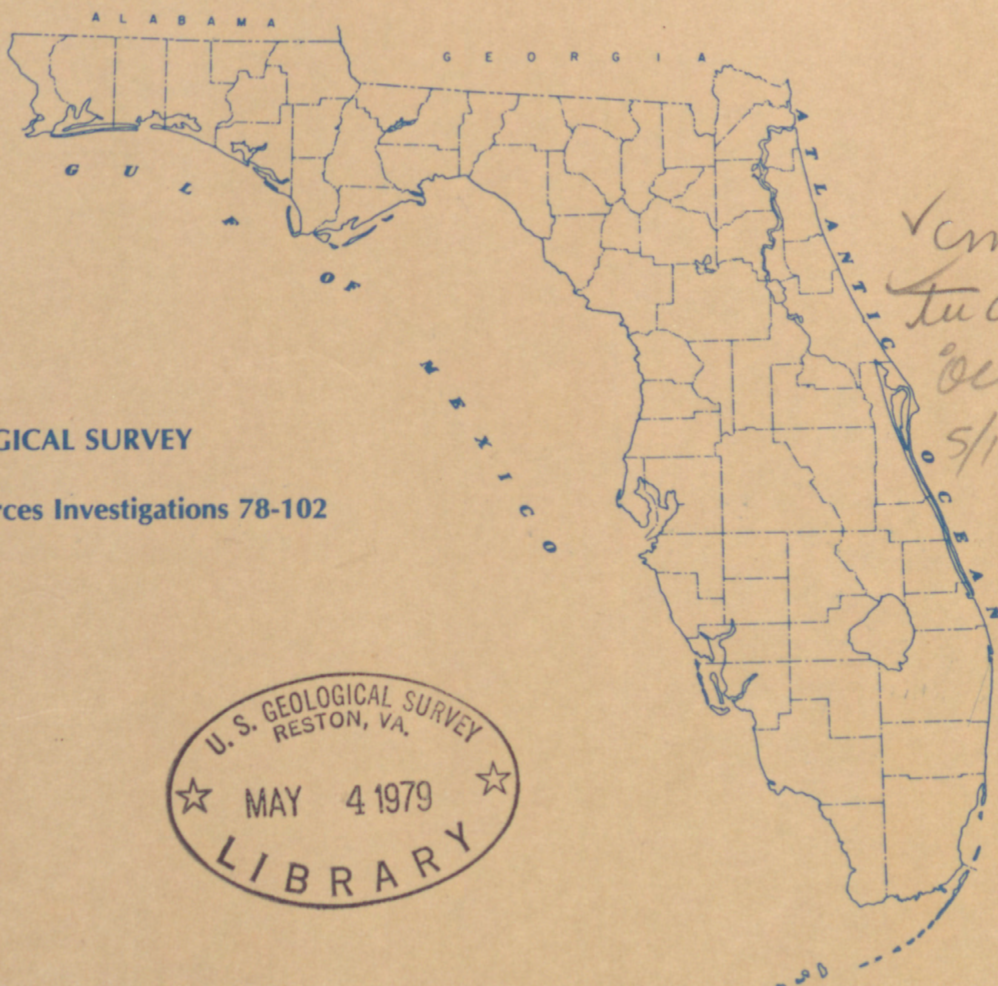
STREAMFLOW SIMULATION STUDIES OF THE HILLSBOROUGH, ALAFIA, AND ANCLOTE RIVERS, WEST-CENTRAL FLORIDA



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-102

Prepared in cooperation with the
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
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16. Abstracts

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STREAMFLOW SIMULATION STUDIES OF THE HILLSBOROUGH, ALAFIA, AND ANCLOTE RIVERS, WEST-CENTRAL FLORIDA

By

J. F. Turner, Jr.

ABSTRACT

A modified version of the Georgia Tech Watershed Model was applied for the purpose of flow simulation in three large river basins of west-central Florida. The model was calibrated for six streamflow stations located in these basins using 4 years of historical and current rainfall, runoff, and estimated evapotranspiration data. Watersheds modeled range in size from about 70 to 650 square miles.

Calibrations were evaluated by comparing the following synthesized and observed data: annual hydrographs for the 1959, 1960, 1973 and 1974 water years, flood hydrographs (maximum daily discharge and flood volume), and long-term annual flood-peak discharges (1950-72).

Annual hydrographs, excluding the 1973 water year, were compared using average absolute error in annual runoff and daily flows and correlation coefficients of monthly and daily flows. For stations used in the study, average absolute errors in simulated runoff range from 9 to 21 percent and errors in daily flows range from 48 to 71 percent. Correlation coefficients for monthly flows range from 0.81 to 0.95 and correlation coefficients for daily flows range from 0.68 to 0.87.

Correlation coefficients for simulated and observed maximum daily discharges and flood volumes used for calibration range from 0.91 to 0.98 and average standard errors of estimate range from 18 to 45 percent. Correlation coefficients for simulated and observed annual flood-peak discharges range from 0.60 to 0.74 and average standard errors of estimate range from 33 to 44 percent. The number of flood events used for calibration varies for each streamflow station, but range from 6 to 18. The number of annual flood-peak discharges used also vary but average about 20 for each station.

On the basis of these results, it is concluded that flood calibrations have been achieved for stations used in this study; however, because of data limitations, calibrations and prediction errors cannot be completely verified until additional rainfall, runoff, and evapotranspiration data become available.

INTRODUCTION

Serious water-management problems are being caused by flood-plain development in the Tampa Bay area of west-central Florida. Urban development has encroached into flood-prone areas in recent years to the extent that costly flood-control structures are being considered at key points in major river basins to protect these developments.

Large-scale flooding in coastal areas of west-central Florida has not occurred since 1960. Consequently, construction of waterfront homes on the flood plain has become commonplace along the lower reaches of major streams in the Tampa Bay area, particularly along the Hillsborough River which traverses large urban areas of northeast Tampa and Temple Terrace. Large-scale urban complexes, agricultural developments, and small residential subdivisions and trailer parks are also appearing in increasing numbers in adjacent suburban areas. Residents of these and other urban developments that have encroached on the flood plain are subject to increased risk of inundation from small and moderate size floods, as well as to the risk of infrequent large-scale floods.

The U.S. Army Corps of Engineers (1961) proposed flood-control measures for several west-central Florida streams, including the Hillsborough River. These measures involve construction of flood-detention areas and diversion channels, including the Tampa By-Pass Canal currently under construction in the lower Hillsborough River basin. When completed, the canal will be used to divert a large part of Hillsborough River flood water to the east of highly urbanized areas in northeast Tampa and Temple Terrace (fig. 1). Until proposed flood-control measures are implemented, residents of these and other high-risk flood-prone areas need advance warning of impending flooding. Following construction, effective water-management procedures will be required to operate flood-control structures, particularly in the Hillsborough River basin. Efficient operational schemes will require use of flow models having intrabasin flood-prediction and flood-routing capability.

Recognizing these needs, SWFWMD (Southwest Florida Water Management District), local sponsor of the proposed flood-control measures, entered into a first-phase cooperative study with the U.S. Geological Survey in 1968 to develop a predictive flood-hydrograph model for the lower Hillsborough River. In 1970, the Alafia River was incorporated into the study and similar models were developed for the lower Alafia River and a principal upstream tributary. Models developed as part of the first-phase study are based on unit hydrograph and rainfall-runoff procedures and are described by Turner (1972). Daily rainfall measured by the National Weather Service at three sites located on the periphery of the Hillsborough and Alafia River basins is used as input to the models. These models have limited water-management capability because they have no provision for intrabasin flood prediction and routing and because they do not simulate with acceptable accuracy floods associated with small storms.

The second-phase study was begun in 1971 to improve and expand flow-simulation capability. Model development and evaluation studies were continued to obtain a digital streamflow model having intrabasin flow-simulation and routing capability for use in the study area. The study area was extended to include the Anclote River basin which lies about 25 mi northeast of Tampa (fig. 1). The extent of probable flooding along the Hillsborough River in northeast Tampa and Temple Terrace area was also evaluated as part of the second-phase study. Recurrence-interval flood profiles for a 10-mile reach of Hillsborough River between Tampa Dam and Fletcher Avenue are described by Turner (1974).

A comprehensive rainfall data collection network was established. Digital recorders were installed at 11 rainfall stations in the study area, including two in the Anclote, six in the Hillsborough, and three in the Alafia River basins. A streamflow station was established on the Hillsborough River at Morris Bridge Road (site 28, fig. 1) near the confluence of the proposed Tampa By-Pass Canal (fig. 1).

Collection of streamflow records on the Hillsborough River at Fowler Avenue (site 24, fig. 1) was also begun. Two ground-water monitoring stations were also established in Hillsborough River State Park (fig. 1).

The Georgia Tech Watershed Simulation Model (GTWS) was selected for use in the second-phase study because the model is based on soil-moisture accounting procedures and has intrabasin flood-simulation and flood-routing capability. Modifications to GTWS include expansion of the model to accomodate broad-crested long-duration flood hydrographs that typify west-central Florida streams, addition of subprograms providing for reservoir routing, and reprogramming required in adapting the model to the Geological Survey computer system. Additional changes were also made in the original model to modify input formats, and to revise statistical and channel routing subprograms. However, the original GTWS soil-moisture accounting procedure was not modified for use in this study. Many model options were deleted.

Calibration data used as input to the model include hourly rainfall (from network stations) and daily evapotranspiration and streamflow. The procedure used in estimating evapotranspiration data is described in Supplement I. Model input data (card format and sequence) are described in Supplement II, and a complete listing of the FORTRAN source programs are given in Supplement III.

Predictive models developed as part of this second-phase study of the Hillsborough, Alafia, and Anclote Rivers broaden and enhance water-management capabilities in the study area. Initially, they may be used by Southwest Florida Water Management District as an aid in flood warning and surveillance activities. Later, improved models may also be used to simulate hydrologic information for use in evaluating alternative flood-control and abatement plans under natural and developing conditions.

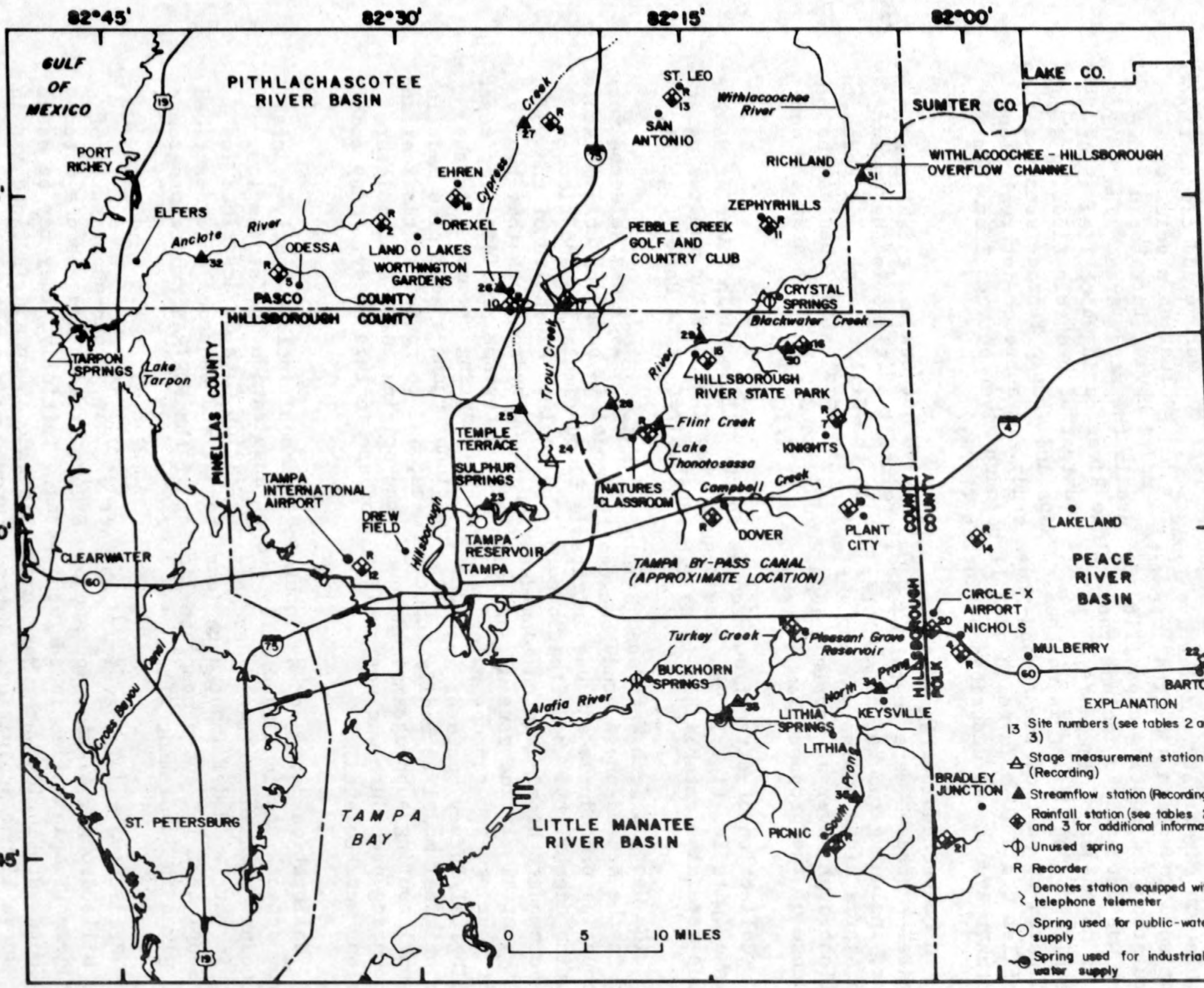


Figure 1.--Study area showing location of rainfall and streamflow stations.

Original GTWS soil-moisture accounting procedure used as part of this study is undergoing further testing. A complete technical evaluation of the accounting procedure is currently underway; however, results are incomplete at this writing. Modified GTWS soil-moisture accounting procedure, resulting from this evaluation, is being considered along with similar procedures from other watershed models, for development of an improved model more consistent with Florida hydrology.

For readers who may prefer to use metric units rather than U.S. inch-pound units, the conversion factors for the terms used in this report are listed below:

U.S. inch-pound unit	Multiply by	To obtain metric unit
acre-ft (acre-foot)	1.233×10^{-3}	hm^3 (cubic hectometer)
ft^3/s (cubic foot per second)	2.832×10^{-2}	m^3/s (cubic meter per second)
ft (foot)	3.048×10^{-1}	m (meter)
in. (inch)	$2.540 \times 10^{+1}$	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi/h (mile per hour)	1.609	km/h (kilometer per hour)
mi^2 (square mile)	2.590	km^2 (square kilometer)
in/h (inch per hour)	2.540	cm/h (centimeter per hour)
ft/mi (foot per mile)	0.1895	m/km (meter per kilometer)

Purpose and Scope

The purpose of this report is to provide results of the second-phase study including:

(1) Evaluation of the Georgia Tech Watershed Simulation Model (modified version) for use in simulating flood hydrographs for large west-central Florida basins; and

(2) Model documentation and user manual.

The watershed model is evaluated for three large rural basins using results of calibration studies for six streamflow stations located in the Anclote, Hillsborough, and Alafia River basins. Unfortunately, rainfall data required to fully test calibrations developed as part of this study are not available. Model evaluation is based on comparison of simulated and observed annual hydrographs for the 1959, 1960, 1973 and 1974 water years with emphasis on flood hydrographs (maximum daily discharge and flood volumes). Observed long-term annual flood-peak discharges and discharges synthesized from historical rainfall records, available for two sites outside the study area, are also compared, including flood-frequency distributions.

Suggestions for improving model accuracy and potential use of the model in future studies are also presented.

Acknowledgments

This study was supported through a cooperative program between the U.S. Geological Survey and the Southwest Florida Water Management District and the City of Tampa. The model adapted for use in the study is a modified version of GTWS, developed by Dr. Alan M. Lumb, at the Georgia Institute of Technology, Atlanta, Georgia. The Georgia Tech Watershed Simulation Model is described in a report by Lumb (1975). The U.S. Geological Survey's version of the model is called Hydrologic Watershed Simulator (HWS) because of modifications to the original version.

Mr. Pedro A. Hernandez, a Southwest Florida Water Management District Engineer, participated in model calibration studies conducted in the U.S. Geological Survey Tampa Office to gain experience using the model.

The author wishes to thank Chuck Reeter, Mike Mallory and Kathi Hammett for assistance provided in programming and analyses.

Study Area

The study area is located in the Tampa Bay region of west-central Florida and includes the Anclote, Hillsborough, and Alafia River basins (fig. 1). The area extends north from Tampa to the Withlachoochee River, east to Lakeland and the Peace River, south to the Little Manatee River, and north from Hillsborough Bay to the Pithlachascotee River. The basins have a combined area of about 1,200 mi^2 and lie in parts of Hillsborough, Pasco, Hernando, and Polk Counties.

The upper parts of these basins are generally rural and consist of open and wooded upland areas and numerous low-lying swamp areas covered with dense cypress heads and undergrowth. Agricultural development in these areas consists chiefly of pasture and small row crops. Large urban developments have encroached on the flood plains in the lower parts of each basin.

Climate

The study area has distinct wet and dry seasons. The wet or rainy season usually begins in early June and lasts about through September. Normal wet-season rainfall occurs as the result of late afternoon and evening thunderstorms and accounts for more than half the annual rainfall. Rainfall during the normally dry season (October through May) is principally due to frontal systems and is more general than wet-season rainfall. Areal variability and intensity of rainfall during the wet season is much higher than during the dry season.

A hurricane is expected to occur in the study area about once every 5 years. A large tropical storm is expected to occur about once every 2 years (U.S. Army Corps of Engineers, 1961).

Normal annual temperature over the study area is about 72°F (22°C). Daily temperatures range approximately between 72°F to 92°F (22°C to 33°C) during the summer and 55°F to 76°F (13°C to 24°C) during the winter.

Annual evapotranspiration in the study area is estimated to vary from 30 to 50 in. and monthly evapotranspiration is greatest during May, June, and July.

Physiography

Selected basin parameters of the study area are summarized in table 1 for points on streams where flow records are collected. These parameters include average annual runoff, drainage area, mean channel length and slope, surface storage (lakes and swamps), forest cover, mean annual precipitation, rainfall intensity and soils index. Soils index values represent maximum potential infiltration capacity for each basin under average soil-moisture conditions. These data were summarized from Rabon (1971) and annual records published as part of the Water Resources Data for Florida (U.S. Geological Survey, 1974). Approximate range in variation of selected basin parameters were summarized from table 1 and are listed below as follows:

Basin parameter	Approximate range in variation
Mean annual runoff (inches)	9 to 18 in.
Mean channel slope (feet/mile)	2 to 5 ft/mi
Surface storage, lakes and swamps (area in percent)	1 to 18 percent
Forest cover (percent)	12 to 56 percent
Soils index (inches)	2 to 4 in.

Table 1.--Selected basin parameters for selected streamflow stations in the study area

Streamflow station	Mean annual runoff[1] (in)	Drainage area (mi^2)	Mean channel slope (ft/mi)	Main channel length (mi)	Surface storage (area in percent)		Forest cover (percent)	Mean annual precipitation (in)	2-year 24-hour rainfall (in)	Soils index (in)
					Lakes	Swamps				
Alafia River North Prong at Keysville	17.6 (10-50 to 9-74)	135	5.0	19.6	3.1	7.5	22.3	52.8	4.2	2.7
Alafia River at Lithia	15.3 (10-32 to 9-74)	335	3.4	32.2	1.2	7.4	12.5	54.1	4.1	2.1
Blackwater Creek near Knights	11.2 (10-51 to 9-74)	110	3.5	19.4	2.6	13.8	19.1	52.6	4.6	2.7
Hillsborough River near Zephyrhills	17.0 (10-39 to 9-74)	220	3.9	26.7	1.8	15.1	15.6	53.6	4.6	2.8
Cypress Creek near Sulphur Springs	9.0 (10-64 to 9-74)	160	2.4	28.4	2.6	18.3	25.0[2]	54.3	4.6	3.9

Table 1.--Selected basin parameters for selected streamflow stations in the study area - continued

Streamflow station	Mean annual runoff[1] (in)	Drainage area[2] (mi^2)	Mean channel slope (ft/mi)	Main channel length (mi)	Surface storage (area in percent)		Forest cover (percent)	Mean annual precipitation (in)	2-year 24-hour rainfall (in)	Soils index (in)
					Lakes	Swamps				
Hillsborough River near Tampa	13.0 (10-38 to 9-74)	650	2.0	57.0	2.7	15.2	16.4	55.0	4.6	2.8
Anclote River near Elfers	14.8 (10-46 to 9-74)	72.5	3.5	19.1	3.2	16.7	55.8	56.2	4.9	2.4

1 Runoff values are computed from available streamflow records (as indicated in table 3); period of record is shown in parenthesis.

2 Estimated.

Soils in the study area are highly permeable and rainfall infiltrates rapidly. The study area is underlain by a regional artesian system which receives recharge from numerous sinks and depressions, and swamp areas. Base flow of streams in the study area is sustained by the shallow water-table aquifer system and discharge (springflow) from the deeper artesian system. Large springs include Crystal and Sulphur Springs located in the upper and lower Hillsborough River basin respectively, and Lithia and Buckhorn Springs in the upper Alafia River basin (fig. 1).

Basins in the study area have mild stream-channel slopes and considerable surface storage in areas of depression. Flood hydrographs are therefore broad crested and frequently extend over periods of several weeks. Flood hydrographs for the Hillsborough River near Tampa streamflow station (site 23, fig. 1) frequently cover periods longer than a month; flood hydrographs of 3-weeks duration are not uncommon for the Alafia River at Lithia streamflow station (site 33, fig. 1). Flood hydrographs for the Anclote River are much sharper crested and are generally less than 2 weeks in duration.

Data Available

Model development, calibration, and testing requires streamflow, rainfall, and evapotranspiration data. Precipitation data used include rainfall records collected by the U.S. Geological Survey and the National Weather Service. Locations of these and other data collection sites related to the study are shown in figure 1. Specific locations and site numbers and other pertinent information regarding available rainfall records are summarized in table 2.

U.S. Geological Survey streamflow records used as part of this investigation are listed by river basin in table 3 and gage locations are shown in figure 1. Accuracy of these records is generally rated as fair (errors in streamflow data do not exceed 15 percent).

Evapotranspiration data are required by the model for simulation. Normally, daily evaporation from a Class A land pan is used as a measure of potential evapotranspiration. Acceptable land-pan evaporation data are not available for the study area, and therefore daily evapotranspiration values computed from available meteorological records were used in this study.

The method used to compute daily evapotranspiration is based on the Penman equations described by Veihmeyer (1964) and Gray (1970). A computer program developed to calculate daily evapotranspiration values is described in Supplement I. Observed daily values for the following variables are used as input to the computer program:

(1) air temperature, in degrees Fahrenheit;

(2) dew point temperature, in degrees Fahrenheit, or relative humidity (decimal fraction);

(3) duration of bright sunshine to maximum possible (decimal fraction);

(4) wind speed, in miles per hour.

A reflectivity coefficient of 0.15, calibrated for the model, was obtained by adjusting reflectivity coefficient values until computed evapotranspiration values agreed with basin evapotranspiration estimates derived from long-term rainfall and streamflow records.

Meteorological data for Tampa International Airport and Drew Field (fig. 1) used in making these computations are available in publications and other records of the National Weather Service.

Statistical Procedures

Multiple and simple linear regression analyses are used in the study to develop functional relations and to evaluate results of the model study. Regression analyses refers to the determination of the relationship between two or more variables by use of standard statistical methods (Bryant, 1960; and Davies, 1961). As part of regression analyses, a regression equation, correlation coefficient (or multiple correlation coefficient), and standard error of estimate are obtained. The regression equation expresses the relationship between the variables and may be used for predictive purposes. In this report, regression data points are displayed on logarithmic graph paper with the independent variable plotted on the horizontal scale and dependent variable on the vertical scale. The correlation coefficient expresses the degree of relation. For example, a value of 1.0 indicates perfect positive correlation and a value of -1.0 indicates perfect inverse correlation; a value of 0.0 indicates no correlation. The standard error of estimate expresses reliability of the regression equation. In this report, standard errors of estimate are given as average percent values and represent the average range that includes about 68 percent of all data points defining the regression.

Correlation coefficients are tested for significance (to determine if they are significantly different from zero). The probability at which the test indicates chance occurrence of the correlation coefficient (the correlation coefficient is not significantly different from zero) is referred to as the level of significance. Regression constant and coefficient are tested in a similar manner to evaluate possible bias in simulated data.

Table 2.--Rainfall records used in model studies

[Observation period is 15 minutes at stations 1-11, hourly at stations 12-14, and daily at stations 15-22.]

Site number	Station name	Location	Operator[1]	Period of record
1	Dover, Florida	Lat 28°01'08", long 82°14'17", near intersection of U.S. 92 and Gallagher Road, 6 miles west of Plant City, Hillsborough County.	USGS	June 1972 to present
2	Land O'Lakes, Florida	Lat 28°15'01", long 82°29'51", at S. C. Baxley ranch, 2-1/2 miles northwest of Land O'Lakes, Pasco County.	do.	June 1972 to present
3	Nature's Classroom, Florida	Lat 28°05'10", long 82°20'00", at Nature's Classroom, 11 miles northeast of Tampa, Hillsborough County.	do.	June 1972 to present
4	Nichols, Florida	Lat 27°53'28", long 82°01'59", at Mobile Chemical Plant, Nichols, Polk County.	do.	June 1972 to present
5	Odessa, Florida	Lat 28°12'04", long 82°36'07", at J. B. Starkey Ranch, 1 mile northwest at Odessa, Pasco County.	do.	May 1972 to present
6	Picnic, Florida	Lat 27°45'34", long 82°08'48", at A. T. Carter residence, 0.2 miles south of Picnic, Hillsborough County.	do.	June 1972 to present

Footnotes appear at end of table.

Table 2.--Rainfall records used in model studies - continued

Site number	Station name	Location	Operator[1]	Period of record
7	Plant City, Florida	Lat 28°05'18", long 82°06'41", at C. S. Bailey residence, 0.55 mile north of Knights Griffin Road and 1.8 miles east of State Road 39, Hillsborough County.	USGS	June 1972 to present
8	Pleasant Grove Reservoir, Florida	Lat 27°54'37", long 82°10'08", at Pleasant Grove Reservoir Dam, Hillsborough County.	do.	June 1972 - July 1975[2], Aug. 1975 - present
9	San Antonio, Florida	Lat 28°19'05", long 82°21'28", 0.4 mile south of intersection of State Roads 52 and 581, Pasco County.	do.	June 1972 to present
10	Worthington Gardens, Florida	Lat 28°10'41", long 82°23'59", at S. D. Marvil residence, 1/2 mile south of Worthington Gardens, Pasco County.	do.	June 1972 to present
11	Zephyrhills, Florida	Lat 28°13'14", long 82°09'36", at Zephyrhills Sewage Treatment Plant, Pasco County.	do.	June 1972 to present
12	Tampa WSMO, Florida	Lat 27°58', long 82°32', at Tampa International Airport, Hillsborough County.	NOAA	June 1948 - Aug. 1952, July 1958 - present

Table 2.--Rainfall records used in model studies - continued

Site number	Station name	Location	Operator[1]	Period of record
13	St. Leo, Florida	Lat 28°21', long 82°16', at St. Leo Abby, Pasco County.	NOAA	Aug. 1944 to present
14	Lakeland WSO, Florida	Lat 28°02", long 81°57', at Lakeland City Hall, Polk County.	NOAA	Mar. 1943 to present
15	Hillsborough River State Park, Florida	Lat 28°09', long 82°14', at Hillsborough River State Park, Hillsborough County.	FPS	Sept. 1943 to present
16	Knights, Florida	Lat 28°08', long 82°09', 4.4 miles northwest of Knights, Hillsborough County.	USGS	June 1970 to present
17	Peeble Creek, Golf and Country Club, Florida	Lat 28°09', long 82°21', approximately 15 miles northeast of Tampa, Hillsborough County.	do.	June 1970 to present
18	Ehren, Florida	Lat 28°16'45", long 82°26'19", 1 mile northeast of Land O'Lakes, Hillsborough County.	do.	June 1970 to present
19	Plant City, Florida	Lat 28°05'18", long 82°06'41", at Plant City, Hillsborough County.	NOAA	Oct. 1892 to present

Table 2.--Rainfall records used in model studies - continued

Site number	Station name	Location	Operator [1]	Period of record
20	Circle-X Airport, Florida	Lat. 27°56', long 82°02', at Circle-X Airport, 5 miles northeast of Mulberry, Polk County.	USGS	June 1970 to present
21	Bradley Junction, Florida	Lat 27°45'30", long 82°01'45", 3.8 miles southwest of Bradley Junction, Polk County.	do.	Aug. 1970 to Dec. 1974
22	Bartow, Florida	At Bartow, Polk County.	NOAA	Aug. 1895 to present

1 USGS, U.S. Geological Survey, Tampa, Florida; NOAA, National Oceanic and Atmospheric Administration (Environmental Data Service); FPS, Florida Park Service.

2 Gage located at L. L. Watkins residence, 2 miles west of intersection of State Roads 39 and 60, Hillsborough County.

Table 3.--Streamflow records used in model studies

Site number	Station name	Location	Type of record	Period of record
23	Hillsborough River near Tampa, Florida.	At Tampa Reservoir Dam, Hillsborough County.	Stage and discharge	Oct. 1938-present
24	Hillsborough River at Fowler Avenue near Tampa, Florida[A].	At Fowler Avenue, Hillsborough County.	Stage (read once daily) and discharge[1]	Oct. 1933-Dec. 1939, Jan. 1961-present
25	Cypress Creek near Sulphur Springs, Florida.	At State Road 581, Hillsborough County.	Stage and discharge	Feb. 1964-present
26	Cypress Creek at Worthington Gardens, Florida[A].	At State Road 54, Pasco County.	(2)	May 1964-Oct. 1971, Nov. 1971-May 1974, June 1974-present
27	Cypress Creek near San Antonio, Florida.	At State Road 52, Pasco County.	Stage and discharge	Dec. 1962-present
28	Hillsborough River at Morris Bridge near Thonotosassa, Florida[A].	At State Road 579, Hillsborough County.	(3)	Apr. 1964-Apr. 1965, May 1965-Sept. 1968, Oct. 1968-June 1972, July 1972-present
29	Hillsborough River near Zephryhills, Florida[A].	At Hillsborough River State Park, Hillsborough County.	do.	Oct. 1939-present
30	Blackwater Creek near Knights, Florida.	At State Road 39, Hillsborough County.	Stage and discharge	Jan. 1951-present

Footnotes appear at end of table.

Table 3.--Streamflow records used in model studies - continued

Site number	Station name	Location	Type of record	Period of record
31	Withlacoochee-Hillsborough overflow near Richland, Florida.	At U.S. Highway 98, 2.9 miles east of Richland, Pasco County.	(4)	Feb. 1930-Sept. 1931, Sept. 1950, July 1958-Mar. 1960, Apr. 1960-present
32	Anclote River near Elfers, Florida.	At State Road 54, 3.5 miles east of Elfers, Pasco County.	Stage and discharge	May 1946-present
33	Alafia River at Lithia, Florida.	At State Road 640, 4.3 miles west of Lithia, Hillsborough County.	do.	Oct. 1932-present
34	Alafia River, North Prong at Keysville, Florida.	0.6 miles north of Keysville, Hillsborough County.	do.	May 1950-present
35	Alafia River, South Prong near Lithia, Florida.	At County Road, 5.0 miles southeast of Lithia, Hillsborough County.	do.	Dec. 1962-present

1 Miscellaneous discharge measurements are only available after January 1961.
2 Annual peak discharge and periodic discharge measurements available May 1964 to October 1971; gage heights and periodic discharge measurements available November 1971 to May 1974; daily stage and discharge available June 1974 to present.
3 Fragmentary stage and discharge records available April 1964 to April 1965; gage heights only available May 1965 to September 1968; gage heights and miscellaneous discharge measurements available October 1968 to June 1972; daily stage and discharge available July 1972 to present.
4 Stage and discharge available February 1930 to September 1931, September 1950, and April 1960 to present; only discharge measurements available July 1958 to March 1960.
A Telemeter station.

MODEL DESCRIPTION

The model is an organized collection of mathematical formulations used to approximate the hydrologic response and condition of a watershed given specific meteorologic and physiographic data inputs. The land-phase of the hydrologic cycle is simulated using soil-moisture accounting procedures. Model outputs for a watershed include synthesized outflow hydrograph, evapotranspiration and moisture storage for input data consisting of precipitation and potential evapotranspiration. A modeled watershed may consist of one or more subwatersheds connected by discrete stream-channel reaches. A typical subwatershed has both pervious and impervious areas, and has a soil profile consisting of upper, lower, and ground-water zone storages (fig. 2). Precipitation falling on impervious areas connected directly to the stream-channel system contributes to direct runoff. On pervious areas, part of the precipitation is intercepted by vegetation and other natural and man-made objects (interception storage). Precipitation in excess of interception storage appears at land surface and may directly infiltrate the upper soil zone; the remaining precipitation is stored in surface depressions, such as lakes (surface-retention storage) or appears as overland flow (surface-detention storage).

According to the model schematic shown in figure 2, water infiltrates the upper soil zone (upper-zone storage) and percolates to three lower soil zone types (lower-zone storage) referred to as upland (or ridge), alluvium, and hillside areas. Upland lower-zone storage drains (as seepage) to the alluvium and hillside areas when upland lower-zone storage capacity limits are reached. Interflow depletes hillside lower-zone storage and occurs when hillside storage exceeds lower-zone storage capacity. Water drains from alluvium lower-zone storage to ground-water storage by way of deep percolation. Base flow depletes ground-water storage and underflow depletes both lower-zone and ground-water storages. Evapotranspiration depletes surface, soil-moisture and ground-water storages; however, the principal source is upper- and lower-zone storages.

Streamflow is composed of direct runoff, interflow, and base flow. Direct runoff is the sum of overland and impervious area flows, and is translated into a direct-runoff hydrograph by application of a distribution graph (dimensionless unit hydrograph). The streamflow hydrograph is determined by the addition of interflow and base-flow ordinates to ordinates of the direct-runoff hydrograph.

Streamflow is routed through the stream-channel system using an analytical procedure referred to as the Muskingum Method (Gray, 1970). Flow is routed through reservoirs using a procedure based on the Puls Method (Lawler, 1964).

Unit precipitation, PX, used in the soil-moisture accounting procedure corresponds to precipitation for the time simulation interval, IMIN, and is computed as the product of measured hourly precipitation, PR, and DELMIN,

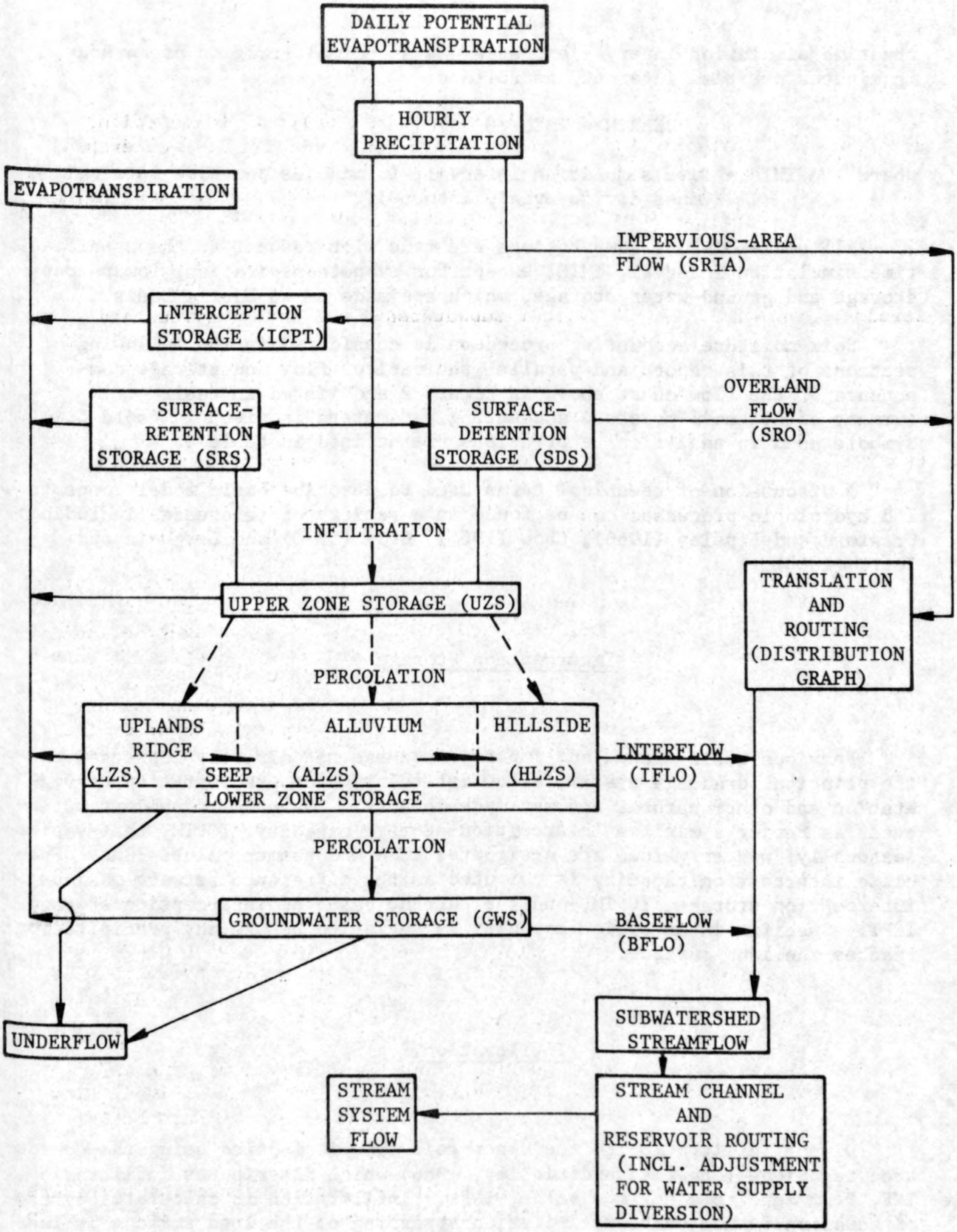


Figure 2.--Schematic diagram of flow simulation from rainfall.

the time simulation interval expressed as a decimal fraction of an hour, in minutes per time interval, as follows:

$$DELMIN = IMIN/60 \qquad (1)$$

where IMIN = Time simulation interval, in minutes per time interval (must divide evenly into 60).

All soil-moisture computations are made with respect to the specified time simulation interval, IMIN, except for evapotranspiration, lower-zone storage and ground-water storage, which are made on an hourly basis.

Soil-moisture accounting procedure is considered in the following sections of this report and parallel the various flow and storage components of the flow chart shown in figure 2 and listed in table 4. A summary of all soil-moisture accounting parameters is given in table 5. Symbols used in analytical expressions are defined in table 6.

A discussion of technical terms used to describe basic model concepts and hydrologic processes can be found in a variety of references including: Crawford and Linsley (1966), Chow (1964), Gray (1970) and Langbein and Iseri (1960).

Interception Storage

Pervious basin areas, and impervious areas not directly connected to the principal drainage system, allow interception of precipitation by vegetation and other natural and man-made objects. The model considers watersheds as having a maximum interception-storage capacity, ICPTM, that varies seasonally; winter values are designated ICMN and summer values ICMX. Specific interception capacity is computed as the difference between maximum interception storage, ICPTM, and the current value of interception storage, ICPT. Specific interception capacity is satisfied before any precipitation reaches the land surface.

Infiltration

Direct infiltration to the upper soil zone is modeled using the source-area technique (Crawford and Linsley, 1966) which distributes infiltration, INF, from zero to a maximum value, INF2. Infiltration is calculated by use of equation 2 when unit precipitation appearing at the land surface is less than the maximum infiltration rate, as follows:

Table 4.--Components of soil-moisture accounting procedure

Area or storage component	Source	Depletion components	Streamflow component
Impervious area	Precipitation on impervious area.	Direct runoff.	Direct runoff.
Interception storage	Precipitation intercepted by vegetative foilage.	Evaporation.	None.
Surface-retention storage	Precipitation on pervious land-surface areas in excess of interception storage and direct infiltration that enters surface depressions, lakes, etc.	Evaporation; drainage to upper-zone storage.	None.
Surface-detention storage	Precipitation on pervious land-surface areas that avoids interception storage, direct infiltration, and surface-retention storage.	Overland flow; drainage to upper-zone storage.	Direct runoff.
Upper-zone storage	Direct infiltration; and infiltration from surface-retention and surface-detention storages.	Evapotranspiration and drainage to lower-zone storage.	None.
Lower-zone storage	Drainage from upper-zone storage to: Upland (ridge), Hillside, and Alluvium areas.	Evapotranspiration; interflow; underflow and drainage to ground-water storage.	Interflow.
Ground-water storage	Drainage from alluvium lower-zone storage (percolation).	Transpiration, base flow, and under flow.	Base flow.

Table 5.--Summary of soil-moisture accounting parameters

[Modified from Lumb, 1975]

PARAMETER	DEFINITION
	(AREA PARAMETERS)
SWAREA[2]	Subwatershed area, in square miles;
IMPA[2]	Fraction impervious area (percent total);
FALZ[2]	Fraction alluvial area (subwatershed);
FHLZ[2]	Fraction hillside area (subwatershed);
PSRP[2]	Maximum area for SRS (fraction subwatershed);
PSDP[2]	Area when SDS = SDSN (fraction subwatershed).
	(STORAGE PARAMETERS - inches)
ICMN[3]	Winter interception storage;
ICMX[3]	Summer interception storage;
SRSN[2,3]	Surface-retention storage capacity;
SDSN[2,3]	Surface-detention storage capacity;
UZSN[4]	Upper soil zone capacity;
LZSN[4]	Lower soil zone capacity;
GWSF	Ground-water storage for zero base flow.
	(DRAINAGE PARAMETERS)
PINF (PPIF)[1,5]	Infiltration, in inches per time interval;
PSUP[5]	Infiltration function shape, (dimensionless);
PULP (PPUL)[1,2]	Percolation from upper- to lower-zone storage, in inches per time interval; also used as parameter for ridge seepage to hillside and alluvium lower-zone storages, in units per hour;
PLGP[5]	Percolation from alluvium lower-zone storage to ground-water storage, in inches per hour;
PDGP	Underflow from ground-water storage, in units per hour;
PLZU	Underflow from ridge lower-zone storage, in units per hour;
TTM[3]	Overland-flow storage constant, in units per time interval;
INFP[3]	Interflow, in inches per hour;
KGWF[6]	Base-flow recession constant.

Table 5.--Summary of soil-moisture accounting parameters - continued

PARAMETER	DEFINITION
	(EVAPOTRANSPIRATION PARAMETERS - DIMENSIONLESS)
EIP[3]	Interception-storage evaporation;
EVP[3]	Evapotranspiration from upper- and lower-zone storages;
ETGWP[3]	Ground-water storage transpiration.
	(INITIAL STORAGE VALUES - inches)
SRS[5]	Surface-retention storage;
SDS[5]	Surface-detention storage;
UZS[5]	Upper-zone storage (must be greater than 0.0);
LZS, HLZS, ALZS[5]	Ridge, hillside, and alluvium lower-zone storages (must be greater than 0.0);
GWS[5]	Ground-water storage.

1 Parenthetical parameter is actually input to the model and has units of inches per hour; preceeding parameter shown is adjusted to desired time simulation interval and for the ratio of water viscosity at mean monthly temperature to viscosity at mean annual temperature.

2 Initial parameter value selected using topographic maps and aerial photographs.

3 Initial parameter value selected using results of GTWS model studies of other areas (oral commun. Alan Lumb, 1974).

4 Initial parameter value selected using suggested guidelines of Crawford and Linsley (1966).

5 Initial parameter value selected arbitrarily.

6 Initial parameter value determined from streamflow records.

Table 6.--Symbols used in analytical expressions in this report

A	Slope of saturation vapor pressure curve, in millimeters of mercury per degree Fahrenheit;
AA, B, C	Multiple-linear regression coefficients of a relation involving reservoir outflow (dependent variable) and preceeding reservoir stage and preceeding reservoir inflow (independent variables);
ALZS	Alluvium lower-zone soil moisture storage, in inches;
B'	Temperature coefficient (Boltzman constant), in millimeters of water per day;
BFLO	Hourly base-flow component of streamflow, in inches per hour;
BFP	Base-flow parameter for ground-water storage, in units per hour, (see equation 30);
CF	Crop adjustment factor used in evapotranspiration calculations (dimensionless);
COF	Reservoir outflow for stage values less than a minimum specified elevation, EGO, in cubic feet per second;
COFF	A percentage value applied to preceeding reservoir inflow values to calculate minimum acceptable routed flows;
CO, C1, C2	Muskingum routing coefficients;
CORINF	Ratio of water viscosity at mean monthly temperature to the viscosity at mean annual temperature (decimal fraction);
D	Conversion factor for translating wind observation height, in feet, to a height of 2 meters;
DELMIN	Time simulation interval expressed as decimal fraction of an hour, in hours per time interval;
EA	Saturation vapor pressure at ambient air temperature, in millimeters of mercury;
ED	Saturation vapor pressure at dew point temperature, in millimeters of mercury;
EFSD	Reservoir elevation of free-surface discharge, in feet above sea level;
EGW	Hourly transpiration loss from ground-water storage, in inches per hour;
EIP	Model parameter for interception-storage evaporation (dimensionless);
EIS	Hourly evaporation loss from interception storage, in inches per hour;
EL	Reservoir elevation, feet above sea level;

Table 6.--Symbols used in analytical expressions in this report - continued

ESR	Hourly evaporation loss from surface-retention storage, in inches per hour;
ETGWP	Model parameter for ground-water transpiration loss rate (dimensionless);
ETI	Daily potential evapotranspiration, in inches per day;
EUZ	Hourly evaporation from upper-zone storage, in inches per hour;
EVAPD	Daily evaporation, in millimeters of water per day;
EVP	Model parameter for rate of upper- and lower-zone storage evaporation (dimensionless);
EZU	Non-linear root-density function used in upper-zone soil-moisture storage evapotranspiration computations (dimensionless);
F	Daily average relative humidity, expressed as a decimal fraction; (observed at Tampa International Airport);
FALZ	Model parameter for alluvium proportion of lower soil zone storage based on percentage of alluvium area to total watershed area (dimensionless);
FHLZ	Model parameter for hillside proportion of lower soil zone storage based on percentage of hillside area to total watershed area (dimensionless);
FIN	Hourly inflow to a stream reach or reservoir, in cubic feet per second;
FRCT, Y	Surface-retention storage weighting parameters (dimensionless);
FRLZ	Model parameter for ridge proportion of lower soil zone storage based on percentage of ridge area to total watershed area (dimensionless);
GWS	Model parameter for ground-water storage, in inches;
GWSF	Model parameter for ground-water storage at zero base flow, in inches;
HEATD	Daily heat budget at evaporating surface, in millimeters of water per day;
HEP	Hourly potential evapotranspiration, in inches per hour, available to the following storages: interception, surface retention, surface detention, upper and lower zone, and ground water. Hourly potential values diminish as depletion computations progress from one storage component to the next;
HLZS	Hillside lower-zone soil-moisture storage, in inches;
IAM1	Pervious watershed area expressed as a decimal fraction;

Table 6.--Symbols used in analytical expressions in this report - continued

IAM2	Effective area of lower-zone soil capacity (dimensionless), computed by use of equation 14;
ICMN	Model parameter for winter interception-storage capacity, in inches;
ICMX	Model parameter for summer interception-storage capacity, in inches;
ICPT	Hourly interception storage, in inches;
ICPTM	Interception-storage capacity, in inches;
IFLO	Hourly interflow component of streamflow, in inches per hour;
IMIN	Specified time simulation interval (an integer quotient of 60), in minutes per time interval;
IMPA	Model parameter for subwatershed impervious area (expressed as a decimal fraction of subwatershed area);
INF	Infiltration, in inches per time interval;
INF2	Maximum infiltration rate, in inches per time interval;
INFP	Model parameter for interflow rate, in inches per hour;
K	Muskingum storage parameter reflecting approximate flood travel time through a channel reach, hours;
$\overline{K}$	Exponent for equation describing relation between saturation vapor pressure and air temperature;
KGWF	Model parameter for daily base-flow recession constant;
LZS	Model parameter for upland or ridge lower-zone soil-moisture storage, in inches;
LZSN	Model parameter for lower-zone soil-moisture storage capacity, in inches;
OUT	Routed hourly outflow from a stream reach or reservoir, in cubic feet per second;
PDGP	Model parameter for ground-water storage underflow depletion rate, in units per hour;
PERC	Percolation rate of water draining from upper- to lower-zone storages, in inches per time interval; also, percolation from alluvium lower-zone storage to ground-water storage, in inches per hour;
PINF	Model parameter for infiltration rate (adjusted for the ratio of water viscosity at mean monthly temperature to viscosity at mean annual temperature), in inches per time interval;
PLGP	Model parameter for percolation rate to ground-water storage, in inches per hour;

Table 6.--Symbols used in analytical expressions in this report - continued

PLZU	Model parameter for ridge lower-zone storage underflow depletion rate, in units per hour;
PPIF	Model parameter for infiltration rate, in inches per hour;
PPUL	Model parameter for percolation rate (from upper to lower soil zone), in inches per hour;
PR	Measured hourly precipitation, in inches per hour;
PSDP	Model parameter for surface-detention storage area (at maximum storage capacity) expressed as fraction of subwatershed area;
PSRP	Model parameter expressing maximum land-surface depression area as a fraction of subwatershed area;
PSUP	Model parameter for infiltration function shape, dimensionless;
PULP	Model parameter for percolation rate from upper- to lower-zone storage (adjusted for the ratio of water viscosity at mean monthly temperature to viscosity at mean annual temperature), in inches per time interval; also, parameter for ridge seepage to hillside and alluvium lower-zone storages, in units per hour;
PX	Unit precipitation at various computational steps within the model. Initial unit precipitation is the product of measured hourly precipitation and DELMIN, time simulation interval expressed as a decimal fraction of an hour, in inches per time interval. Unit values are diminished by storage requirements determined in preceeding computational steps.
QCON	Maximum discharge above which reservoir is uncontrollable, in cubic feet per second;
R	Mean monthly extra-terrestial radiation in millimeters of water per day;
RK	Reflectivity coefficient or reflecting surface (albedo) in percent;
S	Ratio of daily duration of bright sunshine to maximum possible sunshine, estimated from meteorologic records for Tampa International Airport;
SDS	Model parameter for surface-detention storage, in inches;
SDSN	Model parameter for surface-detention storage capacity, in inches;
SEEP	Hourly seepage from ridge to hillside and alluvium lower-zone soil-moisture storages, in inches per hour;
SRIA	Impervious area flow, in inches per time interval;
SRO	Overland flow, in inches per time interval;
SRS	Model parameter for surface-retention storage, in inches;

Table 6.--Symbols used in analytical expressions in this report - continued

SRSN	Model parameter for surface-retention storage capacity, in inches;
SWAREA	Model parameter for subwatershed area, square miles;
t	Length of reservoir-routing period, hours;
T	Air temperature, in degrees Fahrenheit;
TD	Daily average dew point temperature, in degrees Fahrenheit (estimated from daily air temperature observed at Tampa International Airport);
TEST	Uncontrolled free-fall rating discharge, in cubic feet per second;
TTM	Model parameter for overland-flow storage constant, in units per time interval;
UF	Ridge lower-zone storage and ground-water storage underflow depletion rate, in inches per hour;
UX	Upper soil zone percolation rate function (dimensionless); symbol is also used as a weighting factor for upper and lower soil zone evapotranspiration computations (dimensionless);
UZS	Model parameter for upper-zone soil moisture, in inches;
UZSN	Model parameter for upper-zone soil-moisture capacity, in inches;
W	Daily average wind speed, in miles per hour; (observed at Tampa International Airport);
x	Dimensionless weighting factor for stream-reach inflow and outflow; also a measure of the translatory component of wave motion;
X	That part of unit precipitation contributing directly to surface-retention storage, in inches per time interval;
XLX	Interflow-rate parameter for hillside lower-zone soil-moisture storage, in inches per hour.

$$INF = PX - \frac{(PX)^2}{2(INF2)} \qquad (2)$$

$$\text{for } PX \leq INF2$$

where PX = Unit precipitation (in excess of interception storage) appearing at land surface, in inches per time interval;

INF2 = Maximum infiltration rate, in inches per time interval.

INF is equal to half the maximum infiltration rate, INF2, when unit precipitation, PX, exceeds INF2.

Maximum infiltration rate, INF2, is calculated by use of a nonlinear function given by equation 3, as follows:

$$INF2 = PINF \quad 2^{-[PSUP \cdot (UZS/UZSN)]} \qquad (3)$$

where PINF = Infiltration rate parameter, in inches per time interval;

PSUP = Infiltration function shape parameter, (dimensionless);

UZS = Upper-zone soil-moisture storage, in inches;

UZSN = Upper-zone soil-moisture storage capacity, in inches.

The infiltration rate parameter, PINF, is determined in the model by use of equation 4, as follows:

$$PINF = PPIF \cdot CORINF \cdot DELMIN \qquad (4)$$

where PPIF = Infiltration rate parameter, in inches per hour;

CORINF = Ratio of water viscosity at mean monthly temperature to the viscosity at mean annual temperature (decimal fraction);

DELMIN = Simulation time increment, expressed as decimal fraction of an hour.

Infiltration also occurs from surface-retention and surface-detention storages (discussed below) and is calculated using a procedure similar to that described above.

Surface-Retention (Depression) Storage

Precipitation that does not infiltrate directly, may enter surface depressions and lakes, and is referred to as surface-retention storage, SRS, and has a maximum capacity, SRSN. The amount of precipitation, X, that contributes directly to surface-retention storage is calculated by use of equation 5, as follows:

$$X = PX \cdot PSRP \cdot FRCT \quad (5)$$

where PX = Unit precipitation, in excess of interception storage and direct infiltration, in inches per time interval;

PSRP = Parameter expressing maximum land-surface depression area as a percentage of total subwatershed area;

FRCT = Surface-retention storage weighting parameter, (dimensionless).

The storage parameter, FRCT, is calculated by use of equation 6 or 8 depending on the ratio of surface-retention storage, SRS, to maximum storage capacity, SRSN, as follows:

$$FRCT = [1.0/(1.0 + Y)]^{y} \quad \text{for } (SRS/SRSN) \geq 2.0 \quad (6)$$

$$\text{and } Y = 2.0\ [ABS(SRS/SRSN - 2.0)] + 1.0 \quad (7)$$

$$\text{or } FRCT = 1.0 - 0.5\ (SRS/SRSN)\ [(1.0/(1.0 + Y)]^{y} \quad \text{for } (SRS/SRSN) < 2.0 \quad (8)$$

$$\text{and } Y = 2.0\ [ABS(0.5\ (SRS/SRSN) - 1.0] + 1.0 \quad (9)$$

The symbol, ABS, indicates that absolute value of parenthetical expression is to be used.

Surface-retention storage is depleted by evaporation and infiltration to the upper soil zone.

Surface-Detention Storage

Precipitation appearing at pervious land-surface areas which avoids interception storage, direct infiltration, and surface-retention storage becomes surface-detention storage, SDS. Surface-detention storage has a maximum storage capacity, SDSN, and is depleted by contributions to overland flow and infiltration to the upper soil zone. Surface-detention storage that is not drained each time simulation increment by overland flow is available for infiltration to the upper soil zone.

Upper- and Lower-Zone Storages

Upper-zone soil-moisture storage, UZS, is derived from direct infiltration of excess precipitation at the land surface and infiltration from surface-retention (depression) and detention storages. Upper-zone soil-moisture storage has a maximum storage capacity, UZSN, and is depleted by evapotranspiration and drainage (percolation) into three lower-zone storages, including upland (or ridge), hillside, and alluvium. Lower-zone soil-moisture storage capacity is denoted LZSN. The upland (or ridge) zone is depleted by seepage to the hillside and alluvium lower storage zones. Seepage occurs from ridge zone to the alluvium zone when ridge soil moisture, LZS, exceeds the lower-zone soil-moisture storage capacity, LZSN. The alluvium lower zone is depleted by deep percolation to ground-water storage and hillside lower-zone storage is depleted by interflow. Ridge, alluvium, and hillside storages are depleted by evapotranspiration.

Upper-zone soil-moisture storage does not directly support any flow component.

After infiltration at the initial upper soil zone (fig. 2), the model distributes drainage on an hourly basis to each of the three lower zones by use of an analytical percolation function. Drainage rates are proportional to percent of the basin designated as ridge, hillside, and alluvium. The hillside and alluvium areas of the lower soil zone receive drainage from the upper zone only under saturated conditions (of the upper zone).

All storage calculations that follow percolation from upper- to lower-zone storage are made on an hourly basis including evapotranspiration and various flow components.

Percolation

When the upper soil zone approaches saturation condition, water begins to percolate (or drain) to lower soil zones at a rate, PERC, given by equation 10, as follows:

$$PERC = UX \cdot PULP \cdot (IAM1/IAM2) \qquad (10)$$

where PULP = Percolation rate parameter for water draining from upper to lower soil zones, in inches per time interval;

UX = Percolation rate function depending on upper-zone soil-moisture storage and upper-zone capacity, (dimensionless);

IAM1 = Previous watershed area expressed as a decimal fraction;

IAM2 = Effective area of lower-zone soil capacity (dimensionless). See equation 14.

The percolation rate function, UX, is equal to zero when upper-zone storage, UZS, is less than half the upper-zone storage capacity, UZSN; equation 11 is used to calculate the percolation rate function, UX, for upper-zone storage values between one-half and full capacity, as follows:

$$UX = 4.0\ [(UZS/UZSN) - 0.5]^2 \qquad (11)$$

Percolation rate function, UX, is determined by equation 12 when storage exceeds storage capacity of the upper soil zone, as follows:

$$UX = 2.825\ [(UZS/UZSN) - 0.875]^{0.5} \qquad (12)$$

The percolation rate parameter, PULP, is determined within the model by use of equation 13, as follows:

$$PULP = PPUL \cdot CORINF \cdot DELMIN \qquad (13)$$

where PPUL = Percolation rate parameter (from upper to lower soil zones), in inches per hour;

CORINF = Ratio of water viscosity at mean monthly temperature to viscosity at mean annual temperature (decimal fraction);

DELMIN = Simulation time increment expressed as decimal fraction of an hour.

The effective area of lower-zone soil capacity, IAM2, depends on impervious watershed area and is calculated by an exponential expression given by equation 14, as follows:

$$IAM2 = [1 - IMPA]^{0.7} \qquad (14)$$

where IMPA = Impervious watershed area expressed as a decimal fraction.

Seepage

Alluvium and hillside lower-zone storages receive seepage from ridge lower-zone storage, LZS, when ridge storage exceeds lower-zone storage capacity, LZSN. Seepage, SEEP, from ridge lower-zone storage is calculated by use of equation 15, as follows:

$$SEEP = PULP \cdot (LZS-LZSN) \cdot FRLZ/(1-FRLZ) \qquad (15)$$

where PULP = Seepage parameter for lower-zone storage, in units per hour (see equation 13 above);

LZS = Ridge lower-zone soil-moisture storage, in inches;

LZSN = Lower-zone soil-moisture storage capacity, in inches;

FRLZ = Parameter expressing fraction of lower-zone storage as ridge area (dimensionless).

The ratio FRLZ/(1-FRLZ), as shown above in equation 15, expresses proportion of ridge area to hillside and alluvial areas of lower-zone storage.

Ground-Water Storage

Ground-water storage, GWS, receives drainage from alluvium lower-zone storage and is depleted by transpiration, base flow, and underflow. Percolation from alluvium lower-zone storage to ground-water storage is calculated by use of equation 16, as follows:

$$PERC = PLGP \cdot [(ALZS/LZSN) - 0.5] \cdot FALZ \cdot IAM2 \qquad (16)$$

where PLGP = Percolation rate parameter for ground-water storage, in inches per hour;

ALZS = Alluvium lower-zone soil-moisture storage, in inches;

LZSN = Lower-zone soil-moisture storage capacity, in inches;

FALZ = Parameter expressing fraction of lower-zone storage as alluvial area (dimensionless);

IAM2 = Effective area of lower-zone soil capacity (dimensionless).

Percolation is zero when alluvium soil moisture is less than half lower-zone storage capacity.

Evapotranspiration

Evapotranspiration depletes interception, surface, soil-moisture and ground-water storage components. Evapotranspiration is determined as the sum of evaporation from interception and surface-retention storages, evaporation and transpiration from upper- and lower-zone storages, and transpiration from ground-water storage. Upper- and lower-zone soil-moisture storages are the principal sources of evapotranspiration in the model. Evapotranspiration is calculated for each of these storage components using hourly potential evapotranspiration as an upper limit. Hourly potential evapotranspiration values, HEP, are computed as the product of estimated evapotranspiration values input to the model and the hourly distribution ordinates listed in table 7. Hourly evapotranspiration diminishes as depletion computations progress from one storage component to the next as shown in figure 2. Diminished values represent evapotranspiration potential for subsequent storage component.

Table 7.--Hourly distribution of potential evapotranspiration

[From Lumb, 1975]

Ending hour	Hourly distribution rate	Ending hour	Hourly distribution rate
0100	0.0	1300	0.110
0200	0.0	1400	0.110
0300	0.0	1500	0.105
0400	0.0	1600	0.095
0500	0.0	1700	0.081
0600	0.0	1800	0.055
0700	0.19	1900	0.017
0800	0.041	2000	0.0
0900	0.069	2100	0.0
1000	0.088	2200	0.0
1100	0.102	2300	0.0
1200	0.110	2400	0.0

Surface Evaporation

Surface evaporation depletes both interception and surface-retention storages. Interception and surface-retention storages are totally depleted by surface evaporation when evaporation potential equals or exceeds available storage. For all other conditions, interception and surface-retention storages are depleted at rates determined from relations described below.

Interception-storage evaporation, EIS, is determined by use of equation 17, as follows:

$$EIS = EIP \cdot HEP \cdot (ICPT/ICPTM) \cdot IAM1 \quad (17)$$

where EIP = Evaporation parameter for interception storage (dimensionless);

HEP = Hourly potential evaporation, in inches per hour;

ICPT = Interception storage, in inches;

ICPTM = Interception-storage capacity, in inches;

IAM1 = Pervious watershed area expressed as a decimal fraction.

Surface-retention storage evaporation, ESR, is determined by use of equation 18, as follows:

$$ESR = HEP \cdot PSRP \cdot (SRS/SRSN) \cdot IAM1 \quad (18)$$

where HEP = Hourly potential evapotranspiration available to surface-retention storage, in inches per hour;

PSRP = Maximum area parameter for surface-retention storage (expressed as fraction of subwatershed area);

SRS = Surface-retention storage, in inches;

SRSN = Surface-retention storage capacity, in inches;

IAM1 = Pervious watershed area expressed as a decimal fraction.

Upper and Lower Soil Zone Evapotranspiration

The principal sources of evapotranspiration are upper- and lower-zone soil-moisture storages. Upper soil zone evapotranspiration, EUZ, depletes half of the upper-zone soil moisture, UZS, when potential evapotranspiration exceeds soil-moisture storage; for all other upper-zone soil-moisture conditions, evapotranspiration is computed by use of equation 19, as follows:

$$EUZ = HEP \cdot EZU \cdot UX \cdot IAM1 \quad (19)$$

where HEP = Hourly potential evapotranspiration available to upper-zone storage, in inches per hour;

EZU = Root-density function (see equation 20);

UX = Upper-zone storage weighting factor (see equation 21);

IAM1 = Pervious watershed area expressed as a decimal fraction.

The dimensionless upper soil zone root-density function, EZU, is defined by a non-linear relation given by equation 20, as follows:

$$EZU = 1.0 - [(LZSN)/(LZSN + UZSN)]^2 \qquad (20)$$

where LZSN = Lower-zone soil-moisture storage capacity, in inches;

UZSN = Upper-zone soil-moisture storage capacity, in inches.

The dimensionless upper-zone storage weighting factor, UX, can vary between 0 and 1, and is calculated by use of equation 21, as follows:

$$UX = EVP \cdot [UZS/UZSN]^{0.5} \qquad (21)$$

where EVP = Evapotranspiration parameter for upper- and lower-zone storages (dimensionless);

UZS = Upper-zone soil-moisture storage, in inches.

Ridge, hillside, and alluvium lower-zone storages are also depleted by evapotranspiration. Each of these storages is depleted by one-half when potential evapotranspiration exceeds available soil moisture; for all other soil-moisture conditions, evapotranspiration is computed as the product of lower-zone potential evapotranspiration and respective storage component rate functions.

Lower-zone potential evapotranspiration used is determined as the product of available hourly potential evapotranspiration and a weighting factor reflecting differences in upper- and lower-zone storage capacities.

Storage component rate functions used are determined as the product of the evapotranspiration parameter for upper- and lower-zone storages, EVP, with respective storage component ratios (component soil moisture to capacity raised to the 0.8 power), and storage component effective areas. Effective areas are determined as the product of the lower-zone soil capacity effective area parameter, IAM2, and the respective storage component parameters (FRLZ, FHLZ, or FALZ) expressing the proportion of lower-zone storage designated as ridge, hillside, and alluvium areas.

Ground-Water Transpiration

The model assumes that evapotranspiration loss from ground-water storage occurs primarily as transpiration. Ground-water transpiration, EGW, is calculated by use of equation 22, as follows:

$$EGW = 4 \cdot HEP \cdot ETGWP \cdot GWS \cdot FALZ \cdot IAM2 \qquad (22)$$

where HEP = Hourly potential evapotranspiration available to ground-water storage, in inches per hour;

ETGWP = Transpiration parameter for ground-water storage (dimensionless);

GWS = Ground-water storage, in inches;

FALZ = Parameter expressing fraction of lower-zone storage as alluvial area (dimensionless);

IAM2 = Effective area of lower-zone soil capacity (dimensionless).

The coefficient, 4, in equation 22 is a proportionality constant, in units per inch.

Underflow

Ridge lower-zone storage and ground-water storage are depleted by underflow, or the downgradient flow of water through permeable deposits underlying the stream.

Underflow occurs when ridge lower-zone soil moisture, LZS, exceeds lower-zone storage capacity, LZSN, and is calculated by use of equation 23, as follows:

$$UF = PLZU \cdot LZS \cdot FRLZ \cdot IAM2 \qquad (23)$$

where PLZU = Underflow parameter for ridge lower-zone soil-moisture storage, in units per hour;

LZS = Ridge lower-zone soil-moisture storage, in inches;

FRLZ = Parameter expressing fraction of lower-zone storage as ridge area (dimensionless);

IAM2 = Effective area of lower-zone soil capacity (dimensionless).

Underflow from ground-water storage is calculated by use of equation 24, as follows:

$$UF = PDGP \cdot GWS \cdot FALZ \qquad (24)$$

where PDGP = Underflow parameter for ground-water storage, in units per hour;

GWS = Ground-water storage, in inches;

FALZ = Parameter expressing fraction of lower-zone storage as alluvial area (dimensionless).

Streamflow

Simulated streamflow consists of direct runoff, interflow, and base flow. Direct runoff is translated into a surface-runoff hydrograph by use of a distribution graph. Interflow and base-flow ordinates are combined directly with ordinates of the surface-runoff hydrograph to produce a streamflow hydrograph. Distribution graphs (dimensionless unit hydrographs) are computed from available gaging station records using flood hydrographs for selected independent storms.

Direct-runoff flow components may be calculated on time simulation intervals shorter than an hour. Base flow and interflow are calculated on an hourly basis.

Direct Runoff

Direct runoff results from impervious-area flow and pervious-area overland flow. Rainfall on those areas of the land surface that are impervious and connected to the stream channel system results in impervious-area flow, SRIA, and is calculated by use of equation 25, as follows:

$$SRIA = IMPA \cdot PX \qquad (25)$$

where IMPA = Ratio of impervious area to total basin area expressed as a decimal fraction;

PX = Unit precipitation, in inches per time interval.

Unit precipitation, PX, is computed as the product of hourly precipitation, PR, and time simulation interval DELMIN (expressed as decimal fraction of an hour).

Overland flow, SRO, depends on the magnitude of surface-detention storage and is calculated by use of equation 26, as follows:

$$SRO = SDS \cdot TTM \qquad (26)$$

where SDS = Surface-detention storage, in inches;

TTM = Overland-flow storage parameter for surface-detention storage, in units per time interval.

Interflow

Interflow is water that moves laterally through the lower soil zone to the stream channel system. Interflow may appear quickly in the stream, or may be delayed, depending on lower-zone soil-moisture condition.

Interflow depletes hillside lower-zone storage, and occurs when hillside lower-zone soil moisture, HLZS, exceeds lower-zone storage capacity, LZSN. Under this condition, interflow, IFLO, is calculated by use of equation 27, as follows:

$$IFLO = XLX \cdot FHLZ \cdot IAM2 \qquad (27)$$

where XLX = Interflow parameter, in inches per hour (see equation 28);

FHLZ = Parameter expressing fraction of lower-zone storage as hillside area (dimensionless);

IAM2 = Effective area of lower-zone soil capacity (dimensionless).

The interflow rate parameter, XLX, is calculated by use of a nonlinear function given by equation 28, as follows:

$$XLX = INFP \cdot [0.8+0.2\ (HLZS/LZSN)-0.5] \cdot [(HLZS/LZSN)-0.5]^2 \qquad (28)$$

where INFP = Interflow parameter for hillside lower-zone storage, in inches per hour;

HLZS = Hillside lower-zone soil moisture, in inches;

LZSN = Lower-zone soil-moisture capacity, in inches.

Base Flow

Base flow is sustained or fair-weather runoff and is derived from ground-water storage. Base flow, BFLO, is calculated by use of equation 29, as follows:

$$BFLO = FALZ \cdot BFP \cdot (GWS - GWSF) \qquad (29)$$

where FALZ = Parameter expressing fraction of lower-zone storage as alluvial area (dimensionless);

BFP = Base-flow parameter for ground-water storage, in units per hour (see equation 30);

GWS = Ground-water storage, in inches;

GWSF = Ground-water storage at zero base flow, in inches.

The base-flow parameter, BFP, is calculated by use of a non-linear function given by equation 30, as follows:

$$BFP = 1.0 - [KGWF]^{0.04167} \tag{30}$$

where KGWF = Daily base-flow recession constant (estimated from observed streamflow records).

Flow Routing

Streamflow hydrographs are routed within the stream channel system using an analytical procedure referred to as the Muskingum Method. The procedure involves routing of incremental inflow values through segments of stream channel reach. Routed outflow, OUT (N), from a specific channel reach is computed by use of equation 31, as follows:

$$OUT(N) = CO \cdot FIN(N) + C1 \cdot FIN(N-1) + C2 \cdot OUT(N-1) \tag{31}$$

where OUT(N-1) = Preceding outflow from stream reach;

FIN(N) = Current inflow to reach;

FIN(N-1) = Preceding inflow to reach.

The coefficients, C0, C1, and C2, are calculated by use of the following set of expressions:

$$CO = \frac{-Kx + 0.5t}{K(1-x) + 0.5t}$$

$$C1 = \frac{Kx + 0.5t}{K(1-x) + 0.5t} \tag{32}$$

$$C2 = \frac{K(1-x) - 0.5t}{K(1-x) + 0.5t}$$

where K = Storage parameter reflecting approximate flood travel time through stream reach, in hours;

x = Weighting parameter (dimensionless) for reach inflow and outflow; also a measure of the translatory component of wave motion;

t = Length of routing or simulation period, in hours; in this study, a 1-hour routing period is used.

Routing parameters K and x are determined from available streamflow records and adjusted by comparing simulated and observed hydrographs.

Reservoir routing is accomplished by use of an analytical procedure based on the modified Puls method. The method provides for computation of both controlled and uncontrolled reservoir outflow. The modified procedure assumes that (1) outflow can be controlled when reservoir stage is less than elevation of free-surface discharge and (2) outflow is uncontrolled for higher stage values.

Uncontrolled flow is determined from a free-fall stage-discharge relation. Controlled outflow values, OUT, are computed from preceding reservoir stage and inflow values using equation 33, as follows:

$$\mathrm{OUT(I)} = \mathrm{AA} + \mathrm{B}\cdot\mathrm{EL} + \mathrm{C}\cdot\mathrm{FIN(NR,I-1)} \qquad (33)$$

where EL = Current reservoir stage value, in feet;

FIN(NR,I-1) = Preceding reservoir inflow, for reach NR, in cubic feet per second;

AA, B, C = Coefficients determined in a regression analysis of observed inflow, reservoir stage and outflow values.

Reservoir stage values are updated using a stage-volume table and a preceding reservoir volume value adjusted for the difference in inflow minus outflow (including water-supply diversion).

Reservoir inflow is simulated discharge for the flow point at the head of the reservoir reach.

Boundary conditions for outflow values computed by use of equation 33 are as follows:

(1) Reservoir outflow can be assigned a constant value when reservoir stage falls below the point at which gated operation begins;

(2) Equation 33 may conceivably produce negative outflow values for small inflow values. Under this condition, or when routed outflow values are less than a specified minimum acceptable outflow, reservoir outflow can be set equal to the preceding inflow. Minimum acceptable routed flows are calculated as a percentage of preceding inflow values.

(3) Equation 33 may also produce unreasonably high outflow values. Computed outflow values are compared to a free-fall discharge corresponding to the current reservoir stage value. Outflow values exceeding the free-fall rating assume the free-fall discharge value.

MODEL OPERATION

The watershed being modeled may consist of one or more distinct subwatersheds connected by stream channel reaches. Application of the model to a watershed first requires identification of subwatersheds and connecting stream reaches. Subwatersheds, stream channel reaches, and associated flow points, have been illustrated for a hypothetical watershed as shown in figure 3. Flow points are generally sites where streamflow records are available. The sketch shows the overall watershed boundary containing 5 subwatersheds connected by 3 stream channel reaches. Subwatershed 1, SUBWS-1, flows into flow-point 1, FP-1, and subwatershed 2, SUBWS-2, flows into flow-point 3, FP-3. The first stream reach, R-1, connects flow-points 1 and 3. Subwatershed 3, SUBWS-3, flows into flow-point 2, FP-2, and subwatershed 4 flows into flow-point 3, FP-3. In general, a stream reach is assigned a number equal to the flow-point number at the head of the reach so that the ending flow-point number of the last stream reach is always greater than the number of stream reaches. Subwatershed and connecting stream reaches are numbered sequentially in downstream order beginning with the farthest upstream subwatershed and stream reach.

The model will simulate one or more water years using hourly rainfall and daily values of evapotranspiration as input data. A generalized flow chart is shown in figure 4. Rainfall values are required for each subwatershed modeled; daily evapotranspiration values used are assumed to apply to the entire basin. Measured streamflow data for subwatersheds and other key points may be input for comparison with simulated flow values. Flow simulation and routing for a watershed is done on a monthly basis, using an assigned sequence of subwatershed and stream reaches as outlined in figure 3. Upon completion of flow simulation and routing for a water year, the model outputs desired types of data for selected flow points including summaries of monthly evapotranspiration, storage and flow components, annual streamflow tables and hydrographs (daily discharge) and an annual water-budget analyses of change in storage computed as annual rainfall minus annual evapotranspiration, runoff, and underflow. Simulated flow statistics are also available. Model options are summarized in Supplement II, under section I, watershed identification and program options.

CALIBRATION PROCEDURE

A manual procedure was used in this study for model calibration. The procedure is designed to induce changes in hydrologic processes controlling model output through sequential adjustment of important parameters.

The procedure considers a full range of streamflow variation in basins modeled, and is similar to a procedure described by Fleming (1975). However, major emphasis of this study lies with flood simulation, and

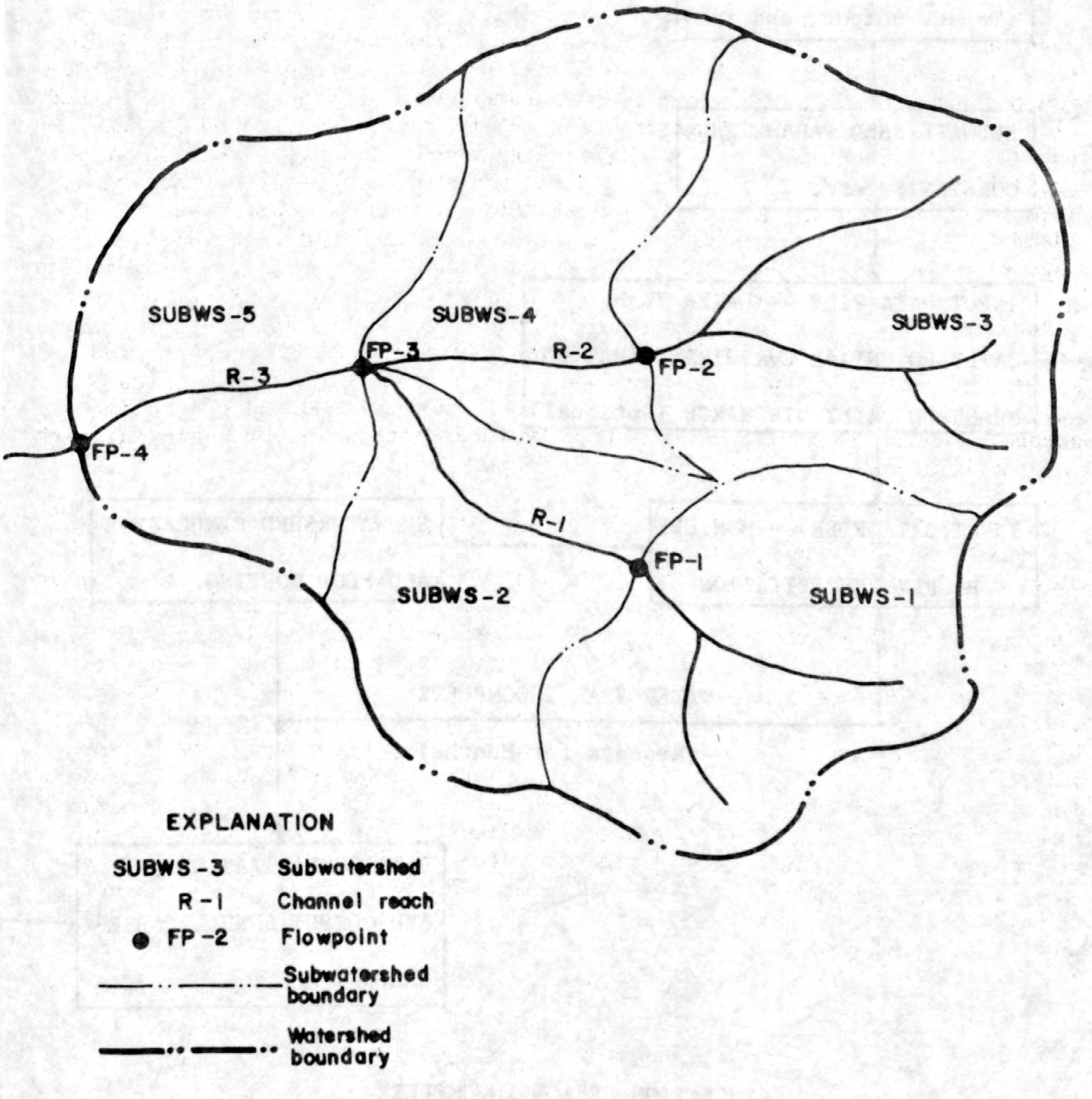


Figure 3.--Subwatershed configuration, channel reaches, and flow points for a typical watershed.

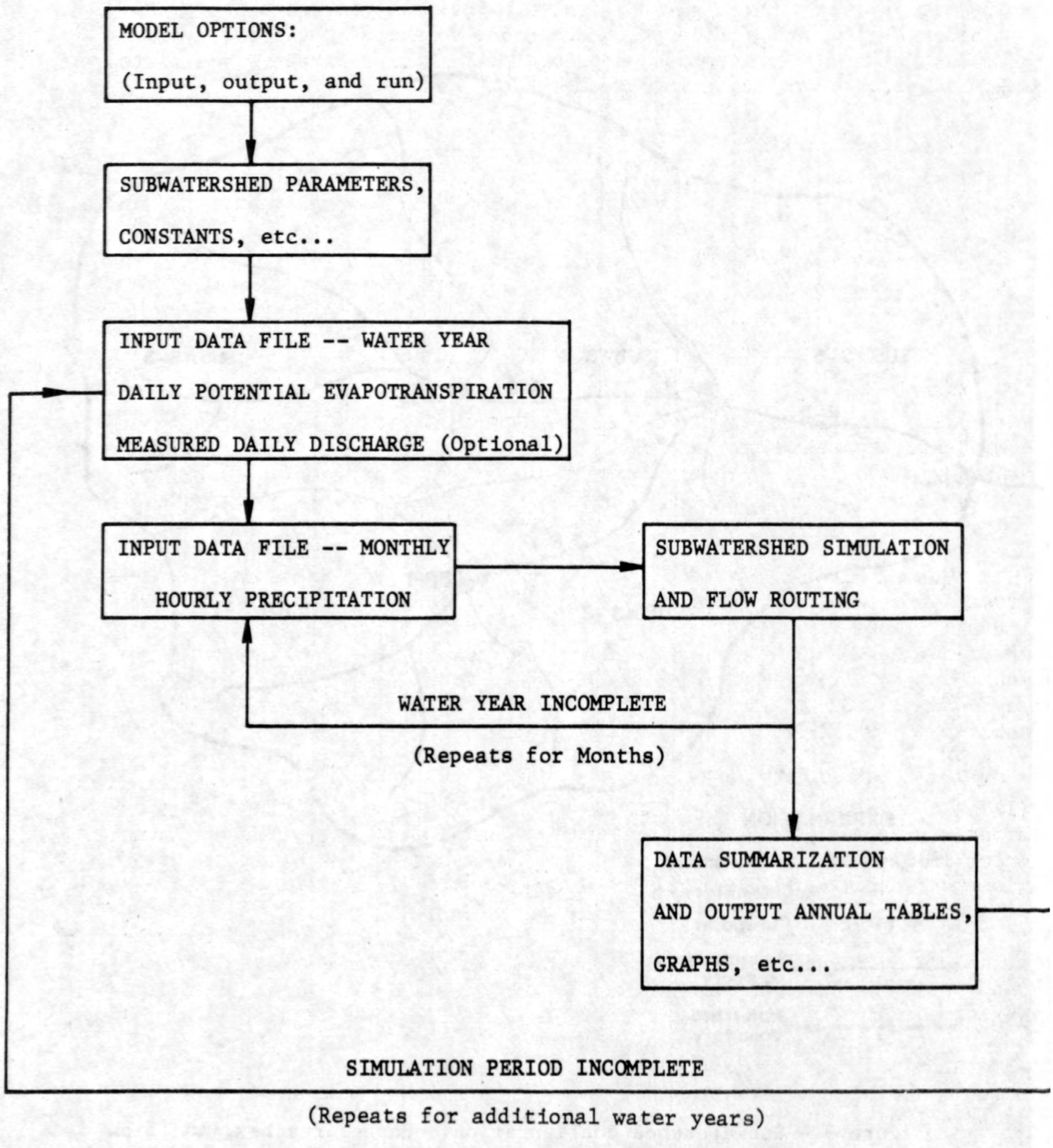


Figure 4.--Flow chart showing model operational sequence.

therefore, model calibration is oriented principally toward those parameters having greatest influence on shape and volume of the flood hydrographs. Hydrologic processes and subordinate model parameters are listed below in order of relative importance:

Hydrologic process	Model parameter
Infiltration	PPIF, PSUP
Storage	UZSN, LZSN, FALZ[1], FHLZ[1], PSRP[1]
Percolation and seepage	PPUL
Evapotranspiration	EVP, ETGWP

[1]Area parameters that affect surface and soil-moisture storage.

Parameters listed above are the most sensitive model parameters. Parameter sensitivity refers to the relative changes in various model components, expressed as percent increases or decreases, that are produced by a specified percent increase in the value of each model parameter, evaluated one at a time. Results of the Anclote River sensitivity analysis, listed in table 9, is an example.

Optimization is difficult because adjustment of a parameter value may produce response in several flow components. Optimization strategy outlined in table 8 consists of 5 steps covering parameter sequence and type of adjustment (increase or decrease) to produce an increase in various model and hydrograph components. The magnitude of parameter adjustment may be estimated using sensitivity analysis results, such as listed in table 9.

Model response to parameter adjustment is evaluated indirectly through (1) line-printer plots of observed and simulated mean daily discharges for a water year displayed on a logarithmic scale versus time, (2) absolute error in simulated annual, monthly, and mean-daily flows, and (3) correlation coefficients of simulated and observed monthly and mean-daily flows.

Initial values for many model parameters were obtained using modified guidelines and relations suggested by Crawford and Linsley (1966), and preliminary results of GTWS model studies for other areas (oral and written commun. with Alan Lumb, 1974). Initial values for remaining parameters were estimated from available streamflow records, topographic maps, and recent aerial photographs. Initial values for several parameters were selected arbitrarily. The method used in initial value selection is indicated in table 5 for each model parameter.

The first calibration step (table 8) is to insure that values for parameters controlling model operation are in range. A streamflow hydrograph is simulated for an entire water year, using the initial set of model parameter values selected. Simulated and observed hydrographs (line-printer plots of simulated and observed mean daily flows) are compared;

Table 8.--Suggested strategy for manual optimization of model parameters

Calibration step	Model response[1]	Parameter adjustment sequence
I	Annual streamflow hydrograph adjusted upward and total annual runoff increased.	1. Decrease PPIF 2. Increase PSUP 3. Decrease UZSN 4. Decrease PSRP 5. Decrease PPUL 6. Decrease EVP 7. Decrease LZSN
II	Direct runoff increased.	1. Decrease PSRP 2. Decrease PPIF 3. Increase PSUP 4. Decrease UZSN
III	Base flow increased.	1. Increase FALZ 2. Decrease LZSN 3. Increase PPUL 4. Decrease ETGWP
IV	Interflow increased.	1. Increase FHLZ 2. Increase PPUL 3. Decrease LZSN 4. Decrease EVP
V	Flood volume and peak discharge increased.	1. Increase PSUP 2. Decrease UZSN 3. Decrease PPUL 4. Increase PSRP

1 Model response can be reversed by applying opposite parameter changes. For example, to decrease base flow, first decrease FALZ, then increase LZSN, and so on.

Table 9.--Sensitivity of GTWS model parameters (as applied to Anclote River)

[Percentage change in model component produced by 10 and 25 percent increases in indicated model parameter.]

Model component	IMPA		FALZ		FHLZ		PSRP		PSDP		ICMN		ICMX	
	10	25	10	25	10	25	10	25	10	25	10	25	10	25
STORAGES:														
Interception	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	2.86	3.46	7.90
Surface retention	.00	- .06	.00	.00	.00	.00	6.92	16.99	.00	- .06	- .28	- .61	- .94	2.16
INFILTRATION:														
Direct	0.00	-0.08	0.00	0.00	0.00	0.00	-3.91	-9.42	-0.16	-0.32	-0.32	-0.80	-0.64	-1.44
From surface retention	.00	- .06	.00	.00	.00	.00	6.18	15.02	- .06	- .06	- .24	- .53	- .71	-1.65
From surface detention	.00	.00	.00	.00	.00	.00	-12.90	-29.03	9.68	22.58	.00	.00	.00	.00
PERCOLATION:														
Upper to lower soil zone	0.00	-0.05	0.00	0.00	0.00	0.00	1.95	4.90	0.05	0.10	-0.29	-6.62	-0.52	-1.24
Lower zone storage to ground-water storage	5.67	5.67	5.67	13.96	-1.61	-3.91	2.15	5.37	.08	.15	- .15	- .46	- .31	- .69
Ridge seepage	-16.86	-16.86	-16.86	-41.72	-6.80	-16.86	3.25	7.10	.00	- .30	- .30	- .59	- .39	- .59
STREAMFLOW:														
Impervious area	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surface runoff	.00	- .03	.00	.00	.00	.00	-2.26	-5.61	- .06	- .12	- .25	- .56	- .65	-1.55
Interflow	-4.05	-4.05	-4.05	-9.25	8.09	19.85	2.12	5.39	.00	.00	- .19	- .58	- .39	- .77
Baseflow	6.80	6.80	6.80	16.50	- .97	-2.91	2.91	6.80	.00	.00	.97	1.94	.97	1.94
EVAPOTRANSPIRATION:														
Interception storage	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	2.88	3.33	7.65
Surface retention storage	.00	.00	.00	.00	.00	.00	10.45	29.85	.00	1.49	.00	-1.49	-5.97	-13.43
Upper zone storage	.00	.00	.00	.00	.00	.00	.60	.91	.00	.00	- .60	-1.51	-1.81	-4.53
Lower zone storage	-3.39	-3.39	-3.39	-8.19	-1.41	-3.39	- .28	- .56	.00	- .28	- .85	-1.69	-1.69	-3.95
Ground-water storage	5.76	5.79	5.76	14.18	-1.56	-3.84	2.10	5.12	.00	.09	- .27	- .73	- .73	-1.65
Total	1.64	1.64	1.64	4.01	- .70	-1.68	.98	2.47	.03	.63	.25	.57	.63	1.45
SELECTED HYDROGRAPH COMPONENT:														
Maximum mean daily flow	-0.03	-0.03	-0.03	-0.50	0.05	0.13	0.81	2.34	-0.03	-0.03	-0.25	-0.59	-0.08	-0.18
Maximum mean hourly flow	- .03	- .03	- .03	- .05	.05	.15	.86	2.32	.00	- .03	- .23	- .58	- .08	- .18
Annual flow	- .36	- .36	- .36	- .83	1.13	2.79	-1.36	-3.40	- .03	- .08	- .03	- .50	- .58	-1.36
Flood volume	- .07	- .06	- .07	- .16	.16	.40	1.08	2.23	- .01	- .03	- .25	- .60	- .07	- .18

Table 9.--Sensitivity of GTWS model parameters (as applied to Anclote River) - continued

Model component	SRSN		SDSN		UZSN		LZSN		PPIF		PSUP		PPUL	
	10	25	10	25	10	25	10	25	10	25	10	25	10	25
STORAGES:														
Interception	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surface retention	1.33	3.27	.00	.00	- .28	- .50	.06	.17	- .72	-1.72	.77	1.49	- .22	- .55
INFILTRATION:														
Direct	-0.32	-0.72	0.08	0.16	4.79	11.42	-0.72	-1.68	3.67	8.79	-11.82	-26.00	5.75	13.66
From surface retention	.77	1.88	.00	.06	.18	.59	.00	.00	- .53	-1.35	- .53	-1.77	.65	1.35
From surface detention	.00	-3.23	-9.68	-19.35	3.23	9.68	.00	.00	3.23	6.45	-12.90	-25.81	6.45	12.90
PERCOLATION:														
Upper to lower soil zone	0.33	0.81	-0.05	-0.10	-1.09	-2.95	0.52	1.19	1.19	2.81	-4.81	-11.23	5.09	11.90
Lower zone storage to ground-water storage	.38	.92	- .08	- .15	- .61	-1.69	-4.52	-11.20	1.23	2.91	-4.91	-11.35	5.52	12.96
Ridge seepage	.59	1.18	- .30	- .30	- .59	-1.78	-10.36	-26.04	1.78	4.14	-7.10	-16.57	9.47	22.49
STREAMFLOW:														
Impervious area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surface runoff	- .62	-1.58	.03	.09	-1.77	-4.27	.25	.56	-1.08	-2.54	4.24	9.72	-2.20	-5.14
Interflow	.39	.96	- .19	- .19	- .58	-1.73	-4.62	-11.56	1.16	2.89	-5.01	-11.75	5.59	13.29
Baseflow	.00	.97	.00	.00	-1.94	-4.85	-5.83	-13.59	.97	1.94	-3.88	-7.77	4.85	10.68
EVAPOTRANSPIRATION:														
Interception storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surface retention storage	10.45	25.37	.00	.00	-8.96	-20.90	1.49	2.99	-2.99	-5.97	20.90	53.73	-10.45	-22.39
Upper zone storage	.00	- .30	.00	.00	6.95	16.62	-6.34	-14.50	.60	1.51	-3.02	-6.95	-1.51	-3.63
Lower zone storage	- .28	- .85	.00	.00	-3.67	-8.72	2.54	5.37	.00	.28	-1.13	-2.82	.28	.85
Ground-water storage	.27	.64	- .09	- .09	- .55	-1.46	-4.76	-12.08	1.28	3.02	-5.03	-11.80	5.49	12.90
Total	.28	.66	- .03	- .03	- .03	- .16	-1.99	-5.03	.47	1.14	-1.74	-3.95	1.58	3.67
SELECTED HYDROGRAPH COMPONENT:														
Maximum mean daily flow	-0.46	-1.22	0.00	0.03	-1.76	-4.40	0.05	0.03	-0.69	-1.60	3.16	6.98	-1.20	-2.77
Maximum mean hourly flow	- .43	-1.21	.00	.03	-1.76	-4.40	.05	.03	- .68	-1.59	3.15	6.92	-1.18	-2.74
Annual flow	- .44	-1.13	.03	.08	-1.71	-4.15	- .61	-1.52	- .72	-1.71	2.93	6.64	- .91	-2.16
Flood volume	- .53	-1.36	.01	.02	-1.79	-4.45	- .01	- .23	- .68	-1.18	3.18	6.90	-1.07	-2.48

Table 9.--Sensitivity of GTWS model parameters (as applied to Anclote River) - continued

Model component	PLGP		TTM		INFP		KGWF[1]		EIP[1]		EVP		ETGWP	
	10	25	10	25	10	25	10	25	10	25	10	25	10	25
STORAGES:														
Interception	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-4.06	-11.29	0.00	0.00	0.00	0.00
Surface retention	.00	.00	.00	.00	.00	.00	.00	.00	1.16	3.27	- .11	- .33	.00	.00
INFILTRATION:														
Direct	0.00	0.00	0.16	0.40	0.00	0.00	0.00	0.00	0.80	2.32	1.04	2.64	0.00	0.00
From surface retention	.00	.00	.00	.60	.00	.00	.00	.00	.29	.94	- .06	- .06	.00	.00
From surface detention	.00	.00	-16.13	-38.71	.00	.00	.00	.00	.00	.00	.00	3.23	.00	.00
PERCOLATION:														
Upper to lower soil zone	0.00	0.00	-0.10	-0.19	0.00	0.00	0.00	0.00	0.43	1.24	-0.81	-2.00	0.00	0.00
Lower zone storage to ground-water storage	.38	.77	- .08	- .23	.00	.00	.00	.00	.23	.61	-2.68	-6.60	.00	.00
Ridge seepage	.00	.00	- .30	- .30	.00	.00	.00	.00	.00	.59	-5.33	-13.02	.00	.00
STREAMFLOW:														
Impervious area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surface runoff	.00	.00	.09	.19	.00	.00	.00	.00	.68	1.92	- .37	- .90	.00	.00
Interflow	.00	.00	- .19	- .19	.00	.39	.00	.00	.19	.58	-2.70	-6.74	.00	.00
Baseflow	.00	.00	.00	.00	.00	.00	(2)	(2)	-1.94	-4.85	-1.94	-5.83	-7.77	-17.48
EVAPOTRANSPIRATION:														
Interception storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-4.17	-11.59	0.00	0.00	0.00	0.00
Surface retention storage	.00	.00	.00	.00	.00	.00	.00	.00	23.37	65.67	-1.49	-2.99	.00	.00
Upper zone storage	.00	.00	.00	.00	.00	.00	.00	.00	1.81	5.14	9.67	23.87	.00	.00
Lower zone storage	- .28	- .56	.00	.00	- .28	- .28	.00	.00	1.41	4.24	9.60	24.01	.00	.00
Ground-water storage	.37	.82	- .09	- .18	.00	.00	-58.37	-78.59	.64	1.83	-2.84	-6.95	1.28	2.93
Total	.13	.25	- .03	- .09	.00	.00	-20.16	-27.12	- .60	-1.77	1.11	2.75	.47	1.01
SELECTED HYDROGRAPH COMPONENT:														
Maximum mean daily flow	0.00	0.00	0.03	0.08	0.00	0.00	1.04	1.34	0.18	0.53	-0.15	-0.23	-0.03	-0.03
Maximum mean hourly flow	.00	.00	.05	.08	.00	.03	1.03	1.36	.18	.53	- .15	- .38	.00	- .03
Annual flow	.03	.03	.03	.14	.03	.08	19.52	26.22	.58	1.60	- .75	-1.88	- .19	- .47
Flood volume	.00	.01	.02	.05	.01	.02	2.83	3.77	.20	.59	- .19	- .48	- .03	- .08

1 Model parameter value used is limiting value (1.0); therefore, effects of negative rather than positive changes are listed.
2 Value exceeds 100 percent.

typical hydrographs are shown in figures 6, 10, and 13. Appropriate parameter(s) are adjusted following guidelines given in table 8 and a second hydrograph is simulated. This procedure is repeated until simulated and observed annual hydrographs are balanced. A simulated hydrograph is balanced when it has the same overall size and shape as the observed hydrograph. Seasonal trends should be apparent with error in maximum and minimum flows averaging no more than about 50 percent; absolute error in annual runoff should not exceed 30 percent.

Parameter adjustment sequence covers establishment of threshold values for infiltration, storage, percolation, and evapotranspiration. A decrease in infiltration rate (PPIF), upper-zone storage capacity (UZSN), maximum area for surface retention storage (PSRP), percolation rate from upper- to lower-zone storage (PPUL), and increase in infiltration function shape (PSUP) will adjust the hydrograph upward, and conversely. Upper- and lower-zone storage evapotranspiration (EVP) and lower-zone storage capacity (LZSN) may require adjustment to balance hydrograph. A decrease in EVP and LZSN will tend to adjust the hydrograph upward.

The first calibration step is highly subjective and requires considerable experience with the model and understanding of flow regime being modeled. Parameter values that provide a general balance of simulated and observed annual hydrographs for both flood and base-flow periods, should also provide a reasonable match of simulated and observed annual runoff volumes.

The second and third calibration steps listed in table 8 are related conceptually, as are most steps in the calibration procedure. Acceptable parameter values that minimize error in simulated annual runoff can be determined only after separation of direct runoff and base flow has been achieved.

Objectives of the second and third calibration steps are to: (1) develop seasonal trends in the annual hydrograph, including direct runoff and base flow, and (2) minimize error in simulated annual runoff.

Direct runoff depends on surface-detention storage, or residual precipitation, not accounted for by interception, direct infiltration and surface-retention storage. Direct runoff can, therefore, be increased by decreasing maximum area for surface-retention storage (PSRP) and infiltration rate (PPIF), and increasing the infiltration function shape (PSUP). Upper-zone storage capacity (UZSN) may also require some adjustment. A decrease in UZSN will increase direct runoff.

Base flow depends on ground-water storage, and can be increased by increasing alluvial area (FALZ), and decreasing lower-zone storage capacity (LZSN). Percolation rate from upper- to lower-zone storage (PPUL) and ground-water transpiration parameter (ETGWP) may also require adjustment to establish acceptable base-flow level. An increase in PPUL and a decrease in ETGWP will increase base flow.

Observed values of direct runoff and base flow were not available for direct comparison with simulated values. Therefore, comparison of simulated and observed hydrograph segments, covering high- and low-flow periods and the absolute error in simulated monthly flows (selected months with and without precipitation) were used to establish direct runoff and base-flow trends.

The fourth calibration step involves further refinement of trends in the annual hydrograph, particularly flood periods. In the study area, interflow is a significant flow component having a significant influence on shape and timing of the annual hydrograph, particularly small to moderate floods. Interflow is derived from hillside lower-zone storage, when hillside lower-zone soil moisture exceeds lower-zone storage capacity. Interflow can be increased by increasing hillside area (FHLZ), and upper- to lower-zone storage percolation rate (PPUL). Lower-zone storage capacity (LZSN), and upper- and lower-zone storage evapotranspiration (EVP), may require additional adjustment to attain satisfactory flood hydrograph shapes. A decrease in both LZSN and EVP will increase interflow.

Observed interflow values were not available for direct comparison during calibration. Therefore, visual comparison of simulated and observed hydrograph segments covering small to moderate size floods, the average absolute error in simulated mean daily flows, and correlation coefficient of simulated and observed mean daily flows were used in the final refinement of annual hydrograph trends.

The fifth calibration step covers refinement of flood hydrograph volume and peak discharge. Two parameters significantly influence simulated flood volume and peak discharge. Volume and peak discharge increase as infiltration function shape (PSUP) increases, and as upper-zone storage capacity (UZSN) decreases. Flood volume can also be increased by decreasing percolation rate from upper- to lower-zone storage (PPUL) and increasing maximum area for surface retention storage (PSRP). Simulated and observed flood volumes and peak discharges (and time of occurrence) were matched by visual inspection of hydrograph plots.

Step-wise adjustment of remaining model parameters may be useful in improving other hydrologic aspects, such as low flows. These adjustments, however, probably will not lead to significant improvement in flood simulation capability.

Initial parameter values were refined using simulated and observed hydrographs for the 1959, 1960, 1973 and 1974 water years. Maximum daily discharge and flood volume (for selected flood events from the annual hydrographs) were given primary consideration in model calibration. The 1973 and 1974 water year hydrographs used are based on rainfall data for 11 U.S. Geological Survey rainfall stations (fig. 1). The 1959 and 1960 hydrographs are based on rainfall data for National Weather Service gages located at Tampa, St. Leo, and Lakeland (fig. 1).

The 1973 water year was relatively dry whereas the 1974 water year was near normal. The 1959 and 1960 water years were the highest flow years of record in the study area.

Calibrations were developed for six streamflow stations located in the Hillsborough, Alafia, and Anclote River basins (including principal main stem tributaries) using daily streamflow, hourly rainfall, and estimated daily evapotranspiration computed from meteorologic records available in the study area.

Configuration of basins used in the study are summarized in the following table according to number of subwatersheds, stream-channel reaches, and flow points:

River Basin	Subwatersheds	Stream Reaches	Flow points
Anclote River	1	1	1
Hillsborough River	5	5[a]	6
Alafia River	3	3	4

[a]Includes one controlled reservoir reach (reach 5).

Anclote River Basin

The Anclote River originates in Pasco County near Drexel (fig. 1) and flows in a southwesterly direction through the northwest corner of Pinellas County to the Gulf of Mexico. The basin is primarily rural in the upper and middle reaches while the lower tidal reaches have numerous large residential developments. The Anclote River estuary traverses the corporate limits of Tarpon Springs and Port Richey (fig. 1). The Anclote River has one principal tributary, South Fork Anclote River, which is basically rural.

Mean annual runoff measured at the Elfers streamflow station (site 32, fig. 1) since 1946 averages about 14.8 in. Mean basin slope is about 3.5 ft/mi. Surface depression storage (lakes and swamps) amounts to nearly 20 percent of the basin. Nearly 56 percent of the basin area has forest cover.

Part of the basin selected for the study lies above the Elfers streamflow station, and has an area of about 72.5 mi^2. The basin configuration is shown in figure 5 along with location of U.S. Geological Survey rainfall and streamflow stations used.

Basin configuration used in modeling consists of one watershed having one flow point. The watershed coincides with the basin boundary shown in figure 5 with the single flow point at the Elfers streamflow station (site 32, fig. 1). Calibrated values are summarized in table 10. Simulated and

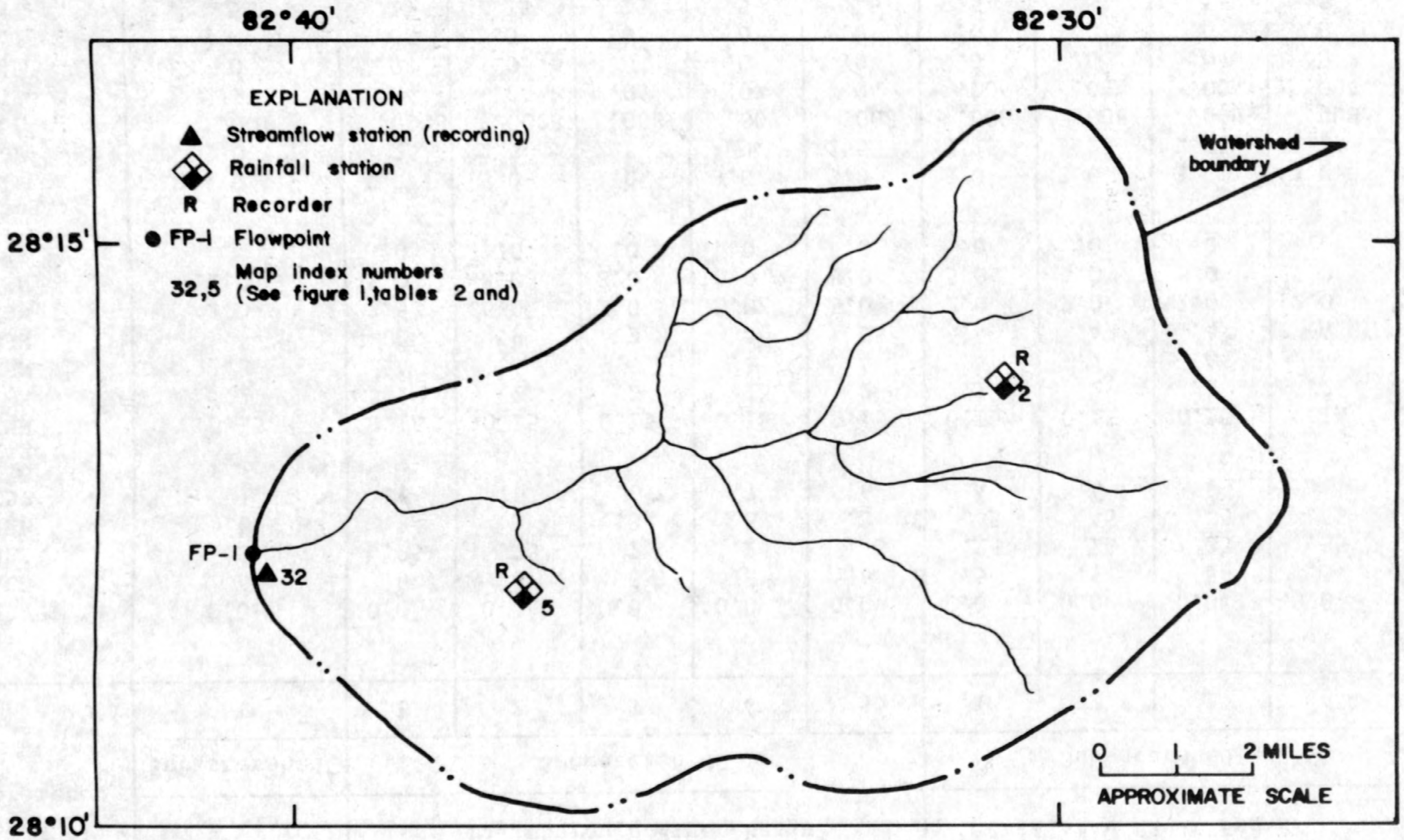


Figure 5.--Sketch map of Anclote River basin showing watershed configuration and location of rainfall and streamflow stations.

Table 10.--Summary of calibration parameter values

Model parameter	Model parameter values									
	Anclote River Basin	Hillsborough River Basin					Alafia River Basin			
	Subwatershed[1]	Subwatershed[2]					Subwatershed[3]			
	1	1	2	3	4	5	1	2	3	4
Area:										
IMPA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FALZ	.5	.6	.6	.6	.6	.6	.5	.5	.5	.5
FHLZ	.2	.25	.25	.2	.25	.25	.25	.25	.35	.35
PSRP	.6	.3	.3	.3	.5	.3	.45	.45	.45	.45
PSDP	.1	.6	.6	.6	.7	.6	.4	.4	.4	.4
Storage:										
ICMN	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
ICMX	.2	.2	.2	.2	.15	.2	.2	.2	.2	.2
SRSN	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4
SDSN	.4	.9	.9	.9	.4	.25	.4	.4	.4	.4
UZSN	3.0	3.5	5.0	5.0	3.0	5.0	2.0	2.0	2.0	2.0
LZSN	12.0	5.0	8.0	8.0	10.0	8.0	5.0	5.0	5.0	5.0
GWSF	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Drainage:										
PPIF	4.0	4.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
PSUP	3.0	3.25	2.5	2.5	.9	2.5	3.25	3.25	3.25	3.25
PPUL	.001	.0008	.0008	.008	.007	.008	.008	.008	.008	.008
PLGP	.07	.04	.04	.04	.07	.04	.004	.004	.004	.004
PDGP	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PLZU	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TTM	.5	.25	.25	.25	.5	.25	.5	.5	.5	.5
INFP	1.0	1.5	1.5	1.5	2.0	1.5	1.5	1.5	1.5	1.5
KGWF	.995	.985	.985	.985	.995	.985	.995	.995	.995	.995

Table 10.--Summary of calibration parameter values - continued

Model parameter	Model parameter values									
	Anclote River Basin	Hillsborough River Basin					Alafia River Basin			
	Subwatershed[1]	Subwatershed[2]					Subwatershed[3]			
	1	1	2	3	4	5	1	2	3	4
Evapotranspiration:										
EIP	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
EVP	.3	.25	.25	.25	.5	.25	.25	.25	.25	.25
ETGWP	.25	.1	.1	.1	.25	.1	.1	.1	.1	.1

1 Watershed configuration shown on figure 5.

2 Subwatershed configuration shown on figure 7.

3 Subwatershed configuration shown on figure 9.

observed annual streamflow hydrographs are shown in figure 6. Rainfall data used to simulate the 1974 water year hydrograph were observed at two U.S. Geological Survey stations (sites 2 and 5, figs. 1 and 5). Rainfall data for the St. Leo National Weather Service rainfall station (site 13, fig. 1), more than 25 mi from the center of the basin, were used to simulate the 1959 water year and 1960 water year streamflow hydrographs.

The Anclote River calibration was used to evaluate sensitivity of model parameters. Calibrated values were increased by 10 and 25 percent and the resulting percent change in various model and hydrograph components was determined. Percent changes were determined individually for each increase in each calibrated value. Model components evaluated include storage, infiltration, percolation, streamflow, and evapotranspiration. Hydrograph components evaluated include maximum mean daily and mean hourly flows, annual flow, and flood volume. Results of the analysis are summarized in table 9. Use of the data is described in a preceeding report section entitled "Calibration Procedure". The analysis is based on streamflow, evapotranspiration and rainfall data for the 1960 water year. Rainfall data used were observed at the St. Leo rainfall station (site 13, fig. 1).

Data listed in table 9 apply, in a general way, to other basins discussed in following sections of this report. These basins have multiple subwatersheds, whereas, the Anclote River has only one. In addition, calibrated values for the Anclote River and other basins studied differ, and therefore, results would not be expected to apply exactly.

Hillsborough River Basin

The upper Hillsborough River basin is generally rural consisting of open and wooded upland areas and numerous low-lying swampy areas. Development is primarily agricultural, although several phosphate mining complexes are located in the area.

A flood-control structure (overflow channel) connects the Withlacoochee and Hillsborough Rivers (fig. 1). During high-flow periods, flood water is diverted from the Withlacoochee River to the Hillsborough River. An analysis of streamflow records collected at the overflow channel (site 31, fig. 1) indicate that the effect of this diversion on the Hillsborough River is insignificant during most flood periods. Base flow of the Hillsborough River is sustained by discharge from Crystal Springs located northeast of the Hillsborough River State Park (fig. 1).

In the lower basin, the Hillsborough River flows through large urban areas of Temple Terrace, including Tampa Reservoir, and continues south through dense residential areas of north Tampa to its mouth in Hillsborough Bay. Tampa Reservoir is the City of Tampa's municipal water supply. Maximum reservoir storage is about 2,300 acre-ft.

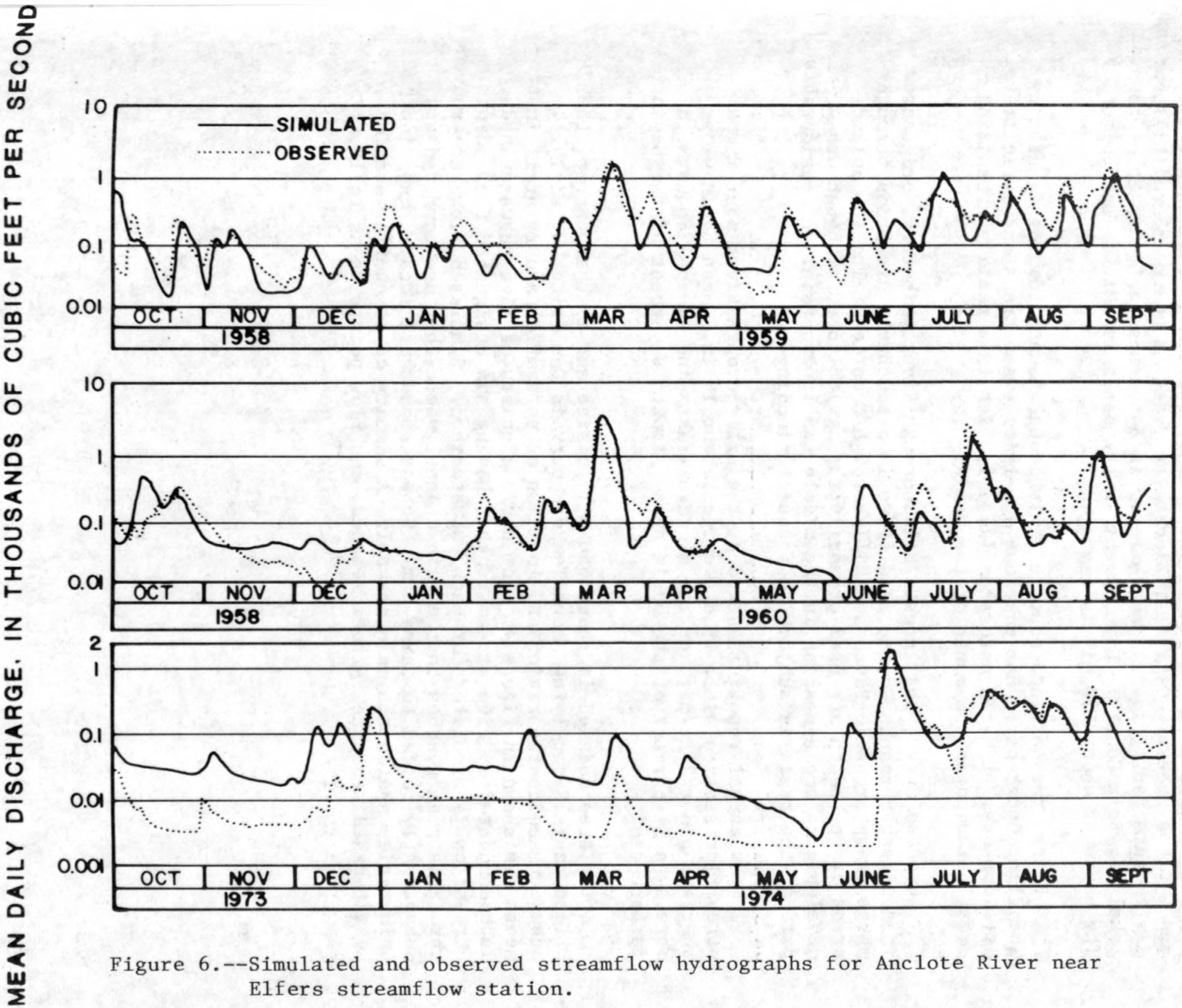


Figure 6.--Simulated and observed streamflow hydrographs for Anclote River near Elfers streamflow station.

The Hillsborough River has three major tributaries, Blackwater, Flint, and Cypress Creeks. Of these, Blackwater Creek is upstream from Hillsborough River State Park (fig. 1), and extends in a southeasterly direction towards Lakeland, Polk County. Development in the basin is chiefly agricultural. The basin is about 120 mi^2 in size.

Flint Creek extends east in Hillsborough County towards Plant City. The Flint Creek basin has numerous low-lying swamp areas and agricultural developments. Lake Thonotosassa (fig. 1) lies in a rapidly urbanizing area located near the mouth of the basin.

Cypress Creek, the largest Hillsborough River tributary, originates in southern Hernando County, and flows in a southerly direction through large swamp areas in Pasco and Hillsborough Counties. The few upland areas of the basin are used primarily for agriculture, although urban developments are appearing in the middle and lower basin. A considerable part of the basin is subject to frequent flooding.

Mean annual runoff measured at the Hillsborough River near Tampa streamflow station since 1938 averages about 13 in. Mean basin slope averages about 2 ft/mi; surface storage (lakes and swamps) amounts to more than 17 percent of the basin area. About 16 percent of the basin is forested.

The area modeled is about 650 mi^2 in size and is that part of the Hillsborough River lying above Tampa Reservoir Dam (site 23, fig. 1). Subwatershed configuration and location of streamflow and rainfall instruments are shown in figure 7. The basin consists of five subwatersheds, interconnected by five stream reaches having six designated flow points. Streamflow is simulated for each subwatershed. Simulated flows are routed through stream reaches to the main channel where they are combined and subsequently routed to Tampa Dam. Subwatersheds are located on principal tributaries and on the main channel. A summary of streamflow stations, subwatershed sequence, stream reaches, and flow points is as follows:

Site no.[1]	Streamflow station	Subwatershed information			
		Description	Area (mi^2)	Flow point	Sequence
29	Hillsborough River near Zephyrhills	Upper Hillsborough River (including Blackwater Creek)	220	1	1
28	Hillsborough River at Morris Bridge Road near Thonotosassa	Intervening area (including New River and Flint Creek)	155	2	2
	(Hillsborough River above Cypress Creek)	Intervening area (including Trout Creek)	55	4	3
25	Cypress Creek near Sulphur Springs	Cypress Creek	160	3	4
24	Hillsborough River at Fowler Avenue near Tampa	Intervening area (including Hillsborough River below Cypress Creek to Fowler Avenue)	60	5	5
23	Hillsborough River near Tampa (at Tampa Dam)	Intervening area (including Hillsborough River below Fowler Avenue to Tampa Dam)	20[2]	6	-

[1]Refers to site numbers shown in figures 1 and 7 and listed in tables 2 and 3.

[2]Intervening area included in subwatershed 5 to simplify computations.

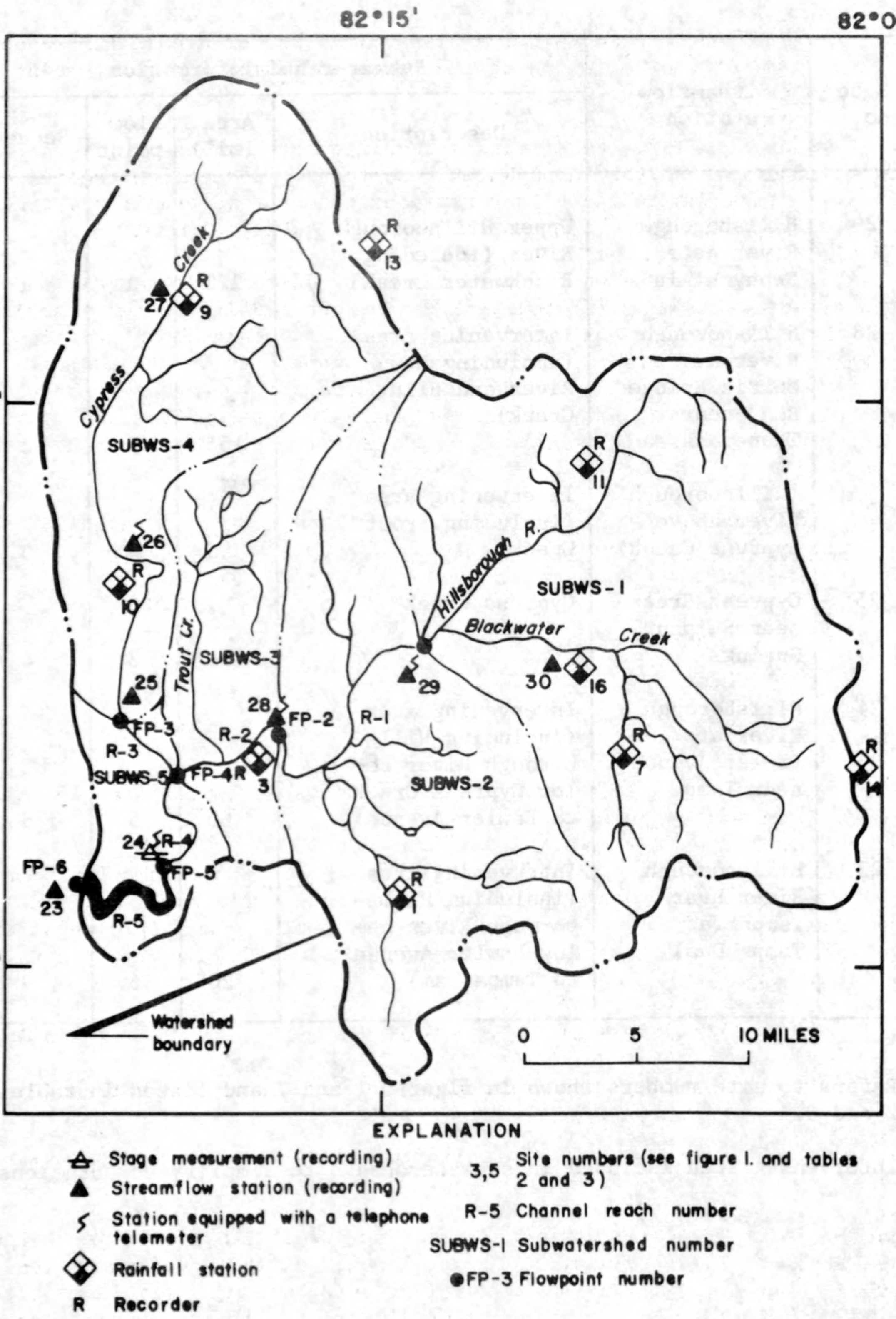


Figure 7.--Sketch map of Hillsborough River basin showing sub-watershed configuration and location of rainfall and streamflow stations.

Stream reach 5 includes Tampa Reservoir. Fowler Avenue (flow-point 5, fig. 7) is at the beginning of the reach and Tampa Dam (flow-point 6) is at the end.

Outflow from Tampa Reservoir is regulated by changes in gate settings made by employees of the Tampa Water Department. Streamflow records collected at Tampa Dam indicate that releases from the reservoir are erratic and as such are subject to a random (nonpredictable) element.

The effect of reservoir regulation on flood-peak discharges was evaluated by analyzing annual flood-peak discharges (1961-74 water years) available for Fowler Avenue and Tampa Dam. These peaks are shown graphically in figure 8. A second order regression curve was fitted to these data. This relation has a correlation coefficient of 0.98 and an average standard error of about 12.7 percent. Inflow and outflow values taken from this curve were used in calculating percent reduction in selected peak inflows and are listed as follows:

Peak inflow (mean daily discharge) cubic feet per second	Reduction in annual peak discharge, percent
1,800	44.0
2,000	38.0
3,000	23.0
4,000	16.0

These data indicate that small peak inflows are significantly attenuated by reservoir regulation.

Reservoir routing was used to minimize simulation errors for flood-peak discharges less than 4,000 ft^3/s. Streamflow records available for Tampa Dam and Fowler Avenue were used in developing a multiple relation used for calculating controlled reservoir outflow, OUT, given by equation 34, as follows:

$$OUT(I) = 3800 - 216.9\ EL + 0.95\ FIN(NR,I-1) \qquad (34)$$

where EL = Current reservoir stage, at Tampa Dam, in feet above sea level;

FIN(NR,I-1) = Preceding reservoir inflow (at Fowler Avenue), cubic feet per second.

Equation 34 is generally applicable when reservoir stage, EL, is in the range 16.00 to 23.00 ft above mean sea level, and when outflow is less than 25,900 ft^3/s. Equation 34 has a multiple correlation coefficient of 0.98 and average standard error estimate of 350 ft^3/s. The reservoir assumes free-fall conditions when routed outflow exceeds free-fall rating discharge. Free-fall rating discharge is computed by use of equation 35, as follows:

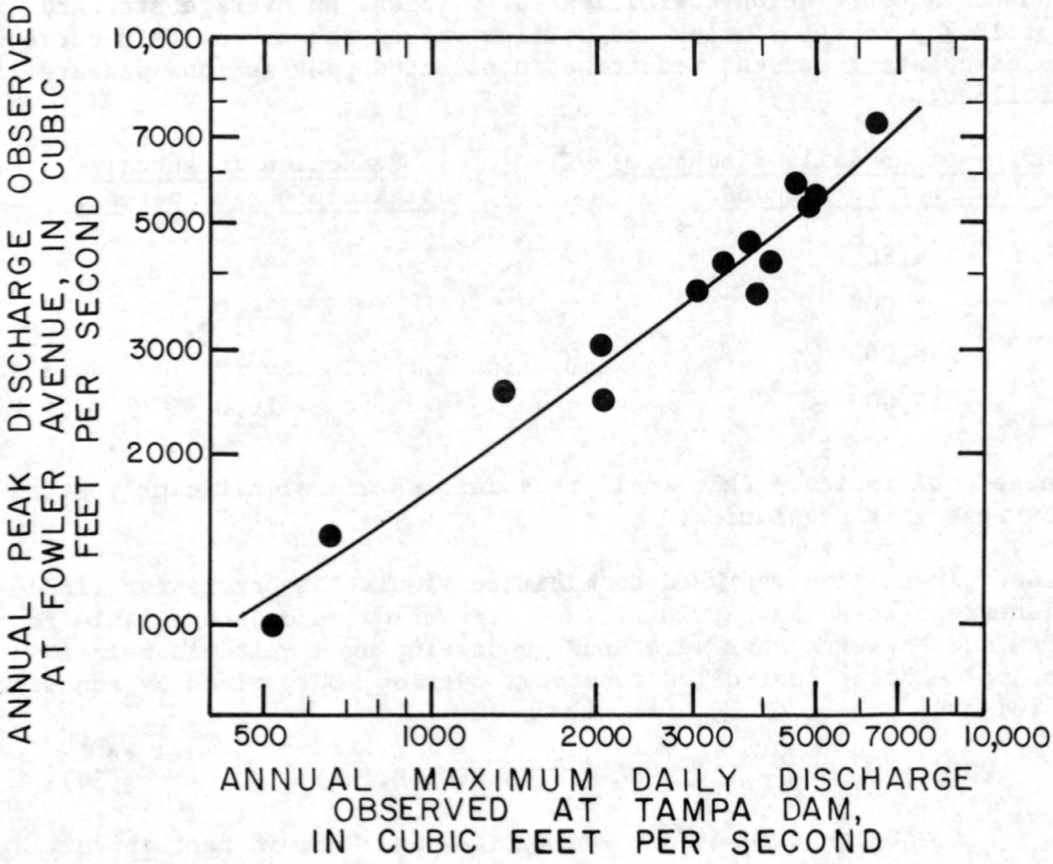


Figure 8.--Annual flood-peak discharges for Hillsborough River at Fowler Avenue and Tampa Dam.

$$TEST = -83,398.72 + 18,466.22 [EL] - 1,355.11 [EL]^2 + 33.28 [EL]^3 \quad (35)$$

where EL = Reservoir stage at Tampa Dam, in feet above sea level.

Equation 35 has a correlation coefficient of 0.99 and average standard error of estimate of 535 ft^3/s. For reservoir stages below 16.00 ft, outflow assumes a constant value of 4 ft^3/s.

The model was calibrated for the entire basin lying above Tampa Dam. Subwatersheds 1 and 4 were calibrated independently. Parameter values for subwatersheds 2, 3, and 5 were adjusted as required to achieve calibration for the entire basin.

Simulated and observed annual streamflow hydrographs for Hillsborough River near Zephyrhills streamflow station (site 29, figs. 1 and 7) are shown in figure 9. Rainfall records for two U.S. Geological Survey rainfall stations in the basin (sites 7 and 11, figs. 1 and 7) were used to simulate the 1974 water year hydrograph. Rainfall records for two National Weather Service rainfall stations, St. Leo and Lakeland (sites 13 and 14, figs. 1 and 7) were used to simulate the 1959 water year and 1960 water year streamflow hydrographs.

Rainfall records for six U.S. Geological Survey rainfall stations (sites 1, 3, 7, 9, 10, and 11; figs. 1 and 7) were used to simulate the 1974 water year streamflow hydrograph shown in figure 10 for the Tampa station. Rainfall records for St. Leo and Lakeland were used to simulate the 1959 water year and 1960 water year streamflow hydrographs.

The 1974 hydrograph covers moderate size floods and the 1960 hydrographs cover several of the highest floods of record.

Model parameter values determined for each subbasin are listed in table 10.

Alafia River Basin

The Alafia River basin lies adjacent to and south of the Hillsborough River basin (fig. 1). The Alafia River has three principal main stem tributaries including the North Prong, which originates near Lakeland in Polk County, the South Prong, which originates near Bradley Junction in Polk County, and Turkey Creek which originates near Plant City, Hillsborough County. Pleasant Grove Reservoir is located on lower Turkey Creek in Hillsborough County, several miles below State Highway 60 (fig. 1). The Alafia River flows westerly from its headwaters in Polk County through south-central Hillsborough County to its mouth in Hillsborough Bay.

Mean annual runoff measured at the Alafia River at Lithia streamflow station (site 33, figs. 1 and 11) since 1932 averages 15.3 in. Mean basin

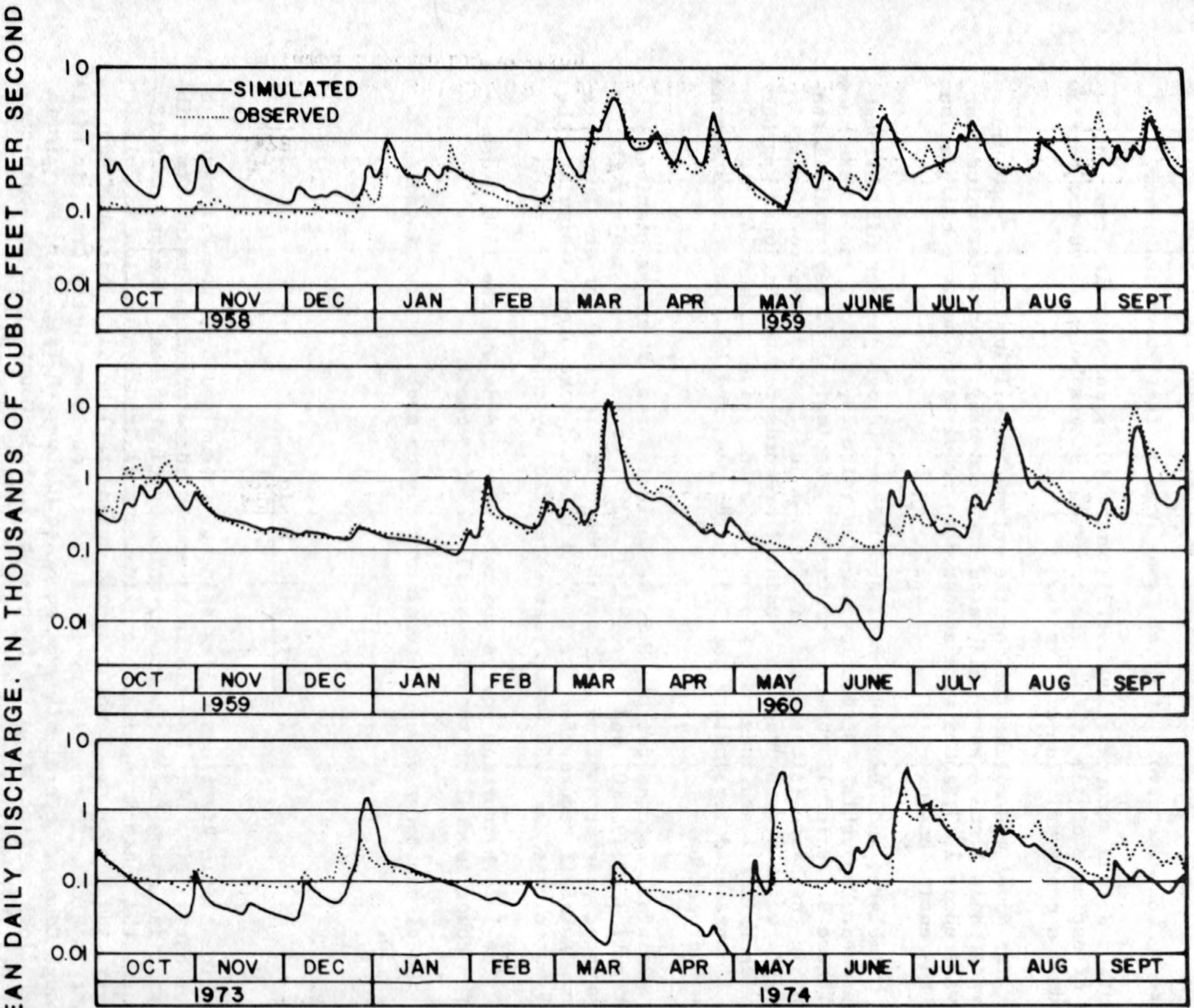


Figure 9.--Simulated and observed streamflow hydrographs for Hillsborough River near Zephyrhills streamflow station.

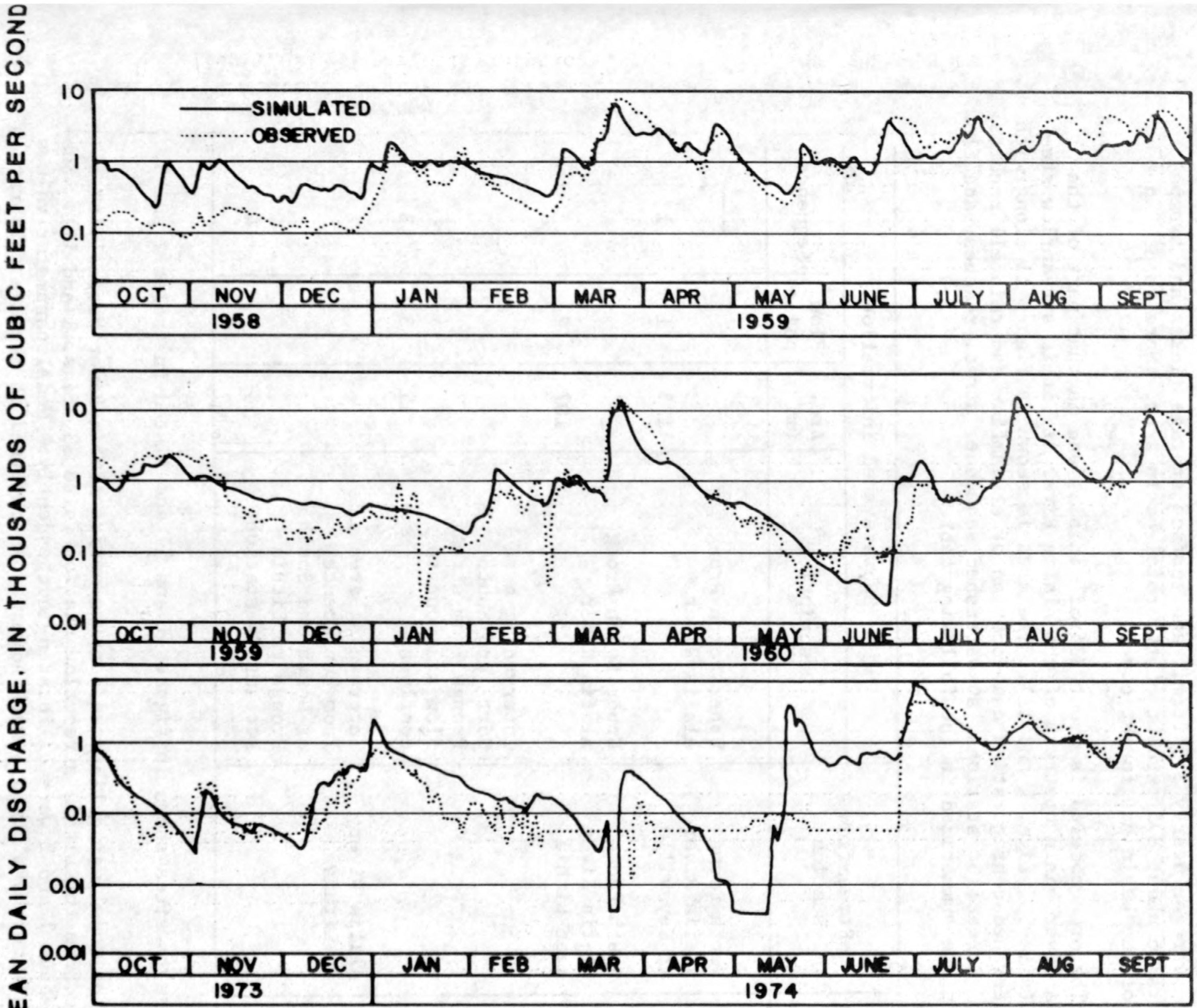


Figure 10.--Simulated and observed streamflow hydrographs for Hillsborough River near Tampa streamflow station.

slope averages nearly 3.5 ft/mi, and surface storage (lakes and swamps) amounts to about 8.5 percent of the total basin area. More than 12 percent of the basin has forest cover.

The area modeled is about 335 mi^2 in size and is that part of the Alafia River basin upstream of the Alafia River at Lithia streamflow station (site 33, figs. 1 and 11). The area is shown in figure 11 along with subwatershed configuration and location of streamflow and rainfall records used. Streamflow stations, subwatershed sequence, stream reaches, and flow points are summarized in the following table:

Site no.[1]	Streamflow station	Subwatershed information			
		Description	Area (mi^2)	Flow point	Sequence
34	North Prong Alafia River at Keysville	Upper North Prong Alafia River	135	1	1
35	South Prong Alafia River near Lithia	Upper South Prong Alafia River	107	2	2
--	---	Intervening area North and South Prongs from streamflow stations to confluence	35	3	3
33	Alafia River at Lithia	Intervening area from confluence of North and South Prongs to Lithia streamflow station	58	4	4

[1]Refers to sites shown in figures 1 and 11 and listed in tables 2 and 3.

The model was calibrated for the entire Alafia River basin lying upstream from the Lithia streamflow station (site 33, figs. 1 and 11). Subwatersheds 1 and 2 were calibrated independently. Model parameter values for subwatersheds 3 and 4 were adjusted as required to achieve calibration for the entire basin.

Simulated and observed annual streamflow hydrographs for the North Prong Alafia River at Keysville and Alafia River at Lithia streamflow stations (sites 34 and 33, figs. 1 and 11) are shown in figures 12 and 13,

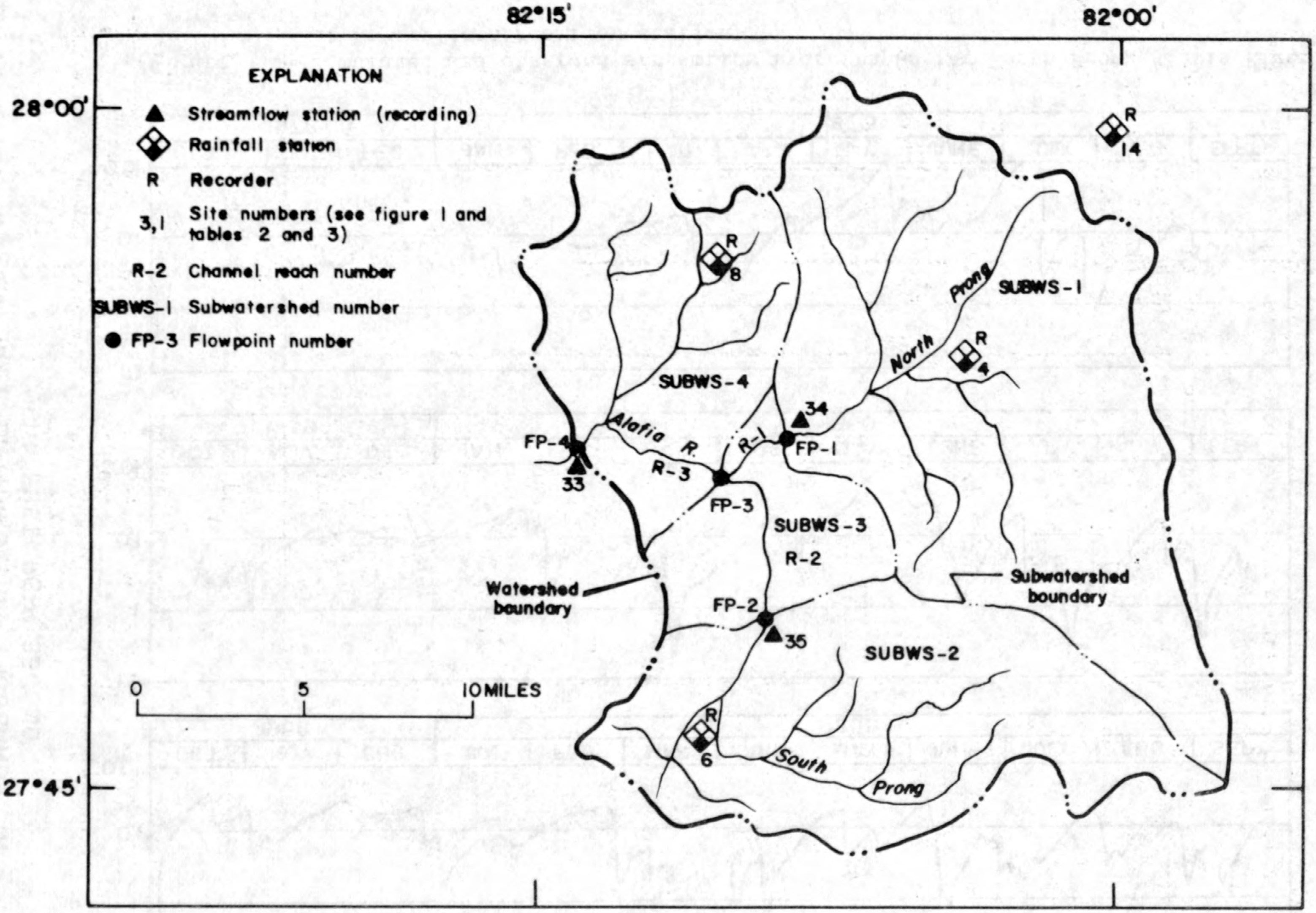


Figure 11.--Sketch map of Alafia River basin showing subwatershed configuration and location of rainfall and streamflow stations.

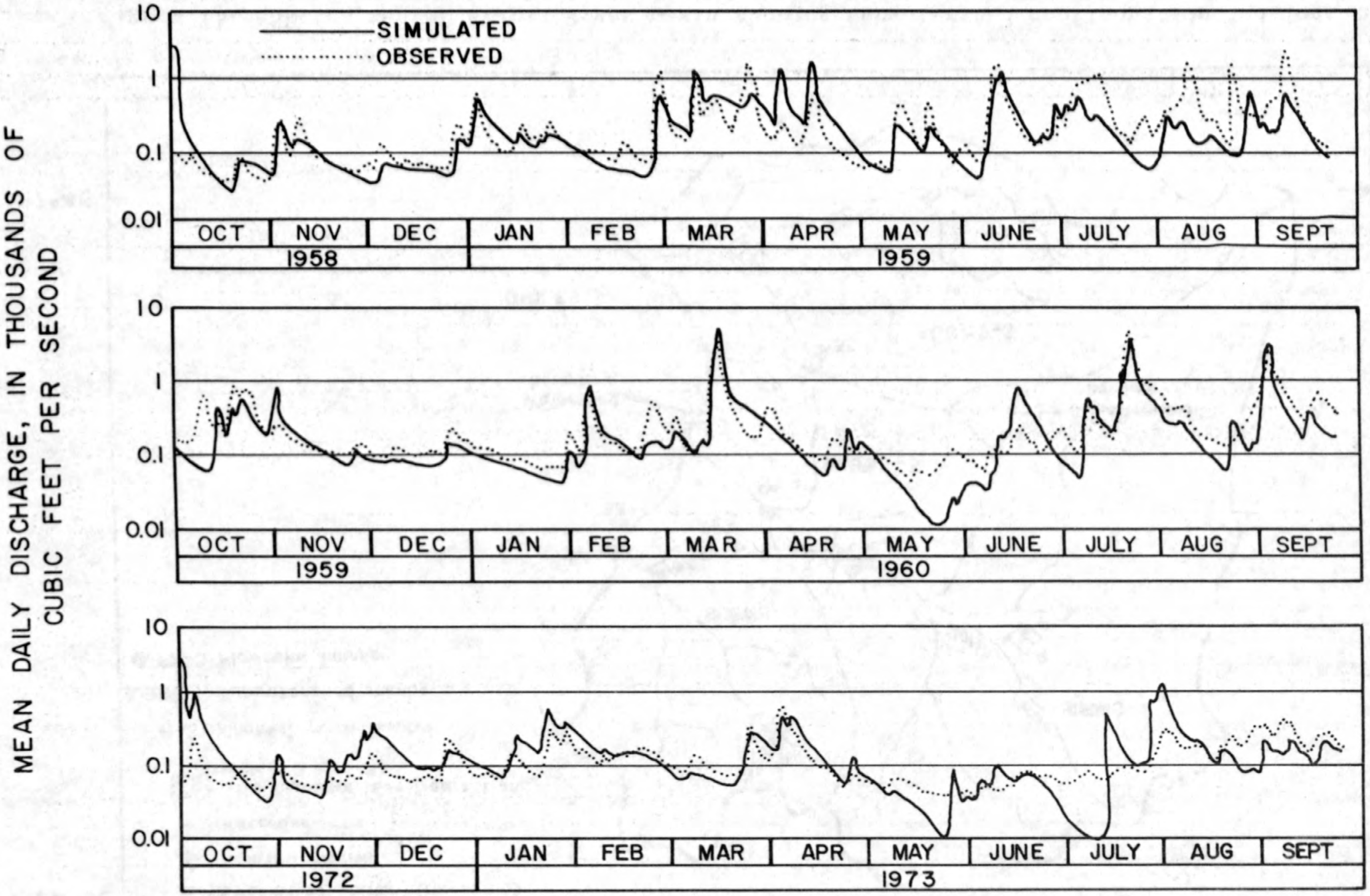


Figure 12.--Simulated and observed streamflow hydrographs for North Prong Alafia River at Keysville streamflow station.

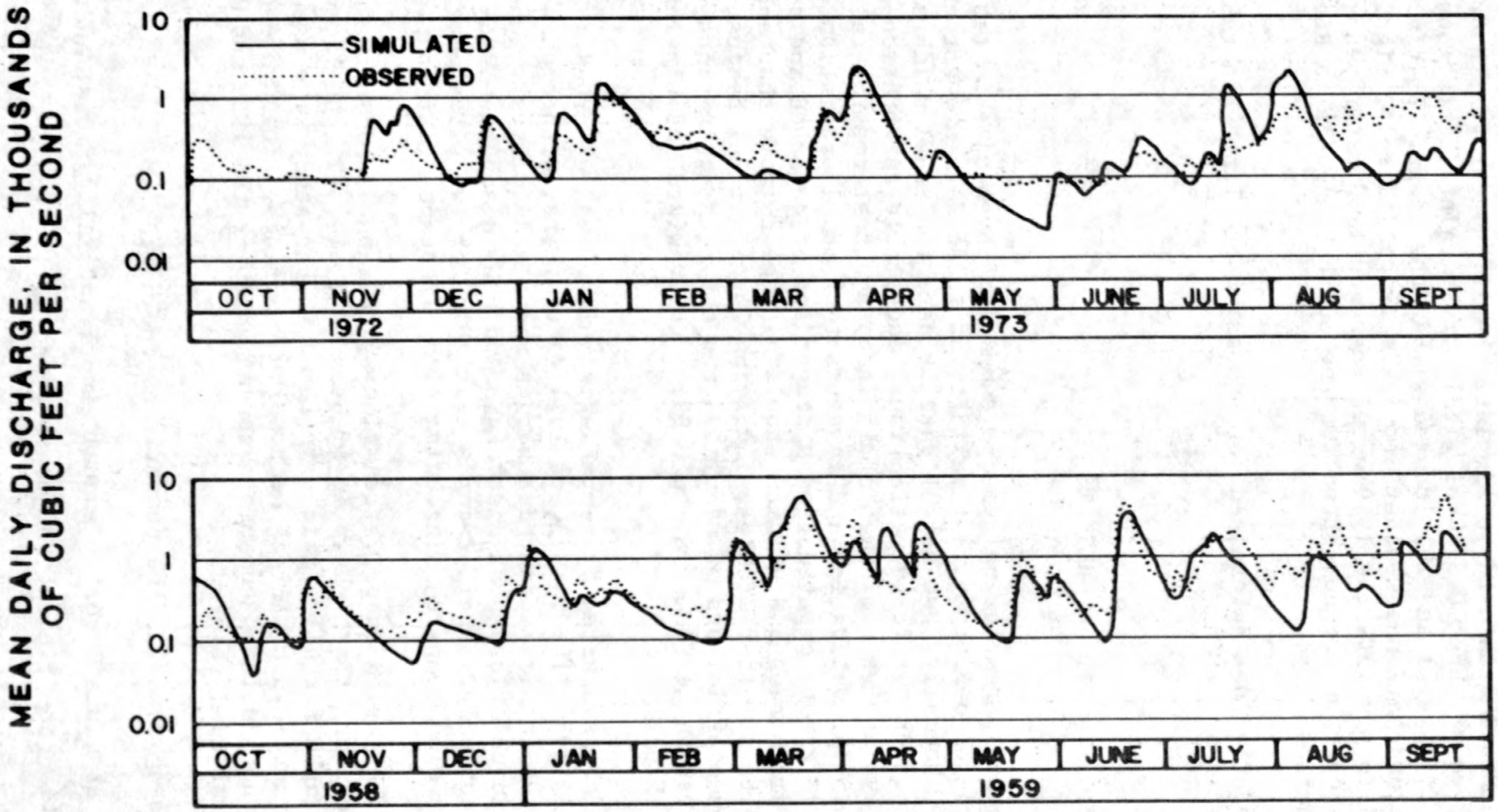


Figure 13.--Simulated and observed streamflow hydrographs for the Alafia River at Lithia streamflow station.

respectively. Rainfall data used to simulate the 1973 water year hydrographs were observed at three U.S. Geological Survey rainfall stations (sites 4, 6, and 8, figs. 1 and 11) located within the basin. Rainfall data for the Lakeland National Weather Service station (site 14, figs. 1 and 11) were used to simulate the 1959 water year and 1960 water year hydrographs. Hydrographs are not shown for the South Prong Alafia River near Lithia streamflow station.

Model parameter values determined for subbasins are listed in table 10.

RESULTS

Calibrated model parameter values are summarized by basins in table 10. Data required to completely test validity of these data are not currently available. Normally, one set of data is used for model calibration and testing and another set for verification. Acceptable calibration criteria would ideally involve a minimum of 15 independent storms for calibration and another 15 for validation and assessment of model prediction error. Acceptable standard error computed from a comparison of observed and synthesized flood-peak discharges and volumes should average no more than about 35 percent. Results of other studies, involving large natural basins, indicate correlation coefficients of simulated and observed daily flows, for the water year, that range from 0.82 to 0.99. See Crawford and Linsley (1966) and Lumb (1976).

Calibrations are evaluated by comparing simulated and observed annual hydrographs for the 1959, 1960, 1973 and 1974 water years, with emphasis on flood hydrographs (maximum daily discharges and flood volumes). Observed long-term annual flood-peak discharges and peak discharges synthesized from historical rainfall records available for two sites outside the study area are also compared, including flood-frequency distributions.

Simulated and observed annual streamflow hydrographs used in the calibration study, including those shown in figures 6, 9, 10, 12, and 13, were compared. Hydrographs for all stations included in the study were used in the comparison, except Cypress Creek near Sulphur Springs. The Cypress Creek station was not included because observed data for the 1959 and 1960 water years were not available.

Statistics used in making the comparisons include:

(1) Average absolute error in annual runoff and daily flows; and,

(2) Correlation coefficient for monthly and daily flows.

Statistical values determined for annual hydrographs were averaged for each station, using all years, and then excluding the worst year (1973).

Results of the analysis, summarized below, includes the range of average values determined for the stations:

Water years	Range in station statistics			
	Average absolute error, percent		Correlation coefficient	
	Annual runoff	Daily flow	Monthly flow	Daily flow
1959, 1960, 1973, and 1974	8-67	56-90	0.62-0.80	0.56-0.77
1959, 1960, and 1974	9-21	48-71	0.81-0.95	0.68-0.87

Flood events used for calibration average about 12 per basin. Calibration data (maximum daily discharges and flood volumes) are shown as plots in figures 14, 15, 16, 17, 18, and 19 for each basin. These data were evaluated by regression analyses. Results of the statistical evaluation summarized in table 11 indicate that (1) standard errors of estimate range from 26 to 45 percent (maximum daily discharges) and 18 to 40 percent (flood volumes); and (2) correlation coefficients range from 0.91 to 0.98 (maximum daily discharges) and 0.93 to 0.98 (flood volumes). Correlation coefficients (maximum daily discharges and flood volumes) were tested and found to be significantly different from 0.0 at the 5 percent probability level (that is, the implied statistical relation between observed and simulated data have a 5 percent chance of being spurious).

Regression constants and coefficients (constant terms and slopes of the linear regression equations of the data shown as plots in figures 14, 15, 16, 17, 18, and 19) were also tested for significance. Constants were not significantly different from zero and slopes were not significantly different from unity, at the 5 percent probability level (that is, there is only a 5 percent chance that simulated maximum daily discharges and flood volumes are biased).

Historical rainfall data available for St. Leo and Lakeland (fig. 1) were used in making long-term simulations (1950-72) for the calibrated basins. Simulated and observed data were compared to determine annual floods that occurred simultaneously. Maximum daily discharges and flood volumes for concurrent annual floods were added (as x's) to the calibration plots shown in figures 14, 15, 16, 17, 18, and 19. These data were regressed with calibration data. Results are summarized in table 12. Additional data points increase the number of flood events to about 18 per station, excluding Cypress Creek near Sulphur Springs. A comparison of regression analysis results for calibration data (table 11) and extended data (table 12) indicates that results of both analyses are virtually identical, thereby strengthening calibration results.

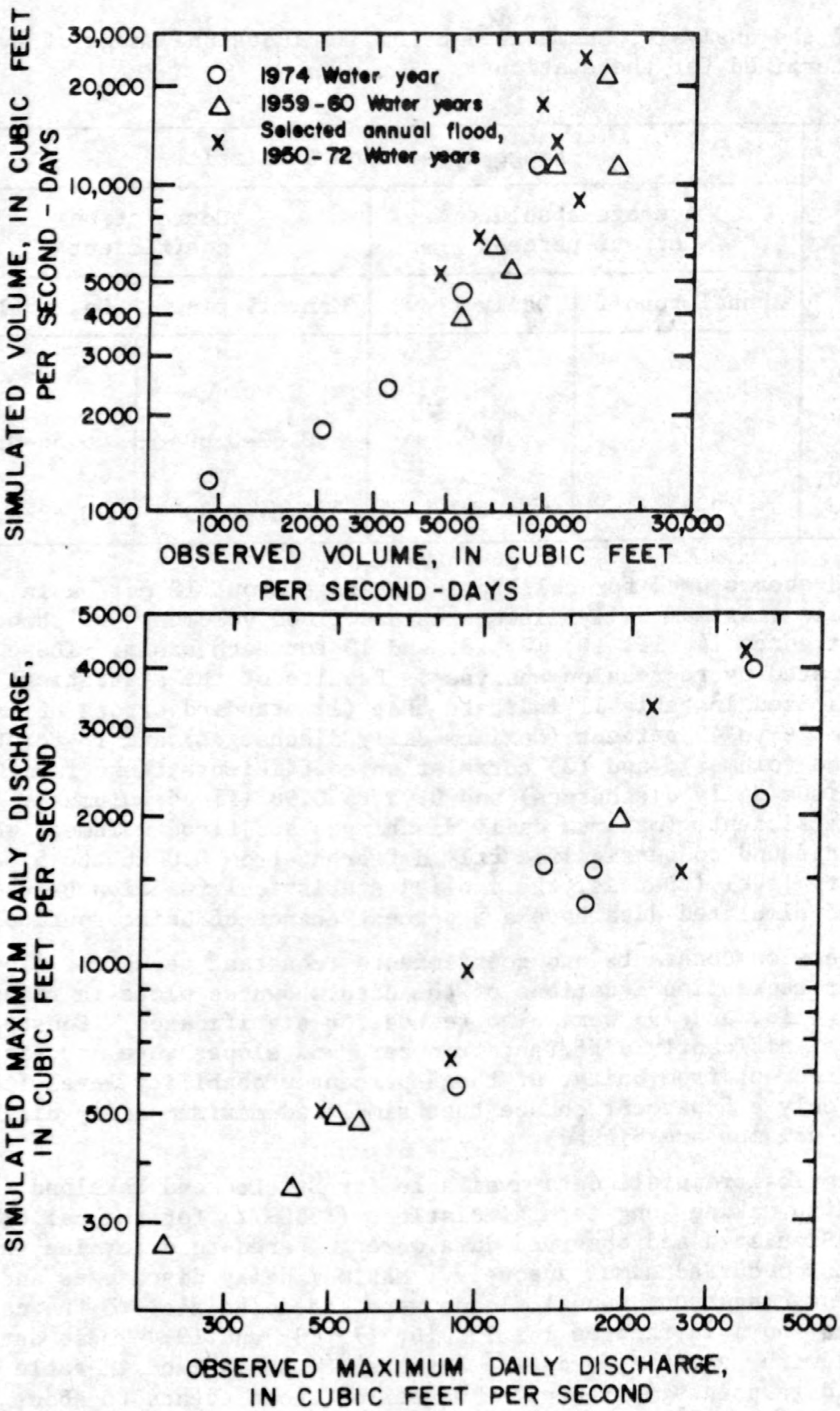
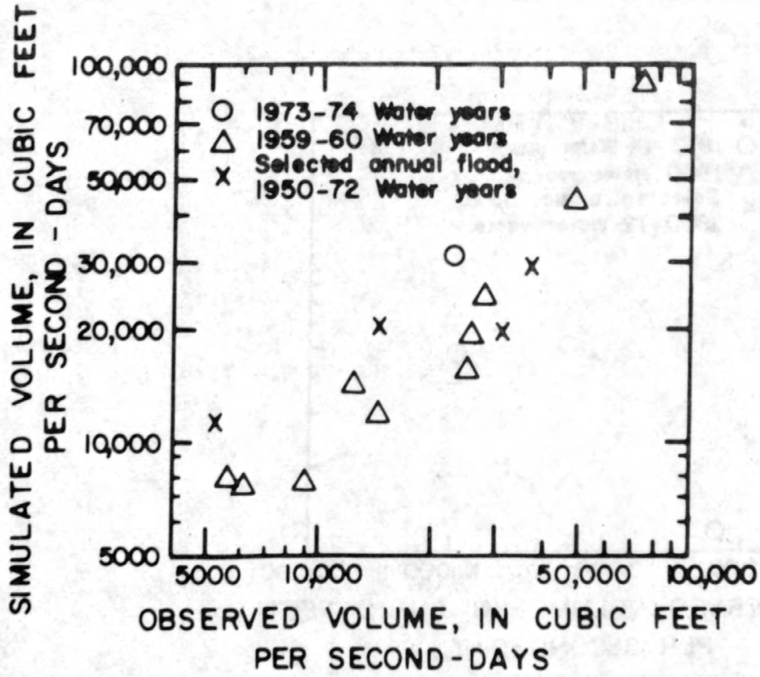


Figure 14.--Simulated and observed flood volumes and maximum daily discharges used for calibration - Anclote River near Elfers streamflow station.



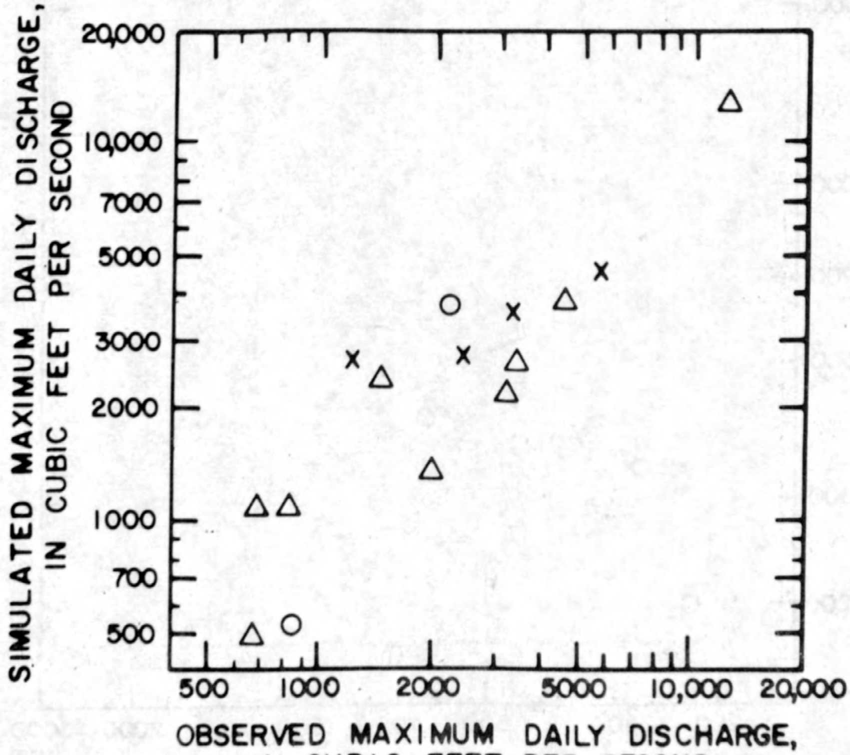


Figure 15.--Simulated and observed flood volumes and maximum daily discharges used for calibration - Hillsborough River near Zephyrhills streamflow station.

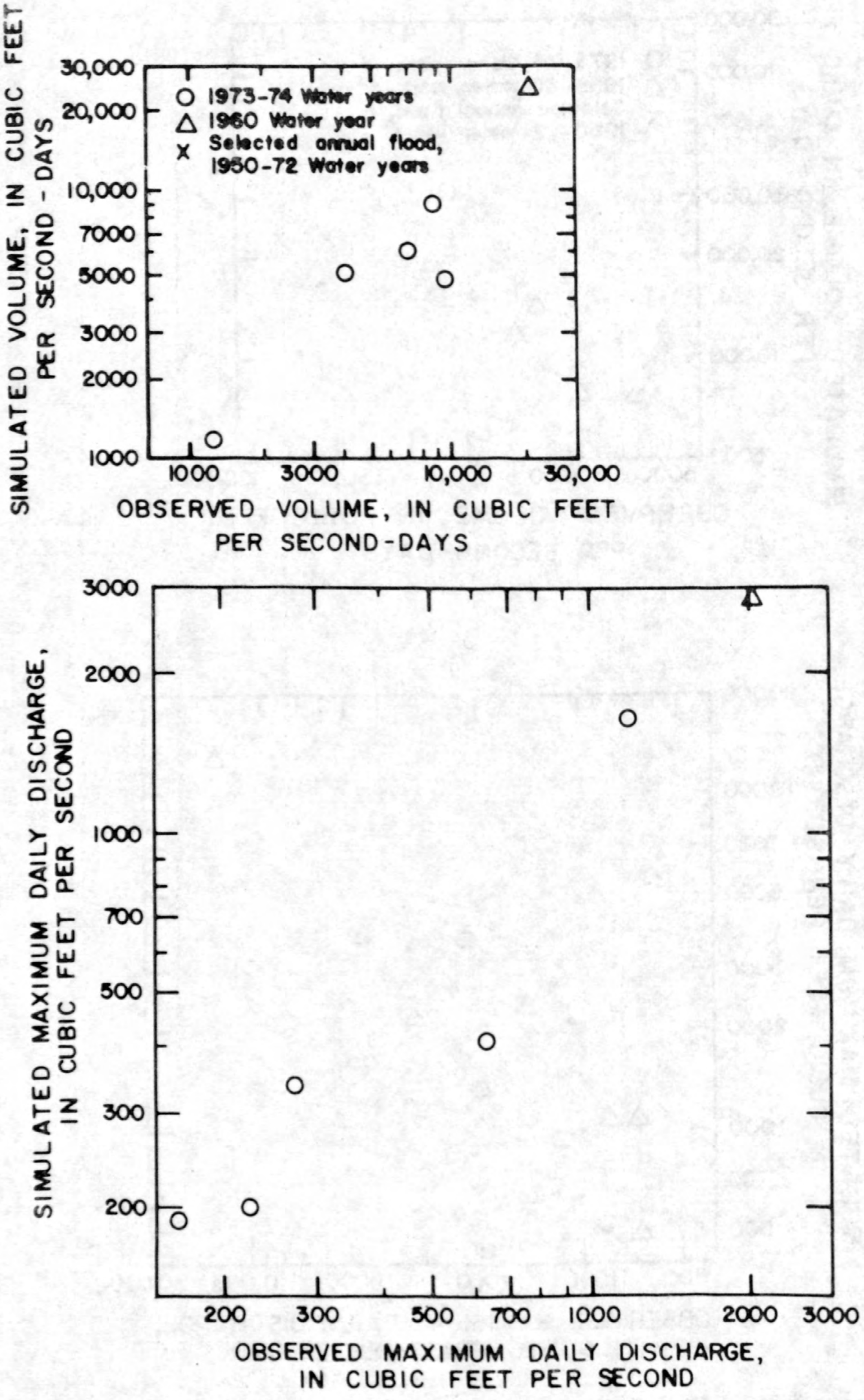


Figure 16.--Simulated and observed flood volumes and maximum daily discharges used for calibration - Cypress Creek near Sulphur Springs streamflow station.

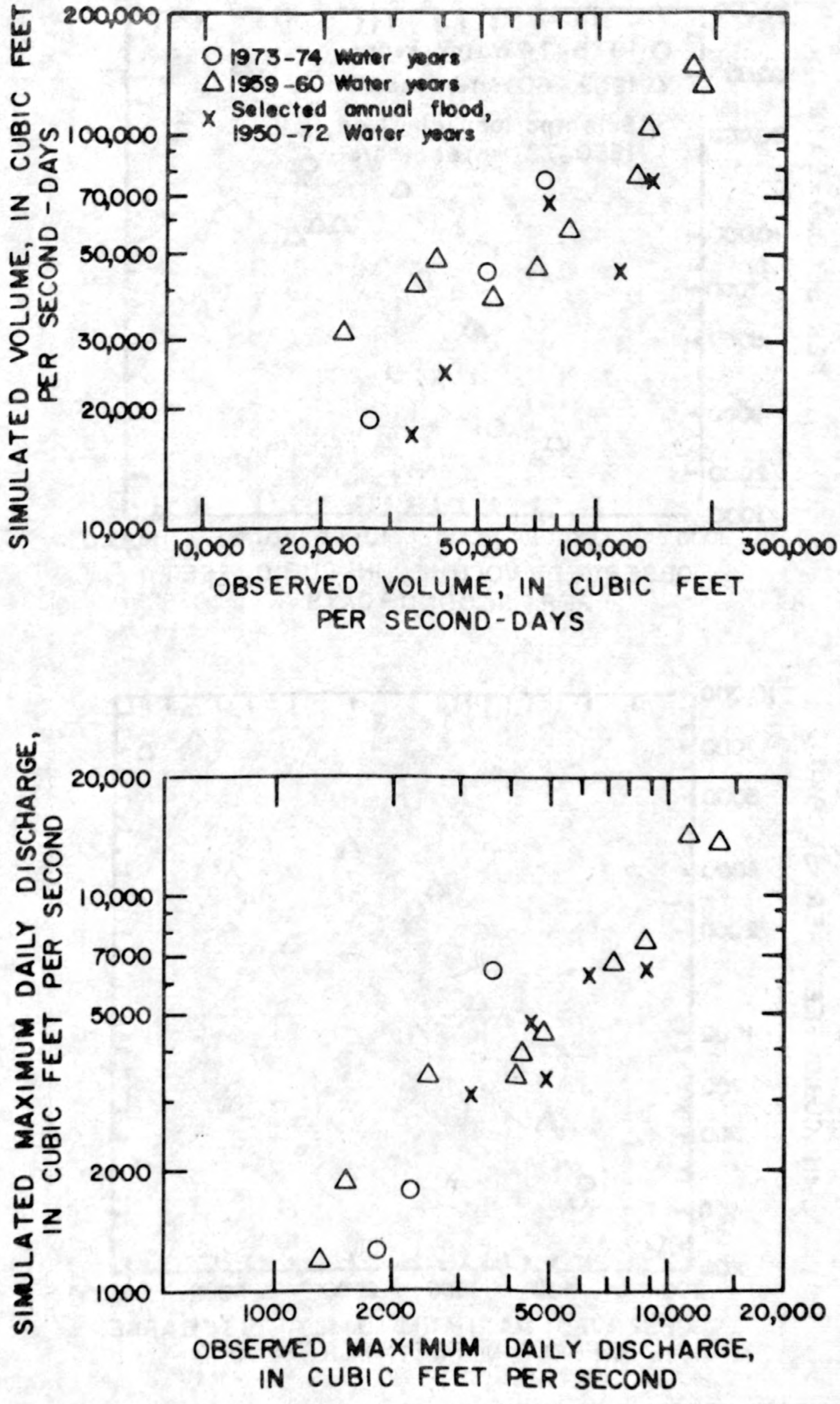


Figure 17.--Simulated and observed flood volumes and maximum daily discharges used for calibration - Hillsborough River near Tampa streamflow station.

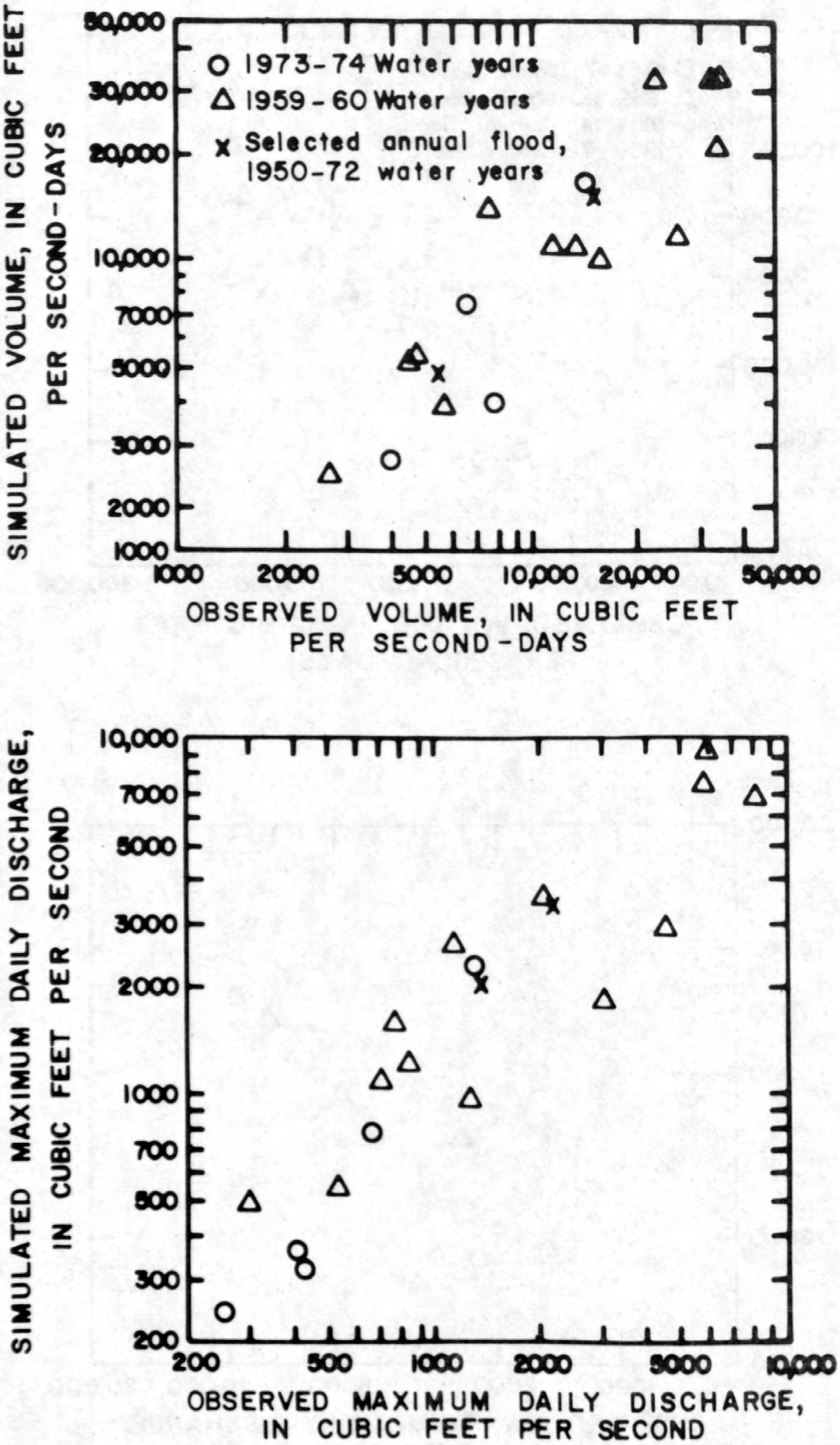


Figure 18.--Simulated and observed flood volumes and maximum daily discharges used for calibration - North Prong Alafia River at Keysville streamflow station.

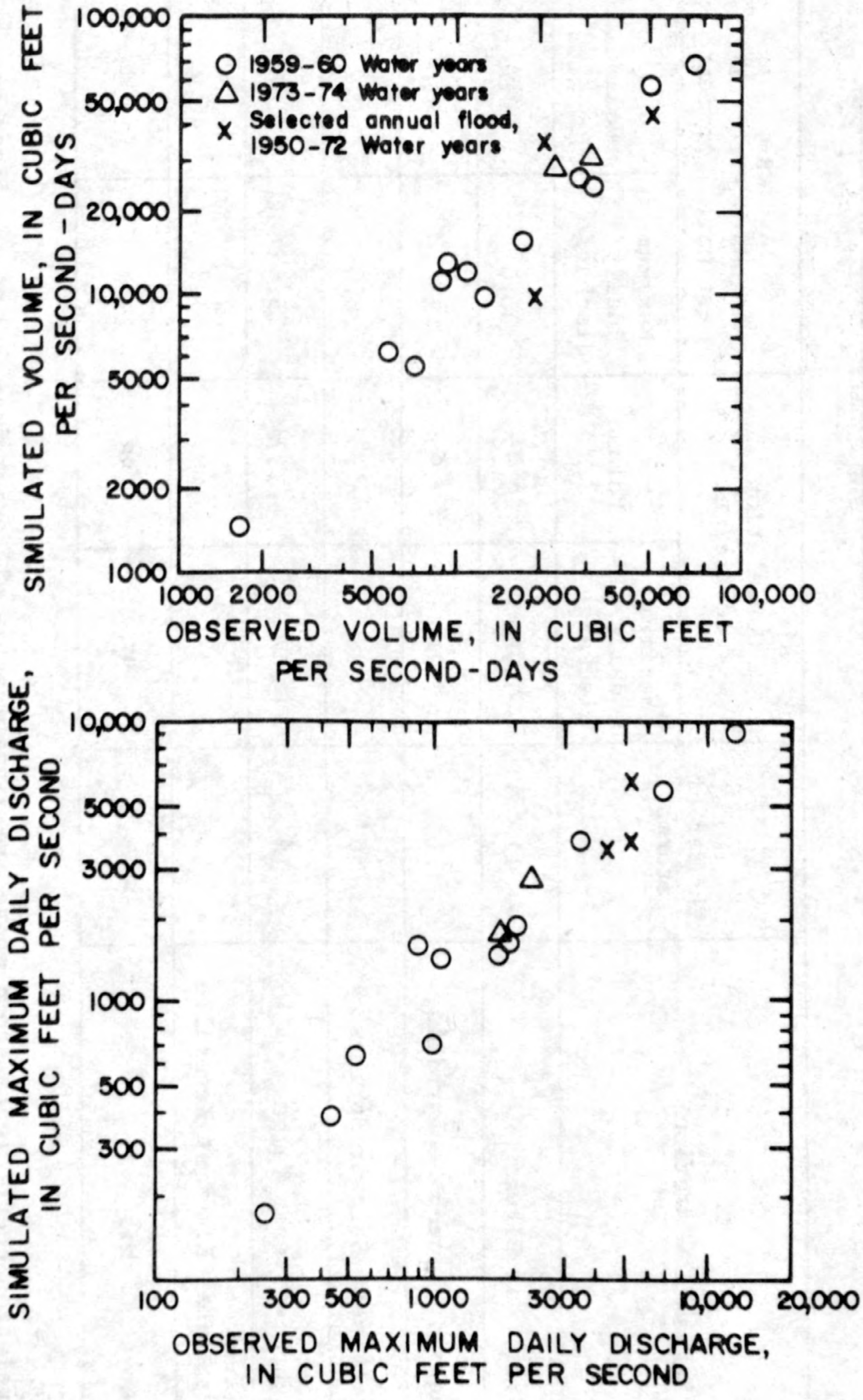


Figure 19.--Simulated and observed flood volumes and maximum daily discharges used for calibration - Alafia River at Lithia streamflow station.

Table 11.--Comparative statistics of observed and simulated flood data used for calibration

Streamflow station	Number of storms	Correlation coefficient[1]		Average standard error of estimate[2], percent	
		Maximum daily discharge	Volume	Maximum daily discharge	Volume
Anclote River near Elfers	11	0.96	0.95	30.0	30.0
Hillsborough River near Zephyrhills	11	.91	.95	42.6	28.0
Cypress Creek near Sulphur Springs	6	.98	.93	28.0	40.2
Hillsborough River near Tampa	14	.97	.97	25.6	32.8
North Prong Alafia River at Keysville	18	.93	.93	45.2	40.2
Alafia River at Lithia	14	.97	.98	28.0	18.5

1 All correlation coefficients shown above are significantly different from 0.0 at the 5 percent level.

2 Computed as standard deviation of residual error about a linear relation line having slope at 1.0 and constant term of 0.0.

Table 12.--Comparative statistics of observed and simulated flood data used for calibration and selected annual floods from long-term simulation

Streamflow station	Number of storms	Correlation coefficient[1]		Average standard error of estimate[2], percent	
		Maximum daily discharge	Volume	Maximum daily discharge	Volume
Anclote River near Elfers	17	0.95	0.92	30	35
Hillsborough River near Zephyrhills	15	.89	.91	43	35
Hillsborough River near Tampa	19	.97	.95	26	45
North Prong Alafia River at Keysville	20	.93	.93	45	38
Alafia River at Lithia	17	.97	.96	28	28

1 All correlation coefficients shown are significantly different from 0.0 at the 5 percent probability level.

2 Computed as standard deviation of residual error about a linear relation line having a slope of 1.0 and a constant term of 0.0.

Observed and simulated annual flood-peak discharges for each basin were also evaluated by regression analyses. Results of these analyses are summarized in table 13. Correlation coefficients range from 0.60 to 0.74 and average standard errors of estimate range from 33 to 44 percent. Significance tests indicate that all correlation coefficients were significantly different from zero at the 5 percent probability level, with the exception of Cypress Creek near Sulphur Springs. All regression constants were significantly different from zero and regression coefficients were significantly different from unity at the 5 percent probability level, except for the Cypress Creek near Sulphur Springs station. Simulated long-term peak discharges are therefore probably biased for all stations, except Cypress Creek.

Uniformly distributed rainfall, for basins modeled as part of this study, was not available for long-term simulation. Therefore, the bias is believed to be the result of peak discharges spuriously generated from non-uniform rainfall from thunderstorms during the summer months. A comparison of flood-frequency distributions for simulated and observed long-term flood-peak discharges indicate that the bias is most noticeable in low recurrence interval floods. Simulated and observed annual peak discharges (long-term) were analyzed by log-Pearson Type III flood-frequency analyses. (See Water Resources Council (1976) for a discussion of the log-Pearson Type III flood-frequency analyses.) Graphical plots of observed and simulated recurrence-interval peak discharges are shown in figures 20, 21, and 22 for selected stations. In most plots, simulated data exceed observed data up to about the 5-year recurrence interval, above which, both sets of data appear to merge satisfactorily.

Based on results of the statistical evaluation discussed above, calibration is assumed for basins modeled as part of this investigation. However, until additional rainfall, runoff, and evapotranspiration data become available, it will not be possible to verify calibrations or prediction errors. Prediction errors of flood hydrographs simulated using current rainfall data (from the expanded network) hopefully will not exceed standard errors of estimate listed in tables 11 and 12.

SUMMARY AND SUGGESTIONS FOR FURTHER STUDY

A digital watershed model was calibrated for three river basins located in the Tampa Bay area of west-central Florida. These basins include the Anclote, Hillsborough, and Alafia Rivers. The study area is more than 1,200 mi^2 in size and probably experiences more thunderstorms than any other area in the conterminous United States. More than half the mean annual precipitation (48 to 54 in.) occurs from thunderstorms during the summer. Watersheds used in the study range in size from about 70 to 650 mi^2.

Table 13.--Comparative statistics of observed and simulated long-term annual flood-peak discharges

Streamflow station	Number of annual peak discharges	Correlation coefficient[1]	Average standard error of estimate, percent	Regression coefficient[2]
Anclote River near Elfers	23	0.74	43	0.61
Hillsborough River near Zephyrhills	23	.66	33	.41
Cypress Creek near Sulphur Springs	8	.69	44	.59
Hillsborough River near Tampa	23	.61	35	.35
North Prong Alafia River at Keysville	23	.60	35	.36
Alafia River at Lithia	22	.68	33	.41

1 All correlation coefficients are significantly different from 0.0 at the 5 percent probability level (except Cypress Creek near Sulphur Springs).

2 All regression coefficients are significantly different from 1.0 at the 5 percent probability level.

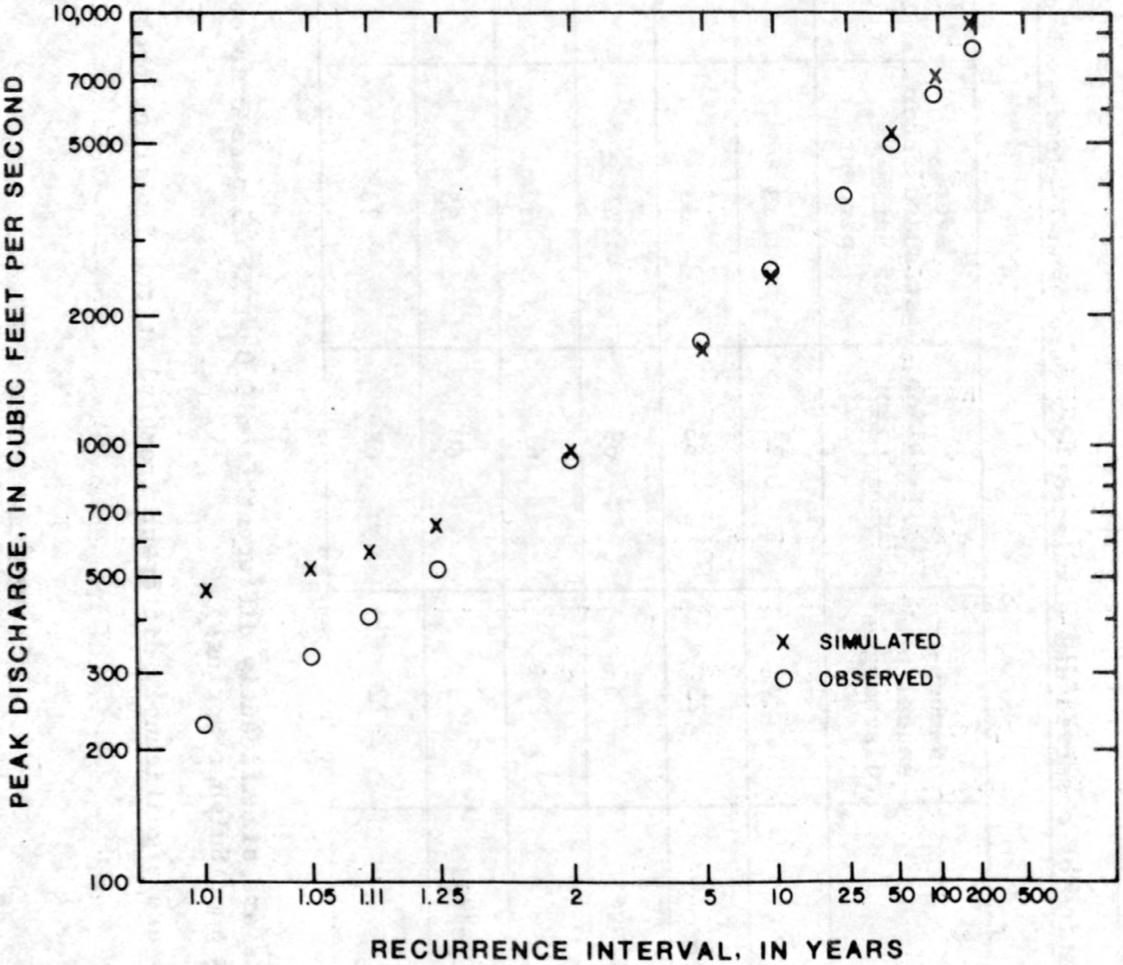


Figure 20.--Simulated and observed flood-frequency data for Anclote River near Elfers streamflow station, 1950-72.

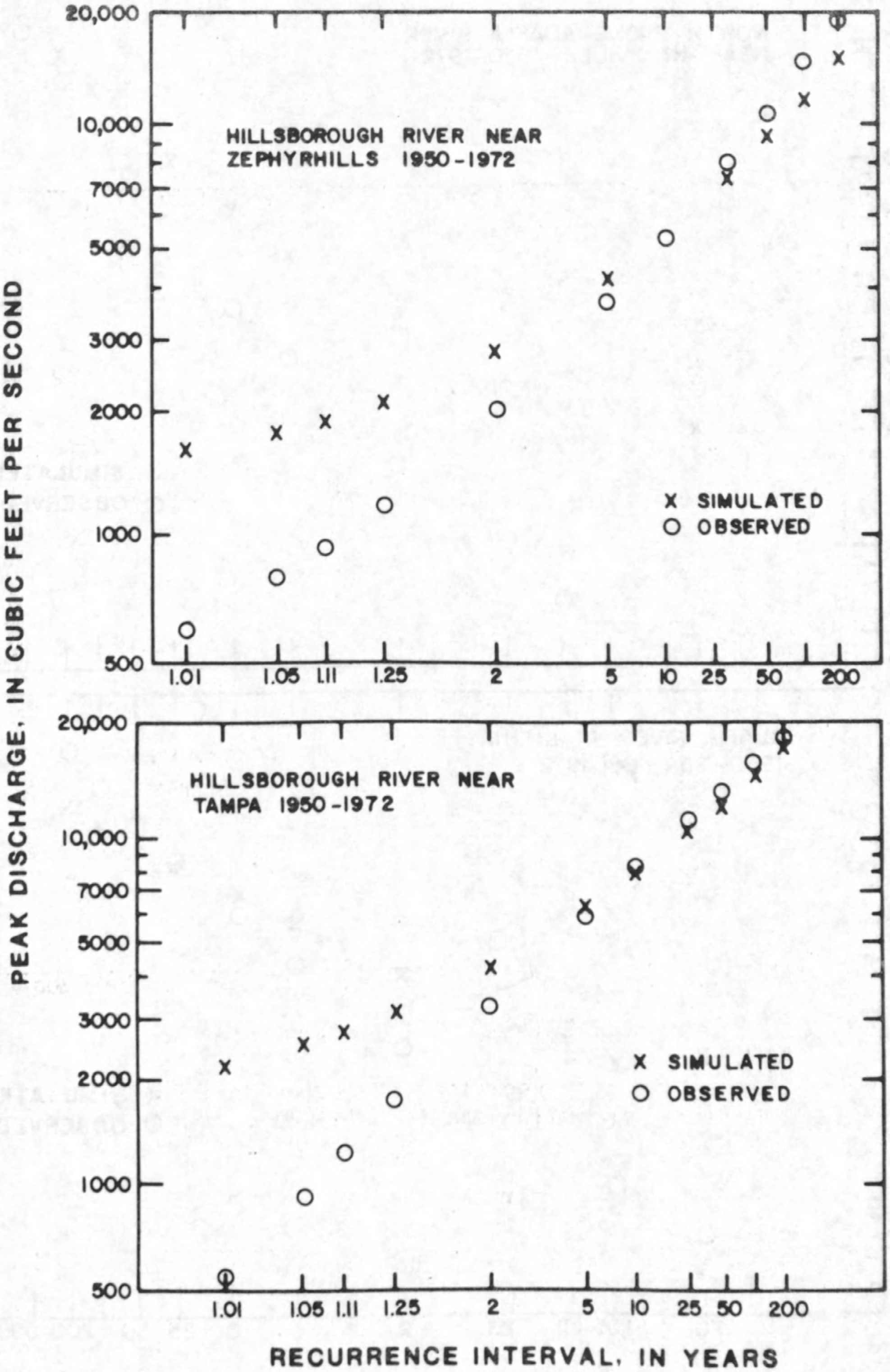


Figure 21.--Simulated and observed flood-frequency data for Hillsborough River near Zephyrhills and near Tampa streamflow stations, 1950-72.

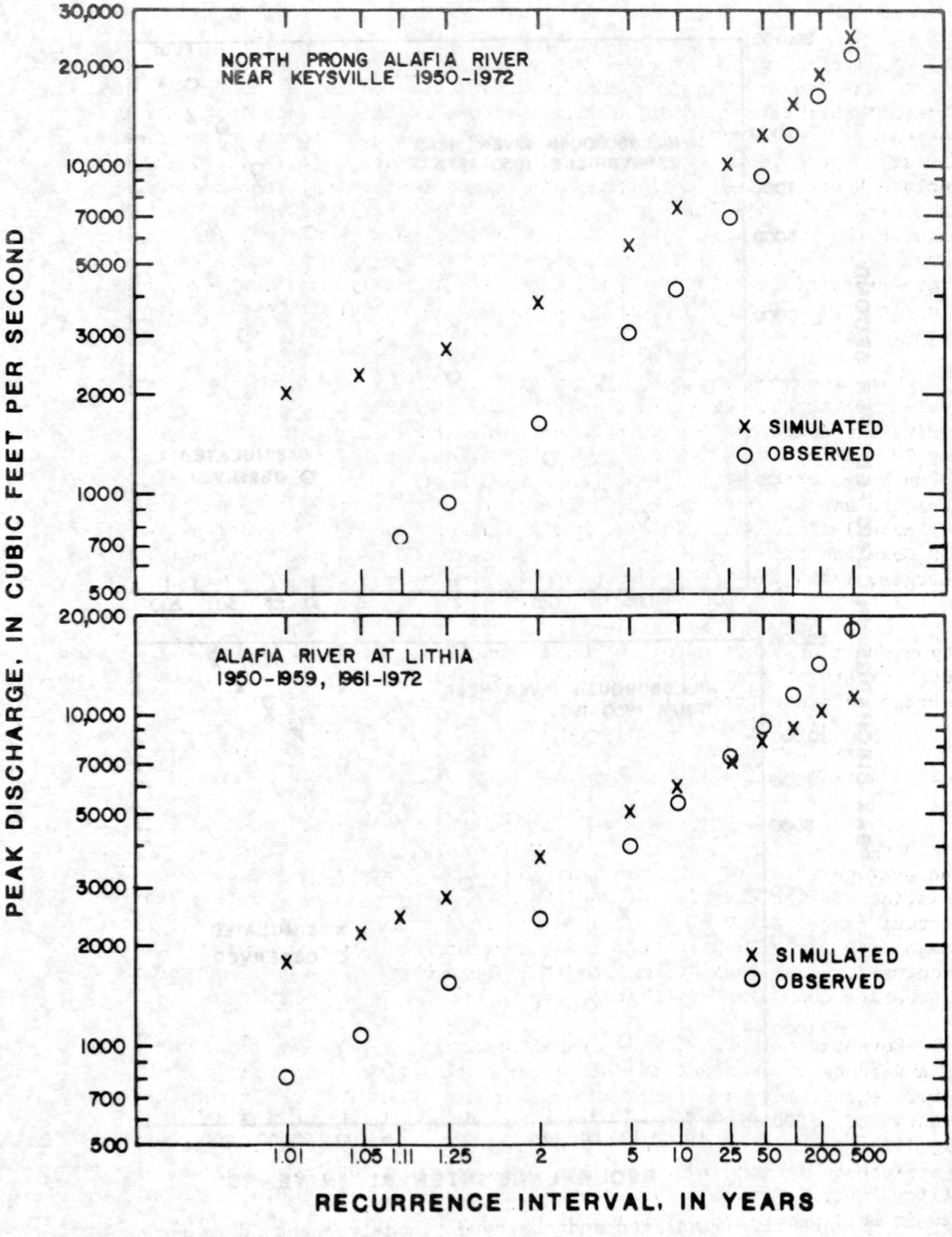


Figure 22.--Simulated and observed flood-frequency data for North Prong Alafia River at Keysville and Alafia River at Lithia streamflow stations, 1950-72.

A digital watershed model was obtained, modified, and evaluated for use in the study. The model is a modified version of the Georgia Tech Watershed Simulation Model, GTWS, developed at the Georgia Institute of Technology. Model evaluation is based on results of calibration studies for six streamflow stations located in the Hillsborough, Alafia, and Anclote River basins, including main stem and principal tributaries. Data used for model calibration include: daily streamflow records available at the various calibration points; long-term hourly precipitation (available for three sites on the periphery of the study area); and 2 years of rainfall records (available for 11 sites within the study area); and estimated daily evapotranspiration values computed from long-term meteorologic records available for the study area.

Data required to adequately verify calibrations are not currently available; therefore, validity of the calibrations is evaluated by comparing simulated and observed annual hydrographs for the 1959, 1960, 1973 and 1974 water years. Flood hydrographs (maximum daily discharge and volume) are emphasized. For each basin, about 12 flood events (selected from the annual hydrographs) were used for calibration. Long-term (1950-72) annual flood-peak discharges synthesized from hourly rainfall records for Lakeland and St. Leo (fig. 1) were compared with observed peak discharges, including flood-frequency distributions.

Annual hydrographs, excluding the 1973 water year, were compared using average absolute error in annual runoff and daily flows and correlation coefficients of monthly and daily flows. For stations used in the study, average absolute errors in simulated runoff range from 9 to 21 percent, and errors in daily flows range from 48 to 71 percent. Correlation coefficients for monthly flows range from 0.81 to 0.95 and correlation coefficients for daily flows range from 0.68 to 0.87.

Correlation coefficients for simulated and observed maximum daily discharges and flood volumes used for calibration range from 0.91 to 0.98 and average standard errors of estimate range from 18 to 45 percent. Correlation coefficients for simulated and observed annual flood-peak discharges range from 0.60 to 0.74 and average standard errors of estimate range from 33 to 44 percent. The number of flood events used for calibration varies, but range from 6 to 18. The number of annual flood-peak discharges used also vary but average about 20 for each station.

Correlation coefficients of calibration and long-term data were tested and found to be statistically significant at the 5 percent probability level, except for long-term period data for one station. Regression constants and coefficients for calibration data were tested and found to be significant at the 5 percent probability level. Regression constants and coefficients for the long-term data appear biased at the 5 percent probability level. This bias affects all streamflow stations used in the study and is believed to result from nonuniform rainfall. The bias appears to affect small to moderate size floods.

Based on study results, calibration is assumed for models developed as part of this investigation. However, until additional rainfall, runoff, and evapotranspiration data become available, calibrations and prediction errors cannot be completely verified.

Streamflow models developed as part of this investigation broaden and enhance water-management capability within the study area. Initially, they may be used by Southwest Florida Water Management District as an aid in flood forecasting. Later, as calibrations become more refined and more completely verified, they may be used to simulate hydrologic information for flood-evaluation studies. Results of this investigation also indicate the feasibility of modeling large rural basins in similar areas using digital watershed models.

Future development in suburban and rural areas of west-central Florida will include flood control, water conservation and basin improvement projects, urban and agricultural expansion, and development of large industrial complexes. Developments, such as these, are occurring rapidly and will have a significant impact on water resources. Streamflow simulation studies should be continued to evaluate the effects of future development on area water resources.

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SUPPLEMENT I

EVAPOTRANSPIRATION

According to Gray (1970), evapotranspiration determined by use of Penman's method may be used as an estimate of potential evapotranspiration. The method is related to the amount of radiant energy gained at the land surface and requires determination of free-surface evaporation and a sensible heat budget. Daily potential evapotranspiration, ETI, (inches per day), is given by equation 36, as follows:

$$ETI = \frac{A \cdot HEATD + 0.27\ EVAPD}{25.4\ [A + 0.27]} \qquad (36)$$

where A = Slope of saturation vapor pressure curve, millimeters of mercury per degree Fahrenheit, (see equation 38);

HEATD = Daily heat budget at evaporating surface, millimeters of water per day, (see equation 39);

EVAPD = Daily evaporation, millimeters of water per day, (see equation 42).

The coefficient, 0.27, is a dimensional constant having units of millimeters of mercury per degree Fahrenheit.

Average annual evapotranspiration estimated from computed potential values, by application of seasonal adjustment factors given in Gray (1970), agree within acceptable accuracy limits with average annual basin evapotranspiration estimated from corresponding period runoff and rainfall records.

Saturation Vapor Pressure Relations Used

Saturation vapor pressure relations are used in heat budget and evaporation calculations described in the following sections of Supplement I. A statistical expression describing the relation between saturation vapor pressure, EA (millimeters of mercury), and air temperature, T, is given by equation 37, as follows:

$$EA = 0.968\ [10]^{\overline{K}} \qquad (37)$$

where $\overline{K} = [(6.998T)/(T + 311.31)]$

T = Air temperature, in degrees Fahrenheit.

A relation for calculating slope of the saturation vapor pressure relation, A, is obtained by differentiating equation 37 with respect to temperature. Computational form of the slope equation is given as follows by equation 38:

$$A = 5016.28\ (T + 311.31)^{-2}\ EA \qquad (38)$$

where EA = Saturation vapor pressure, in millimeters of mercury;

T = Air temperature, in degrees Fahrenheit.

Daily Heat Budget, HEATD

The daily heat budget, HEATD, is calculated at the evaporating surface by use of the following equation:

$$HEATD = R \cdot (1.0 - RK) \cdot (0.18 + 0.55S) - B' \cdot (0.56 - 0.092ED^{0.5}) \cdot (0.10 + 0.9S) \qquad (39)$$

where R = Mean monthly extra-terrestial radiation, in millimeters of water per day, (see Chow, 1965, table 11-6);

RK = Reflectivity coefficient (calibration parameter; 0.15 determined for use in this study);

S = Ratio of daily duration of bright sunshine to maximum possible sunshine;

B' = Temperature coefficient, in millimeters of water per day (see equation 40);

ED = Saturation vapor pressure at dew point temperature, in millimeters of mercury.

The temperature coefficient, B', is calculated by use of the following equation:

$$B' = 2.01 \times 10^{-9}\ [5/9\ (T - 32) + 273]^4 \qquad (40)$$

where T = Daily air temperature, in degrees Fahrenheit.

Saturation vapor pressure, ED, corresponding to daily dew point temperature, TD, is computed by use of equation 37 substituting average daily dew point temperature, TD, for air temperature, T. For periods of missing dew point temperature, saturation vapor pressure, ED, is calculated as the product of average daily relative humidity and saturation vapor pressure, EA. For periods when both dew point temperature and relative humidity are missing, saturation vapor pressure, ED, is calculated using equation 37, and estimated daily dew point temperature, calculated by use of the following regression:

$$TD = 1.3217 + 1.0333\ T \tag{41}$$

where T = Average daily air temperature, in degrees Fahrenheit.

Daily Evaporation, EVAPD

Daily evaporation, EVAPD, in inches, that is used with equation 36 to calculate potential evapotranspiration, is computed by use of the following expression:

$$EVAPD = 0.35\ (EA - ED) \cdot (1.0 + 0.2352D \cdot W) \tag{42}$$

where EA = Saturation vapor pressure corresponding to daily air temperature, T, in millimeters of mercury;

ED = Saturation vapor pressure corresponding to daily dew point temperature, TD, in millimeters of mercury;

D = Conversion factor for translating wind observation height to a height of 2 meters;

W = Daily average wind speed, in miles per hour.

A listing of the FORTRAN source program follows:

```
C     EVAPOTRANSPIRATION        V E R S I O N  II    JANUARY 1974
C      **********  US GEOLOGICAL SURVEY, TAMPA, FLORIDA  ***************
C
C
C
C
C     THIS PROGRAM COMPUTES DAILY VALUES OF ACTUAL AND POTENTIAL
C     EVAPOTRANSPIRATION USING THE PENMAN EQUATIONS (1948).  CLIMATIC
C     AND METEOROLOGIC DATA USED ARE FROM THE NATIONAL WEATHER SERVICE
C     RECORDS FOR TAMPA INTERNATIONAL AIRPORT, TAMPA, FLORIDA.
C     NWS STATION NO. WBAN 12842.
C
C     DEFINITION OF PARAMETERS USED IN THE PENMAN EQUATION
C
C     A        SLOPE OF SATURATION VAPOR PRESSURE CURVE
C     B        TEMPERATURE COEFFICIENT (STEFAN-BOLTZMAN LAW)
C     CF       CROP FACTOR (APPLIED TO POTENTIAL EVAPOTRANSPIRATION
C              TO OBTAIN ACTUAL EVAPOTRANSPIRATION) SUPPLIED IN PGM
C     D        COEFFICIENT WHICH CONVERTS WIND OBS HEIGHT TO 2-METERS
C     EA       SAT VAPOR PRESSURE CORRESP TO DAILY AIR TEMP, T, MM OF HG
C     ED       SAT VAPOR PRESSURE AT DEW POINT TEMP, IN MM OF HG
C     ETI      DAILY VALUES OF POTENTIAL OR ACTUAL EVAPOTRANSPIRATION,
C              INCHES PER DAY
C     EVAP     DAILY EVAPORATION, INCHES PER DAY
C     EVAPD    DAILY EVAPORATION, MILLIMETERS OF WATER PER DAY
C     F        DAILY AVERAGE RELATIVE HUMIDITY (DECIMAL),TAMPA INT'L
C     HEATD    DAILY HEAT BUDGET AT EVAPORATING SURFACE, MM OF WATER
C     ICARD    DAILY EVAPOTRANSPIRATION VALUES OUTPUT ON PUNCHED CARDS
C              WHEN ICARD = 1
C     ICODE    PROGRAM CALCULATES POTENTIAL EVAPOTRANSPIRATION FOR
C              ICODE = 1; ACTUAL EVAPOTRANSPIRATION IS CALCULATED WHEN
C              ICODE = 0.
C     IDAY     DAY
C     IMON     MONTH
C     IYEAR    YEAR
C     NCARD    NUMBER OF DAYS OF RECORD PER MONTH
C     R        MEAN MONTHLY EXTRATERRESTIAL RADIATION, MM OF WATER
C              DATA VALUES FOR FLORIDA ARE SUPPLIED IN THE PROGRAM
C     RK       ESTIMATED REFLECTING SURFACE (ALBEDO) (%)----------0.15
C     S        RATIO OF DURATION OF BRIGHT SUNSHINE TO MAX POSSIBLE
C     T        DAILY TEMPERATURE, DEGREES FAHRENHEIT, TAMPA INT'L
C     TD       DAILY AVERAGE DEW POINT TEMPERATURE, DEG F; ALSO ESTIMATED
C              FROM AIR TEMPERATURE REGRESSION
C     W        DAILY AVERAGE WIND SPEED, MILES PER HOUR, TAMPA INT'L
C
C
C
C     DEW POINT TEMPERATURE, TD, OR RELATIVE HUMIDITY, F, MUST BE SUPPLIED
C
C
    5 FORMAT ('0','ACTUAL EVAPOTRANSPIRATION OPTION SELECTED')
   10 FORMAT ('0','POTENTIAL EVAPOTRANSPIRATION OPTION SELECTED')
   15 FORMAT (F5.2,2I3)
   50 FORMAT (F5.1,8X,I2,A4,2I3)
  100 FORMAT (3I2,5F10.2)
  111 FORMAT ('0','MONTHLY EVAPOTRANSPIRATION = ',F6.3///)
  112 FORMAT ('1',' ESTIMATED REFLECTING SURFACE (%) = ',F5.3///)
 3000 FORMAT (' ',3X,'DATE',2X,'TEMP(F)',1X,'DEW PT',2X,'E(A)',4X,
     1' E(D) ',1X,'EVAP(IN)',3X,'B',5X,'HEATD',5X,'A',5X,'ET(IN)',//)
 4000 FORMAT (' ',3I2,9F8.2)
 5000 FORMAT (' ',1X,' 12842',A4,'1',10F6.3)
 6000 FORMAT (' ',1X,' 12842',A4,'2',10F6.3)
 7000 FORMAT (' ',1X,' 12842',A4,'3',11F6.3)
 8000 FORMAT (1X,' 12842',A4,'1',10F6.3)
 9000 FORMAT (1X,' 12842',A4,'2',10F6.3)
 9500 FORMAT (1X,' 12842',A4,'3',11F6.3)
```

```
      DIMENSION ETI(31)
      RK=0.15
      READ (5,15)RK,ICODE,ICARD
      IF(ICODE.EQ.1)WRITE (6,10)
      IF(ICODE.NE.1)WRITE(6,5)
  400 DO 200 I=1,31
      ETI(I)=0.00
  200 CONTINUE
      ETM=0.0
      READ (5,50)H,NCARD,MONYR,IEND
      WRITE(6,112)RK
      WRITE(6,3000)
      D=(ALOG10(6.60))/(ALOG(H))
      DO 300 I=1,NCARD
      READ(5,100)IMON,IDAY,IYEAR,T,TD,W,S,F
      IF(IMON.EQ.1)  R=8.96
      IF(IMON.EQ.2)  R=10.9
      IF(IMON.EQ.3)  R=12.9
      IF(IMON.EQ.4)  R=14.9
      IF(IMON.EQ.5)  R=15.9
      IF(IMON.EQ.6)  R=16.4
      IF(IMON.EQ.7)  R=16.1
      IF(IMON.EQ.8)  R=15.3
      IF(IMON.EQ.9)  R=13.7
      IF(IMON.EQ.10)  R=11.6
      IF(IMON.EQ.11)  R=9.50
      IF(IMON.EQ.12)  R=8.4
      EA=.968*(10.0)**((6.998*T)/(T+311.3))
      IF(TD.GT.0.0) GO TO 20
      IF(F.GT.0.0) GO TO 40
      TD=1.3217+1.0333*T
      GO TO 20
   40 ED=F*EA
      GO TO 30
   20 ED=0.968*(10.0)**((6.998*TD)/(TD+311.3))
   30 EVAPD=0.35*(EA-ED)*(1.0+0.2352*D*W)
      EVAP=EVAPD/25.4
      R=2.01*(10.0**(-6.0))*(10.0**(-3.0))*((5.0/9.0)*(T-32.0)+273.0)**4.0
      HEATD=R*(1.0-RK)*(0.18+0.55*S)-B*(0.56-0.092*ED**0.5)*(0.1+0.9*S)
      ZZ = (T + 311.31)**2
      A = (5016.28/ZZ)*EA
      ETD=(A*HEATD+0.27*EVAPD)/(A+0.27)
      IF(IMON.EQ.1)   CF=0.6
      IF(IMON.EQ.2)   CF=0.6
      IF(IMON.EQ.3)   CF=0.7
      IF(IMON.EQ.4)   CF=0.7
      IF(IMON.EQ.5)   CF=0.8
      IF(IMON.EQ.6)   CF=0.8
      IF(IMON.EQ.7)   CF=0.8
      IF(IMON.EQ.8)   CF=0.8
      IF(IMON.EQ.9)   CF=0.7
      IF(IMON.EQ.10) CF=0.7
      IF(IMON.EQ.11) CF=0.6
      IF(IMON.EQ.12) CF=0.6
      IF(ICODE.EQ.1)ETI(I) = ETD/25.4
      IF(ICODE.NE.1)ETI(I) = CF*ETD/25.4
      ETM = ETM + ETI(I)
      WRITE(6,4000)IMON,IDAY,IYEAR,T,TD,EA,ED,EVAP,R,HEATD,A,ETI(I)
  300 CONTINUE
      WRITE(6,111)ETM
      WRITE(6,5000)MONYR,(ETI(I),I=1,10)
      WRITE(6,6000)MONYR,(ETI(I),I=11,20)
      WRITE(6,7000)MONYR,(ETI(I),I=21,NCARD)
      IF(ICARD.EQ.1)WRITE(7,8000)MONYR,(ETI(I),I=1,10)
      IF(ICARD.EQ.1)WRITE(7,9000)MONYR,(ETI(I),I=11,20)
      IF(ICARD.EQ.1)WRITE(7,9500)MONYR,(ETI(I),I=21,NCARD)
      IF(IEND.NE.999) GO TO 400
      STOP
      END
```

SUPPLEMENT II

HYDROLOGIC WATERSHED SIMULATOR USER MANUAL

This section of the report provides detailed information required in watershed simulation. Model operation is controlled by card input involving 5-run options, 10-output options, and 9-input options. The run options control such features as flow simulation, channel and reservoir routing. The output options provide for a variety of program outputs, including: monthly storage and flow tables, daily and hourly streamflow hydrographs, statistics of simulated daily flows, card output for simulated flows, and printer plots of simulated flows at desired flow points. The input options provide for various data inputs including: potential evapotranspiration, precipitation, streamflow, channel diversions, distribution graphs, and factors for adjusting or weighting both monthly evapotranspiration and precipitation.

Sequence and format specifications of input data are grouped under the following general headings; specific groups of input card sequences required for each category are also given.

Section	Title
I	Watershed identification and program options (card seq. 1-6)
II	Required input data for subwatersheds (card seq. 7-20)
III	Channel routing (card seq. 21-29)
IV	Reservoir routing (card seq. 30-33)
V	Printer plots (card seq. 34-35)
VI	Input data required for simulation (card seq. 36-47)

Each section covers a specific operational or computational phase of the program. Selection of various program options requires specific input-data card sequence. A card sequence refers to a card or group of cards defining or relating to a specific program option or function. Required card input sequence for desired program options is summarized in table 14 and a detailed description of each card sequence follows later in this section. Card format, variable name, and order in which variables and data appear on card is also given. Card format codes are given in FORTRAN IV format specifications, and variable names are given in FORTRAN IV syntax as they appear in the program. Data arrays are indicated by variable name followed by an open set of parenthesis, i.e., INFO ( ). Card sequences required for selected program options must be provided by the user. Card sequences are generally omitted for program options that are not selected. Card sequence numbers are provided only for organizational purposes and user assistance and are not used as input data when preparing cards.

Table 14.--Summary of required input-data card sequences for indicated program options

Section	Card sequence number	Program options			Explanation of program options
		Run	Input	Output	
I	1-6	1,2,5, 11,19	3,4,12, 14,15, 16,17, 19,20	1,2,3, 4,5,8, 9,16, 17,18	General watershed information and program options[1]
II	7-16	1			Input unique subwatershed parameters
	17	1			Card sequence appears only if nonunique subwatershed(s) included in simulation
	18	1,5			Input time simulation increment
	19	1	17		Input monthly evapotranspiration adjustment factors (all water years)
	20	1,2		16	Card output-simulated daily streamflow
III	21-22[2]	1,2	16		Program determines distribution graph ordinates
	23[2]	1,2	15		Input hourly distribution graph ordinates for each subwatershed
	24	1,2	15		Number of stream reaches and routing parameters
	25-28[3]	1,2			Channel route in one or more stream reaches
	29	1,2			Subwatershed(s) output desired
IV	30-33	1,2,19			Reservoir routing
V	34-35	1,2		17&18	Printer plots

Table 14.--Summary of required input-data card sequences for indicated program options - continued

Section	Card sequence number	Program options			Explanation of program options
		Run	Input	Output	
VI	36[4]	1,2			Beginning and ending dates of simulation period
	37	1,2	14		Input monthly evapotranspiration adjustment factors (individual water years)
	38	1,2	4		Monthly precipitation adjustment factors
	39	1,2		2	Simulated hourly streamflow hydrographs
	40	1,2	3		Input daily potential evapotranspiration
	41-43	1,2	12		Input daily streamflow
	44-45	1,2	19		Input streamflow diversions
	46-47	1,2	20		Input hourly precipitation

1 Desired program options are input on card sequence numbers 2, 3, and 4. Most program options als require additional input data as indicated by card sequences summarized in this table. No additional input data or card sequences are required for: (1) run option 11, and (2) output options 1, 3, 4, 5, 8, and 9. Card sequences are omitted for program options not selected.

2 Input option 15 or 16 must be selected for simulation.

3 Card sequences are omitted for no stream reaches (see first parameter in card sequence 24).

4 Card sequences 36-47 must be provided for all additional water years that are to be simulated.

SECTION I--WATERSHED IDENTIFICATION AND PROGRAM OPTIONS

***General Watershed Information (on 3 cards)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
1	20A4	INFO ( )	General information to identify watershed and simulation run. Note: 3 cards must be supplied by user.

***Input Run Options (on 1 card)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
2	20I4	IDXD ( )	Integer sequence identifying run options.

Option CODE	MEANING
1	Flow simulation;
2	Channel routing;
5	Change time increment (default is 15 minutes);
11	Alternate percolation function;
19	Reservoir routing.

***Output options (on 1 card)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
3	20I4	IDXD ( )	Integer sequence identifying output options.

Option CODE	MEANING
1	Storage and flow table of monthly sums for entire watershed;
2	Hourly flow hydrographs for selected days;
3	Daily flow hydrographs;
4	Output flow table of measured daily discharge;

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS

Option CODE	MEANING
5	Storage and flow table of monthly sums for each month and each subwatershed;
8	Statistics of simulated daily flow;
9	Summaries of evapotranspiration and precipitation data that are input;
16	Card output of simulated daily discharge;
17	Plot mean daily streamflow for flow points with measured input data;
18	Plot of simulated mean daily streamflow for specified flow points where there is no measured input data (option 17 must also be specified).

***Input options (on 1 card)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
4	20I4	IDXD ( )	Integer sequence identifying model and data input options.

Option CODE	MEANING
3	Daily potential evapotranspiration;
4	Monthly precipitation correction;
12	Input measured streamflow;
14	Monthly potential evapotranspiration adjustments for individual water years;
15	Distribution graph ordinates for each subwatershed;
16	Model to determine distribution graph ordinates automatically for each subwatershed;
17	Monthly potential evapotranspiration adjustment (for all water years);
19	Diversion into or out of watershed;
20	Hourly precipitation.

***Input of watershed information (on 2 cards)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
5	4I4,16A4	STMO,	Beginning month of simulation (1-12);
		STYR,	Beginning year of simulation (last two digits);
		ENDM,	Ending month of simulation (1-12);
		ENDY,	Ending year of simulation (last two digits);
		NAME ( )	Name of watershed (16 characters).
6	4F8.0	ELEV,	Watershed elevation at mouth (feet above mean sea level);
		LAT,	Latitude (degrees to left of decimal, minutes to right);
		LONG,	Longitude (degrees to left of decimal, minutes to right);
		AREA	Watershed area in square miles.

SECTION II--REQUIRED INPUT DATA FOR SUBWATERSHEDS

***Begin input of information for subwatersheds

***Run option 1 - Number of subwatersheds and classification (on 1 card)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
7	20I4	NSUBWS,	Total number of subwatersheds (both unique and non-unique) used in simulation (max. 20);
		SWLIKE ( )	Integer sequence specifying whether subwatershed is unique (its own number) or whether it is similar in input and response to another subwatershed (sequence number of similar subwatershed). Subwatersheds are numbered in downstream order beginning with 1.

***Begin input identifying subwatershed precipitation gages

***Run option 1 - The following 3 card sequence (8, 9, and 10) required for each unique subwatershed, and will appear in downstream order beginning with subwatershed 1 (on 3 cards per subwatershed)

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
8	20I4	NUM,	Number of rain gages used in simulation (max. 15);
		INRG ( )	Sequence number of each gage;
9	10F8.0	THAREA ( )	Theissen coefficients for each rain gage used;
10	10F8.0	PCOR ( )	Precipitation catch adjustment factor for each rain gage used.

***Begin input identifying subwatershed soil-moisture accounting parameters.

***Run option 1 - The following 6 card sequence (11 through 16) required for each unique subwatershed; each card sequence will appear in downstream order beginning with subwatershed 1 (on 6 cards per subwatershed).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
11	I4	LIKN	Sequence number of unique subwatershed.
			(AREA PARAMETERS)
12	6F8.0	SWAREA	Subwatershed area, in square miles;
		IMPA[1],	Fraction impervious area (subwatershed);
		FALZ[2],	Fraction alluvial area (subwatershed);
		FHLZ[2],	Fraction hillside area (subwatershed);
		PSRP[1],	Maximum area for SRS (fraction subwatershed);
		PSDP[1]	Area when SDS = SDSN (fraction subwatershed.
			(STORAGE PARAMETERS - inches)
13	7F8.0	ICMN,	Winter interception storage;
		ICMX,	Summer interception storage;
		SRSN,	Surface-retention storage capacity;
		SDSN,	Surface-detention storage capacity;
		UZSN,	Upper soil zone capacity;
		LZSN,	Lower soil zone capacity;
		GWSF	Ground-water storage for zero baseflow.

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
			(DRAINAGE PARAMETERS)
14	10F8.0	PINF (PPIF)[3],	Infiltration, inches per time interval;
		PSUP,	Infiltration function shape (dimensionless);
		PULP (PPUL)[3],	Percolation from upper- to lower-zone storages, inches per time interval; also used as parameter for ridge seepage to hillside and alluvium lower-zone storages, units per hour;
		PLGP,	Percolation from alluvium lower-zone storage to ground-water storage, inches per hour;
		PDGP[1],	Underflow from ground-water storage, units per hour;
		PLZU,	Underflow from ridge lower-zone storage, units per hour;
		TTM[1],	Overland flow storage constant, units per time interval;
		INFP,	Interflow, inches per hour;
		KGWF[1]	Base-flow recession constant.
			(EVAPOTRANSPIRATION PARAMETERS) (Dimensionless)
15	3F8.0	EIP[1],	Interception evaporation;
		EVP,	Evapotranspiration from upper- and lower-zone storages;
		ETGWP	Ground-water storage transpiration.
			(INITIAL STORAGE VALUES - inches)
16	5F8.0	SRS,	Surface-retention storage;
		SDS,	Surface-detention storage;
		UZS,	Upper-zone storage (must be greater than 0.0);
		LZS[4],	Upland or ridge lower-zone storage (must be greater than 0.0);
		GWS	Ground-water storage.

1 Parameter value must be less than or equal to 1.0.

2 Sum of these parameter values must be less than or equal to 1.0.

3 Parenthetical parameter is actually input to the model and has units of inches per hour; preceeding parameter shown is adjusted to desired time simulation interval and for the ratio of water viscosity at mean monthly temperature to viscosity at mean annual temperature.

4 Initial storage value also used for hillside and alluvium lower-zone storages.

***The following card required for each non-unique subwatershed.

***Run option 1 - Begin input of data for non-unique subwatersheds (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
17	I8,F8.0	LIKN,	Sequence number of non-unique subwatershed;
		SWAREA	Area of non-unique subwatershed in square miles.

***Simulation time increment.

***Run option 1 and 5 - Designate time increment to be used for simulation; default time increment of 15 minutes is used when this card does not appear (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
18	I4	IMIN	Simulation time increment in minutes (must be a whole number divisor of 60).

***Monthly evapotranspiration adjustments (for all years).

***Run option 1 and input option 17 - The following is required to adjust monthly evapotranspiration values (on 2 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
19	10F8.0	EVPCOR ( )	Monthly potential evapotranspiration adjustment factors for all years.

***Punch simulated streamflow (daily values).

***Run option 1 and 2 and output option 16 - The following card required for punching simulated flows (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
20	I6	NSTA	Flow point sequence number for which simulated streamflow are to be punched on cards (by computer).

SECTION III - CHANNEL ROUTING

***Computer determines hourly distribution graph ordinates.

***Run option 1 and 2, and input option 16 - The following data sequences required for computer to determine distribution graph ordinates (on 2 cards for each subwatershed).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
21	2F8.0	CT,	Parameters to calculate time to hydrograph peak, TP, in following equation: TP = (CT*L*LC)/S**ZX L = basin length, miles; LC = basin centroid length, miles; S = basin slope, feet per mile; ZX = CN/2.0.
22	I8, 9F8.0	LIKN,	Subwatershed sequence number;
		SLOPE,	Basin slope, feet per mile;
		LENGTH,	Basin length, miles;
		LC,	Basin centroid length, miles;
		TP,	Time to peak, hours (max. TP=12.5 hours);
		TB	Time base of unit hydrograph, hours; (if TB and TP are not given, they will be calculated).

***Input hourly distribution ordinates for each subwatershed (unique and non-unique).

***Run options 1 and 2, and input option 15 - The following card sequence required for reading in distribution graph ordinates for all subwatersheds.

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
23	I8, 9F8.0/ (10F8.0)	NUM, DISTRO ( )	Number of hourly distribution graph ordinates (maximum 900), and hourly ordinates.
24	I8, 9F8.0/ (10F8.0)	NRCHS, RK ( )	Number of stream reaches (maximum 7), and Muskingum K for each reach in downstream order.

***Stream reaches and flow points.

***Run options 1 and 2 - The following 4 card sequence is required if flow is to be routed in one or more channel reaches (on 4 cards). If NRCHS (card sequence 24) is zero, card sequences 25-28 are omitted.

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
25	10F8.0	RX ( )	Muskingum x for each reach in sequential order. NOTE: $RK \cdot RX < 0.5$, and $RK \cdot (1-X) > 0.5$.
26	20I4	RCHI ( )	Nth flowpoint into which Nth reach flows;
27	20I4	SWSI ( )	Reach into which Nth subwatershed flows;
28	20I4	NRO ( )	Flow point output desired (last number must be 99). (If more than one subwatershed is used, output must be requested for at least 2 flow points.)

***Output for selected subwatershed.

***Run option 1 and 2 - The following card sequence is required always (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
29	20I4	NSO ( )	Subwatersheds output desired (last number must be 99).

***Begin input for reservoir routing (modified Puls method).

***Run option 1, 2 and 19 - The following 4 card sequences are required for reaches that are to have reservoir routing.

***Stream reach reservoir routing desired (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
30	20I4	RRR ( )	Reach sequence number for which reservoir routing is desired; last sequence number must be 99.

***Input parameters describing controlled phase of reservoir operation (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
31	8F10.5	AA, B, C,	Multiple linear regression coefficients describing controlled phase of reservoir operations;
		B0, B1, B2, B3,	Coefficients of 3rd order regression describing free-fall reservoir condition in the controlled flow range.
		COFF	Reservoir inflow coefficient used to specify minimum acceptable routed outflow from reservoir; unacceptable outflows are set equal to the product of COFF and inflow value.

***Input reservoir data--Stage vs Storage and Stage vs Outflow (uncontrolled) (on a maximum of 25 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
32	I3, 3F8.0/ (3X,3F8.0)	NNXX,	Number of ordinates of reservoir free-fall rating (maximum 25);
		RELEV ( )	Reservoir elevation (feet above sea level);

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
		O2 ( )	Reservoir free-fall outflow in cubic feet per second, corresponding to stage given in RELEV array;
		S2 ( )	Reservoir storage in acre-feet, corresponding to stage given in RELEV array; (First card contains NNXX and RELEV (1), O2 (1), and S2 (1). Succeeding cards contain one value each of RELEV (I), O2 (I), and S2 (I).).

***Initial reservoir condition at beginning of simulation period (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
33	6F8.0, I8, 2F8.0	SINT,	Initial reservoir storage at beginning of simulation period, acre-feet;
		ELINT,	Initial reservoir elevation at beginning of simulation period, feet, msl;
		EFSD,	Elevation of free-surface discharge, or the elevation above which free-fall rating applies, feet, msl;
		COF,	Constant reservoir outflow (below elevation of gate operation), cubic feet per second;
		EGO,	Reservoir elevation at which gate operation begins, feet, msl;
		QCON,	Maximum controlled reservoir flow, cubic feet per second;
		ICODE1,	Integer designating type of reservoir operation (1 for uncontrolled flow, and 0 for controlled flow);
		ECSD,	Minimum reservoir inflow in cubic feet per second, below which outflow is computed by use of equation 33;
		DIV	Constant diversion rate for water supply withdrawal, in cubic feet per second.

SECTION V -- PRINTER PLOTS

Begin input to obtain streamflow hydrograph printer plots (by water years).

***Run option 1 and 2, and output options 17 and 18 - The following 2 card input sequences are required to obtain line printer plots of mean daily discharge for subwatersheds and flow points with and without measured streamflow data as input (on 2 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
34	20I4	PSN ( )	Sequence numbers of subwatersheds for which a streamflow hydrograph printer plot is desired. Last number must be 99.
35	20I4	PFN ( )	Sequence number of flow points for which a streamflow hydrograph printer plot is desired. Last number must be 99.

SECTION VI -- INPUT DATA REQUIRED FOR SIMULATION

***Begin input data for each water year of simulation. Card sequence 36-47 must be provided for each additional year to be simulated.

***Run option 1 and 2 - The following card always required for simulation (on 1 card).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
36	20I4	MONB,	Beginning month of simulation (1-12);
		YRB,	Beginning year of simulation (last 2 digits);
		MONE,	Ending month of simulation (1-12);
		YRE,	Ending year of simulation (last 2 digits);
		FILENO,	Integer designating input device for precipitation data;
		FILEVP,	Integer designating input device for evapotranspiration data;
		FILEQ	Integer designating input device for measured streamflow data.

Monthly evapotranspiration and precipitation adjustments.

***Run option 1 and 2 and input option 14 - The following card sequence required to adjust monthly evapotranspiration by water years (on 2 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
37	10F8.0	EVPCOR ( )	Monthly potential evapotranspiration adjustment factors for individual water years (October - September).

***Run option 1 and 2 and input option 4 - The following card required for adjusting monthly precipitation by water years (on 2 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
38	10F8.0	PCMO ( )	Monthly precipitation adjustment factor by water year (October - September).

***Run option 1 and 2 and output option 2 - The following array required if hourly hydrographs are desired for selected days (on no more than 2 cards).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
39	20I4	IK (,)	Month (1-12) and day, selected for hourly hydrograph information.

***Begin input of streamflow, evapotranspiration, and precipitation data.

***Run option 1 and 2 and input option 3 - The following card sequence required for input of daily evapotranspiration for a water year (on no more than 3 cards per month).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
40	1/	NOSTA,	Station index number;
		JMO,	Beginning month (1-12);
		JYR,	Beginning year (last 2 digits);
		JNZ,	Integer (1, 2, or 3) indicating 1st, 2nd, or 3rd data card for month;

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
		ARRA ( )	Eleven daily potential evapotranspiration values, except for 3rd card. Last card of each year must have 99 in cols. 10 and 11.

***Run option 1 and 2 and input option 12 - The following 3 card sequence required for input of daily streamflow (maximum 2 flow points) with no more than 49 cards per station per water year.

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
41	I4	NOST	Number of stations measured streamflow data input (maximum 2);
42	2/	IID,	Integer (1, 2, 3, or 4) identifying data card type;
		NOSTA,	Station index number;
		JYR,	Beginning year (last 2 digits);
		JMO,	Beginning month (1-12);
		JNZ,	Integer (1, 2, 3, or 4) indicating 1st, 2nd, 3rd, or 4th data card for month;
		ARRA ( )	Eight mean daily streamflow values (cubic feet per second) per card, except 4th card which will vary depending on number of days in month. Last card must have 99 in columns 10 and 11.
43	20I4	NMR,	Total number of subwatersheds or flow points measured data is input (maximum 2);
		MRN ( )	Sequence number of each flow point (preceded by a + for subwatershed and a - for a flow point).

Input of streamflow diversions.

***Run option 1 and 2 and input option 19 - The following 2 card sequence is required if streamflow diversions are to be used in simulation (on no more that 49 cards per water year).

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
44	I4	MDF	Flow point sequence number to be added or subtracted. Sequence number preceded by + for subwatershed and a - for flow points.
45	2/	IID,	Integer (1, 2, 3, or 4) identifying data card type;
		NOSTA,	Station index numbers;
		JYR,	Beginning year (last 2 digits);
		JMO,	Beginning month (1-12);
		JNZ,	Integer (1, 2, 3, or 4) indicating 1st, 2nd, 3rd, or 4th data card per month;
		ARRA ( )	Eight mean daily flow diversion values, cubic feet per second, per card, except 4th card which will vary depending on number of days in month. Last card must have 99 in columns 10 and 11.

Begin input of hourly precipitation.

***Run option 1 and 2 and input option 20 - The following 2 card sequence required for input hourly rainfall data for a water year. Rainfall data are arranged by months in the water year format. Data are input by months with stations arranged sequentially within each month. Data appear on no more than 62 cards per station per month, not including card sequence 46.

CARD SEQUENCE NUMBER	FORMAT	VARIABLE SEQUENCE	COMMENTS
46	2I4	NRGAGE,	Number of rainfall gages to be read;
		NFOR,	Format Code (0 - Stanford, 1 - National Weather Service).
47	3/	NOSTA,	Station index number;
		JYR,	Beginning year (last 2 digits);
		JMO,	Beginning month (1-12);
		JDY,	Beginning day;
		NC,	Integer (1 or 2) indicating AM or PM;
		ARRA ( )	12 hourly precipitation values. Last card each month must have 99 in columns 10 and 11. Precipitation data are read in by months by station sequences - all the precipitation data for all stations will be read in monthly.

Special input FORTRAN data formats.

1/ USGS special card format for daily evapotranspiration: (1X, I6, 2I2, I1, 11F6.2);

2/ USGS standard card format for daily discharge: (I1, 9X, I6, 2X, 3I2, 8F7.0);

3/ Stanford card format for hourly precipitation: (2X, I7, 3I3, I2, 12F5.2);

National Weather Service card format for hourly precipitation: (I6, 3I2, I1, 12F3.2, 29X, I2).

SUPPLEMENT III

Listing of Source Programs for Hydrologic Watershed Simulator

The model consists of a main program and six subroutines listed as follows:

1. Main program -----------------------HWS
2. Block data--------------------------BLKD
3. Channel routing---------------------CHISM
4. Output of annual data and plotting--OUPT
5. Summary of flow and storage data----OPTM
6. Reservoir routing-------------------REST, TBLE

Listing of source programs is given in following section, in the order indicated above.

```
C
C
C*****************************************************************
C************                                         ************
C************                                         ************
C************   U. S. GEOLOGICAL SURVEY, TAMPA, FLORIDA  ************
C************                                         ************
C************                                         ************
C*****************************************************************
C************                                         ************
C************                                         ************
C************   HWS - HYDROLOGIC WATERSHED SIMULATOR   ************
C************                                         ************
C************      VERSION I - FEBRUARY 20, 1975       ************
C************                                         ************
C************                                         ************
C*****************************************************************
C*                                                               *
C*****************************************************************
C*                                                               *
C*                                                               *
C*    THIS MODEL SIMULATES THE HYDROLOGIC RESPONSE AND CONDITION OF
C*    RURAL AND DEVELOPING WATERSHEDS OF WEST-CENTRAL FLORIDA FOR *
C*    SPECIFIC METEOROLOGIC AND PHYSIOGRAPHIC INPUTS.  HWS IS A   *
C*    MODIFIED VERSION  (WITH ADDITIONAL COMPUTATIONAL ROUTINES) OF *
C*    THE GEORGIA TECH WATERSHED SIMULATOR, GTWS, DEVELOPED IN THE *
C*    SCHOOL OF CIVIL ENGINEERING, GEORGIA INSTITUTE OF TECHNOLOGY, *
C*    ATLANTA, GEORGIA, BY DR. A. M. LUMB, ASSISTANT PROFESSOR.  GTWS *
C*    IS BASED LARGELY ON SOIL-MOISTURE ACCOUNTING CONCEPTS DEVELOPED *
C*    FOR THE STANFORD WATERSHED MODEL IV BY N. H. CRAWFORD AND   *
C*    R. K. LINSLEY.  MODEL DEVELOPMENT WAS DONE IN COOPERATION WITH *
C*    THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT, BROOKSVILLE, *
C*    FLORIDA.                                                   *
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```
C DECLARATIONS
      DIMENSION SRS(20),SDS(20),UZS(20),LZS(20),GWS(20)
      DIMENSION IRLS(9),JCLS(9),DELK(9),SSN(9,11)
      DIMENSION FO(9),FN(9),CHKR(9),DV(9),DDS(9)
C
C
C DECLARATIONS
      INTEGER NUMI(20)
      INTEGER OPTI,DPLOT,DAYS,OPTO,YEAR,PLTNO,OPTS
      INTEGER RRR
      INTEGER PSN(20),PFN(20)
      INTEGER SWLIKE,RCHI,SWSI,WNUM
      INTEGER NRGSW(20),IK(2,10),INFO(20),OPTR(20),IDXD(20),INRG(20,5),
     1         INFOWS(20),DAY,V,YRMO,HR,YRB,YRE,FILENO,START,ENDR,ENDM,
     1ENDY,STMO,STYR,FILEVP,FILFQ,IV,IIV,IFILE1,IFILE2,IFILE3
C
C
C DECLARATIONS
      REAL   IMPA,LZSN,INFP,ICMN,ICMX
      REAL HRDIST(24),LAT,LONG,IAREA,THAREA(20,5),KGWF(20),ICPC(12)
      REAL SRSI,SDSI,UZSI,LZSI,GWSI,ICPTI(20),ICPTCN
      REAL PINF(20),PULP(20),ICPTM(20)
      REAL SLOPE(20),LENGTH(20),LC(20),TP(20),TB(20),RK(20),RX(20),INF2,
     1 EPAN(366),TMIN(366),TMAX(366),RAD(366),EVPCOR(12),PCOR(20,5),INF,
     1     UH(16),PREC(15,745),PR(744),ARRA(24)
      REAL LZSR,CT(20),CN(20),IAM2
      REAL MSFLO,MMF,MAXFLO,ICPT,IAM1,LZS,IFLO,MHFLO
      REAL SSS(9,11),PCMO(12)
C
C
C  COMMON BLOCKS FOR SUBROUTINES
      COMMON/MR/RELEV(25),Q2(25),SINT,ELINT,EFSD,COF,EGO,ICODE1,AA,B,C,N
     1HR,RRR(20),B0,B1,B2,B3,QCON,YRB,ECSD,COFF,DIV,STYR
      COMMON/MRT/S2(25),NNXX
      COMMON/PLT/IPTYPE,FACT,TFACT
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1        OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BOM/ SUM(33,20),IAM1,IAM2,ICPT(20),DELTA(20),WNUM(20),
     1 FRLZ(20),HLZS(20),ALZS(20),CORINF(20)
      COMMON /BCS/OUT(745),FIN(15,745),FLOW(745),FIN1(20),FIN2(20),
     1          DISTRO(20,900),NRCHS,SWSI(20),C0(20),C1(20),C2(20),
     1          NDIST(20),STRFLO(20,900),IFLO(744),BFLO(744),SRO(744),
     1          OUTED(20),RCHI(20),NSO(20),KPL(12,31),NRO(20)
      COMMON /BCSOY/ FLOT(34,12),MSFLO(2,366),NRCOWS(20),IPFRN(20),
     1                CPTS(20),
     1          NPLOT,DPLOT(50),MPLOT(50),HFLO(50,24),PLTNO(50),NOUNQ,
     1          MRN(20),IBUF(1008),MMF(13),CUMA(20),TOT(33,13),STI(8),
     1          MAXFLO(20),XPLT(744),NOSFO,ILY,MONF,NMR,PEAK(20,30),
     1          MHFLO(50,24),IVARB1,IVARB2,PVC,VARC,NSTA,MDF,DIVRT(367)
      COMMON /PARM/ SWAREA(20),IMPA(20),FALZ(20),FHLZ(20),
     1      PSRP(20),PSDP(20),ICMN(20),ICMX(20),SRSN(20),SDSN(20),
     1      UZSN(20),LZSN(20),GWSF(20),PPIF(20),PSUP(20),
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   1      PPUL(20),PLGP(20),PDGP(20),PLZU(20),TTM(20),
   1      INFP(20),BFP(20),EIP(20),EVP(20),ETGWP(20),SRSI(20),
   1      SDSI(20),UZSI(20),LZSI(20),GWSI(20),EZU,EZL,HEP
      COMMON /MP/DP(12,31)
C
      EQUIVALENCE (FIN(15,745),PREC(15,745))
C
C
CONSTANT DATA ARRAYS
C    ILY = 1 FOR LEAP YEAR
      DATA HRDIST/0.0,0.0,0.0,0.0,0.0,0.0,0.019,0.041,0.067,0.088,0.102,
     10.11,0.11,0.11,0.105,0.095,0.081,0.055,0.017,0.0,0.0,0.0,0.0,0.0/
      DATA UH/0.01,0.06,0.19,0.37,0.55,0.69,0.79,0.865,0.913,0.945,
     1        0.968,0.983,0.992,0.998,1.0,1.0/
      DATA ICPC/0.0,0.0,0.3,0.7,0.9,1.0,1.0,1.0,0.9,0.7,0.3,0.0/
C
C
C
C INPUT FORMATS
    1 FORMAT(I3,3F8.0/(3X,3F8.0))
    3 FORMAT(6F8.0,I8,2F8.0)
    9 FORMAT(8F10.5)
  570 FORMAT(10X,13HCHANNEL REACH,I3,21H FLOWS INTO FLOWPOINT ,I3,
     159H AND CONSISTS OF A RESERVOIR WITH THE FOLLOWING PARAMETERS:,/,
     115X,5HSINT=,F8.2,7H ELINT=,F8.2,6H EFSD=,F8.2,5H COF=,F8.2,5H EGO=
     1,F8.2,6H QCON=,F8.2,8H ICODE1=,I2,6H ECSD=,F6.0,/,15X,6HCOFF =,
     1F10.2,15X,5HDIV =,F10.2,/,15X,9HAA, B, C=,3F10.5,/,15X,15HB0, B1,
     1B2, B3=,4F15.5)
 1001 FORMAT(20I4)
 1002 FORMAT(4I4,16A4)
 1003 FORMAT(20A4)
 1004 FORMAT(10F8.0)
 1005 FORMAT(10F8.0)
 1006 FORMAT(//10X,20A4)
 1007 FORMAT(I8,9F8.0/(10F8.0))
 1008 FORMAT(/5X,28HPARAMETERS FOR SUBWATERSHED ,I2,5X,6HAREA =,F7.2/
     18X,'AREA PARAMETERS' /10X,'IMPA=',F7.2,3X,'FALZ=',F7.2,3X,'FHLZ=',
     2F7.2,3X,'PSRP=',F7.2,3X,'PSDP=',F7.2 /  8X,'STORAGE PARAMETERS'/
     310X,'ICMN=',F7.2,3X,'ICMX=',F7.2,3X,'SRSN=',F7.2,3X,'SDSN=',F7.3,
     43X,'UZSN=',F7.2,3X,'LZSN=',F7.2,3X,'GWSF=',F7.2 /
     58X,'DRAINAGE PARAMETERS' /10X,'PPIF=',F7.2,3X,'PSUP=',F7.2,3X,
     6'PPUL=',F7.3,3X,'PLGP=',F7.3,3X,'PDGP=',F7.3,3X,'PLZU=',F7.3 /
     710X,'TTM=',F8.2,3X,'INFP=',F7.3,3X,'KGWF=',F7.3 /
     88X,'EVAPOTRANSPIRATION PARAMETERS' /10X,'EIP=',F8.2,3X,'EVP=',
     9F8.2,3X,'ETGWP=',F6.2/)
 1010 FORMAT(5X,50HSURFACE RUNOFF DISTRIBUTION GRAPH FOR SUBWATERSHED ,
     1I3,4H FOR,I4,6H HOURS/(10X,10F8.3))
 1011 FORMAT(/5X,20HUNITGRAPH PARAMETERS/10X,6HSLOPE=,F7.2,3X,
     17HLENGTH=,F7.2,3X,4HLC =,F7.2,3X,4HTP =,F7.2,3X,4HTB =,F7.2,3X,
     24HCT =,F7.3,3X,4HCN =,F7.3/)
 1012 FORMAT(/5X,13HSUBWATERSHED ,I2,36H PARAMETERS SIMILAR TO SUBWATERS
     1HED ,I2, 8H, AREA =,F7.2/)
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1013 FORMAT(5X,30HCHANNEL SYSTEM CHARACTERISTICS /)
1014 FORMAT(10X,13HSUBWATERSHED ,I3,21H FLOWS INTO FLOWPOINT ,I3)
1015 FORMAT(10X,13HCHANNEL REACH,I3,21H FLOWS INTO FLOWPOINT ,I3,
    129H AND HAS MUSKINGUM K AND X = ,2F8.3)
1016 FORMAT(5X,9HRAINGAGE(,I3,46H) NUMBER, THEISSEN FRACTION AND CORREC
    1TION ARF,3(I5,2F6.3)/63X,3(I5,2F6.3))
1017 FORMAT(//5X,'INPUT DATA FOR ',I2,1H/,I2,4H TO ,
    1I2,1H/,I2,19H, FROM FILE NUMBER ,I2/10X,5H FOR ,20A4/10X,19HWITH I
    2NPUT OPTIONS ,20I4//)
1018 FORMAT(/5X,22HINITIAL STORAGE VALUES /10X,5HSRS =,F7.2,3X,5HSDS =,
    1F7.2,3X,5HUZS =,F7.2,3X,5HLZS =,F7.2,3X,5HGWS =,F7.2//)
1019 FORMAT(//5X,12HOPTION TABLE,1X,'/',1X,20I4/5X,13('-'),'/','-',
    1 20('----')/12X,5HINPUT,1X,'/',1X,20I4/12X,5H RUN ,1X,'/',1X,
    2 20I4/11X,6HOUTPUT,1X,'I',1X,20I4)
1020 FORMAT(5X,50HMONTHLY POTENTIAL EVAPORATION ADJUSTMENTS JAN-DEC /
    12X,12F6.2/)
1021 FORMAT(5X,21HSUBWATERSHED NUMBER =,3X,20I4)
1022 FORMAT(5X,21H IS LIKE SUBWATERSHED,3X,20I4)
1023 FORMAT(/1H0)
1024 FORMAT(//5X,36HTOTAL NUMBER OF SUBWATERSHEDS EQUALS ,I4/)
1025 FORMAT(2X,I7,3I3,I2,12F5.2)
1026 FORMAT(1X,I6,2I2,I1,11F6.2)
1027 FORMAT(1H1/5X,25HWATERSHED SIMULATION FOR ,16A4,5X,I2,1H/,I2,3H TO
    1,I3,1H/,I2//10X,7HAREA = ,F8.1,23H SQ.MI.     ELEVATION = ,F5.0,4X,
    211HLATITUDE = ,F6.2,5X,12HLONGITUDE = ,F6.2)
1028 FORMAT(I6,3I2,I1,12F3.2,29X,I2)
1029 FORMAT(2X,I7,3I3,I2,12F5.0)
1031 FORMAT(/5X,I4,13HSUBWATERSHED,,I4,10HRAINGAGES,,I4,26HGAGE HAS PCO
    1R AND THAREA =,2F10.3)
1032 FORMAT(1H1,5X,27HPRECIPITATION DATA FOR GAGE,I3,3H OF,I3,6H  FOR ,
    1A4,3H 19,I2//1X,3HDAY,I4,23I5,6H TOTAL)
1034 FORMAT(2X,6H  DATE,3I3,12F8.3/5X,17F7.3)
1035 FORMAT(/5X,9HSIMULATE ,A4,3H 19,I2,4H TO ,A4,3H 19,I2,5X,47HINPUT
    1HOURLY PRECIPITATION DATA ON FILE NUMBER ,I3//41X,49HINPUT DAILY P
    2OTENTIAL EVAPORATION ON FILE NUMBER ,I3//41X,47HINPUT MEASURED DAI
    3LY STREAMFLOW ON FILE NUMBER ,I3//)
1036 FORMAT(/5X,27HMEASURED DATA AT FLOWPOINT ,20I4)
1037 FORMAT(/5X,33HSELECTED DAYS FOR DETAILED OUTPUT )
1038 FORMAT(10X,10(I6,I3))
1039 FORMAT(1H1,5X,26HDAILY PAN EVAPORATION DATA//(5X,10F8.3))
1040 FORMAT(2X,10F12.6)
1041 FORMAT(10X,9HFLOWPOINT ,I3,7H DRAINS,F7.2,8H SQ. MI. )
1042 FORMAT(1X,I2,1X,24F5.2,F6.2)
1043 FORMAT(1H1//5X,25HPAN EVAPORATION DATA FOR ,14A4,3X,13HWATER YEAR
    119,I2,1H-,I2,18H(VALUES IN INCHES))
1044 FORMAT(//6X,3HDAY,1X,12(4X,A4)//)
1045 FORMAT(7X,I2,1X,12F8.3)
1046 FORMAT(10X,12(2X,6H------)/3X,5HTOTAL,F10.3,11F8.3)
1047 FORMAT(5I3,2F6.3,11F7.4,4F6.3)
1048 FORMAT(1H1/5X,39HDETAILED STORM OUTPUT FOR SELECTED DAYS //5X,4HDA
    1TE,6X,12H  PREC   SRIA,77H  ITCPT    INF   LSRS    LSDS     SRO    ISDS
    1   ISRS    PERC     EIS     ESR    EUZ ,24H  ICPT     SDS     SRS   UZS/)
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1050 FORMAT(///10X,'*** WARNING *** IF YOU ARE GOING TO INPUT HOURLY DA
    1TA FOR ',A4,I3/15X,'THEN YOU SHOULD ALSO SELECT THAT DAY FOR DETAI
    2LED OUTPUT ***')
1055 FORMAT(///10X,'*** WARNING *** NUMBER OF DAYS OF OBSERVED HOURLY H
    1YDROGRAPHS (',I3,') SHOULD EQUAL NUMBER OF DAYS SELECTED FOR DETAI
    2LED OUTPUT(',I3,')')
1056 FORMAT( /5X,'TIME INCREMENT FOR SIMULATION EQUALS',I3,' MINUTES.'
    1        /)
1057 FORMAT(1H1,5X,'MONTHLY POTENTIAL EVAPORATION ADJUSTMENTS OCT-SEP',
    12X,12F6.2/)
1059 FORMAT(2A4,2F8.0)
1060 FORMAT(I4,F6.0)
1061 FORMAT(12F6.0)
1717 FORMAT (I1,9X,I6,2X,3I2,8F7.0)
8888 FORMAT(//2X,'UGH---',5I4,I8,3E14.6)
9009 FORMAT(1H1,10X,7HEND RUN//)
9011 FORMAT(5X,20HRUN OPTIONS IMPROPER  ,20I4)
9012 FORMAT(5X,23HOUTPUT OPTIONS IMPROPER  ,20I4)
9013 FORMAT(5X,38HINPUT PARAMETER DATA FOR SUBWATERSHED ,I2,11H IMPROPE
    1R  )
9014 FORMAT(5X,34HSENSITIVITY COEF. OPTIONS IMPROPER ,20I4)
9015 FORMAT(5X,43HSUBWATERSHED AREA INFORMATION IMPROPER FOR ,I3)
9016 FORMAT(5X,43HINPUT FOR SUBWATERSHED ROUTING IMPROPER FOR,I3)
9017 FORMAT(5X,33HNO INPUT FOR SUBWATERSHED ROUTING )
9018 FORMAT(5X,12HDATA ON FILE,I3,27H DOES NOT BEGIN UNTIL WY 19,I2)
9019 FORMAT(5X,37HINPUT INDEX NUMBER FROM FILE IMPROPER )
9020 FORMAT(5X,I4,26H IS TOO MANY SUBWATERSHEDS )
9021 FORMAT(5X,35HA WATERSHED PARAMETER IS TOO LARGE  /10X,13F8.4)
9022 FORMAT(5X,13HSUBWATERSHED ,I3,23H HAS TOO MANY RAINGAGES )
9023 FORMAT(5X,38HSUM OF THIESSEN AREAS OF SUBWATERSHED ,I3,20H DOES NO
    1T EQUAL ONE. )
9024 FORMAT(5X,5HMONTH,I3,7H OR DAY,I3,51H INVALID FOR HOURLY HYDROGRAP
    1H OUTPUT SPECIFICATION )
9025 FORMAT(5X,44HINPUT ON START AND END OF RUN INCONSISTANT, ,I3,
    11H/,I3,3H - ,I3,1H/,I3)
9026 FORMAT(5X,32HHOURLY DATA FROM CARDS FOR MONTH,I4,5X,24HCOMPUTER TH
    1INKS MONTH IS,I3)
9027 FORMAT(5X,22HINPUT OPTIONS IMPROPER  ,20I4)
9028 FORMAT(5X,13HMONTH NUMBERS,2I4,9H IMPROPER )
9031 FORMAT(5X,45HMUSKINGUM ROUTING CONSTANT TO LARGE FOR REACH ,I3,22H
    1, PRODUCT OF CONSTANTS ,F8.2,6H TIMES,F8.2,23H MUST BE LESS THAN 0
   2.5 )
9032 FORMAT(5X,45HMUSKINGUM ROUTING CONSTANT TO SMALL FOR REACH ,I3,36H
    1 K - KX MUST GREATER THAN 0.5 , K = ,F8.2,5H X = ,F8.2)
9034 FORMAT(5X,10HTOTAL AREA,F8.2,41H MUST EQUAL SUM OF AREAS OF SUBWAT
    1ERSHED ,/(10X,10F8.2))
9035 FORMAT(5X,29HUNIT HYDROGRAPH BASE TIME OF ,I3,17H HOURS TOO LARGE.
    1 )
9036 FORMAT(5X,46HPRECIPITATION CORRECTION FACTORS UNREASONABLE  /
    1(10X,10F10.3))
9037 FORMAT(5X,43HEVAPORATION CORRECTION FACTOR UNREASONABLE  /
    1(10X,10F10.4))
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9038 FORMAT(5X,43HAREA UNDER UNIT HYDROGRAPH FOR SUBWATERSHED,I3,14H NO
    1T EQUAL ONE /(10X,10F10.4))
9039 FORMAT(5X,I4,34HREACHES IS TOO MANY, MAXIMUM IS 7. )
9040 FORMAT(5X,5HREACH,I3,30H FLOWS INTO NON-EXISTANT REACH ,I6)
9041 FORMAT(5X,12HSUBWATERSHED,I3,30H FLOWS INTO NON-EXISTANT REACH,I6)
9944 FORMAT(5X,'TIME INCREMENT IN MINUTES MUST DIVIDE EVENLY INTO 60( R
    1UN OPTION 5).',I4,' MINUTES DOES NOT.')
     IFILE1 = 0
     IFILE2 = 0
     IFILE3 = 0
     DO 7010 J=1,33
     DO 7010 I=1,20
     SUM(J,I) = 0.0
7010 CONTINUE
     DO 7009 J=1,12
     DO 7802 I=1,34
     FLOT(I,J)=0.0
7802 CONTINUE
     DO 7009 I=1,31
     DP(J,I)=0.0
     KPL(J,I)=0
7009 CONTINUE
     DO 7007 J=1,20
     PSN(J)=0
     PEN(J)=0
     IPERN(J)=0
     FIN1(J)=0.0
     FIN2(J)=0.0
     DO 7007 I=1,900
     DISTRO(J,I)=0.0
     STRFLO(J,I)=0.0
7007 CONTINUE
     DO 7008 J=1,15
     DO 7008 I=1,745
     PREC(J,I)=0.0
7008 CONTINUE
     DO 7803 I=1,744
     OUT(I)=0.0
     IFLO(I)=0.0
     BFLO(I)=0.0
     SRO(I)=0.0
7803 CONTINUE
     DO 7804 I=1,366
     DIVRT(I)=0.0
     DO 7804 J=1,2
     MSFLO(J,I)=0.0
7804 CONTINUE
     DIVRT(367)=0.0
     OUT(745)=0.0
     DO 7006 J=1,20
     OUTED(J)=0.0
     DO 7006 I=1,5
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      INRG(J,I)=0
 7006 CONTINUE
      DO 7001 I=1,24
      ARRA(I)=0.0
 7001 CONTINUE
 7003 CONTINUE
      DO 7004 I=1,20
      RRR(I)=0
      NUMI(I)=0
      RX(I)=0.0
      RK(I)=0.0
      RCHI(I)=0
      SWSI(I)=0
      MRN(I)=0
      NRCOWS(I)=0
      SWAREA(I)=0.0
      NRGSW(I)=0
      SWLIKE(I)=0
 7004 CONTINUE
C INPUT INFORMATION ON THE PURPOSE OF THE RUN
      DO 2 I = 1,3
       READ(5,1003) (INFO(N),N=1,20)
       WRITE(6,1006) (INFO(N),N=1,20)
    2 CONTINUE
C INPUT  RUN OPTIONS
  101 READ(5,1001) (IDXD(K),K=1,20)
      IF(IDXD(1).LT.1.OR.IDXD(1).GT.20) GO TO 9997
      DO 11 N=1,20
   11 OPTR(N) = 0
      DO 12 N=1,20
      IF(IDXD(N).LT.1) GO TO 14
      M = IDXD(N)
      IF(M.GT.20) GO TO 9997
   12 OPTR(M) = 1
   14 CONTINUE
C INPUT OPTIONS FOR OUTPUT
   22 READ(5,1001) (IDXD(N),N=1,20)
      IF(IDXD(1).GE.1.AND.IDXD(1).LE.20)  GO TO 25
      IF(OPTR(6).NE.1) GO TO 9996
   25 CONTINUE
      DO 23 N=1,20
   23 OPTO(N) =0
      DO 24 N=1,20
      IF(IDXD(N).LT.1) GO TO 26
      M = IDXD(N)
      IF(M.GT.20) GO TO 9996
   24 OPTO(M) = 1
   26 CONTINUE
C  INPUT OPTIONS FOR INPUT DATA
      READ(5,1001) (IDXD(N),N=1,20)
      IF(IDXD(1).LT.1.OR.IDXD(1).GT.20) GO TO 9981
      DO 7 N = 1,20
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    7 OPTI(N) = 0
      DO 6 N = 1,20
      IF(IDXD(N).LT.1) GO TO 5
      M = IDXD(N)
      IF(M.GT.20) GO TO 9981
    6 OPTI(M) = 1
    5 CONTINUE
    8 CONTINUE
C BEGIN WATERSHED INPUT INFORMATION
      READ(5,1002)STMO,STYR,ENDM,ENDY,(NAME(N),N=1,16)
C                  STMO,STYR = MONTH AND LAST TWO DIGITS OF YEAR
C                              WHEN SIMULATION BEGINS
C                  ENDM,ENDY = MONTH AND LAST TWO DIGITS OF YEAR
C                              OF MONTH SIMULATION ENDS
C                  NAME(N) =   NAME OF WATERSHED
      IF((STMO + ENDM).GT.24) GO TO 9983
      IF(STYR.GT.ENDY.OR.STYR.GT.99) GO TO 9983
      IENDR = 100*ENDY + ENDM
      READ(5,1004)ELEV,LAT,LONG,AREA
C INPUT INFORMATION ON SUBWATERSHED SYSTEM
      READ(5,1001) NSUBWS,(SWLIKE(N),N=1,NSUBWS)
C                   NSUBWS = NUMBER SUBWATERSHEDS
C                   SWLIKE = N IF SUBWATERSHED UNIQUE
C                   SWLIKE = NUMBER OF ANOTHER SUBWATERSHED IF ITS INPUT
C                            AND RESPONSE IS SIMILAR
C INPUT INFORMATION ON UNIQUE SUBWATERSHEDS
      NOUNQ = 0
      DO 30 N= 1,NSUBWS
      IF(SWLIKE(N).NE.N) GO TO 30
      NOUNQ = NOUNQ + 1
      READ(5,1001) (NUM,(INRG(N,K),K=1,NUM))
      READ(5,1004) (THAREA(N,K),K=1,NUM)
      READ(5,1004) (PCOR(N,K),K=1,NUM)
      NRGSW(N) = NUM
      IF(NRGSW(N).GT.5) GO TO 9986
      ST = 1.0
      DO 29 K=1,NUM
      IF(PCOR(N,K).GT.3.0.OR.PCOR(N,K).LT.0.3) GO TO 9972
   29 ST = ST - THAREA(N,K)
      IF(ABS(ST).GT.0.001) GO TO 9985
   30 CONTINUE
      IF(NSUBWS.GT.20) GO TO 9988
C              NUM,NRGSW(N) = NUMBER OF RAINGAGES FOR SUBWATERSHED N
C              INRG(N,K) = INDEX NUMBER FOR THE K PRECIPITATION GAGES FOR
C                          SUBWATERSHED N
C              THAREA(N,K) = THIESSEN AREA OF SUBWATERSHED N AND RAINGAGE
C                     PCOR(N,K) = PRECIPITATION CATCH CORRECTION FOR
C                                 SUBWATERSHED N AND RAINGAGE K
C INPUT SUBWATERSHED PARAMETERS
      DO 40 N= 1,NSUBWS
      IF(SWLIKE(N).NE.N) GO TO 40
      READ(5,1001) LIKN
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C                   LIKN = NUMBER OF THE UNIQUE SUBWATERSHED HAVING THE
C                               FOLLOWING INPUT PARAMETERS
      IF(LIKN.NE.N) GO TO 9995
C  INPUT AREA FACTORS
      READ(5,1005)SWAREA(N),IMPA(N),FALZ(N),FHLZ(N),PSRP(N),PSDP(N)
C  INPUT STORAGE FACTORS
      READ(5,1005)ICMN(N),ICMX(N),SRSN(N),SDSN(N),UZSN(N),LZSN(N),
     1             GWSF(N)
C  DRAINAGE   PARAMETERS
      READ(5,1005) PPIF(N),PSUP(N),PPUL(N),PLGP(N),PDGP(N),PLZU(N),
     1              TTM(N),INFP(N),KGWF(N)
C  EVAPOTRANSPIRATION PARAMETERS
      READ(5,1005) EIP(N),EVP(N),ETGWP(N)
C        INPUT INITIAL VALUES
      READ(5,1005) SRS(N),SDS(N),UZS(N),LZS(N),GWS(N)
      ICPTI(N)= 0.0
      SRSI(N) = SRS(N)
      SDSI(N) = SDS(N)
      UZSI(N) = UZS(N)
      LZSI(N) = LZS(N)
      GWSI(N) = GWS(N)
       HLZS(N) = LZS(N)
      ALZS(N) = LZS(N)
      FRLZ(N) = 1.0 - FALZ(N) - FHLZ(N)
      INITST = 0
      BFP(N) = 1.0 - KGWF(N)**0.04167
      IF(IMPA(N).GT.1.0) GO TO 9987
      IF(PSRP(N).GT.1.0)  GO TO 9987
      IF(EIP(N).GT.1.0)   GO TO 9987
      IF(PSDP(N).GT.1.0)  GO TO 9987
      IF(KGWF(N).GT.1.0) GO TO 9987
      IF(BFP(N).GT.1.0) GO TO 9987
      IF(PDGP(N).GT.1.0)  GO TO 9987
      IF(FALZ(N)+FHLZ(N).GT.1.001)  GO TO 9987
      IF(TTM(N).GT.1.0)  GO TO 9987
      ICPT(N)= 0.0
   40 CONTINUE
C INPUT INFORMATION FOR REMAINING SUBWATERSHEDS
      DO 41 N=1,NSURWS
      IF(SWLIKE(N).EQ.N) GO TO 41
      READ(5,1007) LIKN,SWAREA(N)
      IF(LIKN.NE.N) GO TO 9993
   41 CONTINUE
      CHK = AREA
      DO 341 N = 1,NSUBWS
  341 CHK = CHK - SWAREA(N)
      CHK = CHK/AREA
      IF(ABS(CHK).GT.0.01) GO TO 9974
C  INPUT IF RUN OPTION 5 SELECTED
      IMIN = 15
      IF(OPTR(5).NE.1) GO TO 539
      READ(5,1001) IMIN
```

```
      IF(IMIN.GT.60) IMIN = 60
      IF(MOD(60,IMIN).EQ.0) GO TO 539
      GO TO 9964
  539 CONTINUE
      RDMIN = 60/IMIN
      DELMIN = 1.0/RDMIN
C        INPUT MONTHLY EVAPORATION CORRECTION
      IF(OPTI(17).NE.1) GO TO 38
      READ(5,1004) (EVPCOR(M),M=1,12)
      DO 441 M = 1,12
      IF(EVPCOR(M).GT.3.0.OR.EVPCOR(M).LT.0.001) GO TO 9971
  441 CONTINUE
      GO TO 536
   38 DO 37 M=1,12
   37 EVPCOR(M) = 1.0
  536 CONTINUE
C     INPUT FOR CARD OUTPUT OF ANNUAL VOLUMES
      IF(OPTO(15).EQ.1)  READ(5,1059) IVARB1,IVARB2,PVC,VARC
C    INPUT FOR OUTPUT OPTION 16
      IF(OPTO(16).EQ.1) READ(5,1028) NSTA
C INPUT CHANNEL SYSTEM INFORMATION IF CHANNEL FLOW SIMULATION DESIRED
      IF(OPTR(2).NE.1) GO TO 34
C        INPUT DATA NECESSARY FOR SUBWATERSHED ROUTING
      ICK=0
      IF(OPTI(15).NE.1) GO TO 44
      DO 42 N=1,NSUBWS
      READ(5,1007) NUM,(DISTRO(N,K),K=1,NUM)
C           DISTRO(N,K) = HOURLY ORDINATES OF DISTRIBUTION GRAPH FOR
C                         SURFACE RUNOFF FOR SUBWATERSHED N
      SDZ = 1.0
      NOZ = N
      DO 442 K = 1,NUM
  442 SDZ = SDZ - DISTRO(N,K)
      IF(ABS(SDZ).GT.0.011) GO TO 9970
   42 NDIST(N) = NUM
      ICK=1
   44 IF(OPTI(16).NE.1) GO TO 48
      READ(5,1004) CT(1),CN(1)
      DO 46 N = 1,NSUBWS
      CT(N) = CT(1)
      CN(N) = CN(1)
      READ(5,1007)LIKN,SLOPE(N),LENGTH(N),LC(N),TP(N),TB(N)
      IF(TP(N).GT.0.01)  GO TO 544
      TP(N) = CT(1)*(LENGTH(N)*LC(N)/SQRT(SLOPE(N)))**CN(1)
      TP(N) = TP(N) + 0.25*(1.0-0.182*TP(N))
  544 TB(N) = TP(N)*3.75
C         CT,CN = CONSTANTS OF BASIN LAG EQUATION
C         INPUT SLOPE,LENGTH,LENGTH TO CENTROID,TIME TO PEAK, AND TIME
C                 BASE FOR CALCULATION OF DISTRIBUTION GRAPH
      NUM = TB(N) + 0.5
      IF(NUM.GT.1) GO TO 436
      NUM = 1
```

```
      NDIST(N) = 1
      DISTRO(N,1) = 1.0
      GO TO 46
  436 NDIST(N) = NUM
      DUH = 0.0
      DNM = NUM
      DO 36 M = 1,NUM
      DM = M
      DN = 15.0*DM/DNM
      NN = DN
      D = NN
      DIF = DN - D
      DISTRO(N,M) = DUH
      DUH = UH(NN) + DIF*(UH(NN+1)-UH(NN))
   36 DISTRO(N,M) = DUH - DISTRO(N,M)
      IF(LIKN.NE.N) GO TO 9992
   46 CONTINUE
      ICK=1
   48 IF(ICK.EQ.0) GO TO 9991
C        INPUT DATA NECESSARY FOR CHANNEL ROUTING
      READ(5,1007) NRCHS,(RK(N),N=1,NRCHS)
      IF(NRCHS.GT.7) GO TO 9969
      IF(NRCHS.LE.0) GO TO 434
      READ(5,1004) (RX(N),N=1,NRCHS)
      READ(5,1001) (RCHI(N),N=1,NRCHS)
      READ(5,1001) (SWSI(N),N=1,NSUBWS)
      NFLPT = NRCHS + 1
      DO 448 N = 1,NRCHS
      NOZ = N
      IF(RCHI(N).GT.NFLPT) GO TO 9968
  448 CONTINUE
      DO 449 N = 1,NSUBWS
      NOZ = N
      IF(SWSI(N).GT.NFLPT) GO TO 9967
  449 CONTINUE
C        RK(N),RX(N) = MUSKINGUM ROUTING CONSTANTS FOR REACH N
C        THE TOP OF EACH REACH HAS A FLOWPOINT WITH THE SAME NUMBER
C        AS THE REACH. THE BOTTOM OF THE LAST REACH IS FLOWPOINT NRCHS+1.
C        NRCHS = TOTAL NUMBER OF REACHS = NUMBER OF FLOWPOINTS - 1
C        RCHI(N) = NUMBER OF THE FLOWPOINT TO WHICH REACH N FLOWS
C        SWSI(N) = NUMBER OF THE FLOWPOINT TO WHICH SUBWATERSHED N FLOWS
      READ(5,1001) (NRO(N),N=1,20)
  434 READ(5,1001) (NSO(N),N=1,20)
C
C
      IF(OPTR(19).NE.1)GO TO 7399
      READ(5,1001)(RRR(N),N=1,20)
      READ(5,9)AA,B,C,B0,B1,B2,B3,COFF
      READ(5,1)NNXX,(RELEV(I),O2(I),S2(I),I=1,NNXX)
      READ(5,3)SINT,ELINT,EFSD,COF,EGO,QCON,ICODE1,ECSD,DIV.
 7399 IF(OPTO(18).NE.1)GO TO 34
      READ(5,1001)(PSN(N),N=1,20)
```

```
      READ(5,1001)(PFN(N),N=1,20)
C                      NSO(N) = NUMBER OF THE SUBWATERSHED FOR WHICH
C                               OUTPUT IS DESIRED. LAST NO.MUST EXCEED 20.
C                      NRO(N) = NUMBER OF THE REACHS FOR WHICH OUTPUT
C                                IS DESIRED. LAST NUMBER MUST EXCEED 20.
C
C                        PSN(N)=NUMBER OF SUBWATERSHEAD FOR WHICH
C                        A PRINTER PLOT OF SIMULATED FLOW IS
C                        DESIRED. LAST NUMBER SHOULD EXCEED 20.
C                        PFN(N)=NUMBER OF  FLOWPOINT    FOR WHICH
C                        A PRINTER PLOT OF SIMULATED FLOW IS
C                        DESIRED. LAST NUMBER SHOULD EXCEED 20.
      I=1
      DO 7400 N=1,20
      IF(PSN(N).GT.20)GO TO 7401
      IPFRN(I)=PSN(N)
      I=I+1
 7400 CONTINUE
 7401 CONTINUE
      DO 7402 N=1,20
      IF(PFN(N).GT.20)GO TO 7403
      IPFRN(I)=-PFN(N)
      I=I+1
      IF(I.GE.20)GO TO 7403
 7402 CONTINUE
 7403 CONTINUE
C        IPFRN(N)=NUMBER OF FLOWPOINT IF NEG OR SUBWATERSHED IF POS FOR
C          N'TH PLOT
C
C
CALCULATION OF CONSTANTS
   34 IAREA = 1.0/AREA
      NUMYR = 0
      ICNT = 0
      DO 28 N = 1,20
   28 CUMA(N) = 0.0
      DO 32 N = 1,NSUBWS
      DO 328 K=1,900
  328 STRFLO(N,K) = 0.0
      NSI = SWSI(N)
   32 CUMA(NSI) = CUMA(NSI) + SWAREA(N)
      IF(NRCHS.LT.1) GO TO 333
      DO 31 N = 1,NRCHS
      NRI = RCHI(N)
      FIN2(N) = 0.0
   31 CUMA(NRI) = CUMA(NRI) + CUMA(N)
      FIN2(NRCHS+1) = 0.0
      DO 33 N = 1,NRCHS
      XK = RK(N)*RX(N)
      DDD = RK(N) - XK + 0.5
      NOZ = N
      IF(XK.GT.0.5) GO TO 9977
```

```
      IF(RK(N)-XK.LF.0.5)  GO TO 9976
      C0(N) = -(XK-0.5)/DDD
      C1(N) = (XK + 0.5)/DDD
   33 C2(N) = (RK(N)-XK-0.5)/DDD
  333 CONTINUE
      NHR = 744
      DO 35 N =1,8
   35 STI(N) = 0.0
      DO 335 N = 1,12
  335 PCMO(N) = 1.0
C OUTPUT OF WATERSHED SYSTEM PARAMETERS AND CHARACTERISTICS
      WRITE(6,1027)(NAME(N),N=1,16),STMO,STYR,ENDM,ENDY,AREA,ELEV,LAT,
     1LONG
      WRITE(6,1019) (K,K=1,20),(OPTI(K),K=1,20),(OPTR(K),K=1,20),(OPTO(K
     1),K=1,20)
      WRITE(6,1024) NSUBWS
      WRITE(6,1056) IMIN
      WRITE(6,1021) (K,K=1,NSUBWS)
      WRITE(6,1022) (SWLIKF(N),N=1,NSUBWS)
      DO 49 N = 1,NSUBWS
      IF(SWLIKE(N).NE.N) GO TO 47
      WRITE(6,1008) N,SWAREA(N),IMPA(N),FALZ(N),FHLZ(N),PSRP(N),PSDP(N),
     1             ICMN(N),ICMX(N),SRSN(N),SDSN(N),UZSN(N),LZSN(N),
     2             GWSF(N), PPIF(N),PSUP(N),PPUL(N),PLGP(N),PDGP(N),
     3             PLZU(N),TTM(N),INFP(N),KGWF(N),EIP(N),EVP(N),ETGWP(N)
      WRITE(6,1018) SRS(N),SDS(N),UZS(N),LZS(N),GWS(N)
      NUM = NRGSW(N)
      WRITE(6,1016) NRGSW(N),(INRG(N,K),THAREA(N,K),PCOR(N,K),K=1,NUM)
      WRITE(6,1023)
      GO TO 45
   47 WRITE(6,1012) N,SWLIKE(N),SWAREA(N)
   45 IF(OPTR(2).NE.1) GO TO 49
      NUM = NDIST(N)
      WRITE(6,1010) N,NUM,(DISTRO(N,K),K=1,NUM)
   43 IF(OPTI(16).NE.1) GO TO 49
      WRITE(6,1011) SLOPE(N),LENGTH(N),LC(N),TP(N),TR(N),CT(N),CN(N)
      IF(NUM.GT.48)  GO TO 9973
   49 CONTINUE
      IF(OPTI(17).EQ.1) WRITE(6,1020) (EVPCOR(K),K=1,12)
C     OUTPUT CHANNEL SYSTEM CHARACTERISTICS
      IF(OPTR(2).NF.1) GO TO 59
      WRITE(6,1013)
      DO 52 N=1,NSURWS
   52 WRITE(6,1014) N,SWSI(N)
      IF(NRCHS.LE.0) GO TO 59
      I=1
      DO 56 N= 1,NRCHS
      IF(RRR(I).NE.N)GO TO 560
      WRITE(6,570)N,RCHI(N),SINT,ELINT,EFSD,COF,EGO,QCON,ICODE1,ECSD,
     1COFF,DIV,AA,B,C,B0,B1,B2,B3
      I=I+1
      GO TO 56
```

```
  560 WRITE(6,1015) N,RCHI(N),RK(N),RX(N)
   56 CONTINUE
      I=0
      DO 556 N = 1,NFLPT
  556 WRITE(6,1041) N,CUMA(N)
   59 CONTINUE
C FINISHED WATERSHED INPUT LOOP - BEGIN ANNUAL LOOPS FOR ABOVE WATERSHED
C
C     DEFINITION OF INPUT DEVICES
C     PRECIPITATION DATA    FILENO----V
C     POTENTIAL EVAPOTRANSPIRATION DATA  FILEVP----IV
C     MEASURED STREAMFLFOW DATA  FILEQ----IIV
C
   50 READ(5,1001) MONB, YRB, MONE, YRE, FILENO,FILEVP,FILEQ
      IRPT=0
C   INPUT MONTHLY EVAPORATION CORRECTION
      IF(OPTI(14).NE.1) GO TO 5053
      READ(5,1004)(EVPCOR(M),M=10,12),(EVPCOR(M),M=1,9)
      WRITE(6,1057)(EVPCOR(M),M=10,12),(EVPCOR(M),M=1,9)
      DO 5052 M = 1,12
      IF(EVPCOR(M).GT.3.0.OR.EVPCOR(M).LT.0.0001) GO TO 9971
 5052 CONTINUE
 5053 CONTINUE
      IF(OPTI(4).EQ.1)READ(5,1004)(PCMO(M),M=10,12),(PCMO(M),M=1,9)
      START = 100*YRB +MONB
      ENDR  = 100*YRE +MONE
      IF(MONE.LT.1.OR.MONE.GT.13) GO TO 9980
      V = FILENO
      IV = FILEVP
      IIV = FILEQ
      IF(FILENO.LE.0) V = 5
      IF(FILEVP.LE.0) IV = 5
      IF(FILEQ.LE.0)IIV = 5
      WRITE(6,1035)MOCHAR(MONB),YRB,MOCHAR(MONE),YRE,V,IV,IIV
C       INPUT MONTH AND DAY FOR DAYS SELECTED FOR DETAILED OUTPUT.
C       (LAST DAY MUST EXCEED A VALUE OF 31.)
      IF(OPTO(2).NE.1) GO TO 159
      KKD = 0
      DO 156 M=1,12
      DO 156 N=1,31
  156 KPL(M,N) = 0
      WRITE(6,1037)
  157 READ(5,1001)((IK(I,J),I=1,2),J=1,10)
      WRITE(6,1038)((IK(I,J),I=1,2),J=1,10)
      DO 158 J=1,10
      IF(IK(2,J).GT.31) GO TO 159
      II = IK(1,J)
      JJ = IK(2,J)
      KKD = KKD + 1
      IF(II.GT.12) GO TO 9984
  158 KPL(II,JJ) = 1
      GO TO 157
```

```
  159 CONTINUE
      DO  144 J=1,50
      DO  144 K=1,24
  144 MHFLO(J.K) = 0.0
      DO 5044  K = 1,20
 5044 PEAK(K,5) = 0.0
  160 CONTINUE
      GO TO 357
C
C     BEGIN INPUT FOR DAILY POTENTIAL EVAPOTRANSPIRATION
C   INPUT DATA FROM CARDS, DISK, OR OTHER MAGNETIC INPUT DEVICE
C
  357 READ(IV,1026)NOSTA,JMO,JYR,JNZ,(ARRA(N),N=1,11)
      IF(IV.EQ.5) GO TO 3000
      IF(IFILE1.GT.0) GO TO 3000
      IF(JYR.GE.99) GO TO 357
      IF(JYR.LT.YRB) GO TO 357
      IF(JYR.EQ.YRB.AND.JMO.LT.MONB) GO TO 357
      IF(JYR.EQ.YRB.AND.JMO.EQ.MONB)IFILE1 = 1
 3000 IF(JMO.GT.12)  GO TO 510
C     LAST CARD FOR PAN EVAPORATION DATA SHOULD HAVE 99 IN COLUMN 10 +
      ILY =2
      IF(MOD(JYR,4).EQ.0) ILY = 1
      DO 358 N=1,11
      J = DAYS(ILY,JMO) +N + 10*(JNZ-1)
      IF (J.GT.366) GO TO 357
  358 EPAN(J) = ARRA(N)
      GO TO 357
  510 IF(OPTO(9).NE.1)  GO TO 359
C   OUTPUT PAN EVAPORATION DATA
      WRITE(6,1043) (NAME(N),N=1,14),YRB,YRE
      WRITE(6,1044) (MOCHAR(K),K=10,12),(MOCHAR(K),K=1,9)
      DO 285 M = 1,12
      ARRA(M)=0.0
  285 XPLT(M) = 0.0
       ILY=2
      IF(MOD(YRB,4).EQ.0.OR.MOD(YRE,4).EQ.0)  ILY=1
      DO 284 N = 1,31
      DO 283 M = 1,12
      MS = DAYS(ILY,M) + N
       IF(MS.GT.366)   MS=366
      ARRA(M) = EPAN(MS)
      IF(N.GT.LASTDA(ILY,M))   ARRA(M) = 0.0
  283 XPLT(M) = XPLT(M) + EPAN(MS)
  284 WRITE(6,1045) N,(ARRA(K),K=10,12),(ARRA(K),K=1,9)
      WRITE(6,1046) (XPLT(K),K=10,12),(XPLT(K),K=1,9)
C     INPUT MEASURED STREAMFLOW AT NOST GAGE SITES
  359 IF(OPTI(12).NE.1) GO TO 366
      READ(5,1001) NOST
      DO 363 K = 1,NOST
C
  360 READ(IIV,1717)IID,NOSTA,JYR,JMO,JNZ,(ARRA(N),N=1,8)
```

```
      IF(IID.EQ.1)READ(IIV,1717)IID
      IF(IID.EQ.2)READ(IIV,1717)IID,NOSTA,JYR,JMO,JNZ,(ARRA(N),N=1,8)
      IF(IIV.EQ.5) GO TO 3100
      IF(IFILE2.GT.0) GO TO 3100
      IF(JYR.GE.99) GO TO 360
      IF(JYR.LT.YRB) GO TO 360
      IF(JYR.EQ.YRB.AND.JMO.LT.MONB) GO TO 360
      IF(JYR.EQ.YRB.AND.JMO.EQ.MONB)IFILE2 = 1
 3100 IF(JMO.GT.12)GO TO 363
      ILY=2
      IF(MOD(JYR,4).EQ.0)ILY=1
      NN=8
      DO 361 N=1,NN
      J=DAYS(ILY,JMO)+N+8*(JNZ-1)
      IF (J.GT.366) GO TO 360
  361 MSFLO(K,J) = ARRA(N)
      GO TO 360
  363 CONTINUE
  366 CONTINUE
C       INPUT NUMBER OF SUBWATERSHEDS (+) ORDERED BY ABS VALUE THEN
C        NUMBER OF REACH (-) FOR WHICH MEASURED DATA IS INPUT.
      IF(OPTI(12).EQ.1) READ(5,1001) NMR,(MRN(N),N=1,NMR)
      IF(OPTI(19).EQ.1) READ(5,1001) MDF
      IF(OPTI(12).EQ.1) WRITE(6,1036) (MRN(N),N=1,NMR)
C       INPUT STREAMFLOW DIVERSION
      IF(OPTI(19).NE.1) GO TO 286
C
  280 READ(5,1717)IID,NOSTA,JYR,JMO,JNZ,(ARRA(N),N=1,8)
      IF(IID.EQ.1)READ(5,1717)IID
      IF(IID.EQ.2)READ(5,1717)IID,NOSTA,JYR,JMO,JNZ,(ARRA(N),N=1,8)
      IF(JMO.GT.12)GO TO 286
      ILY=2
      IF(MOD(JYR,4).EQ.0)ILY=1
      NN=8
      DO 281 N=1,NN
      J=DAYS(ILY,JMO)+N+8*(JNZ-1)
      IF(J.GT.366)GO TO 280
C
  281 DIVRT(J) = ARRA(N)
  286 CONTINUE
  289 CONTINUE
C       INPUT NUMBER OF RAINGAGES TO BE READ EACH MONTH
C        NFOR - TYPE FORMAT 0=STANFORD MODEL, 1=WEATHER BUREAU
      READ(5,1001) NRGAGE,NFOR
C
C BEGIN YEAR OF SIMULATION
C
   58 DAY = 0
      MONTH = 9
      YEAR = YRB
      IF(MONB.LT.10) YEAR = YRB - 1
      NUMYR = NUMYR + 1
```

```
      DO 65 M = 1,13
      DO 65 N = 1,33
   65 TOT(N,M) = 0.0
      DO 365 N=1,20
      PEAK(N,NUMYR) =0.0
  365 MAXFLO(N) = 0.0
      NPLOT = 0
C
C BEGIN MONTHLY LOOP
C
   60 IF(MONTH.LT.12) GO TO 61
      YEAR = YEAR +1
      MONTH = 0
   61 MONTH = MONTH + 1
      DAY = 0
      YRMO = 100*YEAR + MONTH
      IF(YRMO.GT.ENDR) GO TO 199
 4460 CONTINUE
C  HOURLY PRECIPITATION READ FROM DEVICE V,  READ IN AS FILENO
  364 IF(YRMO.LT.START) GO TO 60
      DO 370 N=1,NRGAGE
C     AT LEAST ONE DATA CARD MUST EXIST FOR EACH MONTH EVEN IF ZEROS
      DO 368 K = 1,744
  368 PREC(N,K) = 0.0
  369 IF(NFOR.LT.1) READ(V,1025)NOSTA,JYR,JMO,JDY,NC,(ARRA(M),M=1,12)
      IF(NFOR.GE.1) READ(V,1028)NOSTA,JYR,JMO,JDY,NC,(ARRA(M),M=1,12)
      IF(V.EQ.5) GO TO 3200
      IF(IFILE3.GT.0) GO TO 3200
      IF(JYR.GE.99) GO TO 369
      IF(JYR.LT.YRB) GO TO 369
      IF(JYR.EQ.YRB.AND.JMO.LT.MONB) GO TO 369
      IF(JYR.EQ.YRB.AND.JMO.EQ.MONB)IFILE3 = 1
 3200 IF(JMO.GT.12) GO TO 370
C     LAST CARD EACH MONTH MUST HAVE 9 S IN COLUMNS 9 THRU 16
      IF(JMO.NE.MONTH) GO TO 9982
      DO 367 J=1,12
      JJ = 24*(JDY-1) + 12*(NC-1) + J
       IF(JJ.GT.744)  GO TO 369
  367 PREC(N,JJ) = ARRA(J)
      GO TO 369
  370 CONTINUE
  371 CONTINUE
      ILY = 2
      IF(MOD(YEAR,4).EQ.0) ILY= 1
      IF(OPTO(9).NE.1) GO TO 372
C   OUTPUT HOURLY PRECIPITATION DATA
      DO 373 N=1,NRGAGE
      WRITE(6,1032) N,NRGAGE,MOCHAR(MONTH),YEAR,(I,I=1,24)
      DO 373 M=1,31
      MM = 1 + (M-1)*24
      MMM = MM + 23
      TOTP = 0.0
```

```
      DO 374 K = MM,MMM
  374 TOTP = TOTP + PREC(N,K)
  373 WRITE(6,1042) M,(PREC(N,K),K=MM,MMM),TOTP
  372 CONTINUE
      IF(OPTO(11).EQ.0)  GO TO 462
      DO 463 K = 1,31
      IF(KPL(MONTH,K).GT.0)  GO TO 464
  463 CONTINUE
      GO TO 462
  464 WRITE(6,1048)
  462 CONTINUE
C
C BEGIN SUBWATERSHED  LOOP
C
      NSW =0
      ICKQ = 0
   62 IF(ICKQ.GT.1.AND.NOUNQ.GT.1) WRITE(4) NSW,(SPO(M),M=1,744),
     1        (IFLO(M),M=1,744),(BFLO(M),M=1,744)
   63 NSW = NSW +1
      IF(NSW.GT.NSUBWS) GO TO 106
C                   ALL SUBWATERSHEDS COMPLETE, CHECK FOR OUTPUT
      IF(SWLIKE(NSW).NE.NSW) GO TO 63
      MHR = 0
      ICKQ = 2
 4432 CONTINUE
C     ZERO SUMATION ARRAY
      DO 76 N = 1, 25
   76 SUM(N,NSW) = 0.0
C     CODE FOR N IS AS FOLLOWS'
C     1=INTERCEPTION, 3=DIRECT INFILTRATION, 4=LOSS TO SRS, 5=SURFACE RU
C     6=INFILTRATION SDS-UZS, 7=INFILTRATION SRS-UZS, 8=PERCOLATION UZS-
C     2=EVAP INTERCEPTION STORAGE, 9=EVAP SRS, 10=EVAP UZS, 11=EVAP LZS,
C     12=PERCOLATION LZS-GWS, 13=EVAP GWS, 14=INTERFLOW, 15= BASEFLOW,
C     16=PRECIPITATION, 17=UNDERFLOW, 25=BALANCE OF BUDGET EQUATION
C     18=POTENTIAL EVAPOTRANSPIRATION, 19=IMPERVIOUS AREA RUNOFF
C     21=SEEPAGE FROM RIDGE, 22=DIVERSIONS OUT, 23=TOT.SF, 24=TOT.ET,
C      26=SDS, 27=SRS, 28=UZS, 29=LZS-RIDGE, 30=GWS, 31=LZS-ALLUVIUM
C     32=LZS-HILLSIDE, 33=INTERCEPTION,
C     CONTINUE SIMULATION FOR UNIQUE SUBWATERSHED
C PRECIP FOR 2ND+ TIME THRU ON OPTIMIZATION
 4463 CONTINUE
C     CALCULATION OF THEISSEN AVERAGE PRECIPITATION FOR SUBWATERSHEDS
      DO 64 J = 1,744
   64 PR(J) = 0.0
      N = NRGSW(NSW)
      DO 66 I = 1,N
      K = INRG(NSW,I)
      PT = PCOR(NSW,I)*THAREA(NSW,I)
      DO 66 J = 1,744
   66 PR(J) = PR(J) + PREC(K,J)*PT
 4466 CONTINUE
      ID = DAYS(ILY,MONTH)
```

```
      DAY = 0
      IAM1 = 1.0 - IMPA(NSW)
      IAM2 = IAM1**0.7
      ICPTM(NSW) = ICMN(NSW) + ICPC(MONTH)*(ICMX(NSW)-ICMN(NSW))
      EZL = LZSN(NSW)*LZSN(NSW)/(LZSN(NSW)+UZSN(NSW))**2
      EZU = 1.0 - EZL
      RTAH = FRLZ(NSW)/(1.0-FRLZ(NSW))
      PINF(NSW) = PPIF(NSW)*CORINF(MONTH)*DELMIN
      PULP(NSW) =PPUL(NSW)*CORINF(MONTH)*DELMIN
C
C BEGIN DAILY  LOOP
C
   75 ID = ID +1
      DAY = DAY + 1
      IF(DAY.GT.LASTDA(ILY,MONTH))  GO TO 62
      HR = 0
C     CALCULATION OF DAILY EVAPORATION AND/OR TRANSPIRATION POTENTIALS
      EV = EPAN(ID)*EVPCOR(MONTH)
      TRP= EV
      IF(OPTI(19).EQ.1) TOT(22,MONTH) = TOT(22,MONTH) + DIVRT(ID)
      DP(MONTH,DAY) = 0.0
C
C BEGIN  HOURLY  LOOP
C
   80 HR = HR +1
      IF(HR.GT.24) GO TO 75
      MIN = 0
      MHR = MHR + 1
      SRO(MHR) = 0.0
      PR(MHR) = PR(MHR)*PCMO(MONTH)
      DP(MONTH,DAY) = DP(MONTH,DAY) + PR(MHR)*SWAREA(NSW)
      SUM(16,NSW) = SUM(16,NSW) + PR(MHR)
      HEP = EV*HRDIST(HR)
      SUM(18,NSW) = SUM(18,NSW) + EV*HRDIST(HR)
C
C  BEGIN IMIN-MINUTE LOOP
C
   85 MIN = MIN + IMIN
      IF(MIN.GT.60) GO TO 105
      PX = PR(MHR)*DELMIN
      PRM = PX
      LZSR = LZS(NSW)/LZSN(NSW)
      IF(LZSR.GT.1.0E-9.AND.LZSR.LT.1.0E9) GO TO 8889
      ICNT = ICNT + 1
      IF(ICNT.GT.50) CALL EXIT
      WRITE(6,8888)YEAR,MONTH,DAY,HR,MIN,NSW,LZSR,LZS(NSW),LZSN(NSW)
 8889 CONTINUE
      HLZSR = HLZS(NSW)/LZSN(NSW)
      ALZSR = ALZS(NSW)/LZSN(NSW)
      PLZSR=ALZSR*FALZ(NSW) +LZSR*FRLZ(NSW) +HLZSR*FHLZ(NSW)
      UZSR = UZS(NSW)/UZSN(NSW)
      IF(PX.LT.1.0E-12)  GO TO 86
```

```
C
C  IMPERVIOUS AREA SURFACE RUNOFF
C
         S19I = S19I + PX
      SRIA = IMPA(NSW)*PX
      SUM(19,NSW) = SUM(19,NSW) + SRIA
      SRO(MHR) = SRO(MHR) + SRIA
C
C   LOSS TO INTERCEPTION STORAGE AND INITIAL SURFACE WETTING
C
      CAP = ICPTM(NSW) - ICPT(NSW)
      IF(CAP.GT.PX) GO TO 87
      IF(CAP.LT.0.0) GO TO 86
      PX = PX - CAP
      SUM(1,NSW) = SUM(1,NSW) + CAP*IAM1
         S1I = S1I - CAP
      ICPT(NSW) = ICPTM(NSW)
      CPT = CAP
      GO TO 86
   87 ICPT(NSW) = ICPT(NSW) + PX
      SUM(1,NSW) = SUM(1,NSW) + PX*IAM1
         S1I = S1I - PX
      CPT = PX
      PX = 0.0
   86 CONTINUE
C
C   INFILTRATION LOSS TO UPPER ZONE STORAGE
C
      IF(PX.LT.1.0E-12)  GO TO 93
      INF2 = PINF(NSW)/2.0**(PSUP(NSW)*UZS(NSW)/UZSN(NSW))
      IF(PX.GT.INF2) INF = INF2 * 0.5
      IF(PX.LE.INF2) INF = PX - PX * PX/(2.0 * INF2)
      PX = PX - INF
      XIF = INF
      UZS(NSW) = UZS(NSW) + INF
      SUM(3,NSW) = SUM(3,NSW) + INF*IAM1
C
C   LOSS TO SURFACE DETENTION OR SURFACE RETENTION STORAGE
C
      IF(PX.LT.1.0E-12)  GO TO 93
      RTO = SRS(NSW)/SRSN(NSW)
      IF(RTO.LT.2.0) GO TO 89
      X = 2.0*ABS(RTO-2.0) + 1.0
      FRCT =(1.0/(1.0+X))**X
      GO TO 90
   89 X = 2.0*ABS(0.5*RTO-1.0) + 1.0
      FRCT = 1.0 - 0.5*RTO*(1.0/(1.0+X))**X
   90 PSRS = PSRP(NSW)*FRCT
      X = PX*PSRS
      SRX = X
      PX = PX - X
      SRS(NSW) = SRS(NSW) + X
```

```
      SUM(4,NSW) = SUM(4,NSW) + X*IAM1
C
C   PX = AMOUNT OF PRECIPITATION LEFT FOR SURFACE DETENTION STORAGE
C
   93 SDS(NSW) = SDS(NSW) + PX
      IF(SDS(NSW).LT.1.0E-12)  GO TO 95
      RO = SDS(NSW)*TTM(NSW)
      SDS(NSW) = SDS(NSW) - RO
      RO = RO*IAM1
      SRO(MHR) = SRO(MHR) + RO
      SUM(5,NSW)  = SUM(5,NSW) + RO
C
C   STORAGE DEPLETIONS - INFILTRATION OF SDS TO UZS
C
   95 IF(SDS(NSW).LT.1.0E-12)  GO TO 97
      PSDS = SDS(NSW)/SDSN(NSW)*PSDP(NSW)
          PSDSCN = PSDS
      IF(PSDS.GT.1.0) PSDS = 1.0
      SX = SDS(NSW)/PSDS
      IF(SX.GE.INF2) INF = INF2 * 0.5
      IF(SX.LT.INF2) INF = SX - SX*SX/(2.0 * INF2 )
      X=INF*PSDS
      SDX = X
      UZS(NSW) = UZS(NSW) + X
      SDS(NSW) = SDS(NSW) - X
      SUM(6,NSW) = SUM(6,NSW) + X*IAM1
      SRS3 = SRS(NSW)
C
C   STORAGE DEPLETIONS - INFILTRATION OF SRS TO UZS
C
          CPSRS = PSRS
          SRSCNS = SRS(NSW)
   97 IF(SRS(NSW).LT.1.0E-12)  GO TO 98
      PSRS = SRS(NSW)/SRSN(NSW)*PSRP(NSW)
          PSRSCN = PSRS
      IF(PSRS.GT.1.0) PSRS = 1.0
      SX = SRS(NSW)/PSRS
      IF(SX.GE.INF2) INF = INF2*0.5
      IF(SX.LE.INF2) INF = SX - SX*SX/(2.0*INF2)
      X = INF*PSRS
       SRXX = X
      UZS(NSW) = UZS(NSW) + X
       SRS(NSW) = SRS(NSW) - X
      SUM(7,NSW) = SUM(7,NSW) + X * IAM1
   98 CONTINUE
C
C   STORAGE DEPLETION - PERCOLATION FROM UZS TO LZS
C
      UX = 0.0
      IF(OPTR(11).NE.1) GO TO 980
C     ALTERNATE PERCOLATION FCN.
      IF(UZSR.LE.0.5) GO TC 982
```

```
      UX = (UZSR-0.5)
      IF(PLZSR.LE.0.5) GO TO 982
      UX = UX*(2.0-PLZSR)*0.6667
      IF(UX.LE.0.0) UX = 0.0
      GO TO 982
  980 CONTINUE
  982 CONTINUE
      IF(UZSR.GT.1.0) UX = 2.825 * SQRT(UZSR - 0.875 )
      IF(UZSR.LE.1.0.AND.UZSR.GT.0.5) UX =4.0*(UZSR-0.5)**2
      PERC = PULP(NSW)*UX
      PERX = PERC
      UZS(NSW) = UZS(NSW) - PERC
      PERC = PERC*IAM1
      SUM(8,NSW) = SUM(8,NSW) + PERC
      LZS(NSW) = LZS(NSW) + PERC/IAM2
      HLZS(NSW) = HLZS(NSW) + PERC/IAM2
      ALZS(NSW) = ALZS(NSW) + PERC/IAM2
C
C    RETURN FOR 15-MIN LOOP
      IF(OPTO(11).NE.1) GO TO 85
      IF(KPL(MONTH,DAY).LE.0) GO TO 85
      IF(PR(MHR).GT.0.01) GO TO 96
      IF(MIN.LT.60) GO TO 85
   96 WRITE(6,1047)YEAR,MONTH,DAY,HR,MIN,PRM,SRIA,CPT,XIF,SRX,PX,RO,SDX,
     1SRXX,PERX,EIS,ESR,EUZ,ICPT(NSW),SDS(NSW),SRS(NSW),UZS(NSW)
      CPT = 0.0
      SRIA = 0.0
      XIF = 0.0
      SRX = 0.0
      RO = 0.0
       SDX =0.0
       SRXX = 0.0
       ESR = 0.0
      EUZ = 0.0
       EIS = 0.0
      GO TO 85
C END 15-MINUTE LOOP - CONTINUE HOURLY LOOP
C    EVAPOTRANSPIRATION LOSSES
C
  105 CONTINUE
      IF(HEP.LT.1.0E-9)  GO TO 99
         ICPTCN = ICPT(NSW)
C
C     EVAPORATION LOSS OF INTERCEPTION STORAGE
C
      EIS = EIP(NSW)*ICPT(NSW)/ICPTM(NSW)*HEP
      IF(EIS.GT.ICPT(NSW)) EIS = ICPT(NSW)
      SUM(2,NSW) = SUM(2,NSW) + EIS*IAM1
      CI2 = ICPT(NSW)
      ICPT(NSW) = ICPT(NSW) - EIS
      HEP = HEP - EIS*IAM1
      HEP3 = HEP
```

```
      HEP2 = HEP
C
C     EVAPORATION LOSS FROM SURFACE RETENTION STORAGE
C
      ESR = HEP*PSRS
         ESRCN = ESR
         HEPCN = HEP
      IF(ESR.GT.SRS(NSW)) ESR = SRS(NSW)
      SRS2 = SRS(NSW)
         SRSCN = SRS(NSW)
      HEP = HEP - ESR*IAM1
      SRS(NSW) = SRS(NSW)   - ESR
      SUM(9,NSW) = SUM(9,NSW) + ESR*IAM1
C
C     EVAPOTRANSPIRATION FROM UZS AND LZS
C
C
      IF(HEP.LT.1.0E-9) GO TO 99
      UX = EVP(NSW)*SQRT(UZSR)
      IF(UX.GT.1.0)   UX = 1.0
      EUZ = HEP*EZU*UX
      IF(EUZ.GT.UZS(NSW)) EUZ = 0.5*UZS(NSW)
  993 CONTINUE
      SUM(10,NSW) = SUM(10,NSW) + EUZ*IAM1
      UZS(NSW) = UZS(NSW) -EUZ
      HEPE = HEP*EZL
      IF(LZSR.LT.1.0E-9.OR.LZSR.GT.1.0E9) WRITE(6,8888)YEAR,MONTH,DAY,
     1                      HR,MIN,NSW,LZSR,LZS(NSW),LZSN(NSW)
      FLX = EVP(NSW)*LZSR**0.8
      IF(FLX.GT.1.0) FLX = 1.0
      IF(FLX.GE.1.0) OPTZ=1.0
      IF(FLX.LT.1.0) OPTZ=2.0
      ELZ  = HEPE*FLX
      IF(ELZ.GT.LZS(NSW)) ELZ = 0.5*LZS(NSW)
      SUM(11,NSW) = SUM(11,NSW) + ELZ*IAM2*FRLZ(NSW)
      LZS(NSW) = LZS(NSW) - ELZ
      FLX = EVP(NSW)*HLZSR**0.8
      IF(FLX.GE.1.0) OPTY=1.0
      IF(FLX.LT.1.0) OPTY=2.0
      IF(FLX.GT.1.0) FLX = 1.0
      CLZ = HEPE*FLX
      IF(CLZ.GT.HLZS(NSW)) CLZ = HLZS(NSW)*0.5
      SUM(11,NSW) = SUM(11,NSW) + CLZ*IAM2*FHLZ(NSW)
      HLZS(NSW) = HLZS(NSW) - CLZ
      FLX = EVP(NSW)*ALZSR**0.8
      IF(FLX.GE.1.0) OPTX=1.0
      IF(FLX.LT.1.0) OPTX=2.0
      IF(FLX.GT.1.0) FLX = 1.0
      ALZ = HEPE*FLX
      IF(ALZ.GT.ALZS(NSW)) ALZ = 0.5*ALZS(NSW)
      SUM(11,NSW) = SUM(11,NSW) + ALZ*IAM2*FALZ(NSW)
      DIMPA = -1.2*((1.0 - IMPA(NSW))**0.2)
```

```
 4249 CONTINUE
      ALZS(NSW) = ALZS(NSW) - ALZ
      IF(MIN.NE.60)   GO TO 99
      ELZX = (FALZ(NSW)*ALZ+FHLZ(NSW)*CLZ+FRLZ(NSW)*ELZ)*IAM2 + EUZ*IAM1
      HEP = HEP - ELZX
C
   99 CONTINUE
C
C   PERCOLATION FROM ALZS TO GWS
C
      PERC = PLGP(NSW)*(ALZSR-0.5)
      IF(PERC.LT.0.0) PERC = 0.0
 1501 CONTINUE
      GWS(NSW) = GW$(NSW) + PERC*IAM2
      ALZS(NSW) = ALZS(NSW) - PERC
      SUM(12,NSW) = SUM(12,NSW) + PERC*IAM2*FALZ(NSW)
C
C     TRANSPIRATION FROM GROUNDWATER
C
      EGW = HEP*4.0*ETGWP(NSW)*GWS(NSW)
 1331 CONTINUE
      SUM(13,NSW) = SUM(13,NSW) + EGW *IAM2*FALZ(NSW)
      GWS(NSW) = GW$(NSW) - EGW*IAM2
C
C     LZS LOSS TO INTERFLOW
C
      XLX = 0.0
      IF(HLZSR.GT.0.5)XLX=INFP(NSW)*(0.8+0.2*(HLZSR-0.5))*(HLZSR-0.5)**2
 1791 CONTINUE
      HLZS(NSW) = HLZS(NSW) - XLX
      IFLO(MHR) = XLX*FHLZ(NSW)*IAM2
      SUM(14,NSW) = SUM(14,NSW) + IFLO(MHR)
C
C     GWS LOSS TO BASEFLOW
C
      BF = BFP(NSW)*(GWS(NSW)-GWSF(NSW))
      IF(BF.LT.0.0)  BF = 0.0
      GWS(NSW) = GW$(NSW) - BF
      BF = BF*FALZ(NSW)
      BFLO(MHR) = BF
 1793 CONTINUE
      SUM(15,NSW) = SUM(15,NSW) + BF
C
C     GWS LOSS TO UNDERFLOW
C
      IF(PDGP(NSW).LT.1.0E-9)  GO TO 103
      UF = PDGP(NSW)*GWS(NSW)
      IF(UF.LT.1.0E-9)  UF = 0.0
        CGWS = GWS(NSW)
      SUM(17,NSW) = SUM(17,NSW) + UF*FALZ(NSW)
      GWS(NSW) = GW$(NSW) - UF
C
```

```
C     LZS LOSS TO UNDERFLOW
C
  103 IF(PLZU(NSW).LT.1.0E-9)  GO TO 104
      UF = PLZU(NSW)*LZS(NSW)
      IF(UF.LT.1.0E-9)  UF = 0.0
      SUM(17,NSW) = SUM(17,NSW) + UF*IAM2*FRLZ(NSW)
 1771 CONTINUE
      LZS(NSW) = LZS(NSW) - UF
  104 CONTINUE
C
C    SEEPAGE - RIDGE LZS TO HILLSIDE AND ALLUVIUM
C
      IF(LZS(NSW).LT.LZSN(NSW))  GO TO 505
      SEEP = PULP(NSW)*(LZS(NSW)-LZSN(NSW))
      LZS(NSW) = LZS(NSW) - SEEP
      SUM(21,NSW) = SUM(21,NSW) + SEEP*IAM2*FRLZ(NSW)
      SEEP = SEEP*RTAH
      ALZS(NSW) = ALZS(NSW) + SEEP
      HLZS(NSW) = HLZS(NSW) + SEEP
  505 CONTINUE
C
C    RETURN FOR HOURLY LOOP
C
      IF(OPTO(10).NE.1) GO TO 80
      IF(HR.NE.12) GO TO 80
      IF(MIN.NE.60) GO TO 80
      WRITE(6,1034)NSW,YEAR,MONTH,DAY,(SUM(KN,NSW),KN=1,20),
     1ICPT(NSW),SDS(NSW),SRS(NSW),UZS(NSW),LZS(NSW),GWS(NSW)
      GO TO 80
C
C END HOURLY LOOP, DAILY LOOP, AND SUBWATERSHED LOOP
C
C BEGIN MONTHLY SUMS
C    CALCULATE AVERAGE STORAGE VALUES
  106 DO 122 L=1,NSUBWS
      LL = SWLIKE(L)
      DO 117 M = 1,21
  117 TOT(M,MONTH) = TOT(M,MONTH) + SUM(M,LL)*SWAREA(L)
      IAM1 = 1.0 - IMPA(LL)
      IAM2 = IAM1**0.7
      IF(SUM(29,1).GT.0.01) GO TO 107
      IF(SWLIKE(L).NE.L) GO TO 107
      SUM(26,L) =  SDSI(L)*IAM1
      SUM(27,L) =SRSI(L)*IAM1
      SUM(28,L) =UZSI(L)*IAM1
      SUM(29,L) = LZSI(L)*FRLZ(L)*IAM2
      SUM(31,L) = LZSI(L)*FALZ(L)*IAM2
      SUM(32,L) = LZSI(L)*FHLZ(L)*IAM2
      SUM(33,L) = ICPTI(L)*IAM1
      SUM(30,L) = GWSI(L)*FALZ(LL)
  107 CONTINUE
      IF(INITST.GE.1) GO TO 112
```

```
      STI(1) = STI(1) + SDSI(LL)*SWAREA(L)*IAREA
      STI(2) = STI(2) + SRSI(LL)*SWAREA(L)*IAREA
      STI(3) = STI(3) + UZSI(LL)*SWAREA(L)*IAREA
      STI(4) = STI(4) + LZSI(LL)*SWAREA(L)*IAREA
      STI(5) = STI(5) + GWSI(LL)*SWAREA(L)*IAREA
      STI(6) =  STI(4)
      STI(7) =  STI(4)
      STI(8) = STI(8) + ICPTI(LL)*SWAREA(L)*IAREA
  112 TOT(26,MONTH) = TOT(26,MONTH) + SDS(LL)*SWAREA(L)
      TOT(27,MONTH) = TOT(27,MONTH) + SRS(LL)*SWAREA(L)
      TOT(28,MONTH) = TOT(28,MONTH) + UZS(LL)*SWAREA(L)
      TOT(29,MONTH) = TOT(29,MONTH) + LZS(LL)*SWAREA(L)
      TOT(30,MONTH) = TOT(30,MONTH) + GWS(LL)*SWAREA(L)
      TOT(31,MONTH) = TOT(31,MONTH) + ALZS(LL)*SWAREA(L)
      TOT(32,MONTH) = TOT(32,MONTH) + HLZS(LL)*SWAREA(L)
      TOT(33,MONTH) = TOT(33,MONTH) + ICPT(LL)*SWAREA(L)
  122 CONTINUE
      IF(OPTI(19).EQ.1) TOT(22,MONTH) = TOT(22,MONTH)/26.9
      DO 522 J = 1,33
  522 TOT(J,MONTH) = TOT(J,MONTH)*IAREA
      DO 523 J = 1,31
  523 DP(MONTH,J) = DP(MONTH,J)*IAREA
      INITST = 1
  131 CONTINUE
C OUTPUT STORAGE AND FLOW TABLE EACH MONTH FOR ALL UNIQUE SUBWATERSHEDS
C     WHEN OUTPUT OPTION 5 SELECTED
      IF(OPTO(5).LE.0) GO TO 120
      CALL OUPTM
  120 CONTINUE
C BEGIN MONTH OF CHANNEL SIMULATION IF REQUESTED
  121 IF(OPTR(2).EQ.1) CALL CHSIM
C RETURN TO MONTHLY LOOP
      GO TO 60
C END MONTH AND YEAR OF SIMULATION
  199 CONTINUE
      I = 100*YEAR + 10
      IF(YRMO.EQ.I) GO TO 175
      IF(MONTH.LT.10) GO TO  172
      DO   171 N = MONTH,12
      DO   171 K = 1,32
  171 FLOT(K,N) = 0.0
      MONTH = 1
  172 CONTINUE
      DO   173 N = MONTH,9
      DO   173 K = 1,32
  173 FLOT(K,N) = 0.0
  175 CONTINUE
      DO 190 K = 1,22
      DO 190 N = 1,12
  190 TOT(K,13) = TOT(K,13) + TOT(K,N)
  198 CONTINUE
      CALL OUPTS
```

```
  195 CONTINUE
      IF(ENDR.LT.IENDR) GO TO 50
      GO TO 9999
C END YEAR OF SIMULATION - RETURN TO YEAR LOOP
C OUTPUT WHEN ERROR LOCATED IN INPUT DATA
 9997 WRITE(6,9011) (IDXD(N),N=1,20)
      GO TO 9999
 9996 WRITE(6,9012) (IDXD(N),N=1,20)
      GO TO 9999
 9995 WRITE(6,9013) LIKN
      GO TO 9999
 9994 WRITE(6,9014) (IDXD(N),N=1,20)
      GO TO 9999
 9993 WRITE(6,9015) LIKN
      GO TO 9999
 9992 WRITE(6,9016) LIKN
      GO TO 9999
 9991 WRITE(6,9017)
      GO TO 9999
 9990 WRITE(6,9018) FILENO,IDXD(1)
      GO TO 9999
 9989 WRITE(6,9019)
      GO TO 9999
 9988 WRITE(6,9020) NSUBWS
      GO TO 9999
 9987 WRITE(6,9021) IMPA(N),PSRP(N),EIP(N),PSDP(N),KGWF(N),
     1BFP(N),PDGP(N),FALZ(N),FHLZ(N),TTM(N)
      GO TO 9999
 9986 WRITE(6,9022) NUM
      GO TO 9999
 9985 WRITE(6,9023) NUM
      GO TO 9999
 9984 WRITE(6,9024) II,JJ
      GO TO 9999
 9983 WRITE(6,9023) STMO,STYR,ENDM,ENDY
      GO TO 9999
 9982 WRITE(6,9026) JMO,MONTH
      GO TO 9999
 9981 WRITE(6,9027) (IDXD(N),N=1,20)
      GO TO 9999
 9980 WRITE(6,9028) MONE,MONB
      GO TO 9999
 9977 WRITE(6,9031) NQZ,RK(NQZ),RX(NQZ)
      GO TO 9999
 9976 WRITE(6,9032) NQZ,RK(NQZ),RX(NQZ)
      GO TO 9999
 9974 WRITE(6,9034) AREA,(SWAREA(N),N=1,NSUBWS)
      GO TO 9999
 9973 WRITE(6,9035) NUM
      GO TO 9999
 9972 WRITE(6,9036) (PCOR(N,K),K=1,NUM)
      GO TO 9999
```

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9971 WRITE(6,9037) (EVPCOR(M),M=1,12)                              HWS1403
     GO TO 9999                                                    HWS1404
9970 WRITE(6,9038) NQZ,(DISTRO(NQZ,K),K=1,NUM)                     HWS1405
     GO TO 9999                                                    HWS1406
9969 WRITE(6,9039) NRCHS                                           HWS1407
     GO TO 9999                                                    HWS1408
9968 WRITE(6,9040) NQZ,RCHI(NQZ)                                   HWS1409
     GO TO 9999                                                    HWS1410
9967 WRITE(6,9041) NQZ,SWSI(NQZ)                                   HWS1411
     GO TO 9999                                                    HWS1412
9964 WRITE(6,9944) IMIN                                            HWS1413
9999 CONTINUE                                                      HWS1414
     WRITE(6,9009)                                                 HWS1415
     STOP                                                          HWS1416
     END                                                           HWS1417
```

```
      BLOCK DATA
C DECLARATIONS
      INTEGER YEAR,DAYS,OPTI,OPTO,SWLIKE,WNUM
      REAL IAM1,IAM2,ICPT
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1       OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BOM/ SUM(33,20),IAM1,IAM2,ICPT(20),DELTA(20),WNUM(20),
     1 FRLZ(20),HLZS(20),ALZS(20),CORINF(20)
      DATA MOCHAR/'JAN','FEB','MAR','APR','MAY','JUNE','JULY','AUG',
     1'SEPT','OCT','NOV','DEC'/
      DATA LASTDA/31,31,29,28,31,31,30,30,31,31,30,30,31,31,31,31,30,30,
     131,31,30,30,31,31/
      DATA DAYS/92,92,123,123,152,151,183,182,213,212,244,243,274,273,
     1305,304,336,335,0,0,31,31,61,61/
      DATA CORINF/0.78,0.80,0.87,0.99,1.12,1.23,1.26,1.24,1.17,1.01,
     10.86,0.77/
      END
```

```
      SUBROUTINE CHSIM
C DECLARATIONS
      INTEGER  OPTS,RCHI
      INTEGER RRR
      INTEGER YEAR,DAYS,OPTO,OPTI,SWLIKE,SWSI,DPLOT,PLTNO
      INTEGER YRB,STYR
      REAL MAXFLO,MMF,MSFLO,IFLO
      COMMON/MRT/S2(25),NNXX
      COMMON/MR/RELEV(25),O2(25),SINT,ELINT,EFSD,COF,EGO,ICODE1,AA,B,C,N
     1HR,RRR(20),B0,B1,B2,B3,QCON,YRB,ECSD,COFF,DIV,STYR
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1       OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BCS/OUT(745),FIN(15,745),FLOW(745),FIN1(20),FIN2(20),
     1     DISTRO(20,900),NRCHS,SWSI(20),C0(20),C1(20),C2(20),
     1          NDIST(20),STRFLO(20,900),IFLO(744),BFLO(744),SRO(744),
     1          OUTED(20),RCHI(20),NSO(20),KPL(12,31),NRO(20)
      COMMON /BCSOY/ FLOT(34,12),MSFLO(2,366),NRCOWS(20),IPERN(20),
     1                    OPTS(20),
     1          NPLOT,DPLOT(50),MPLOT(50),HFLO(50,24),PLTNO(50),NOUNQ,
     1          MRN(20),IBUF(1008),MMF(13),CUMA(20),TOT(33,13),STI(8),
     1          MAXFLO(20),XPLT(744),NOSFO,ILY,MONE,NMR,PEAK(20,30),
     1          MHFLO(50,24),IVARB1,IVARB2,PVC,VARC,NSTA,MDF,DIVRT(367)
      COMMON /PARM/ SWAREA(20),IMPA(20),FALZ(20),FHLZ(20),
     1      PSRP(20),PSDP(20),ICMN(20),ICMX(20),SRSN(20),SDSN(20),
     1      UZSN(20),LZSN(20),GWSF(20),PPIF(20),PSUP(20),
     1      PPUL(20),PLGP(20),PDGP(20),PLZU(20),TTM(20),
     1      INFP(20),BFP(20),EIP(20),EVP(20),ETGWP(20),SRSI(20),
     1      SDSI(20),UZSI(20),LZSI(20),GWSI(20),EZU,EZL,HEP
 9009 FORMAT(1H1,10X,29HEND RUN FROM CHSIM SUBROUTINE )
 9033 FORMAT(5X,54HSUBWATERSHED FLOW DATA READ FROM FILE FOR SUBWATERSHE
     1D ,I3,40H. IT WAS SUPPOSED TO BE FOR SUBWATERSHED ,I3)
 9034 FORMAT(5X,60HSUBWATERSHED FLOW COMPONENTS READ FROM FILE FOR SUBWA
     1TERSHED ,I3,40H. IT WAS SUPPOSED TO BE FOR SUBWATERSHED ,I3)
C        OUT(NR,N) = OUTFLOW FROM REACH NR FOR THE N-TH HOUR OF THE MONTH
C        FIN(NR,N) = FLOW INTO REACH NR FOR THE N-TH HOUR OF THE MONTH.
C        FLOW(LL,N)= FLOW OUT OF SUBWATERSHED LL FOR N-TH HOUR.
C     ROUTING RUNOFF IN SUBWATERSHEDS TO APPROPRIATE REACHES
      NRCP1 = NRCHS + 1
      IF(OPTI(19).NE.1)  MDF = 0
      REWIND 4
      DO 124 N = 1,NRCP1
      FIN1(N) = FIN2(N)
      FIN2(N) = 0.0
      DO 124 K = 1,744
  124 FIN(N,K) = 0.0
      DO 131 LW = 1,NSUBWS
      LN = SWLIKE(LW)
      IF(NOUNQ.LE.1)  GO TO 122
      IF(LW.EQ.LN) READ(4) LL,(SRO(M),M=1,744),(IFLO(M),M=1,744),
     1              (BFLO(M),M=1,744)
```

```
      IF(LL.NE.LN)  GO TO 9976
  122 CONTINUE
      NHRM1 = 744
      IF(MONTH.GT.1) NHRM1 = 24*LASTDA(ILY,MONTH-1)
      NHR = 24*LASTDA(ILY,MONTH)
      DO 126 N = 1,744
  126 FLOW(N) = 0.0
      NUM = NDIST(LW)
      DO 127 N = 1,NUM
  127 FLOW(N) = STRFLO(LW,N)
      DO 123 K=1,900
  123 STRFLO(LW,K) = 0.0
      IF(LW.NE.MDF) GO TO 120
      DO 121 N = 1,NHR
      K = DAYS(ILY,MONTH) + 1 + N/24
  121 FLOW(N) = FLOW(N) + DIVRT(K)*0.04167
  120 CONTINUE
      DO 130 N =1,NHR
      FLOW(N) = 645.6*SWAREA(LW)*(IFLO(N)+BFLO(N))+FLOW(N)
      IF(SRO(N).LT.1.0E-6)  GO TO 125
      DO 129 NN = 1,NUM
      NPN = N-1+NN
      IF(NPN.LE.NHR) GO TO 128
      NZ = NPN - NHR
      STRFLO(LW,NZ) = DISTRO(LW,NN)*SRO(N)*645.6*SWAREA(LW)
     1 + STRFLO(LW,NZ)
      GO TO 129
  128 FLOW(NPN) = FLOW(NPN)+SRO(N)*DISTRO(LW,NN)*645.6*SWAREA(LW)
  129 CONTINUE
  125 IF(NRCHS.LE.0) GO TO 130
      NR = SWSI(LW)
      FIN(NR,N) = FLOW(N) + FIN(NR,N)
  130 CONTINUE
      IF(NSUBWS.GT.1.AND.NSO(2).GT.0) WRITE(3) LW,(FLOW(N),N=1,744)
      IF(NRCHS.GT.0) FIN2(NR) = FIN2(NR) + FLOW(NHR)
  131 CONTINUE
      REWIND 3
POUTING OF FLOWS THROUGH THE CHANNEL SYSTEM
      IF(NRCHS.LE.0) GO TO 137
      DO 138 NR=1,NRCHS
      NNR=RCHI(NR)
      DO 1100 N=1,20
      IF(RRR(N).GT.20) GO TO 1200
      IF(RRR(N).EQ.NR) GO TO 151
 1100 CONTINUE
 1200 CONTINUE
      OUT(1) = C0(NR)*FIN(NR,1) + C1(NR)*FIN1(NR)+C2(NR)*OUTED(NR)
      K = DAYS(ILY,MONTH) + 1
      IF(MDF.EQ.-NR) OUT(1) = OUT(1) + DIVRT(K)*0.04167
      DO 140 N = 2,NHR
      OUT(N) = C0(NR)*FIN(NR,N) + C1(NR)*FIN(NR,N-1)
     1         + C2(NR)*OUT(N-1)
```

```
      IF(MDF.NE.-NR) GO TO 140
      KK = K + N/24
      OUT(N) = OUT(N) + DIVRT(KK)*0.04167
  140 CONTINUE
      GO TO 150
  151 CALL REST(NR)
  150 CONTINUE
      DO 153 N=1,NHR
  153 FIN(NNR,N)=FIN(NNR,N)+OUT(N)
      OUTED(NR) = OUT(NHR)
      FIN2(NNR) = FIN2(NNR) + OUT(NHR)
  138 CONTINUE
  137 CONTINUE
CALCULATION OF INFORMATION FOR OUTPUT TABLE ON DAILY FLOWS
      MNS = 0
      NS = 0
      N = 1
      LW = 1
      L = LASTDA(ILY,MONTH)
  148 NS = NS + 1
      IF(NS.GT.NSUBWS) GO TO 147
      IF(NSO(N).GT.NSUBWS) GO TO 147
      IF(NSUBWS.GT.1.AND.NSO(2).GT.0) READ(3) LW,(FLOW(K),K=1,744)
      IF(NS.NE.LW)  GO TO 9975
      IF(NS.LT.NSO(N)) GO TO 148
C    NSO(N) = NUMBER OF THE SUBWATERSHED FOR WHICH N-TH OUTPUT DESIRED
      IF(N.LE.1) GO TO 444
      IV = 10 + N
      WRITE(IV) N,MONTH
      WRITE(IV) (FLOT(I,MONTH),I=1,31)
  444 CONTINUE
      DO 445 I =1,32
  445 FLOT(I,MONTH) = 0.0
      DO 146 I =1,L
      DO 145 J =1,24
      JJ = 24*(I-1) + J
      IF(FLOW(JJ).LT.PEAK(N,5))  GO TO 145
      PEAK(N,1) = YEAR
      PEAK(N,2) = MONTH
      PEAK(N,3) = I
      PEAK(N,4) = J
      PEAK(N,5) = FLOW(JJ)
  145 FLOT(I,MONTH) = FLOT(I,MONTH) + FLOW(JJ)
      FLOT(I,MONTH) = FLOT(I,MONTH)/24.0
      IF(FLOT(I,MONTH).GT.MAXFLO(N)) MAXFLO(N) = FLOT(I,MONTH)
      NRCOWS(N) = NS
C     NRCOWS(N) = NUMBER REACH IF NEG OR SUBWATERSHED IF POS FOR N-TH
C                 OUTPUT.
      IF(OPTO(2).NE.1) GO TO 146
      IF(KPL(MONTH,I).NE.1) GO TO 146
C   CALCULATION OF INFORMATION FOR PLOTTING HOURLY FLOWS
C    KPL(MONTH,I) = 1 IF HOURLY PLOT FOR DAY I AND MONTH DESIRED
```

```
C      NPLOT = ACCUMULATED NUMBER OF DAYS FOR HOURLY PLOTTING
C      DPLOT(NPLOT) = DAY FOR ACCUMULATED NPLOT
C      MPLOT(NPLOT) = MONTH FOR ACCUMULATED NPLOT
C        HFLO(NPLOT,J) = HOURLY DATA TO BE PLOTTED FOR ACCUMULATED
C                      NPLOT-TH REACH-DAY AND J-TH HOUR.
C      PLTNO(NPLOT) = NUMBER OF REACH IF NEG OR SUBWATERSHED IF POS
C                       FOR NPLOT-TH DAY OF OUTPUT.
       NPLOT = NPLOT + 1
       DPLOT(NPLOT) = I
       MPLOT(NPLOT) = MONTH
       PLTNO(NPLOT) = NS
       DO 243 J=1,24
       JJ = 24*(I-1) + J
  243  HFLO(NPLOT,J) = FLOW(JJ)
  146  CONTINUE
       N = N + 1
       IF(NS.LE.NSURWS) GO TO 148
  147  CONTINUE
       M = N
       NOSFO = N - 1
       IF(NRCHS.LE.0) GO TO 149
       NR = 0
       N = 1
       IF(NRO(1).EQ.99)GO TO 144
  141  NR = NR + 1
       IF(NR.GT.NFLPT)GO TO 555
       IF(NR.LT.NRO(N)) GO TO 141
C      NRO(N) = NUMBER OF THE FLOWPOINT FOR WHICH N-TH OUTPUT DESIRED
       IF(M.LE.1) GO TO 342
  555  IV = 10 + M
       WRITE(IV) M,MONTH
       WRITE(IV) (FLOT(I,MONTH),I=1,31)
  342  DO 343 I = 1,32
  343  FLOT(I,MONTH) = 0.0
       IF(NRO(N).GT.NFLPT) GO TO 144
       DO 143 I=1,L
       DO 142 J = 1,24
       JJ = 24*(I-1) + J
       IF(FIN(NR,JJ).LT.PEAK(M,5))  GO TO 142
       PEAK(M,1) = YEAR
       PEAK(M,2) = MONTH
       PEAK(M,3) = I
       PEAK(M,4) = J
       PEAK(M,5) = FIN(NR,JJ)
  142  FLOT(I,MONTH) = FLOT(I,MONTH) + FIN(NR,JJ)
       FLOT(I,MONTH) = FLOT(I,MONTH)/24.0
       NRCOWS(M) = -NR
C      FLOT(I,MONTH) = FLOW IN DAY I AND MONTH FOR M-TH REACH OF OUTPUT
C      CALCULATION OF MAXIMUM AVERAGE DAILY FLOW
       IF(FLOT(I,MONTH).GT.MAXFLO(M)) MAXFLO(M) = FLOT(I,MONTH)
       IF(OPTO(2).NE.1) GO TO 143
       IF(KPL(MONTH,I).NE.1) GO TO 143
```

```
      NPLOT = NPLOT +1                                                  CHSM 207
      DPLOT(NPLOT) = I                                                  CHSM 208
      MPLOT(NPLOT) = MONTH                                              CHSM 209
      PLTNO(NPLOT) = -NR                                                CHSM 210
      DO 242 J=1,24                                                     CHSM 211
      JJ = 24*(I-1) + J                                                 CHSM 212
  242 HFLO(NPLOT,J) = FIN(NR,JJ)                                        CHSM 213
  143 CONTINUE                                                          CHSM 214
      M = M + 1                                                         CHSM 215
      N = N + 1                                                         CHSM 216
      IF(NR.LE.NFLPT)GO TO 141                                          CHSM 217
  144 CONTINUE                                                          CHSM 218
      NOSFO = M - 1                                                     CHSM 219
  149 CONTINUE                                                          CHSM 220
      REWIND 3                                                          CHSM 221
      REWIND 4                                                          CHSM 222
      RETURN                                                            CHSM 223
 9975 WRITE(6,9033) LW,NS                                               CHSM 224
      GO TO 9999                                                        CHSM 225
 9976 WRITE(6,9034) LW,LN                                               CHSM 226
 9999 CONTINUE                                                          CHSM 227
      WRITE(6,9009)                                                     CHSM 228
      CALL EXIT                                                         CHSM 229
      RETURN                                                            CHSM 230
      END                                                               CHSM 231
```

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C  SUBROUTINE OUPT HANDLES ANNUAL OUTPUT AND PLOTTING.
      SUBROUTINE OUPTS
C DECLARATIONS
      DIMENSION NCSM(26),PCM(26),NCSS(26),PCS(26),AFM(26),AFS(26),
     1     AECFS(26),AEIN(26),TECFS(26),FINT(2,25),STDE(26)
      INTEGER OPTI,DPLOT,DAYS,OPTO,YEAR,PLTNO
      INTEGER OPTS,SWLIKE
      REAL PLTR(2,31)
      REAL MSFLO,MMF,MAXFLO,ARRA(12),MHFLO
      REAL IAM1,IAM2,ICPT,LZSI
C  COMMON BLOCK FOR OUPT
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1        OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BOM/ SUM(33,20),IAM1,IAM2,ICPT(20),DELTA(20),WNUM(20),
     1           FRLZ(20),HLZS(20),ALZS(20),CORINF(20)
      COMMON /BCSOY/ FLOT(34,12),MSFLO(2,366),NRCOWS(20),IPFRN(20),
     1                   OPTS(20),
     1           NPLOT,DPLOT(50),MPLOT(50),HFLO(50,24),PLTNO(50),NOUNQ,
     1           MRN(20),IBUF(1008),MMF(13),CUMA(20),TOT(33,13),STI(8),
     1           MAXFLO(20),XPLT(744),NOSFO,ILY,MONE,NMR,PEAK(20,30),
     1           MHFLO(50,24),IVARB1,IVARB2,PVC,VAPC,NSTA,MDF,DIVRT(367)
      REAL   IMPA,LZSN,INFP,ICMN,ICMX
      COMMON /PARM/ SWAREA(20),IMPA(20),FALZ(20),FHLZ(20),
     1     PSRP(20),PSDP(20),ICMN(20),ICMX(20),SRSN(20),SDSN(20),
     1     UZSN(20),LZSN(20),GWSF(20),PPIF(20),PSUP(20),
     1     PPUL(20),PLGP(20),PDGP(20),PLZU(20),TTM(20),
     1     INFP(20),BFP(20),EIP(20),EVP(20),ETGWP(20),SPSI(20),
     1     SDSI(20),UZSI(20),LZSI(20),GWSI(20),EZU,EZL,HEP
      COMMON/PLT/IPTYPE,FACT,TFACT
 1055 FORMAT(/' LOSES (WATERSHED INCHES)')
 1056 FORMAT(/' PERCOLATION (WATERSHED INCHES)')
 1057 FORMAT(/' STREAMFLOW (WATERSHED INCHES)')
 1058 FORMAT(/' EVAPOTRANSPIRATION (WATERSHED INCHES)')
 1059 FORMAT(/' END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES)')
 1072 FORMAT(1H1//5X,27HFLOW AND STORAGE TABLE FOR ,14A4,4X,13HWATER YEA
     1R 19,I2,22H  (VALUES IN INCHES)  //)
 1073 FORMAT(/20X,12(4X,A4),4X,5HTOTAL/)
 1075 FORMAT(//5X,86HANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS
     1 STREAMFLOW MINUS UNDERFLOW EQUALS ,F8.3)
 1076 FORMAT(/5X,31HCHANGE IN STORAGE EQUALS         ,F8.3)
 1082 FORMAT(1H1//5X,25HDAILY DISCHARGE DATA FOR ,16A4,11H,FLOWPOINT ,I3
     1,4X,13HWATER YEAR 19,I2/)
 1083 FORMAT(5X,I3,F10.1,11F8.1,3X,4HCSFD)
 1084 FORMAT(10X,12(2X,6H------)/3X,5HTOTAL,F10.1,11F8.1,3X,4HCFSD)
 1085 FORMAT(4X,4HAVE.,F10.1,11F8.1,3X,4HCSFD)
 1086 FORMAT(3X,5HTOTAL,F10.2,11F8.2,3X,6HINCHES)
 1087 FORMAT(4X,4HOBS.,F10.2,11F8.2,3X,6HINCHES)
 1088 FORMAT(//3X,'MAXIMUM MEAN DAILY FLOW EQUALS',F10.1)
 1092 FORMAT(1H1//5X,26HHOURLY DISCHARGE DATA FOR ,16A4,4X,
     113HWATER YEAR 19,I2//5X,10HMONTH  DAY,10X,25HAVERAGE HOURLY FLOWS(
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```
    2CFS))                                                                  OUPT
1093 FORMAT(5X,I3,I6,5X,12F8.1,3X,2HAM/19X,12F8.1,3X,2HPM)                  OUPT
1096 FORMAT(1H1//5X,25HDAILY DISCHARGE DATA FOR ,14A4,14H,SUBWATERSHED OUPT
    1,I3,4X,13HWATER YEAR 19,I2/)                                           OUPT
1097 FORMAT(10X,12(4X,A4)//)                                                OUPT
1098 FORMAT(1H1//5X,29HMEASURED STREAMFLOW DATA FOR ,16A4,10H,FLOWPOINTOUPT
    1,I3/55X,13HWATER YEAR 19,I2/)                                          OUPT
1102 FORMAT(/3X,26HMAXIMUM MEAN HOURLY FLOW = ,F8.1,24H CFS AND OCCURREOUPT
    1D DURING ,I5,4H ON ,A4,I3,I6/)                                         OUPT
1107 FORMAT(/5X,'TOTAL SIMULATED FLOW =',F8.2,' INCHES')                    OUPT
1108 FORMAT(/5X,'TOTAL OBSERVED FLOW  =',F8.2,' INCHES')                    OUPT
1254 FORMAT(21H   PRECIPITATION      ,13F8.3)                               OUPT
1260 FORMAT(21H   INTERCEPTION       ,13F8.3)                               OUPT
1261 FORMAT(21H  INFILTRATION-DIRECT,13F8.3)                                OUPT
1262 FORMAT(21H             -FROM SRS ,13F8.3)                              OUPT
1263 FORMAT(21H             -FROM SDS ,13F8.3)                              OUPT
1264 FORMAT(21H   SURFACE RETENTION ,13F8.3)                                OUPT
1265 FORMAT(21H   UZS-LZS            ,13F8.3)                               OUPT
1266 FORMAT(21H   LZS-GWS            ,13F8.3)                               OUPT
1267 FORMAT(21H   UNDERFLOW          ,13F8.3)                               OUPT
1268 FORMAT(21H   IMPERVIOUS AREA    ,13F8.3)                               OUPT
1269 FORMAT(21H   SURFACE            ,13F8.3)                               OUPT
1270 FORMAT(21H   INTERFLOW          ,13F8.3)                               OUPT
1271 FORMAT(21H   BASEFLOW           ,13F8.3)                               OUPT
1272 FORMAT(21H   INTERCEPTION       ,13F8.3)                               OUPT
1273 FORMAT(21H   SRS                ,13F8.3)                               OUPT
1274 FORMAT(21H   UZS                ,13F8.3)                               OUPT
1275 FORMAT(21H   LZS                ,13F8.3)                               OUPT
1276 FORMAT(21H   GWS                ,13F8.3)                               OUPT
1278 FORMAT(21H   SDS                ,13F8.3)                               OUPT
1279 FORMAT(21H   SRS                ,13F8.3)                               OUPT
1280 FORMAT(21H   UZS                ,13F8.3)                               OUPT
1281 FORMAT(21H   LZS(RIDGE)         ,13F8.3)                               OUPT
1282 FORMAT(21H   GWS                ,13F8.3)                               OUPT
1283 FORMAT(21H   LZS(ALLUVIAL)      ,13F8.3)                               OUPT
1284 FORMAT(21H   LZS(HILLSIDE)      ,13F8.3)                               OUPT
1285 FORMAT(21H   INTC               ,13F8.3)                               OUPT
1291 FORMAT(21H   SEEPAGE RIDGE      ,13F8.3)                               OUPT
1293 FORMAT(21H   TOTAL FLOW         ,13F8.3)                               OUPT
1294 FORMAT(21H   TOTAL              ,13F8.3)                               OUPT
1295 FORMAT(21H   POTENTIAL          ,13F8.3)                               OUPT
1296 FORMAT(21H   DIVERSIONS OUT      ,13F8.3)                              OUPT
1301 FORMAT(/19X,12HREACH NUMBER,I4)                                        OUPT
1302 FORMAT(/19X,19HSUBWATERSHED NUMBER,I4)                                 OUPT
1311 FORMAT(2A4,8X,2F8.5)                                                   OUPT
1312 FORMAT(10F8.3)                                                         OUPT
1403 FORMAT(4X,2F8.1,I5,F6.1,F7.1,I7,F6.1,F7.1,2G10.2,F10.4,F10.2,         OUPT
    1G12.4)                                                                 OUPT
1409 FORMAT(1H1,19X,'MEAN DAILY STREAMFLOW FOR ',12A4,' - WATER YEAR 19OUPT
    1',I2//38X,'DISCHARGE IN CUBIC FEET PER SECOND (X=SIMULATED, O=OBSEOUPT
    2RVED)')                                                                OUPT
1411 FORMAT(126X,'RAIN'/124X,'(INCHES)'//6X,'10',37X,'100',36X,'1000', OUPT
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     1      36X,'10000'/6X,'-',12('----------'))
1412 FORMAT(6X,'1',38X,'10',38X,'100',36X,'1000')
1601 FORMAT(1H1//5X,'DAILY FLOW DURATION AND ERROR TABLE FOR ',12A4,' W
    1Y 19',I2//)
1602 FORMAT(24X,'MEASURED FLOW',7X,'SIMULATED FLOW',5X,'AVERAGE',5X,
    1' TOTAL  ERROR',4X,'STANDARD'/
    27X,'FLOW INTERVAL',2X,'CASES',2X,'PCT',4X,'AVE',3X,'CASES',2X,'PCT
    3',4X,'AVE',5X,'ERROR',5X,'CFSD',5X,'INCHES',5X,'ERROR'/
    47X,'-------------',                             3X,'------------
    4-----',2X,'----------------',4X,'-------',4X,'----------------',
    53X,'---------')
1604 FORMAT(6X,'--------------  ----------------  -----------------
    1 ',                                                        '--
    1---    -------  -------    --------'/ 5X,        'TOTAL OR AVERA
    2GE',I4,F6.1,F7.1,I7,F6.1,F7.1,2F10.2,F10.4,F10.2,F12.4)
1606 FORMAT(//5X,'FOR WY 19',I2/5X,'AVERAGE ABSOLUTE ERROR IN DAILY FLO
    1WS =',F10.4,' CFSD'/43X,'=',F10.4,' PERCENT')
1607 FORMAT(/5X,' AVERAGE ERROR IN MONTHLY FLOWS FOR WY 19',I2,' =',F10
    1.6,' INCHES')
1608 FORMAT(/5X,'STANDARD ERROR IN MONTHLY FLOWS FOR WY 19',I2,' =',F10
    1.6,' INCHES')
1609 FORMAT(//5X,'CORRELATION COEFFICIENT FOR WY 19',I2,
    1      ' (DAILY FLOWS) =',F8.5/39X,'(MONTHLY FLOWS) =',F8.5)
1612 FORMAT(///5X,'***** STATISTICAL OUTPUT REQUIRES SELECTION OF INPUT
    1 OPTION 12 *****'///)
1887 FORMAT(1X,I6,2I2,I1,11F6.0)
9009 FORMAT(1H1,10X,7HEND RUN//)
9031 FORMAT(5X,8HDATA SET ,I3,15H READ FROM FILE ,I3,30H. COMPUTER THIN
    1KS ITS DATA SET ,I3)
 199 IF(OPTO(1).NE.1) GO TO 161
C     OUTPUT STORAGE AND FLOW TABLE
     WRITE(6,1072)  (NAME(N),N=1,14),YEAR
     WRITE(6,1073)  (MOCHAR(N),N=10,12),(MOCHAR(N),N=1,9)
     WRITE(6,1254)(TOT(16,N),N=10,12),(TOT(16,N),N=1,9),TOT(16,13)
     WRITE(6,1055)
     WRITE(6,1260)(TOT( 1,N),N=10,12),(TOT( 1,N),N=1,9),TOT( 1,13)
     WRITE(6,1261)(TOT( 3,N),N=10,12),(TOT( 3,N),N=1,9),TOT( 3,13)
     WRITE(6,1262)(TOT( 7,N),N=10,12),(TOT( 7,N),N=1,9),TOT( 7,13)
     WRITE(6,1263)(TOT( 6,N),N=10,12),(TOT( 6,N),N=1,9),TOT( 6,13)
     WRITE(6,1264)(TOT( 4,N),N=10,12),(TOT( 4,N),N=1,9),TOT( 4,13)
     WRITE(6,1056)
     WRITE(6,1265)(TOT( 8,N),N=10,12),(TOT( 8,N),N=1,9),TOT( 8,13)
     WRITE(6,1266)(TOT(12,N),N=10,12),(TOT(12,N),N=1,9),TOT(12,13)
     WRITE(6,1291)(TOT(21,N),N=10,12),(TOT(21,N),N=1,9),TOT(21,13)
     WRITE(6,1267)(TOT(17,N),N=10,12),(TOT(17,N),N=1,9),TOT(17,13)
     WRITE(6,1057)
     WRITE(6,1268)(TOT(19,N),N=10,12),(TOT(19,N),N=1,9),TOT(19,13)
     WRITE(6,1269)(TOT( 5,N),N=10,12),(TOT( 5,N),N=1,9),TOT( 5,13)
     WRITE(6,1270)(TOT(14,N),N=10,12),(TOT(14,N),N=1,9),TOT(14,13)
     WRITE(6,1271)(TOT(15,N),N=10,12),(TOT(15,N),N=1,9),TOT(15,13)
     DO 165 N = 1,13
 165 TOT(23,N) = TOT(19,N)+TOT(5,N)+TOT(14,N)+TOT(15,N)
```

```
      WRITE(6,1293)(TOT(23,N),N=10,12),(TOT(23,N),N=1,9),TOT(23,13)
      IF(OPTI(19).EQ.1) WRITE(6,1296)(TOT(22,N),N=10,12),(TOT(22,N),N=1,
     19), TOT(22,13)
      WRITE(6,1058)
      WRITE(6,1272)(TOT( 2,N),N=10,12),(TOT( 2,N),N=1,9),TOT( 2,13)
      WRITE(6,1273)(TOT( 9,N),N=10,12),(TOT( 9,N),N=1,9),TOT( 9,13)
      WRITE(6,1274)(TOT(10,N),N=10,12),(TOT(10,N),N=1,9),TOT(10,13)
      WRITE(6,1275)(TOT(11,N),N=10,12),(TOT(11,N),N=1,9),TOT(11,13)
      WRITE(6,1276)(TOT(13,N),N=10,12),(TOT(13,N),N=1,9),TOT(13,13)
      DO 166 N=1,13
  166 TOT(24,N) = TOT(2,N)+TOT(9,N)+TOT(10,N)+TOT(11,N)+TOT(13,N)
      WRITE(6,1294)(TOT(24,N),N=10,12),(TOT(24,N),N=1,9),TOT(24,13)
      WRITE(6,1295)(TOT(18,N),N=10,12),(TOT(18,N),N=1,9),TOT(18,13)
      WRITE(6,1059)
      WRITE(6,1285)(TOT(33,N),N=10,12),(TOT(33,N),N=1,9)
      WRITE(6,1278)(TOT(26,N),N=10,12),(TOT(26,N),N=1,9)
      WRITE(6,1279)(TOT(27,N),N=10,12),(TOT(27,N),N=1,9)
      WRITE(6,1280)(TOT(28,N),N=10,12),(TOT(28,N),N=1,9)
      WRITE(6,1281)(TOT(29,N),N=10,12),(TOT(29,N),N=1,9)
      WRITE(6,1283)(TOT(31,N),N=10,12),(TOT(31,N),N=1,9)
      WRITE(6,1284)(TOT(32,N),N=10,12),(TOT(32,N),N=1,9)
      WRITE(6,1282)(TOT(30,N),N=10,12),(TOT(30,N),N=1,9)
      DST = TOT(16,13) - TOT(2,13) - TOT(9,13) - TOT(10,13) -TOT(11,13)
     1      - TOT(13,13) - TOT(5,13) - TOT(14,13) - TOT(15,13)
     2      - TOT(19,13) - TOT(17,13)
      WRITE(6,1075) DST
      DLST = 0.0
      DO 167 N = 1,3
      NP = N+25
      DLST = DLST + (TOT(NP,9)-STI(N))*IAM1
  167 STI(N) = TOT(NP,9)
      DLST = DLST + IAM1*(TOT(33,9)-STI(8))
      DO 6167 L =1,NSUBWS
      LL = SWLIKE(L)
      DLST = DLST + IAM2*FRLZ(LL)*(TOT(29,9)-STI(4))
      DLST = DLST + IAM2*FALZ(LL)*(TOT(31,9)-STI(6))
      DLST = DLST + IAM2*FPLZ(LL)*(TOT(32,9)-STI(7))
 6167 DLST = DLST +        FALZ(LL)*(TOT(30,9)-STI(5))
      STI(4) = TOT(29,9)
      STI(5) = TOT(30,9)
      STI(6) = TOT(31,9)
      STI(7) = TOT(32,9)
      STI(8) = TOT(33,9)
      WRITE(6,1076) DLST
C     PUNCH ANNUAL VOLUMES ON CARDS
      IF(OPTO(15).NE.1)  GO TO 1313
      VARC2 = VARC*(1.0+PVC/100.0)
      WRITE(7,1311) IVARB1,IVARB2,VARC,VARC2
      WRITE(7,1312)TOT( 1,13),TOT( 3,13),TOT( 7,13),TOT( 6,13),
     1TOT( 4,13),TOT( 8,13),TOT(12,13),TOT(17,13),TOT(19,13),TOT( 5,13)
      WRITE(7,1312)TOT(14,13),TOT(15,13),TOT( 2,13),TOT( 9,13),
     1  TOT(10,13),TOT(11,13),TOT(13,13)
```

```
 1313 CONTINUE
C OUTPUT ANNUAL TABLE OF DAILY DISCHARGES AT DESIRED FLOWPOINTS
  161 IF(OPTO(3).LE.0.AND.OPTO(6).LE.0) GO TO 189
      NR=0
      NZ = 0
  171 NR = NR + 1
      IF(NR.GT.NOSFO) GO TO 189
      NC = NRCOWS(NR)
      IF(OPTO(3).LE.0) GO TO 485
      IF(NC.GT.0) GO TO 172
      NX =IABS(NC)
      WRITE(6,1082)(NAME(N),N=1,16),NX,YEAR
      AP = CUMA(NX)
      GO TO 173
  172 WRITE(6,1096)  (NAME(N),N=1,14),NC,YEAR
      AP = SWAREA(NC)
  173 CONTINUE
      IF(NOSFO.LE.1)  GO TO 176
      NRE=NR+1
      IV=10 + NRE
      WRITE(IV) NZ,NZ
      REWIND IV
  175 READ(IV) NK,M
      IF(NK.EQ.0)  GO TO 176
      IF(NRE.NE.NK) GO TO 9977
      READ(IV)  (FLOT(N,M),N=1,31)
      GO TO 175
  176 CONTINUE
      IF(NOSFO.GT.1) REWIND IV
      WRITE(6,1097)  (MOCHAR(K),K=10,12),(MOCHAR(K),K=1,9)
      DO 181 N = 1,31
      DO 181 M = 1,12
  181 FLOT(32,M) = FLOT(32,M)  + FLOT(N,M)
      DO 182 M = 1,12
      DD = 1.0/LASTDA(ILY,M)
      FLOT(33,M) = FLOT(32,M)*DD
      IF(NC.LE.0) XZ = 1.0/(CUMA(NX)*26.9)
      IF(NC.GT.0) XZ = 1.0/(SWAREA(NC)*26.9)
  182 FLOT(34,M) = FLOT(32,M)*XZ
      DO 184 N = 1, 31
  184 WRITE(6,1083) N,(FLOT(N,K),K=10,12),(FLOT(N,K),K=1,9)
      WRITE(6,1084)   (FLOT(32,K),K=10,12),(FLOT(32,K),K=1,9)
      WRITE(6,1085)   (FLOT(33,K),K=10,12),(FLOT(33,K),K=1,9)
      WRITE(6,1086)   (FLOT(34,K),K=10,12),(FLOT(34,K),K=1,9)
C   PUNCH DAILY STREAMFLOW (SIMULATED)
      IF(OPTO(16).NE.1)  GO TO 1888
      DO 1880 K = 1,12
      M = K + 9
      IF(M.GT.12)  M = M-12
      I = YEAR
      IF(M.GT.9)  I = I - 1
      L = 1
```

```
      WRITE(7,1887) NSTA,I,M,L,(FLOT(N,M),N=1,10)
      L = 2
      WRITE(7,1887) NSTA,I,M,L,(FLOT(N,M),N=11,20)
      L = 3
 1880 WRITE(7,1887) NSTA,I,M,L,(FLOT(N,M),N=21,31)
 1888 CONTINUE
C     OUTPUT MEASURED MONTHLY FLOWS IF GIVEN AS INPUT
      JI = 1
      JC = 1
      IFSO = 0
      IF(OPTI(12).NE.1) GO TO 484
      DO 185 JI = 1,NMR
      JC = JI
      IF(MRN(JI).EQ.NC) GO TO 186
  185 CONTINUE
      GO TO 484
  186 CONTINUE
      IFSO = 1
      MS = 1
      DO 183 NN = 1,12
      MMF(NN) = 0.0
      MS = DAYS(ILY,NN) + 1
      ME = MS -1 + LASTDA(ILY,NN)
      DO 183  M = MS,ME
  183 MMF(NN) = MMF(NN) + MSFLO(JC,M)
      NM = NM + 1
      TMMF = 0.0
      DO 483 K=1,12
      TMMF = TMMF + MMF(K)
  483 MMF(K) = MMF(K)*XZ
      TMMF = TMMF*XZ
      WRITE(6,1087) (MMF(K),K=10,12),(MMF(K),K=1,9)
  484 WRITE(6,1088) MAXFLO(NR)
      IY = 1900.1 + PEAK(NR,1)
      IM = PEAK(NR,2) + 0.1
      ID = 0.1 + PEAK(NR,3)
      IH = PEAK(NR,4)*100.0 + 0.1
      WRITE(6,1102) PEAK(NR,5),IH,MOCHAR(IM),ID,IY
      TFLT = 0.0
      DO 1109 K = 1,12
 1109 TFLT = TFLT + FLOT(34,K)
      WRITE(6,1107) TFLT
      IF(MRN(JI).EQ.NC) WRITE(6,1108) TMMF
C   OUTPUT MEASURED DAILY FLOWS IF GIVEN AS INPUT
      IF(OPTO(4).NE.1.OR.OPTI(12).NE.1) GO TO 485
      IF(IFSO.LE.0)  GO TO 485
      WRITE(6,1098) (NAME(N),N=1,16),MRN(JC),YEAR
      WRITE(6,1097) (MOCHAR(K),K=10,12),(MOCHAR(K),K=1,9)
      DO 284 N = 1,31
      DO 283 M = 1,12
      MS = DAYS(ILY,M) + N
      ARRA(M) = MSFLO(JC,MS)
```

```
  283 IF(N.GT.LASTDA(ILY,M))  ARRA(M) = 0.0
  284 WRITE(6,1083) N,(ARRA(K),K=10,12),(ARRA(K),K=1,9)
      DO 285 K = 1,12
  285 MMF(K) = MMF(K)/XZ
      WRITE(6,1084)  (MMF(K),K=10,12),(MMF(K),K=1,9)
  485 CONTINUE
CALCULATION AND OUTPUT OF STATISTICS OF DAILY FLOWS
      IF(OPTO(8).NE.1) GO TO 1650
      IF(OPTI(12).EQ.1) GO TO 1611
      WRITE(6,1612)
       GO TO 1650
 1611 IF(IFSO.LE.0) GO TO 1650
      IF(NOSFO.LE.1.AND.OPTO(4).EQ.5) GO TO 602
      DO 600 K = 1,25
      NCSM(K) = 0
      NCSS(K) = 0
      AECFS(K)=0.0
      AEM(K) = 0.0
      AES(K) = 0.0
      STDE(K) = 0.0
      YYY = 0.0
  600 TECFS(K) = 0.0
      OPTO(4) = 5
  602 CONTINUE
      NCSM(26) = 0
      NCSS(26) = 0
      PCM(26) = 0.0
      PCS(26) = 0.0
      TECFS(26) = 0.0
      STDE(26) = 0.0
      AEM(26) = 0.0
      AECFS(26)=0.0
      AES(26) = 0.0
      AEMY = 0.0
      AESY = 0.0
      CORCOD = 0.0
      CORCOM = 0.0
      STYM = 0.0
      STMM = 0.0
      PABF = 0.0
      STM = 0.0
      AABF = 0.0
      STY = 0.0
      DO 616 K = 1,12
      SSM = 0.0
      SMM = 0.0
      DO 614 J = 1,31
      IF(J.GT.LASTDA(ILY,K)) GO TO 614
      MS = DAYS(ILY,K) + J
      M = MSFLO(JC,MS) + 1.0
      IF(MSFLO(JC,MS).GT.1.6487) M = 2.0*ALOG(MSFLO(JC,MS)) + 2.0
      N = FLOT(J,K) + 1.0
```

```
      IF(FLOT(J,K).GT.1.6487) N = 2.0*ALOG(FLOT(J,K)) + 2.0
      IF(M.GT.25) M = 25
      IF(N.GT.25) N = 25
      NCSM(M) = NCSM(M) + 1
      NCSS(N) = NCSS(N) + 1
      AFM(M) = AFM(M) + MSFLO(JC,MS)
      AFS(N) = AFS(N) + FLOT(J,K)
      AFSY = AFSY + FLOT(J,K)
      AFMY = AFMY + MSFLO(JC,MS)
      XXX = FLOT(J,K) - MSFLO(JC,MS)
      ZZZ = MSFLO(JC,MS) + FLOT(J,K)
      STM = STM + MSFLO(JC,MS)**2
      STDE(M) = STDE(M) + XXX**2
      STY = STY + FLOT(J,K)**2
      TECFS(M) = TECFS(M) + XXX
      AABE = AABE + ABS(XXX)
      IF(ZZZ.GT.1.0E-9) PABE = PABE + ABS(XXX)/ZZZ
      CORCOD = CORCOD + FLOT(J,K)*MSFLO(JC,MS)
      SMM = SMM + MSFLO(JC,MS)
      SSM = SSM + FLOT(J,K)
  614 CONTINUE
      CORCOM = CORCOM + SMM*SSM
      STYM = STYM + SSM**2
      STMM = STMM + SMM**2
  616 CONTINUE
      DYR = 365
      IF(ILY.EQ.1) DYR = 366
      IF(NOSFO.LE.1) YYY = YYY + DYR
      IF(NOSFO.GT.1) YYY = DYR
       DO 615 K = 1,25
      XXX = NCSM(K)
      PCM(K) = 100.0*XXX/YYY
      IF(XXX.GT.0.9) AFM(K) = AFM(K)/XXX
      ZZZ = NCSS(K)
      PCS(K) = 100.0*ZZZ/YYY
      IF(ZZZ.GT.0.9) AFS(K) = AFS(K)/ZZZ
      IF(XXX.GT.0.9) AECFS(K) = TECFS(K)/XXX
      AEIN(K) = TECFS(K)*XZ
      STDE(26) = STDE(26) + STDE(K)
      IF(XXX.GT.0.9) STDE(K) = SQRT(STDE(K)/XXX)
      NCSM(26) = NCSM(26) + NCSM(K)
      NCSS(26) = NCSS(26) + NCSS(K)
      PCM(26) = PCM(26) + PCM(K)
      PCS(26) = PCS(26) + PCS(K)
      AFM(26) = AFM(26) + AFM(K)*PCM(K)
      AFS(26) = AFS(26) + AFS(K)*PCS(K)
      TECFS(26) = TECFS(26) + TECFS(K)
  615 CONTINUE
      AFM(26) = AFM(26) * 0.01
      AFS(26) = AFS(26) * 0.01
      AABE = AABE/DYR
      PABE = 200.0*PABE/DYR
```

```
      AECFS(26) = TECFS(26)/YYY
      AEIN(26) = TECFS(26)*XZ
      STDE(26) = STDE(26)/YYY
      STDE(26) = SQRT(STDE(26))
      STM = STM - AFMY**2/DYR
      STY = STY - AFSY**2/DYR
      STYM = STYM - 12.0*(AFSY/12.0)**2
      STMM = STMM - 12.0*(AFMY/12.0)**2
      CORCOD = (CORCOD-AFMY*AFSY/DYR)/SQRT(STY*STM)
      CORCOM = (CORCOM - AFMY*AFSY/12.0)/SQRT(STMM*STYM)
C  OUTPUT STATISTICAL TABLE
      WRITE(6,1601) (NAME(N),N=1,12),YEAR
      WRITE(6,1602)
      FINT(1,2) = 1.0
      FINT(2,25) = 0.0
      FINT(2,1) = 1.0
      FINT(1,1) = 0.0
      XXX = 0
      DO 617 K = 2,24
      XXX = XXX + 0.5
      FINT(2,K) = EXP(XXX)
  617 FINT(1,K+1) = FINT(2,K)
      DO 1400 K = 1,25
 1400 WRITE(6,1403)(FINT(N,K),N=1,2),NCSM(K),PCM(K),AFM(K),
     1                                 NCSS(K),PCS(K),AFS(K),
     1 AECFS(K),TECFS(K),AEIN(K),STDE(K)
      WRITE(6,1604) NCSM(26),PCM(26),AFM(26),NCSS(26),PCS(26),AFS(26),
     1 AECFS(26),TECFS(26),AEIN(26),STDE(26)
      WRITE(6,1606) YEAR,AABE,PABE
      WRITE(6,1609) YEAR,CORCOD,CORCOM
      DIFF =0.0
      DO 515 J = 1,12
  515 DIFF = DIFF + ABS(MMF(J) - TOT(23,J))
      OPTIM = DIFF/12.0
      WRITE(6,1607)YEAR,OPTIM
      DIFF = 0.0
      DO540 J=1,12
  540 DIFF = (MMF(J)-TOT(23,J))**2 +DIFF
      OPTIM = SQRT(DIFF/12.0)
      WRITE(6,1608)YEAR,OPTIM
      IF(NOSFO.GT.1)  GO TO 1650
      DO 622 K = 1,25
      ZZZ = NCSS(K)
      IF(ZZZ.GT.0.9) AFS(K) = AFS(K)*ZZZ
      XXX = NCSM(K)
      IF(XXX.LT.0.9)   GO TO 622
      AFM(K) = AFM(K)*XXX
      STDE(K) = XXX*STDE(K)**2
  622 CONTINUE
 1650 CONTINUE
C PLOT DAILY FLOWS ON PRINTOUT IF OPTION 17 SELECTED
      IF(OPTO(17).NE.1) GO TO 500
```

```
C
C
      IF(IFSO.EQ.1)GO TO 7300
      DO 7250 N=1,20
      IF(IPFRN(N).GT.20)GO TO 500
      IF(IPFRN(N).EQ.NC)GO TO 7300
 7250 CONTINUE
      GO TO 500
C
C
 7300 K=0
      IF(AP.GT.50.0) K = 1
      WRITE(6,1409)(NAME(KI),KI=1,12),YEAR
      WRITE(6,1412)
      WRITE(6,1411)
      DO 410 MM = 1,12
      M = MM + 9
      IF(M.GT.12) M = M - 12
      IDY = LASTDA(ILY,M)
      DO 405 I = 1,IDY
      II = DAYS(ILY,M) + I
      PLTR(1,I) = MSFLO(JC,II)
  405 PLTR(2,I) = FLOT(I,M)
  410 CALL PLOTT(IDY,PLTR,M,K,IFSO)
  500 CONTINUE
      DO 7001 J=1,12
      FLOT(32,J) = 0.0
      FLOT(33,J) = 0.0
      FLOT(34,J) = 0.0
 7001 CONTINUE
  188 GO TO 171
  189 CONTINUE
C OUTPUT HOURLY HYDROGRAPHS FOR SPECIFIED DAYS
      IF(OPTO(2).NE.1) GO TO 198
      WRITE(6,1092) (NAME(M),M=1,16),YEAR
      DO 192 M = 1,NPLOT
      MO = MPLOT(M)
      ID = DPLOT(M)
      IF(PLTNO(M).LT.0) WRITE(6,1301) PLTNO(M)
      IF(PLTNO(M).GT.0) WRITE(6,1302) PLTNO(M)
  192 WRITE(6,1093) MO,ID,(HFLO(M,J),J=1,24)
  198 CONTINUE
      GO TO 9998
 9977 WRITE(6,9031) NK,IV,NR
 9999 CONTINUE
      WRITE(6,9009)
      CALL EXIT
 9998 RETURN
      END
```

```
      SUBROUTINE PLOTT(IDY,PLTR,M,K,IFSO)
C DECLARATIONS
      DIMENSION ICHAR(122),PLTR(2,31),MMTH(5,12)
      COMMON /MP/DP(12,31)
      DATA IOBS/'O'/
      DATA IBLK/' '/
      DATA ICAL/'X'/
      DATA IDSH/'I'/
      DATA MMTH/' ','J','A','N','.',' ','F','E','B','.','M','A','R','C',
     1 'H','A','P','R','I','L',' ','M','A','Y',' ',' ','J','U','N','E',
     2 ' ','J','U','L','Y',' ','A','U','G','.','S','E','P','T','.',' ',
     3 'O','C','T','.',' ','N','O','V','.',' ','D','E','C','.'/
  199 FORMAT(1X,A1,I2,1X,122A1,F4.2)
      DO 100 ID = 1,IDY
      DO  90  K = 1,122
   90 ICHAR(K) = IBLK
      DO 92  K = 2,122,40
   92 ICHAR(K) = IDSH
      IF(PLTR(1,ID).LE.0.0001) PLTR(1,ID) = 0.0001
      IF(PLTR(2,ID).LE.0.0001) PLTR(2,ID) = 0.0001
      N1 = 40.0*ALOG10(PLTR(1,ID)) + 2.49
      IF(K.EQ.1) N1 = N1 - 40
      IF(N1.GT.0)  GO TO 74
      N1 = N1 + 120
      ICHAR(1) = IOBS
      IF(IFSO.NE.1)ICHAR(1)=IBLK
      IF(N1.LT.1) N1 = 1
   74 CONTINUE
      IF(N1.LT.122) GO TO 75
      N1 = N1 - 120
      ICHAR(1) = IOBS
      IF(IFSO.NE.1)ICHAR(1)=IBLK
   75 ICHAR(N1) = IOBS
      IF(IFSO.NE.1)ICHAR(N1)=IBLK
      N2 = 40.0*ALOG10(PLTR(2,ID)) + 2.49
      IF(K.EQ.1) N2 = N2 - 40
      IF(N2.GT.0)  GO TO 84
      N2 = N2 - 120
      ICHAR(1) = ICAL
      IF(N2.LT.1) N2 = 1
   84 CONTINUE
      IF(N2.LT.122) GO TO 85
      N2 = N2 - 120
      ICHAR(1) = ICAL
   85 ICHAR(N2) = ICAL
      MC = IBLK
      IF(ID.LE.5.AND.M.LE.12)  MC = MMTH(ID,M)
      IF(DP(M,ID) - 0.005) 98,98,99
   98 WRITE(6,199) MC,ID,(ICHAR(K),K=1,122)
      GO TO 100
   99 WRITE(6,199) MC,ID,(ICHAR(K),K=1,122),DP(M,ID)
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUPTM
C DECLARATIONS
      INTEGER YEAR,DAYS,OPTI,OPTO,SWLIKE,WNUM
      REAL ICPT,IAM1,IAM2,LZS
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1    OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BOM/ SUM(33,20),IAM1,IAM2,ICPT(20),DELTA(20),WNUM(20),
     1 FRLZ(20),HLZS(20),ALZS(20),CORINF(20)
      COMMON /PARM/ SWAREA(20),IMPA(20),FALZ(20),FHLZ(20),
     1     PSRP(20),PSDP(20),ICMN(20),ICMX(20),SRSN(20),SDSN(20),
     1     UZSN(20),LZSN(20),GWSF(20),PPIF(20),PSUP(20),
     1     PPUL(20),PLGP(20),PDGP(20),PLZU(20),TTM(20),
     1     INFP(20),BFP(20),EIP(20),EVP(20),ETGWP(20),SRS(20),
     1     SDS(20),UZS(20),LZS(20),GWS(20),          EZU,EZL,HEP
 1023 FORMAT(/1H0)
 1052 FORMAT(1H1//5X,27HFLOW AND STORAGE TABLE FOR ,16A4,4X,A4,4H, 19,I2
     1,22H   (VALUES IN INCHES)   //)
 1053 FORMAT(/17H SUBWATERSHED NO.,2X,10G8.0)
 1154 FORMAT(21H    PRECIPITATION      ,10F8.3)
 1055 FORMAT(/6H LOSES)
 1056 FORMAT(/12H PERCOLATION)
 1057 FORMAT(/11H STREAMFLOW)
 1058 FORMAT(/19H EVAPOTRANSPIRATION)
 1059 FORMAT(/22H END-OF-MONTH STORAGES)
 1140 FORMAT(1H0)
 1160 FORMAT(21H    INTERCEPTION       ,10F8.3)
 1161 FORMAT(21H   INFILTRATION-DIRECT,10F8.3)
 1162 FORMAT(21H               -FROM SRS ,10F8.3)
 1163 FORMAT(21H               -FROM SDS ,10F8.3)
 1164 FORMAT(21H    SURFACE RETENTION ,10F8.3)
 1165 FORMAT(21H    UZS-LZS            ,10F8.3)
 1166 FORMAT(21H    LZS-GWS            ,10F8.3)
 1167 FORMAT(21H    UNDERFLOW          ,10F8.3)
 1168 FORMAT(21H    IMPERVIOUS AREA    ,10F8.3)
 1169 FORMAT(21H    SURFACE            ,10F8.3)
 1170 FORMAT(21H    INTERFLOW          ,10F8.3)
 1171 FORMAT(21H    BASEFLOW           ,10F8.3)
 1172 FORMAT(21H    INTERCEPTION       ,10F8.3)
 1173 FORMAT(21H    SRS                ,10F8.3)
 1174 FORMAT(21H    UZS                ,10F8.3)
 1175 FORMAT(21H    LZS                ,10F8.3)
 1176 FORMAT(21H    GWS                ,10F8.3)
 1177 FORMAT(21H    POTENTIAL          ,10F8.3)
 1178 FORMAT(21H    SDS                ,10F8.3)
 1179 FORMAT(21H    SRS                ,10F8.3)
 1180 FORMAT(21H    UZS                ,10F8.3)
 1181 FORMAT(21H    LZS(NON-CONTRB.)   ,10F8.3)
 1182 FORMAT(21H  GWS                  ,10F8.3)
 1183 FORMAT(21H    BALANCE            ,10F8.3)
 1184 FORMAT(21H    TOTAL FLOW         ,10F8.3)
```

```
1185 FORMAT(21H    TOTAL                ,10F8.3)
1186 FORMAT(21H    ICPT                 ,10F8.3)
1187 FORMAT(21H    LZS(ALLUVIAL)        ,10F8.3)
1188 FORMAT(21H    LZS(HILLSIDE)        ,10F8.3)
     WRITE(6,1052)  (NAME(N),N=1,16),MOCHAR(MONTH),YEAR
      NSW = 0
      NCK = 0
 114 NSW = NSW + 1
     IF(NSW.GT.NSURWS) GO TO 115
     IF(SWLIKE(NSW).NE.NSW) GO TO 114
     NCK = NCK + 1
     DO 116 N = 1,33
 116 SUM(N,NCK) = SUM(N,NSW)
     DELTA(NCK) =                   IAM1*(SDS(NSW)+UZS(NSW)+SRS(NSW))
    1   + IAM1*ICPT(NSW)
    1   + IAM2*(LZS(NSW)*FRLZ(NSW)+ALZS(NSW)*FALZ(NSW)
    1     + HLZS(NSW)*FHLZ(NSW)) +GWS(NSW)-SUM(26,NCK)-SUM(27,NCK)
    2          -SUM(28,NCK) - SUM(29,NCK) - SUM(30,NCK)
    2  - SUM(31,NCK) - SUM(32,NCK) - SUM(33,NCK)
     SUM(26,NCK) =                  SDS(NSW)*IAM1
     SUM(27,NCK) = SRS(NSW)*IAM1
     SUM(28,NCK) = UZS(NSW)*IAM1
     SUM(29,NCK) =  IAM2*LZS(NSW)*FRLZ(NSW)
     SUM(30,NCK) = GWS(NSW)
     SUM(31,NCK) = IAM2*ALZS(NSW)*FALZ(NSW)
     SUM(32,NCK) = IAM2*HLZS(NSW)*FHLZ(NSW)
     SUM(33,NCK) = IAM1*ICPT(NSW)
     WNUM(NCK) = NSW
     GO TO 114
 115 CONTINUE
     WRITE(6,1053)  (WNUM(N),N=1,NCK)
     WRITE(6,1023)
     WRITE(6,1154)(SUM(16,N),N=1,NCK)
     WRITE(6,1055)
     WRITE(6,1160)(SUM(1,N),N=1,NCK)
     WRITE(6,1161)(SUM(3,N),N=1,NCK)
     WRITE(6,1162)(SUM(7,N),N=1,NCK)
     WRITE(6,1163)(SUM(6,N),N=1,NCK)
     WRITE(6,1164)(SUM(4,N),N=1,NCK)
     WRITE(6,1056)
     WRITE(6,1165)(SUM(8,N),N=1,NCK)
     WRITE(6,1166)(SUM(12,N),N=1,NCK)
     WRITE(6,1167)(SUM(17,N),N=1,NCK)
     WRITE(6,1057)
     WRITE(6,1168)  (SUM(19,N),N=1,NCK)
     WRITE(6,1169)(SUM(5,N),N=1,NCK)
     WRITE(6,1170)(SUM(14,N),N=1,NCK)
     WRITE(6,1171)(SUM(15,N),N=1,NCK)
     DO 113 N=1,NCK
 113 SUM(23,N) = SUM(19,N)+SUM(5,N)+SUM(14,N)+SUM(15,N)
     WRITE(6,1184)(SUM(23,N),N=1,NCK)
     WRITE(6,1058)
```

```
      WRITE(6,1172)(SUM(2,N),N=1,NCK)
      WRITE(6,1173)(SUM(9,N),N=1,NCK)
      WRITE(6,1174)(SUM(10,N),N=1,NCK)
      WRITE(6,1175)(SUM(11,N),N=1,NCK)
      WRITE(6,1176)(SUM(13,N),N=1,NCK)
      DO 119 N = 1,NCK
  119 SUM(24,N) = SUM(2,N)+SUM(9,N)+SUM(10,N)+SUM(11,N)+SUM(13,N)
      WRITE(6,1185)  (SUM(24,N),N=1,NCK)
      WRITE(6,1177)  (SUM(18,N),N=1,NCK)
      WRITE(6,1059)
      WRITE(6,1186)  (SUM(33,N),N=1,NCK)
      WRITE(6,1178)(SUM(26,N),N=1,NCK)
      WRITE(6,1179)(SUM(27,N),N=1,NCK)
      WRITE(6,1180)(SUM(28,N),N=1,NCK)
      WRITE(6,1181)(SUM(29,N),N=1,NCK)
      WRITE(6,1187)  (SUM(31,N),N=1,NCK)
      WRITE(6,1188)  (SUM(32,N),N=1,NCK)
      WRITE(6,1182)(SUM(30,N),N=1,NCK)
      DO 118 N = 1,NCK
  118 SUM(25,N) = SUM(16,N) - SUM(2,N)  - SUM(9,N) - SUM(10,N)
     1           -SUM(11,N) - SUM(13,N) - SUM(5,N) - SUM(14,N)
     2           -SUM(15,N) - SUM(17,N) - DELTA(N) - SUM(19,N)
      WRITE(6,1140)
      WRITE(6,1183)(SUM(25,N),N=1,NCK)
  120 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE REST(NR)
C DECLARATIONS
      INTEGER YRB,YEAR,STYR
      COMMON /BA/NAME(16),MOCHAR(12),YEAR,MONTH,LASTDA(2,12),DAYS(2,12),
     1        OPTI(20),OPTO(20),NSUBWS,SWLIKE(20),NFLPT
      COMMON /BCS/OUT(745),FIN(15,745),FLOW(745),FIN1(20),FIN2(20),
     1            DISTRO(20,900),NRCHS,SWSI(20),C0(20),C1(20),C2(20),
     1            NDIST(20),STRFLO(20,900),IFLO(744),BFLO(744),SRO(744),
     1            OUTED(20),RCHI(20),NSO(20),KPL(12,31),NRO(20)
      COMMON/RT/O1,S1(25),S3(25),C3(25),WV(25),IZAP,H,C4(25),ST
      COMMON/MRT/S2(25),NNXX
      COMMON/MR/RELEV(25),O2(25),SINT,ELINT,EFSD,COF,EGO,ICODE1,AA,B,C,N
     1HR,RRR(20),B0,B1,B2,B3,QCON,YRB,ECSD,COFF,DIV,STYR
      IF(MONTH.NE.10.OR.YEAR.NE.STYR)GO TO 83
C       CONSTRUCT 2S/DT + O  VARIABLES
      DO 10 I=1,NNXX
      S2(I)=S2(I)*12.1
      WV(I)=2.*S2(I)+O2(I)
   10 CONTINUE
C              HOURLY INFLOWS CARRIED IN FIN(NR,N)
C     CALCULATE INTERPOLATION VALUES FOR TABLE
      DO 8 I=2,NNXX
      S3(I)=(RELEV(I)-RELEV(I-1))/(S2(I)-S2(I-1))
      C3(I)=RELEV(I)-S3(I)*S2(I)
      S1(I)=(O2(I)-O2(I-1))/(WV(I)-WV(I-1))
      C4(I)=O2(I)-S1(I)*WV(I)
    8 CONTINUE
  102 CONTINUE
C       RESERVOIR ROUTING
      EL=ELINT
      ST=SINT*12.1
   83 CONTINUE
      DO 60 I=1,NHR
      IF(MONTH.EQ.10.AND.YEAR.EQ.STYR.AND.I.EQ.1) GO TO 533
      GO TO 700
  533 IF(FIN1(NR).LE.0.0)FIN1(NR)=ST/744.
      GO TO 600
  700 IF(ICODE1.EQ.1)GO TO 51
C       CONSTANT OUTFLOW UNTIL EL>EGO
      IF(EL.GT.EGO)GO TO 52
      OUT(I)=COF
      GO TO 53
   52 IF(I-1.LE.0)GO TO 600
      OUT(I)=AA + B*EL + C*FIN(NR,I-1)
      TOUT=COFF*FIN(NR,I-1)
      GO TO 601
  600 OUT(I)=AA + B*EL + C*FIN1(NR)
      TOUT=COFF*FIN1(NR)
      IF(TOUT.LE.0.0)TOUT=COF
      IF(OUT(I).LT.TOUT) OUT(I)=TOUT
```

```
      IF(OUT(I).LE.COF) OUT(I)=COF
      IF(I-1.LE.0)GO TO 53
  601 CONTINUE
      TEST=B0+B1*EL+B2*EL**2+B3*EL**3
      IF(TOUT.LE.0.0)TOUT=COF
      IF(TEST.LE.0.0)TEST=TOUT
      IF(FIN(NR,I-1).GE.ECSD)OUT(I)=TEST
      IF(FIN(NR,I-1).LT.ECSD.AND.OUT(I).GE.TEST) OUT(I)=TEST
      IF(FIN(NR,I-1).LT.ECSD.AND.OUT(I).LT.TOUT) OUT(I)=FIN(NR,I-1)
      IF(OUT(I).LE.COF) OUT(I)=COF
   53 IF(I-1.LE.0)GO TO 400
      DELS=FIN(NR,I)-OUT(I)
      GO TO 401
  400 DELS=FIN1(NR)-OUT(I)
  401 ST=ST+DELS-DIV
      IZAP=0
      CALL TABLE(ST)
      EL=H
      ICODE1=0
      IF(EL.GT.EFSD.AND.OUT(I).GT.QCON)ICODE1=1
      IF(ICODE1.EQ.1)STT=2.*ST+OUT(I)
      GO TO 50
C      MODIFIED PULS ROUTING
   51 IF(I-1.LE.0)GO TO 200
      S202=STT-OUT(I-1)+FIN(NR,I)
      GO TO 201
  200 S202=STT-OUTED(NR)+FIN1(NR)
  201 IZAP=1
      CALL TABLE(S202)
       OUT(I)=O1
      IF(OUT(I).LT.COF)OUT(I)=COF
      STT=S202
      GO TO 50
   48 OUT(I)=COF
      STT=2.*ST+OUT(I)
   50 IF(OUT(I).LE.QCON)ICODE1=0
   60 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TABLE(F)                                               TBLE
      COMMON/RT/O1,S1(25),S3(25),C3(25),WV(25),IZAP,H,C4(25),ST         TBLE
      COMMON/MRT/S2(25),NNXX                                            TBLE
      IF(IZAP.NE.1)GO TO 2                                              TBLE
      DO 1 I=2,NNXX                                                     TBLE
      IF(F.LT.WV(I))GO TO 4                                             TBLE
    1 CONTINUE                                                          TBLE
      I=NNXX                                                            TBLE
    4 O1=S1(I)*F+C4(I)                                                  TBLE
      STU = S2(I)                                                       TBLE
      STUC = STU - O1                                                   TBLE
      ST = STUC                                                         TBLE
      RETURN                                                            TBLE
    2 DO 6 I=2,NNXX                                                     TBLE
      IF(F.LT.S2(I))GO TO 7                                             TBLE
    6 CONTINUE                                                          TBLE
      I=NNXX                                                            TBLE
    7 H=S3(I)*F+C3(I)                                                   TBLE
      RETURN                                                            TBLE
      END                                                               TBLE
```

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