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Environmental Protection Technology Series

DEVELOPMENT AND APPLICATION OF A SIMPLIFIED STORMWATER MANAGEMENT MODEL

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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DEVELOPMENT AND APPLICATION OF A SIMPLIFIED STORMWATER MANAGEMENT MODEL

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The deleterious effects of storm sewer discharges and combined sewer overflows upon the nation's waterways have become of increasing concern in recent times. Efforts to alleviate the problem depend upon characterization of these flows in both a quantity and quality sense. This report describes the development and application of a simplified stormwater management model that can be used to provide an inexpensive, flexible tool for planning and preliminary sizing of stormwater facilities.

Francis T. Mayo
Director
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ABSTRACT

A simplified stormwater management model has been created to provide an inexpensive, flexible tool for planning and preliminary sizing of stormwater facilities.

The model delineates a methodology to be used in the management of stormwater and consists of a series of interrelated tasks that combine small computer programs and hand computations. The model successfully introduces time and probability into stormwater analysis, promotes total system consciousness on the part of the user, and assists in establishing size-effectiveness relationships for facilities.

Throughout this report, data from the City of Rochester, New York, is presented and analyzed as a working example.

This report was submitted in partial fulfillment of Grant No. YOO5141 to the Monroe County Division of Pure Waters under the sponsorship of the Environmental Protection Agency. Work was completed as of June 1976.

CONTENTS

CONTENTS (Continued)

CONTENTS (Concluded)

FIGURES

FIGURES (Concluded)

TABLES

TABLES (Continued)

TABLES (Concluded)

ABBREVIATIONS

ADWF	-	average dry-weather flow
avg	-	average
BOD	-	biochemical oxygen demand
BOD_5	-	5-day biochemical oxygen demand
COD	-	chemical oxygen demand
ft/ft	-	feet per foot
hr	-	hour
in.	-	inch
mgd	-	million gallons per day
mg/kg	-	milligrams per kilogram
mg/l	-	milligrams per liter
mil gal.	-	million gallons
min	-	minute
NOD	-	nitrogenous oxygen demand
SS, ss	-	suspended solids
TSS	-	total suspended solids
VS	-	volatile solids
VS., vs.	-	versus
yr	-	year

ACKNOWLEDGMENTS

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This report has been prepared in the Western Regional Office of Metcalf & Eddy, Inc., in Palo Alto, California, by George Otte and Theodor Didriksson under the direction of John Lager, Vice President.

SECTION I

INTRODUCTION

Computer modeling of stormwater systems is currently achieving a high degree of precision and complexity. The complex models provide very valuable data for the design and final sizing of stormwater facilities. At the same time, the existing models are extremely expensive to set up and operate, requiring large blocks of time on extremely large computer systems. A void has thus appeared in the area of computer modeling. A tool is needed for the planning and preliminary sizing of facilities. This tool must be inexpensive to set up and use, flexible enough to be applicable to a variety of system configurations, and accurate even though only very moderate expenditures are made for data collection and preparation.

PURPOSE

The purpose of this report is to delineate an approach methodology to be used for the management of stormwater that meets these criteria. The approach is formulated as a simplified stormwater management model. The model consists of a series of uncomplicated interrelated tasks that can be used either singly or together. This permits the user to build on his individual data strengths and to focus on individual study objectives.

The goals of this simplified model are:

- To introduce time and probability to stormwater analyses
- To promote total system consciousness on the part of the user or reviewer
- To establish size-effectiveness relationships

Just as time and probability analyses are important in sizing water supply impoundments and safe yields, they are--or should be--equally important in determining the effective use of stormwater facilities. Since total capture is not a necessary goal, as it is in flood control works, for example, there is greater latitude in facility sizing and staged implementation. The trick is to determine the relative merits of alternatives, a task for which modeling is ideally suited.

This model is based on the premise that the simplest model that will do the job is usually the best, and has as its primary target the breaking down of data into a form that is meaningful to the user. In so doing, a degree of precision is sacrificed for breadth of coverage. Because of the low cost of the model (both for setup and execution), multiple assumptions can be tested with relative ease and over a short period of time.

TASKS

In this simplified model five tasks are performed:

- Data preparation
- Rainfall characterization
- Storage-treatment balance
- Overflow-quality assessment
- Receiving water response

Each task actually is a combination of small computer programs and hand computations.

ORGANIZATION

In the presentation of the five tasks in this report, the logic of the analysis is discussed, the computer program logic in the form of flow charts and the computer input-output requirements are documented, and examples are presented.

Throughout this report a system of combined sewers is analyzed. The City of Rochester, New York, is used as a working example. The data on Rochester were supplied by the Monroe County Division of Pure Waters.

SECTION II

CONCLUSIONS

1. A schematic of the existing system of stormwater facilities, outlining major conduits and overflow discharge locations and sizes, is an essential part of the data preparation.

2. Overflow quantities and qualities must be measured to provide information for calibration of the model.

3. Rankings can be prepared from long historical records for important storm parameters, such as magnitude, duration, and intensity.

4. Frequency of occurrence curves are easily generated from the ranking of storm parameters.

5. The interrelationship between containment of runoff in storage and the capacity of treatment plant or interceptors can be quickly reviewed using the storage-treatment computer program.

6. The quantity, frequency and duration of overflows can be accurately tabulated by the storage-treatment program because it uses real rainfall records for a long period of time as the data source.

7. The quality of overflows can be predicted on the basis of storm characteristics using linear regression techniques.

8. Gross averages of the quality data by subarea can provide an indication of overflow quality and areal trends in overflow quality.

9. The receiving water analysis provides the final test of a control alternative to determine if an adequate solution has been reached.

SECTION III

RECOMMENDATIONS

1. The simplified stormwater management model should be implemented as a preliminary design and planning tool.

2. The rainfall characterization should be used to check "design storms" and to provide historical perspective on storm events as they occur.

3. The storage-treatment program should be used repeatedly to analyze various combinations of storage capacities and interceptor rates to determine possible optimum conditions.

4. Areal trends in overflow quality should be determined using simple statistical techniques.

5. Any promising control alternative should be tested on a reliable and operating receiving water simulation.

SECTION IV

MODEL DEVELOPMENT

The simplified stormwater management model is composed of five tasks. In this chapter an overview of each task is presented. The interrelationship of the tasks, highlighted in Figure 1, is also discussed.

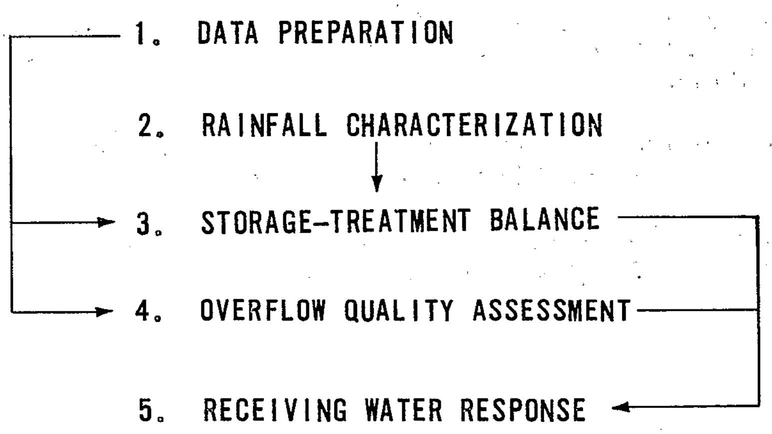


FIGURE 1. INTERRELATIONSHIP OF TASKS IN THE SIMPLIFIED STORMWATER MANAGEMENT MODEL

A PERT diagram for the simplified model is presented in Figure 2. This diagram, developed for the Rochester project, illustrates the tying of the various tasks together while focusing on the results. The broken lines in the diagram indicate where information is exchanged between tasks and where critical decision points are reached in the flow of work.

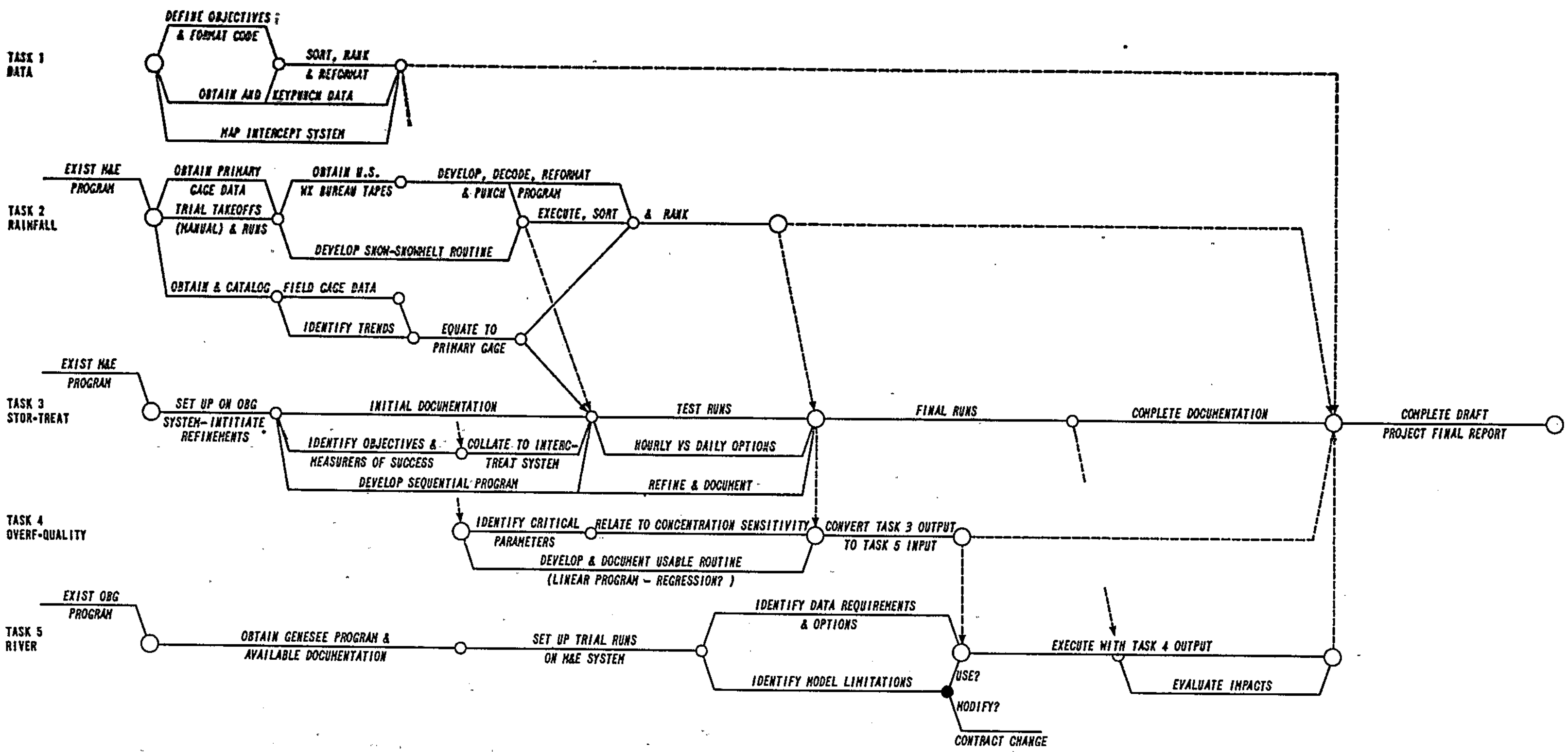


FIGURE 2. PERT DIAGRAM OF SIMPLIFIED STORMWATER MANAGEMENT MODEL

Task 1--DATA is the data preparation task of simplified modeling. In this task, the questions, what do we have and how does it work, are answered. A schematic diagram of the system is synthesized, and data on overflow quantities and qualities are collected. The data are collected for the primary purpose of calibrating other tasks in the simplified model. These data feed into both the storage-treatment task (Task 3) and the overflow quality task (Task 4).

Task 2--RAINFALL is the rainfall characterization task of the model. In this task, the raw rainfall data are collected and analyzed. The emphasis is on the ranking of critical rainfall characteristics--the design-sensitive parameters. The results of this rainfall characterization depend to a great extent on obtaining data for a long period of record (approximately 20 years). While not every community has such long records, ways of synthesizing these data from other available long historical records in concert with local data are discussed. The actual rainfall record is a critical input for the storage-treatment task (Task 3).

Task 3--STOR-TREAT is an assessment of the storage-treatment balance. In this task, rainfall is imposed on the city and its system of separate or combined sewers. The interrelationship between storage volumes and interceptor or treatment plant capacities is analyzed. The primary output from this task is the time and volume of stormwater that is overflowing from the system. This output is a significant input to the river response task (Task 5).

Task 4--OVERF-QUALITY is an evaluation of the quality of potential overflows from a system of interceptors or treatment facilities. The data prepared in Task 1 are analyzed using statistical techniques to develop trends. The magnitude of overflow constituents is predicted for input into the river response task (Task 5).

Task 5--RIVER is the task in which the response of the receiving waters to overflows is determined. Overflow volumes determined in Task 3 are paired with overflow qualities developed in Task 4 to become loadings on the river. The receiving waters are analyzed with the best simulation that is available. For Rochester, a model of the Genesee River, prepared by O'Brien and Gere, is used.

The relative success of stormwater control alternatives can be checked at two major points in the simplified model. After the storage-treatment task has been performed, the duration, volume, and frequency of overflows can be checked to determine the impact of an alternative. And, after the river task has been completed, the impact on the receiving water of a control alternative can also be checked.

SECTION V

DATA PREPARATION

The establishment of a firm data base is a very important step in the modeling process. The data that are collected must answer the questions: What do we have and how does it work? In answering these questions, input for the storage-treatment task and the overflow- quality task will be developed.

SYSTEM SCHEMATIC

A good way to gain an understanding of the sewer system and its relationship to the existing overflow points is to prepare a schematic of the system showing the overflows, drainage areas associated with the overflows, and the pertinent interceptor capacities. An essential first step in developing these data is to acquire the best and most recent sewer and storm drainage maps for the region under investigation.

Overflows

Overflows are defined as any point on the collection and interceptor system specifically designed to permit excess flows to bypass routing to the treatment plant. Some of the important characteristics of the overflows as they relate to the system schematic are:

- Location of the overflows on the interceptor system
- The hydraulic capacity of the overflows and/or regulating structures that control the overflows
- The capacity of any restrictions within the interceptor system that restrict flow to the overflow

The overflows and their related characteristics should be identified by a unique numbering system.

Drainage Areas or Subareas

Drainage areas or subareas are defined by delineating the sewered area that is tributary to a particular overflow structure (one overflow for each subarea). These drainage subareas fit together so that the entire sewered area is subdivided. The significant characteristics of each drainage subarea are:

- The total surface area
- Percent of the subarea that is impervious
- Percent distribution of the industrial, commercial, and residential (single-family and multifamily) land uses
- Average slope of the ground
- Average dry-weather flow

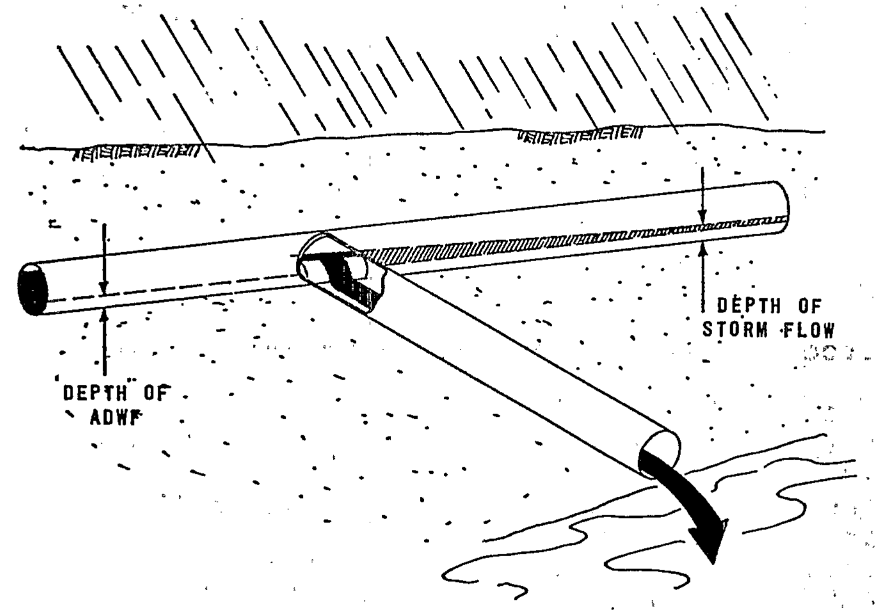
Interceptors

The interceptor system is the last feature of the system that is developed within the schematic. The specific aspects of the interceptor systems that are analyzed are:

- The components that connect each subarea to the treatment plant
- The maximum capacity of these components
- The capacity of components that are particularly restrictive in the system near an overflow
- The available in-system storage

The maximum capacities of the interceptor system are often calculated using Manning's equation and assuming unsurcharged, open channel flow. If the system can surcharge, significantly higher flowrates can occur. The true maximum would therefore be for flow under surcharged conditions which would probably occur during a heavy storm.

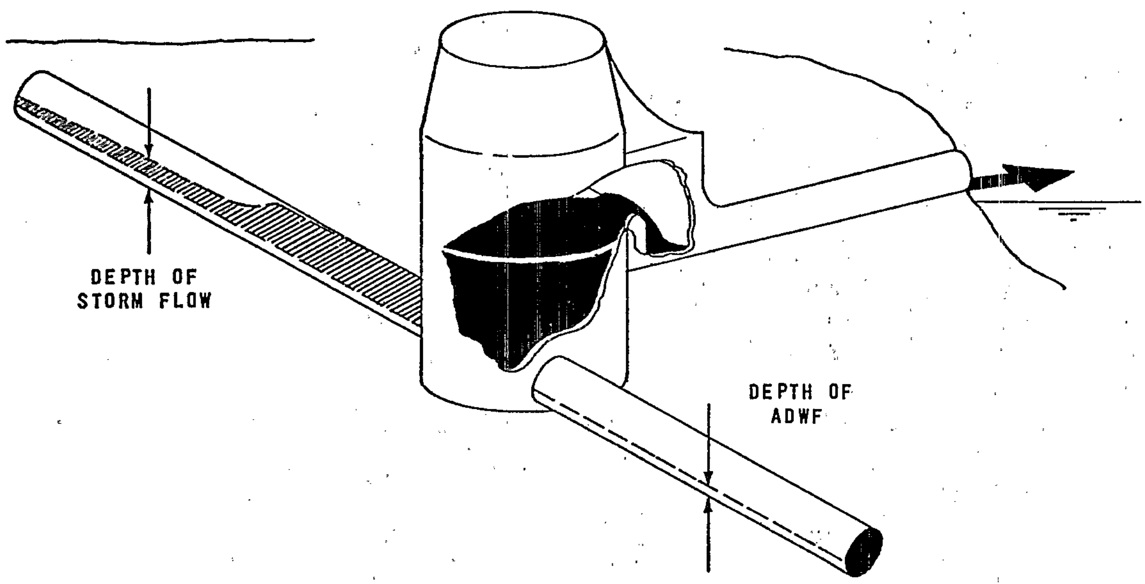
Two types of in-system storage can be created for storm flows by an overflow structure, as illustrated in Figure 3. The type A configuration of an overflow usually does not provide a significant amount of storage, while the type B configuration can retain a large volume in the system before an overflow occurs.



TYPE A

LEGEND

VOLUME OF IN-SYSTEM STORAGE



TYPE B

FIGURE 3. TYPES OF IN-SYSTEM STORAGE

Each of the foregoing items--overflows, drainage areas, and interceptors--are connected in the system schematic.

Example of a System Schematic

Maps of the combined sewer system of the City of Rochester were carefully studied. The overflows on the system were noted, and the drainage subareas were defined, as shown in Figure 4. The important characteristics of each subarea are presented in Table 1, along with the average dry-weather flow for each subarea.

The interceptor system that connects the subareas and the overflows is presented in Figure 5. The number in parenthesis indicates the maximum flow that each segment of the system can carry. Of particular interest is the connection of Subareas 8 and 9 to the main interceptor. This connection is made via a siphon under the Genesee River that has very limited capacity. These types of constrictions can significantly affect both the number of times that overflows occur and the volume of wastewater that overflows, so they must be identified in the schematic.

An example of the calculation of wet-weather flow capacity is presented in Table 2. The sum of the average dry-weather flow (Column 2) from each subarea is subtracted from the maximum interceptor capacity (Column 3) to determine the real available wet-weather capacity (Column 4).

An example of the calculation of the available in-system storage for each subarea is summarized in Table 3. Most of the overflows have the type A configuration and therefore very little in-system storage is available.

A summary of the important characteristics that will be used in the storage-treatment task for each subarea is presented in Table 4. The schematic of the Rochester sewer system is illustrated in Figure 6.

QUANTITY AND QUALITY

Quantity and quality data, which are usually derived from the monitoring of overflows, are necessary for the calibration and development of the tasks.

Quantity

The first step in the monitoring of overflows is flow measurement within the sewer system such that both the overflow and intercepted flow can be determined. This

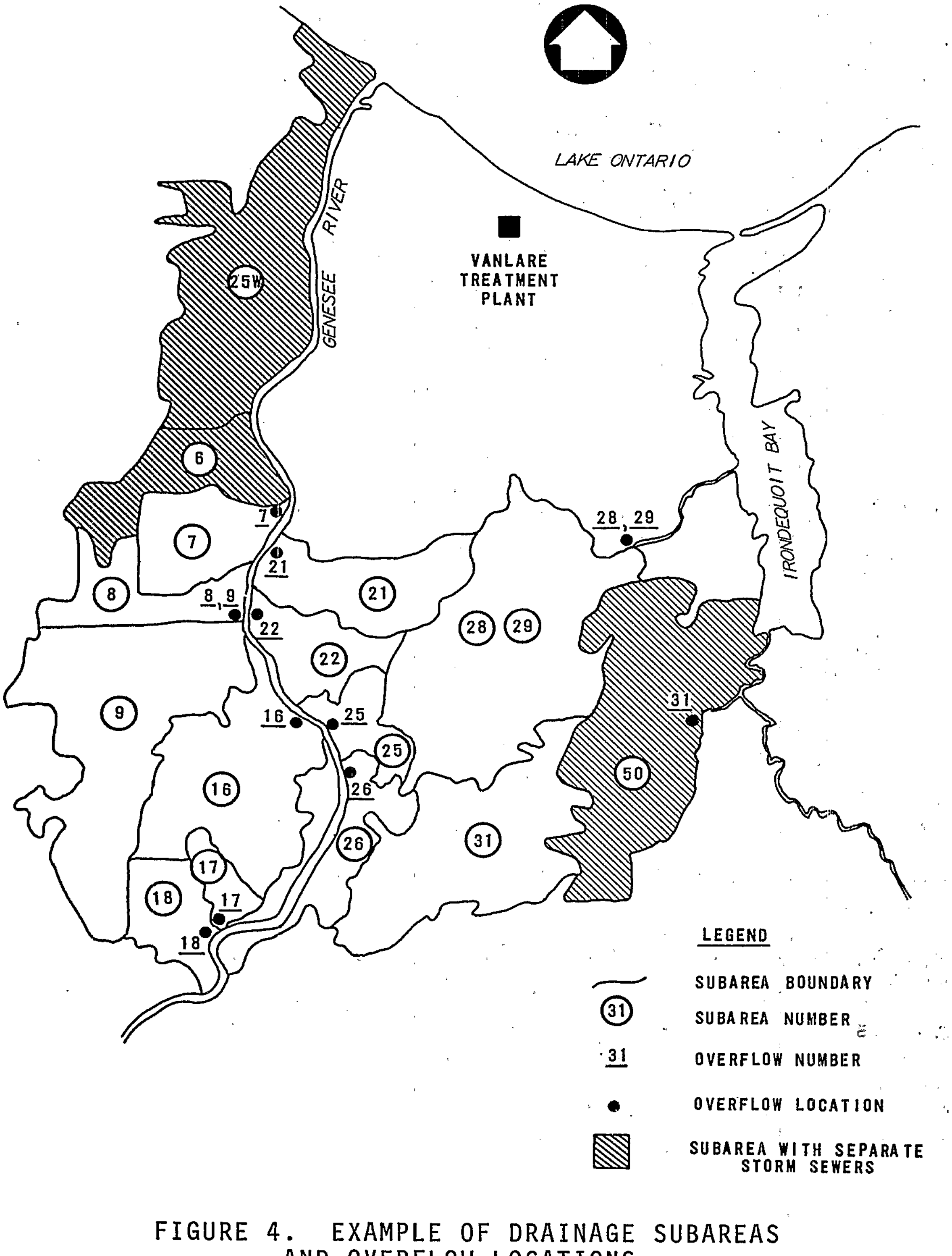


FIGURE 4. EXAMPLE OF DRAINAGE SUBAREAS AND OVERFLOW LOCATIONS

Table 1. EXAMPLE OF DRAINAGE SUBAREA CHARACTERISTICS

Sub-area No.	Total area, acres	Land use, %: Residential: Single-family	Land use, %: Residential: Multi-family	Land use, %: Commercial	Land use, %: Industrial	Land use, %: Open	Average slope, ft/ft	Impervious area, %	ADWF (maximum avg), mgd
6[a]	1,277	19.3	1.3	1.9	65.8	11.8	0.0074	55.0	7.06
7	715	83.9	1.0	7.3	0.2	5.5	0.0118	50.0	3.21
8	984	34.5	2.2	47.0	3.2	13.2	0.0066	45.0	6.36
9	2,603	52.5	0	4.1	37.1	6.4	0.0060	50.0	14.00
16	826	50.0	9.4	33.8	1.1	5.7	0.0070	55.0	5.78
17	235	83.8	3.8	2.1	0	10.2	0.0067	40.0	1.33
18	541	93.7	0.6	3.8	0	2.2	0.0073	40.0	2.60
21	821	79.4	0	9.0	6.8	4.9	0.0065	35.0	4.60
22	569	59.8	25.3	6.7	4.9	3.3	0.0070	50.0	3.41
25	348	30.0	9.9	44.9	5.0	10.2	0.0080	80.0	4.50
25W[a]	1,390	50.0	10.0	20.0	10.0	10.0	0.0150	35.0	6.01
26	554	30.0	9.9	44.9	5.2	9.9	0.0100	65.0	5.91
28	778	65.0	10.0	10.0	4.9	10.0	0.0100	50.0	4.36
29	1,430	65.0	10.0	10.0	5.0	10.0	0.0100	55.0	7.86
31	1,592	50.0	10.0	20.0	15.0	5.0	0.0100	47.0	10.13
50[a]	1,720	65.0	20.0	5.0	5.0	5.0	0.0150	40.0	11.90

a. Serviced by separate storm sewers.

information will determine the total runoff from the area for a particular storm and can be used to calculate or check the "K factor" (gross runoff coefficient.) The K factor is used in the task to calculate the total runoff from rainfall.

The flow data that are developed can include faulty data because of equipment and maintenance weaknesses. It is essential, therefore, to screen the data carefully to ensure a reasonable correlation between predicted and measured values. Time history (variation of a parameter over a specific time period) and volumes of runoff can be compared with rainfall records to check if the runoff actually reflects the real storm event.

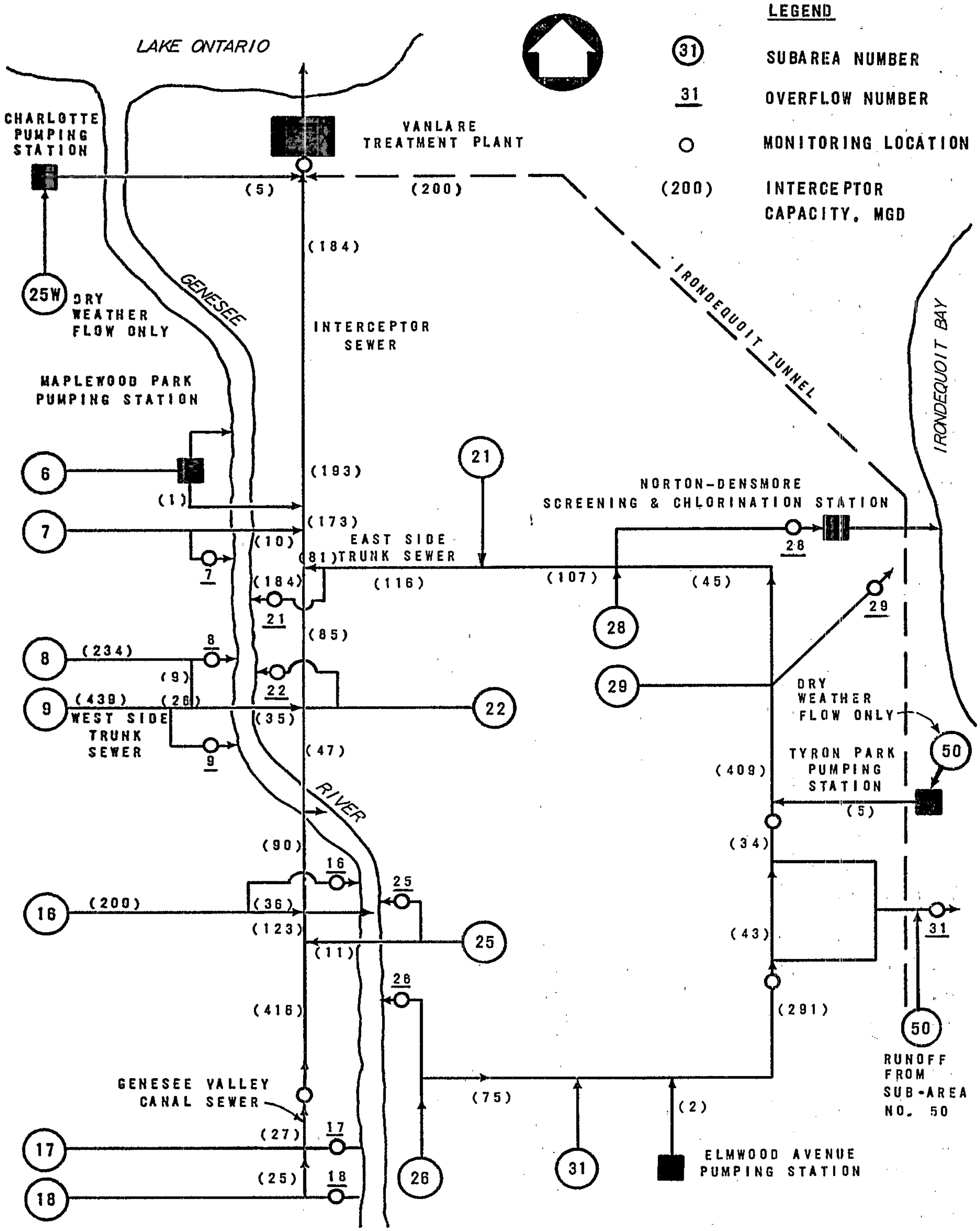


FIGURE 5. EXAMPLE OF FUNCTIONAL ELEMENTS OF SEWERAGE SYSTEM

Table 2. EXAMPLE OF CALCULATION OF WET-WEATHER FLOW CAPACITY, mgd

Subarea No.	ADWF, maximum avg (1)	Sum of ADWF (2)	Maximum interceptor capacity (3)	Available wet-weather capacity (4)
West side system				
17 and 18	3.9	3.9	416	412.1
25	4.5	8.4	123	114.6
16	5.8	14.2	47	32.8
8 and 9	20.4	34.6	35	14.6[a]
22	3.4	38.0	84.7	46.7
21	44.7[b]	82.7	173.4	90.7
7	3.2	85.9	10.0	6.8[a]
6	7.0	92.9	184	100.0
East side system				
26	5.9	5.9	.....	.....
31	22.0	27.9[c]	200	200
28 and 29	12.2	40.1[c]	200	200

a. The limiting segment is not on the main interceptor.

b. Of this amount, 4.6 mgd is from Subarea 21; 40.1 mgd is from the East side trunk sewer.

c. The equivalent of ADWF is carried by the east side trunk sewer.

Quality

The best quality data from a monitoring program would reflect the time history through various storm events for each overflow location. The variations in quality through time indicate the magnitude of the "first-flush" phenomenon. The measurement of quality for each subarea reflects the impact of the mix of various land uses on the wastewater discharged from each subarea.

The use of composite or grab samples from overflows, by subarea, can be substituted for the complete time-history measurements. This may cause a distortion in the results because the first-flush phenomenon, if it occurs, is not acknowledged; yet it provides an insight into the real

Table 3. EXAMPLE OF IN-SYSTEM STORAGE BY SUBAREA

Subarea No.	Description	Storage volume, mil gal.
7	Maplewood Park	0.009
8	Lake and Lexington	0.004
9	West side trunk	0.006
16	Mill and Factory	0.011
17	Plymouth and RR	0.004
18	Brooks	0.005
21	Norton at Seth Green	0.298
22	Carthage	0.035
25	Central	0.007
26	Court	.....
28	Screenhouse	0.250
29	Densmore bypass	0.026
31	Thomas Creek	0.023

Table 4. EXAMPLE OF SUBAREA CHARACTERISTICS USED IN STORAGE-TREATMENT TASK

Subarea No.	Area, acres	Impervious area, %	In-system storage, mil gal.	Downstream interceptor capacity, mgd
West side system				
17 and 18	776	40.0	....	412.1
25	423	80.0	....	114.6
16	650	55.0	0.01	32.8
8 and 9	3,666	48.0	0.01	14.6[a]
22	569	50.0	0.04	46.7
21	800	35.0	0.30	90.7
7	726	50.0	....	6.8[a]
6	.....[b]	....[b]	....[b]	100.0
East side system				
26	554	65.0	....	75[c]
31	1,592	47.0	0.02	200
28 and 29	2,178	53.0	0.28	200

a. The limiting segment is not on the main interceptor.

b. This information is not required because the area is serviced by a separate storm sewer.

c. Estimated.

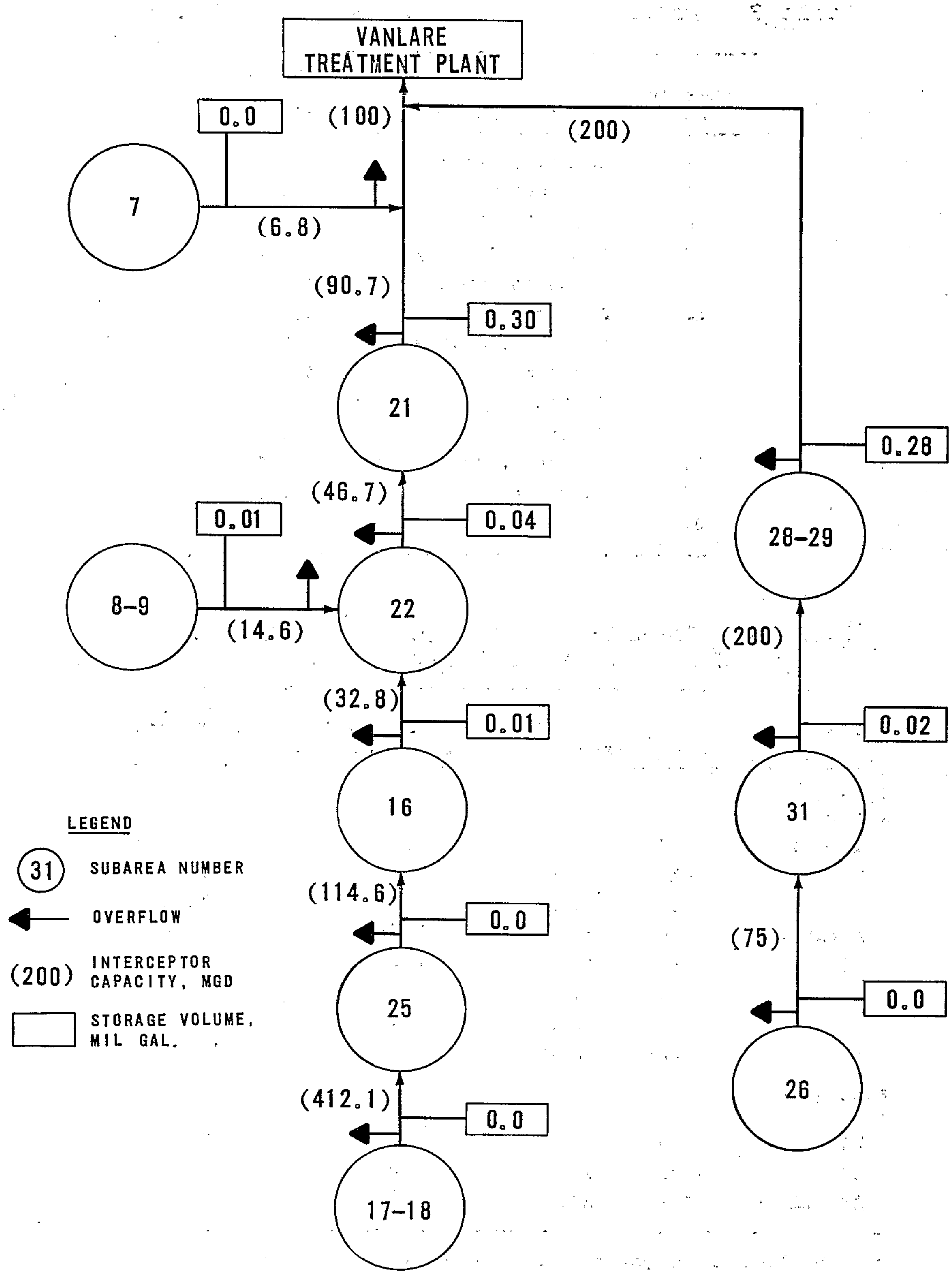


FIGURE 6. EXAMPLE OF SYSTEM SCHEMATIC

quality of the overflow. Whether or not the first- flush phenomenon occurs is dependent upon catchment area and storm characteristics.

Measurements on a single overflow can also be extrapolated into results for the entire region. This compromises the impact of land uses on overflow quality and further reduces the reliability of quality modeling.

It is essential to have some quality measurements to evaluate the quality of the overflows. "Textbook" values provide very little knowledge of the overflow quality caused by a particular region's climate and terrain.

The reliability of the quality analysis is directly related to the data that are developed. The more complete the data, the more reliable the analysis. A careful review of the data is important, and any major deviations should be readily explainable.

Example of Quantity and Quality Data

The City of Rochester created a high-quality monitoring system to carefully measure the overflow on the combined sewer system. This system measured the quantity and the quality of the overflows. All of the data handling is via paper tapes with computer processing and printing of the output. An example of this elaborate output is presented in Appendix A.

The Rochester data correlate rainfall, overflow quantity, and overflow quality for each subarea. Although there are some weaknesses in the collection and the data, the results do represent what can be collected. One important parameter that was not measured is the quantity of water intercepted for any of the storms. Otherwise, the Rochester data are more complete than required for the simplified modeling effort. Measurement of a few of the most important quality constituents and of overflow and interceptor quantity as these factors vary in time through the storm would be the ideal. The most common quality constituents of importance are biochemical oxygen demand (BOD) or chemical oxygen demand (COD), nitrogen, and phosphorus. Coliform or fecal coliform could also be measured to reflect bacterial contamination.

SECTION VI

RAINFALL CHARACTERIZATION

Rainfall characterization provides valuable insight into the characteristics of rainfall that occurs in an area. The specific goal of this task is to create a ranking of the design parameters. Four important analyses are performed:

- Collection of reliable historic rainfall data
- Correlation of rainfall data to study area
- Definition of discrete storm events
- Ranking of design parameters from each storm

These analyses can be accomplished with the aid of a computer. The analyses as well as the computer program logic and input-output requirements will be discussed in this chapter.

COLLECTION OF RAINFALL DATA

Data from rainfall records over a long period of time are essential for the characterization of storm events and future analysis. If at least 20 years of records are analyzed, statistically valid results are generated. Rainfall records for storm definition should be available on an hourly basis, i.e., a specific intensity for each hour of rainfall for each day of record over the period of record. The hourly intensity is short enough to record a variation in rainfall intensity for the length of most storms but long enough to be manageable within the framework of simplified modeling.

Rainfall data are available from many sources--fire departments, sewage treatment plants, water treatment plants, and local water supply facilities. The most readily obtainable data and the most compatible data with computer analysis are obtained from U.S. Weather Bureau records, either through tape files or published daily and hourly summaries. Tapes are issued by:

U.S. Department of Commerce
National Climatic Center
NOAA Environmental Data Service
Federal Building
Asheville, NC 28801
Tel. (704) 258-2850

Data are available on two record files: Deck 488-USWB HOURLY PRECIPITATION and Deck 345-WBAN SUMMARY OF DAY. These stations range in number from 1 in Delaware to 19 in Texas. The period of record is generally from 1948-1949 to the current date with some gaps. Tapes are furnished on 9 track-800 BPI, unless otherwise specified, and are forwarded air parcel post. (Recent experience with these tapes has been excellent. The two tape files for Rochester were ordered and received within 15 days for a combined cost of approximately $140).

CORRELATION OF RAINFALL DATA

The rainfall data that are available on tapes are from Weather Bureau primary gages. The closest primary gage may or may not be close enough to the area being studied to portray local rainfall conditions accurately. Local rain gage data from one of the sources mentioned earlier, or from a gage specifically set up for comparison purposes, can be used to check local performance with the Weather Bureau primary gage. If a major difference is found, it may be possible to apply a factor to the Weather Bureau data.

In Rochester, 12 local rain gages, which recorded the rainfall in 0.1-inch increments, were set up across the city. Records from these rain gages were compared with those of the primary gage, located at the Rochester Airport, which records rainfall to the nearest 0.01 inch. On the basis of an analysis of 19 storms between January and August, 1975, the Weather Bureau gage recorded an average of 0.44 inch per storm and the local gages recorded an average of 0.51 inch per storm. Thus, the Weather Bureau gage recorded magnitudes 14 percent lower than the average magnitudes recorded by the in-town gages. The Weather Bureau gage also records durations of storms 46 percent longer than the average durations recorded by the in-town gages. The Weather Bureau gage recorded an average of 8.05 hours per storm, while the local gages recorded an average duration of only 5.5 hours per storm. The difference in duration is mostly due to the lag inherent in the measuring equipment. The local gage must accumulate 0.10 inch of rain before signaling the start of a storm. While the local rain gages exhibited some variation in results, they indicated that rainfall across the entire city is fairly uniform.

DEFINITION OF DISCRETE STORM EVENTS

The hourly rainfall record is a continuous record of rainfall and can be segregated into discrete storm events. This segregation is essential to the characterization of a particular storm event. For this analysis, Metcalf & Eddy has defined a storm event as starting with the first measurable rainfall after a minimum of 6 hours with no rainfall and ending when a gap in measured rainfall (precipitation) of at least 6 hours is first encountered. Trace rainfall amounts are disregarded. The 6-hour gap was selected to ensure relative independence between events. In addition to defining the storm, a check for the presence of snowfall for each storm event can be made, and, in the process of listing the storm events, the annual totals of important characteristics can also be tabulated. Each of these tasks is accomplished by a separate computer program. The flow of these programs is illustrated in Figure 7.

For each event in the historical record, the following are noted and punched on data cards or filed on disk: date, starting hour, duration, total rainfall, maximum hourly rainfall and the hour in which it occurred, elapsed days since the previous storm, and occurrences of excessive precipitation and snow.

RANKING OF DESIGN PARAMETERS FROM EACH STORM

The sorting and ranking of the storm events develops the data in a format from which characteristics of the storm can be readily observed. The items that can be examined are those characterized in the storm event definition.

Careful observation of the ranked characteristics can provide valuable information on the nature of the rainfall that occurs in an area. An example of the first page of the ranking by magnitude of the Rochester rainfall is presented in Table 5. The storms that are highlighted are those that would have a recurrence interval of approximately 2 years.

The events with a different recurrence interval can be calculated using the following formula:

$$RC = \frac{N + 1}{M}$$

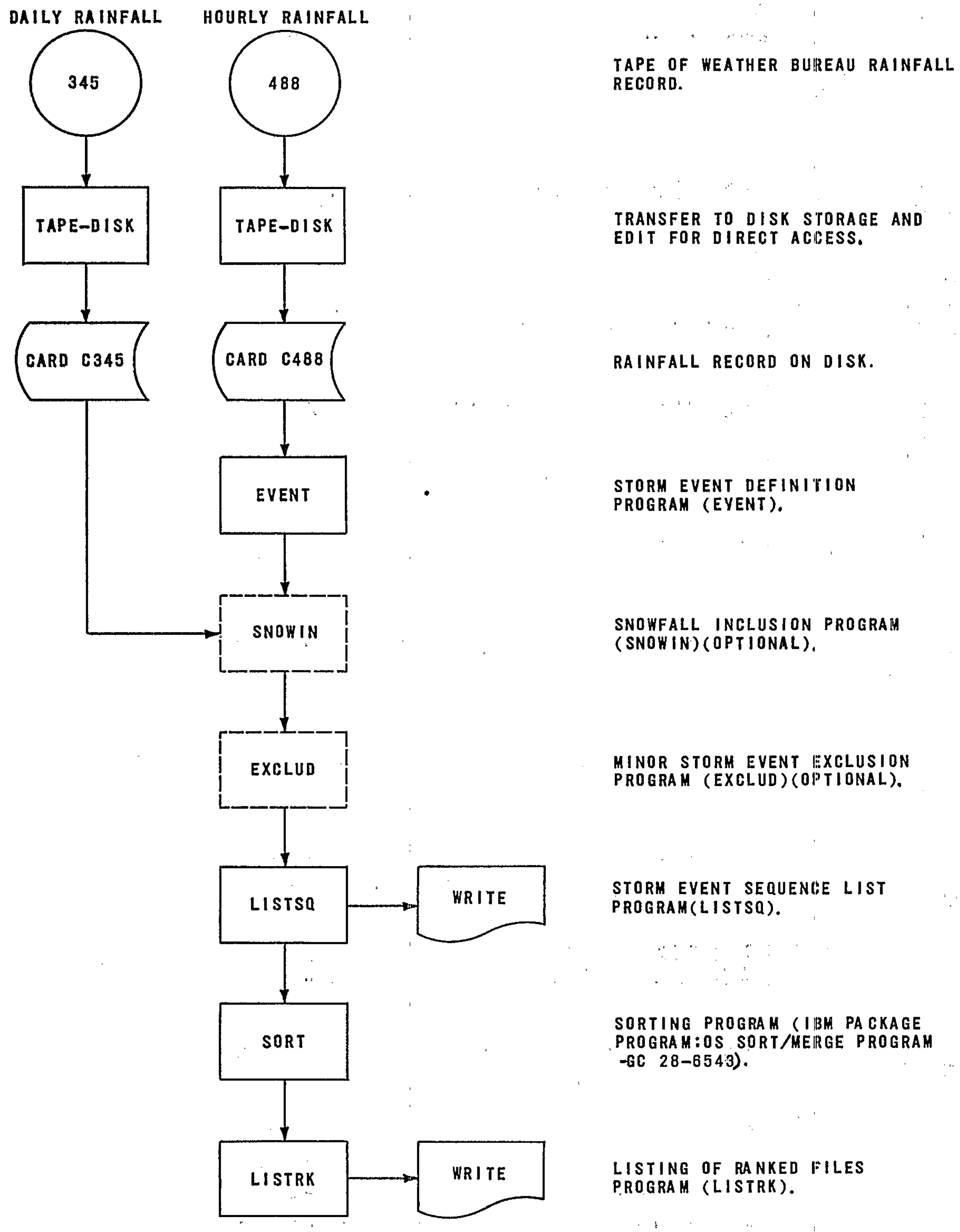


FIGURE 7. PROGRAMS FOR RAINFALL ANALYSIS

Table 5. EXAMPLE OF USE OF STORM EVENT RANKING - 2-YEAR STORM

YEAR	MONTH	DAY	DURAT. HOURS	TOTAL RAINFALL	MAX HOUR RAINFALL	HOUR AFTER START	DAYS SINCE LAST STORM	EXCESS PRECIP	REAL TIME START HOUR	SNOW INCLUDED	RANKED	RANKED BY MAGNITUDE
1955	OCT	13	87	3.91	0.27	24	6	NO	15	NO	1	1
1972	JUNE	21	36	3.35	0.46	9	0	NO	15	NO	2	2
1950	FEB	13	32	2.93	0.18	25	4	NO	13	YES	3	3
1959	SEPT	30	35	2.88	0.36	18	8	NO	3	NO	4	4
1950	JUNE	23	14	2.86	1.32	2	7	NO	21	NO	5	5
1958	OCT	16	16	2.48	0.59	11	3	NO	17	NO	6	6
1955	OCT	5	23	2.44	0.41	10	7	NO	21	NO	7	7
1968	AUG	23	7	2.39	0.81	5	0	NO	21	NO	8	8
1950	NOV	3	35	2.30	0.29	12	0	NO	22	NO	9	9
1971	JULY	13	9	2.25	1.03	8	7	NO	12	NO	10	10
1962	SEPT	27	33	2.22	0.25	20	2	NO	10	NO	11	11
1971	MAR	3	35	2.16	0.14	14	4	NO	12	YES	12	12
1958	JUNE	25	8	2.15	1.35	1	0	NO	21	NO	13	13
1971	FEB	12	48	2.11	0.17	34	2	NO	13	NO	14	14
1960	FEB	18	40	2.07	0.14	16	1	NO	24	NO	15	15
1967	SEPT	27	28	1.99	0.28	1	3	NO	20	NO	16	16
1957	MAY	19	34	1.99	0.15	22	4	NO	2	NO	17	17
1966	JULY	28	11	1.94	1.27	1	0	NO	11	NO	18	18
1966	JAN	30	36	1.94	0.22	18	6	NO	2	YES	19	19
1972	NOV	7	35	1.93	0.12	30	2	NO	20	NO	20	20
1967	OCT	17	46	1.91	0.31	25	0	NO	20	NO	21	21
1962	AUG	6	16	1.88	0.77	4	2	NO	19	NO	22	22
1961	FEB	25	24	1.86	0.33	15	2	NO	9	NO	23	23
1955	AUG	13	14	1.85	0.29	6	2	NO	6	NO	24	24
1953	NOV	7	19	1.85	0.26	5	9	NO	2	YES	25	25
1970	NOV	11	69	1.77	0.18	35	0	NO	9	NO	26	26
1962	MAY	23	10	1.76	0.65	5	15	NO	17	NO	27	27
1960	JUNE	14	34	1.72	0.46	16	2	NO	7	NO	28	28
1953	AUG	9	10	1.71	0.77	10	0	NO	15	NO	29	29
1950	AUG	31	29	1.70	0.25	2	2	NO	7	NO	30	30
1970	JUNE	26	12	1.67	0.59	1	2	NO	19	NO	31	31
1963	NOV	29	35	1.66	0.17	14	6	NO	6	NO	32	32
1973	NOV	15	40	1.66	0.45	15	6	NO	2	NO	33	33
1957	JUNE	28	15	1.65	0.31	8	1	NO	12	NO	34	34
1951	JUNE	10	11	1.62	0.27	8	0	NO	5	NO	35	35
1972	FEB	18	39	1.60	0.16	24	2	NO	17	YES	36	36
1950	NOV	24	37	1.58	0.38	35	1	NO	10	YES	37	37
1950	OCT	8	12	1.55	0.22	9	4	NO	18	NO	38	38
1960	AUG	3	9	1.52	0.75	1	4	NO	2	NO	39	39
1954	OCT	2	9	1.50	0.68	7	3	NO	2	NO	40	40
1953	AUG	4	21	1.47	0.65	4	6	NO	11	NO	41	41
1954	FEB	16	35	1.46	0.11	2	3	NO	4	NO	42	42
1959	DEC	6	35	1.45	0.12	17	6	NO	14	NO	43	43
1963	AUG	13	12	1.45	0.41	9	2	NO	2	NO	44	44
1949	AUG	28	16	1.45	0.50	11	0	NO	22	NO	45	45
1959	JUNE	1	11	1.43	0.77	8	6	NO	8	NO	46	46
1965	AUG	19	16	1.42	0.71	3	6	NO	2	NO	47	47
1970	OCT	30	40	1.41	0.09	13	7	NO	4	NO	48	48
1964	AUG	21	32	1.41	0.43	8	1	NO	14	NO	49	49
1970	JULY	11	12	1.40	1.01	2	1	NO	5	NO	50	50

where M = number of event (13 for RC = 2)
N = number of years of record (25 for Rochester)
RC = recurrence interval in years

Several other facts can be gleaned from careful review of the data:

- The number of storms having a total rain of less than 0.10 inch
- The number of storms having duration greater than 24 hours
- The average number of days between storms
- The number of storms starting between midnight and 6 a.m., or at any one particular hour

The list of questions is limited only by the imagination of the user. The more these rankings are studied, the more useful the tool becomes. Examples of frequency curves, on the basis of ranked data for the rainfall in Rochester, are presented in Figures 8, 9, 10, and 11. These curves can be compared with curves for a design storm.

The validity of these curves is directly related to the length of the period of record that is being analyzed. The longer the period of record, the greater the statistical significance.

COMPUTER PROGRAM LOGIC AND INPUT-OUTPUT REQUIREMENTS

Five small computer programs are used to perform the complete analysis of the rainfall records:

1. Storm Event Definition Program (EVENT)
2. Snowfall Inclusion Program (SNOWIN)
3. Minor Storm Event Exclusion Program (EXCLUD)
4. Storm Event Sequence List Program (LISTSQ)
5. Listing of Ranked Files Program (LISTRK)

These programs are normally used in the sequence listed. The Snowfall Inclusion Program and the Minor Storm Event Exclusion Program are optional. The input and output data

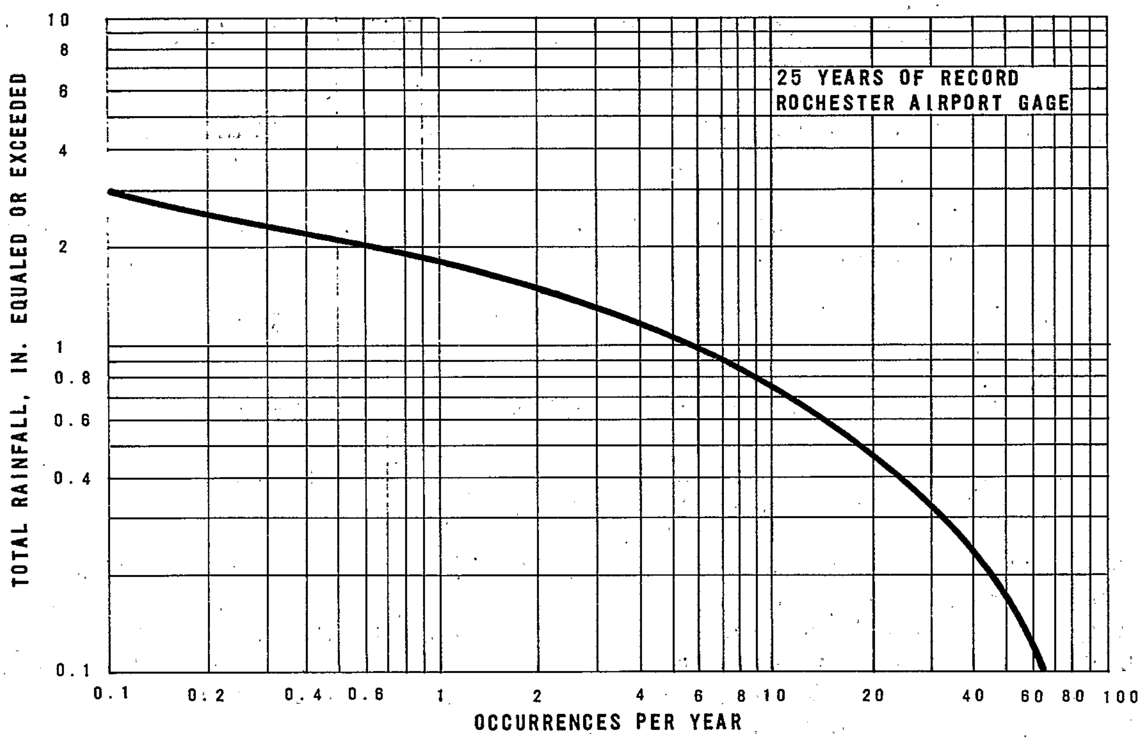


FIGURE 8. EXAMPLE CURVE - STORM MAGNITUDE VS. FREQUENCY

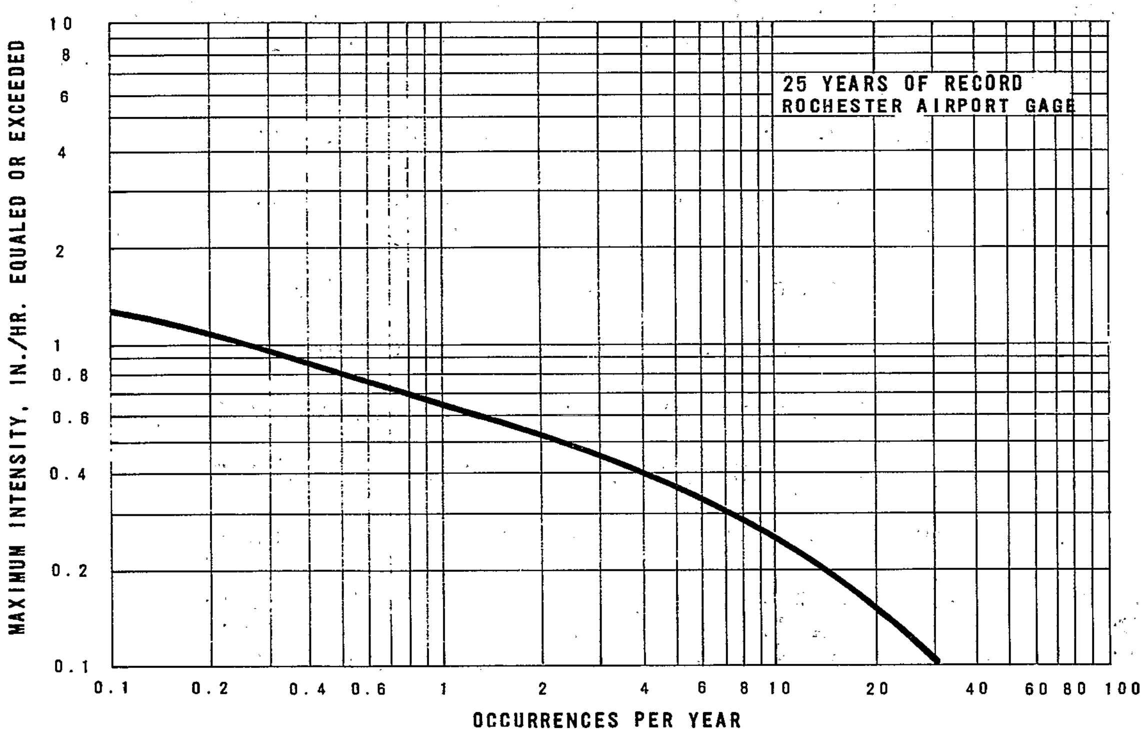


FIGURE 9. EXAMPLE CURVE - STORM INTENSITY VS. FREQUENCY

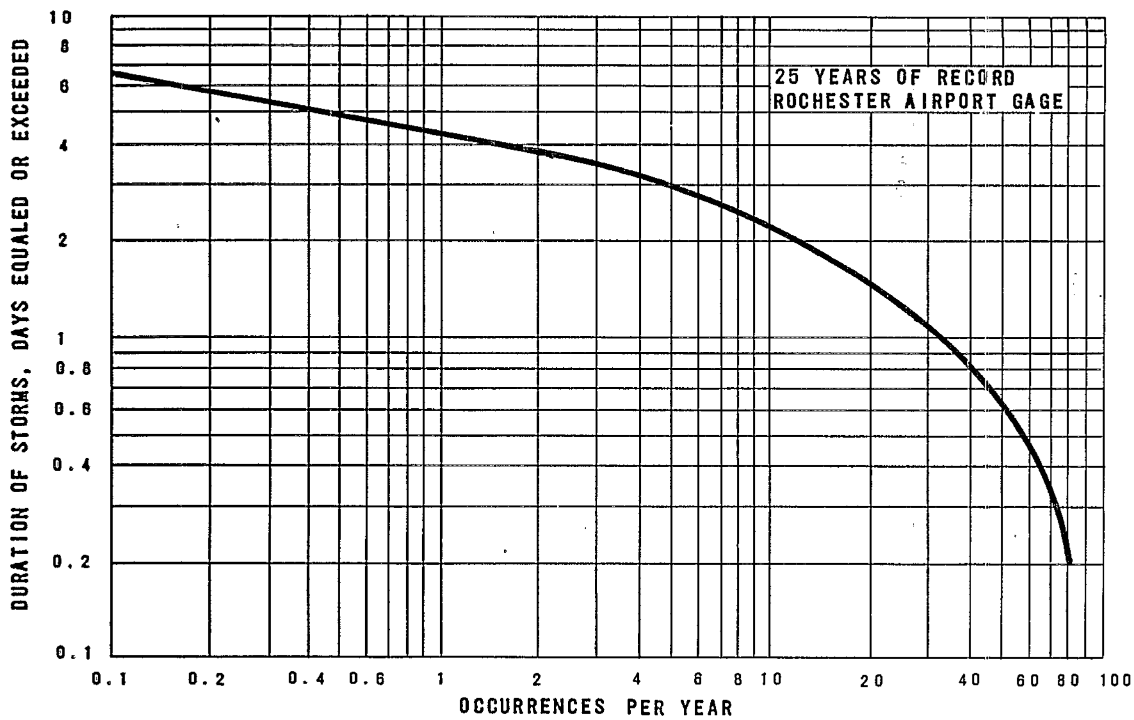


FIGURE 10. EXAMPLE CURVE - STORM DURATION VS. FREQUENCY

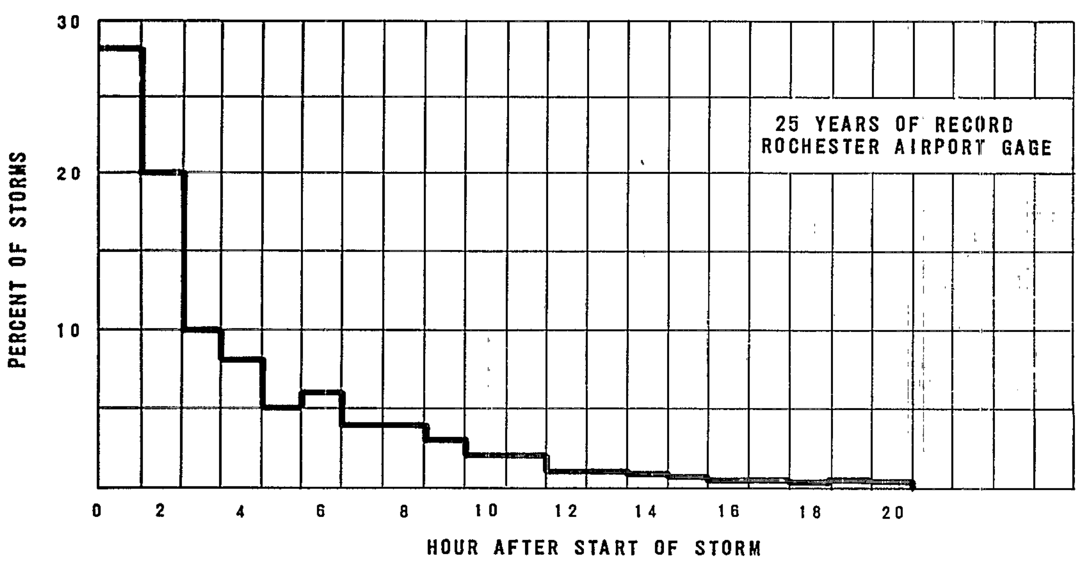


FIGURE 11. EXAMPLE CURVE - PERCENT OF STORMS HAVING MAXIMUM 1-HOUR INTENSITY VS. HOUR AFTER START OF STORM

for each program are compatible; therefore, the programs can be run in any desired sequence. The programs are written in FORTRAN, and, while not extremely complex, they could be used most effectively by a person with the ability to manipulate the input and output files on the computer system that is being used. The complete listing of these programs is given in Appendix B.

Storm Event Definition Program (EVENT)

EVENT, the first program in the sequence, is used to perform the initial translation of the hourly record into storm events using the prescribed definition. The program listing for EVENT is presented in Table B-1 and Table B-2 is a list of variables for EVENT. The input for this program is the hourly rainfall record in the format listed in Table 6, which corresponds with the format used on the Weather Bureau's hourly tapes.

The flow chart displaying the program logic is presented in Figure 12. This program initially reads the hourly rainfall records one day at a time and inspects it for errors. The program then starts checking if rain is occurring and when the last rain occurred. If it just started raining, the interval between storms is checked. The peak hourly intensity for the storm is also checked. The characteristics of each storm are accumulated. When the storm ends, the characteristics of the storm are recorded on disk in the format listed in Table 7. The program is terminated when all of the data have been read.

The output format for this program is compatible with the input format for each of the succeeding programs. Therefore, any of the following programs can be used. If the user would like to see the results of this analysis, the Storm Event Sequence List Program or the Listing of Ranked Files Program could be used with the output file that has been created.

Snowfall Inclusion Program (SNOWIN)

The input for the SNOWIN program consists of both the output from the Storm Event Definition Program and data from the Weather Bureau daily rainfall records. The program listing for SNOWIN is presented in Table B-3 and a list of variables for SNOWIN is shown in Table B-4. The storm event data are in the format presented in Table 7. The daily rainfall records are in the format presented in Table 8, which is compatible with the Weather Bureau daily rainfall tapes. In this program the daily records are inspected for days on which snowfall occurs, and these days are matched with storm

Table 6. FORMAT FOR HOURLY RAINFALL DATA

Card group	Format	Card columns	Description	Variable name
	3I2	7-12	Date of rainfall	
		(7-8)	Year (last 2 digits)	NY(I)
		(9-10)	Month	MO(I)
		(11-12)	Day	ND(I)
	I1	13	Switch indicating time of day; 0 indicates a.m. and 1 indicates p.m.	NX(I)
	12F3.2	14-16	Quantity of rainfall in Hour 1	FR(I,1)
		16-18	Quantity of rainfall in Hour 2	FR(I,2)
		⋮		⋮
		47-49	Quantity of rainfall in Hour 12	FR(I,12)
	12F3.2	14-16	Quantity of rainfall in Hour 13	FR(I,13)
		⋮		⋮
		47-49	Quantity of rainfall in Hour 24	FR(I,24)
	I2	79-80	Day of next recorded rainfall	NEXT(I)

Table 7. FORMAT FOR STORM DATA

Card group	Format	Card columns	Description	Variable name
	I4	2-5	Number of year of storm	NYA/IYE
	3I3	6-8	Number of month of storm	MOA/MON
		9-11	Day of month of storm	NDA/NDA
		12-14	Duration of storm	LD/NDU
	2F6.2	15-20	Total rainfall for storm	FRS/TR
		21-26	Maximum 1-hour intensity for storm	FAX/TMR
	2I3	27-29	Number of hours into storm that peak intensity occurs	ITA/NHR
		30-32	Number of days between storms	LLD/NDT
	I2	33-34	Snowfall index	IS/ISN
	I3	35-37	Clock hour for start of storm	IRT/IHR
	I5	43-47	Sequence numbers	IFXX/NRR/IPP
	I5	43-47	Magnitude sequence number	IQ/IFXX

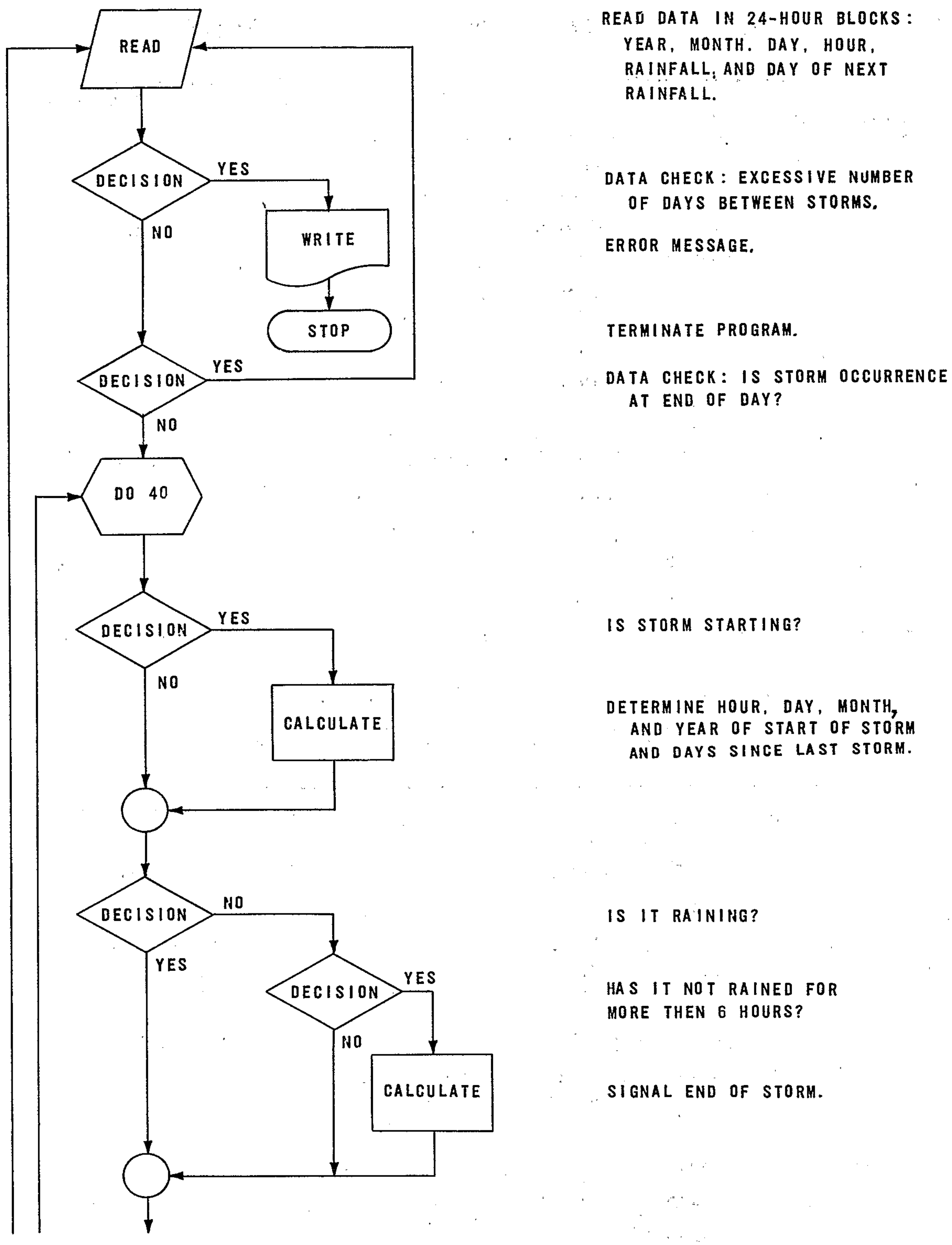


FIGURE 12. FLOW CHART FOR STORM EVENT DEFINITION PROGRAM (EVENT)

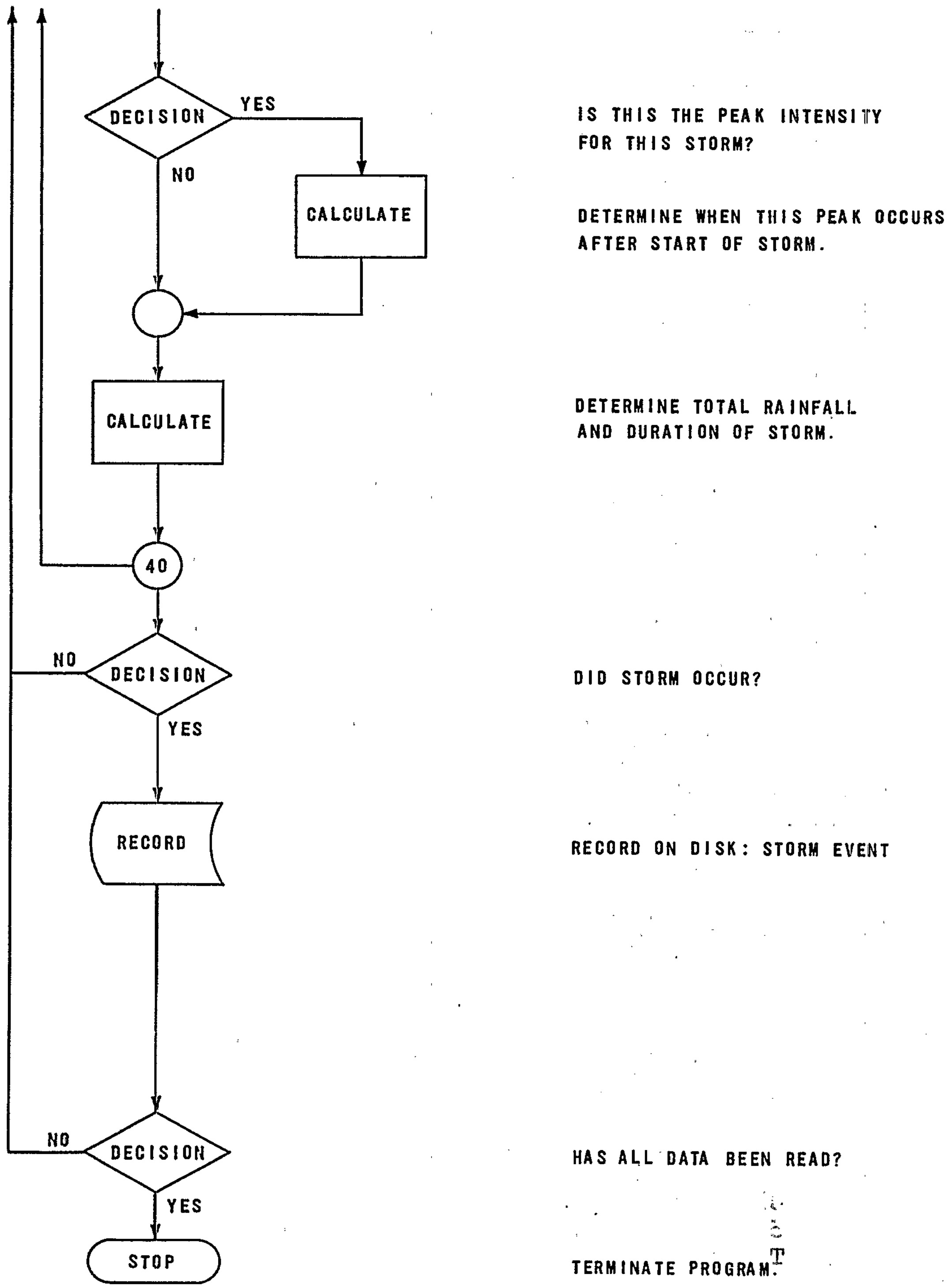


FIGURE 12. (CONCLUDED)

events. An index is set if snowfall is present or not present for a particular storm. The flow chart for this program is presented in Figure 13. The output is in the format presented in Table 7, and is listed on a disk for future reference.

Table 8. FORMAT FOR SNOWFALL DATA

Card group	Format	Card columns	Description	Variable name
	3I2	6-11	Date of precipitation	
		(6-7)	Year (last 2 digits)	NYB
		(8-9)	Month	MOB
		(10-11)	Day	NDB
	F3.1	22-24	Quantity of snowfall	SNOW

Minor Storm Event Exclusion Program (EXCLUD)

The function of the EXCLUD program is to eliminate the very small rainfalls that occur from the storm file. This reduces the amount of data to be sorted and ranked. These small storms are sometimes the tailing or leading edge of a large storm that became isolated due to the rigid application of the 6-hour storm event definition, or they are parts of large storms that fell somewhere else in the region and are just passing through. In either case, in Rochester these storms amount to an average of 51 occurrences, for a total of 1.21 inches of rain annually, or 4.1 percent of the total annual rainfall. Metcalf & Eddy has defined small storms as those with rainfall amounting to 0.05 inches or less. The program logic is presented in Figure 14. The program also uses the format presented in Table 7 for both input and output. The input and output is handled on disks. A program listing for EXCLUD is presented in Table B-5 and the list of variables for EXCLUD is presented in Table B-6.

Storm Event Sequence List Program (LISTSQ)

The output from the Snowfall Inclusion Program or the Minor Events Exclusion Program is usually used with the LISTSQ

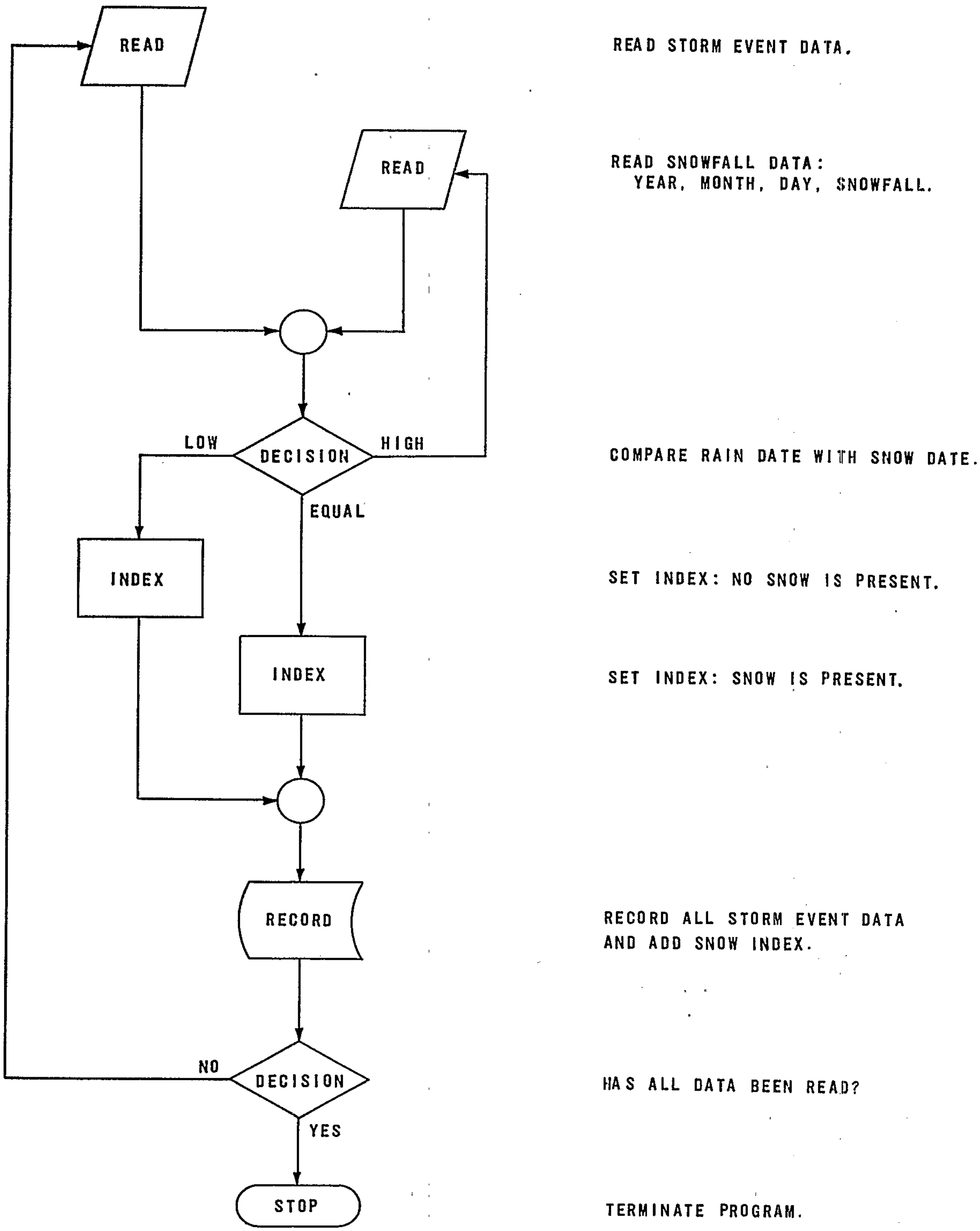


FIGURE 13. FLOW CHART FOR SNOWFALL INCLUSION PROGRAM (SNOWIN)

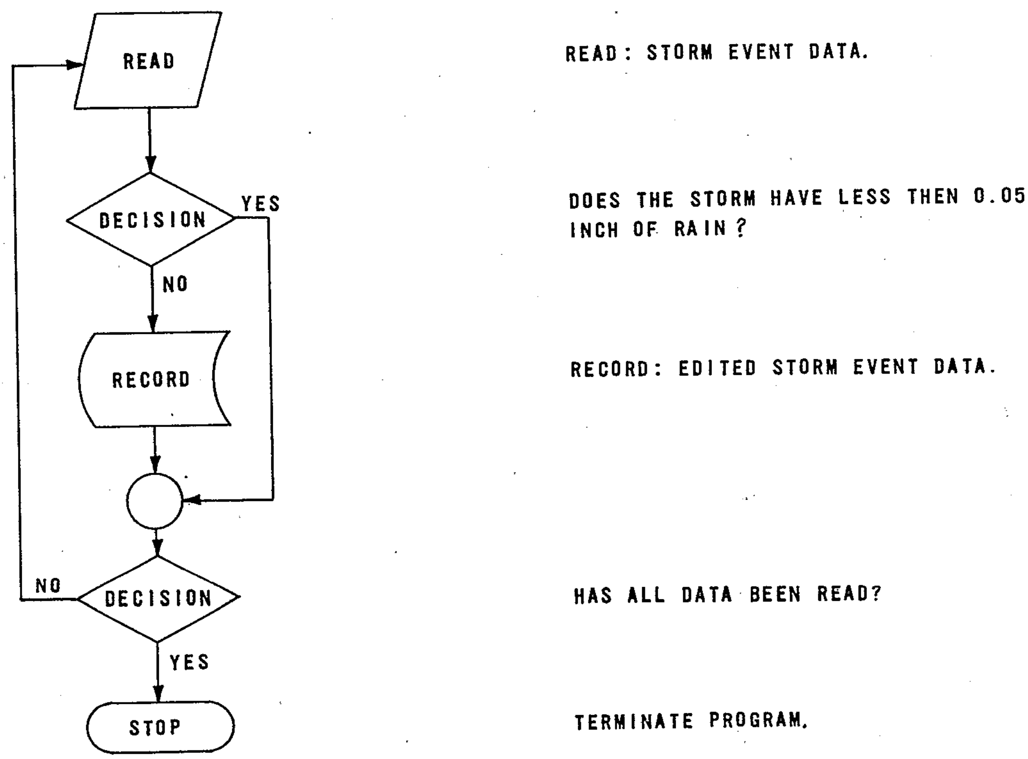


FIGURE 14. FLOW CHART FOR MINOR STORM EVENT EXCLUSION PROGRAM (EXCLUD)

program in the format presented in Table 7. The logic for the program is presented in Figure 15. Its primary function is to provide a chronological listing of the storm event data. In the program, data on the duration of storms, the total rainfall, and the maximum hourly intensity for each year are accumulated and listed at the end of each year. When all of the data have been read, the program is terminated. The results of this analysis are printed by this program. An example of the output for the year 1962 is presented in Table 9. Table B-7 is a program listing for LISTSQ. Table B-8 is a list of variables for LISTSQ.

Sorting and Ranking Program (SORT)

The SORT program used to analyze rainfall is a package program developed by IBM (OS SORT/MERGE Program GC28-6543). An important characteristic of this program is that it sorts the data on the basis of a particular characteristic and carries along with it the remaining characteristics of the particular storm.

This program uses the same input-output format presented in Table 7, and also uses disks for input and output files.

Listing of Ranked Files Program (LISTRK)

The LISTRK program provides output from any of the previous programs. The program listing for LISTRK is shown in Table B-9 and Table B-10 is a list of variables for LISTRK. The program logic is presented in Figure 16. The program reads disk files in the format presented in Table 7, assigns a sequence number, and prints the information on the line printer. An example of the output is presented in Table 10. This output has been ranked by maximum 1-hour intensity.

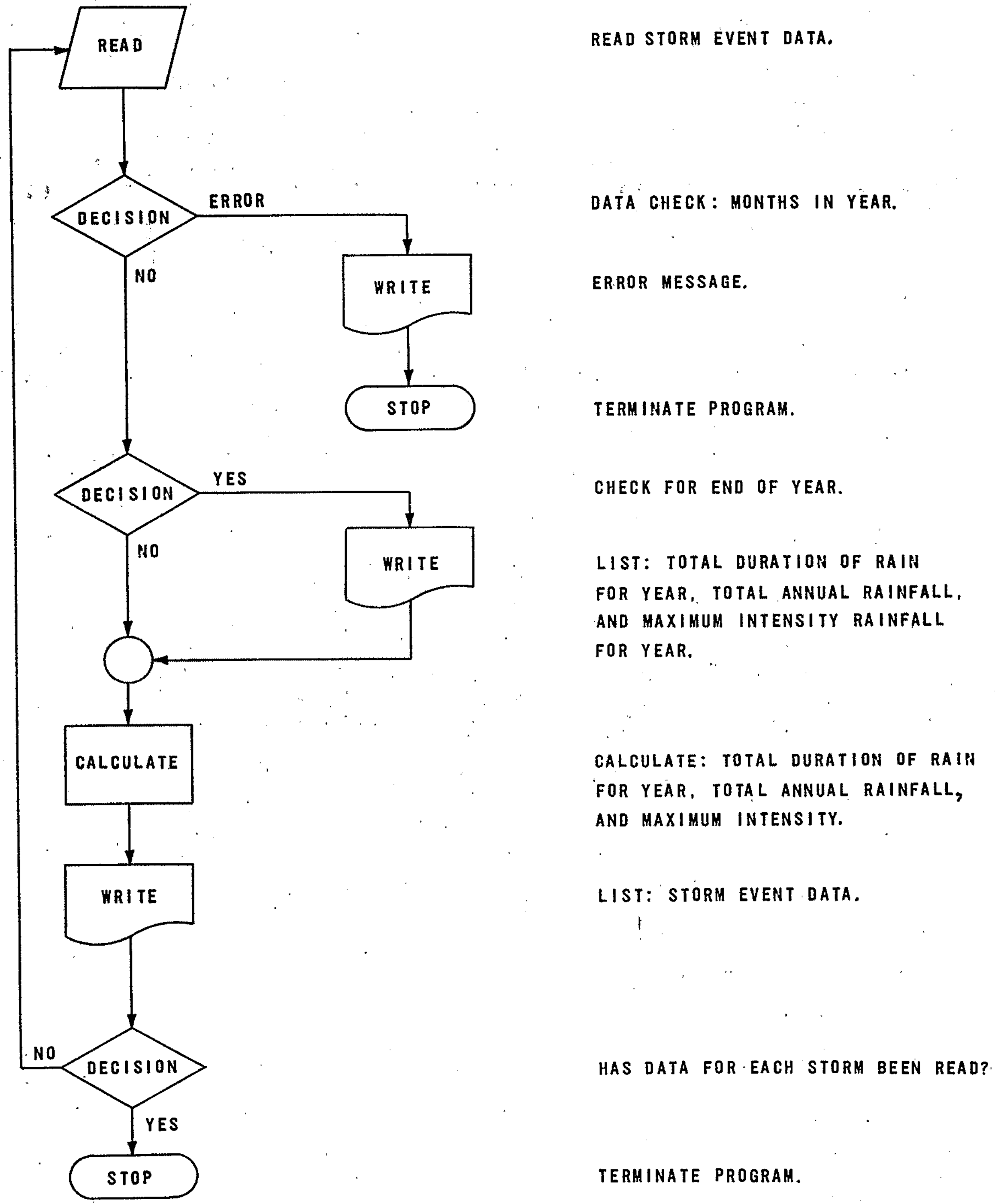


FIGURE 15. FLOW CHART FOR STORM EVENT SEQUENCE LISTING PROGRAM (LISTSQ)

Table 9. EXAMPLE OF OUTPUT FROM STORM EVENT SEQUENCE LISTING PROGRAM (LISTSQ)

YEAR	MONTH	DAY	DURAT. HOURS	TOTAL RAINFALL	MAX HOUR RAINFALL	HOUR AFTER START	DAYS SINCE LAST STORM	EXCESS PRECIP	REAL TIME START HOUR	SNOW INCLUDED	SEQUNCE
1962	JAN	2	6	0.03	0.01	1	6	NO	7	YES	1831
1962	JAN	3	2	0.05	0.04	1	1	NO	21	NO	1832
1962	JAN	4	7	0.03	0.01	1	0	NO	9	YES	1833
1962	JAN	5	29	0.56	0.13	29	1	NO	22	NO	1834
1962	JAN	15	8	0.21	0.11	1	8	NO	12	NO	1835
1962	JAN	20	3	0.06	0.03	2	5	NO	2	YES	1836
1962	JAN	20	2	0.02	0.01	1	0	NO	15	YES	1837
1962	JAN	22	10	0.19	0.05	3	2	NO	5	NO	1838
1962	JAN	26	11	0.31	0.06	1	4	NO	13	NO	1839
1962	JAN	26	9	0.06	0.01	1	2	NO	8	YES	1840
1962	JAN	29	2	0.02	0.01	1	1	NO	3	YES	1841
1962	JAN	29	17	0.30	0.08	6	0	NO	23	YES	1842
1962	FEB	1	8	0.07	0.03	2	2	NO	3	YES	1843
1962	FEB	3	8	0.06	0.03	2	2	NO	5	YES	1844
1962	FEB	6	1	0.01	0.01	1	3	NO	7	YES	1845
1962	FEB	9	4	0.06	0.02	2	3	NO	18	YES	1846
1962	FEB	14	18	0.55	0.17	4	5	NO	1	YES	1847
1962	FEB	16	6	0.16	0.06	2	2	NO	12	YES	1848
1962	FEB	18	7	0.02	0.01	1	2	NO	6	YES	1849
1962	FEB	19	8	0.37	0.11	1	1	NO	6	YES	1850
1962	FEB	22	5	0.14	0.06	1	3	NO	1	YES	1851
1962	FEB	23	18	0.77	0.08	7	1	NO	23	YES	1852
1962	FEB	26	3	0.21	0.11	1	2	NO	9	NO	1853
1962	FEB	28	3	0.05	0.03	2	2	NO	8	NO	1854
1962	MAR	12	7	0.31	0.15	7	12	NO	3	NO	1855
1962	MAR	12	19	0.23	0.13	1	0	NO	19	NO	1856
1962	MAR	14	10	0.05	0.02	2	1	NO	1	YES	1857
1962	MAR	21	6	0.10	0.05	5	7	NO	17	NO	1858
1962	MAR	30	3	0.02	0.01	1	9	NO	16	NO	1859
1962	MAR	31	9	0.54	0.18	4	0	NO	9	YES	1860
1962	APR	1	23	0.40	0.05	2	1	NO	1	YES	1861
1962	APR	7	11	0.23	0.04	7	6	NO	6	NO	1862
1962	APR	9	5	0.20	0.09	4	2	NO	9	NO	1863
1962	APR	12	23	0.63	0.08	6	3	NO	16	NO	1864
1962	APR	14	4	0.06	0.03	3	1	NO	3	YES	1965
1962	APR	14	5	0.06	0.03	1	0	NO	21	YES	1866
1962	APR	15	10	0.07	0.02	9	0	NO	12	YES	1867
1962	APR	18	9	0.13	0.05	1	3	NO	8	YES	1868
1962	APR	22	3	0.15	0.09	1	4	NO	19	NO	1869
1962	APR	29	7	0.69	0.17	1	7	NO	18	NO	1870
1962	MAY	1	3	0.30	0.12	2	2	NO	22	NO	1871
1962	MAY	2	3	0.22	0.12	2	0	NO	19	NO	1872
1962	MAY	8	2	0.05	0.04	1	6	NO	16	NO	1873
1962	MAY	23	10	1.76	0.65	5	15	NO	17	NO	1874
1962	MAY	30	7	0.34	0.26	1	6	NO	16	NO	1875
1962	MAY	31	1	0.03	0.03	1	0	NO	12	NO	1876
1962	JUNE	5	19	0.84	0.20	12	5	NO	4	NO	1877
1962	JUNE	10	1	0.04	0.04	1	5	NO	22	NO	1878
1962	JUNE	11	18	1.07	0.40	2	0	NO	13	NO	1879
1962	JUNE	13	16	0.24	0.05	13	1	NO	16	NO	1880

Table 9. (Continued)

YEAR	MONTH	DAY	DURAT. HOURS	TOTAL RAINFALL	MAX HOUR RAINFALL	HOUR AFTER START	DAYS SINCE LAST STORM	EXCESS PRECIP	REAL TIME START HOUR	SNOW INCLUDED	SEQUNCE
1962	JUNE	19	6	0.71	0.28	4	5	NO	1	NO	1881
1962	JUNE	24	2	0.12	0.11	1	5	NO	11	NO	1882
1962	JULY	8	8	0.21	0.11	6	14	NO	19	NO	1883
1962	JULY	12	9	0.37	0.25	8	3	NO	6	NO	1884
1962	JULY	18	7	0.10	0.04	6	6	NO	7	NO	1885
1962	JULY	20	11	0.34	0.08	9	2	NO	16	NO	1886
1962	JULY	23	10	0.65	0.28	4	2	NO	11	NO	1887
1962	JULY	25	1	0.10	0.10	1	2	NO	23	NO	1888
1962	JULY	26	8	0.09	0.07	1	0	NO	10	NO	1889
1962	JULY	30	1	0.03	0.03	1	4	NO	17	NO	1890
1962	AUG	4	3	0.11	0.06	2	5	NO	14	NO	1891
1962	AUG	6	16	1.88	0.77	4	2	NO	19	NO	1892
1962	AUG	10	2	0.05	0.03	2	3	NO	10	NO	1893
1962	AUG	13	13	0.51	0.12	1	3	NO	5	NO	1894
1962	AUG	14	5	0.03	0.02	1	1	NO	5	NO	1895
1962	AUG	16	9	0.19	0.06	5	2	NO	23	NO	1896
1962	AUG	20	1	0.01	0.01	1	3	NO	17	NO	1897
1962	AUG	21	2	0.25	0.24	2	1	NO	1	NO	1898
1962	AUG	27	9	0.40	0.17	7	6	NO	8	NO	1899
1962	AUG	28	2	0.10	0.09	1	1	NO	11	NO	1900
1962	SEPT	1	1	0.30	0.30	1	4	NO	16	NO	1901
1962	SEPT	4	1	0.05	0.05	1	3	NO	15	NO	1902
1962	SEPT	5	11	0.09	0.03	10	1	NO	3	NO	1903
1962	SEPT	10	2	0.25	0.21	2	5	NO	20	NO	1904
1962	SEPT	13	1	0.01	0.01	1	3	NO	23	NO	1905
1962	SEPT	17	9	0.67	0.42	8	4	NO	9	NO	1906
1962	SEPT	18	8	0.18	0.15	1	1	NO	12	NO	1907
1962	SEPT	19	1	0.01	0.01	1	0	NO	16	NO	1908
1962	SEPT	22	1	0.01	0.01	1	3	NO	7	NO	1909
1962	SEPT	22	3	0.04	0.02	2	0	NO	19	NO	1910
1962	SEPT	25	9	0.15	0.04	2	3	NO	12	NO	1911
1962	SEPT	27	33	2.22	0.25	20	2	NO	10	NO	1912
1962	SEPT	29	6	0.03	0.01	1	0	NO	11	NO	1913
1962	OCT	3	1	0.01	0.01	1	4	NO	22	NO	1914
1962	OCT	4	1	0.01	0.01	1	0	NO	16	NO	1915
1962	OCT	4	7	0.28	0.10	3	0	NO	24	NO	1916
1962	OCT	5	10	0.36	0.11	8	0	NO	23	NO	1917
1962	OCT	11	1	0.01	0.01	1	5	NO	3	NO	1918
1962	OCT	11	3	0.09	0.06	1	0	NO	15	NO	1919
1962	OCT	16	1	0.04	0.04	1	5	NO	1	NO	1920
1962	OCT	16	2	0.06	0.05	1	0	NO	21	NO	1921
1962	OCT	20	16	0.11	0.02	1	4	NO	19	NO	1922
1962	OCT	22	4	0.10	0.04	1	1	NO	21	NO	1923
1962	OCT	23	11	0.55	0.16	7	0	NO	11	NO	1924
1962	OCT	24	1	0.02	0.02	1	0	NO	17	YES	1925
1962	OCT	26	2	0.07	0.05	1	2	NO	16	YES	1926
1962	OCT	28	2	0.05	0.04	1	2	NO	18	NO	1927
1962	OCT	30	9	0.19	0.04	3	2	NO	11	NO	1928
1962	NOV	1	2	0.04	0.03	2	2	NO	4	NO	1929
1962	NOV	3	9	0.28	0.05	2	2	NO	20	NO	1930

Table 9. (Concluded)

YEAR	MONTH	DAY	DURAT. HOURS	TOTAL RAINFALL	MAX HOUR RAINFALL	HOUR AFTER START	DAYS SINCE LAST STORM	EXCESS PRECIP	REAL TIME START HOUR	SNOW INCLUDED	SEQUNCE
1962	NOV	9	15	0.76	0.17	5	5	NO	21	NO	1931
1962	NOV	10	8	0.15	0.04	7	0	NO	20	NC	1932
1962	NOV	17	8	0.44	0.09	6	6	NO	15	YES	1933
1962	NOV	21	2	0.03	0.02	1	4	NO	14	NO	1934
1962	NOV	22	3	0.08	0.04	2	1	NO	3	NO	1935
1962	NOV	22	1	0.01	0.01	1	0	NO	18	NO	1936
1962	NOV	24	5	0.16	0.05	2	2	NO	4	NO	1937
1962	DEC	6	6	0.50	0.16	4	12	NO	11	NO	1938
1962	DEC	7	5	0.08	0.03	4	1	NO	14	NO	1939
1962	DEC	8	2	0.03	0.02	2	0	NO	11	NO	1940
1962	DEC	10	2	0.03	0.02	1	2	NO	11	YES	1941
1962	DEC	12	2	0.02	0.01	1	2	NO	22	YES	1942
1962	DEC	14	3	0.04	0.02	2	2	NO	5	YES	1943
1962	DEC	14	1	0.01	0.01	1	0	NO	15	YES	1944
1962	DEC	15	4	0.05	0.02	3	1	NO	16	YES	1945
1962	DEC	17	3	0.08	0.03	1	2	NO	5	YES	1946
1962	DEC	17	5	0.02	0.01	1	0	NO	19	YES	1947
1962	DEC	21	11	0.27	0.06	7	4	NO	23	YES	1948
1962	DEC	23	2	0.04	0.03	2	1	NO	14	YES	1949
1962	DEC	26	2	0.02	0.01	1	3	NO	4	YES	1950
1962	DEC	29	9	0.16	0.03	2	3	NO	11	YES	1951
1962	DEC	30	28	0.19	0.03	28	0	NO	3	YES	1952
1962	DEC	31	3	0.04	0.02	2	0	NO	14	YES	1953
			850	29.25	0.77						

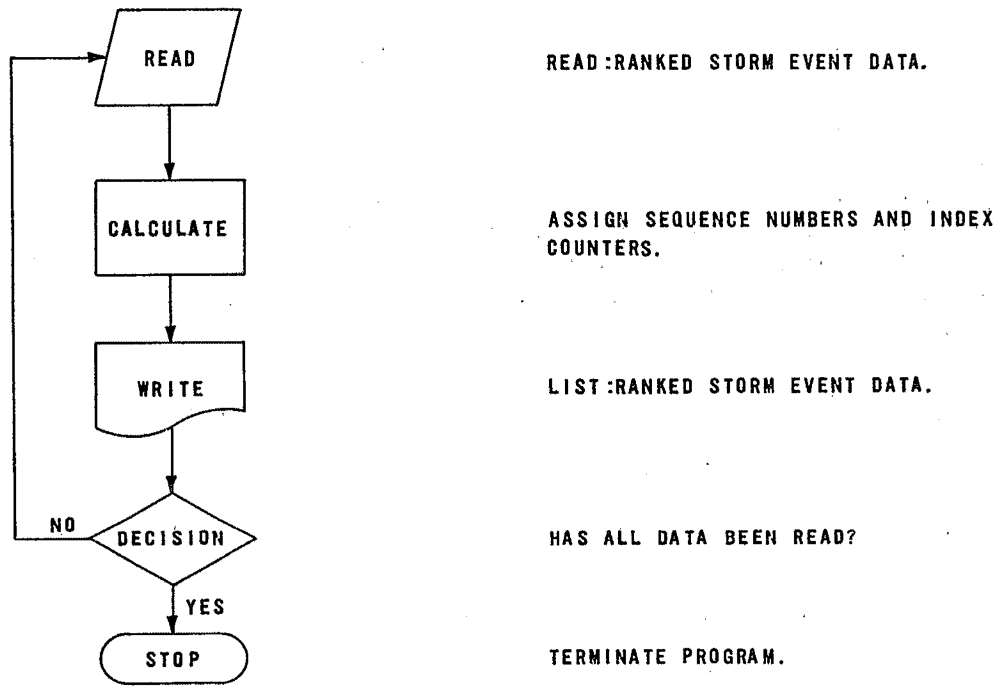


FIGURE 16. FLOW CHART FOR LISTING OF RANKED FILES PROGRAM (LISTRK)

Table 10. EXAMPLE OF OUTPUT FROM LISTING OF RANKED FILES PROGRAM (LISTRK)

YEAR	MONTH	DAY	DURAT. HOURS	TOTAL RAINFALL	MAX HOUR RAINFALL	HOUR AFTER START	DAYS SINCE LAST STORM	EXCESS PRECIP	REAL TIME START HOUR	SNOW INCLUDED	RANKED	RANKED BY MAGNITUDE
1958	JUNE	25	8	2.15	1.35	1	0	NO	21	NO	1	13
1950	JUNE	23	14	2.86	1.32	2	7	NO	21	NO	2	5
1966	JULY	28	11	1.94	1.27	1	0	NO	11	NO	3	18
1970	JULY	29	2	1.25	1.12	1	8	NO	14	NO	4	79
1973	AUG	27	3	1.27	1.08	2	6	NO	7	NO	5	77
1971	JULY	13	9	2.25	1.03	8	7	NO	12	NO	6	10
1970	JULY	11	12	1.40	1.01	2	1	NO	5	NO	7	50
1967	AUG	8	1	0.92	0.92	1	0	NO	15	NO	8	159
1954	AUG	10	7	0.91	0.86	1	5	NO	12	NO	9	166
1968	AUG	6	6	1.29	0.84	5	5	NO	1	NO	10	73
1955	AUG	22	4	0.91	0.81	1	7	NO	13	NO	11	163
1968	AUG	23	7	2.39	0.81	5	0	NO	21	NO	12	8
1953	AUG	9	10	1.71	0.77	10	0	NO	15	NO	13	29
1962	AUG	6	16	1.88	0.77	4	2	NO	19	NO	14	22
1959	JUNE	1	11	1.43	0.77	8	6	NO	8	NO	15	46
1960	AUG	3	9	1.52	0.75	1	4	NO	2	NO	16	39
1969	JUNE	2	12	1.30	0.75	4	0	NO	15	NO	17	69
1965	AUG	19	16	1.42	0.71	3	6	NO	2	NO	18	47
1956	AUG	9	5	0.94	0.70	1	2	NO	18	NO	19	154
1961	AUG	6	2	0.76	0.70	1	0	NO	13	NO	20	239
1954	OCT	2	9	1.50	0.68	7	3	NO	2	NO	21	40
1970	AUG	30	2	0.86	0.68	2	0	NO	20	NO	22	186
1959	MAY	19	10	0.81	0.66	10	2	NO	11	NO	23	209
1955	AUG	6	1	0.66	0.66	1	0	NO	16	NO	24	297
1953	AUG	4	21	1.47	0.65	4	6	NO	11	NO	25	41
1967	JULY	11	13	1.40	0.65	10	0	NO	4	NO	26	51
1964	MAY	13	26	1.38	0.65	2	5	NO	15	NO	27	55
1962	MAY	23	10	1.76	0.65	5	15	NO	17	NO	28	27
1971	AUG	21	3	0.76	0.64	2	1	NO	6	NO	29	237
1949	JAN	7	10	1.40	0.60	7	0	NO	14	YES	30	52
1970	JUNE	26	12	1.67	0.59	1	2	NO	19	NO	31	31
1958	OCT	16	16	2.48	0.59	11	3	NO	17	NO	32	6
1949	JUNE	29	11	0.67	0.59	7	4	NO	14	NO	33	294
1957	SEPT	20	2	0.60	0.58	1	0	NO	15	NO	34	341
1952	JULY	20	15	0.87	0.58	14	0	NO	17	NO	35	180
1953	SEPT	12	2	1.06	0.58	1	7	NO	16	NO	36	114
1972	JUNE	15	7	0.80	0.57	3	6	NO	13	NO	37	214
1951	JULY	5	10	0.91	0.57	2	1	NO	7	NO	38	165
1949	MAY	5	2	0.73	0.57	2	4	NO	22	NO	39	254
1961	JUNE	29	1	0.57	0.57	1	6	NO	7	NO	40	370
1948	JULY	30	2	0.58	0.57	1	2	NO	17	NO	41	362
1958	JULY	19	1	0.56	0.56	1	3	NO	1	NO	42	388
1949	JULY	9	7	0.81	0.56	5	5	NO	24	NO	43	208
1963	JULY	29	10	0.79	0.56	1	0	NO	13	NO	44	223
1972	MAY	30	10	1.02	0.56	6	15	NO	13	NO	45	128
1951	JULY	19	5	1.30	0.56	4	2	NO	2	NO	46	70
1951	JUNE	3	9	1.22	0.56	7	1	NO	24	NO	47	84
1956	AUG	30	7	0.87	0.55	6	1	NO	13	NO	48	183
1955	JUNE	7	2	0.56	0.55	1	9	NO	18	NO	49	385
1951	JULY	11	26	1.05	0.54	3	6	NO	16	NO	50	118

SECTION VII

STORAGE-TREATMENT BALANCE

In the storage-treatment task, rainfall is converted into runoff and overflows. In this chapter the general characteristics of the program will be presented, the program logic and specific input and output requirements will be discussed, and examples using portions of the City of Rochester will be modeled to illustrate the utility and versatility of the program.

CHARACTERISTICS OF THE STORAGE-TREATMENT PROGRAM

The program is described in three parts: (1) the concept upon which it is based, (2) the major operational controls and general data requirements, and (3) the philosophy or method of approach to its application and the usefulness of its output.

Concept of the Program

The concept of the storage-treatment program is presented graphically in Figure 17. In the program rainfall is converted into runoff using a K factor (gross runoff coefficient). This runoff is stored in a specific storage volume that is drained by a specific treatment rate. The treatment rate could be determined by an actual treatment facility or an interceptor capacity. When the runoff exceeds the storage capacity and the treatment rate, an overflow occurs.

Operational Controls and Data Requirements

The program can function on either a daily or hourly time step. The daily time step is used initially for analysis based on the entire period of record. For specific periods of interest--including critical storms--the analysis may be performed on the hourly time step.

The starting of the treatment rate also can be controlled. In the daily analysis, the percentage of the full treatment

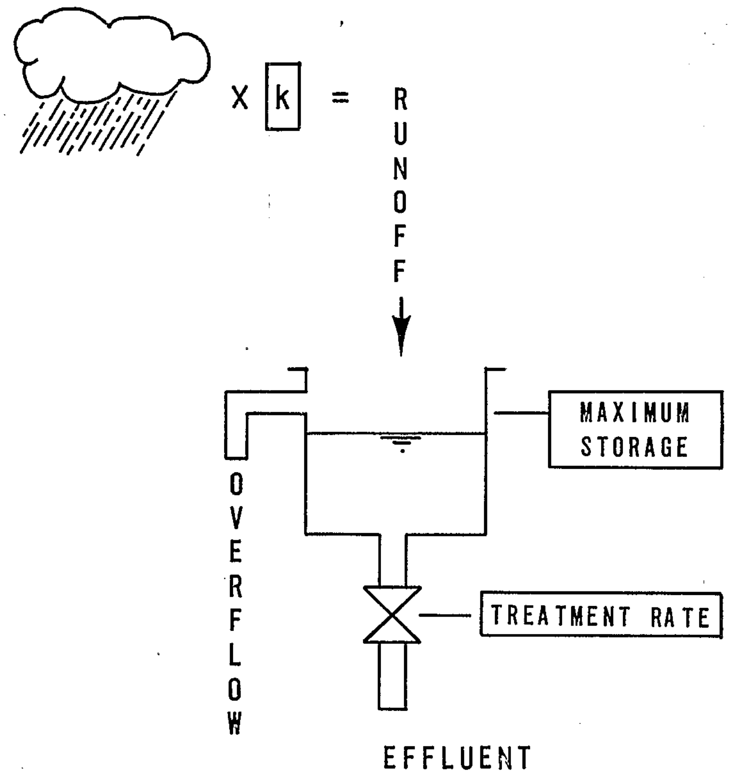


FIGURE 17. CONCEPT OF STORAGE-TREATMENT PROGRAM

rate for the first day of rain can be controlled. This control can be used to reflect the uncertainty of when a storm starts during the day or the length of time required to start a treatment facility. In the hourly analysis, the start of the treatment rate can be delayed a specified number of hours to reflect the real time required for start-up of a stormwater treatment facility.

The program, when used with a computer system capable of on-line storage of input and output files, can also be used to analyze a system of linked subareas. The treatment rate for a system would represent the capacity of the interceptor system between subareas. The program has the ability to create a time-varying interceptor capacity for upstream areas based on the runoff from downstream areas and downstream interceptor capacities.

The major data requirements for the program are simply the land area, the K factor, the storage capacity, and the treatment rate. The area of land for a particular subarea is developed as described in Section V. The K factor can be developed and checked from (1) quantity measurements as described in Section V; (2) analysis of detailed computer programs, such as the Storm Water Management Model (SWMM); or (3) other traditional empirical equations based on land use or impervious area (as illustrated in Appendix C). The storage capacity should be the real in-system storage, again as presented in Section V, added to the existing or proposed tunnel, cavern, and/or diked storage volume. The treatment rate is the existing or proposed available peak wet-weather treatment capacity or excess interceptor capacity immediately downstream from the subarea.

The other input variables trigger the operational controls. The factor for starting of the treatment rate is the most significant of these triggers. This factor would normally be zero when an interceptor is downstream rather than a treatment facility. There is a switch for daily or hourly analysis, and the number of upstream interceptors converging on the area must also be noted.

Output Data and Application Philosophy

The output from the program is the record of the time and volume of overflows and runoff, and a summation of these parameters. The summation is terminated at the end of each year for the daily analysis and at the end of each month for the hourly analysis.

The program is intended primarily for use in the analysis of alternatives and general evaluation of the number of occurrences and volumes of overflows.

The storage capacities or treatment rate can be varied. Generally, one parameter is varied while the other parameters are held constant, so that curves can be generated to indicate the impact of the particular variable on the system.

The base or uncontrolled condition is run initially to provide a base for comparison of the control approaches. The success of an overflow abatement program can be measured by a reduction in the volume, duration, and number of overflows. The objectives of the control philosophy should be defined early in the analysis and should be correlated to to some improvement in receiving water quality.

The program operates on the real rainfall records, and therefore it internally takes into account the synergistic effects of storms coming close together with overlapping demands on storage capacities. If the period of rainfall records is long enough--say 20 to 50 years--the runoff, overflow volumes, and durations can be filed and ranked, and statistically significant frequency of occurrence curves can be generated.

A series of linked subareas are analyzed by independent computer runs. The analysis starts with the subarea closest to the treatment plant or discharge point and proceeds upstream through the series of subareas. The important data are passed from one computer run to the next by means of files stored on the computer system.

COMPUTER PROGRAM LOGIC AND INPUT-OUTPUT REQUIREMENTS

The storage-treatment program is written in FORTRAN computer language. This program records information on input and output files and therefore can be most productive when used by a person familiar with the manipulation of files on the computer system. The complete listing of this program is presented in Appendix B.

The program is composed of a control block with four subroutines:

- HOUCRD - Hourly analysis from card input
- DLYCRD - Daily analysis from card input
- DLYTAP - Daily analysis from tape input
- HOUTAP - Hourly analysis from tape input

These subroutines are quite similar; the major differences are in the types of computer input used (cards or magnetic tape) and in the time steps being analyzed (daily or hourly). The logic for the control block is presented in Figure 18. The format for the control block input data is presented in Table 11.

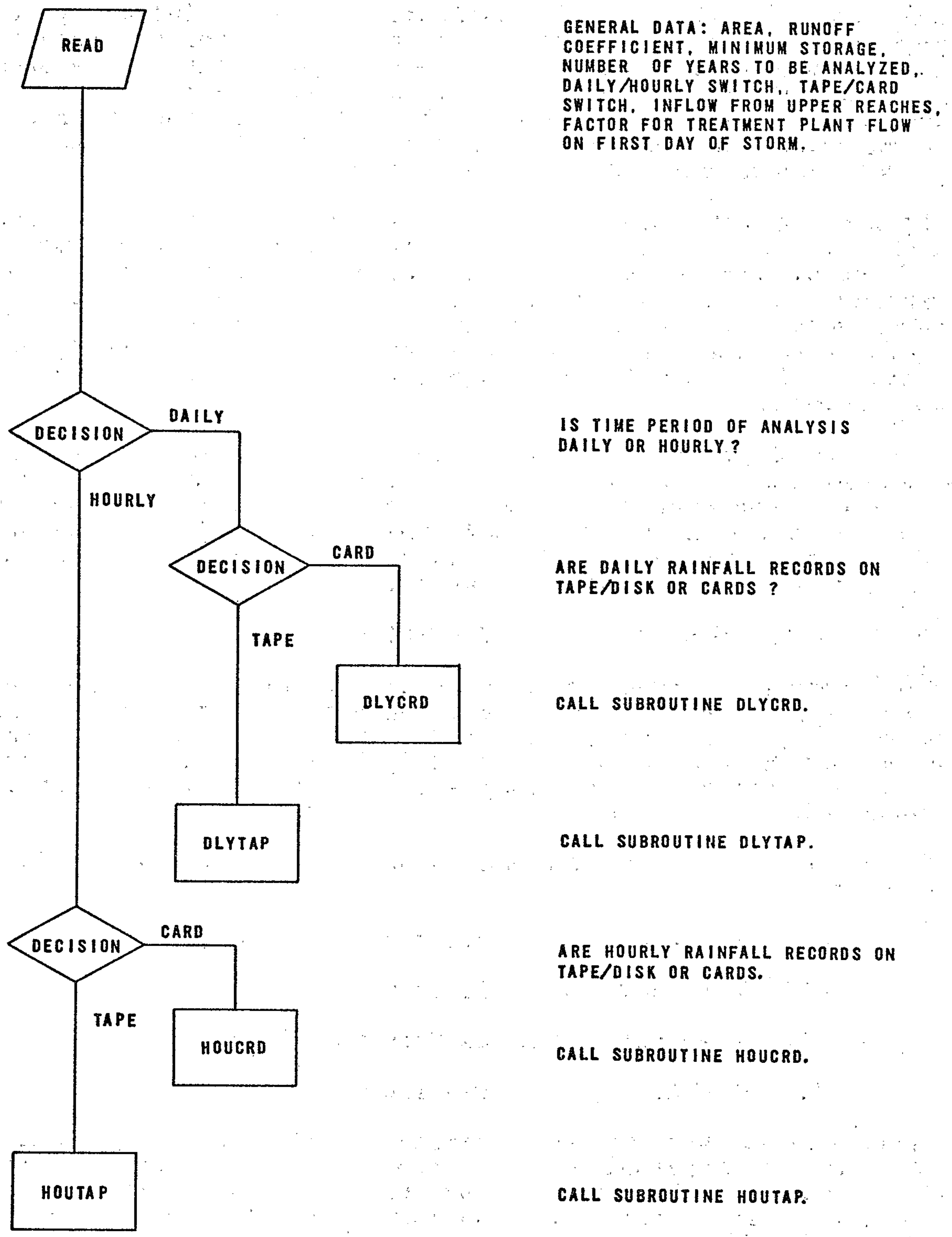


FIGURE 18. FLOW CHART FOR CONTROL BLOCK OF STORAGE-TREATMENT PROGRAM

Table 11. FORMAT FOR CONTROL BLOCK DATA OF STORAGE-TREATMENT PROGRAM

Card group	Format	Card columns	Description	Variable name
	5A4	1-4	Identifier of first area to be analyzed	ARN(1)
		5-8	Identifier of second area to be analyzed	ARN(2)
		⋮		⋮
		17-20	Identifier of last area to be analyzed	ARN(5)
	5F8.0	21-28	Area of area to be analyzed	AREA
		29-36	Gross runoff coefficient "K factor"	COEF
		37-44	Maximum volume of storage available	STMAX
		45-52	Treatment rate or adjacent downstream interceptor capacity	TREAT
		53-60	Minimum volume of storage	STOPS
	I2	61-62	Number of years or months of record to be analyzed	NYEAR
	3I1.	63	Switch 0 for daily analysis; 1 for hourly analysis	NSS
		64	Switch 0 for card input; 1 for tape input	IOTAP
		65	Number of interceptors converging at point of runoff	IPFL
	I4	66-69	Years or months to be analyzed	MYEAR
	1X	70	....	.....
	F100	71-80	Factor used to determine volume of runoff routed to treatment plant on first day of rain	TFAC

The four subroutines function on basically the same logic, which is presented in Figure 19. The slight differences in input requirements and other minor functional differences in the four subroutines are described in the discussion that follows.

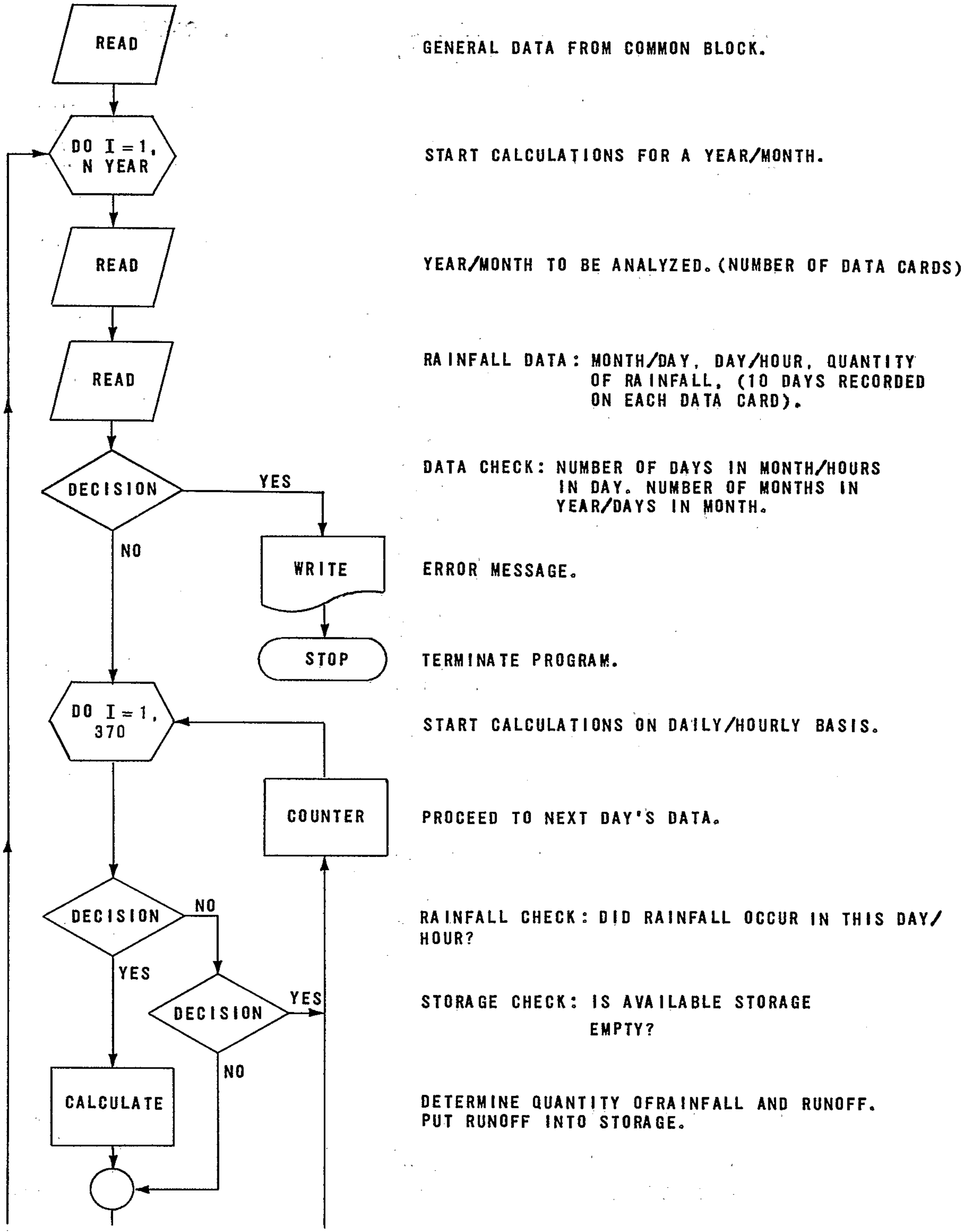
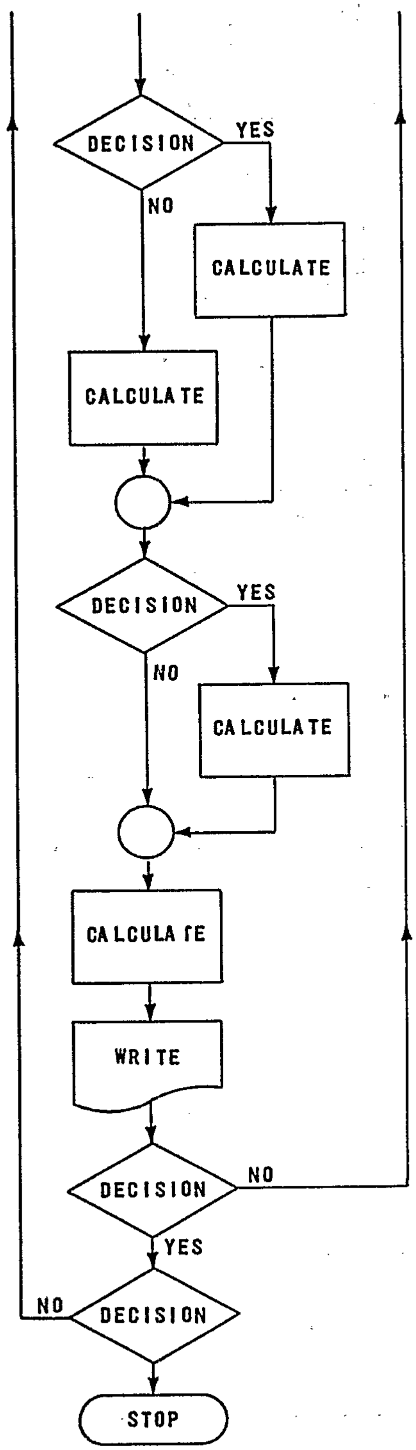


FIGURE 19. BASIC FLOW CHART FOR SUBROUTINES OF STORAGE-TREATMENT PROGRAM



IS TREATMENT OPERATIONAL FOR THIS CYCLE?

REDUCE STORAGE AT RATE OF TREATMENT.

START TREATMENT FOR NEXT CYCLE.

IS MAXIMUM STORAGE EXCEEDED?

CALCULATE QUANTITY OF WATER IN EXCESS OF MAXIMUM STORAGE AND DECLARE IT TO BE OVERFLOW.

CALCULATE: TOTAL RAINFALL FOR MONTH/DAY, QUANTITY OF RUNOFF, OVERFLOW TREATED, STORED, AND DAYS/HOURS OF RAIN AND OVERFLOW TO DATE FOR YEAR/MONTH.

LIST: DATE (MONTH AND DAY)/(DAY AND HOUR), RAINFALL, RUNOFF, STORAGE, TREATMENT, AND OVERFLOW FOR DAY/HOUR OF OCCURRENCE AND SUM OF QUANTITIES TO DATE OF RUNOFF, OVERFLOW, STORAGE, TREATMENT, DAYS/HOURS OF RAIN AND OVERFLOW.

HAS DATE FOR EACH DAY/HOUR OF YEAR/MONTH BEEN READ?

HAS EACH YEAR/MONTH OF RECORD BEEN ANALYZED?

TERMINATE PROGRAM.

FIGURE 19. (CONCLUDED)

In the HOUCRD subroutine, the input data are read from computer cards in the format presented in Table 12. Of the four subroutines, this one has the most limited capacity. Subareas cannot be connected for analysis, and the treatment rate cannot be turned off for the first hours of a storm. The hourly time increment is used.

In the DLYCRD subroutine, the input data are read from computer cards in the format presented in Table 13, which is very similar to the format of the hourly data. Connected subareas cannot be analyzed, but the treatment can be adjusted on the first day of rain. Calculations are made on a daily time step.

In the DLYTAP subroutine, the input data are read from magnetic tape or disks in the format presented in Table 14, which is compatible with the Weather Bureau's daily rainfall record tapes. This subroutine can be used with all of the operational controls described earlier in this chapter. The daily time increment is used.

Table 12. FORMAT FOR HOUCRD SUBROUTINE DATA

Card group	Format	Card columns	Description	Variable name
	2I10	1-10	Number of month to be analyzed	MYEAR
		2-20	Number of data cards to be read	NCARD
	10(2I2,F4.2)	1-8	First hour and quantity of rainfall	
	(2I2)	(1-2)	Day	MON(1)
		(3-4)	Hour	MDAT(1)
	(F4.2)	(5-8)	Quantity	RAIN(1)
		9-16	Second hour and quantity of rainfall	
	(2I2)	(9-10)	Day	MON(2)
		(11-12)	Hour	MDAT(2)
	(F4.2)	(13-16)	Quantity	RAIN(2)
		17-24	Third hour and quantity of rainfall	
		⋮		
		73-80	Tenth hour and quantity of rainfall	
			Ten hours and quantities on each data card	

Table 13. FORMAT FOR DLYCRD SUBROUTINE DATA

Card group	Format	Card columns	Description	Variable name
	2I10	1-10	Number of year to be analyzed	MYEAR
		11-20	Number of data cards to be read	NCARD
	10(2F2,F4.2)	1-8	First date and quantity of rainfall	
	(2I2)	(1-2)	Month	MON(1)
		(3-4)	Day	MDAT(1)
	(F4.2)	(5-8)	Quantity	RAIN(1)
		9-16	Second date and quantity of rainfall	
	(2I2)	(9-10)	Month	MON(2)
		(11-12)	Day	MDAT(2)
	(F4.2)	(13-14)	Quantity	RAIN(2)
		17-24	Third date and quantity of rainfall	
		⋮		
		73-80	Tenth date and quantity of rainfall	
			Ten dates and quantities on each data card	

Table 14. FORMAT FOR DYLTAP SUBROUTINE DATA

Card group	Format	Card columns		Variable name
	3I2	6-11	Date of precipitation	
		(6-7)	Year (last 2 digits)	NYZ
		(8-9)	Month	MON
		(10-11)	Day	MDAT
	F4.2	18-21	Quantity of rain for day	RAIN

In the HOUTAP subroutine, the input data are read in the format presented in Table 15, which is compatible with the Weather Bureau's hourly tapes. Again, all of the operational controls can be used. The time increment is hourly.

In all of the subroutines, basically the same output format is used. The daily and hourly times are recorded slightly differently. An example of the daily output is presented in Table 16, and an example of the hourly output is presented in Table 17.

EXAMPLE OF STORAGE-TREATMENT PROGRAM APPLICATION

The storage-treatment program was used on the City of Rochester system of combined sewers to analyze the performance of the existing system as well as to evaluate the suggested overflow control alternatives. Examples of the results are presented in this section.

Table 15. FORMAT FOR HOUTAP SUBROUTINE DATA

Card group	Format	Card columns	Description	Variable name
	3I2	7-12	Date of rainfall	
		(7-8)	Year (last 2 digits)	NY(I)
		(9-10)	Month	MO(I)
		(11-12)	Day	ND(I)
	I1	13	Switch indicating time of day; 0 indicates a.m. and 1 indicates p.m.	NX(I)
	12F3.2	14-16	Quantity of rainfall in Hour 1	FR(I,1)
		16-18	Quantity of rainfall in Hour 2	FR(I,2)
		⋮		⋮
		47-49	Quantity of rainfall in Hour 12	FR(I,12)
	12F3.2	14-16	Quantity of rainfall in Hour 13	FR(I,13)
		⋮		⋮
		47-49	Quantity of rainfall in Hour 24	FR(I,24)
	I2	79-80	Day of next recorded rainfall	NEXT(I)

Table 16. EXAMPLE OF OUTPUT FROM STORAGE-TREATMENT PROGRAM FOR DAILY ANALYSIS

YEAR 1972

MONTH	DAY	RAIN IN	RAIN DAYS	OCCURRING ON THE DATE: RUNOFF MG	STORAGE MG	OVERFLOW MG	TREATED MG	ACCUMULATED FROM START OF THE YEAR: T. RUNOFF MG	T.OVERFLOW MG	OVERFL DAYS	T.TREAT MG	TREAT DAYS	MAX STORAGE MG
6	1	0.00	79	0.00	0.00	0.00	0.00	1623.34	0.00	0	1623.34	16.23	36.77
6	2	0.01	80	1.19	0.00	0.00	1.19	1624.53	0.00	0	1624.53	16.25	36.77
6	3	0.00	80	0.00	0.00	0.00	0.00	1624.53	0.00	0	1624.53	16.25	36.77
6	4	0.04	81	4.76	0.00	0.00	4.76	1629.28	0.00	0	1629.28	16.29	36.77
6	5	0.00	81	0.00	0.00	0.00	0.00	1629.28	0.00	0	1629.28	16.29	36.77
6	6	0.00	81	0.00	0.00	0.00	0.00	1629.28	0.00	0	1629.28	16.29	36.77
6	7	0.00	81	0.00	0.00	0.00	0.00	1629.28	0.00	0	1629.28	16.29	36.77
6	8	0.09	82	10.70	0.00	0.00	10.70	1639.99	0.00	0	1639.99	16.40	36.77
6	9	0.11	83	13.08	0.00	0.00	13.08	1653.07	0.00	0	1653.07	16.53	36.77
6	10	0.00	83	0.00	0.00	0.00	0.00	1653.07	0.00	0	1653.07	16.53	36.77
6	11	0.00	83	0.00	0.00	0.00	0.00	1653.07	0.00	0	1653.07	16.53	36.77
6	12	0.00	83	0.00	0.00	0.00	0.00	1653.07	0.00	0	1653.07	16.53	36.77
6	13	0.00	83	0.00	0.00	0.00	0.00	1653.07	0.00	0	1653.07	16.53	36.77
6	14	0.00	83	0.00	0.00	0.00	0.00	1653.07	0.00	0	1653.07	16.53	36.77
6	15	0.80	84	95.14	0.00	0.00	95.14	1748.21	0.00	0	1748.21	17.48	36.77
6	16	0.00	84	0.00	0.00	0.00	0.00	1748.21	0.00	0	1748.21	17.48	36.77
6	17	0.00	84	0.00	0.00	0.00	0.00	1748.21	0.00	0	1748.21	17.48	36.77
6	18	0.00	84	0.00	0.00	0.00	0.00	1748.21	0.00	0	1748.21	17.48	36.77
6	19	0.00	84	0.00	0.00	0.00	0.00	1748.21	0.00	0	1748.21	17.48	36.77
6	20	0.06	85	7.14	0.00	0.00	7.14	1755.34	0.00	0	1755.34	17.55	36.77
6	21	1.23	86	146.28	46.28	0.00	100.00	1901.62	0.00	0	1855.34	18.55	46.28
6	22	2.15	87	255.69	99.50	102.47	100.00	2157.31	102.47	1	1955.34	19.55	99.50
6	23	0.57	88	67.79	67.29	0.00	100.00	2225.10	102.47	1	2055.34	20.55	99.50
6	24	0.17	89	20.22	0.00	0.00	87.51	2245.32	102.47	1	2142.85	21.43	99.50
6	25	0.00	89	0.00	0.00	0.00	0.00	2245.32	102.47	1	2142.85	21.43	99.50
6	26	0.00	89	0.00	0.00	0.00	0.00	2245.32	102.47	1	2142.85	21.43	99.50
6	27	0.00	89	0.00	0.00	0.00	0.00	2245.32	102.47	1	2142.85	21.43	99.50
6	28	0.00	89	0.00	0.00	0.00	0.00	2245.32	102.47	1	2142.85	21.43	99.50
6	29	0.87	90	103.47	3.47	0.00	100.00	2348.78	102.47	1	2242.85	22.43	99.50
6	30	0.46	91	54.71	0.00	0.00	58.17	2403.49	102.47	1	2301.02	23.01	99.50

TOTAL RAIN 6.56

Table 17. EXAMPLE OF OUTPUT FROM STORAGE-TREATMENT PROGRAM FOR HOURLY ANALYSIS

MONTH 6

DAY	HOUR	RAIN IN	RAIN HOUR	OCCURRING ON THE HOUR: RUNOFF MG	STORAGE MG	OVERFLOW MG	TREATED MG	ACCUMULATED FROM START OF THE MONTH: T. RUNOFF MG	T.OVERFLOW MG	OVERFL HOUR	T.TREAT MG	TREAT HOUR	MAX STORAGE MG
22	1	0.10	30	11.89	98.67	0.00	4.17	290.18	0.00	0	191.50	45.96	98.67
22	2	0.03	31	3.57	98.08	0.00	4.17	293.75	0.00	0	195.67	46.96	98.67
22	3	0.03	32	3.57	97.48	0.00	4.17	297.31	0.00	0	199.84	47.96	98.67
22	4	0.02	33	2.38	95.69	0.00	4.17	299.69	0.00	0	204.00	48.96	98.67
22	5	0.01	34	1.19	92.71	0.00	4.17	300.88	0.00	0	208.17	49.96	98.67
22	6	0.14	35	16.65	99.50	5.69	4.17	317.53	5.69	1	212.34	50.96	99.50
22	7	0.07	36	8.32	99.50	4.16	4.17	325.86	9.85	2	216.50	51.96	99.50
22	8	0.09	37	10.70	99.50	6.54	4.17	336.56	16.39	3	220.67	52.96	99.50
22	9	0.17	38	20.22	99.50	16.05	4.17	356.78	32.44	4	224.84	53.96	99.50
22	10	0.23	39	27.35	99.50	23.19	4.17	384.13	55.63	5	229.00	54.96	99.50
22	11	0.09	40	10.70	99.50	6.54	4.17	394.83	62.16	6	233.17	55.96	99.50
22	12	0.02	41	2.38	97.71	0.00	4.17	397.21	62.16	6	237.34	56.96	99.50
22	13	0.01	42	1.19	94.73	0.00	4.17	398.40	62.16	6	241.50	57.96	99.50
22	14	0.00	42	0.00	90.57	0.00	4.17	398.40	62.16	6	245.67	58.96	99.50
22	15	0.00	42	0.00	86.40	0.00	4.17	398.40	62.16	6	249.84	59.96	99.50
22	16	0.00	42	0.00	82.23	0.00	4.17	398.40	62.16	6	254.00	60.96	99.50
22	17	0.00	42	0.00	78.07	0.00	4.17	398.40	62.16	6	258.17	61.96	99.50
22	18	0.01	43	1.19	75.09	0.00	4.17	399.59	62.16	6	262.34	62.96	99.50
22	19	0.16	44	19.03	89.95	0.00	4.17	418.62	62.16	6	266.50	63.96	99.50
22	20	0.16	45	19.03	99.50	5.31	4.17	437.65	67.48	7	270.67	64.96	99.50
22	21	0.06	46	7.14	99.50	2.97	4.17	444.78	70.45	8	274.84	65.96	99.50
22	22	0.04	47	4.76	99.50	0.59	4.17	449.54	71.04	9	279.00	66.96	99.50
22	23	0.36	48	42.81	99.50	38.65	4.17	492.35	109.68	10	283.17	67.96	99.50
22	24	0.35	49	41.62	99.50	37.46	4.17	533.98	147.14	11	287.34	68.96	99.50

TOTAL RAIN 2.15

Data Development

The characteristics of the system were developed in Table 4, which contains the basic information on subarea characteristics. These characteristics must be considered fixed during the alternative analysis so that the critical parts of the alternatives can be analyzed.

In the City of Rochester, the subareas that drain directly to the Genesee River were analyzed. Initially, the areas indicated in the schematic shown in Figure 20 were analyzed to determine the level of runoff control offered by the existing sewer system. The output from the program was translated into a plot showing the frequency of occurrence of runoff and overflows versus volume as presented in Figure 21.

Several alternatives were analyzed. The results from each analysis were translated into plots showing the frequency of occurrence versus volume. Two of the alternatives, identified as Rochester West Side Alternatives 1 and 2, appear to have a distinct advantage in reducing the number of overflows.

Alternative Analysis

In West Side Alternative 1, large drainage-storage tunnels would be connected to a modified interceptor system. The drainage tunnels would be constructed in the City of Rochester as shown in Figure 22. The flow capacities of the modified interceptor sewer and the size of the drainage-storage tunnels are indicated. The drainage-storage tunnels could be connected to the main interceptor by pumps or by some other flow-controlling structure. This alternative is presented schematically in Figure 23.

In West Side Alternative 2, an interceptor tunnel would be used along the river to connect the drainage-collector tunnels. This interceptor tunnel would be connected to the existing interceptor downstream of the city. This connection would also have a controlled discharge rate. The configuration of this alternative is presented in Figure 24, and the schematic is presented in Figure 25.

A major assumption of these two alternatives is that each subarea, when improved, will have a single point of overflow.

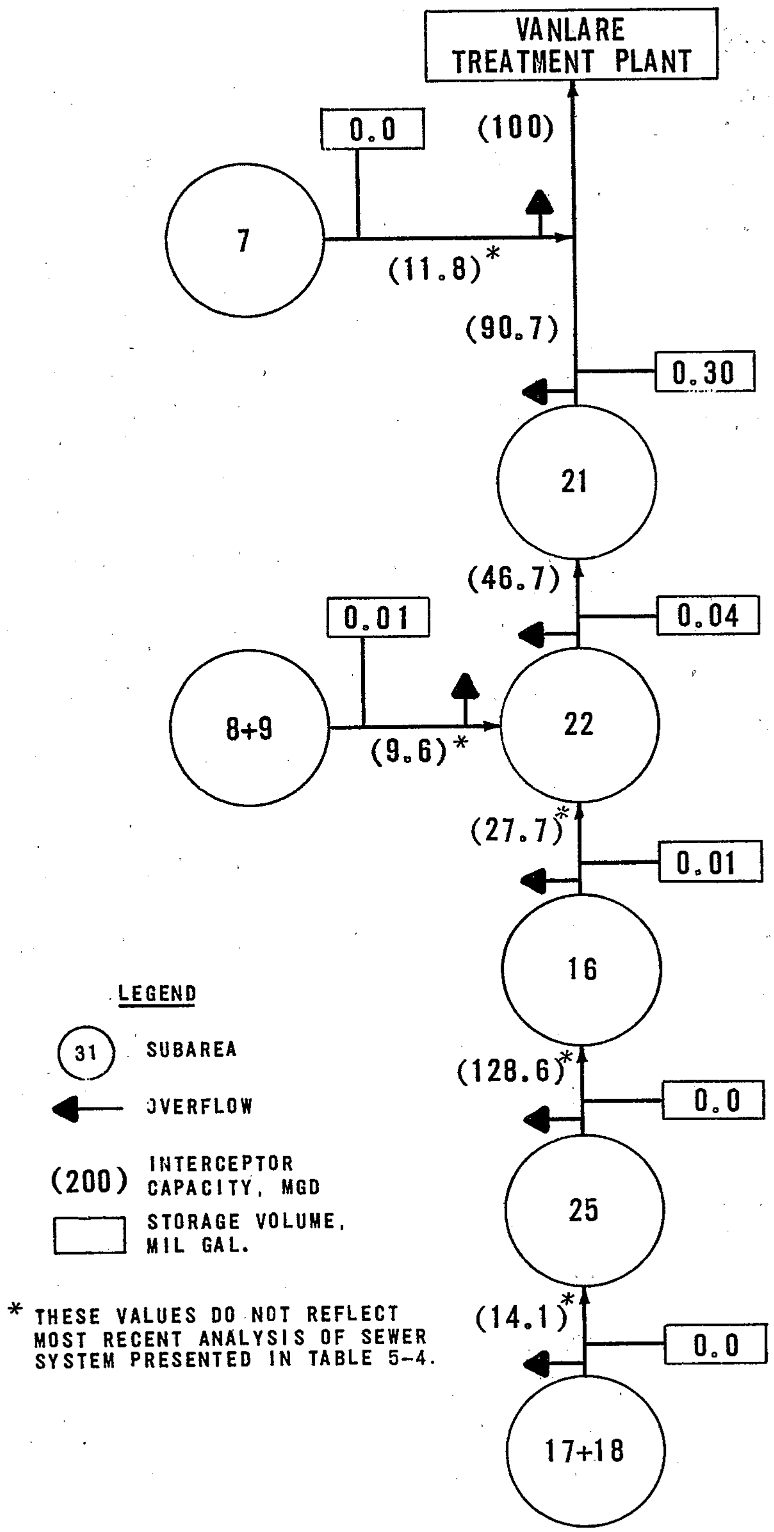


FIGURE 20. EXAMPLE OF SYSTEM SCHEMATIC - EXISTING ROCHESTER WEST SIDE INTERCEPTORS

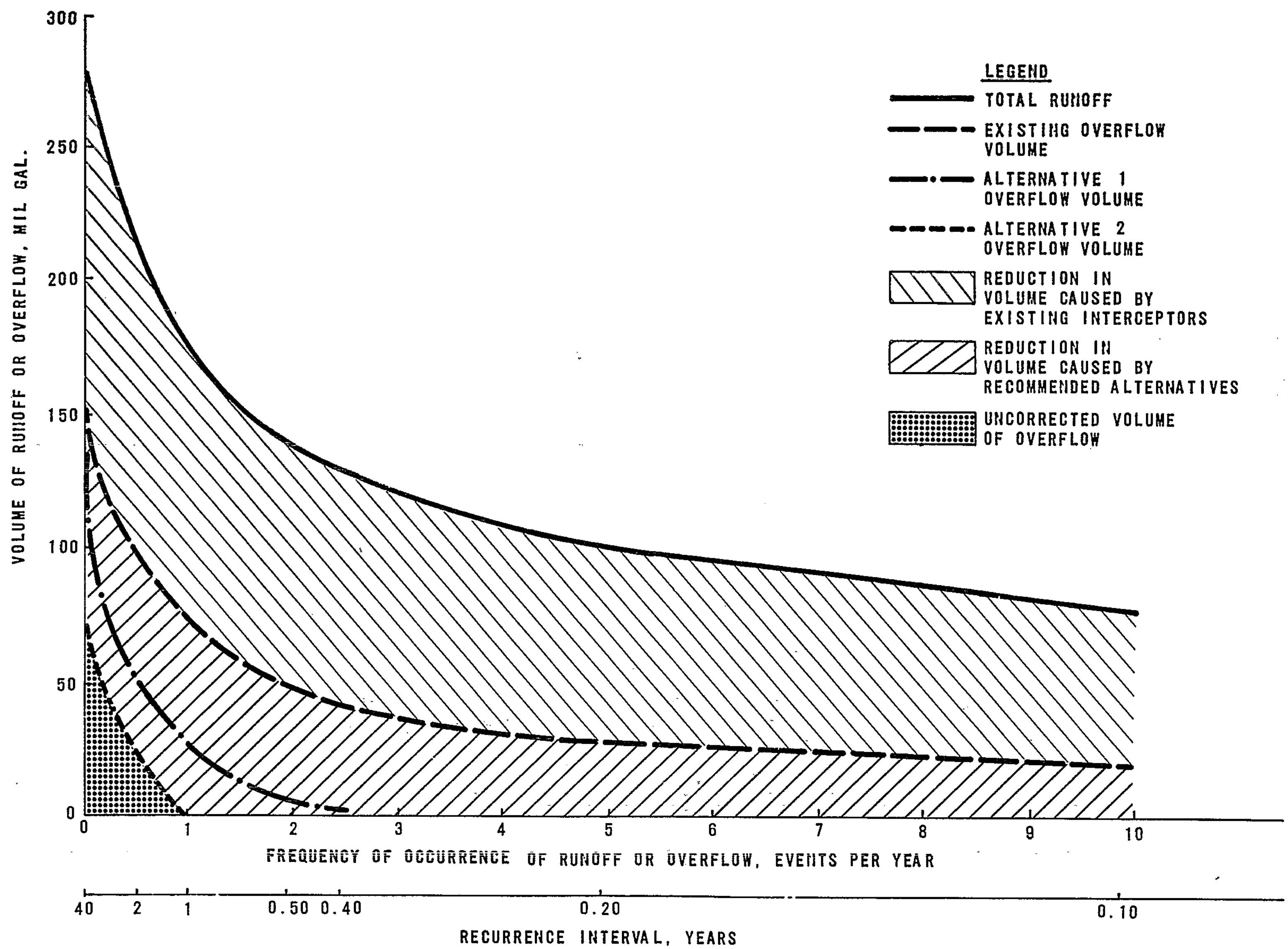


FIGURE 21. FREQUENCY OF OCCURRENCE OF RUNOFF AND OVERFLOWS

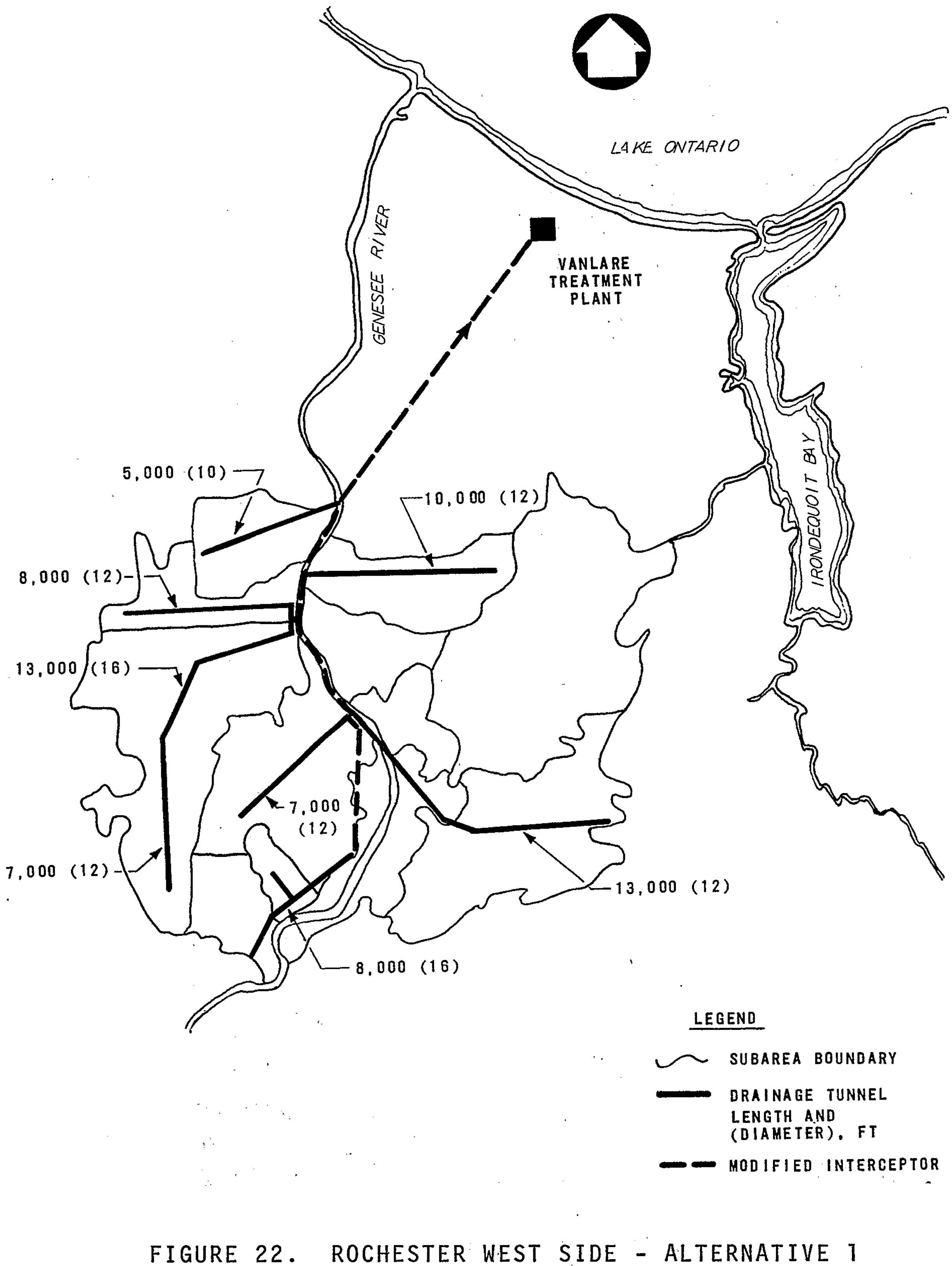


FIGURE 22. ROCHESTER WEST SIDE - ALTERNATIVE 1

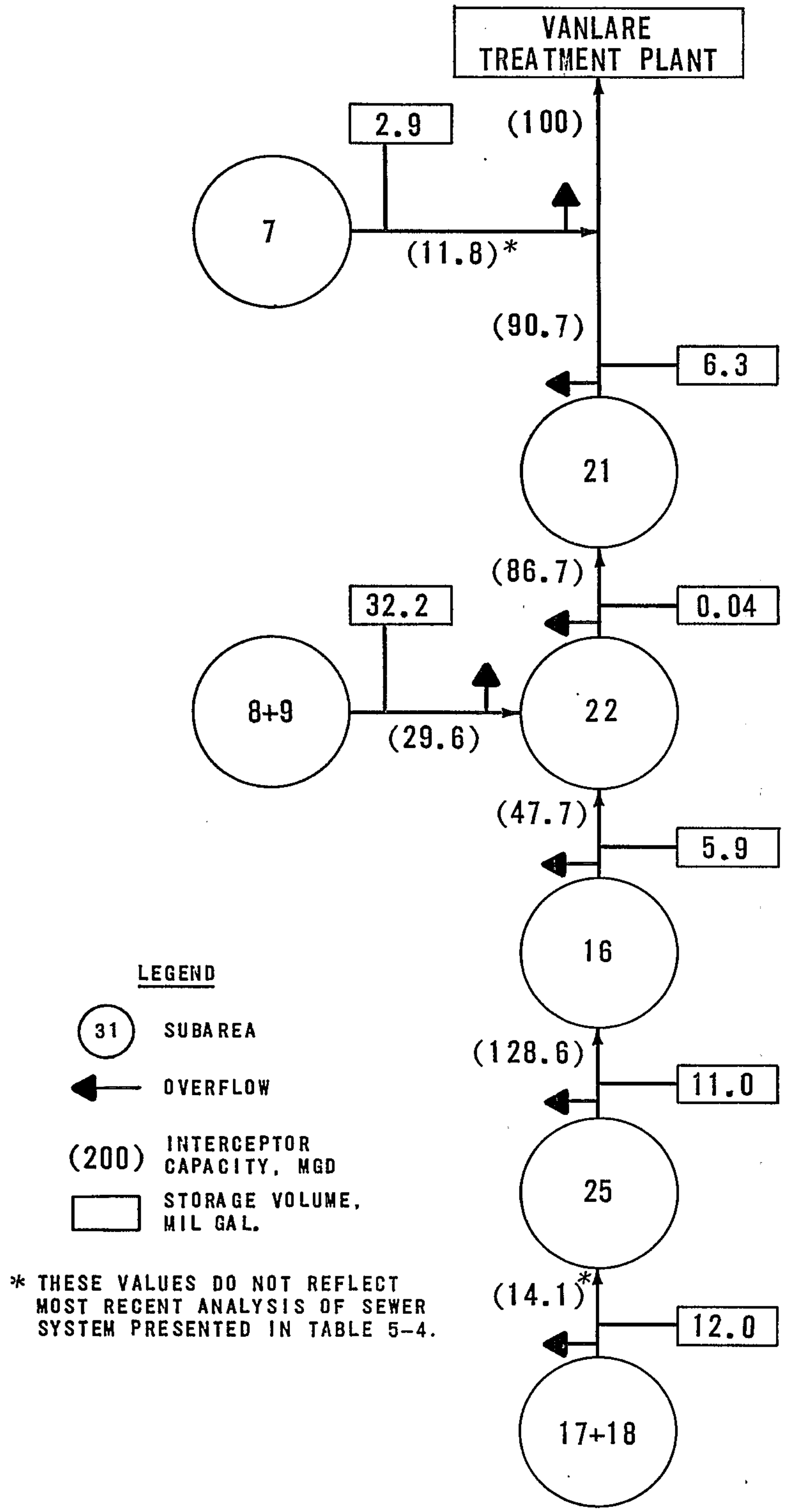


FIGURE 23. EXAMPLE OF SYSTEM SCHEMATIC - MODIFIED ROCHESTER WEST SIDE INTERCEPTORS

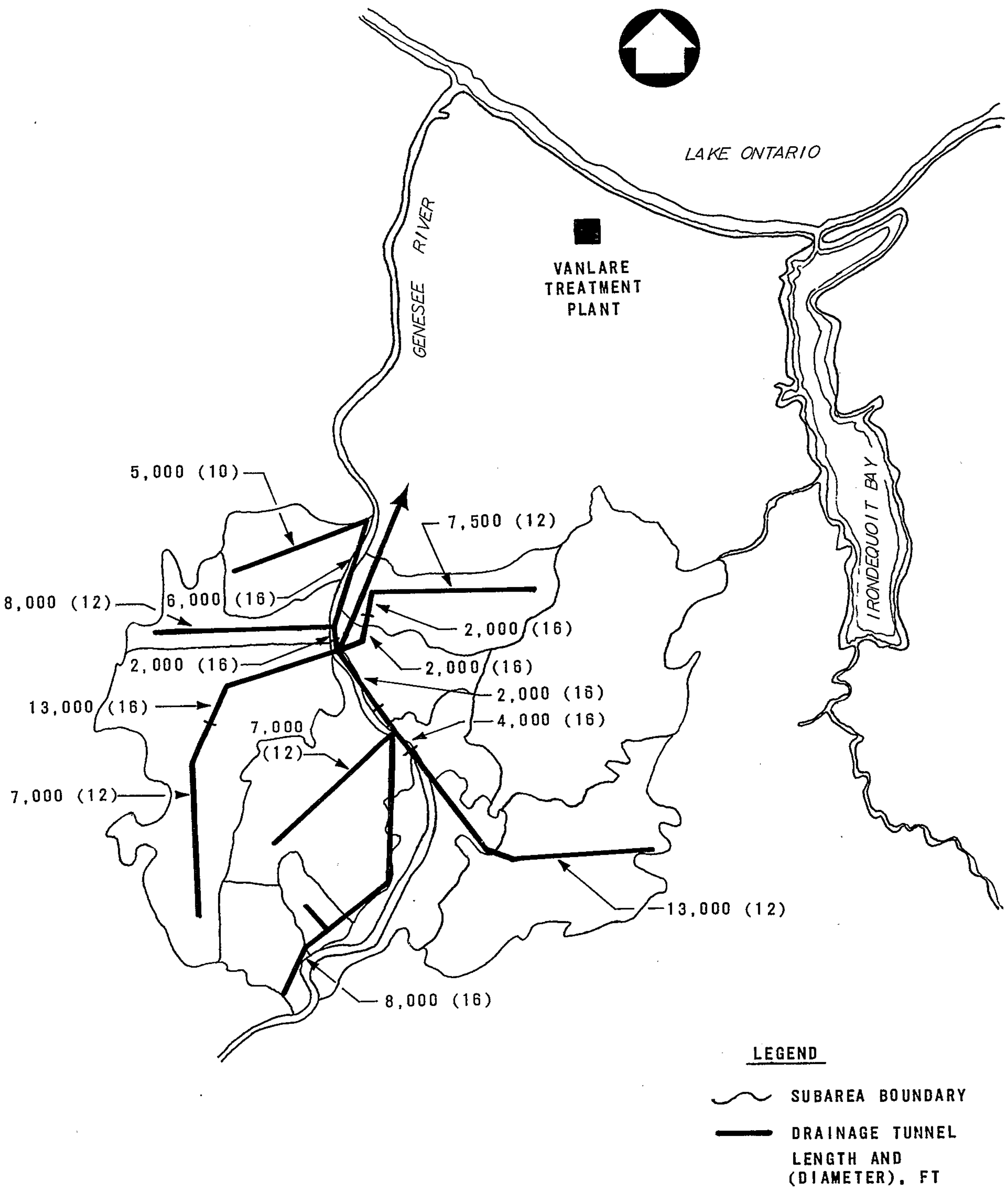


FIGURE 24. ROCHESTER WEST SIDE - ALTERNATIVE 2

The results from the analysis, presented in Figure 21, are based on use of the daily time step and the last 20 years of record from the Weather Bureau tapes. The volume of runoff and overflow for each day that runoff or overflow occurred was ranked, and the the frequency of occurrence curves were developed. These curves are based on real rainfall for a long period of record and therefore present statistically valid data.

Comparison of Daily and Hourly Analysis

Two critical periods were analyzed using the hourly interval on Alternative 2. These periods covered three of the largest storms in the period of record. The hourly analysis, as expected, provides more sensitive data than the daily analysis. These two analyses are compared in Table 18.

The daily and hourly results are compared graphically in Figure 26. One of the periods analyzed represents a large storm that was known locally as hurricane Agnes.

The concept of simplified modeling and the degree of precision in the basic assumption of the input data limit analysis on any finer time step than hourly. The input data to the model are limited by three assumptions: (1) that rainfall over the subarea is uniform, (2) that the K factor is a gross runoff coefficient, and (3) that travel times in the sewers (displacement of peak flow) are not accounted for.

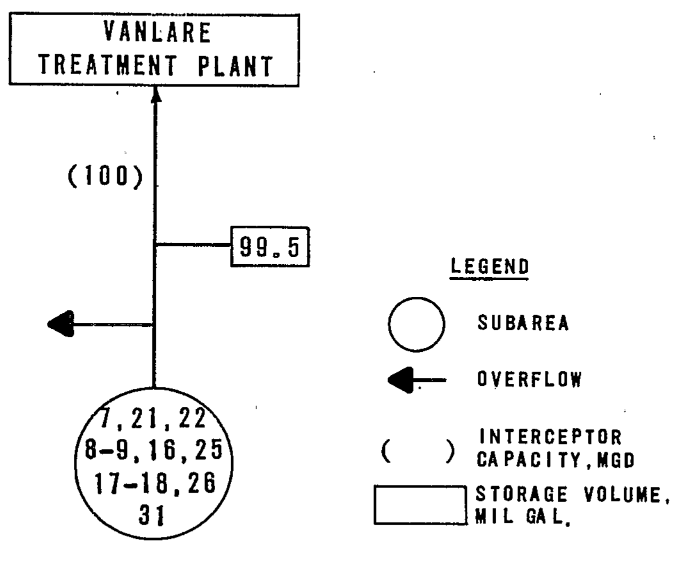


FIGURE 25. EXAMPLE OF SYSTEM SCHEMATIC - ALTERNATIVE 2

Table 18. COMPARISON OF DAILY AND HOURLY TIME INCREMENT ANALYSIS[a]

	Test Period 1	Test Period 2
Number of days	91	92
Number of days of rainfall	29	33
Total rainfall, in.	11.4	11.1
Percentage above 20-yr average	50.9	32.5
	Daily increment	Hourly increment
Total runoff, mil gal.[a]	2,679.3	2,679.3
Total overflow volume, mil gal.[a]	238.7	383.6
Overflow, % of total runoff[a]	8.9	14.3
Total number of days of rain[a]	62	62
Total number of days of overflow[a]	3	5[b]

a. Totals represent sum of Test Periods 1 and 2.

b. Storm of January 22-23 overflowed on both days when computed hourly. The second added overflow occurred on June 29-30 from a 6-hr storm that started 3 hrs before midnight and ended 3 hrs after midnight. The daily simulation distributed the storm's impact over 48 hrs; thus, no overflow. The hourly simulation properly compacted the storm to 6 hrs and the system capacity was exceeded between 12:00 midnight and 3:00 a.m. on June 30.

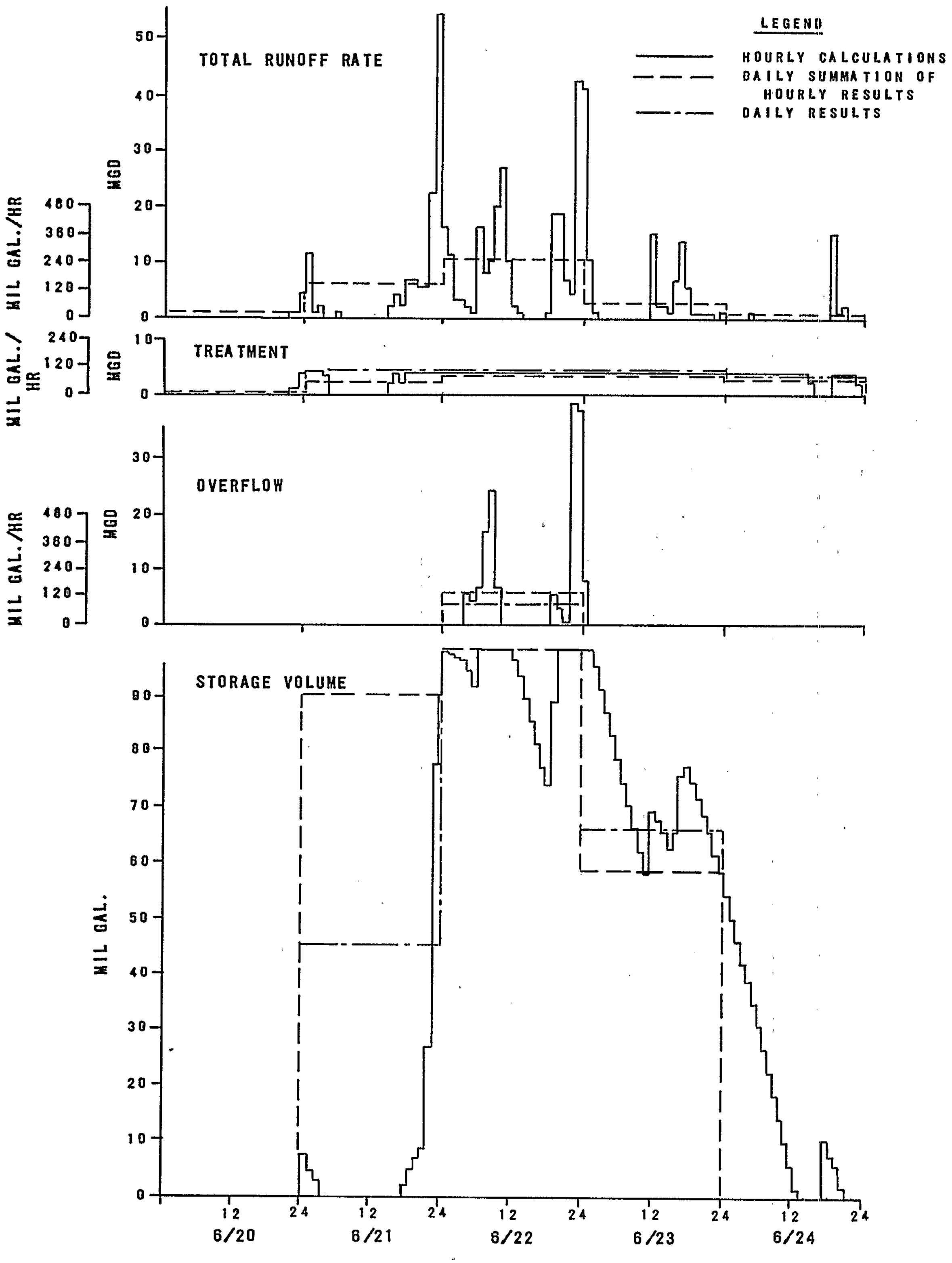


FIGURE 26. COMPARISON OF HOURLY AND DAILY ANALYSIS

SECTION VIII

OVERFLOW QUALITY ASSESSMENT

The assessment of overflow quality can be approached by two methods. In the first method, dirt and nutrient suspension and transportation are taken into consideration as in SWMM and STORM. In the second method, regression techniques and statistical manipulations of observations are used to extrapolate quality parameters from existing data. The second method is more direct and quite consistent with the concept of simplified modeling. A third method using geographic and demographic data based on nationally collected statistics also can be used. This technique is summarized in Appendix D.

Using the second method, two analyses are performed in this chapter to derive quality characteristics. In the first analysis, regression equations are developed on the basis of measured data that have been collected. In the second analysis, averages of selected subsets of the measured data are used to develop quality parameters.

(A third analysis based on polynominal regression techniques is presented in Appendix D. This third technique was not applied successfully in Rochester.)

The quality characteristics are developed in the form of a concentration that can be paired with an overflow volume. The volume overflowing is a function of the storm characteristics, the configuration of the drainage area, and the control alternative. This volume is calculated in the storage-treatment task. The quality of the overflow is also a function of the storm characteristics and the drainage area configuration.

REGRESSION ANALYSIS

The regression analysis is described in two parts: procedure and example of equations.

Procedure

Regression analysis is part of the broad area of fitting curves to measured data. In this analysis, equations based on linear regression are developed. (Specific equations based on the data acquired in Rochester are used in this discussion).

The linear regression analysis creates equations of the following form:

$$Q_1 = ax_1 + bx_2 + cx_3 + d$$

where Q_1 = quality parameter

$x_1 \ldots x_n$ = measured parameters

$a \ldots z$ = calculated regression coefficient

By using logarithms of the measured values and the same type of linear regression analysis, an equation of the following form can be developed:

$$Q_1 = x_1^a \; x_2^b \; x_3^c \; d$$

The quality of the regression analysis can be evaluated by checking the correlation of the values predicted from the equation with the real measured values using the correlation coefficient. The correlation coefficient has a maximum value of one and a minimum value of zero. The closer the calculated coefficient is to one, the better the correlation and, therefore, the better the predicting equation. These analyses can be performed with a package computer program, a programmable desk-top calculator, or hand calculations using matrix techniques.

From experience in the analysis of combined sewer overflows, it is known that the quality of the overflow varies with many factors. The most significant factors are the intensity of the rainfall, the antecedent condition (days since last rain), and the duration of the storm. Land use parameters, such as population density, quantity of commercial-industrial areas, and street cleaning policies, can also affect overflow quality.

Example of Equations

The regression equations are based on the quality data that are collected, as described in Section V. In the following analysis, two data sets are used. Data Set 1 (not included) contains the average of the composite samples from each subarea for each storm. This data set covers 29 storms between March 1974 and August 1975; two to seven subareas were averaged for each storm.

Data Set 2 (not included) contains all of the composite samples of all of the storms for each of the subareas. This data set covers the same storm period as Data Set 1 and is the unaveraged data set used to create Data Set 1. It contains 142 points covering 29 storms and 12 subareas.

Equations were fitted to these data using a package computer program that performs linear regression analysis. Several sets of equations to project COD, suspended solids, and nitrogenous oxygen demand (NOD) were developed. In the first and best set of equations, the rainfall characteristics and Data Set 1 were used to create equations to project the quality parameters. These equations are presented in Table 19. The quality parameters projected from these equations were correlated with Data Set 1 to check the equations. The correlation coefficients are not

Table 19. EQUATIONS FOR QUALITY PROJECTION

Equation	Correlation coefficient
$COD = 50.17\ X_1^{0.0705}\ X_2^{0.0761}\ X_3^{-0.407}$	0.257
$TSS = 159.62\ X_1^{0.220}\ X_2^{-0.345}\ X_3^{-0.329}$	0.181
$NOD = 1.89\ X_1^{-0.191}\ X_2^{-0.439}\ X_3^{-0.494}$	0.487

where COD = chemical oxygen demand, mg/l
TSS = total suspended solids, mg/l
NOD = nitrogenous oxygen demand, mg/l
X_1 = number of days since last rain, days
X_2 = duration of rainfall, hr
X_3 = average intensity of rainfall, in./hr

high because stormwater quality is highly variable, and the data that were developed from the sampling program had some major irregularities.

Attempts were also made to develop equations including population density to reflect the impact of land use patterns on stormwater quality. These equations were correlated with Data Set 2. The correlation coefficient indicated that there was essentially no correlation between the measured values and the predicted values from these equations. This lack of correlation may be because of irregularities in the data and because of the particular blend of land uses in the City of Rochester.

The composite samples used for the regression analysis were composited from individual samples taken at regular intervals in time starting with the beginning of an overflow occurrence. The individual samples that were taken are not directly related to flow and do not reflect quality variations that are flow related. A possibly more realistic composite would be one that is sampled proportionately with flow. A flow proportionate average could also be calculated if both the time of sample and volume of overflow were correlated. This correlation was not effectively achieved even with the extensive data collected in Rochester.

ANALYSIS OF AVERAGES

The analysis of averages is also described in two parts: procedure and example of averages.

Procedure

A large volume of data is generated from a sampling program. These data can be manipulated in several ways. One of the easiest ways is to calculate averages of meaningful subsets of the data. Two of the significant averages are (1) gross averages of the data by subarea and (2) averages for time increments by subarea.

These subarea averages can be ranked to indicate trends. The significant land use or surface characteristics can also be ranked. If these rankings are indicated on a simplified map of the study area, areal trends in overflow quality can be noted. The areas that create the most pollution can be assigned a high priority when projects to relieve overflows are to be designed and constructed.

While averaging by time increment and subarea can provide information on trends, it also can have another more valuable use. Because of the first-flush phenomenon, the concentrations of the overflow change. If the first flush is captured by a storage facility, then only the higher-quality wastewater overflows. This time increment average can provide more realistic quality values.

Examples of Averages

In Table 20, the average data from 31 storms in 1974 and 1975 are presented by subarea. Approximately 500 data points were averaged for each subarea. The values in Table 20 are arithmetic averages of the measured values. The geometric mean is usually used to characterize these phenomena, but, because of the large number of zero values from both actual measurement and inoperative equipment, the geometric mean is not truly valid and the arithmetic value more closely reflects the data.

In Table 21, the data have been averaged in time increments from the start of the storm and by subarea. These values are also arithmetic averages. From the data in Table 21, the phenomenon of decreasing concentrations of pollutants with time through the storm can be clearly seen.

Table 20. AVERAGE OVERFLOW QUALITY BY SUBAREA
mg/l

Subarea No.	Total inorganic phosphate	Biochemical oxygen demand	Total suspended solids	Nitrogenous oxygen demand
7	1.42	161	316	4.09
8	1.28	158	319	4.21
9	1.37	178	358	4.42
16	1.37	188	366	4.31
17	1.38	186	358	4.29
18	1.37	183	354	4.25
21	1.34	203	381	4.04
22	1.35	205	...	4.06
25	1.04	53	...	2.35
26	1.08	52	205	2.27
28	2.85	66	291	3.38
31	0.50	60	168	2.41

Table 21. EXAMPLE OF AVERAGE OVERFLOW QUALITY BY SUBAREA AND TIME INCREMENT

Subarea	BOD, mg/l				TSS, mg/l			
	0-30 min	30-60 min	60-90 min	90+ min	0-30 min	30-60 min	60-90 min	90+ min
7	224	136	66	--[a]	578	506	216	198
8	208	63	53	59	247	136	137	210
9	146[b]	176[b]	147[b]	122	--[c]	200[b]	228[b]	219
16	152	159	138	55	260	357	718	313
17	131[b]	--[c]	140[b]	23	114	--[c]	469[b]	129
18	143	140	65	50	368	586	229	142
21	83	45	43	75	147	101	80	127
22	--[a]	--[a]	--[a]	--[a]	836	559	539	425
25	75	48	65	44	435	347	316	123
26	48	68	17	13	685	--[a]	429	117
28	74	61	55	62	270	231	244	239
29	33	34	39	22	165	137	158	120
31	196	105	83	47	251	216	227	140

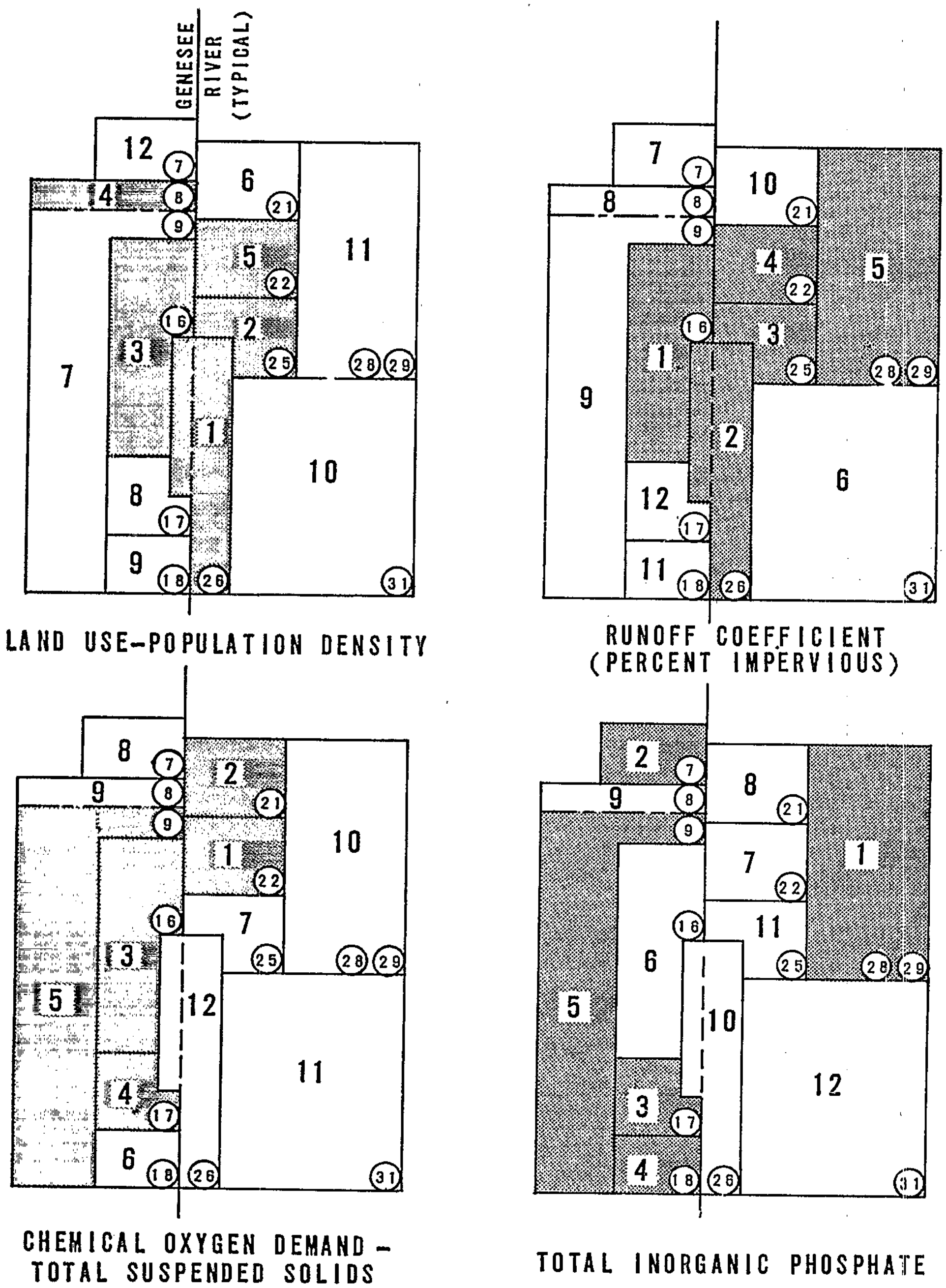
a. Average values are extremely high due to data irregularities and therefore are not valid.

b. Insufficient data for statistically significant results.

c. No data recorded.

In Figure 27, the rankings of population density and the runoff coefficients are presented along with the rankings of some significant quality parameters (based on data in Table 20). The land use-population density ranking was developed by creating a weighted average of the ranking of commercial-industrial land and the ranking of the population density. This means that the area with the greatest population density and the most commercial-industrial land would be the source of the greatest pollution. In this figure, the low numbers imply the worst conditions. The five areas with the lowest numbers in each category are shaded for emphasis and to highlight any trends that may be present.

The area served by the West Side trunk sewer (Area 9--shaded in the lower half of Figure 27) are not the sources of highly concentrated pollutants that might be expected (possibly because of the location of the overflow and system characteristics). The information presented in Figure 27 can assist the decision maker in translating an abundance of data into specific problems in various parts of the study area.



LEGEND: LOWEST RANKING NUMBER GIVEN TO HIGHEST CONCENTRATION, POPULATION, OR PERCENTAGE OF COMMERCIAL INDUSTRIAL AREA. RANKS 1-5 SHADED FOR EMPHASIS.

(31) SUBAREA NUMBER

7 RANK NUMBER

FIGURE 27. EXAMPLE OF OVERFLOW QUALITY TRENDS

SECTION IX

RECEIVING WATER RESPONSE

The impact of combined sewer overflows on the receiving water is the most difficult and the most critical task that must be performed. At the present time, a simplified solution does not exist. The next alternative is to use the best available simulation of the receiving water that has a record of use in the area. Even when a program has a history of use, it is important to define the specific characteristics, limitations, and input-output requirements of the program as they apply to the system of discharges and receiving water being analyzed.

CHARACTERISTICS OF THE RECEIVING WATER PROGRAM

The basic approach and assumptions of the receiving water program are important. There are many approaches that can be used, and it is important to document the specific approach so that any internal limitations of the program are clearly understood.

Some of the most significant aspects of the approach are:

- The quality parameters that are analyzed
- The time frame of the program: steady state or dynamic
- The basic equations that are used
- The source of reaction or decay rates
- The factors used for calibration of the program

For the City of Rochester, a program of the Genesee River prepared by O'Brien and Gere for the Environmental Protection Agency (Contract No. 68-01-1574) was used[1]. In this program a modified Streeter-Phelps formulation was used to calculate steady-state dissolved oxygen concentrations in the Genesee River. The purpose of the modification was to allow the use of separate decay rates for carbonaceous material and for nitrogenous material. An additional term was also added to the equation to calculate the benthic oxygen demand. This benthic factor was used to calibrate the program.

The decay coefficients used in the program were calculated for each section of the river by the standard O'Connor equation. These coefficients are based on existing river characteristics and were not adjusted to calibrate the program.

LIMITATIONS OF THE RECEIVING WATER PROGRAM

Many factors can limit the applicability of a program. The most significant limitations are the range of flows and conditions for which the program is calibrated. The program could be calibrated for only summer conditions which may be significantly different from winter conditions. Flows during the spring rainy season and winter thaw may be substantially different from flows during a dry spell in the fall. If the program is not calibrated for the time of year and flow conditions that are thought to be critical, recalibration may be required, or a new program may have to be found.

The Genesee River program was calibrated for an "average" condition. This average condition is the period from mid-July through mid-October of 1973. The program was also operated under the Minimum Average Seven Consecutive Day flow condition that is expected to recur once in a 10-year period (MA7CD/10). Data on river flows and reaction rates were developed for these two conditions. While these two conditions represent critical flow period in the river, they do not necessarily represent a typical condition when storm overflows would occur.

The average condition that the Genesee River program was calibrated for does not represent the river during storms. Imposing simulated storm overflows on this average condition will result in dissolved oxygen depletions greater than those actually occurring during storms. This deviation is not expected to be extreme enough to warrant recalibration of the program.

SPECIFIC REQUIREMENTS OF THE RECEIVING WATER PROGRAM

This program and the Genesee River are discussed at length in the report prepared for the Environmental Protection Agency titled *The Investigation of Eleven Special Attention Areas in the Great Lakes Region - Genesee River Basin* [1].

The specific details of the program are presented in that report. The program itself is written in FORTRAN and was modified slightly for use in the simplified approach.

The format for the input data is presented in Table 22. Most of the data that are required describe the river and its reaction rates. The data for the base condition are presented in Table 23. Only a small portion of these data must be altered for input of a stormwater overflow.

The river was modeled by a series of "reaches." Each reach is a segment of the river that has, at its beginning, a pollution source. The reaches are shown in Figure 28.

For each reach the characteristics of the river and data on any discharges to the river are input to the program. To include a stormwater overflow, the loading from an overflow is added to the existing parameters. This creates a new data set that can be input to the program.

EXAMPLE OF THE GENESEE RIVER PROGRAM APPLIED TO STORMWATER OVERFLOWS

The data for the base condition, as mentioned earlier, represent an average of the summer-fall flow conditions. The overflow data are derived from the storage-treatment and quality tasks.

The important flow and quality parameters for the overflow from the existing interceptor system that occurred on June 22, 1973, are presented in Table 24. This information is combined with the data for the base condition and forms a new data set for the program. The data are combined on the basis of a mass loading. This means that if a discharge exists, the flows are added. The quality parameters are combined by adding the individual flows multiplied by quality concentration and divided by the total flow to get a new quality value. This method was used for the Court SW discharge. There was no storm flow for the Maplewood and Sethgreen overflows, and the stormwater quality was substituted for the existing discharge quality. (This substitution may not be valid and would depend on the specific relationship between the existing discharges and the stormwater discharges). The new data set is presented in Table 25.

A partial sample of the output for the condition that is discussed is presented in Table 26. The dissolved oxygen concentrations calculated for the portion of the river that

Table 22. FORMAT FOR RECEIVING WATER PROGRAM DATA

Card group	Format	Card columns	Description	Variable name
	3I2	1-6	Date of computer printout	
		(1-2)	Month	NMO
		(3-4)	Day	NDAY
		(5-6)	Year	NYR
	2F5.0	41-45	Calculation interval in river miles	CINT
		46-50	Print interval in river mile	PINT
	29A1	52-80	Title	ITIT
	I1	1	Card number	LX
	14A1	2-15	Name of reach	KCARD
	12F5.0	16-20	Distance of reach	XIN(1)
		21-25	Velocity in reach	XIN(2)
		26-30	Time in reach	XIN(3)
		31-35	Streamflow	XIN(4)
		36-40	Dissolved oxygen level	XIN(5)
		41-45	Carbon oxygen demand	XIN(6)
		46-50	Nitrogen oxygen demand	XIN(7)
		51-55	Deoxygenation coefficient (carbon)	XIN(8)
		56-60	Deoxygenation coefficient (nitrogen)	XIN(9)
		61-65	Reaeration coefficient	XIN(10)
		66-70	Dispersion coefficient (estuary)	XIN(11)
		71-75	Benthic demand	XIN(12)
		76-80	Bottom surface area	XIN(13)
	14F5.0	11-15	Dissolved oxygen concentration at saturation	DOSAT
		16-20	Distance before first reach	DO
		21-25	Velocity before first reach	UO
		26-30	Time before first reach	TO
		31-35	Streamflow	FO
		36-40	Dissolved oxygen level	DØO
		41-45	Carbon oxygen demand	ØDCO
		46-50	Nitrogen oxygen demand	ØDNO
		51-55	Deoxygenation coefficient (carbon)	XK10
		56-60	Deoxygenation coefficient (nitrogen)	XK20
		61-65	Reaeration coefficient	XK30
		66-70	Dispersion coefficient (estuary)	EO
		71-75	Benthic demand	BO
		76-80	Bottom surface area	AO

Table 23. EXAMPLE OF RECEIVING WATER PROGRAM
INPUT DATA FOR BASE CONDITION

REACH NAME	REACH LENGTH	VELOC.	TIME	START TIME	FLOW	D.O.	COD	NCD	K1	K2	K3	ESTU. CONST	BENTH. DEMAND	BOTTOM AREA
	0.00	8.20	0.00		214.00	7.80	3.24	1.76	0.080	0.075	0.208	0.000	0.00	0.00

OXYGEN SATURATION LEVEL = 9.20

REACH NAME	REACH LENGTH	VELOC.	TIME	START TIME	FLOW	D.O.	COD	NCD	K1	K2	K3	ESTU. CONST	BENTH. DEMAND	BOTTOM AREA
NO INFLOW	0.30	8.20	0.04	0.00	0.00	0.00	0.00	0.00	0.080	0.075	0.208	0.000	0.00	0.00
AVON STP	7.70	8.20	0.94	0.04	2.75	4.00	9.00	42.00	0.080	0.075	0.208	0.000	0.00	0.00
HONEOYE CREEK	4.30	7.35	0.59	0.98	1.20	8.00	2.17	2.83	0.080	0.075	0.208	0.000	0.00	0.00
OATKA CREEK	2.20	7.35	0.30	1.56	22.00	10.80	1.00	4.00	0.080	0.075	0.318	0.000	0.00	0.00
SCOTTSVILLE	6.00	7.22	0.83	1.86	0.01	4.00	13.12	61.25	0.080	0.075	0.318	0.000	0.00	0.00
BLACK CREEK	0.50	7.40	0.07	2.69	15.00	8.00	2.17	2.83	0.067	0.060	0.208	0.000	0.00	0.00
GCO STP	2.30	7.40	0.31	2.76	11.90	4.00	11.11	51.80	0.067	0.060	0.208	0.000	0.00	0.00
BARGE CANAL	0.70	7.17	0.10	3.07	242.00	6.60	5.71	3.27	0.070	0.063	0.205	0.000	0.00	0.00
BROOKS SW	0.40	7.35	0.05	3.17	0.00	0.00	0.00	0.00	0.070	0.063	0.208	0.000	0.00	0.00
PLYMOUTH SW	2.00	7.60	0.26	3.22	0.00	0.00	0.00	0.00	0.070	0.063	0.208	0.000	0.00	0.00
COURT SW	0.75	7.60	0.10	3.48	2.00	2.00	22.47	32.51	0.070	0.063	0.210	0.000	0.00	0.00
CENTRAL SW	0.40	7.60	0.05	3.58	0.00	0.00	0.00	0.00	0.070	0.063	0.210	0.000	0.00	0.00
MILL-FACTORY	0.20	7.60	0.03	3.64	0.00	0.00	0.00	0.00	0.070	0.063	0.210	0.000	0.00	0.00
BAUSCH & LOMB	0.50	7.60	0.07	3.66	15.00	4.00	1.85	1.85	0.070	0.063	0.210	0.000	0.00	0.00
CARTHAGE SW	0.50	7.60	0.07	3.73	0.00	0.00	0.00	0.00	0.070	0.063	0.210	0.000	0.00	0.00
LEXINGTON SW	0.50	7.60	0.07	3.79	0.00	0.00	0.00	0.00	0.070	0.063	0.210	0.000	0.00	0.00
SETHGREEN SW	0.70	7.60	0.09	3.86	2.00	2.00	164.40	35.60	0.070	0.063	0.210	0.000	0.00	0.00
MAPLEWOOD SW	0.45	8.15	0.06	3.95	3.00	2.00	290.00	5.50	0.090	0.084	0.155	0.000	0.00	0.00
KODAK STP	3.60	7.55	0.48	4.01	28.00	4.00	5.36	8.50	0.090	0.084	0.120	1.500	0.62	1.00
IRON-ST PAUL	0.70	7.92	0.09	4.48	1.25	4.00	11.00	51.23	0.085	0.101	0.047	1.500	0.13	0.74

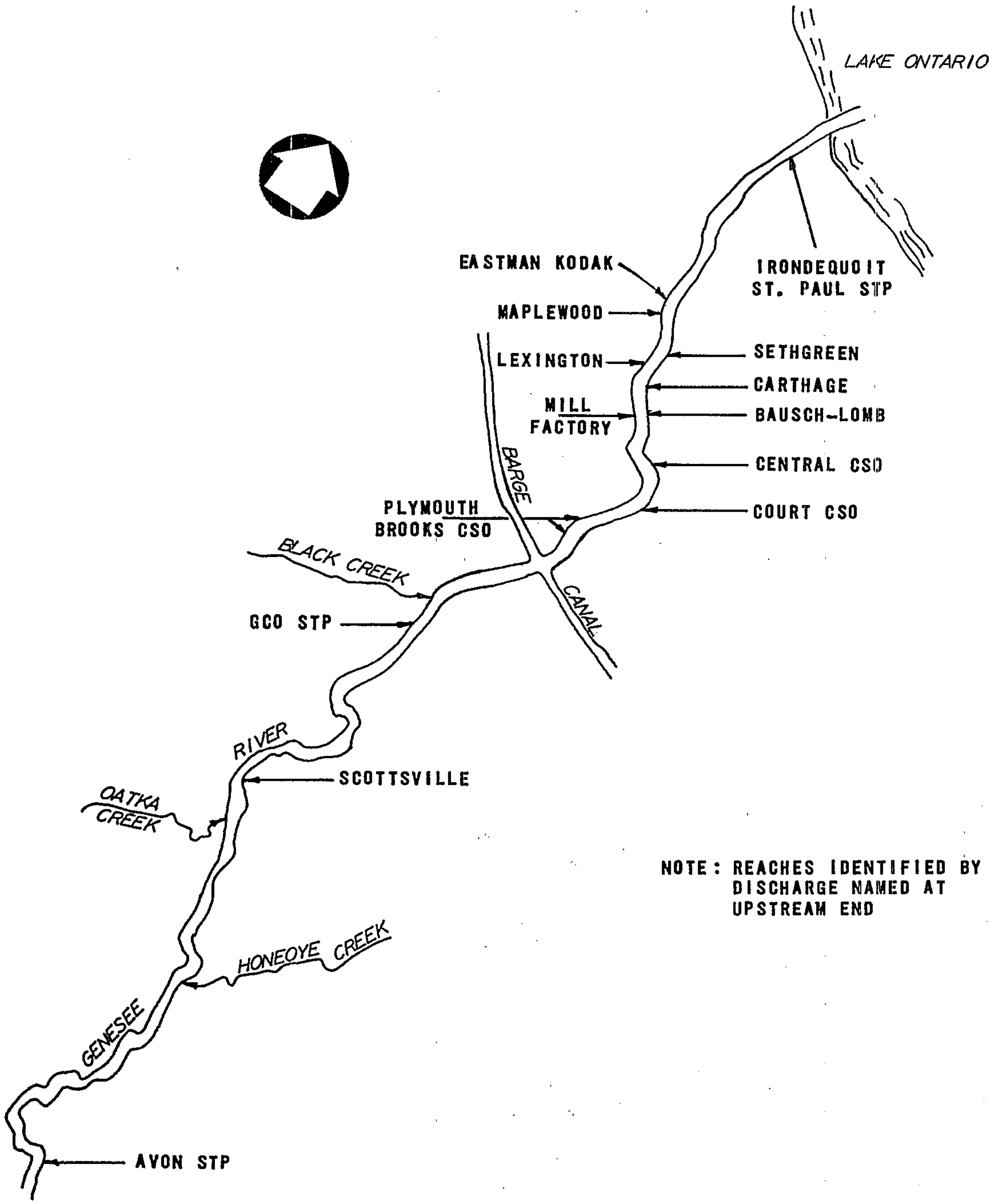


FIGURE 28. GENESEE RIVER REACHES FOR THE RECEIVING WATER PROGRAM

Table 24. EXAMPLE OF DATA FOR OVERFLOWS FROM STORM ON JUNE 22, 1973

Reach name	Flow, mgd	Dissolved oxygen, mg/l	Carbonaceous oxygen demand, mg/l	Nitrogenous oxygen demand, mg/l
Plymouth SW	16.29	3.5	74.0	14.2
Court SW	8.88	3.8	154.3	36.5
Central SW	5.14	3.5	87.0	9.9
Mill-Factory	46.93	3.5	94.0	5.0
Lexington	77.73	3.5	145.9	15.1
Sethgreen	.....	3.5	134.0	32.4
Maplewood	.....	3.5	82.0	14.9

a. Carbonaceous oxygen demand - 5-day biochemical oxygen demand is used.

b. Nitrogenous oxygen demand - usually the concentration of ammonia plus organic nitrogen is used. A stochiometric factor is used to calculate the oxygen demand for these compounds.

was analyzed are presented graphically in Figure 29. The dissolved oxygen concentrations for the base condition are also indicated as a reference.

There are two specific limitations in the analysis of storm flows. During storms the flow in the river would be higher than the condition that is modeled due to rainfall over the entire basin. The effect of this increase in flow cannot be readily tabulated. The program also uses a plug flow type of analysis. This means that a specific volume of water moves downstream as a slug, with reactions occurring and pollutants accumulating within this slug.

These two limitations are significant, and therefore this particular program (type of model) should be used only to indicate trends and not to tabulate the specific dissolved oxygen concentration. A revision to this program, currently being prepared by O'Brien and Gere, will make it possible to analyze more constituents and will also result in a dynamic representation of the river.

Table 25. EXAMPLE OF RECEIVING WATER PROGRAM INPUT DATA FROM STORM ON JUNE 22, 1973

REACH NAME	REACH LENGTH	VELOC.	TIME	START TIME	FLOW	D.O.	COD	NOD	K1	K2	K3	ESTU. CONST	BENTH. DEMAND	BOTTOM AREA
	0.00	8.20	0.00		214.00	7.80	3.24	1.76	0.080	0.075	0.208	0.000	0.00	0.00
OXYGEN SATURATION LEVEL = 9.20														
NO INFLOW	0.30	8.20	0.04	0.00	0.00	0.00	0.00	0.00	0.080	0.075	0.208	0.000	0.00	0.00
AVON STP	7.70	8.20	0.94	0.04	2.75	4.00	9.00	42.00	0.080	0.075	0.208	0.000	0.00	0.00
HONEOYE CREEK	4.30	7.35	0.59	0.98	1.20	8.00	2.17	2.83	0.080	0.075	0.208	0.000	0.00	0.00
OATKA CREEK	2.20	7.35	0.30	1.56	22.00	10.80	1.00	4.00	0.080	0.075	0.318	0.000	0.00	0.00
SCOTTSVILLE	6.00	7.22	0.83	1.86	0.01	4.00	13.12	61.25	0.080	0.075	0.318	0.000	0.00	0.00
BLACK CREEK	0.50	7.40	0.07	2.69	15.00	8.00	2.17	2.83	0.067	0.060	0.208	0.000	0.00	0.00
GCC STP	2.30	7.40	0.31	2.76	11.90	4.00	11.11	51.80	0.067	0.060	0.208	0.000	0.00	0.00
BARGE CANAL	0.70	7.17	0.10	3.07	242.00	6.60	5.71	3.27	0.070	0.063	0.205	0.000	0.00	0.00
BROOKS SW	0.40	7.35	0.05	3.17	0.00	0.00	0.00	0.00	0.070	0.063	0.208	0.000	0.00	0.00
PLYMOUTH SW	2.00	7.60	0.26	3.22	16.29	3.50	74.00	14.20	0.070	0.063	0.208	0.000	0.00	0.00
COURT SW	0.75	7.60	0.10	3.48	10.88	3.50	130.00	36.01	0.070	0.063	0.210	0.000	0.00	0.00
CENTRAL SW	0.40	7.60	0.05	3.58	5.14	3.50	87.00	9.90	0.070	0.063	0.210	0.000	0.00	0.00
MILL-FACTORY	0.20	7.60	0.03	3.64	46.93	3.50	94.00	5.00	0.070	0.063	0.210	0.000	0.00	0.00
BAUSCH & LOMB	0.50	7.60	0.07	3.66	15.00	4.00	1.85	1.85	0.070	0.063	0.210	0.000	0.00	0.00
CARTHAGE SW	0.50	7.60	0.07	3.73	0.00	0.00	0.00	0.00	0.070	0.063	0.210	0.000	0.00	0.00
LEXINGTON SW	0.50	7.60	0.07	3.79	77.73	3.50	145.90	15.10	0.070	0.063	0.210	0.000	0.00	0.00
SETHGREEN SW	0.70	7.60	0.09	3.86	2.00	3.50	134.00	32.40	0.070	0.063	0.210	0.000	0.00	0.00
MAPLEWOOD SW	0.45	8.15	0.06	3.95	3.00	3.50	82.00	14.90	0.090	0.084	0.155	0.000	0.00	0.00
KODAK STP	3.60	7.55	0.46	4.01	28.00	4.00	5.36	8.50	0.090	0.084	0.120	1.500	0.62	1.00
IRON-ST PAUL	0.70	7.92	0.09	4.48	1.25	4.00	11.00	51.23	0.085	0.101	0.047	1.500	0.13	0.74

Table 26. EXAMPLE OF OUTPUT FROM RECEIVING WATER PROGRAM FOR STORM ON JUNE 22, 1973

		OXYGEN DEMAND								OXYGEN			
		CARBONACEOUS		NITROGENEOUS		BENTHIC		TOTAL		DEFICIT	LEVEL	FLOW	
TIME	DIST.	MG/L	POUNDS	MG/L	POUNDS	MG/L	POUNDS	MG/L	POUNDS	MG/L	MG/L	MGD	
3.37	25.50	6.26	27384.	4.02	17606.	0.00	1.	10.28	44989.	2.18	7.03	525.15	
3.38	25.60	6.25	27358.	4.02	17592.	0.00	1.	10.27	44950.	2.18	7.03	525.15	
3.40	25.70	6.25	27333.	4.02	17577.	0.00	1.	10.26	44910.	2.19	7.02	525.15	
3.41	25.80	6.24	27308.	4.01	17562.	0.00	1.	10.25	44870.	2.19	7.02	525.15	
3.42	25.90	6.23	27283.	4.01	17548.	0.00	1.	10.24	44830.	2.19	7.02	525.15	
3.44	26.00	6.23	27258.	4.01	17533.	0.00	1.	10.23	44791.	2.19	7.02	525.15	
3.45	26.10	6.22	27233.	4.00	17519.	0.00	1.	10.22	44751.	2.20	7.01	525.15	
3.46	26.20	6.22	27208.	4.00	17504.	0.00	1.	10.21	44711.	2.20	7.01	525.15	
3.48	26.30	6.21	27183.	4.00	17490.	0.00	1.	10.20	44672.	2.20	7.01	525.15	
3.49	26.40	8.72	38967.	4.65	20750.	0.00	1.	13.36	59717.	2.28	6.93	536.03	COURT SW
3.50	26.50	8.71	38931.	4.64	20733.	0.00	1.	13.35	59664.	2.28	6.93	536.03	
3.52	26.60	8.71	38895.	4.64	20716.	0.00	1.	13.34	59611.	2.29	6.92	536.03	
3.53	26.70	8.70	38859.	4.64	20699.	0.00	1.	13.33	59558.	2.29	6.92	536.03	
3.54	26.80	8.69	38824.	4.63	20682.	0.00	1.	13.32	59505.	2.30	6.91	536.03	
3.56	26.90	8.68	38788.	4.63	20665.	0.00	1.	13.30	59452.	2.30	6.91	536.03	
3.57	27.00	8.67	38752.	4.62	20647.	0.00	1.	13.29	59399.	2.31	6.90	536.03	
3.58	27.10	8.67	38717.	4.62	20630.	0.00	1.	13.28	59346.	2.31	6.90	536.03	
3.59	27.20	9.41	42427.	4.67	21046.	0.00	1.	14.07	63473.	2.35	6.86	541.17	CENTRAL SW
3.61	27.30	9.40	42388.	4.66	21029.	0.00	1.	14.06	63417.	2.36	6.85	541.17	
3.62	27.40	9.39	42349.	4.66	21012.	0.00	1.	14.04	63360.	2.36	6.85	541.17	
3.63	27.50	9.38	42310.	4.66	20994.	0.00	1.	14.03	63304.	2.37	6.84	541.17	
3.65	27.60	16.13	79067.	4.68	22942.	0.00	1.	20.80	102008.	2.64	6.57	588.10	MILL-FACTORY
3.66	27.70	16.11	78994.	4.68	22923.	0.00	1.	20.78	101916.	2.65	6.56	588.10	
3.67	27.80	15.75	79190.	4.61	23145.	0.00	1.	20.35	102335.	2.72	6.49	603.10	BAUSCH & LOMB
3.69	27.90	15.73	79118.	4.60	23126.	0.00	1.	20.33	102243.	2.73	6.48	603.10	
3.70	28.00	15.72	79045.	4.60	23107.	0.00	1.	20.31	102151.	2.74	6.47	603.10	
3.71	28.10	15.71	78972.	4.60	23088.	0.00	1.	20.30	102059.	2.75	6.46	603.10	
3.73	28.20	15.69	78899.	4.59	23069.	0.00	1.	20.28	101967.	2.76	6.45	603.10	
3.74	28.30	15.68	78865.	4.59	23060.	0.00	1.	20.27	101924.	2.77	6.44	603.10	GARTHAGE SW
3.75	28.40	15.67	78792.	4.59	23040.	0.00	1.	20.25	101832.	2.78	6.43	603.10	
3.77	28.50	15.66	78719.	4.58	23021.	0.00	1.	20.23	101740.	2.79	6.42	603.10	
3.78	28.60	15.64	78647.	4.58	23002.	0.00	1.	20.21	101649.	2.80	6.41	603.10	
3.79	28.70	15.63	78575.	4.57	22983.	0.00	1.	20.20	101557.	2.81	6.40	603.10	
3.81	28.80	30.49	173081.	5.77	32759.	0.00	1.	36.26	205839.	3.15	6.06	680.83	LEXINGTON SW
3.82	28.90	30.46	172921.	5.77	32732.	0.00	1.	36.22	205653.	3.18	6.03	680.83	
3.83	29.00	30.43	172762.	5.76	32705.	0.00	1.	36.19	205466.	3.20	6.01	680.83	
3.84	29.10	30.40	172603.	5.76	32678.	0.00	1.	36.16	205280.	3.22	5.99	680.83	
3.86	29.20	30.37	172444.	5.76	32651.	0.00	1.	36.13	205094.	3.25	5.96	680.83	
3.87	29.30	30.66	174603.	5.83	33178.	0.00	1.	36.49	207780.	3.27	5.94	682.83	SETHGREEN SW
3.88	29.40	30.64	174442.	5.83	33151.	0.00	1.	36.46	207592.	3.29	5.92	682.83	
3.90	29.50	30.61	174281.	5.82	33123.	0.00	1.	36.42	207404.	3.31	5.90	682.83	
3.91	29.60	30.58	174121.	5.82	33096.	0.00	1.	36.39	207216.	3.34	5.87	682.83	
3.92	29.70	30.55	173961.	5.81	33068.	0.00	1.	36.36	207028.	3.36	5.85	682.83	
3.94	29.80	30.52	173800.	5.81	33041.	0.00	1.	36.33	206841.	3.39	5.82	682.83	
3.95	29.90	30.50	173640.	5.80	33013.	0.00	1.	36.29	206653.	3.41	5.80	682.83	
3.96	30.00	30.71	175600.	5.84	33370.	0.00	1.	36.54	208969.	3.43	5.78	685.83	MAPLEWOOD SW
3.97	30.10	30.67	175406.	5.83	33336.	0.00	1.	36.50	208741.	3.47	5.74	685.83	
3.99	30.20	30.64	175213.	5.83	33301.	0.00	1.	36.46	208513.	3.50	5.71	685.83	
4.00	30.30	30.60	175019.	5.82	33267.	0.00	1.	36.42	208286.	3.53	5.68	685.83	
4.01	30.40	29.62	176281.	5.93	35255.	0.01	52.	35.55	211587.	3.62	5.59	713.83	KODAK STP
4.02	30.50	28.90	172016.	5.79	34431.	0.03	154.	34.71	206600.	3.92	5.29	713.83	

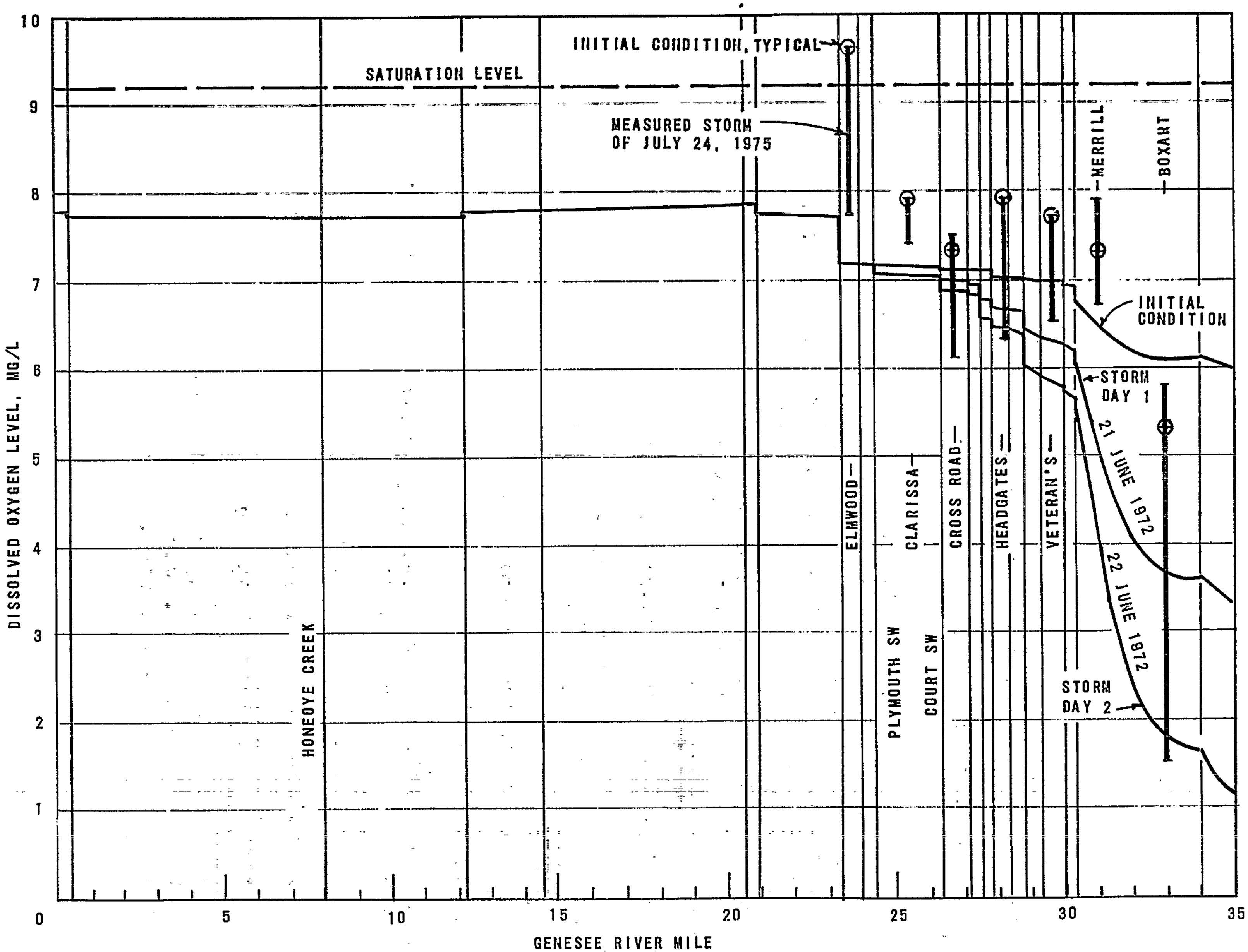


FIGURE 29. COMPUTED DISSOLVED OXYGEN IN GENESEE RIVER

SECTION X

APPLICATION OF THE SIMPLIFIED STORMWATER MANAGEMENT MODEL

In the introduction the characteristics of a simplified model were enumerated.

> "...This tool must be inexpensive to set up and use, flexible enough to be applicable to a variety of system configurations, and accurate even though only very moderate expenditures are made for data collection and preparation."

In this chapter the specifics of how the simplified model meets these needs will be presented. Among the items that will be discussed are:

- The computer size requirements and operating costs
- The ability of the simplified model to analyze various drainage basins
- The relationship between simplified stormwater management modeling and the more complex models.

COMPUTER REQUIREMENTS

In the simplified stormwater management model a high speed digital computer is used in three tasks:

- Rainfall Characterization
- Storage-Treatment Balance
- Receiving Water Response

As described in Section I small independent computer programs are used for each analysis. The use of small programs effectively reduces the overall computer hardware requirement of the simplified model.

Hardware Requirements

The computer programs for the simplified stormwater management model have been developed on an IBM 360/67 digital computer. The storage-treatment program (the most complex program in the model) has been used successfully on a XEROX 560 computer (approximately equal to an IBM 1620) and an IBM 1130. For continued use on an IBM 1130 some program modifications would have to be made.

For general use of all of the simplified stormwater management model's programs a computer with approximately 40K of core storage and a FORTRAN compiler would be required. In addition, the programs use both disk and tape peripheral storage devices and a card reader.

Cost of Computer Usage

The programs are currently being used on an IBM 370/168 computer. Approximate CPU (central processing unit) time, execution time, and dollar cost for using this computer on each of the programs is summarized in Table 27.

It is important to note that these costs represent a single computational run for the computer. The rainfall analysis will require several runs of the SORT and LISTRK programs. One run of each program is required to provide a listing of the ranking of each of the rainfall parameters. The storage-treatment program also may be run many times in the course of analyzing a system of alternatives. The actual number of runs will vary significantly depending on the configuration of the system being analyzed and the number of control strategies that are investigated.

No costs or times are presented for the receiving water analysis because these costs are dependent on the specific river model used for the area being analyzed.

APPLICATION TO STORM SEWER AND NONURBAN AREAS

In this report primary attention has been directed at applying the simplified stormwater management model to a system of combined sewers. This simplified modeling approach is equally valid for drainage basins served by separate storm sewers and for nonurban drainage basins.

Because the simplified model is a series of interrelated tasks, it is extremely flexible and can be readily adapted to various types of drainage basins. The data preparation task is the only task that is directly affected by the type

Table 27. APPROXIMATE COMPUTER COST FOR SIMPLIFIED STORMWATER MANAGEMENT MODEL

Program	CPU[a] min	Exec[b] min	Cost[c] $
Rainfall characterization			
TAPE-Disk	0.01	0.07	0.61
EVENT	0.01	0.25	5.80
SNOWIN	0.01	0.60	0.10
EXCLUD	0.01	0.10	1.10
LISTSQ	0.01	0.50	0.90
SORT	0.01	0.18	4.40
LISTRK	0.01	0.25	3.93
Storage-Treatment 20 years of record			
DLYCRD	0.79	0.84	14.50
DLYTAP	0.90	0.96	16.25
1 year of record			
HOUCRD	0.60	0.64	13.45
HOUTAP	0.74	0.80	14.25

a. Actual computation time in computer core not including the time needed to execute the read and write (I/O) statements or to run the peripheral devices.

b. Time required in the computer including I/O statements.

c. Cost based on use of IBM 370/168.

of basin being analyzed. The other tasks are affected only by the data that is collected. The alternatives that are analyzed with the model may also be significantly different for a system of combined sewers than for a nonurban area, but the basic principles of the analysis remain unchanged. When applying the model to any area, the determination of the K factor (see Section VII and Appendix C) and the determination of the quality associated with the runoff (see Section VIII and Appendix D) are portions of the model that are accomplished by hand computations rather than by the computer program.

Data Preparation

The system schematic that is developed for a drainage basin reflects the type of basin being analyzed, and differs significantly for combined sewers, separate storm sewers, and nonurban areas. Yet the quantity and quality data requirements for analysis of various drainage basins do not change.

For separate sewer systems and nonurban areas, the point of discharge to receiving waters that would be focused on is a storm sewer outlet or the mouth of creeks rather than an overflow structure on an interceptor. In fact, an interceptor system would probably not exist for a system that is affected only by flows during wet weather. The drainage areas for a system of separate storm sewers or a nonurban area would follow natural topography very closely and may have a very low total percentage of impervious area.

The need for collection of quantity and quality information is still the same for separate sewer systems and nonurban areas as it is for combined sewers. It is necessary to collect some data to provide a point from which the model can be calibrated. For nonurban areas "textbook" values for quality are a partial guide, but a few good quality samples are valuable to provide a firm reference point.

Rainfall Analysis

The analysis of rainfall is completely independent of the specific type of drainage basin being analyzed. Because nonurban areas would possibly be remote from a primary weather bureau gage, it is useful to check a reliable local gage with the weather bureau gage. A factor may have to be applied to the primary gage data to provide rain data reflecting local conditions.

Storage-Treatment Balance

The analysis of alternatives and the use of the storage-treatment program should be less complex for a system of separate sewers or a nonurban area. The need for running the storage-treatment program sequentially working upstream along an interceptor may be completely eliminated for nonurban areas. Each drainage area may be looked at independently. Yet the ability to investigate an alternative that considers collecting stormflows in an interceptor with overflows at points on the system is still within the capabilities of the program.

Quality Assessment

The techniques of monitoring and analysis used to assess stormwater quality are also independent of the drainage area being analyzed. The actual quality values that are generated may be significantly different for various drainage basins particularly in the relationship between BOD and suspended solids, but these values do not affect the techniques being used. The quality assessment is accomplished through a series of hand computations.

Receiving Water Response

The analysis of receiving water is based on a locally available river model and again would be independent of the specific drainage basin being analyzed.

SIMPLIFIED AND COMPLEX MODELING

The model that has been presented in this report is a simplified stormwater management model. Complex stormwater management models exist [2, 3] and have been used extensively in several cities and parts of the country. These two types of modeling effort are compatible, and in fact, complementary.

The advantage of a simplified model is the ability to process long periods of record and broad areal coverage at low cost. The advantage of a detailed model is the ability to make a comprehensive analysis of singular events and systems with a corresponding increase in accuracy when supported by a viable data base.

An example of the difference between the simplified and the complex modeling effort is clearly evident in the development and use of design storms. In the rainfall analysis of simplified modeling, hourly increments of rainfall are examined and grouped into storms. When these storms are ranked and arrayed, statistical techniques can be used to indicate the characteristics of design storms. The entire analysis of alternatives, however, is performed on the actual rainfall records for a selected extended period of time. For complex modeling, rainfall for shorter time increments would be examined, and critical intensities from the entire period of record may be composited into a single storm that would represent the design storm. All atlernatives would then be analyzed using this particular design storm. An alternative to the use of a design storm is the use of an historical storm event for comparison of sewer system modification alternatives.

It is readily apparent that the design storm developed in the course of a complex modeling effort is clearly a precise, discrete, critical event. This kind of precision, characteristic of complex modeling, is necessary for an accurate technical evaluation of closely competing plans. Yet in planning studies, the simplified models offer a flexible screening device to identify consequential storm events and potentially attractive alternatives.

Further, in the design phase, the complex and simplified models can continue to interact providing valuable information on the selected plan. The complex model can be used to fix component size and configuration while the simplified model can be used to test the decisions that are made against the historical record.

SECTION XI

OTHER STORMWATER CONSIDERATIONS

Within the broad area of stormwater management there are many complex problems. Two areas not specifically addressed by this simplified mathematical model are sludges generated within stormwater systems and "nonstructural" alternatives for stormwater quality improvement.

SLUDGES

Sludge is a byproduct of any water collection, and treatment system and stormwater systems are not an exception. Stormwater sludges are the solids that accumulate in the stormwater system and the solids that are specifically removed by stormwater treatment facilities. This area has been studied in recent literature [4, 5].

Stormwater sludges are typically high in grit and silt, and usually low in organic materials. These sludges also tend to accumulate high concentrations of heavy metals as compared with sludges from typical domestic sewage. Typical composition of sludge from combined stormwater systems are presented in Table 28.

Solids in the stormwater system are important in two ways: (1) they are generally a settleable fraction of the flow and can affect the capacity of facilities, and (2) solids are a treatment and disposal problem.

The solids in stormwater that form the sludges are subject to the basic rules governing settling of materials in sewers. Typically, if velocities exceeding 2 feet per second are maintained in the collection system, excessive sedimentation should not occur. Problems with sludge deposits can occur in stormwater storage or detention facilities. Specific provisions must be made to provide for cleaning of these facilities so that the total storage volume will not be affected.

Table 28. COMPOSITION OF SLUDGE FROM THE TREATMENT OF COMBINED SEWAGE OVERFLOWS [4]

Location	Treatment method	Sludge characteristics, mg/l					
		SS	VSS	BOD	Total phosphorus as P	Total Kjeldahl nitrogen as N	Pb[a]
Milwaukee (Humboldt Ave.)	Settling	17,400	8,425	2,200	109	56	2,063
Boston	Settling	110,000	41,400	12,000	293	28	1,261
Philadelphia	Microscreens	7,000	1,755	--	12	46	2,448
Racine	Screens/Flotation	8,433	3,340	1,100	39	112	1,023
Milwaukee (Hawley Rd.)	Flotation	41,900	10,570	3,200	149	517	164
San Francisco	Flotation	22,500	8,850	1,000	166	375	1,583
Kenosha	Activated sludge	8,300	5,225	1,700	194	492	528

a. mg/kg of dry solids.

The treatment and disposal of these sludges is a complex and unique problem. Three major alternatives have been investigated by recent research in this area:

- "Bleedback" to dry-weather facilities
- Onsite treatment
- Land disposal

Bleedback to dry-weather facilities is the most commonly considered alternative. In this system, sludges that are separated from storm flows are stored during the storm and slowly metered into an existing dry-weather sewage treatment facility after the storm has passed. This system is constrained by the hydraulic and solids handling capacity of the dry-weather treatment facility.

The second alternative for sludge handling is onsite treatment. In this alternative facilities for treating the stormwater flows and solids would be constructed near the point of discharge of the sewer or overflow. Most often this onsite system takes the form of physical-chemical treatment plant. The sludge is treated and dewatered using mechanical equipment. Typical processes that may be employed are:

- Dissolved air flotation
- Vacuum filtration
- Centrifugation
- Anaerobic digestion
- Gravity thickening

Land disposal is also being considered as a sludge handling option. Initial investigations (4, 5) dictate sludge stabilization prior to disposal and maximum loading rates based on the sludge nitrogen and heavy metal concentrations. Residual solids from the other two alternatives must be placed in a landfill or some other ultimate disposal site.

NONSTRUCTURAL ALTERNATIVES

Nonstructural alternatives are those alternatives that affect a reduction in quantity or improvement in quality of of the runoff, yet can be implemented without construction of major new facilities. These alternatives have been discussed extensively in the literature [6, 7, 8]. The possibilities are limited only by the imagination of those charged with management of the stormwater facilities.

The nonstructural alternatives can generally be discussed in two categories: (1) alternatives that control the source of pollutants and runoff, and (2) alternatives that affect control and management of pollutants and runoff within the system of sewers. Some typical nonstructural control alternatives are listed in Table 29.

Table 29. NONSTRUCTURAL CONTROL ALTERNATIVES

Source Control Alternatives
Roof storage
Ponding
Porous pavements
Erosion control
Street cleaning
Deicing methods
Utilize natural drainage features
Collection System Control Alternatives
Sewer flushing
Inflow/infiltration
Sewer cleaning
Polymer injection
Inline storage
Remote Monitoring and Control

Source Control Alternative

Three examples of source control measures that may be important in an urban area are:

- Street sweeping
- Deicing methods
- Erosion control

Street Sweeping. There is a direct relationship between the amount of dirt and grit that accumulates on city streets and the quality of runoff. Recent research has shown that a great portion of the pollution is related to fine materials relatively unaffected by conventional broom type street sweeping equipment. Modern vacuum type street cleaning equipment can remove as much as 95 percent of the fine materials. No parking signs can be posted indicating the hours of street cleaning operation to maximize the effectiveness of the cleaning equipment that is currently being used.

Deicing Methods. In cold climates various chemicals have been used on pavement for control of ice. These chemicals enter the stormwater collection system as thawing occurs. Recent studies in Michigan have suggested: (1) no salt application on straight, flat sections, (2) better training for operators of salt spreading equipment, and (3) keeping records of salt use as a means of reducing salt consumption. At a minimum, salts without highly toxic substances, such as cyanide or chromium compounds, should be used. These toxic chemicals have been added to some deicing salts as anticaking agents or corrosion inhibitors, but have very damaging effects on the environment.

Erosion Control. In an urban situation, a heavy load of silt and dirt often can be generated by simply poor management of a construction site. Graveling of entrance roads to the site and control of runoff from the site during construction can help minimize pollutants that enter the sewer system.

System Control Alternatives

Two examples of system control alternatives for a typical urban area might be:

- Sewer cleaning and flushing
- Inflow/infiltration control

Sewer Cleaning and Flushing. This control measure may have a dual benefit, particularly on a system of combined sewers. The capacity of a sewer system is inversely related to the quantity of grit that deposits within it. A regular cleaning program can maintain flow capacity throughout the collection system, but special attention should be directed at any area where deposits regularly occur along the main interceptor lines. If the capacity of the main interceptors are reduced by sediment , overflow will occur on the system unnecessarily. The cleaning and flushing maintains capacity in lines while at the same time reducing the total volume of pollutants that will be scoured out of the lines and discharged to receiving waters during periods of high flow.

Inflow/Infiltration Control. Inflow is the stormwater that enters the system unnecessarily from the surface of the ground. Examples of this may be roof leaders or area drains connected directly to the sewer system. Infiltration is groundwater that enters the sewer unnecessarily. Typically infiltration occurs through leaking pipe joints and structurally damaged pipe. It is somewhat costly to determine sources of inflow/infiltration. Usually smoke testing or television inspection is required. Quite often though significant reductions in flow can be realized from a thorough location and correction program.

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NOTE: The following report is recommended as a companion document for this report:

Heaney, J.P. Stormwater Management Model Level I, Preliminary Screening Procedure for Wet-Weather Flow Planning. (Draft Report), U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, June 1976.

Appendix A

EXAMPLE OF MONITORING DATA
FROM ROCHESTER, NEW YORK

Table A-1. EXAMPLE OF MONITORING DATA FROM ROCHESTER, NEW YORK

888003517   REPORT PRINTED 1/ 8/76 PAGE 2 - 1

ROCHESTER OVERFLOWS UNEDITED PRELIMINARY DATA

STNO	PLOC	SLOC	TYPE	SQNO	SAMP	DATE	TIME	FLOWRATE	RAIN	RAININT	PH	BOD5	TOC	TKN	NH3N	ORGN
1	25	1	20	1	12708	1/29/75	1450	41.1069			7.1		33.	3.5	1.39	2.1
1	28	1	1	1	12646	1/29/75	945		0.16	0.00	7.1	83.0	61.	3.2	2.44	0.8
1	28	1	1	2	12647	1/29/75	1005		0.17	0.00	7.0	107.0	27.	0.7	0.06	0.6
1	28	1	1	3	12648	1/29/75	1025		0.18	0.00	7.2	90.0	88.	4.2	2.62	1.6
1	28	1	1	4	12649	1/29/75	1045		0.19	0.00	7.2	63.0	31.	6.1	3.44	2.7
1	28	1	1	5	12650	1/29/75	1105		0.22	0.00	7.1	96.0	49.	7.0	3.96	3.0
1	28	1	1	6	12651	1/29/75	1125		0.26	0.00	7.1	60.0	31.	6.7	3.33	3.4
1	28	1	1	7	12652	1/29/75	1145		0.30	0.00	7.1	63.0	41.	5.2	2.57	2.6
1	28	1	1	8	12653	1/29/75	1205				6.9	63.0	64.	4.2	2.06	2.1
1	28	1	1	9	12654	1/29/75	1225				7.0	51.0	60.	3.2	1.33	1.9
1	28	1	1	10	12655	1/29/75	1245				7.1	47.0	55.	3.2	1.23	2.0
1	28	1	1	11	12656	1/29/75	1305				7.1	41.0	39.	1.5	1.50	0.0
1	28	1	1	12	12657	1/29/75	1325				7.0	40.0	62.	2.3	1.58	0.7
1	28	1	1	13	12658	1/29/75	1345				7.1	38.0	25.	2.6	1.78	0.8
1	28	1	1	14	12659	1/29/75	1405				7.1	29.0	31.	2.5	1.73	0.8
1	28	1	1	15	12660	1/29/75	1425				7.2	29.0	26.	2.2	1.61	0.6
1	28	1	1	16	12661	1/29/75	1445				7.2	22.0	19.	2.5	1.23	1.3
1	28	1	16	1	12662	1/29/75	1445				7.0	58.0	83.	2.7	1.73	1.0
1	31	1	1	1	12663	1/29/75	745	9.3547			7.1	78.0	82.	1.5	0.95	0.6
1	31	1	1	2	12664	1/29/75	805	84.7345	0.05	0.00	7.2	120.0	103.	2.7	2.17	0.5
1	31	1	1	3	12665	1/29/75	825	139.7900	0.22	0.00	7.2	140.0	101.	4.0	1.78	2.2
1	31	1	1	4	12666	1/29/75	845	115.8680	0.30	0.00	7.2	110.0	93.	2.5	1.28	1.2
1	31	1	1	5	12667	1/29/75	905	69.1143	0.34	0.00	7.2	100.0	61.	1.8	1.10	0.7
1	31	1	1	6	12668	1/29/75	925	36.3038	0.39	0.00						
1	31	1	1	7	12669	1/29/75	945	21.6427	0.41	0.00	7.2	59.0	63.	2.3	1.98	0.3
1	31	1	1	8	12670	1/29/75	1005	13.1880	0.42	0.00						
1	31	1	1	9	12671	1/29/75	1025	14.7730	0.43	0.00	7.1	53.0	43.	3.1	2.18	0.9
1	31	1	1	10	12672	1/29/75	1045	12.8933	0.44	0.00	7.3	56.0	36.	5.1	2.11	3.0
1	31	1	1	11	12673	1/29/75	1105	14.6584	0.45	0.00	7.1	33.0	36.	6.8	2.40	4.4
1	31	1	1	12	12674	1/29/75	1125	16.4234	0.47	0.00	7.1	55.0	25.	10.0	2.17	7.8
1	31	1	1	13	12675	1/29/75	1145	18.1885	0.48	0.00	7.2	47.0	44.	1.9	1.33	0.6
1	31	1	1	14	12676	1/29/75	1205	43.9825	0.49	0.00	7.4	48.0	47.	4.2	0.96	3.2
1	31	1	1	15	12677	1/29/75	1225	97.9956	0.50	0.00	7.3	75.0	86.	7.1	0.78	6.3
1	31	1	1	16	12678	1/29/75	1245	100.8940	0.56	0.00	7.3	39.0	48.	1.7	0.72	1.0
1	31	1	1	17	12679	1/29/75	1305	73.9975			7.2	34.0	43.	1.6	0.77	0.8
1	31	1	1	18	12680	1/29/75	1325	40.6927			7.2	36.0	44.	2.2	0.89	1.3
1	31	1	1	19	12681	1/29/75	1345	23.0398			7.2	38.0	26.	2.3	1.06	1.2
1	31	1	1	20	12682	1/29/75	1405				7.1	33.0	31.	3.0	1.23	1.8
1	31	1	1	21	12683	1/29/75	1425				7.1	39.0	27.	2.8	0.95	1.9
1	31	1	1	22	12684	1/29/75	1445					36.0				
1	31	1	1	23	12685	1/29/75	1505				7.1	95.0	49.	4.5	1.28	3.2
1	31	1	23	1	12687	1/29/75	1505				7.2	57.0	51.	2.7	1.43	1.3

Table A-1 (Continued)

888003517 REPORT PRINTED 1/ 8/76 PAGE 2 - 2

ROCHESTER OVERFLOWS UNEDITED PRELIMINARY DATA

SAMP	NO2N	NO3N	TIP	CL	CL-M	FE	CR	CU	CD	NI	PB	ZN	TSS	VSS	TCOLI
12708	0.094	0.33	0.29	167.		4.50	0.00	0.16	0.00	0.00	0.00	0.275	104.0	52.0	695000.
12646	0.090	0.06	0.08	120.	120.	2.05	0.00	0.14	0.00	0.00	0.00	0.195	404.0	136.0	605000.
12647	0.020	0.04	0.03	35.	34.	0.60	0.00	0.16	0.00	0.00	0.00	0.260	128.0	24.0	6100000.
12648	0.070	0.01	0.14	123.	122.	2.70	0.00	0.16	0.00	0.00	0.00	0.160	787.0	300.0	
12649	0.105	0.30	0.28	130.	124.	1.05	0.00	0.10	0.00	0.00	0.00	0.115	236.0	76.0	460000.
12650	0.084	0.08	0.39	141.	134.	1.33	0.00	0.15	0.00	0.00	0.00	0.250	364.0	128.0	6400000.
12651	0.134	0.33	0.41	124.	125.	1.18	0.00	0.16	0.00	0.00	0.80	0.155	152.0	44.0	3200000.
12652	0.121	0.37	0.29	108.	105.	1.94	0.00	0.18	0.00	0.00	0.80	0.185	292.0	84.0	4400000.
12653	0.087	0.29	0.19	92.	91.	2.70	0.00	0.14	0.00	0.00	0.00	0.205	420.0	133.0	2280000.
12654	0.089	0.31	0.12	79.	81.	4.50	0.00	0.20	0.00	0.00	0.00	0.185	420.0	101.0	1660000.
12655	0.077	0.30	0.11	75.	77.	4.00	0.00	0.16	0.00	0.00	0.00	0.240	427.0	86.0	1820000.
12656	0.076	0.34	0.14	73.	77.	2.30	0.00	0.14	0.00	0.00	0.00	0.175	340.0	76.0	1540000.
12657	0.077	0.38	0.18	80.	81.	3.20	0.00	0.12	0.00	0.00	0.00	0.255	312.0	68.0	1320000.
12658	0.092	0.41	0.25	86.	86.	1.29	0.00	0.10	0.00	0.00	0.00	0.190	308.0	60.0	2290000.
12659	0.078	0.40	0.23	81.	83.	1.33	0.00	0.12	0.00	0.00	0.00	0.180	248.0	48.0	1010000.
12660	0.064	0.40	0.19	80.	81.	1.33	0.00	0.12	0.00	0.00	0.00	0.165	264.0	28.0	1120000.
12661	0.052	0.32	0.14	66.	74.	0.96	0.00	0.10	0.00	0.00	0.00	0.135	184.0	24.0	1400000.
12662	0.094	0.31	0.12	88.	94.	1.62	0.00	0.12	0.00	0.00	0.00	0.240	288.0	81.0	2320000.
12663	0.198	0.30	0.09	520.	56.	5.60	0.00	0.16	0.00	0.00	0.80	0.365	474.0	120.0	6400000.
12664	0.163	0.26	0.22	270.	36.	3.80	0.00	0.16	0.00	0.00	1.20	0.275	580.0	227.0	11700000.
12665	0.064	0.10	0.17	230.	24.	3.80	0.00	0.16	0.00	0.00	0.60	0.205	612.0	259.0	19400000.
12666	0.097	0.05	0.14	188.	19.	3.10	0.00	0.15	0.00	0.00	0.00	0.220	445.0	180.0	17600000.
12667	0.099	0.33	0.19	167.	158.	2.90	0.00	0.13	0.00	0.00	0.60	0.200	420.0	180.0	6250000.
12668					29.										
12669	0.122	0.38	0.25	39.	148.	1.78	0.00	0.10	0.00	0.00	0.00	0.170	290.0	120.0	5900000.
12670											0.00				
12671	0.099	0.37	0.22	156.	152.	1.27	0.00	0.11	0.00	0.00	0.00	0.145	216.0	80.0	5200000.
12672	0.105	0.48	0.28	171.	164.	1.67	0.00	0.10	0.00	0.00	0.00	0.220	225.0	76.0	5100000.
12673	0.117	0.48	0.30	173.	175.	1.07	0.00	0.12	0.00	0.00	0.00	0.165	180.0	60.0	2820000.
12674	0.110	0.49	0.28	181.	177.	0.78	0.00	0.10	0.00	0.00	0.00	0.145	264.0	64.0	3900000.
12675	0.122	0.45	0.14	157.	150.	1.49	0.00	0.10	0.00	0.00	0.00	0.200			2270000.
12676	0.071	0.40	0.14	131.	127.	2.80	0.00	0.13	0.00	0.00	0.00	0.210	296.0	96.0	1260000.
12677	0.093	0.32	0.10	115.	117.	3.10	0.00	0.12	0.00	0.00	0.00	0.250	487.0	154.0	9000000.
12678	0.061	0.34	0.06	66.	93.	3.30	0.00	0.10	0.00	0.00	0.00	0.235	330.0	110.0	1400000.
12679	0.061	0.37	0.11	88.	82.	2.90	0.00	0.10	0.00	0.00	0.00	0.175	287.0	92.0	1280000.
12680	0.059	0.41	0.14	100.	95.	3.20	0.00	0.12	0.00	0.00	0.00	0.205	297.0	96.0	1080000.
12681	0.064	0.43	0.17	106.	107.	2.90	0.00	0.12	0.00	0.00	0.00	0.205	232.0	72.0	1310000.
12682	0.062	0.36	0.22	115.	109.	2.18	0.00	0.10	0.00	0.00	0.00	0.435	236.0	72.0	1050000.
12683	0.089	0.67	0.14	125.	123.	1.05	0.00	0.10	0.00	0.00	0.00	0.290	196.0	60.0	1310000.
12684					130.								152.0	48.0	1160000.
12685	0.290	0.60	0.14	136.	146.	1.33	0.00	0.10	0.00	0.00	0.00	0.270	268.0	117.0	2220000.
12687	0.124	0.39	0.17	171.	164.	1.85	0.00	0.10	0.00	0.00	0.00	0.225	276.0	84.0	1110000.

Table A-1 (Concluded)

888003517 REPORT PRINTED 1/ 8/76 PAGE 2 - 3

ROCHESTER OVERFLOWS UNEDITED PRELIMINARY DATA

SAMP	FCOLI	FSTREP	TS	VS	TDS	VDS	SETTS	COD-M	O&G	HG	CHP
12708		32500.	650.0	87.0	546.0	35.0	0.9	142.	34.	2.00	0.001
12646	605000.										
12647	710000.										
12648											
12649	820000.										
12650	980000.										
12651	635000.										
12652	540000.										
12653	395000.										
12654	465000.										
12655	276000.										
12656	28000.										
12657	177000.										
12658	390000.										
12659	144500.										
12660	245000.										
12661	150000.										
12662	360000.	47500.	637.0	125.0	349.0	44.0	2.2	230.	37.	2.00	0.000
12663	195000.										
12664	590000.										
12665	1015000.										
12666	630000.										
12667	3505000.										
12668											
12669	550000.										
12670											
12671	480000.										
12672	505000.										
12673	630000.										
12674	515000.										
12675	275000.										
12676	275000.										
12677	375000.										
12678	210000.										
12679	132000.										
12680	206000.										
12681	165000.										
12682	174000.										
12683	154000.										
12684	103000.										
12685	345000.										
12687	126000.	41500.	754.0	150.0	478.0	66.0	2.6	265.	42.	8.00	0.000

Appendix B

PROGRAM LISTING AND LIST OF VARIABLES

Table B-1. RAINFALL TASK - PROGRAM LISTING FOR EVENT

```
//J4073 JOB 'C802,322','DIDRIKSSON'
/* SERVICE EXEC=U
//STEP1 EXEC WATFIV
//GO.FT08F001 DD DSN=C802.STORM1,UNIT=2314,
//     DISP=(NEW,KEEP),SPACE=(TRK,(100,10),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=3520)
//GO.SYSIN DD *
$WATFIV
       DIMENSION MON(12),NY(100),MO(100),ND(100),NX(100),FR(100,24),
      *NEXT(100),FAX(100),FRS(100),LD(100),NYA(100),MOA(100),NDA(100),
      *ITA(100),IRT(100),LLD(100),NEE(100),NR(100),LCC(100)
       DATA MON/31,28,31,30,31,30,31,31,30,31,30,31/
        NE=0
         NQ=0
       NLAST=0
         NLM=0
       LL=0
       DO11I=1,100
        LCC(I)=0
11     LLD(I)=0
12     CONTINUE
       I=1
14     CONTINUE
       MON(2)=28
142    CONTINUE
       READ(5,144)NY(I),MO(I),ND(I),NX(I),(FR(I,J),J=1,12)
144    FORMAT(6X,3I2,I1,12F3.2)
        IF(NY(I)-99)1444,8,8
1444       CONTINUE
       IF(NX(I)-1)142,145,142
145     CONTINUE
       READ(5,146)(FR(I,J),J=13,24),NEXT(I)
146    FORMAT(13X,12F3.2,29X,I2)
       NY(I)=NY(I)+1900
       XL=NY(I)
       XL=XL/4.
       L=XL
       XXL=L
       IF(XL-XXL)16,15,16
15     MON(2)=29
16     CONTINUE
          IF(MO(I)-NLM)161,1614,161
161         NE=NQ+NE
            NLM=MO(I)
             NQ=MON(NLM)
1614          CONTINUE
               NR(I)=ND(I)+NE
       IC=MO(I)
       IF(MON(IC)-ND(I))18,162,18
162     CONTINUE
17     I=I+1
       IF(I-100)176,176,174
174      CONTINUE
       L=I-1
       WRITE(6,175)NY(L),MO(L),ND(L)
175    FORMAT(1H ,'ERROR',3I2)
       STOP
176    CONTINUE
       GOTO14
```

Table B-1 (Continued)

```
18      CONTINUE
        IC=ND(I)+1-NEXT(I)
        IF(IC)21,17,21
21      CONTINUE
        DO22 IA=1,100
        FAX(IA)=0.
        FRS(IA)=0
        LD(IA)=0
22      CONTINUE
        JX=0
        JXX=0
        JCC=0
        DO40IA=1,I
        DO38IB=1,24
        IF(JXX)24,222,24
222     IF(FR(IA,IB))38,38,224
224     CONTINUE
        JXX=1
        JX=JX+1
          NEE(JX)=NR(IA)
            IF(JX-1)228,226,228
226           LLD(JX)=NEE(JX)-NLAST
              GOTO23
228          LLD(JX)=NEE(JX)-NEE(JX-1)
23              CONTINUE
        IRT(JX)=IB
        NYA(JX)=NY(IA)
        MOA(JX)=MO(IA)
        NDA(JX)=ND(IA)
24      CONTINUE
        IF(FR(IA,IB))25,25,26
25      JCC=JCC+1
                LCC(JX)=JCC
        IF(JCC-6)262,262,252
252     JXX=0
26      CONTINUE
              NEE(JX)=NR(IA)
                NLAST=NR(IA)
        JCC=0
262     CONTINUE
        IF(FR(IA,IB)-FAX(JX))29,29,28
28      FAX(JX)=FR(IA,IB)
            IF(MOA(JX)-MO(IA))282,286,282
282             LL=MOA(JX)
                        IFAC=ND(IA)+MON(LL)-NDA(JX)
                    GOTO288
286             CONTINUE
        IFAC=ND(IA)-NDA(JX)
288             CONTINUE
        ITA(JX)=IFAC*24+IB-IRT(JX)+1
29      CONTINUE
        FRS(JX)=FRS(JX)+FR(IA,IB)
        LD(JX)=LD(JX)+1
38      CONTINUE
40      CONTINUE
         IF(JX)12,12,41
41       CONTINUE
          DO414IA=1,JX
                      LD(IA)=LD(IA)-LCC(IA)
```

Table B-1 (Concluded)

```
414      CONTINUE
      DO44 IA=1,JX
      WRITE(8,42)NYA(IA),MOA(IA),NDA(IA),LD(IA),FRS(IA),FAX(IA),
     *ITA(IA),LLD(IA),IRT(IA)
42    FORMAT(1H ,I4,3I3,2F6.2,2I3,2X,I3)
44    CONTINUE
            DO5IA=1,100
5         LCC(IA)=0
      GOTO12
8     CONTINUE
         WRITE(8,82)
82       FORMAT(' 9999')
      STOP
      END
```

Table B-2. RAINFALL TASK - LIST OF VARIABLES FOR EVENT

Variable name	Index[a]	Units	Description
FAX	O	in./hr	Maximum 1-hr rainfall intensity for each storm
FR	I	in.	Rainfall for each hr
FRS	O	in.	Total rainfall for each storm
I			Counter and index
IA			Do loop counter
IB			Do loop counter
IC			Number of month
IFAC			Number of days into storm maximum intensity rainfall occurs
IRT	O	hr	Clock hr for start of storm
ITS	O	hr	Number of hrs into storm that peak intensity occurs
J			Do loop counter
JCC			Hrs without rain counter
JX			Number of storms counter
JXX			Storm in progress index
L			Factor used to find leap year
LCC			Record of number of hrs without rain
LD	O	hr	Duration of storm

Variable name	Index[a]	Units	Description
LL			Record of month number
LLD	O	Days	Number of days between storms
MO	I	Month	Month number of rainfall
MOA	O		Month number for storm
MON			Number of days in month
ND	I	Days	Day of month for rain
NDA	O	Days	Day of month for storm
NE			Total of days in month
NEE			Record of day of start of storm
NEXT	I	Days	Day of next recorded rainfall
NLAST			Day of last rainfall
NLM			Month number
NQ			Number of days in month
NR			Day of yr rainfall occurs
NX	I	--	Switch-indicator time of day a.m. or p.m.
NY	I		Number of yr for rainfall
NYA	O	Year	Number of yr for storm
XL			Factor used in finding leap yrs
XXL			Factor used in finding leap yrs

a. O indicated output variable.
b. I indicated input variable.

Table B-3. RAINFALL TASK - PROGRAM LISTING FOR SNOWIN

```
//J4073 JOB (C802,322),'T.DIDRIKSSON'
// EXEC WATFIV
//GO.FT08F001 DD DSN=C802.STORM3,UNIT=2314,VOL=SER=SYS17,DISP=OLD
//GO.FT09F001 DD DSN=C802.CARD.C345,UNIT=2314,VOL=SER=SYS14,DISP=OLD
//GO.FT10F001 DD DSN=C802.STORM2,UNIT=2314,DISP=(NEW,KEEP),
//         SPACE=(TRK,(50,2),RLSE),DCB=(RECFM=FB,LRECL=80,BLKSIZE=3520)
//GO.SYSIN DD *
$WATFIV
           N=0
              M=0
            NRR=0
             SNOW=0.
             NDB=0
             NYB=0
             MOB=0
12         CONTINUE
            READ(8,2)NYA,MOA,NDA,LD,FRS,FAX,ITA,LLD,IS,IRT
2           FORMAT(1X,I4,3I3,2F6.2,2I3,I2,I3,5X,I5)
             NRR=NRR+1
              NYX=NYA-1900
            GOTO32
22         CONTINUE
           READ(9,3)NYB,MOB,NDB,SNOW
3            FORMAT(5X,3I2,10X,F3.1)
32            CONTINUE
               IF(NYA-3000)324,8,8
324           IF(NYB-99)325,64,64
325           IF(NYX-NYB)64,326,22
326           IF(MOA-MOB)64,328,22
328           IF(NDA-NDB)64,6,22
6             IF(SNOW)64,64,66
64           IS=0
              GOTO7
66            IS=1
7          CONTINUE
                WRITE(10,2)NYA,MOA,NDA,LD,FRS,FAX,ITA,LLD,IS,IRT,NRR
            GOTO12
8           CONTINUE
                WRITE(10,9)NYA
9           FORMAT(1X,I4)
             STOP
             END
```

Table B-4. RAINFALL TASK - LIST OF VARIABLES FOR SNOWIN

Variable name	Index[a]	Units	Description
FAX	IO	in./hr	Maximum 1-hr intensity for each storm
FRS	IO	in.	Total rainfall for each storm
IRT	IO	hr	Clock hr for start of storm
IS	IO	--	Snowfall index
ITA	IO	hr	Number of hrs into storm that peak intensity occurs
LD	IO	hr	Duration of storm
LLD	IO	Days	Number of days between storms
M			Not used
MOA	IO	Month	Month number for storm

Variable name	Index[a]	Units	Description
MOB	I	Month	Month number of snowfall
N			Not used
NDA	IO	Days	Day of month for storm
NDB	I	Days	Day of month for snowfall
NRR	O		Counter of storm
NYA	IO	Yrs	Number of yrs of storm
NYB	I		Two-digit number of year for snowfall
NYX			Two-digit number of year for rainfall
SNOW	I	in.	Quantity of snowfall

a. I indicated input variable.
O indicated output variable.

Table B-5. RAINFALL TASK - PROGRAM LISTING FOR EXCLUD

```
//J4073 JOB (C802,322),'T.DIDRIKSSON'
// EXEC WATFIV
//GO.FT08F001 DD DSN=C802.STORM2,UNIT=2314,VOL=SER=SYS13,DISP=OLD
//GO.FT10F001 DD DSN=C802.STORM4,UNIT=2314,DISP=(NEW,KEEP),
//         SPACE=(TRK,(50,2),RLSE),DCB=(RECFM=FB,LRECL=80,BLKSIZE=3520)
//GO.SYSIN DD *
$WATFIV
12         CONTINUE
             READ(8,2)NYA,MOA,NDA,LD,FRS,FAX,ITA,LLD,IS,IRT,NRR
2            FORMAT(1X,I4,3I3,2F6.2,2I3,I2,I3,5X,I5)
                IF(NYA-3000)324,8,8
324            CONTINUE
               IF(FRS-0.05)12,12,6
6              CONTINUE
                  WRITE(10,2)NYA,MOA,NDA,LD,FRS,FAX,ITA,LLD,IS,IRT,NRR
             GOTO12
8            CONTINUE
                  WRITE(10,9)NYA
9            FORMAT(1X,I4)
              STOP
              END
```

Table B-6. RAINFALL TASK - LIST OF VARIABLES FOR EXCLUD

Variable name	Index[a]	Units	Description	Variable name	Index	Units	Description
FAX	IO	in./hr	Maximum 1-hr intensity for each storm	LD	IO	hr	Duration of storm
FRS	IO	in.	Total rainfall for each storm	LLD	IO	Days	Number of days between storms
IRT	IO	hr	Clock hr for start of storm	MOA	IO	Month	Month number for storm
IS	IO	--	Snowfall index	NDA	IO	Days	Day of month for storm
ITA	IO	hr	Number of hrs into storm that peak intensity occurs	NRR	IO	--	Counter for storms
				NYA	IO	Yrs	Number of yr of storm

a. I indicated input variable.

b. O indicated output variable.

Table B-7. RAINFALL TASK - PROGRAM LISTING FOR LISTSQ

```
//J4073TED JOB 'C802,322,1.0,10','T DIDRIK'
/* PRINT COPIES=2
/* SERVICE  CLASS=Q
//STEP1 EXEC WATFIV
//GO.SYSIN DD *
$WATFIV
C          SEQUNCE ALL YEAR
      DIMENSIONA(12),B(2)
      DATA A/'JAN','FEB','MAR','APR','MAY','JUNE','JULY','AUG','SEPT','O
     1CT','NOV','DEC'/,B/'NO','YES'/
      TTR=0.
         I=0
      NTDU=0
      INN=0
      TXR=0.
      IL=0
      WRITE(6,18)
18    FORMAT(1H1,//2X,4HYEAR,2X,5HMONTH,3X,3HDAY,2X,6HDURAT.   ,3X,5HTOTA
     1L,2X,8HMAX HOUR,2X,10HHOUR AFTER,1X,10HDAYS SINCE,4X,6HEXCESS
     23X,9HREAL TIME,4X,4HSNOW, 9X,8HSEQUNCE
     3   /21X,5HHOURS,2X,8HRAINFALL,1X,8HRAINFALL,4X,5HSTART,4X,10HLAST
     4STORM,4X, 6HPRECIP        ,3X,10HSTART HOUR,2X,8HINCLUDED
     5///)
19           CONTINUE
          I=I+1
      READ(5,2) IYE,MON,NDA,NDU,TR,TMR,NHR,NDT,ISN,IHR,IFXX
         IX=0
2     FORMAT(1X,I4,3I3,2F6.2,2I3,I2,I3,5X,I5)
      IF(2000-IYE)9,9,24
24    CONTINUE
      IF(MON)224,224,22
22    IF(MON-12)228,228,224
224   WRITE(6,226)
226   FORMAT(6H ERROR)
          STOP
228   CONTINUE
      IX=IX+1
      ISN=ISN+1
      IF(I-1)244,242,244
242   ICC=IYE
244   CONTINUE
      IF(ICC-IYE)252,258,252
252   WRITE(6,254)NTDU,TTR,TXR
254   FORMAT(////10X,I15,2F9.2)
      IL=0
      NTDU=0
      TTR=0.
      ICC=IYE
      TXR=0.
      WRITE(6,18)
258   CONTINUE
      INN=INN+1
      NTDU=NTDU+NDU
      TTR=TTR+TR
      IF(TMR-TXR)248,248,246
246   TXR=TMR
248   CONTINUE
      IL=IL+1
      IF(IX-2)25,25,224
25     IF(ISN-2)272,272,224
```

Table B-7 (Concluded)

```
272        CONTINUE
        WRITE(6,26) IYE,A(MON),NDA,NDU,TR,TMR,NHR,NDT,B(IX),IHR,B(ISN),INN
26      FORMAT(1H ,I6,2X,A4,I5,I7,4X,F6.2,3X,F6.2,4X,I7,5X,I6,8X,A4,5X,I7,
       17X,A4,7X,I4)
        IF(49-IL) 28,8,8
28      CONTINUE
        WRITE(6,18)
        IL=Ø
8       CONTINUE
           GOTO19
9       CONTINUE
        WRITE(6,254) NTDU,TTR,TXR
        WRITE(6,92)
92      FORMAT(1H1)
        STOP
        END
```

Table B-8. RAINFALL TASK - LIST OF VARIABLES FOR LISTSQ

Variable name	Index[a]	Units	Description
A	O	--	Letter abbreviation for month number
B	O	--	Letter abbreviation Yes, No.
I		--	Counter
ICC		--	Record of number of yr
IFXX	I	--	Storm counter (not used)
IHR	IO	hr	Clock hr for start of storm
IL		--	Counter for output record
INN	O	--	Storm event counter
ISN	IO	--	Index for snowfall
IX	O	--	Index for excess precipitation (not present)
IYE	IO	yr	Number of year of storm
MON	IO	month	Month number for storm
NDA	IO	day	Day of month for storm
NDT	IO	day	Number of days between storms
NDU	IO	hr	Duration of storm
NHR	IO	hr	Number of hrs into storm that peak intensity occurs
NTDU	IO	hr	Total of storm duration for yr
TMR	IO	in./hr	Maximum 1-hr intensity for each storm
TR	IO,	in.	Total rainfall for each storm
TTR	O	in.	Total annual rainfall
TXR	O	in./hr	Maximum 1-hr rainfall intensity for yr

a. O indicated output variable.

b. I indicated input variable.

Table B-9. RAINFALL TASK - PROGRAM LISTING FOR LISTRK

```
//J4Ø73TED JOB 'C8Ø2,322,1.,5','T DIDRIK'
/* PRINT COPIES=2
/* SERVICE  CLASS=Q
//STEP1 EXEC WATFIV
//GO.SYSIN DD *
$WATFIV
      DIMENSIONA(12),B(2)
C         RANK ALL YEAR
      DATA A/'JAN','FEB','MAR','APR','MAY','JUNE','JULY','AUG','SEPT','O
     1CT','NOV','DEC'/,B/'NO','YES'/
      INN=Ø
      IL=Ø
      WRITE(6,18)
18    FORMAT(1H1,//2X,4HYEAR,2X,5HMONTH,3X,3HDAY,2X,6HDURAT.   ,3X,5HTOTA
     1L,2X,8HMAX HOUR,2X,1ØHHOUR AFTER,1X,1ØHDAYS SINCE,4X,6HEXCESS    ,
     23X,9HREAL TIME,4X,4HSNOW, 9X,6HRANKED,5X,9HRANKED BY,
     3   /21X,5HHOURS,2X,8HRAINFALL,1X,8HRAINFALL,4X,5HSTART,4X,1ØHLAST
     4STORM,4X, 6HPRECIP       ,3X,1ØHSTART HOUR,2X,8HINCLUDED,
     517X,9HMAGNITUDE///)
12          CONTINUE
      READ(5,2)IYE,MON,NDA,NDU,TR,TMR,NHR,NDT,ISN,IHR,IPP,IFXX
2     FORMAT(I4,3I3,2F6.2,2I3,I2,I3,5X,I5,5X,I5)
         IX=Ø
      IF(2ØØØ-IYE)9,9,24
24    CONTINUE
      IX=IX+1
      ISN=ISN+1
      INN=INN+1
      IL=IL+1
      WRITE(6,26)IYE,A(MON),NDA,NDU,TR,TMR,NHR,NDT,B(IX),IHR,B(ISN),INN
     1,IFXX
26    FORMAT(1H ,I6,2X,A4,I5,I7,4X,F6.2,3X,F6.2,4X,I7,5X,I6,8X,A4,5X,I7,
     17X,A4,7X,I4,5X,I1Ø)
      IF(49-IL)28,8,8
28    CONTINUE
      WRITE(6,18)
      IL=Ø
8     CONTINUE
          GOTO12
9     CONTINUE
      WRITE(6,92)
92    FORMAT(1H1)
      STOP
      END
```

Table B-10. RAINFALL TASK - LIST OF VARIABLES FOR LISTRK

Variable name	Index[a]	Units	Description	Variable name	Index[a]	Units	Description
A	O	--	Letter abbreviation for month number	IYE	IO	yr	Number of yr of storm
B	O	--	Letter abbreviation Yes, No	MON	IO	month	Month number for storm
IFXX	I	--	Magnitude sequence number	NDA	IO	day	Day of month for storm
IHR	IO	hr	Clock hr for start of storm	NDT	IO	day	Number of days between storms
IL		--	Counter for output record	NDU	IO	hr	Duration of storm
INN	O	--	Storm event counter	NHR	IO	hr	Number of hrs into storm that peak intensity occurs
ISN	IO	--	Index for snowfall				
IPP	I		Previous ranking sequence (not used)	TMR	IO	in./hr	Maximum 1-hr intensity for each storm
IX	O	--	Index for excess precipitation (not present)	TR	IO	in.	Total rainfall for each storm

a. O indicated output variable.

b. I indicated input variable.

Table B-11. STORAGE-TREATMENT TASK - PROGRAM LISTING

```
//J4073TED JOB 'C802,322,1.,3','T DIDRIK'
//STEP1 EXEC FORTHC,PARM.FORT='MAP'
//GO.FT08F001 DD DSN=C802.STORM1,UNIT=2314,
//      DISP=(NEW,KEEP),SPACE=(TRK,(100,10),RLSE),
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=3520)
//GO.FT11F001 DD DSN=C802.STORM3,UNIT=2314,VOL=SER=SYS17,DISP=OLD
//GO.FT09F001 DD DSN=C802.CARD.C345,UNIT=2314,VOL=SER=SYS14,DISP=OLD
//GO.FT10F001 DD DSN=C802.STORM2,UNIT=2314,DISP=(NEW,KEEP),
//GO.SYSIN DD *
C       STORAGE - TREATMENT
C                 THEODOR DIDRIKSSON
C                 METCALF & EDDY, INC., ENGINEERS
C                 1029 CORPORATION WAY
C                 PALO ALTO, CALIF. 94303
      DIMENSIONM(13),ARN(5),MXX(13)
      COMMONM,AREA,COEF,STMAX,TREAT,STOPS,NYEAR,STOR,COEFX,
     *NFL,LD,ND,TRD,FAC,IOTAP,MYEAR
      DATA MXX/0,31,28,31,30,31,30,31,31,30,31,30,31/
      DO11I=1,13
11    M(I)=MXX(I)
      READ(5,12)(ARN(I),I=1,5),AREA,COEF,STMAX,TREAT,STOPS,NYEAR,
     *NSS,IOTAP,IPFL,MYEAR,TFAC
C      NSS=0 FOR DAILY & NSS=1 FOR HOURLY
C      IOTAP=0 INPUT ON CARDS & IOTAP=1 INPUT ON TAPE OR DISK
C      IPFL NUMBER OF INFLOW FROM UPPER REACHES BY INTERSEPTOR
C      TFAC FACTOR TO DETERMIND VOLUMN ROUTED TO TREATMENT PLANT
C      THE FIRST DAY OF RAINFALL OR NUMBER OF HOURS BEFORE
C      TREATMENT STARTS FOR HOURLY SIMULATION
C      NYEAR  NUMBER OF YEARS OR MONTHS READ OF CARDS
C      ARN NAME OR NUMBER OF THE AREA UNDER CONSIDERATION
12    FORMAT(5A4,5F8.0,I2,3I1,I4,1X,F10.0)
      STOR=STOPS
      COEFX=AREA*COEF*0.027156
       TRD=0.
        FAC=1.
      NFL=0
      LD=0
      ND=0
         NFAC=TFAC
      WRITE(6,13)(ARN(I),I=1,5)
13    FORMAT(1H4,60X,'ROCHESTER',10X,5A4,    ///43X,4HAREA,8X,6HR
     1UNOFF,5X,11HMAX STORAGE,3X,14HTREATMENT RATE/43X,5HACRES,6X,10HCOE
     2FFICENT,7X,2HMG,11X,3HMGD///)
      WRITE(6,132)AREA,COEF,STMAX,TREAT
132   FORMAT(1H ,38X,F10.0,5X,F7.2,4X, F10.0,4X,F10.0)
       WRITE(6,14)
14      FORMAT(1H3,85X,'METCALF & EDDY, INC., ENGINEERS'/
     *85X,'1029 CORPORATION WAY'/85X,'PALO ALTO, CALIF. 94303')
          IF(NSS)2,2,3
2       IF(IOTAP)22,22,24
22      CALL DLYCRD(TFAC)
         GOTO4
24      CALL DLYTAP(IPFL,TFAC)
              GOTO 4
3       IF(IOTAP)32,32,34
32        CALL HOUCRD
        GOTO4
34      CALL HOUTAP(IPFL,NFAC)
4        CONTINUE
```

```
          STOP
        END
         SUBROUTINE HOUCRD
     COMMONM,AREA,COEF,STMAX,TREAT,STOPS,NYEAR,STOR,COEFX,
    *NFL,LD,ND,TRD,FAC,IOTAP,MYEAR
     DIMENSIONM(13),MON(10),MDAT(10),RAIN(10)
     TREAT=TREAT/24.
     DO60I1=1,NYEAR
     SRIN=0.
     RUNOF=0.
     NDR=0
     NOV=0
     CTD=0.
     STOS=STOPS
     TRUN=0.
     TOV=0.
     TRE=0.
     LSD=0
     READ(5,14)MYEAR,NCARD
14   FORMAT(2I10)
     WRITE(6,142)MYEAR
142  FORMAT(1H1,///5X,5HMONTH,I6,14X,
    A                20HOCCURING ON THE HOUR,19X,35HACCUMULATED FROM STA
    1RT OF THE MONTH/24X,34H----------------------------------,5X,
    C56H------------------------------------------------------//
    D             6H DAY   ,1X,4HHOUR,2X,4HRAIN,2X,4HRAIN,2X,6HRUNOFF,2
    2X,7HSTORAGE,2X,8HOVERFLOW,2X,7HTREATED,5X,9HT. RUNOFF,2X,10HT.OVER
    3FLOW,7H OVERFL,8H T.TREAT,7H  TREAT,13H  MAX STORAGE/13X,2HIN,3X,4
    4HHOUR,4X,2HMG,6X,2HMG,8X,2HMG,7X,2HMG,12X,2HMG,10X,2HMG,5X,4HHOUR,
    55X,2HMG,5X,4HHOUR,7X,2HMG//)
     MY=MYEAR+1
     MT=M(MY)
     LTOT=0.
     DO166II=1,MT
166  LTOT=LTOT+24
     DO50I2=1,NCARD
     READ(5,168)(MON(J),MDAT(J),RAIN(J),J=1,10)
168  FORMAT(10(2I2,F4.2))
     DO17J=1,10
     IF( MON(J)-MT)1684,1684,1688
1684 IF(MDAT(J)-24)17,17,1688
1688 WRITE(6,1689)
1689 FORMAT(6H ERROR)
     STOP
17   CONTINUE
     JC=1
     DO30I3=1,770
     IF(NFL-0)178,178,176
176  NFL=NFL+1
178  CONTINUE
     TRD=0.
     OVFL=0.
     RUNOF=0.
     RIN=0.
     IF(JC-10)18,18,32
18   CONTINUE
     MX=MON(JC)
     LSD=LSD+1
     IF(LTOT-LSD)2604,21,21
21   CONTINUE
```

```
      IF(MX)26,26,214
214   CONTINUE
      LTD=-24
      DO22I4=1,MX
22    LTD=LTD+24
      ND=LTD+MDAT(JC)
23    CONTINUE
      IF(LSD-ND)26,24,26
24    RUNOF=COEFX*RAIN(JC)
      NFL=NFL+1
      TRUN=TRUN+RUNOF
      RIN=RAIN(JC)
      JC=JC+1
      STOR=STOR+RUNOF
      NDR=NDR+1
26    CONTINUE
      IF(LSD-1)2601,2608,2601
2601  CONTINUE
      LTD=0
      DO2602IQ=1,MT
      LTD=LTD+24
      IF(LTD-LSD+1)2602,2604,2602
2602  CONTINUE
      GOTO2608
2604  CONTINUE
      WRITE(6,2603)SRIN
2603  FORMAT(///11H TOTAL RAIN,F6.2)
      SRIN=0.
      IF(LTOT-LSD)60,2606,2606
2606  CONTINUE
      WRITE(6,142)MYEAR
2608  CONTINUE
      STORA=STOR
      IF(NFL-1)271,271,263
263   STOR=STOR-TREAT
264   IF(STOR-STOPS)266,266,27
266   NFL=0
      STOR=STOPS
27    CONTINUE
      TRD=STORA-STOR
      CTD=CTD+TRD/TREAT
      TRE=TRE+TRD
271   CONTINUE
      STM=STOR-STMAX
      IF(STM)274,274,272
272   NOV=NOV+1
      OVFL=STM
      TOV=TOV+STM
      STOR=STMAX
274   CONTINUE
      IF(STOS.LT.STOR)STOS=STOR
      ILL=0
      MXQ=0
      DO276IL=1,MT
      IF(MXQ-LSD)275,278,278
275   MQQ=MXQ
      MXQ=MXQ+24
      ILL=ILL+1
276   CONTINUE
278   LSX=LSD-MQQ
```

```
      SRIN=SRIN+RIN
      WRITE(6,282)ILL   ,LSX,RIN,NDR,RUNOF,STOR,OVFL,TRD,TRUN,TOV,NOV,TRE
     1 ,CTD,STOS
282   FORMAT(1H ,I3,I5,F6.2,I5,F9.2,F10.2,2F9.2,F14.2,F11.2,I6,F10.2,
     1F8.2,F10.2)
      IF(JC-11)30,29,30
29    IF(I2-NCARD)32,30,32
30    CONTINUE
32    CONTINUE
50    CONTINUE
60    CONTINUE
      WRITE(6,64)
64    FORMAT(1H1)
      STOP
      END
            SUBROUTINE DLYCRD(TFAC)
      COMMONM,AREA,COEF,STMAX,TREAT,STOPS,NYEAR,STOR,COEFX,
     *NFL,LD,ND,TRD,FAC,IOTAP,MYEAR
      DIMENSIONM(13),MON(10),MDAT(10),RAIN(10)
      DO60I1=1,NYEAR
      NDR=0
      NOV=0
      CTD=0.
      SRIN=0.
      RUNOF=0.
      STOS=STOPS
      TRUN=0.
      TOV=0.
      TRE=0.
      LSD=0
      M(3)=28
      READ(5,14)MYEAR,NCARD
14    FORMAT(2I10)
      WRITE(6,142)MYEAR
142   FORMAT(1H1,///5X,4HYEAR,I6,14X,
     A                20HOCCURING ON THE DATE,19X,34HACCUMULATED FROM STA
     1RT OF THE YEAR/24X,34H----------------------------------,5X,
     C56H--------------------------------------------------------//
     D                6H MONTH,1X,3HDAY,2X,4HRAIN,2X,4HRAIN,2X,6HRUNOFF,2
     2X,7HSTORAGE,2X,8HOVERFLOW,2X,7HTREATED,5X,9HT. RUNOFF,2X,10HT.OVER
     3FLOW,7H OVERFL,8H T.TREAT,7H  TREAT,13H  MAX STORAGE/13X,2HIN,3X,4
     4HDAYS,4X,2HMG,6X,2HMG,8X,2HMG,7X,2HMG,12X,2HMG,10X,2HMG,5X,4HDAYS,
     55X,2HMG,5X,4HDAYS,7X,2HMG//)
      XL=MYEAR
      XL=XL/4.
      L=XL
      XXL=L
      IF(XL-XXL)16,15,16
15    M(3)=29
      WRITE(6,154)MYEAR
154   FORMAT(10H LEAP YEARI10)
16    CONTINUE
      LTOT=0.
      DO166II=1,13
166   LTOT=LTOT+M(II)
      DO50I2=1,NCARD
      READ(5,168)(MON(J),MDAT(J),RAIN(J),J=1,10)
168   FORMAT(10(2I2,F4.2))
      DO17J=1,10
      IF( MON(J)-12)1684,1684,1688
```

Table B-11 (Continued)

```
1684  IF(MDAT(J)-31)17,17,1688
1688  WRITE(6,1689)
1689  FORMAT(6H ERROR)
      STOP
17    CONTINUE
      JC=1
      DO30ØI3=1,37Ø
      IF(NFL-Ø)178,178,176
176   NFL=NFL+1
178   CONTINUE
            IF(TRD)1798,1798,1792
1792        IF(RUNOF)1798,1798,1793
1793        NFL=NFL+1
            FAC=1.
1798        CONTINUE
      TRD=Ø.
      OVFL=Ø.
      RUNOF=Ø.
      RIN=Ø.
      IF(JC-1Ø)18,18,32
18    CONTINUE
      MX=MON(JC)
      LSD=LSD+1
      IF(LTOT-LSD)26Ø4,21,21
21    CONTINUE
      IF(MX)26,26,214
214   CONTINUE
      LTD=Ø
      DO22I4=1,MX
22    LTD=LTD+M(I4)
      ND=LTD+MDAT(JC)
23    CONTINUE
      IF(LSD-ND)26,24,26
24    RUNOF=COEFX*RAIN(JC)
      NFL=NFL+1
      TRUN=TRUN+RUNOF
      RIN=RAIN(JC)
      JC=JC+1
      STOR=STOR+RUNOF
      NDR=NDR+1
26    CONTINUE
      IF(LSD-1)26Ø1,26Ø8,26Ø1
26Ø1  CONTINUE
      LTD=Ø
      DO26Ø2IQ=1,13
      LTD=LTD+M(IQ)
      IF(LTD-LSD+1)26Ø2,26Ø4,26Ø2
26Ø2  CONTINUE
      GOTO26Ø8
26Ø4  CONTINUE
      WRITE(6,26Ø3)SRIN
26Ø3  FORMAT(///11H TOTAL RAIN,F6.2)
      SRIN=Ø.
      IF(LTOT-LSD)6Ø,26Ø6,26Ø6
26Ø6  CONTINUE
      WRITE(6,142)MYEAR
26Ø8  CONTINUE
      STORA=STOR
      IF(NFL-1)271,271,263
263   STOR=STOR-TREAT*FAC
```

```
264    IF(STOR-STOPS)266,266,27
266    NFL=Ø
       STOR=STOPS
27     CONTINUE
       TRD=STORA-STOR
       CTD=CTD+TRD/TREAT
       TRE=TRE+TRD
           GOTO 2719
271    CONTINUE
            IF(NFL-1)2712,2712,2718
2712        FAC=TFAC
            GOTO 263
2718        FAC=1
2719        CONTINUE
       STM=STOR-STMAX
       IF(STM)274,274,272
272    NOV=NOV+1
       OVFL=STM
       TOV=TOV+STM
       STOR=STMAX
274    CONTINUE
       IF(STOS.LT.STOR)STOS=STOR
       ILL=Ø
       MXQ=Ø
       DO276IL=1,13
       MXQ=MXQ+M(IL)
       IF(MXQ-LSD)275,278,278
275    MQQ=MXQ
       ILL=ILL+1
276    CONTINUE
278    LSX=LSD-MQQ
       SRIN=SRIN+RIN
       WRITE(6,282)ILL   ,LSX,RIN,NDR,RUNOF,STOR,OVFL,TRD,TRUN,TOV,NOV,TRE
      1 ,CTD,STOS
282    FORMAT(1H ,I3,I5,F6.2,I5,F9.2,F1Ø.2,2F9.2,F14.2,F11.2,I6,F1Ø.2,
      1F8.2,F1Ø.2)
       IF(JC-11)3Ø,29,3Ø
29     IF(I2-NCARD)32,3Ø,32
3Ø     CONTINUE
32     CONTINUE
5Ø     CONTINUE
6Ø     CONTINUE
       WRITE(6,64)
64     FORMAT(1H1)
       STOP
       END
             SUBROUTINE DLYTAP(IPFL,TFAC)
       COMMONM,AREA,COEF,STMAX,TREAT,STOPS,NYEAR,STOR,COEFX,
      *NFL,LD,ND,TRD,FAC,IOTAP,MYEAR
       DIMENSIONM(13),MON(37Ø),MDAT(37Ø),RAIN(37Ø),FINT(37Ø),FP1(37Ø),
      *FP2(37Ø),FP3(37Ø)
         READ(5,167)NZA,MON(1),MDAT(1),RAIN(1)
12       CONTINUE
         MYEAR=NZA+19ØØ
         DO122IQ1=1,37Ø
          FP1(IQ1)=1ØØØØ.
          FP2(IQ1)=Ø.
          FP3(IQ1)=Ø.
122       FINT(IQ1)=Ø.
         IF(IPFL)14,14,124
```

```
124        READ(11,1678)J11
          READ(11,1679)(FP1(JXX),JXX=1,J11)
14        CONTINUE
          FAC=TFAC
        NDR=Ø
        NOV=Ø
        CTD=Ø.
        SRIN=Ø.
        RUNOF=Ø.
        STOS=STOPS
        TRUN=Ø.
        TOV=Ø.
        TRE=Ø.
        LSD=Ø
        M(3)=28
        WRITE(6,142)MYEAR
142     FORMAT(1H1,///85X,'METCALF & EDDY, INC., ENGINEERS'/
       *85X,'1Ø29 CORPORATION WAY'/
       *85X,'PALO ALTO,CALIF.943Ø3'
       *           ,///5X,4HYEAR,I6,14X,
       A                   2ØHOCCURING ON THE DATE,19X,34HACCUMULATED FROM STA
       1RT OF THE YEAR/24X,34H----------------------------------,5X,
       C56H--------------------------------------------------------//
       D                   6H MONTH,1X,3HDAY,2X,4HRAIN,2X,4HRAIN,2X,6HRUNOFF,2
       2X,7HSTORAGE,2X,8HOVERFLOW,2X,7HTREATED,5X,9HT. RUNOFF,2X,1ØHT.OVER
       3FLOW,7H OVERFL,8H T.TREAT,7H  TREAT,13H  MAX STORAGE/13X,2HIN,3X,4
       4HDAYS,4X,2HMG,6X,2HMG,8X,2HMG,7X,2HMG,12X,2HMG,1ØX,2HMG,5X,4HDAYS,
       55X,2HMG,5X,4HDAYS,7X,2HMG//)
        XL=MYEAR
        XL=XL/4.
        L=XL
        XXL=L
        IF(XL-XXL)16,15,16
15      M(3)=29
        WRITE(6,154)MYEAR
154     FORMAT(1ØH LEAP YEARI1Ø)
16      CONTINUE
        LTOT=Ø.
        DO166II=1,13
166     LTOT=LTOT+M(II)
         J=1
1664      CONTINUE
            J=J+1
        READ(5,167)NYZ,MON(J),MDAT(J),RAIN(J)
167     FORMAT(5X,3I2,6X,F4.2)
              IF(NYZ-NZA)1682,1664,1682
1674      CONTINUE
            J=KK
            NZA=NYZ
           MON(1)=MON(J)
          MDAT(1)=MDAT(J)
         RAIN(1)=RAIN(J)
          WRITE(8,1678)J11
1678      FORMAT(I1Ø)
          WRITE(8,1679)(FINT(IXX),IXX=1,J11)
1679       FORMAT(1ØF8.2)
          WRITE(9,1678)J11
          WRITE(9,1679)(FP2(IXX),IXX=1,J11)
            IF(NYZ-9Ø)12,62,62
1682       CONTINUE
```

Table B-11 (Continued)

```
           KK=J
            DO17J=1,KK
       IF( MON(J)-99)1683,17,1683
 1683  IF( MON(J)-12)1684,1684,1688
 1684  IF(MDAT(J)-31)17,17,1688
 1688  WRITE(6,1689)MON(J),MDAT(J)
 1689  FORMAT(6H ERROR,2I10)
       STOP
 17    CONTINUE
       JC=1
       DO30I3=1,370
       IF(NFL-0)178,178,176
 176   NFL=NFL+1
 178   CONTINUE
             IF(TRD)1798,1798,1792
 1792        IF(RUNOF)1798,1798,1793
 1793        NFL=NFL+1
             FAC=1.
 1798        CONTINUE
       TRD=0.
       OVFL=0.
       RUNOF=0.
       RIN=0.
       IF(JC-370)18,18,32
 18    CONTINUE
       MX=MON(JC)
       LSD=LSD+1
       IF(LTOT-LSD)2604,21,21
 21    CONTINUE
       IF(MX)26,26,214
 214   CONTINUE
       LTD=0
       DO22I4=1,MX
 22    LTD=LTD+M(I4)
       ND=LTD+MDAT(JC)
 23    CONTINUE
       IF(LSD-ND)26,24,26
 24    RUNOF=COEFX*RAIN(JC)
         RINT=FP1(JC)
       NFL=NFL+1
       TRUN=TRUN+RUNOF
       RIN=RAIN(JC)
       JC=JC+1
       STOR=STOR+RUNOF
         IF(RUNOF)25,26,25
 25      CONTINUE
       NDR=NDR+1
 26    CONTINUE
       IF(LSD-1)2601,2608,2601
 2601  CONTINUE
       LTD=0
       DO2602IQ=1,13
       LTD=LTD+M(IQ)
       IF(LTD-LSD+1)2602,2604,2602
 2602  CONTINUE
       GOTO2608
 2604  CONTINUE
       WRITE(6,2603)SRIN
 2603  FORMAT(///11H TOTAL RAIN,F6.2)
       SRIN=0.
```

Table B-11 (Continued)

```
      IF(LTOT-LSD)60,2606,2606
2606  CONTINUE
      WRITE(6,142)MYEAR
2608  CONTINUE
      STORA=STOR
      IF(NFL-1)271,271,263
263     CONTINUE
        IF(TREAT-RINT)2632,2632,2634
2632      TREET=TREAT
         GOTO2638
2634    TREET=RINT
2638    CONTINUE
       STOR=STOR-TREET*FAC
264   IF(STOR-STOPS)266,266,27
266   NFL=0
      STOR=STOPS
27    CONTINUE
      TRD=STORA-STOR
         IF(TREET)2704,2719,2704
2704      CONTINUE
      CTD=CTD+TRD/TREET
      TRE=TRE+TRD
          GOTO 2719
271   CONTINUE
           IF(NFL-1)2712,2712,2718
2712       FAC=TFAC
           GOTO 263
2718       FAC=1.
2719       CONTINUE
      STM=STOR-STMAX
      IF(STM)274,274,272
272   NOV=NOV+1
      OVFL=STM
      TOV=TOV+STM
      STOR=STMAX
274   CONTINUE
      IF(STOS.LT.STOR)STOS=STOR
      ILL=0
      MXQ=0
      DO276IL=1,13
      MXQ=MXQ+M(IL)
      IF(MXQ-LSD)275,278,278
275   MQQ=MXQ
      ILL=ILL+1
276   CONTINUE
278   LSX=LSD-MQQ
      SRIN=SRIN+RIN
        IF(IPFL-2)2784,279,279
2784    CONTINUE
         FINT(I3)=TREET-TRD
         GOTO 28
279      FINT(I3)=RINT-TRD
28        CONTINUE
         FP2(I3)=RUNOF
          J11=I3
      WRITE(6,282)ILL   ,LSX,RIN,NDR,RUNOF,STOR,OVFL,TRD,TRUN,TOV,NOV,TRE
     1 ,CTD,STOS
282   FORMAT(1H ,I3,I5,F6.2,I5,F9.2,F10.2,2F9.2,F14.2,F11.2,I6,F10.2,
     1F8.2,F10.2)
30    CONTINUE
```

```
32      CONTINUE
50     CONTINUE
60     CONTINUE
          GOTO1674
62      CONTINUE
       WRITE(6,64)
64     FORMAT(1H1)
       RETURN
       END
             SUBROUTINE HOUTAP(IPFL,NFAC)
       COMMONM,AREA,COEF,STMAX,TREAT,STOPS,NYEAR,STOR,COEFX,
      *NFL,LD,ND,TRD,FAC,IOTAP,MYEAR
       DIMENSIONM(13),MON(24),MDAT(24),RAIN(24)
       TREAT=TREAT/24.
12      CONTINUE
        READ(5,148)MYEAR,MA,MD,NX,(RAIN(J),J=1,12)
        IF(MYEAR-99)122,63,122
122      IF(NX-2)13,12,12
13       CONTINUE
       SRIN=0.
       RUNOF=0.
       NDR=0
       NOV=0
       CTD=0.
       STOS=STOPS
       TRUN=0.
       TOV=0.
       TRE=0.
       LSD=0
       WRITE(6,142)MA
142    FORMAT(1H1,///5X,5HMONTH,I6,14X,
      A                 20HOCCURING ON THE HOUR,19X,35HACCUMULATED FROM STA
      1RT OF THE MONTH/24X,34H----------------------------------,5X,
      C56H--------------------------------------------------------//
      D                6H DAY   ,1X,4HHOUR,2X,4HRAIN,2X,4HRAIN,2X,6HRUNOFF,2
      2X,7HSTORAGE,2X,8HOVERFLOW,2X,7HTREATED,5X,9HT. RUNOFF,2X,10HT.OVER
      3FLOW,7H OVERFL,8H T.TREAT,7H  TREAT,13H  MAX STORAGE/13X,2HIN,3X,4
      4HHOUR,4X,2HMG,6X,2HMG,8X,2HMG,7X,2HMG,12X,2HMG,10X,2HMG,5X,4HHOUR,
      55X,2HMG,5X,4HHOUR,7X,2HMG//)
       MY=MA+1
       MT=M(MY)
       LTOT=0.
       DO144II=1,MT
144    LTOT=LTOT+24
       GOTO 15
145      CONTINUE
         READ(5,148)IC,MA,MD,NX,(RAIN(J),J=1,12)
148     FORMAT(6X,3I2,I1,12F3.2)
        IF(IC-99)149,63,149
149     CONTINUE
        IF(NX-2)15,145,145
15      CONTINUE
         READ(5,152)(RAIN(J),J=13,24),NEXT
152      FORMAT(13X,12F3.2,29X,I2)
         DO154IA=1,24
          MON(IA)=MD
          MDAT(IA)=IA
154       CONTINUE
       DO17J=1,24
       IF( MON(J)-MT)1684,1684,1688
```

Table B-11 (Continued)

```
1684   IF(MDAT(J)-24)17,17,1688
1688   WRITE(6,1689)
1689   FORMAT(6H ERROR)
       STOP
17     CONTINUE
       JC=1
       DO30ØI3=1,77Ø
       IF(NFL-NFAC)178,176,176
176    NFL=NFL+1
178    CONTINUE
       TRD=Ø.
       OVFL=Ø.
       RUNOF=Ø.
       RIN=Ø.
       IF(JC-24)18,18,32
18     CONTINUE
       MX=MON(JC)
       LSD=LSD+1
       IF(LTOT-LSD)26Ø4,21,21
21     CONTINUE
       IF(MX)26,26,214
214    CONTINUE
       LTD=-24
       DO22I4=1,MX
22     LTD=LTD+24
       ND=LTD+MDAT(JC)
23     CONTINUE
       IF(LSD-ND)26,24,26
24     RUNOF=COEFX*RAIN(JC)
       NFL=NFL+1
       TRUN=TRUN+RUNOF
       RIN=RAIN(JC)
       JC=JC+1
       STOR=STOR+RUNOF
        IF(RIN)25,26,25
25      CONTINUE
       NDR=NDR+1
26     CONTINUE
       IF(LSD-1)26Ø1,26Ø8,26Ø1
26Ø1   CONTINUE
       LTD=Ø
       DO26Ø2IQ=1,MT
       LTD=LTD+24
       IF(LTD-LSD+1)26Ø2,26Ø4,26Ø2
26Ø2   CONTINUE
       GOTO26Ø8
26Ø4   CONTINUE
       WRITE(6,26Ø3)SRIN
26Ø3   FORMAT(///11H TOTAL RAIN,F6.2)
       SRIN=Ø.
       IF(LTOT-LSD)6Ø,26Ø6,26Ø6
26Ø6   CONTINUE
       WRITE(6,142)MA
26Ø8   CONTINUE
       STORA=STOR
       IF(NFL-1)271,271,263
263    STOR=STOR-TREAT
264    IF(STOR-STOPS)266,266,27
266    NFL=Ø
       STOR=STOPS
```

Table B-11 (Concluded)

```
27     CONTINUE
       TRD=STORA-STOR
       CTD=CTD+TRD/TREAT
       TRE=TRE+TRD
271    CONTINUE
       STM=STOR-STMAX
       IF(STM)274,274,272
272    NOV=NOV+1
       OVFL=STM
       TOV=TOV+STM
       STOR=STMAX
274    CONTINUE
       IF(STOS.LT.STOR)STOS=STOR
       ILL=Ø
       MXQ=Ø
       DO276IL=1,MT
       IF(MXQ-LSD)275,278,278
275    MQQ=MXQ
       MXQ=MXQ+24
       ILL=ILL+1
276    CONTINUE
278    LSX=LSD-MQQ
       SRIN=SRIN+RIN
       WRITE(6,282)ILL   ,LSX,RIN,NDR,RUNOF,STOR,OVFL,TRD,TRUN,TOV,NOV,TRE
      1 ,CTD,STOS
282    FORMAT(1H ,I3,I5,F6.2,I5,F9.2,F1Ø.2,2F9.2,F14.2,F11.2,I6,F1Ø.2,
      1F8.2,F1Ø.2)
       IF(JC-25)3Ø,29,3Ø
29     IF(NEXT-1)32,3Ø,32
3Ø     CONTINUE
32     CONTINUE
          GOTO 145
6Ø     CONTINUE
        GOTO12
63     WRITE(6,64)
64     FORMAT(1H1)
       STOP
       END
```

Table B-12. STORAGE TREATMENT TASK - LIST OF VARIABLES

Variable name	Index[a]	Units	Description
AREA	IC	Acres	Area to be analyzed
ARN	I	--	Identifier-number of areas to be analyzed
COEF	IC	--	Coefficient of runoff (rational method)
COEFX	C	--	Factor combining area and coefficient of runoff
CTD	O	Day or hr	Cumulative number of days or hrs in which treatment occurs
DLYCRD		--	Name of subroutine for daily analysis of rainfall on punch card input
DLYTAP		--	Name of subroutine for daily analysis of rainfall on tape or disk input
FAC	C	--	Factor for adjusting treatment rate on first day of rain
FINT		mil gal.	New calculated capacity of adjacent downstream interceptor
FPI		mil gal.	Capacity of next downstream interceptor
FP2		mil gal.	New calculated capacity of next downstream interceptor
FP3		mil gal.	Interceptor capacity (not used)
HOUCRD		--	Name of subroutine for hourly analysis of rainfall on punch card input
HOUTAP		--	Name of subroutine for hourly analysis of rainfall from tape input
I		--	Do loop counter
II		--	Do loop counter
IL		--	Do loop counter
ILL	O	--	Number of months or days being analyzed
IOTAP	IC	--	Switch-0 for card input, 1 for tape or disk input
IPFL	I	--	Number of interceptors converging at point of runoff
IQ		--	Do loop counter
IQ1		--	Do loop counter
IXX		--	Do loop counter
I1		--	Do loop counter
I2		--	Do loop counter
I3		--	Do loop counter
I4		--	Do loop counter
J		--	Do loop counter
JC		--	Counter and index
JXX		--	Do loop counter
J11		--	Do loop counter
KK		--	Number of days with rain
L		--	Factor used to find leap yrs
LD	C	--	Not used
LSD		--	Counter of number times through loop counter of days or hrs
LSX	O	Day or hr	Day of month or hr of day
LTD		--	Counter to locate end of month or day
LTOT		Day or hr	Total number of days in yr or hrs in month
M	C	Day	Number of days in each month
MDAT	I	Day or hr	Days or hrs of input data
MON	I	--	Months or days of input data
MQQ		--	Factor used to determine days or hrs fpr output record
MT		--	Month being analyzed for hourly rainfall
MX		--	Number of months or days being analyzed
MXO		Day or hr	Cumulative counter of days or hrs
MY		--	Number of days in month for hourly flow analysis
MYEAR	IC	--	Years or months to be analyzed
NCARD	I	--	Number of cards of input data for yrs or months to be analyzed
ND	C	Day or hr	Days or hrs from beginning of yrs or months
NDR	O	Day or hr	Cumulative count of days or hrs where rain occurs in yrs or months
NFL	C	--	Index recording if flow is directed to treatment from either runoff or storage
NOU	O	Day or hr	Cumulative count of days or hrs of overflows occurring in yrs or months

Table B-12 (Concluded)

Variable name	Index[a]	Units	Description
NSS	I	--	Switch-O for daily analysis, 1 for hourly analysis
NYEAR	IC	--	Number of yrs or months of records to be analyzed
NYZ		--	Last 2 digits in yr being analyzed and yr advance switch
NZA	I	--	Last 2 digits in yr being analyzed
OUFL	O	mil gal.	Volume of runoff, not directed to storage or treatment, discharged to receiving waters
RAIN	I	in.	Quantity of rainfall by days or hrs from input data
RIN	O	in.	Quantity of rainfall by days or hrs
RINT		mil gal.	Capacity of next downstream interceptor
RUNOF	O	mil gal.	Volume of runoff for particular days or hrs
SRIN	O	mil gal.	Cumulative quantity of rain in months or days
STM		mil gal.	Volume of overflow
STMAX	IC	mil gal.	Maximum volume of storage available
STOPS	IC	mil gal.	Minimum volume of storage
STOR	OC	mil gal.	Volume of runoff in storage at end of days or hrs
STORA		mil gal.	Temporary record of volume of runoff in storage
STOJ	O	mil gal.	Maximum volume contained in storage for yrs or months
TFAC	I	--	Factor to determine volume routed to treatment in first days or hrs of rain
TOU	O	mil gal.	Cumulative volume of overflow for yrs or months
TRD	OC	mil gal.	Volume of runoff directed to treatment for days or hrs
TRE	O	mil gal.	Cumulative volume treated for yrs or months
TREAT	IC	mil gal.	Treatment rate or adjacent downstream interceptor capacity
TREET		mil gal.	Treatment rate or effective adjacent downstream interceptor capacity
TRUN	O	mil gal.	Cumulative volume of runoff for yrs or months
XL			Factor used in finding leap yrs
XXL			Factor used in finding leap yrs

a. I indicated input variable.

b. C indicated variable in common block.

c. O indicated output variable.

Appendix C

DETERMINATION OF K FACTOR

Appendix C

DETERMINATION OF K FACTOR

The gross runoff coefficient (K factor) is an integral part of the storage-treatment program. This factor can be determined from reliable measurements of rainfall and total runoff quantities as described in Section V. This factor can also be predicted based on geographic data.

Recent research has developed a correlation between population density and the fraction of impervious land in a region [9]. This relationship is of the form:

$$I = 9.6\ PD_d^{(0.573 - 0.0391\ \mathrm{Log}_{10} PD_d)} \qquad (1)$$

where I = imperviousness in percent

PD_d = population density in developed portion of urbanized area, persons/acre

The results from this equation can be checked with values for a known region. In Figure C-1 the actual data for Rochester are plotted along with the curve resulting from the predicting equation shown above.

The fraction of imperviousness can be used directly as a K factor or it can be adjusted to reflect local conditions. The computer model STORM[11,12] weights pervious and impervious fractions with the following equation[9].

$$K = 0.15\ (1-I) + 0.90I$$

$$K = 0.15 + 0.75I \qquad (2)$$

where K = gross runoff coefficient

I = fraction imperviousness

The values of 0.15 and 0.90 are default values used in STORM.

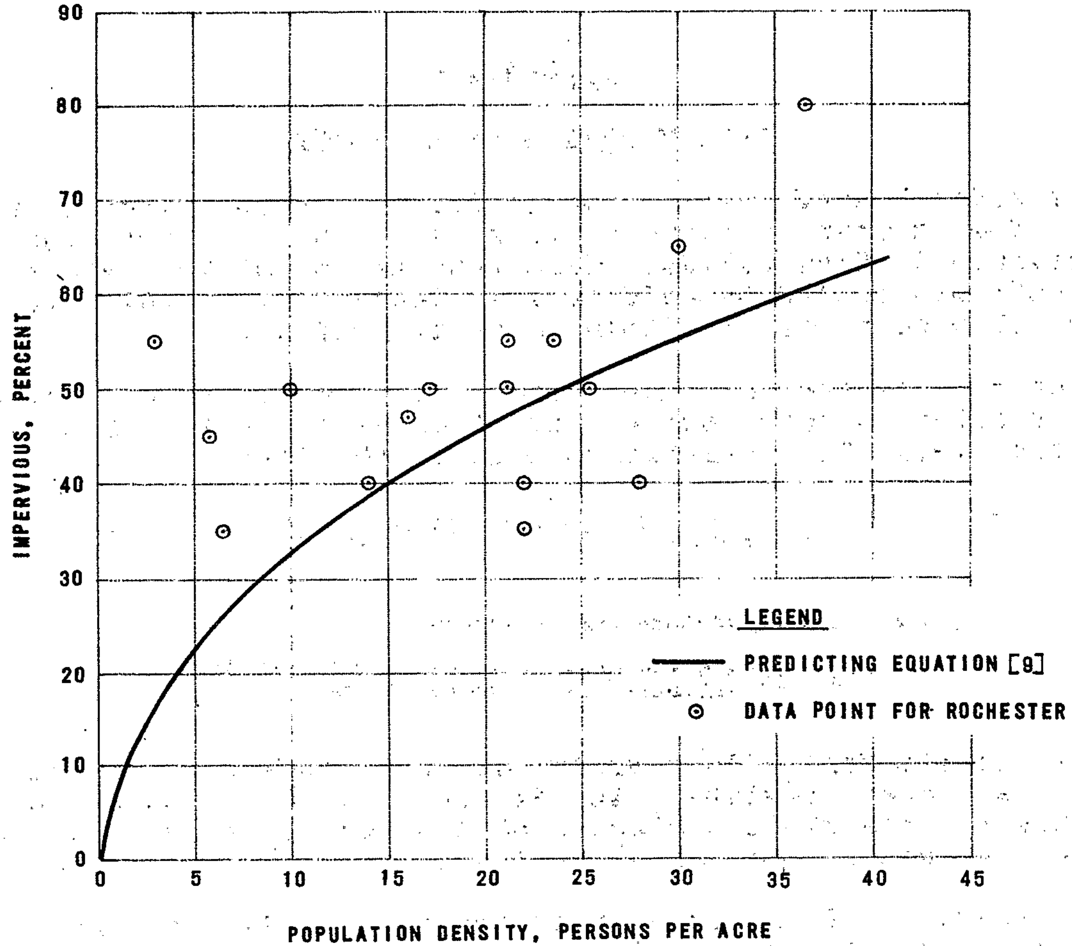

FIGURE C-1. COMPARISON OF ROCHESTER DATA WITH IMPERVIOUSNESS PREDICTING EQUATION

Appendix D

OVERFLOW QUALITY ASSESSMENT-ALTERNATE METHODS

In this section two alternative procedures for computing the quality of stormwater discharges from combined and separate sewer systems are presented. The first method was developed in the course of the nationwide assessment of the stormwater problem [9]. This method uses geographic and demographic characteristics to predict quality parameter. The second procedure that will be discussed is a regression technique.

QUALITY PREDICTION FROM GEOGRAPHIC AND DEMOGRAPHIC DATA

Stormwater quality is a function of land use, population density, and precipitation. From the nationwide assessment the following relationships were developed[9]:

Separate areas: $M_s = a(i,j) \times P \times f(PD)$ (1)

Combined areas: $M_c = b(i,j) \times P \times f(PD)$ (2)

where M = lb of pollutant, lb/acre-yr

$a(i,j)$ = constant for separate storm systems for i land use and j constituent, lb/acre-in.

$b(i,j)$ = constant for combined storm systems for i land use and j constituent, lb/acre-in.

P = annual precipitation, in./yr

$f(PD)$ = population density function

This equation when provided with appropriate constants summarized in Table D-1, will calculate annual pollutant loadings.

However, for use in the simplified mathematical model a concentration of pollutants is required that can be paired with the volume of overflow generated in the

Table D-1. QUALITY CONSTANTS FOR LOADINGS FROM SEWER SYSTEMS Pounds per Acre-Inch

		Pollutant, j				
	Land use, i	1. BOD_5	2. SS	3. VS	4. PO_4*	5. N**
Separate areas a(i,j)	1. Residential	0.799	16.3	9.48	0.034	0.540
	2. Commercial	3.20	22.2	14.0	0.076	0.296
	3. Industrial	1.22	29.1	14.4	0.071	0.276
	4. Other	0.18	2.7	2.60	0.010	0.061
Combined areas b(i,j)	1. Residential	3.29	67.2	38.9	0.139	0.540
	2. Commercial	13.2	91.8	57.9	0.312	1.22
	3. Industrial	5.00	120.0	59.4	0.291	0.140
	4. Other	0.47	11.1	10.8	0.041	0.250

* Total P as PO_4.

**Total N as N.

storage-treatment task. Following the format used in the nationwide assessment the relationship would be of the form:

$$\text{Separate areas: } Q_s = c(i,j) \times f(PD) \quad (3)$$

$$\text{Combined areas: } Q_c = d(i,j) \times f(PD) \quad (4)$$

where Q = concentration of pollutants, mg/l

c(i,j) = constant for separate storm systems for i land use and j constituent, mg/l

d(i,j) = constant for combined sewer systems for i land use and j constituent, mg/l

f(PD) = population density function

The constants a(i, j) and b(i, j) were derived from surface loading to be used with precipitation. These constants can be adjusted to be used with runoff and for dimensional consistency with simplified modeling. The conversion can be effected by the following equation:

$$c(i,j) = [a(i,j) \times F]/k \quad (5)$$

$$d(i,j) = [b(i,j) \times F]/k \quad (6)$$

where F = 4.14, constant, [(mg/l)/(lb/acre-in.)]

k = 0.34 national average runoff coefficient for seven cities [9]

These constants, summarized in Table D-2, can be used with the following population density functions (f(PD)) to predict quality values that can be used in the simplified mathematical model.

Residential

$$f(PD) = 0.142 + (0.218 \times PD^{0.54}) \quad (7)$$

Commercial and industrial

$$f(PD) = 1.0 \quad (8)$$

Other (open and nonurban)

$$f(PD) = 0.142 \quad (9)$$

Table D-2. QUALITY CONSTANTS FOR CONCENTRATIONS FROM SEWER SYSTEMS

		Pollutant, j				
	Land use, i	1. BOD_5	2. SS	3. VS	4. PO_4*	5. N**
Separate areas, c(i,j)	1. Residential	10.4	211.5	123.0	0.44	7.01
	2. Commercial	41.5	288.1	181.7	0.98	3.84
	3. Industrial	15.8	377.6	186.8	0.91	3.58
	4. Other	1.5	35.0	33.7	0.13	0.79
Combined areas, d(i,j)	1. Residential	42.7	871.9	123.0	1.80	7.01
	2. Commercial	171.3	1,191.2	751.3	4.05	15.83
	3. Industrial	64.9	1,557.0	770.8	3.78	1.82
	4. Other	6.1	144.0	140.1	0.53	3.24

* Total P as PO_4.

**Total N as N.

An important fact to remember is that the values predicted by these equations reflect the characteristics of the seven cities on which sampling data was available from the nationwide assessment. It would be very beneficial to have sampling data collected that could be used for comparison and/or adjustment of these equations to reflect local conditions

QUALITY PREDICTION USING REGRESSION TECHNIQUES

In the body of the text two regression techniques, developed for use in Rochester, were described. A third regression analysis, originally developed for analyzing stormwater in Washington, D.C., is presented here as another option for predicting quality parameters[10]. The procedure is outlined sequentially.

1. Compute suspended solids (degritted fraction) in mg/l from the following expression:

$$ss = 400 \times f_1 \times f_2 \times f_3 \qquad (10)$$

where 400 = an average suspended solids value that can be changed if local data are available for a closer fit

f_1 = a function of days since the last rain and time from the start of overflow or discharge

f_2 = a function of rainfall intensity

f_3 = a function of catchment population density

For each time increment compute a value for ss reading f_1, f_2, and f_3 from Tables D-3, D-4, and D-5, respectively.

The computed values will suffice for both combined and separate systems.

2. Compute BOD for separate storm drains from the following expressions:

$$BOD_5(\text{storm}) = .10 \times ss \text{ for ss values equal to or less than 300 mg/l} \qquad (11)$$

$$BOD_5(\text{storm}) = 30 + (ss - 300) \times .08 \text{ for ss values greater than 300 mg/l} \qquad (12)$$

Table D-3. REGRESSION COEFFICIENT f_1

Time since start of overflow, hr/or min	Days since last rainstorm				
	0-6	7-12	13-18	Over 18	Unknown
1st hr/or less than 30 min	1.2	1.9	2.3	2.6	1.9
2nd hr/30-90 min	.9	1.2	1.5	1.7	1.2
3rd hr/90-180 min	.6	.7	.7	.7	.7
4th-6th hr/180-360 min	.5	.5	.5	.5	.5
7th-12th hr/360-720 min	.4	.4	.4	.4	.4
13th or more hr/more than 720 min	.3	.3	.3	.3	.3

Table D-4. REGRESSION COEFFICIENT f_2

	Rainfall intensity, in./hr			
	.01-.09	.10-.20	.21-.50	Over .50
f_2 =	.5	.9	1.2	1.5

Table D-5. REGRESSION COEFFICIENT f_3

	Population density, persons per acre				
	0.10	11-20	21-30	31-40	Over 40
f_3	.5	.65	.80	.95	1.0

3. Compute BOD for combined overflows from the following expression:

$$BOD_5(comb.) = aD + (1 - a) \times BOD_5(storm) \quad (13)$$

where a = proportion of combined flow attributed to average dry-weather sanitary flow

D = average BOD_5 concentration of dry-weather sanitary flow

Note: Knowing the average dry-weather flow from the area in mgd, the hourly rate is simply this value divided by 24. Where a is therefore the hourly sanitary flow plus the storm runoff that hour divided by the sum of the two. A new a must be computed each time step.

4. Compute total nitrogen (all forms as N, mg/l) for both combined and separate systems from the following expression:

$$N = 0.10\ BOD_5 \quad (14)$$

5. Finally, compute total phosphorus (all forms as P, mg/l) for both combined and separate systems from the following expression:

$$P = 0.033\ BOD_5 \quad (15)$$

The above method gives concentrations in a general sense only and should not be used for other than first level approximations without substantial corroborating data.

Total coliforms can be computed similarly, but it is doubtful that the effort is warranted considering the high order numbers involved.

GLOSSARY

Combined sewage--Sewage containing both domestic sewage and surface water or stormwater, with or without industrial wastes. Includes flow in heavily infiltrated sanitary sewer systems as well as combined sewer systems.

Combined sewer--A sewer receiving both intercepted surface runoff and municipal sewage.

Combined sewer overflow--Flow from a combined sewer in excess of the interceptor capacity that is discharged into a receiving water.

First flush--The condition, often occurring in storm sewer discharges and combined sewer overflows, in which a disproportionately high pollutional load is carried in the first portion of the discharge or overflow.

Infiltration--The water entering a sewer system and service connections from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.

Inflow--The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catchbasins, stormwaters, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

In-system--Within the physical confines of the sewer pipe network.

Interceptor--A sewer that receives dry-weather flow from a number of transverse combined sewers and additional predetermined quantities of intercepted surface runoff and conveys such waters to a point for treatment.

Municipal sewage--Sewage from a community which may be composed of domestic sewage, industrial wastes, or both.

Overflow--(1) The flow discharging from a sewer resulting from combined sewage, storm wastewater, or extraneous flows and normal flows that exceed the sewer capacity. (2) The location at which such flows leave the sewer.

Physical-chemical treatment processes--Means of treatment in which the removal of pollutants is brought about primarily by chemical clarification in conjunction with physical processes. The process string generally includes preliminary treatment, chemical clarification, filtration, carbon adsorption, and disinfection.

Plug flow--The passage of liquid through a chamber such that all increments of liquid move only in the direction of flow and at equal velocity.

Pollutant--Any harmful or objectionable material in or change in physical characteristic of water or sewage.

Sewer--A pipe or conduit generally closed, but normally not flowing full, for carrying sewage or other waste liquids.

Storm flow--Overland flow, sewer flow, or receiving stream flow caused totally or partially by surface runoff or snowmelt.

Storm sewer--A sewer that carries intercepted surface runoff, street wash and other wash waters, or drainage, but excludes domestic sewage and industrial wastes.

Storm sewer discharge--Flow from a storm sewer that is discharged into a receiving water.

Stormwater--Water resulting from precipitation which either percolates into the soil, runs off freely from the surface, or is captured by storm sewer, combined sewer, and to a limited degree sanitary sewer facilities.

Surcharge--The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

Surface runoff--Precipitation that falls onto the surfaces of roofs, streets, ground, etc., and is not absorbed or or retained by that surface, thereby collecting and running off.

Urban runoff--surface runoff from an urban drainage area that reaches a stream or other body of water or a sewer.

Wastewater--The spent water of a community. See Municipal Sewage and Combined Sewage.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

A simplified stormwater management model has been created to provide an inexpensive, flexible tool for planning and preliminary sizing of stormwater facilities.

The model delineates a methodology to be used in the management of stormwater and consists of a series of interrelated tasks that combine small computer programs and hand computations. The model successfully introduces time and probability into stormwater analysis, promotes total system consciousness on the part of the user, and assists in establishing size-effectiveness relationships for facilities.

Throughout the report, data from the City of Rochester, New York, is presented and analyzed as a working example.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Combined sewers, Drainage, *Mathematical models, *Overflows--sewers, Regression analysis, *Runoff, *Surface water runoff, *Water quality	*Combined sewer overflows, Drainage systems, Pollution abatement, *Storm runoff, *Urban hydrology	13B

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