METHODOLOGY FOR STORMWATER RUNOFF INVESTIGATION, URBAN LEON COUNTY, FLORIDA

By Marvin A. Franklin

U.S. GEOLOGICAL SURVEY

Open-File Report 82-355

Prepared in cooperation with

LEON COUNTY, FLORIDA

1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

U.S. Geological Survey
Suite F-240
325 John Knox Road
Tallahassee, Florida 32303

CONTENTS

ILLUSTRATIONS

TABLE

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to metric units and abbreviations of those units are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

METHODOLOGY FOR STORMWATER RUNOFF INVESTIGATION, URBAN LEON COUNTY, FLORIDA

By Marvin A. Franklin

ABSTRACT

The U.S. Geological Survey in cooperation with Leon County is currently (1981) developing a lumped-parameter, rainfall-runoff model for the urban area of the county. Flood information from 16 sites is being collected and will be analyzed to define hydrologic relations useful for estimating magnitude and frequency of discharges in urban areas. This report summarizes methods of collection, processing, and analysis of rainfall-runoff data from the drainage basins that will be used in the model.

INTRODUCTION

A knowledge of flood characteristics is essential for designing drainage structures and for using flood-prone land. A reliable estimate of flood magnitude and frequency is necessary to design economical structures and prepare realistic zoning ordinances for a community. Leon County and the city of Tallahassee have a history of local flooding resulting from intense and generally brief storm events. This is evidenced by approximately 6 inches of rainfall, most of which fell within a 1-hour period, on October 6, 1976. Floods not only cause property damage but on occasion result in the loss of life, as occurred May 17, 1974, when two teenage boys drowned. The most recent flooding occurred in February and March 1981 when intense storms moved across the county.

Recognizing the need for reliable flood data and improved techniques for estimating the frequency and magnitude of flooding, the U. S. Geological Survey and the Public Works Department of Leon County, Fla., began a cooperative investigation in 1978 that resulted in the installation of a network of streamflow and rainfall gages and the ongoing collection and analysis of flood data in Leon County. Fifteen rainfall-collection gages and 16 flood-runoff gages were installed in 1979 to collect storm rainfall-runoff data.

The purpose and scope of this investigation are to collect hydrologic data from selected drainage systems in the urban areas of the county, to analyze the data, and to develop regression equations that can be used to estimate the magnitude and frequency of floods in other urban parts of the county. In addition to this flood analysis, limited water-quality samples are also being collected at some gages to provide a data base for future water-quality studies. The purpose of this report is to provide timely information on the objectives, methodology, and time frame of this investigation. After collecting hydrologic records of sufficient length to accurately calibrate a rainfall-runoff model, a comprehensive report on the results of the investigation is planned.

More than 25 years of observed peak-flood data are generally needed to make reliable estimates of the magnitudes of 50- and 100-year floods at a stream-gaging site. To reduce the time required for data collection, runoff and rainfall data collected in the investgation will be used to calibrate a lumped-parameter, rainfall-runoff model that will synthesize a long-term flood record from the long-term rainfall record. About 40 significant storm events are needed at a rainfall-runoff site to achieve a successful model calibration.

The analysis for estimating flood frequencies at ungaged sites involves model calibration with observed data, long-term rainfall input to generate long-term flood record, and log-Pearson type III frequency analysis to establish a flood-frequency relation at each gaging site. A multiple-regression is then made to develop equations that may be used to transfer the flood frequencies from gaged to ungaged sites.

METHODS

The data-acquisition and analytical techniques to be used in the investigation conform to standard Geological Survey methodology. The first phase requires establishment of gaging stations for the collection of storm-rainfall and flood-runoff data on streams in the developed area.

The second phase requires drainage areas of all gaged basins to be delineated and the main-channel lengths measured from recent topographic maps or aerial photographs. The percentage of total area of each drainage basin consisting of impervious surfaces, lakes, and ponds must also be determined. These basin characteristics will be used in the multiple-regression analysis to define common parameters in each basin that can be related to flood magnitude.

Data Acquisition

Data-Collection Sites

A typical rainfall-collection site is shown in figure 1. The rain gage system consists of a catchment that is the same in surface area as the National Weather Service (NWS) standard 8-inch diameter rain gage. Rainwater falling into the catchment drains to a vertical 3-inch diameter galvanized pipe. A float in the pipe is connected to a digital recorder that punches a 16-channel paper tape with the equivalent rainfall depth at 5-minute intervals. By using a calibrated float wheel, the cumulative rainfall is recorded in inches. Unit rainfall in a given 5-minute interval is computed by subtracting the quantity recorded at the start of the 5-minute interval from the reading at the end of that interval. The daily rainfall total is computed by subtracting the first reading of the day from the last reading of the day. Each 5-minute value of rainfall is stored in the computer for storm-event days. On days when rainfall occurs, but no runoff is produced, only the daily total is stored. The storage volume of the pipe is sufficient to hold a 17-inch rainfall.

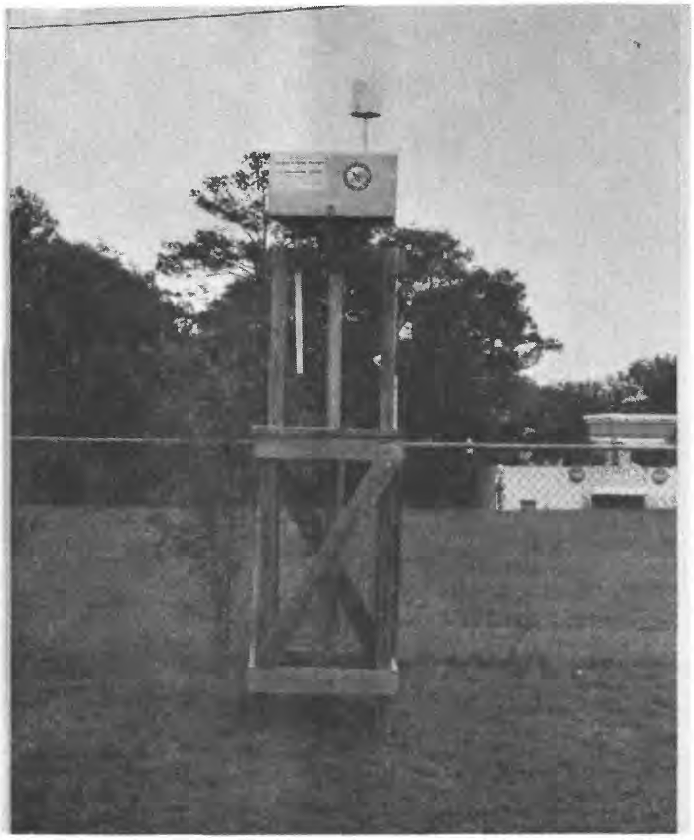

Figure 1.--Typical rainfall-collection site.

A typical discharge data-collection site is shown in figure 2. The stream stage recorder is similar to that used with the rain gage in that it also works on the float and digital-recorder system. A 10-inch stilling well is set in the stream bank and connected to the stream with intakes. The stage (or elevation of the water surface) is recorded at 5-minute intervals. Each stage and rainfall site is visited every 2 to 3 weeks to insure proper operation and to remove the 16-channel punch tape for processing the record.

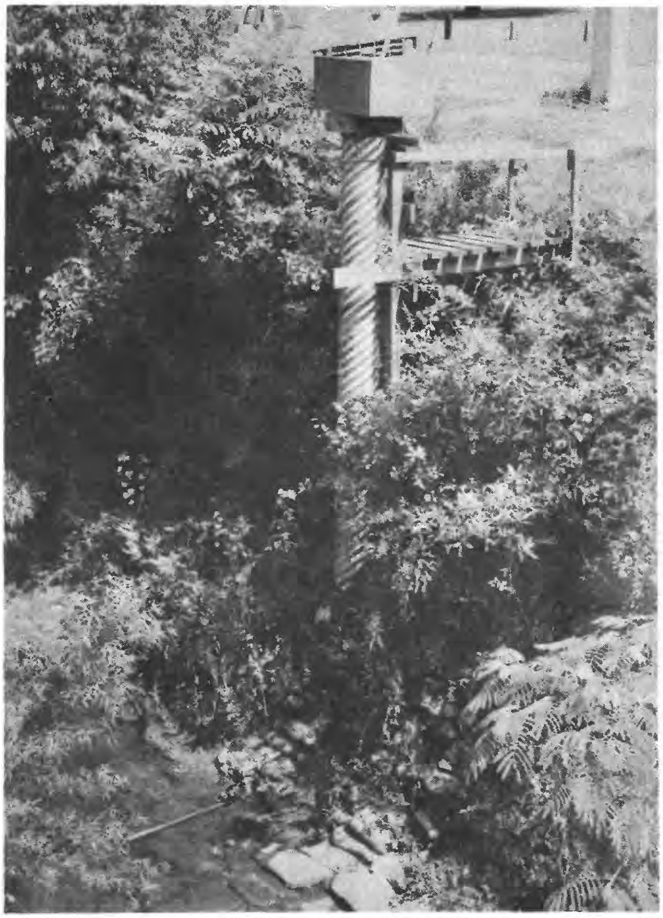

Figure 2.--Typical discharge data-collection site.

Whenever possible, discharge measurements are made during runoff events to develop stage-discharge relations at each site. This involves making measurements of depth and velocity at several sections across the stream. The area of flow is computed from the depth observations and the measured width of each section. The area is then multiplied by the velocity to give the discharge in cubic feet per second (ft^3/s). The discharge for each section is then added to determine the total discharge for the measurement. This discharge is then plotted against the mean stage of the stream during the time of the measurement. By making several measurements at different discharges and stages, a stage-discharge relation can be defined, such as that for the central drainage ditch at Airport Drive (fig. 3). From a 16-channel punch record of the stage and the stage-discharge relation, discharge for each 5-minute interval during storm events is computed and stored in the computer.

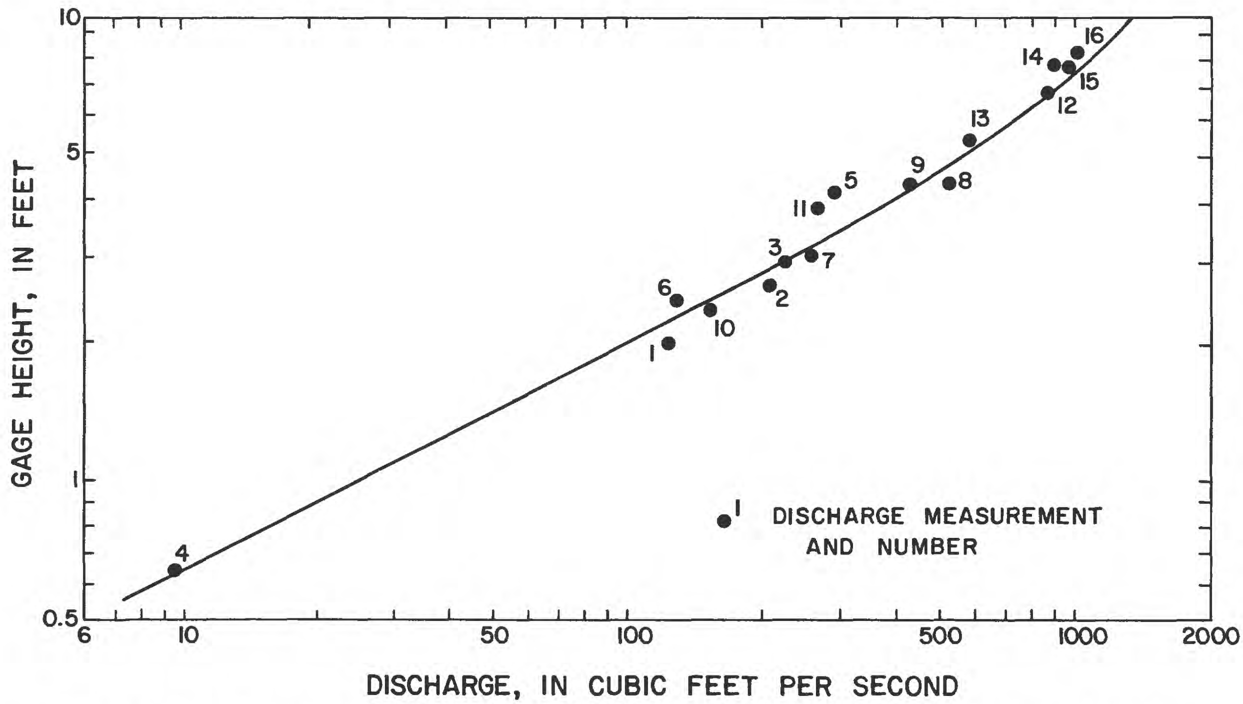

Figure 3.--Stage-discharge relation, central drainage ditch at Airport Drive.

Long-Term Rainfall and Evaporation

Flood-peak synthesis requires an input of long-term daily rainfall and evaporation data, and unit rainfall. Daily and unit rainfall for 1906-80 at Thomasville-Coolidge, Ga., and daily evaporation at Milton, Fla., are available from the National Weather Service. The Thomasville-Coolidge location is the nearest recording long-term rainfall site to the city of Tallahassee. A comparison of the rainfalls at Thomasville-Coolidge and at Tallahassee will be made to determine their relation.

Analytical Techniques

The analysis of flood data is divided into two phases: frequency distributions are determined from records at gaged sites to determine magnitude and frequency of flooding; then a multiple-regression analysis is made to extend this information to ungaged sites.

Long periods of gaged record are needed to make reliable estimates of the larger recurrence-interval floods (50- and 100-year). A Survey rainfall-runoff model will be used to extend the data collected during this investigation into a synthesized long-term record. The rainfall-runoff model and the methods planned to determine frequency distributions are discussed next.

Rainfall-Runoff Model

The rainfall-runoff model developed by Dawdy and others (1972) will be used in this investigation. It combines soil-moisture-accounting and rainfall-excess components with the Clark (1945) flood-routing method. This lumped-parameter model has three basic components: antecedent moisture, infiltration, and rainfall excess and routing.

The antecedent soil-moisture component assesses the change in soil moisture based on daily rainfall and evaporation. Four parameters are used to continually compute antecedent soil moisture. Dawdy and others (1972) describe these parameters as follows:

1. EVC, a pan coefficient for converting measured pan evaporation to potential evapotranspiration;

2. RR, the proportion of daily rainfall that infiltrates into the soil;

3. BMSM, a maximum effective amount of base moisture storage at field capacity, in inches; and

4. DRN, a coefficient controlling the rate of drainage of the infiltrated soil moisture, in inches per day. In the latest version of the model, this parameter has been replaced with EAC, which is effective impervious area.

The output from this component is the amount of base-moisture and infiltrated-surface-moisture storage.

The infiltration component uses the input of storm rainfall and output from the soil-moisture accounting component that indicated the soil moisture at the beginning of the storm rainfall. Three parameters are used in the modified Philip (1954) infiltration equation to compute the infiltration in the basin. These three parameters are:

1. PSP, the suction at the wetted front for soil moisture at field capacity, in inches of pressure;

2. RGF, the ratio of the suction of the wetted front for soil moisture at wilting point to that at field capacity; and

3. KSAT, the effective saturated value of hydraulic conductivity used to determine infiltration rates, in inches per hour.

The rainfall excess computed in the infiltration component is routed to the outlet of the basin. The model uses a modification of the Clark flood-routing as described by Carrigan (1973). Three parameters are also used in this step. They are:

1. Tp, the time to peak in minutes;

2. Tc, basin lag time; and

3. KSW, a time characteristic for linear reservoir routing.

Model Calibration

Calibration of the model requires as input to the soil-moisture and infiltration component the following: unit and daily rainfall; unit discharge; daily evaporation; and impervious area as a percentage of the total drainage area.

The model calibration is accomplished in two steps. First, the seven parameters used to compute the volume of runoff are automatically adjusted until the difference between the synthesized volumes and the observed volumes of runoff are minimized. The initial parameter values are determined from soil type, basin characteristics, and climatological factors.

The method of determining optimum parameter values is based on an optimization technique devised by Rosenbrock (1960). The technique is a trial and error procedure. The model is programmed to change a parameter value and then recompute the objective function based on the new set of values. If an improvement is made, the set is retained; if not, the old set of values is retained. This process is followed for each parameter until improvement stops. The objective function is computed as the sum of the squared deviations of the logarithms of the difference between the synthesized flood volumes and the observed flood volumes.

In the second step, the volume parameters are held constant and the flow is routed to the outlet of the basin. A line printer plot is generated with the synthesized hydrograph overlaying the observed hydrograph. A visual comparison is made; and if there is a significant difference, the parameter input values are checked and corrected.

Flood-Peak Synthesis

Flood-peak synthesis is the process whereby daily rainfall and evaporation and unit rainfall, for the period of record, are put into the calibrated model for each site. The model then generates flood hydrographs for each event entered for each rainfall-runoff site. Annual peak discharges are selected from the synthesized data.

Flood-Frequency Analysis

The U.S. Water Resources Council (1981) recommends the log-Pearson type III distribution for use as the base method for flood-frequency analysis. In this investigation, a Pearson distribution of the annual peak discharges, generated as described in the previous section, is planned. The log-Pearson type III distribution is defined by three statistical parameters: the mean, the standard deviation, and the skew of the logarithms of the data. An alternate method of computing station flood-frequency curves is described by Lichty and Liscum (1978). This method uses model calibration parameters in conjunction with values from "c" curves to develop station frequency curves. This eliminates the task of flood-peak synthesis and log-Pearson frequency analysis. The Lichty and Liscum (1978) method will be used in this investigation.

Figure 4 shows an example of a typical flood-frequency curve for a rainfall-runoff site. This information is only useable at or very near the gage site for which it was determined.

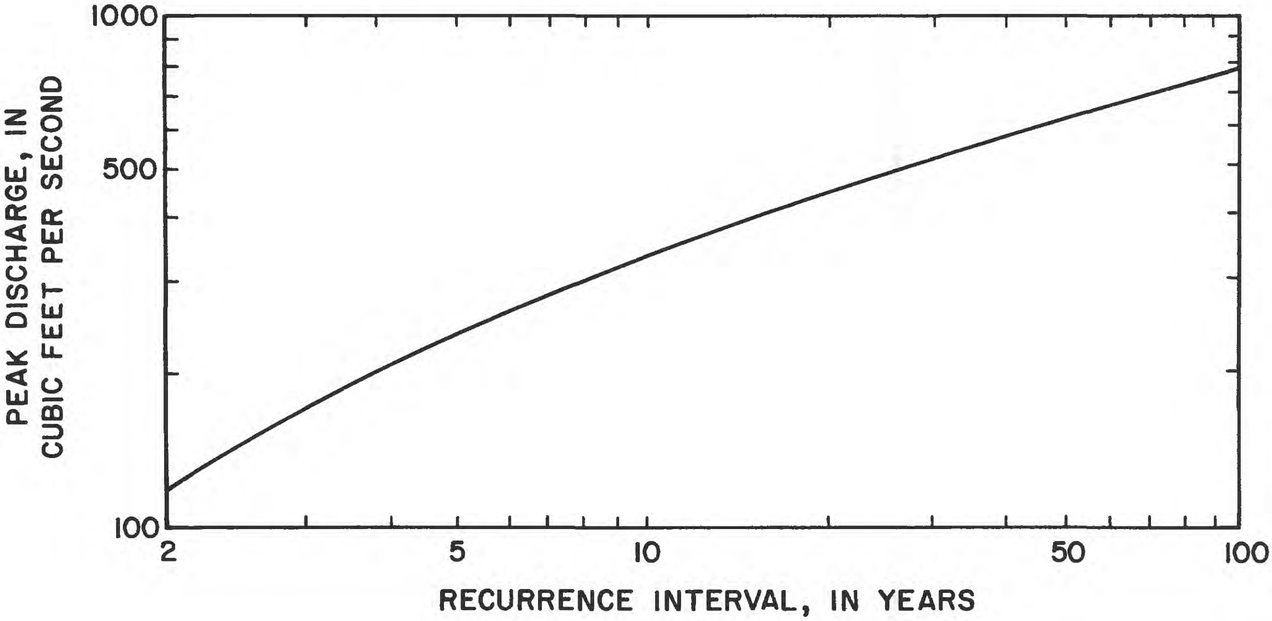

Figure 4.--Typical flood-frequency relation.

Regression Analysis

Because flood information is collected at only a few of the many sites where flood data are needed, hydrologic information must be extended from the gaged to the ungaged sites by regional analysis. Riggs (1973) described the regression method as a useful regionalization tool. Regression relates the discharge of a given flood frequency to basin characteristics. The regression model has the form:

$$Q_n = aA^bB^c, \tag{1}$$

where

Q_n is the peak discharge for a n-year recurrence interval;

A and B are basin characteristics; and

a, b, and c are constants for the recurrence interval n.

Multiple regression provides a mathematical relation between the dependent variable (flood frequency) and the independent variables (basin characteristics) as well as a measure of the accuracy of the relation. A measure of the usefulness of each independent variable in the relation is also defined.

Previous studies indicate that peak discharge is linearly related to basin characteristics if logarithmic transformations of each are used. Therefore, all peaks and basin characteristics are transformed into logarithmic form before the regression is performed. The multiple regression can be performed on a digital computer using both step-forward and step-backward analysis.

The usefulness of an independent variable to the relation is determined by its statistical significance and the reduction in the standard error of the relation by its use. A 95 percent confidence limit will be used to select the variables that are significant in this study.

The resulting regression equations will be useable throughout the county and will provide a tool for the design of drainage structures.

DATA ACQUIRED AS OF SEPTEMBER 1980

After reconnaissance late in 1978, 15 rainfall and 16 discharge gaging stations were installed between January and December 1979. Figure 5 shows the location of these stations. Table 1 gives the map location number, station identification number, and type and location of the gages. The discharge stations were selected on the basis of stability of the stage-discharge relation, range in drainage area, representative coverage of the developed area, and accessibility. The rain gages were originally installed using a grid system; but, as discharge stations were established, some rain gages were moved to provide better coverage of their drainage areas. The drainage areas of all gaged basins have been delineated and the main-channel lengths measured from recent topographic maps or aerial photographs. The percentage of total area of each drainage basin consisting of impervious surfaces, lakes, and ponds has been determined.

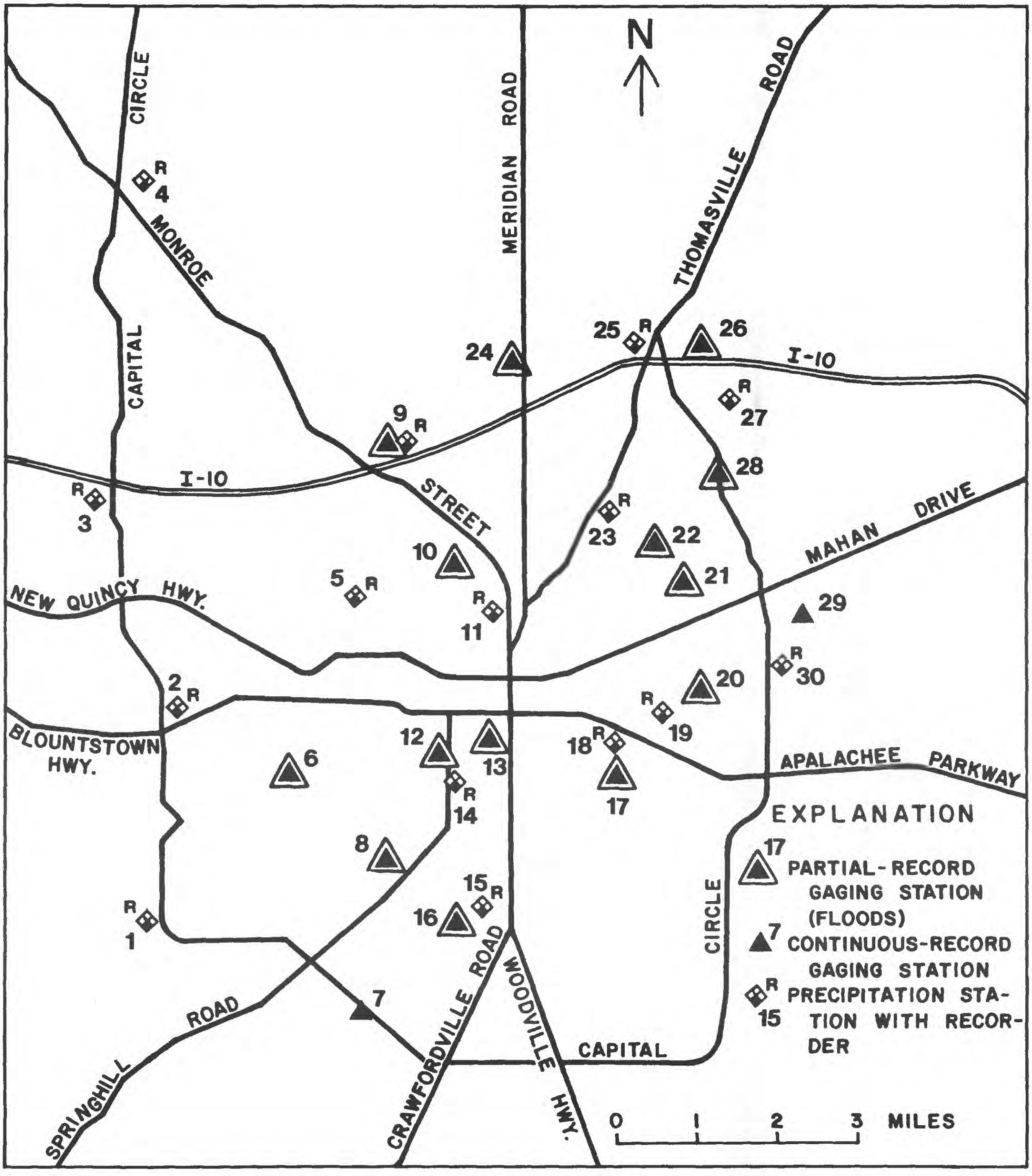

Figure 5.--Location of rainfall- and discharge-collection sites in the Tallahassee area of Leon County, Fla.

Table 1.--Gage descriptions and locations

Map location number	Station identification number	Type and location
1	302347084212300	Rainfall gage at Tallahassee Municipal Airport near National Weather Service rain gage
2	302609084211000	Rainfall gage behind Wayne Coloney plant near intersection of Blountstown Highway and Capital Circle
3	302842084215200	Rainfall gage just west of Capital Circle near intersection with Commonwealth Boulevard
4	303200084212500	Rainfall gage in front of Sunset Fish Camp near end of Lake Drive
5	302731084191600	Rainfall gage near east end of lake between San Luis Road and Ocala Road
6	02327012	Discharge gage on left bank upstream from bridge on Roberts Avenue over west side drainage ditch near intersection with Mabry Street
7	02327017	Discharge gage on downstream side of bridge on Capital Circle over Munson Slough
8	02327015	Discharge gage on right upstream end of culvert over central drainage ditch on Orange Avenue near Springhill Road
9	02329186	Discharge and rainfall gage on right downstream end of culvert over Megginnis Arm Tributary on Megginnis Arm Road near I-10
10	02329181	Discharge gage on right bank 20 feet upstream from detention culvert behind Northwood Mall and adjacent to Boone Boulevard

Table 1.--Gage descriptions and locations--Continued

Map location number	Station identification number	Type and location
11	302731084165400	Rainfall gage in north parking lot of the old National Guard Armory between Seventh and Eighth Avenues
12	02327013	Discharge gage on left bank downstream of bridge over central drainage ditch on Airport Drive at intersection with Eppes Drive
13	02327014	Discharge gage on left bank upstream of bridge over St. Augustine Branch on Wahnish Way at intersection with Canal Street
14	302536084180500	Rainfall gage attached to north wall of sewage disposal plant at intersection of Gamble Street and Lake Bradford Road
15	302438084172400	Rainfall gage under electrical transmission lines adjacent to Wahnish Way and east drainage ditch
16	02327016	Discharge gage on downstream side of bridge over east drainage ditch on Bragg Drive
17	302549084152900	Discharge gage on left bank upstream of culvert over east drainage ditch on Apakin Nene in Indian Head Acres
18	302601084153600	Rainfall gage near electrical substation between Ostin Nene and Chowkeebin Nene in Indian Head Acres
19	302622084145900	Rainfall gage on dam of Governor's Square detention pond adjacent to Blairstone Road

Table 1.--Gage descriptions and locations--Continued

Map location number	Station identification number	Type and location
20	02326842	Discharge gage on left bank upstream of culvert over Governor's Square drainage ditch on Park Avenue near intersection with Blairstone Road
21	02326838	Discharge gage on right bank upstream of culvert over northeast drainage ditch on Miccosukee Road near intersection with Doomar Drive
22	02326836	Discharge gage on right bank upstream of culvert over McCord Park Pond drainage ditch on Centerville Road near intersection with Trescott Drive
23	302822084154400	Rainfall gage near west side of pond in McCord Park between Trescott Drive and Armistead Road
24	02329161	Discharge gage on left bank of Fords Arm Tributary downstream of Meridian Road near intersection with Lexington Road
25	303010084151200	Rainfall gage inside fence enclosure south side of Timberlane Shops on the Square adjacent to I-10
26	02326825	Discharge gage on left bank upstream of culvert over northeast drainage ditch on Hadley Road near intersection with Raymond Diehl Road
27	302935084142100	Rainfall gage at southeast end of Wembley Way in Eastgate
28	02326828	Discharge gage on right upstream end of culvert over northeast drainage ditch on Capital Circle at intersection with Centerville Road

Table 1.--Gage descriptions and locations--Continued

Map location number	Station identification number	Type and location
29	02326845	Discharge gage near upstream right end of wier across northeast drainage ditch just upstream of Weems Road
30	302707084132400	Rainfall gage inside enclosure of National Guard Armory near Federal Correctional Institution

Generally, 40 significant storm events are needed at a rainfall-runoff site to achieve successful model calibration. At the rate significant storm runoff data is being collected, it is anticipated that sufficient storm events will be recorded by late 1982 or early 1983 to calibrate the model. The number of storm events has been less than anticipated because of 1981 drought conditions in Leon County. However, although limited in number, the intensity of storm events has provided important data.

SELECTED REFERENCES

Bodhaine, G. L., 1968, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A3, 60 p.

Buchanan, T. J., and Somers, W. P., 1968, Stage measurement at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A7, 28 p.

_______1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A8, 65 p.

Carrigan, P. H., Jr., 1973, Calibration of U.S. Geological Survey rainfall/runoff model for peak flow synthesis--natural basins: Reston, Va., U.S. Geological Survey, 109 p.

Clark, C. O., 1945, Storage and the unit hydrograph: American Society of Civil Engineers Transactions: v. 110, p. 1419-1488.

Dawdy, D. R., Lichty, R. W., and Bergmann, J. M., 1972, A rainfall-runoff simulation model for estimation of flood peaks for small drainage basins: U.S. Geological Survey Professional Paper 506-B, 28 p.

Dawdy, D. R., Schaake, J. C., Jr., and Alley, W. M., 1978, Users guide for distributed routing rainfall-runoff model: U.S. Geological Survey Water-Resources Investigations 78-90, 146 p.

Golden, H. G., and Price, McGlone, 1976, Flood-frequency analysis for small natural streams in Georgia: U.S. Geological Survey Open-File Report 76-511, 75 p.

Lichty, R. W., and Liscum, F., 1978, Rainfall-runoff modeling procedure for improving estimates of T-year (annual) floods for small drainage basins: U.S. Geological Survey Water-Resources Investigations 78-7, 44 p.

Philip, J. R., 1954, An infiltration equation with physical significance: Soil Science Society of America Proceedings, v. 77, p. 153-157.

Riggs, H. C., 1961, Frequency of natural events: American Society of Civil Engineers Proceedings, v. 87, no. HY-1, p. 15-26.

_______1968a, Some statistical tools in hydrology: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter A1, 39 p.

_______1968b, Frequency curves: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter A2, 15 p.

_______1973, Regional analysis of streamflow characteristics: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter B3, 15 p.

Rosenbrock, H. H., 1960, An automatic method of finding the greatest or least value of a function: Computer Journal, v. 3, p. 175-184.

Lepkin, W. D., DeLapp, M. M., Kirby, W. H., and Wilson, T. A., 1979, Watstore user's guide; instructions for peak flow file: U.S. Geological Survey Open-File Report 79-1336-I, v. 4, p. C1-C57.

U.S. Water Resources Council, 1981, Guidelines for determining flood flow frequency (revised): Bulletin No. 17B of Hydrology Committee, 183 p.