plus Julian date within year, e.g. February 20, 1987 is 87051.
	TZERO	Starting time of day in seconds, e.g., 5:30 p.m. is 63000. This date and time should also be the first time step values found on the interface file.
FROM CURRENT INTERFACING BLOCK	TITLE(3)	First line of title from immediately prior block, maximum of 80 characters.
	TITLE(4)	Second line of title from immediately prior block, maximum of 80 characters.
	SOURCE	Name of immediately prior block, maximum of 20 characters.
	LOCATS	Number of locations (inlets, manholes, outfalls, etc.) on interface file.
	NPOLL	Number of pollutants on interface file.
	TRIBA	Tributary or service area, acres.
	(NLOC(K), K=1, LOCATS) or (KLOC(K), K=1, LOCATS)	Location numbers for which flow/pollutant data are found on interface file. These may be either numbers (JCE=0) ^b , or alphanumeric names (JCE=1). NLOC array if numbers. KLOC if alphanumeric names are used.
	(PNAME(J), J=1, NPOLL)	NPOLL pollutant names, maximum of 8 characters for each.
(PUNIT(J), J=1, NPOLL)	NPOLL pollutant units, e.g. mg/l, MPN/l, JTU, umho, etc., max. of 8 characters for each.	

Table 2-2. Continued

	Variable Name	Description ^a
FROM CURRENT INTERFACING BLOCK (continued)	(NDIM(J),J=1,NPOLL)	Parameter to indicate type of pollutant concentration units. =0, mg/l =1, Aother quantity@ per liter, e.g. for bacteria, units could be MPN/l. =2, other concentration units, e.g., JTU, umho,EC, pH.
	QCONV	Conversion factor to obtain units of flow of cfs, (multiply values on interface file by QCONV to get cfs). All blocks assume inflow is in cfs and convert to m ³ /sec if METRIC = 1.
FLOW AND POLLUTANT DATA FOR EACH LOCATION. REPEAT FOR EACH TIME STEP.	JULDAY	Starting date; 5-digit number, 2-digit year plus Julian date within year, e.g. February 20, 1987 is 87051.
	TIMDAY	Time of day in seconds at the beginning of the time step, e.g., 12:45 p.m. is 45900.
	DELTA	Step size in seconds for the <u>next</u> time step ^c .
	(Q(K),(POLL(J,K),J=1,NPOLL),K=1,LOCATS)	Flow and pollutant loads for LOCATS locations at this time step. Q(K) must be the instantaneous flow at this time (i.e.,at end of time step) in units of volume/time. POLL(J,K) is the flow rate times the concentration (instantaneous value at end of time step) for Jth pollutant at Kth location, e.g.,units of cfs*mg/l or m ³ /sec*JTU ^d .

^aUnformatted file. Use an integer or real value as indicated by the variable names. Integer variables begin with letters I through N.

^bParameter JCE indicates whether \$ANUM has been invoked to use alphanumeric conduit and junction names and is included in COMMON/TAPES in each block.

^cI.e., the next date/time encountered should be the current date/time plus DELTA.

^dIf units other than cfs are used for flow, this will be accounted for by multiplication by parameter QCONV.

Table 2-3. FORTRAN Statements Required to Generate an Interface File

Note: See Subroutine INFACE for example of reading and writing the interface file.

FILE	WRITE(NOUT)	TITLE(1),TITLE(2)
HEADER	WRITE(NOUT)	IDATEZ,TZERO
	WRITE(NOUT)	TITLE(3),TITLE(4)
	WRITE(NOUT)	SOURCE,LOCATS,NPOLL,TRIBA
	IF(JCE.EQ.0)WRITE(NOUT)	(NLOC(K),K=1,LOCATS)
	IF(JCE.EQ.1)WRITE(NOUT)	(KLOC(K),K=1,LOCATS)
	IF(NPOLL.GT.0)WRITE(NOUT)	((PNAME(L,J),L=1,2),J=1,NPOLL)
	IF(NPOLL.GT.0)WRITE(NOUT)	((PUNIT(L,J),L=1,2),J=1,NPOLL)
	IF(NPOLL.GT.0)WRITE(NOUT)	(NDIM(J),J=1,NPOLL)
	WRITE(NOUT)	QCONV

NOUT is the interface file or logical unit
number for output, e.g., NOUT = JOUT(1) for first
computational block.

FLOW AND POLLUTANT DATA FOR EACH LOCATION: REPEAT FOR EACH TIME STEP	IF(NPOLL.GT.0) THEN	WRITE(NOUT) JULDAY,TIMDAY,DELTA,(Q(K), (POLL(J,K),J=1,NPOLL),K=1,LOCATS)
	ELSE	WRITE(NOUT) JULDAY,TIMDAY,DELTA, (Q(K),K=1,LOCATS)
	ENDIF	

Note 1: The interface file should be unformatted. The time step read/write statements must include IF statements to test for the appearance of pollutants.

Note 2: The interface file may be read by the Combine Block to produce an ASCII/text file which can be read by various microcomputer software.

Table 2-4. Interface Limitations for Each Computational Block^a

Block	Input	Output ^b
Runoff	•	150 elements (inlets), 10 pollutants
Transport	80 elements (inlets), 4 pollutants	150 elements (non-conduits), 4 pollutants
Extran	200 elements (inlets), no pollutants (ignored if on the file)	200 junctions
Storage/ Treatment	10 elements (inlets or non-conduits), 3 pollutants	10 elements ^c , 3 pollutants

^aThese limitations are based on the “vanilla” SWMM sent to the user. As explained in Table 2-5, these limitations can easily be changed by the user by modifying the PARAMETER statement accompanying the file ‘TAPES.INC’.

^bThe number of pollutants found on the output file from any block is the lesser of the number in the input file or that specified in the data for each block.

^cAlthough the Storage/Treatment Block will read and write data for as many as 10 elements, the data for only one element pass through the storage/treatment plant; the rest are unchanged from the input file.

Table 2-5. SWMM Parameter Statement Modification

This is file TAPES.INC in SWMM Fortran source code (version 4.2, 10/92).

```

=====
C
C   NW  = NUMBER OF SUBCATCHMENTS IN THE RUNOFF BLOCK
C   NG  = NUMBER OF CHANNEL/PIPES IN THE RUNOFF BLOCK
C   NRQ = NUMBER OF QUALITY PARAMETERS IN THE RUNOFF BLOCK
C   NLU = NUMBER OF DIFFERENT LAND USES IN THE RUNOFF BLOCK
C   NCP = NUMBER OF CONNECTING CHANNEL/PIPES OF SUBCATCHMENTS
C   NET = NUMBER OF ELEMENTS IN THE TRANSPORT BLOCK
C   NTSE = NUMBER OF STORAGE ELEMENTS IN THE TRANSPORT BLOCK
C   NTH = NUMBER OF INPUT HYDROGRAPHS IN TRANSPORT
C   NEE = NUMBER OF ELEMENTS IN EXTRAN BLOCK
C   NGW = NUMBER OF SUBCATCHMENTS WITH GROUNDWATER
C           COMPARTMENTS IN RUNOFF
C   NIE = NUMBER OF INTERFACE LOCATIONS FOR ALL BLOCKS
C   NEP = NUMBER OF EXTRAN PUMPS
C   NEO = NUMBER OF EXTRAN ORIFICES
C   NTG = NUMBER OF TIDE GATES OR FREE OUTFALLS IN EXTRAN
C   NEW = NUMBER OF EXTRAN WEIRS
C   NPO = NUMBER OF EXTRAN PRINTOUT LOCATIONS
C   NTE = NUMBER OF TIDE ELEMENTS IN EXTRAN
C   NNC = NUMBER OF NATURAL CHANNELS IN EXTRAN AND TRANSPORT
C   NVSE = NUMBER OF STORAGE JUNCTIONS IN EXTRAN
C   NTVAL= Number of tidal or time history points in Extran.
C   NVST = NUMBER OF DATA POINTS FOR VARIABLE STORAGE ELEMENTS
C           IN THE EXTRAN BLOCK
C   NEH = NUMBER OF INPUT HYDROGRAPHS IN THE EXTRAN BLOCK
C
C   INSTRUCTIONS - INCREASE DIMENSIONS OF SUBCATCHMENTS ETC.
C                   BY MODIFYING THE PARAMETER STATEMENT
C                   AND RECOMPILING YOUR PROGRAM
=====
C
C   PARAMETER(NW=100,NG=150,NRQ=10,NLU=5,NGW=100,NCP=4,NET=150,
+           NTSE=30,NEE=200,NTH=80,NIE=200,NTE=20,NEW=60,NEO=60,
+           NEP=20,NTG=25,NPO=30,NVSE=20,NVST=25,NNC=50,
+           NEH=100,NTVAL=50)
C   CHARACTER*2 CC,FFNAME*60
C   COMMON /TAPES/INCNT,IOUTCT,JIN(25),JOUT(25),JCE,NOQ,
+           NSCRAT(7),N5,N6,JKP(57),CMET(11,2),FFNAME(57),CC
=====

```

Table 2-6. Example SWMM Execution Times on an 8 Mhz IBM Compatible AT

Block/Schematization	Number of 5 Minute Time Steps	Clock Time
Runoff		
1 Subcat/No Quality	120 steps	30 seconds
10 Subcat/No Quality	1200 steps	60 seconds
1 Subcat/5 Pollutants	120 steps	45 seconds
Runoff + Transport		
29 Subcat, 34 Channel/Pipes, 50 Elements	24 steps	180 seconds

Program Verification, i.e., Bugs

The current state of art in program verification is pretty dismal. It is impossible to prove an algorithm “totally correct” (Harel ,1987). A totally correct algorithm provides the correct answer for all legal forms of input. A partially correct algorithm provides the correct answer for some forms of legal input. As is often said, testing and debugging cannot be used to demonstrate the absence of errors in software, only their presence.

The total program “correctness” of SWMM was increased by the following methods:

- 1) Increasing the number of subroutines in SWMM. Smaller subroutines are easier to debug, test, and verify.
- 2) Testing subroutines for failure. Input data sets are constructed to force failure by straining the limits of the program. For example, test channel/pipe convergence in the Runoff Block using pipes of 1 cm diameter and 1 cm length at time steps of years. Then if the program works correctly for extreme input, it should work for “normal” input.
- 3) Eliminating duplicate coding in SWMM. Test, debug, and verify one subroutine to perform a task in all blocks. Examples are the clock subroutines, statistics subroutines, integration subroutine, interpolation subroutine, etc.

In spite of these ecumenical attempts at debugging, the program authors suspect that some errors will be found by users and earnestly solicit user feedback for model improvements.

Instructions for Executive Block Data Preparation

Logical Units

Logical units or file numbers are simply the numbers assigned to various input/output devices (files) for use in the program. On most mainframes, logical numbers for the card reader, line printer and card punch are:

I/O Device	Logical Unit
Card Reader	5
Line Printer	6
Card Punch	7

“Card reader” is used figuratively as the device for reading user input data files. SWMM is programmed under the assumption that the card reader and line printer are so defined (no cards are punched by SWMM). However, in an attempt to allow versatility, all READ and WRITE statements use parameters N5 and N6 for the logical unit numbers of the card reader and line printer respectively. These are defined only once,

$$\begin{aligned} N5 &= 5 \\ N6 &= 6 \end{aligned}$$

near the beginning of the Executive Block MAIN program and passed to all other blocks through the labeled COMMON/TAPES/. Thus, if other logical numbers are required for input and output, the only programming changes required should be at the above location.

Other files are typically assigned logical units between 1 and 99 (but not 5, 6, 7 or 55). Unit 55 is a special scratch file used by subroutine STRIP (see earlier discussion on SWMM input).

Interface and Scratch Files

The SWMM interface and scratch files are “scratch files,” that is, files that are used during program execution, and erased (lost) at the end of the simulation. As discussed previously, the user can permanently save any interface or scratch file by using the @ function (see Table 2-1 for example and Table 2-9 for input format).

Ordinarily, scratch files will be used for parameters JIN, JOUT, and NSCRAT of the Executive Block. JIN and JOUT are used only to transfer data between blocks, with the exceptions being a JIN data set needed for rainfall input in the Rain and Runoff Blocks, and temperature input in the Temp Block. The NSCRAT files are used for miscellaneous tasks within each block, most typically to store output for later printing. Current requirements are shown in Table 2-7. The Runoff Block potentially requires the largest number of scratch files.

The following example of the interface and scratch data sets may help explain the logic of the SW and MM data lines. Assume Runoff, Transport, and Storage/Treatment are to be run in order. The unit numbers assigned to the various data sets are arbitrary:

Line Identifier	Number of Blocks	RUNOFF		TRANSPORT		STORAGE	
		JIN(1)	JOUT(1)	JIN(2)	JOUT(2)	JIN(3)	JOUT(3)
SW	3	0	9	9	10	10	0

Table 2-7. Scratch Data Sets Required by SWMM

1.	Runoff Block	
	NSCRAT(1)	- Always required.
	NSCRAT(2)	- Always required.
	NSCRAT(3)	- Required for continuous SWMM with snowmelt, may contain temperature, evaporation, and wind speed data.
	NSCRAT(5)	- Required for groundwater simulation.
	NSCRAT(6)	- Required for groundwater simulation.
2.	Transport Block	
	NSCRAT(1)	- Always required.
	NSCRAT(2)	- Always required.
3.	Storage/Treatment Block	
	None required.	
4.	Receiving Water Block (not implemented, see Section 8)	
5.	Extended Transport Block (EXTRAN)	
	NSCRAT(1)	- Always required.
	NSCRAT(2)	- Always required.
	NSCRAT(3)	- Required for “hot start” capability.
6.	Combine Block	
	NSCRAT(1)	- Required if using combine or collate.
7.	Statistics Block	
	NSCRAT(1)	- Always required.
8.	Rainfall Block	
	NSCRAT(1)	- Required only if the storm event data are saved on an output file.
9.	Temperature Block	
	NSCRAT(1)	- Required only if the data are saved on an output file.

Here, JIN(K+1) = I refers to an input file and JOUT(K) = I refers to the same output file from a preceding block. Thus, the output of the Runoff Block, JOUT(1) = 9, is the input of the Transport Block, JIN(2) = 9. For example, a typical read statement in a FORTRAN program may be READ(I,80). The I is replaced by the symbolic unit number of the file, 9 in this case. (Since the numbers 5, 6, 7, and 55 have standard meanings, they are not used.) The sequential execution shown above is not required in general. For instance, a sequence of several Runoff Block runs could be performed, each with different input and output unit files (hence, different unit numbers). However, for this example, the meaning of the unit numbers is as follows:

- JIN(1) = file number for input into the first block to be run (Runoff Block).
JIN(1) = 0 means there is no file input.
- JOUT(1) = file number for output from the first block to be run (Runoff Block).
JOUT(1)=9 means there is an output file.
- JIN(2) = file number for input to the second block to be run (Transport Block).
(This is often the same as the output number from the preceding block.) JIN(2) = 9 means there is an input file (from the Runoff Block).
- JOUT(2) = file number for output from the second block to be run (Transport Block). JOUT(2) = 10 means there is output to be saved.
- JIN(3) = file number for input to the third block to be run (Storage/Treatment Block). JIN(1) = 10 means there is input from the Transport Block.
- JOUT(3) = file number for output from the third block to be run (Storage/Treatment Block). JOUT(3) = 0 means there is no output to be saved.

These files have either the default FORTRAN filenames or a user defined filename (from executing the @ function). The default names are usually FORTn, where n is the logical unit number. Thus, logical unit number 8 has the default filename of FORT8.

Block Selection

The instructions for data preparation are divided into two parts corresponding to control of the SWMM Block selection and graphing capability. Table 2-9 at the end of these instructions gives the procedure for data preparation.

The Executive Block controls the computational block(s) to be executed by reading the name of that block, for example: \$RUNOFF. The program compares this word with a dictionary of such words (first eight characters). If a match is found, as it would be in this case, control is passed to the appropriate part of the Executive Block to read that data. Here, for example, a call would be made to the Runoff Block. After execution of the Runoff Block, control is returned to the Executive Block.

The Executive Block again reads a sentinel (\$) line, which might indicate that another block to be executed. For example, if the Transport Block is to be executed, the control word \$TRANSPORT would be given, etc. If results are to be graphed, the control word \$GRAPH would be on the next input line. If the run is to be terminated \$ENDPROGRAM is entered. A summary of the control words and corresponding action is given in Table 2-8.

The use of control words on sentinel lines allows considerable flexibility in the utilization of the Storm Water Management Model. The most common type of run involves the execution of one of the computational blocks along with the graphing of results on the line printer. Thus, for the

Table 2-8. Summary of Control Words and Corresponding Action^a

Control Word	Action to Be Taken
@	Either: (1) Open an interface or scratch file with a user defined filename and save the file permanently; or, (2) open an existing file for use as an input file
*	Comment line. No action.
\$RUNOFF	Execute Runoff Block
\$TRANSPORT	Execute Transport Block
\$EXTRAN	Execute Extended Transport (EXTRAN) Block
\$STORAGE	Execute Storage/Treatment Block
\$COMBINE	Execute Combine Block
\$STATS	Execute Statistics Block
\$GRAPH	Produce graphs on line printer
\$RAIN	Execute Rainfall Block
\$TEMP	Execute Temperature Block
\$ENDPROGRAM	Terminate run at this point
Any other word	Terminate run ^b

^aProgram compares first four characters only.

^bOnly one additional line will be examined for a possible match prior to terminating the run.

Runoff Block, such a run would be made by appropriate use of the words \$RUNOFF, \$GRAPH, and \$ENDPROGRAM. If the Runoff, Transport and Storage/ Treatment Blocks were to be run with graphical output at the end of the latter two blocks, the sequence would be: \$RUNOFF, \$TRANSPORT, \$GRAPH, \$STORAGE, \$GRAPH, \$ENDPROGRAM.

Graph Routine

Capabilities

When called from the Executive Block, the graph routines will plot predicted and/or measured hydrographs, pollutographs, and loadographs for specified inlets or elements. A hydrograph is a plot of flow rate versus time, a pollutograph is a plot of concentration versus time, and a loadograph is a plot of pollutant load rate (e.g., mass/time) versus time. All three will simply be called “graphs” in the following discussion. Predicted graphs can be generated by the Runoff, Transport, Extran, and Storage/Treatment blocks. Their output (interface) files can be input to the graph routines. Measured graphs (i.e., data input by the user) may also be plotted whether or not predicted graphs are produced. Thus, the graph routines may be treated as stand-alone programs and used independently of the other SWMM blocks. When predicted and measured graphs are available for the same location, they will be overprinted on one plot for comparison purposes. This greatly facilitates calibration work.

A few simple statistics are also computed for each hydrograph and printed below each plot: volume, peak, time of peak, and duration. As an option, the user can request a printout only of the statistics. Similar statistics are printed below the plot of each pollutograph and loadograph: mean concentration or loading rate, peak concentration or loading rate, time of peak, and duration. When both measured and predicted graphs are plotted on the same plot, the above statistics and differences (absolute and percent) are also given for the overlapping time period (recognizing that the period of measurements may not correspond exactly to the period of predictions).

The final plot is produced by printing the array “A”, dimensioned 51 (vertical) by 101 (horizontal). The vertical and horizontal scales are determined on the basis of the range of the input data. The left-most plotting location (at the left vertical axis) corresponds to the graph value at the start of the simulation (TZERO). The user has two options in the plotting of data: (1) all data are plotted, or (2) the program selects only 100 points to be plotted. If the number of points to be plotted exceeds 100 then multiple graphs are generated in option 1 until all points are plotted. In option 2 the program will plot up to 100 points selected evenly from the entire range of the time scale. Thus, option 2 will compress the time scale (if more than 100 time steps are available for plotting).

The particular graph routines used in SWMM “fill in” between separated points, horizontally or vertically, to form a continuous line. Thus, it is sometimes difficult to determine exactly the points that were input for plotting, except that they are usually the end points of line segments.

Input Parameters and Options

The predicted graphs from up to four locations may be plotted on a single sheet. Typically, however, only the predicted and/or measured graphs from a single location are plotted on a sheet. It is not possible to overlay the predicted and measured graphs for multiple locations on a single sheet. If measured and predicted graphs are both supplied for the same location, they will be overprinted on one plot for comparison.

Up to 20 predicted and measured locations may be plotted during one call to GRAPH. (If more locations need to be plotted, GRAPH can be called again.) The predicted and measured

locations need not be the same. For example, the subroutine may be used to plot only predicted or only measured graphs.

The routine will always plot hydrographs (when supplied) but will plot pollutographs/loadographs only if $NQP > 0$ (data group A1). Up to five pollutants may be plotted (data group B1), assuming the pollutant(s) is(are) available on either the interface file or on the E3 lines. Any number of pollutants (maximum of 10) may be input to GRAPH. The parameter IPOL selects the IPOLth pollutant on the interface file.

The time scales for input of the measured graphs need not be the same as for the predicted graphs, nor does the time spacing of measured graphs have to be constant. The plot will run from the minimum to the maximum times of the predicted or measured graphs. Several options are available for input of the times associated with graph ordinates (data group E1).

Input of the horizontal axis label is not required, and it always reads "Time of Day in Hours." The times are actually elapsed time, beginning at the start of the simulation (TZERO). Conversion to hour of day does not include a reset at midnight. Thus, if a simulation period begins at 10 p.m. and last 4 hours, the graph abscissa will run from 22 to 26 hours.

Vertical axis labels are either "Flow in cfs," "Flow in m^3/s ," "Pounds per Day," "Kilograms per Day," or the concentration units of the pollutant being plotted. All pollutographs are plotted in concentration units, and loadographs are plotted in pounds or kilograms per day. The same units are required for both predicted and measured hydrograph/pollutograph/loadograph inputs.

The input format of all measured data may be supplied by the user (data group E2). This facilitates the use of data already prepared under an arbitrary format. In addition, the number of data values per line may be varied (LCARD on data group E1).

Measured data may be read as line input (MEAS=1) or may be previously stored on file number MFILE and read from that file (MEAS=2 on data group A1). Retrieval from file MFILE may avoid reading voluminous data more than once.

Table 2-9. Executive and Graph Block Input Data

SWMM INPUT GUIDELINES		
<p>There have been many changes made to the input format of SWMM. Following is a short list of the major changes along with explanations and guidelines.</p>		
1.	Free format input. Input is no longer restricted to fixed columns. Free format has the requirement, however, that at least one space separate each data field. Free format input also has the following strictures on real, integer, and character data.	
a.	No decimal points are allowed in integer fields. A variable is integer if it has a 0 in the default column. A variable is real if it has a 0.0 in the default column.	
b.	Character data must be enclosed by single quotation marks, including both of the two title lines.	
2.	Data group identifiers are a requirement and <u>must</u> be entered in columns 1 and 2. These aid the program in line and input error identification and are an aid to the SWMM user. Also blank lines no longer are required to signal the end of sets of data group lines; the data group identifiers are used to identify one data group from another.	
3.	The data lines may be up to 230 columns long.	
4.	Input lines can wrap around. For example, a line that requires 10 numbers may have 6 on the first line and 4 on the second line. The FORTRAN READ statement will continue reading until it finds 10 numbers, e.g.,	
	<pre>Z1 1 2 3 4 5 6 7 8 9 10</pre>	
	Notice that the line identifier is <u>not</u> used on the second line.	
5.	An entry must be made for <u>every</u> parameter in a data group, even if it is not used or zero and even if it is the last required field on a line. Trailing blanks are not assumed to be zero. Rather, the program will continue to search on subsequent lines for the “last” required parameter. Zeros can be used to enter and “mark” unused parameters on a line. This requirement also applies to character data. A set of quotes must be found for each character entry field. For instance, if the two run title lines (data group A1) are to consist of one line followed by a blank line, the entry would be:	
	<pre>A1 'This is line 1.' A1 ''</pre>	
6.	See Section 2 for use of comment lines (indicated by an asterisk in column 1) and additional information.	
Variable	Description	Default
I/O File Assignments		
SW	Group identifier	None
NBLOCK	Number of blocks to be run (max of 25)	1
JIN(1)	Input file for the first block	0
JOUT(1)	Output file for the first block	0
■	■	
JIN(NBLOCK)	Input file for the last block	0
JOUT(NBLOCK)	Output file for the last block	0

Table 2-9. Continued

Variable	Description	Default
Scratch File Assignments		
MM	Group identifier	None
NITCH	Number of scratch files to be opened (max of 6)	0
NSCRAT(1)	First scratch file assignment	0
■ NSCRAT(NITCH)	■ Last scratch file assignment	0
Control Data Indicating Files To Be Permanently Saved (Optional)		
REPEAT THE @ LINE FOR EACH SAVED FILE		
@	Group identifier	None
FILENUM	Logical unit number of the JIN, JOUT, or NSCRAT file to be permanently saved (or already saved file to be used) by the SWMM program.	None
FILENAM	Name of permanently saved file. Enclose in single quotes, e.g. 'SAVE.OUT'	None
Control Data Indicating Blocks To Be Called		
REPEAT THE \$CNAME LINE FOR EACH BLOCK TO BE CALLED		
\$	Group identifier	None
CNAME	Name of block to be called. (No space between \$ and CNAME.)	None
\$CNAME	= \$RUNOFF for Runoff Block, = \$TRANSPORT for Transport Block, = \$EXTRAN for Extended Transport Block, = \$STORAGE for Storage Block, = \$COMBINE for Combine Block, = \$STATS for Statistics Block, = \$GRAPH for Graph Block, = \$RAIN for Rainfall Block, = \$TEMP for Temperature Block, and = \$ENDPROGRAM for ending the SWMM run.	

Table 2-9. Continued

Variable	Description	Default
	Data group \$CNAME is the last Executive Block line unless the graph routines are called. From the first \$CNAME line, control is passed to the appropriate block. When execution of that block is complete, control returns to the \$CNAME line that follows the input data for the block just executed.	
Input Data for Graph Block		
	Read data groups A1-E3 only if GRAPH has been called using \$GRAPH in Executive Block. Do not read SW and MM lines again.	
General Graph Information		
A1	Group identifier	None
NTAPE	File (logical unit) where predicted graph information is stored. Will usually equal JOUT value of previous block. If zero, only measured data will be plotted.	0
NPLOT	Number of locations (e.g. inlets) for which predicted hydrographs and pollutographs are to be plotted. Maximum of 20 locations.	0
MEAS	Input and plot measured data. = 0, No measured data to be plotted. = 1, Read (and plot) line-input data. = 2, Read (and plot) data stored as line images on file MFILE	0
THE FOLLOWING TWO PARAMETERS ARE NOT REQUIRED IF MEAS = 0		
MFILE	File (logical unit) where measured data are stored. Not required if $MEAS \leq 1$. (If zero, defaults to input file reader).	N5
MPLOT	Number of locations (e.g., inlets, manholes) for which measured data are to be input and plotted (MEAS = 1, 2). Maximum = 20.	0
NQP	Number of pollutants plotted (max of 5).	0
METRIC	Metric units used for input/output = 0, U.S. customary units. = 1, Metric units used, indicated in brackets [] in the remainder of the table.	0

Table 2-9. Continued

Variable	Description	Default
Pollutant Selection Data		
IF NQP = 0 (A1), SKIP TO GROUP C1 OTHERWISE, REPEAT GROUP B1 NQP TIMES.		
B1	Group identifier	None
IPOL	Pollutant identifier from sequence on interface file. e.g., if IPOL(1) = 3, first pollutant plotted will be third on interface file. User must know sequence, as determined from input to preceding block (e.g. group J3 of Runoff Block). If IPOL =0, pollutant is not found on interfacing file and is special input only.	0
***	If IPOL not = 0, omit all the following parameters since they will be obtained from the interface file. For discussion of these parameters, see group J3 of the Runoff Block and its discussion.	***
NLOAD	Type of pollutant plot = 0, plot concentration vs. time, = 1, plot load (e.g., mass/time) vs. time.	0
PNAME	Pollutant name. Format A8.	'None'
PUNIT	Pollutant units. Format A8.	'None'
NDIM	Type of units = 0, mg/l = 1, 'other' per liter, e.g., MPN/l = 2, other concentration units, e.g. JTU, pH.	0
IF NPLOT = 0, (A1) SKIP TO GROUP C2.		
Locations (e.g. inlets, manholes) for plotting of predicted output. Supply NPLOT values.		
C1	Group identifier	None
IPLOT(1)	First location to be plotted	0
IPLOT(NPLOT)	Last location to be plotted	0
IF MPLOT = 0, (A1) SKIP TO GROUP D1.		
Locations (e.g. inlets, manholes) for input and/or plotting of measured data. Supply MPLOT values.		
C2	Group identifier	None
KPLOT(1)	First location to be input and plotted.	0
KPLOT(MPLOT)	Last location to be input and plotted.	0

Table 2-9. Continued

Variable	Description	Default
	Plot Title	
D1	Group identifier	None
TITL	Title to be printed at bottom of each plot.	'Title'
	IF MPLOT = 0, (A1) SKIP REMAINING GROUPS. OTHERWISE READ MPLOT GROUPS OF DATA GROUP(S) E1 (AND POSSIBLY E2 AND E3) A TOTAL OF NQP + 1 TIMES.	
	First, for measured hydrograph, there are MPLOT data groups, E1, E2, and E3:	
E1	Group identifier	None
MDATA	Measured data for this graph and location corresponding to sequence for Group C2. = 0, No measured data to be entered for this location. = 1, Input measured data according to remaining parameters and format of Group E1.	0
	THE FOLLOWING PARAMETERS ARE NOT REQUIRED IF MDATA = 0 (E1).	
LCARD	Number of graph ordinates per Group (MTIME > 0) or pairs of time-graph ordinates per Group (MTIME = 0). Maximum = 16.	0
MTIME	Option for time of graph ordinates. = 0, Enter a time with each ordinate. Cease input of time-ordinate pairs when entered time is > TQUIT. > 0, The time for each ordinate will be computed starting at TMZERO and using time increment DTMHR. Read a total of MTIME ordinates.	0
MUNIT	Units of time if MTIME = 0. Not required if MTIME > 0. =0, Time is in minutes. =1, Time is in hours.minutes (i.e., decimal point between hours and minutes). =2, Time is in decimal hours (and may have values > 24).	0
TMZERO	Initial time (decimal hours) of measured data if MTIME > 0. Value of TMZERO is added to times entered if MTIME = 0. May be used to provide a time offset for measured data, avoiding revision of their times.	0.0
TQUIT	A time greater than TQUIT ends entry of time -ordinate pairs if MTIME = 0. Not required if MTIME > 0.	0.0
DTMHR	Time increment (hours) if times of graph ordinates are calculated (MTIME > 0). Not required if MTIME = 0.	0.0

Table 2-9. Continued

Variable	Description	Default
	DATA GROUPS E2 AND E3 ARE NOT REQUIRED IF MDATA = 0 (E1) FOR THIS GRAPH AND LOCATION.	
E2	Group identifier	None
FIRMAT	Format by which measured data of group E3 will be read. Include beginning and final parentheses. If blank, the default format will be used. If FIRMAT is 'FREE' then free format input will be used.	(2X,F8.0,7F10.0)
<p>*** Note: If $MEAS \leq 1$ (Group A1) this Group will be read from the card reader (unit N5). Otherwise, the formatted read will be from unit number MFILE (Group A1). ***</p>		
E3	Group identifier	None
TIMX (optional) and YVAL	Time (if MTIME = 0) and graph ordinate, LCARD pairs (if MTIME = 0) per Group, according to format of Group E2. Entries are stopped when a time is > TQUIT (this time is not included as a data entry). If MTIME > 0, only YVAL will be read, a total of MTIME values, LCARD values per line according to format of Group E2. Units of hydrograph ordinate must be cfs [m ³ /sec if METRIC = 1], and pollutograph ordinates must be concentrations corresponding to NDIM of Group B1.	0.0
<p>Repeat groups E1, E2, and E3 for remaining MPlot-1 locations for measured hydrograph inputs. Then, input MPlot groups of Groups E1, E2, and E3 for first pollutograph, second pollutograph, etc., up to NQP pollutographs. Note data for the MPlot locations must appear in the order in which the locations were entered on Group C2. There will be a total of MPlot * (NQP+1) entries of group(s) E1 (and possibly E2 and E3).</p>		
<p>END OF GRAPH BLOCK INPUT DATA</p>		
<p>Control returns to the \$CNAME line of the Executive Block.</p>		

Section 3 Combine Block

Block Description

The Combine Block adds the capability of modeling larger areas by combining the output of SWMM model runs from either the same or disparate blocks. The output of any other model can also be combined or collated with SWMM files by the Combine Block if the model output is in SWMM interface format C see Section 2. This block has five possible objectives.

The first objective is to collate two different interface files into a single interface file that contains the hydrographs/pollutographs for all nodal locations (and sums flows and loads at common locations). For instance, if two separate output interface files, one Transport and one Storage/Treatment, are to be input into the same downstream block, the Combine Block would be used to collate the two output data sets into one input interface file. (Keep in mind that a SWMM computational block can accept only one interface file as input.)

The second objective is to combine hydrographs and pollutographs at different locations and on different interface files into a single hydrograph/pollutograph time series (i.e., at just one location) on a single interface file. For example, suppose the Transport Block is used on two different drainage networks, giving two separate output interface files. Both files contain hydrographs/pollutographs that go to the same treatment facility at the same inlet node; the Combine Block combines the two different Transport output interface files into one interface file at a single node which then can be input into the Storage/Treatment Block.

The third objective is to select and/or renumber nodes from a single file or while collating or combining. For example, if the same number has been used for two different nodes while modeling a large city, one (or both) of these two nodes could be assigned different numbers in order to combine the output files. Alternatively, suppose only a subset of all of the nodes on a file is needed for a subsequent block. The desired nodes can be extracted (and optionally renumbered).

The fourth objective is to aid the user's memory. Eventually, the source of a permanent interface file will be forgotten. Combine will read the file header information and print basic information about the original simulation run. Combine will also let the user know if a file is not a SWMM interface file.

The fifth objective is to convert an unformatted interface file into a formatted ASCII or text file capable of being read by external programs. Such a file can be input to a spreadsheet program or read by a Basic program, for example, for further analysis.

The Combine Block can be used in a number of different ways and gives SWMM the capability of simulating the largest and most diverse cities. For example, Figure 3-1 shows how the Combine Block was used on a combination of SWMM runs for Lancaster, Pennsylvania.

Data Preparation

Collate

Two different output interface files from Runoff, Transport, Storage/Treatment, Extran, or any combination thereof (including two runs of the same block) may be collated. One file is indicated by JIN(K) and the other by NSCRAT(K). The resulting collated interface file (indicated by JOUT(K)) could then be used as input into any block (Transport, Extran, Storage/Treatment or a receiving water model), except Runoff. For example (Figure 3-2), an output file from Transport area 'A' with manhole number 5, 6, 12 was collated with an output file from Transport area 'B' with manhole numbers 1, 3, 6, 19. Manhole number 6 is common between both output data sets, therefore the hydrographs and pollutographs from both manholes are added together (load rates, quantity/time, are added for pollutants). The new output file produced from the Combine Block has manhole numbers 1, 3, 5, 6, 12, 19. This new data set could then be used as input to any other block, including Transport itself.

Combine

The combine section combines two different files (indicated by JIN(K) and NSCRAT(1)) and output locations into a single file with one output location. For example (Figure 3-3), an output file from Transport area 'X' with manhole number 16 and an output data set from Transport area 'Y' with manhole number 23 are to be used as input into a receiving water model at junction number 14. The Combine Block would be used to combine the two output data sets into one data set with one location, assigned the new number 14. This number would correspond to the junction number of the receiving water model.

Extracting and Renumbering

Data groups C1, C2 and C3 may be used to extract only selected nodes for collating or combining, or to select and/or renumber nodes from a single file. The latter option is invoked by setting parameter ICOMB = 2 on data group A1. Then the desired locations will be extracted from the file indicated by JIN(K), optionally renumbered, and placed on file JOUT(K).

While combining or collating two files, the extraction/renumbering option is indicated by parameters NUMX and NUMR on data group C1. If NUMX = 0, then all nodes are extracted from both files, and data group C2 is not required. Otherwise, if NUMX > 0, then NUMX nodes will be extracted; these NUMX locations are indicated on data group C2. The locations on data group C2 apply to both files. The sequence (order) of numbers used in data group C2 need not correspond to the sequence on files JIN(K) and NSCRAT(1).

If parameter NUMR on data group C1 = 0 then all nodes will retain their same numbers, and data group C3 is not required. Otherwise, NUMR must equal NUMX (unless NUMX = 0 -- see below) and a corresponding new node number must be listed on data group C3 for every old number listed on data group C2. Of course, the same numbers may be reassigned as desired. Duplicate numbers may be assigned in data group C3. In this case, hydrographs and pollutographs at the common numbers will be summed, in the manner described earlier. For example, the collate option

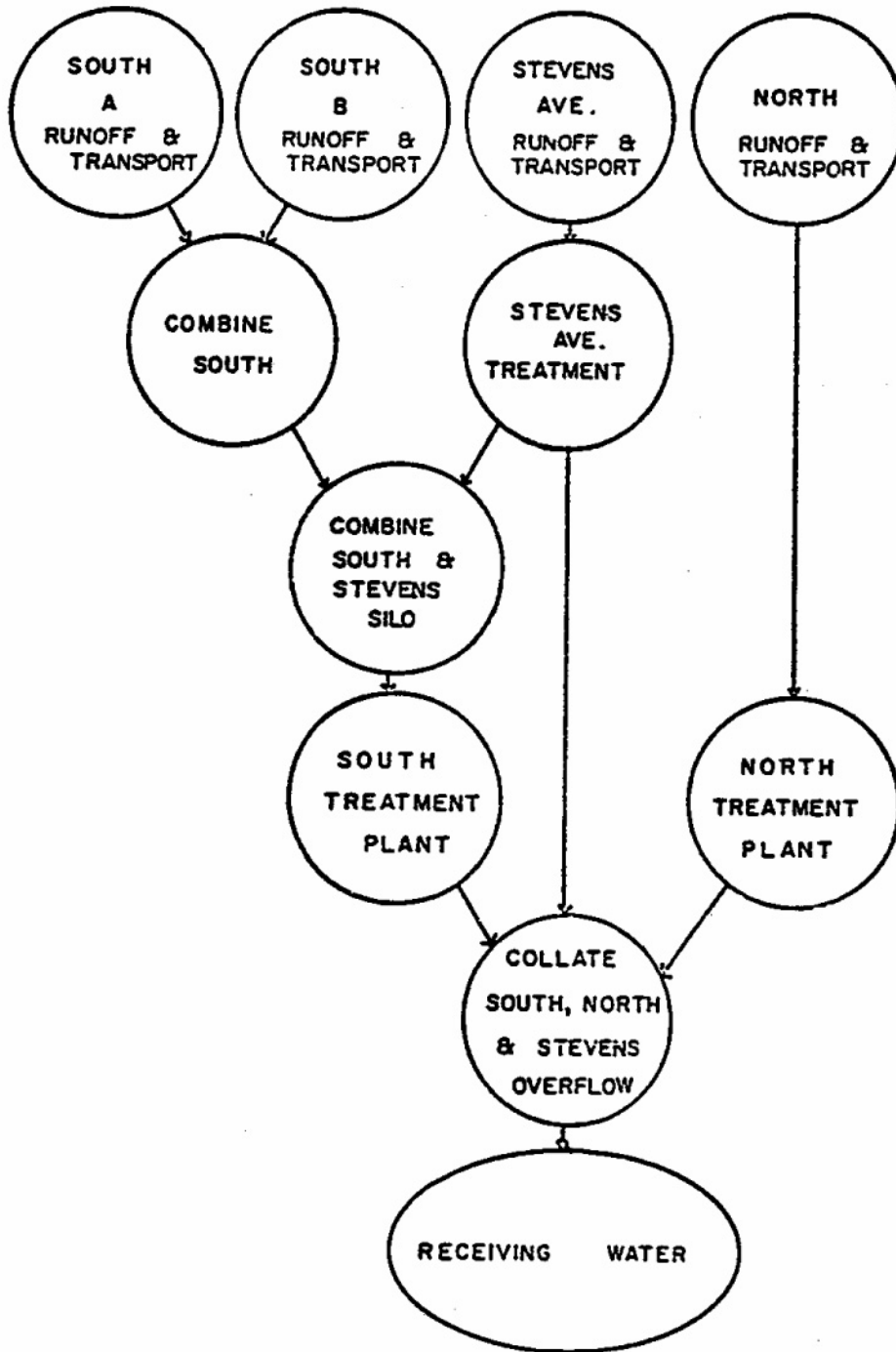


Figure 3-1. Combination of SWMM runs for overall Lancaster simulation.

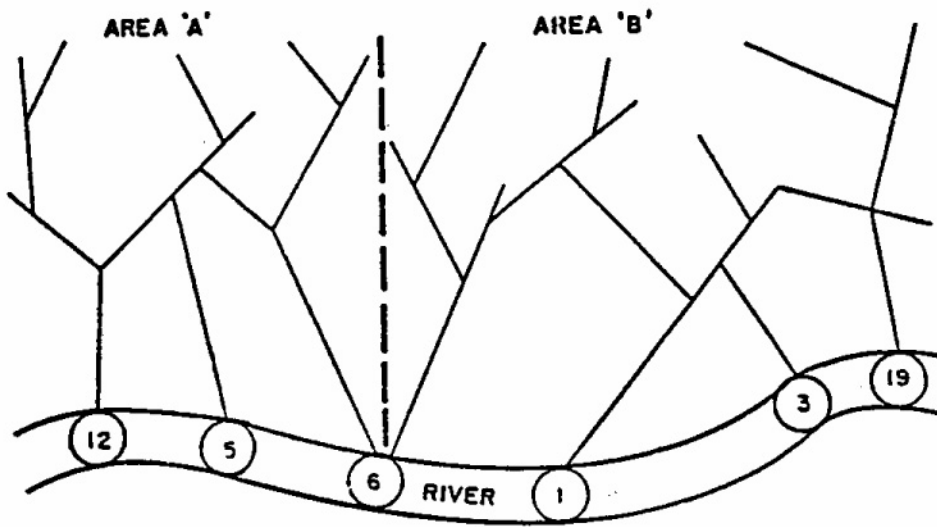


Figure 3-2. Hypothetical drainage network to be collated.

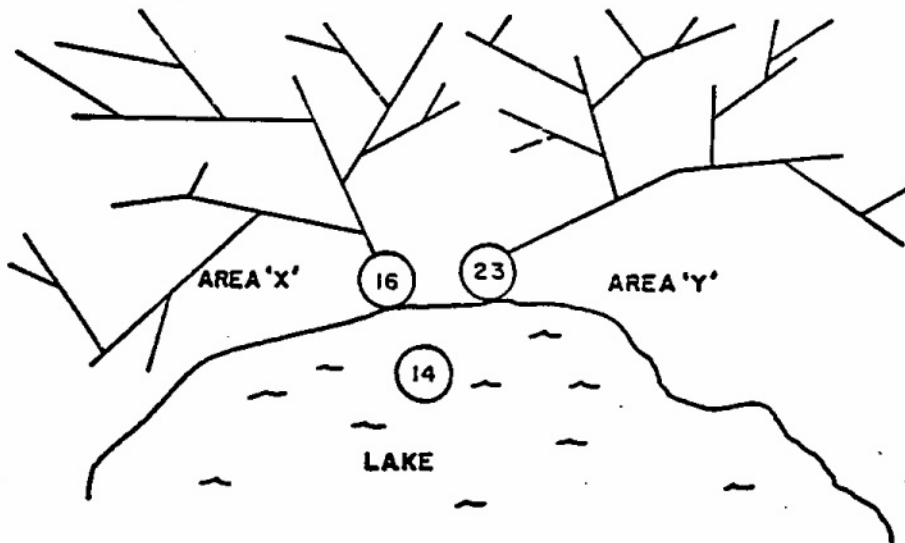


Figure 3-3. Hypothetical drainage network to be combined.

can be used to combine the two networks shown in Figure 3-3. For this case, the input data would be:

```
C1 2 2
C2 16 23
C3 14 14
```

If all nodes are to be extracted ($NUMX = 0$) and renumbering is desired for some (or all), set $NUMR$ equal to the total number of distinct (i.e., not a duplicate number) nodes (including both files if collating). Data group C3 will contain the new numbers corresponding to the order of appearance of the distinct nodes on files $JIN(K)$ and $NSCRAT(K)$, respectively. Since this order may be difficult to determine (unless the $ICOMB = 3$ option is used to read file headers), it may be safer for the user to list all of the nodes on data group C2, followed by the new numbers on data group C3. In this manner exact correspondence can be assured.

ASCII File Output

If $ICOMB = 4$ (data group A1), interface file JIN will be converted to an ASCII or text file (with extracting and renumbering as an option). The file will be written in the form of Table 2-3. Every $WRITE$ statement in Table 2-3 will correspond to one line of the file. With the exception of the Julian date, all numerical values will be written in E-format; the Julian date will be a 5-digit integer. One space will separate values on a line.

Quality Options

The two different input files may have different quality constituents, especially if a Runoff file is combined/collated with a Transport file, etc. The user is responsible for knowing the contents of each input file (possibly by running Combine with $ICOMB = 2$) and may specify in group C1 the constituents to be used for each. For instance, if BOD_5 is the first constituent to be placed on the output file, and if it is the third on file 1 and seventh on file 2, then $NPOS2(1) = 3$ and $NPOS2(1) = 7$. The description (name, units and type of units) will be copied from the first input file. Constituents not accessed will not be placed on the output file.

If a constituent is contained on one file but not the other, it may still be used. However, the file for which the constituent position ($NPOS1$ or $NPOS2$) is zero will be assumed to have zero concentration for that constituent.

If $NPOLL = 0$ in data group B2, no quality constituents will be placed on the new output file regardless of whether they are on the input files.

Timing

If the starting time ($TZERO$) is different for the two input files, the output file will begin at the earlier $TZERO$ using zeroes for the other file until its series begins. Similarly, if one input file ends before the other, zeroes will be used until the end of the other file.

Files

The Combine Block uses one file ($JIN(K)$) when the file headers are read and printed. Three files are used if either the collate or combine options are used: two input interface files and one output interface files. The two input files are $JIN(K)$ and $NSCRAT(1)$. The output file is $JOUT(K)$.

(Obviously, this assumes that Combine is the Kth block called.) Two files, JIN(K) and JOUT(K), are used if ICOMB = 2. The Combine Block advances the block counter of the JIN and JOUT arrays, the same as all other blocks.

NSCRAT(1) may be used for scratch files in other blocks. Hence, following Combine, it may be necessary to end the SWMM run and restart the simulation in order to assign a different unit number to NSCRAT(1). Of course, in this case the resulting JOUT(K) file should be permanently saved using the @ option discussed in Section 2.

Table 3-1. Combine Block Input Data

SWMM INPUT GUIDELINES		
<p>There have been many changes made to the input format of SWMM. Following is a short list of the major changes along with explanations and guidelines.</p>		
1.	<p>Free format input. Input is no longer restricted to fixed columns. Free format has the requirement, however, that at least one space separate each data field. Free format input also has the following strictures on real, integer, and character data.</p> <p>a. No decimal points are allowed in integer fields. A variable is integer if it has a 0 in the default column. A variable is real if it has a 0.0 in the default column.</p> <p>b. Character data must be enclosed by single quotation marks, including both of the two title lines.</p>	
2.	<p>Data group identifiers are a requirement and <u>must</u> be entered in columns 1 and 2. These aid the program in line and input error identification and are an aid to the EXTRAN user. Also 99999 lines no longer are required to signal the end of sets of data group lines; the data group identifiers are used to identify one data group from another.</p>	
3.	<p>The data lines may be up to 230 columns long.</p>	
4.	<p>Input lines can wrap around. For example, a line that requires 10 numbers may have 6 on the first line and 4 on the second line. The FORTRAN READ statement will continue reading until it finds 10 numbers, e.g.,</p> <pre style="margin-left: 40px;">Z1 1 2 3 4 5 6 7 8 9 10</pre> <p>Notice that the line identifier is <u>not</u> used on the second line.</p>	
5.	<p>An entry must be made for <u>every</u> parameter in a data group, even if it is not used or zero and even if it is the last required field on a line. Trailing blanks are not assumed to be zero. Rather, the program will continue to search on subsequent lines for the “last” required parameter. Zeros can be used to enter and “mark” unused parameters on a line. This requirement also applies to character data. A set of quotes must be found for each character entry field. For instance, if the two run title lines (data group A1) are to consist of one line followed by a blank line, the entry would be:</p> <pre style="margin-left: 40px;">A1 'This is line 1.' A1 ''</pre>	
6.	<p>See Section 2 for use of comment lines (indicated by an asterisk in column 1) and additional information.</p>	
Variable	Description	Default
A1	Group identifier.	None
ICOMB	<p>Program control.</p> <p>= 0, Collate only.</p> <p>= 1, Combine only.</p> <p>= 2, Extract (and optionally renumber) from a single file (JIN).</p> <p>= 3, Read the file headers of file JIN.</p> <p>= 4, Create an ASCII (text) file from the unformatted interface file (JIN).</p>	0

Table 3-1. Continued

Variable	Description	Default
* * * End of Input to the Combine Block if ICOMB = 3 * * *		
B1	Group identifier.	None
TITLE	Title, 2 lines to be placed as first title on output file (maximum of 80 characters per line).	Blank
B2	Group identifier.	Blank
NODEOT	Node number on output file for combined location. Enter zero if collating (ICOMB = 1).	None
NPOLL	Number of quality constituents to be placed on new file.	0
POLLUTANT IDENTIFICATION NOT REQUIRED IF NPOLL = 0		
B3	Group identifier.	None
NPOS1(1)	Constituent 1 position on file 1.	0
NPOS2(1)	Constituent 1 position on file 2.	0
■!	!	!
NPOS1(NPOLL)	Constituent NPOLL position on file 1	0
NPOS2(NPOLL)	Constituent NPOLL position on file 2.	0
Extraction/Renumbering Option		
C1	Group identifier.	None
NUMX	= 0, Use all locations. > 0, number of locations (nodes) to be extracted from one or two files.	0
NUMR	= 0, do not renumber any locations. = NUMX, renumber according to data group C3. (If NUMX = 0, NUMR can equal total number of nodes. See text.)	0
Locations (nodes) to be Extracted		
NOT REQUIRED IF NUMX = 0 ON DATA GROUP C1		
C2	Group identifier.	None
NODEX(1)	First node number.	None
■	■	
NODEX(NUMX)	Last node number.	None

Table 3-1. Continued

Variable	Description	Default
Numbers to be Assigned to Extracted Nodes		
NOT REQUIRED IF NUMR = 0 ON DATA GROUP C1 VALUES MUST CORRESPOND TO NODES ENTERED IN DATA GROUP C2		
C3	Group identifier.	None
NODER(1)	Number for first renumbered node.	None
■	■	
NODER(NUMR)	Number for last renumbered node.	None
END OF COMBINE BLOCK		
Program now returns to the Executive Block.		