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FLORIDA GEOLOGICAL SURVEY

Robert O. Vernon, *Director*

REPORT OF INVESTIGATIONS NO. 42

HYDROLOGY OF GREEN SWAMP AREA IN CENTRAL FLORIDA

By
R. W. Pride, F. W. Meyer, and R. N. Cherry

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
FLORIDA GEOLOGICAL SURVEY,
the
FLORIDA DIVISION OF WATER RESOURCES AND CONSERVATION,
and the
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TALLAHASSEE
1966

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LETTER OF TRANSMITTAL

Florida Geological Survey

Tallahassee

February 4, 1966

Honorable Haydon Burns, *Chairman*
Florida State Board of Conservation
Tallahassee, Florida

Dear Governor Burns:

For many years, it has been thought that much of the recharge of water to Florida's prolific artesian aquifer occurred in the Green Swamp area. For this reason, it was believed that a detailed geologic and hydrologic study of the area would be helpful and necessary. I am pleased to report to you that a study, "Hydrology of Green Swamp Area in Central Florida," prepared by R. W. Pride, F. W. Meyer, and R. N. Cherry, of the U. S. Geological Survey, in cooperation with the Division of Geology of the State Board of Conservation, will be published as Florida Geological Survey Report of Investigations No. 42.

This report provides all of the data necessary for the wise utilization, and perhaps for the preservation, of parts of the Green Swamp area. It will also assist in the planning for the Four-Rivers area to alleviate floods and to conserve our water and land.

Respectfully yours,

Robert O. Vernon
Director and State Geologist

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PREFACE

This report was prepared by the Water Resources Division of the U. S. Geological Survey in Cooperation with the Florida Geological Survey, the Florida Division of Water Resources and Conservation, and the Southwest Florida Water Management District.

The authors wish to express their appreciation for the cooperation of the many residents and public officials for information given during the well inventory and reconnaissance of the area. Special acknowledgement is due the Florida State Road Department, the Florida Forest Service, and property owners who granted permission to drill test wells. The following agencies made financial contributions for the collecting of data used in this report: Hillsborough County, Marion County, Pasco County, Polk County, Sumter County, Lake Apopka Recreation and Water Conservation Control Authority, Oklawaha Basin Recreation and Water Conservation and Control Authority, and Tsala Apopka Basin Recreation and Water Conservation Control Authority.

The calcium carbonate equilibrium study of ground water of central Florida was based on data collected and analysed in cooperation with William Back, Geologist, Water Resources Division, Arlington, Virginia, as part of an investigation of ground water along the Atlantic seaboard. Contributions to the knowledge of the geohydrology in the Withlacoochee-Hillsborough overflow area were made by Z. S. Altschuler, Geologist, Geologic Division, Washington, D. C. Assistance in the interpretation of electric and drillers' logs was rendered by C. R. Sproul, Geologist, Florida Geological Survey.

The work on this project was done under the supervision of the Florida Water Resources Division Council comprised of A. O. Patterson, district engineer of the Branch of Surface Water, M. I. Rorabaugh, succeeded by C. S. Conover, district engineers of the Branch of Ground Water, and J. W. Geurin, district chemist, succeeded by K. A. MacKichan, district engineer, of the Branch of Quality of Water.

HYDROLOGY OF GREEN SWAMP AREA IN CENTRAL FLORIDA

By

R. W. Pride, F. W. Meyer, and R. N. Cherry

ABSTRACT

Green Swamp is an area of about 870 square miles of swampy flatlands and sandy ridges near the center of the Florida Peninsula. The elevation of the land surface ranges from about 200 feet above mean sea level in the eastern part to about 75 feet in the western part. The Withlacoochee River drains two-thirds of the area. The Little Withlacoochee River, the headwaters of the Oklawaha River, the Hillsborough River, the headwaters of the Kissimmee River, and the headwaters of Peace River drain the remaining area. The surface is mantled with a varying thickness of sand and clay which comprises the nonartesian aquifer. Porous marine limestones comprising the Floridan aquifer underlie and drain the subsurface. The Floridan aquifer crops out in the western part of the area and occurs at depths ranging from 50 to more than 200 feet in the eastern part. The mineral content of both surface and ground water does not impair the usability of the water for most purposes. However, surface water is generally highly colored and acidic, and ground water is hard and generally contains objectionable amounts of iron.

Hydrologic data were collected during the period, July 1, 1958, to June 30, 1962, for making quantitative and qualitative analyses of the hydrologic budget and for determining the significance of the hydrology of the Green Swamp area with respect to central Florida.

Extremely high and unusually low annual rainfalls were recorded during the period of investigation. The factors of the water budget for each of the 3 complete years of record, 1959-1961, show that average rainfall on the area ranged from 70.9 to 34.7 inches; surface runoff ranged from 31.1 to 2.3 inches; ground-water outflow ranged from 1.8 to 2.2 inches; and water derived from change in storage ranged from insignificant amounts in 1959 and 1960 to about 4.3 inches in 1961. Evapotranspiration losses, which were the residuals in the water-budget equation, ranged from 39.1

to 34.5 inches. Surface runoff varied through a wide range from wet to dry years, while ground-water outflow varied little. The data show that the annual losses by evapotranspiration varied little from wet to dry years. Evaporation losses from Lake Helene amounted to 53.1 inches during 1962.

Comparison of water-budget factors for the eastern and western parts of the area shows that higher rates of ground-water recharge to the Floridan aquifer occur in the eastern part.

The amount of annual runoff from the total area has not significantly changed in recent years. However, the distribution of the runoff has been changed by drainage canals that divert some of the flow from the upper Oklawaha River into the Withlacoochee River.

Impoundment of water in Green Swamp would provide some flood protection for the lower Hillsborough River and the lower Withlacoochee River basins. Impoundment of the total discharge from Green Swamp to the Hillsborough River during the March 1960 flood would have reduced the flood crest at 22nd Street, Tampa, by about 1 foot. Impoundment of the March 1960 flood discharge in reservoirs proposed for the Green Swamp area (Corps of Engineers, 1961) would have reduced the flood crest of the Withlacoochee River at the Trilby gaging station by about 4 feet and at the Croom gaging station by about 1.7 feet.

Impoundment of water in Green Swamp Reservoir would have little effect on ground-water outflow from the total Green Swamp area because of increased seepage rates beneath the levee, increased evaporation losses, and because the aquifer under present conditions is essentially full. Impoundment of water in the Southeastern Conservation Area (Johnson, 1961) would increase the seepage rates during dry periods by about 60 percent. Impoundment of water will become more significant relative to ground-water recharge as pumpage from the Floridan aquifer increases.

High piezometric levels in the southeastern part of the Green Swamp area are caused partly by a relatively slow rate of ground-water outflow due to sand-filled fractures, caverns, and sinkholes in the Floridan aquifer.

Mineral content and calcium carbonate saturation studies show that generally the water in the Floridan aquifer in central Florida is low in mineral content and undersaturated.

Interpretation of quantitative and qualitative data indicate that recharge to the Floridan aquifer in the Green Swamp area is about the same as that in other parts of central Florida.

INTRODUCTION

To satisfy the demands of a rapidly increasing population, many acres of land in Florida are converted each year to residential and industrial uses. Urbanization of these areas and the demand for increasing the food supply thus require that man search for new areas to develop for agricultural uses. This search, in many instances, has led to the development of marginal lands.

The Green Swamp area, shown in figure 1, in central Florida is an area where man is developing agricultural land from marginal land. The present efforts for its development are similar to the early efforts for developing the Everglades in that many miles of canals and ditches have been constructed to improve the drainage.

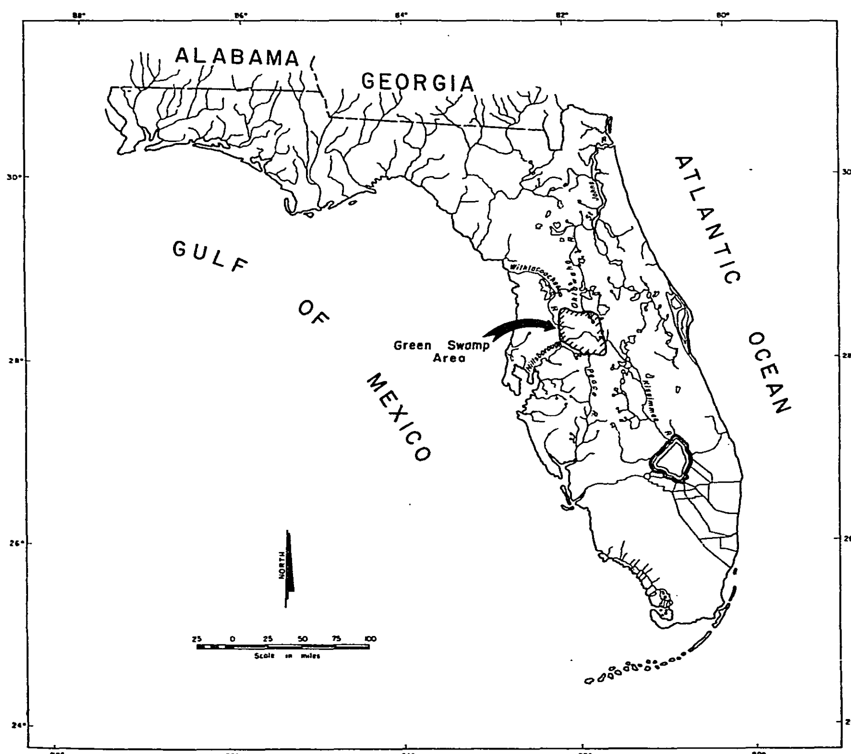


Figure 1. Map of Florida showing location of Green Swamp area.

PURPOSE AND SCOPE

Lest the early mistakes of the Everglades be repeated, the Florida Division of Water Resources and Conservation considered that an appraisal of the physical and hydrologic features of the Green Swamp area was needed for future guidance in planning water-resource policy. Lack of factual hydrologic information has contributed to the controversy on whether the area should be utilized for flood control and water conservation or for agriculture. This investigation provides factual information on the hydrology of the area for determining the feasibility of either choice of utilization.

The hydrology of the Green Swamp area was investigated by the U. S. Geological Survey in cooperation with the Florida Geological Survey, the Florida Division of Water Resources and Conservation, and the Southwest Florida Water Management District. The investigation covered a 4-year period beginning July 1, 1958. A Comprehensive Report on Four River Basins, Florida, was prepared by the Corps of Engineers in 1961.

The following factual data, used to appraise the hydrologic significance of the area, were collected during the investigation; the amount of rainfall on the area; the pattern of surface-water drainage; the effects of improved drainage channels and man-made diversions; the amount and direction of surface-water runoff; the amount and direction of ground-water outflow; the amount of evaporation losses from an open water surface; the interrelationship of rainfall, surface water, and ground water; and the chemical and physical characteristics of water in relation to the hydrologic environment.

A comprehensive appraisal of the hydrology of the Green Swamp area and its significance to central Florida have been made on the basis of the findings of this investigation. The report does not recommend any plan of development or utilization of the water resources of the area. An appraisal was made, however, of the hydrologic effectiveness of a plan of water control and water conservation proposed by the U. S. Corps of Engineers (1961).

PREVIOUS INVESTIGATIONS

Only cursory investigations of the water resources and geology of the Green Swamp area were made prior to this investigation. Few long-term records of streamflow, ground-water levels, and chemical quality had been collected in the vicinity as part of the statewide data-collection programs.

Many of the physical and hydrologic features of the area are given in an interim report by Pride, Meyer, and Cherry (1961).

General descriptions of the geology of the region have been given by Cooke (1945), Vernon (1951), White (1958), and Stewart (1959). Stringfield (1936) defined and described the principal artesian aquifer of Florida.

Analyses of water from surface and ground sources in the vicinity of the Green Swamp area are given in reports by Collins and Howard (1928) and Black and Brown (1951).

METHODS OF INVESTIGATION

Most of the data for the investigation were collected during the 4-year period from July 1958 to June 1962 and covered a wide range of hydrologic conditions.

The investigation of the water resources of the Green Swamp area involves studies of water in three main physical environments: (1) precipitation, which occurs as rainfall; (2) surface water, which occurs on the surface of the ground; and (3) ground water, which occurs beneath the surface of the ground.

Waters in these environments are interrelated. Thus, it was necessary to study the whole process or system, rather than any part, to understand and to evaluate the water resources of the area.

The methods of studying water in each environment are different. Some characteristics of water in the three environments may be measured directly; some may be evaluated by analysis of representative samples from which results may be inferred; and some characteristics and quantities must be determined indirectly. For instance, the chemical characteristics of the water at a particular place can be used as an indication of the environment through which the water has passed. The surface materials in the Green Swamp area are relatively insoluble and the surface waters are therefore low in mineral content. The rock below the surface materials is relatively soluble and the contained water is considerably more mineralized. Mineralized streamflow in areas such as the Green Swamp, where industrial and municipal disposals into streams are minor, indicates ground-water inflow into streams. Therefore, the chemistry of the water can be used as a tool to give a more complete evaluation of the hydrology of the area.

Daily records of rainfall were collected at 24 stations located as shown in the figures on pages 2 and 5. Some of these records are from U. S. Weather Bureau long-term stations. Short-term rainfall records were collected at stream or well data-collection stations during part of the investigation using standard 8-inch gages with tipping-bucket attachments to the water-stage recorders.

Surface-water characteristics of the area were determined by collecting stage, streamflow, and chemical-quality data at gaging stations and at miscellaneous sites; by making field and aerial reconnaissance of the area; and by studying maps and aerial photographs.

All surface-water data-collection stations are presented in table 1 and located in figure 2 and in the figure on page 5. The grid coordinate number shown in column 2 of table 1 is based on the

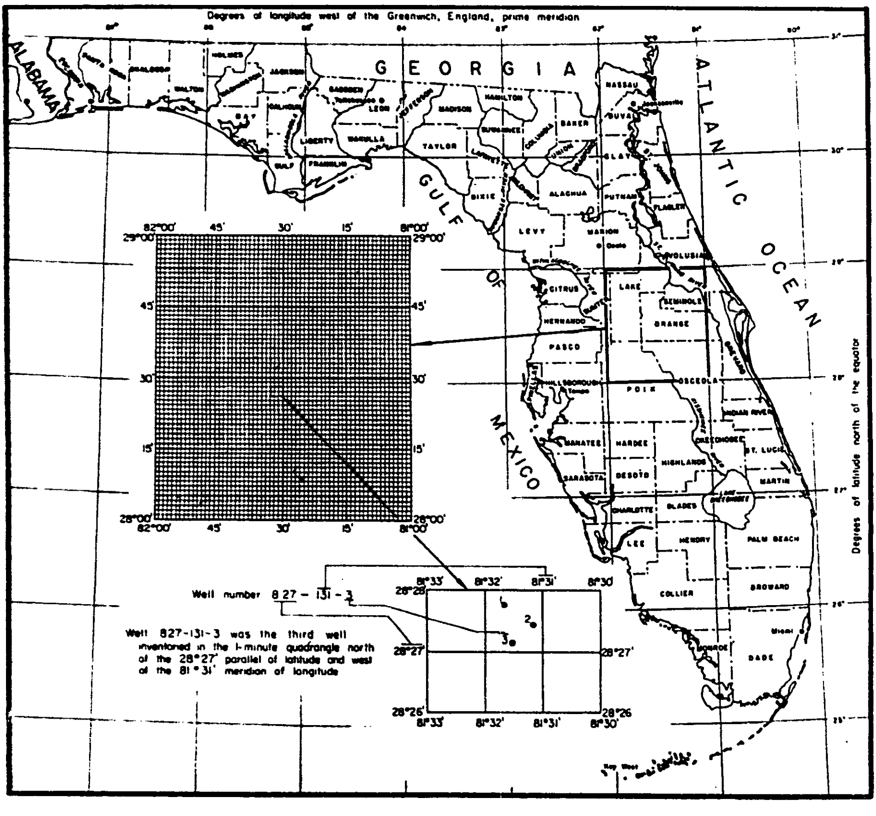


Figure 3. Diagram showing the well-numbering system used in Florida.

TABLE 1. Surface-water data-collection points in Green Swamp area and vicinity.

Type of record: A, Standard chemical analysis; D, Discharge and stage; E, Evaporation; K, Conductivity; S. Stage.

Frequency of record: d, Daily; p, periodic (monthly to bimonthly intervals); r, Continuous; w. Weekly; (9), Total number of analyses of samples or measurements of streamflow.

Station No. on fig. 5	Grid co-ordinate No. on fig. 2	Location (in downstream order)	Drainage area sq. mi.	Type and frequency of record	Period of record
		ST. JOHNS RIVER BASIN			
1	807-140	Lake Lowery near Haines City	----	Sd	June 1960 to June 1962
				A (3)	1959-62
2	815-140	Green Swamp Run near Loughman	33	Dr	March 1961 to June 1962
				A (1)	1959
3	826-144	Big Creek near Clermont	68	Dp (27)	1945-47, 1952-56
				Dr	July 1958 to June 1962
				A (11)	1956-61
4	826-144	Bear Branch near Clermont	1.9	Dp (27)	1958-61
				A (1)	1960
5	825-147	Little Creek at Cooper's Ranch near Clermont	10	Dr	June 1960 to June 1962
				A (3)	1959-61
6	827-145	Little Creek near Clermont	15	Dp (34)	1945-60
				A (6)	1956-59
7	828-147	Lake Glona Outlet near Clermont	8.4	Dp (8)	1959-60
				Dd	April 1961 to June 1962
8	829-144	Lake Louisa near Clermont	----	Sd	March 1957 to June 1962
				A (1)	1959
9	832-145	Lake Minnehaha at Clermont	----	Sr	June 1945 to June 1962
				A (2)	1956, 1961
10	836-146	Lake Apshawa near Minneola	----	Sw	April 1953 to June 1962
11	835-149	Palatlakaha Creek at Cherry Lake Outlet near Groveland	160	Dr	March 1957 to June 1962
12	837-151	Palatlakaha Creek near Mascotte	180	Dr	May 1945 to March 1956
13	832-137	Johns Lake at Oakland	----	Sw	September 1959 to June 1962
14	834-135	Lake Apopka at Winter Garden	----	Sr	September 1942 to June 1962
15	843-141	Apopka-Beauclair Canal near Astatula	180	Dr	July 1958 to June 1962

TABLE 1. (Continued)

Station No. on fig. 5	Grid co-ordinate No. on fig. 2	Location (in downstream order)	Drainage area sq. mi.	Type and frequency of record	Period of record
		KISSIMMEE RIVER BASIN			
16	829-132	Lake Butler at Windermere	—	Sw, Sd	January 1933 to June 1962
17	823-131	Cypress Creek near Vineland	30.3	Dr	August 1945 to June 1962
18	815-132	Reedy Creek near Loughman	—	Dr A(1)	October 1939 to September 1959 1959
19	810-135	Horse Creek at Davenport	22.8	Dr A(10) Kr	June 1960 to June 1962 1959-61 July to November 1960
20	806-131	Lake Marion near Haines City	—	Sd	February 1958 to June 1962
		PEACE RIVER BASIN			
21	802-139	Lake Hamilton at Lake Hamilton	—	Sw	June 1945 to June 1962
22	806-142	Gum Lake marsh outlet at Lake Alfred	4.2	Dd A(2)	October 1960 to June 1962 1960, 1961
23	804-143	Lake Rochelle near Lake Alfred	—	Sd	March 1946 to June 1962
24	805-144	Lake Alfred at Lake Alfred	—	Sd	March 1961 to June 1962
25	801-142	Lake Otis at Winter Haven	—	Sr	August 1954 to June 1962
26	804-145	Lake Mariana near Auburndale	—	Sw	February 1946 to June 1962
27	803-144	Lake Hartridge at Winter Haven	—	Sw	February 1946 to June 1962
28	801-144	Lake Howard at Winter Haven	—	Sr	April 1945 to June 1962
29	802-155	Lake Parker at Lakeland	—	Sw, Sr	1949-54, July 1954 to June 1962
30	801-154	Crystal Lake at Lakeland	—	Sr, Sp A(1)	1951-52, 1954-57 1959
		HILLSBOROUGH RIVER BASIN			
—	811-209	Hillsborough River at State Highway 39	—	A(1)	1959
31	810-211	Crystal Springs near Zephyrhills	—	Dp(227) A(3)	1933-62 1959
32	808-209	Blackwater Creek near Knights	110	Dr	January 1951 to June 1962

TABLE 1. (Continued)

Station No. on fig. 5	Grid co-ordinate No. on fig. 2	Location (in downstream order)	Drainage area sq. mi.	Type and frequency of record	Period of record
33	808-214	Hillsborough River near Zephyrhills	220	Dd A (55)	November 1939 to June 1962 1956-62
		WITHLACOOCHEE RIVER BASIN			
—	809-142	Swamp at Holiday Manor near Haines City	—	A (1)	1959
34	807-147	Lake Juliana near Polk City	—	Sd	December 1961 to June 1962
35	804-147	Lake Mattie near Polk City	—	Sd, Sw A (3)	June 1960 to December 1961 1960-62
—	815-146	Swamp near Polk City	—	A (1)	1959
—	818-148	Withlacoochee River at Van Fleet Road, near Eva	—	A (1)	1959
36	821-149	Withlacoochee River near Eva	130	Dr A (14)	July 1958 to June 1962 1958-61
37	810-148	Lake Helene near Polk City	—	Sr Er A (2)	April 1961 to December 1962 December 1961 to December 1962 1962
38	815-148	Pony Creek near Polk City	9.5	Dr A (9) Kr	June 1960 to June 1962 1960-61 July to November 1960
—	809-148	Little Lake Agnes near Polk City	—	A (1)	1959
—	810-149	Lake Agnes at Polk City	—	Sp	1961-62
—	818-155	Grass Creek near Rock Ridge	—	A (1)	1959
—	819-155	Withlacoochee River near Rock Ridge	—	A (1)	1959
—	819-200	Withlacoochee River near Cumpressco	—	D (2), A (1)	1961
—	818-203	Withlacoochee River upstream from Gator Creek	—	D (2), A (1)	1961
—	818-203	Gator Creek at mouth	—	D (2), A (1)	1961
39	816-205	Withlacoochee-Hillsborough overflow near Richland	—	Dd Dp, Dr A (4)	1930-31 July 1958 to June 1962 1959-60
—	817-206	Withlacoochee River near Richland	—	D (2), A (2)	1959-61

TABLE 1. (Continued)

Station No. on fig. 5	Grid co-ordinate No. on fig. 2	Location (in downstream order)	Drainage area sq. mi.	Type and frequency of record	Period of record
40	821-207	Withlacoochee River near Dade City	390	Dd,Dp (29) A(12)	1930-33; 1958-62 1958--61
41	822-211	Pasco Packing Co. canal at Dade City	----	Dp(48) A(5)	1957-62 1959-61
---	824-209	Hamilton Lake Outlet near Dade City	----	D(2), A(1)	1961
---	826-209	Withlacoochee River near Lacoochee	----	D(2), A(4)	1959-61
---	826-201	Gator Hole Slough near Bay Lake	----	A(1)	1959
--	827-203	Gator Hole Slough near Clay Sink	----	A(1)	1959
---	821-202	Swamp near Cumpressco	----	A(1)	1959
----	828-208	Weaver Hole Slough at Lacoochee	----	A(1)	1959
----	828-209	Withlacoochee River at Lacoochee	----	A(1)	1959
42	828-210	Withlacoochee River at Trilby	580	Dr A(9)	1928-29; February 1930 to June 1962 1959-61
----	829-154	Bay Lake near Bay Lake	----	A(1)	1959
---	829-158	Bayroot Slough near Bay Lake	----	A(1)	1959
---	829-200	Little Withlacoochee River near Clay Sink	----	A(2)	1959
43	834-209	Little Withlacoochee River at Rerdell	160	Dr A(9)	July 1958 to June 1962 1959-61
44	835-213	Withlacoochee River at Croom	880	Dr A(8)	October 1939 to June 1962 1959-61

well-numbering system shown in figure 3. Records of streamflow and stage at 24 sites and of stage of 20 lakes were collected in or near the area of investigation.

Information on the quality of surface water was obtained during high, intermediate, and low flows to determine the general chemical characteristics and the extremes in quality characteristics during the period of study. These data were supplemented with a series of reconnaissances over the entire area generally within a period of

1 to 3 days. The data were used to determine the quality of water prevalent in the area at a given time and to help determine the interrelations between surface water and ground water.

Ground-water characteristics were determined by collecting data concerning water levels, surface and subsurface geology, and water chemistry from an inventory of existing wells in the Green Swamp area and vicinity (fig. 2). Information on the depth of the well, the amount of casing, and the depth to static water level was recorded for more than 600 wells. Most of the inventoried wells penetrated the Floridan aquifer. The approximate elevation of land surface above mean sea level was determined at each well by use of either altimeter, topographic maps, or spirit level. These data were supplemented by selected data collected prior to this investigation and by test drilling to provide better coverage of the area.

The well-numbering system that is derived from latitude and longitude coordinates is based on a state-wide grid of 1-minute parallels of latitude and 1-minute meridians of longitude, shown in figure 3.

Instruments were used to record continuously the water-level fluctuations in the various aquifers. These data were supplemented by periodic determinations of water levels and chemical characteristics of water in selected wells in order to evaluate areas of recharge and discharge for the aquifers.

The wells in which continuous and selected periodic water-level data, and quality-of-water data were collected, are presented in table 2.

During the periods October to December 1959 and May to June 1962, water-level measurements were made to prepare piezometric maps which show the direction of water movement in the Floridan aquifer. Hydraulic gradients scaled from these maps were used to infer rates of water movement.

To obtain general information on the occurrence of artesian and nonartesian ground water in the Green Swamp area, 26 test wells were drilled at 16 different sites. At 9 of these sites a pair of wells were drilled (one into the Floridan aquifer and one into the nonartesian aquifer). A summary of test-well data is presented in table 3. During the drilling, samples of rock cuttings were collected. The lithology of the various formations and significant changes in water levels were recordered in the well log. Examination of rock cuttings of selected wells were supplemented

TABLE 2. Ground-water data-collection points in Green Swamp area and vicinity.

Well number: See figure 3 for explanation of well-numbering system.

County: He, Hernando; Hi, Hillsborough; La, Lake; Or, Orange; Pa, Pasco; Po, Polk; Su, Sumter.

Aquifer(s): F, Floridan; H, secondary artesian; N, nonartesian.

Type and frequency of record: A, standard chemical analysis; B, spectrographic analysis; K, partial chemical analysis; S, water level; T, tritium determination; (3) number of analyses; p, periodic; r, continuous.

Well number	County	Aquifer	Type and frequency of record	Period of record
800-153-1	Po	F, H	Sp	December 1954 to May 1962
801-207-1	Hi	F	A(1)	May 1962
802-135-1	Po	F	Sp	November 1957 to February 1960
802-157-12	Po	F	A(1)	March 1962
803-147-4	Po	F	A(1)	March 1962
803-204-1	Hi	F	Sp	May 1958 to May 1962
804-207-1	Hi	F	Sp	November 1956 to May 1962
805-155-1	Po	N	Sr Sp	August 1955 to February 1960 February 1960 to June 1962
805-155-2	Po	F	Sr Sp A(1)	March 1956 to February 1960 February 1960 to June 1962 November 1959
805-155-3	Po	H	Sr Sp	February 1956 to February 1960 February 1960 to June 1962
806-137-6	Po	F	A(1)	March 1962
806-140-2	Po	F	A(1)	November 1959
806-155-3	Po	F	Sp	July 1954 to February 1960
806-156-1	Po	N	Sp	August 1955 to June 1962
806-156-2	Po	F	Sp	January 1956 to June 1962
807-202-1	Po	F	A(1)	November 1959
808-139-1	Po	N	A(1)	February 1962
808-143-1	Po	F	A(1)	February 1962
808-147-1	Po	F	A(1)	February 1962
808-153-1	Po	F	Sp A(1)	January 1958 to May 1962 November 1959
808-155-1	Po	F	Sp Sr A(1)	June 1955 to March 1956 March 1956 to June 1962 November 1959
808-155-2	Po	N	Sp	June 1955 to June 1962
809-154-4	Po	F	A(1)	February 1962
809-158-1	Po	H	A(1)	February 1962
810-136-1 (P-44)	Po	F	Sr	1946 to June 1962

TABLE 2. (Continued)

Well number	County	Aquifer	Type and frequency of record	Period of record
810-136-2 (P-47)	Po	N	Sr	1948 to June 1962
810-144-1	Po	F	Sp Sr A(21), K(5), T(4), B(4)	July 1959 to October 1960 October 1960 to June 1962 July 1959 to April 1962
810-144-2	Po	N	Sr A(3), K(2)	October 1960 to June 1962 July 1959 to November 1961
810-149-1	Po	F	A(2)	November 1959 to March 1962
810-149-2	Po	F	Sp	January 1955 to May 1962
810-151-2	Po	F	Sp	February 1960 to May 1962
810-207-1	Pa	F	Sp	June 1960 to May 1962
813-147-1	Po	F	A(1)	February 1962
813-149-1	Po	F	Sr A(6)	March 1959 to June 1962 April 1959 to March 1962
813-149-2	Po	N	Sr	April 1959 to June 1962
813-150-2	Po	N	Sr	October 1960 to June 1962
813-201-1	Po	F	Sp A(2)	August 1959 to June 1962 November 1959 to March 1962
814-143-1	Po	F	Sr	October 1960 to June 1962
814-143-2	Po	N	Sr	October 1960 to June 1962
814-148-1	Po	F	Sp Sr	October 1955 to July 1957 July 1957 to April 1959
814-210-1	Pa	F	A(1)	March 1962
814-210-2	Pa	F	A(1)	March 1962
815-134-1	Po	F	Sp Sr A(1)	August 1960 to October 1960 October 1960 to June 1962 March 1962
815-134-2	Po	N	Sp Sr	August 1960 to October 1960 October 1960 to June 1962
815-139-1	Po	F	A(1)	June 1959
815-139-2	Po	F	Sp Sr	August 1960 to October 1960 October 1960 to June 1962
815-139-3	Po	N	Sr	October 1960 to June 1962
815-149-3	Po	F	Sp Sr A(1)	July 1960 to November 1960 November 1960 to June 1962 April 1961
815-157-2	Po	F	Sp Sr A(1)	March 1956 to May 1958 May 1958 to June 1962 November 1959
815-203-1	Po	F	A(1)	February 1962
816-202-1	Po	F	A(2)	May 1951 to March 1962
816-202-2	Po	F	A(1)	May 1961

TABLE 2. (Continued)

Well number	County	Aquifer	Type and frequency of record	Period of record
816-206-1	Pa	F	Sp A(2)	July 1959 to June 1962 November 1959 to March 1962
816-211-1	Pa	F	Sp Sr	1936 to August 1951 August 1951 to March 1962
817-149-1	Po	F	A(1)	February 1962
817-150-1	Po	F	Sp	July 1959 to June 1962
818-155-3	Po	F	A(1)	November 1959
818-156-2	Po	F	A(1)	February 1962
818-209-1	Pa	F	Sp	October 1959 to June 1962
818-209-2	Pa	F	A(1)	February 1962
819-140-1	Po	F	Sp A(1)	May 1959 to June 1962 May 1959
849-147-1	Po	F	A(1)	November 1959
819-151-1	Po	F	Sp	October 1955 to June 1962
819-211-2	Pa	F	Sp	December 1959 to June 1962
821-158-2	Su	F	Sp	October 1959 to June 1962
821-202-1	Su	F	A(1)	May 1959
821-202-3	Su	F	Sr A(2)	March 1959 to June 1962 May 1959 to November 1959
821-207-1	Pa	F		October 1959 to June 1962
821-203-2	Pa	F	A(1)	February 1962
821-210-1	Pa	F	A(1)	November 1959
821-211-1	Pa	F	A(1)	March 1962
822-138-1	Or	F	Sr A(1)	February 1959 to June 1962 March 1962
822-138-2	Or	N	Sr	April 1959 to June 1962
822-149-1	La	F	Sr A(8)	February 1959 to March 1962 April 1959 to March 1962
822-149-2	La	N	Sr	April 1959 to June 1962
822-149-3	La	F	A(1)	February 1962
822-210-1	Pa	F	Sp	October 1959 to June 1962
822-211-1	Pa	F	A(1)	February 1959
824-142-1	La	F	Sp	December 1959 to June 1962
824-206-1	Pa	F	Sp	November 1958 to June 1962
824-211-1	Pa	F	Sp	December 1959 to June 1962
824-211-2	Pa	F	A(1)	February 1962
825-151-1	La	F	Sp	Ocober 1959 to June 1962
826-208-1	Pa	F	Sp	November 1958 to June 1962
826-211-1	Pa	F	Sp Sr	October 1959 to February 1960 February 1960 to June 1962

TABLE 2. (Continued)

Well number	County	Aquifer	Type and frequency of record	Period of record
827-144-1	La	F	A(1)	February 1962
827-149-1	Po	N	A(1)	February 1962
827-154-1	La	N	A(1)	February 1962
827-158-1	Su	F	Sp A(1)	July 1959 to June 1962 July 1959
827-210-1	Pa	F	Sp Sp	1936-50 (U.S. Corps of Engineers) October 1959 to July 1961
827-210-2	Pa	F	Sp	August 1961 to June 1962
828-154-1	La	F	Sp	November 1959 to June 1962
828-203-1	He	F	A(2)	July 1959 to November 1959
828-204-1	Pa	N	A(1)	February 1962
828-209-1	Pa	F	A(1)	February 1962
829-146-2	La	F	Sp	October 1959 to June 1962
829-202-1	Su	F	Sp	December 1959 to June 1962
829-206-1	He	F	Sp A(3)	May 1959 to June 1962 May 1959 to November 1959
830-157-1	Su	F	Sp A(3)	May 1959 to June 1962 May 1959 to November 1959
820-210-2	He	F	A(1)	November 1959
832-154-1	La	F	Sr A(9)	February 1959 to June 1962 April 1959 to March 1962
832-154-2	La	N	Sr	February 1959 to June 1962
832-154-3	La	N	A(3)	May 1959 to November 1959
832-204-1	Su	F	A(1)	February 1962
833-137-2	Or	F	Sr	March 1960 to June 1962
833-144-1	La	F	Sp	November 1959 to June 1962
833-144-2	La	F	A(1)	March 1962
833-151-1	La	F	Sp	November 1959 to June 1962
833-151-5	La	F	A(1)	March 1962
833-209-1	He	F	A(1)	February 1962
834-159-1	Su	F	Sp	November 1959 to June 1962
836-202-1	Su	F	A(1)	March 1962
836-202-2	Su	F	A(1)	February 1962
836-208-2	Su	F	A(1)	February 1962
838-159-2	Su	F	A(1)	November 1959
841-156-1	La	F	Sp	March 1961 to June 1962

TABLE 8. Test-well data in Green Swamp area and vicinity
(Aquifer: F, Floridan; N, Nonartesian)

Well number	Date drilled	Total depth below land surface (feet)	Casing		Open hole		Aquifer	Remarks
			Diameter (inches)	Depth below land surface (feet)	Diameter (inches)	Range in depth (feet)		
Lake County								
822-149-1	February 1959	95	6	59	5½	59- 95	F	
	July 1959	192	6	100	5½	95-192	F	Deepened for geologic control. Added casing.
822-149-2	February 1959	23	6	18	5½	18- 23	N	Gravel packed (limestone pebbles).
832-154-1	February 1959	73			5½	63- 73	F	
	July 1959	160	6	63	2½	73-160	F	Deepened for geologic control.
832-154-2	February 1959	22	6	16	5½	16- 22	N	Gravel packed (limestone peebles).
Orange County								
822-138-1	February 1959	114	6	103	5½	103-114	F	
	October 1960	318			5½	114-318	F	Deepened for geologic control.
822-138-2	February, 1959	30	6	13	5½	13- 30	N	Gravel packed (limestone pebbles).
Pasco County								
816-206-1	July 1959	200	3	41	2½	41-200	F	

TABLE 3. (Continued)

Well number	Date drilled	Total depth below land surface (feet)	Casing		Open hole		Aquifer	Remarks
			Diameter (inches)	Depth below land surface (feet)	Diameter (inches)	Range in depth (feet)		
Polk County								
810-144-1	July 1959	249	6	101	5½	101-249	F	
	October 1960	425			5½	249-425	F	Deepened for geologic control.
810-144-2	October 1960	9	6	6	5½	----	N	Finished with 3-foot section of no. 10 slot steel screen
813-149-1	February 1959	90	6	78	5½	78- 90	F	
	July 1959	217			5½	90-217	F	Deepened for geologic control.
813-149-2	February 1959	27	6	20	5½	20- 27	N	Gravel packed (limestone pebbles).
813-150-1	July 1960	205	6	106	5½	106-205	F	
813-150-2	July 1960	28	6	17	5½	17- 28	N	
813-201-1	July 1959	255	3	40	2½	40-255	F	
814-143-1	July 1960	285	6	80	5½	80-285	F	
814-143-2	August 1960	18	6	15	5½	15- 18	N	
815-134-1	August 1960	250	6	85	5½	83-250	F	
815-134-2	August 1960	32	6	29	5½	----	N	Finished with 3-foot section of no. 10 slot steel screen
815-139-2	August 1960	453	6	358	5½	358-453	F	
815-139-3	August 1960	92	6	89	5½	—	N	Finished with 3-foot section of no. 10 slot steel screen.
815-157-2	July 1959	168	3	52	2½	110-168	F	Existing U. S. Geological Survey well deepened for geologic control.

TABLE 3. (Continued)

Well number	Date drilled	Total depth below land surface (feet)	Casing		Open hole		Aquifer	Remarks
			Diameter (inches)	Depth below land surface (feet)	Diameter (inches)	Range in depth (feet)		
Sumter County								
821-158-1	July 1959	53	3	53	2½	0	F	Chert at 53 feet impenetrable. Well destroyed.
821-158-2	July 1959	40	3	49	2½	0	F	Chert at 49 feet impenetrable. Bottom of casing blasted open for use as observation well.
821-202-3	February 1959	29	6	20	5½	20- 29	F	
	July 1959	143			2½	29-143	F	Deepened for geologic control.
821-202-4	February 1959	12	6	5	5½	5- 12	F	Gravel packed (limestone pebbles).
827-158-1	July 1959	175	3	99	2½	99-175	F	

by interpretation of electric and gamma-ray logs of some wells and geologists' and drillers' logs of wells which are on file with the Florida Geological Survey.

GEOGRAPHY

One of the most prominent topographic features in the central part of the Florida Peninsula is Green Swamp which is an extensive area of flatland and swampland at a relatively high elevation. Five major drainage systems originate in or near the Green Swamp area and flow in several directions to the sea. The area contains the headwaters of the Oklawaha River, which flows generally northward to become the largest tributary of the St. Johns River; the Kissimmee and Peace Rivers that flow southward; the Hillsborough River that flows southwestward; and the Withlacoochee River that flows northwestward.

LOCATION

The Green Swamp area is in central Florida (see fig. 1) west of and adjacent to a high sandy ridge that forms the major axis of the peninsula. For this study the boundaries of the area were established arbitrarily and the Green Swamp area should not be confused with a small drainage basin that is generally known as Green Swamp Run in the headwaters of the Big Creek watershed in southern Lake County and northeastern Polk County. The boundaries of the Green Swamp area, as designated for this investigation, have been extended to encompass a much larger area. The project area includes the southern parts of Lake and Sumter counties, the northern part of Polk County, and the eastern parts of Pasco and Hernando counties (see fig. 2).

The eastern boundary of the Green Swamp area is U. S. Highway 27, from Clermont south-southeastward to Haines City. The southern and southwestern boundaries of the area generally coincide with the divides separating drainage northward to the Big Creek and Withlacoochee River basins from drainage southward to the Peace and Hillsborough River basins. These boundaries follow a meandering line westward from Haines City to a point two miles north of Lakeland and then northwestward to Dade City. The western boundary of the area is U. S. Highway 301 northward from Dade City to St. Catherine. The northern boundary extends from St. Catherine eastward along the Little Withlacoochee River basin divide to State Highway 50 and along State Highway 50 eastward to Clermont. The boundaries described enclose an area of 870 square miles.

TOPOGRAPHY

The Green Swamp area is in the Central Highlands topographic region as defined by Cooke (1945). The area is bordered on the eastern side by the Lake Wales Ridge, on the southern side by the northern termini of the Winter Haven and Lakeland Ridges, and on the western side by the Brooksville Ridge (White, 1958, pp. 9-11). Figure 4 shows the locations of these ridges.

Although the area is designated the Green Swamp, it is not a continuous expanse of swamp but is a composite of many swamps that are distributed fairly uniformly within the area. Interspersed among the swamps are low ridges, hills, and flatlands. Several large and many small lakes of sinkhole origin rim the southeastern and northeastern parts of the area. The elevation of the land surface ranges from about 200 feet above mean sea level (msl) in the eastern part to about 75 feet in the river valleys in the western part.

Prominent topographic features affecting the drainage of the eastern part of the area are the alternating low ridges and swales that trend generally north-northwestward from the southern boundary to the Polk-Lake County line. The ridges parallel the major axis of the Florida Peninsula and their configuration suggests that they were formed by subsidence and erosion along fractures and joints. Aerial photographs of the area between U. S. Highway 27 and the Seaboard Air Line Railroad show five of these long narrow ridges with intervening swales.

In the western part of the Green Swamp area there is little evidence of the elongated ridges, and the main land-surface features are large swamps, flatlands, and rolling hills. There are many small swamps in patches and strips generally less than half a mile wide. Most of these swamps support good growths of cypress trees while in the uplands pine and scrub oak trees grow abundantly. The largest continuous expanse of swampland lies within the valley of the Withlacoochee River and is more than a mile wide at places. Limestone is exposed in the western part of the Green Swamp area.

DRAINAGE

The drainage system of the Green Swamp area and vicinity is shown on the map in figure 5. The headwaters of four stream systems within the Green Swamp area, listed in order of their proportion of the area drained, are: Withlacoochee River, Little Withlacoochee River, Oklawaha River, and Hillsborough River. Other streams that head near the boundaries of the Green Swamp area are: Reedy, Davenport, and Horse creeks in the Kissimmee River basin; Peace Creek drainage canal and Saddle Creek in the Peace River basin; Fox Branch in the Hillsborough River basin; and Jumper Creek Canal and a major canal that head northwest of Mascotte in the Withlacoochee River basin. Of the total area of 870 square miles, 710 square miles are drained by the Withlacoochee River and its tributaries.

The surface drainage of the Green Swamp area is poor because of the flat topography and lack of well developed stream channels. Following heavy rainfall, water stands in large shallow sheets over much of the area.

Boundaries of the elongated north-south drainage basins, in the eastern part of the Green Swamp area, are formed by low ridges. The valleys between the ridges are not deeply incised but their effectiveness as drainage channels has been improved by many miles of canals and ditches. Some parallel drainage basins are interconnected in several places by gaps or saddles through the ridges. Through these gaps water may flow at times from one stream valley into another. The amount and direction of flow depend on the relative elevation of water levels in the adjoining basins and the hydraulic conveyance of the connecting channels.

The canals and ditches, for the most part, have been dug to follow the natural drainage courses through the shallow swamps. However, in some places, probably to provide firm footing for the excavation equipment and to avoid clearing through the dense growth of cypress trees, the ditches have been dug along the edges of the large swamps rather than through the interior. Also, to provide better alignment in some places, the ditches have been cut through ridges to connect the adjacent swamps. These shortcuts have bypassed the circuitous natural drainage routes and have straightened and shortened the courses of the waterways.

Surface drainage from most of the Green Swamp area is generally toward the north and west. However, the headwaters of the Peace River basin originate along the southern boundaries of the area and the flow is generally southward. Along the eastern boundary of the area, drainage is toward the east and southeast into the Kissimmee River basin. Other drainage from the Green Swamp area is toward the southwest into the Hillsborough River via a natural channel in eastern Pasco County.

The subsurface drainage of the Green Swamp area is generally poor. Ground-water levels in the interior of the area remain near the surface most of the time, consequently the aquifers provide little opportunity to store water from heavy rainfall. Ground-water levels fluctuate through a greater range in the ridges that form the eastern, southern, and western boundaries. The wide range of fluctuation indicates better subsurface drainage and greater storage capacity along the boundaries than in the interior.

Subsurface drainage is through both the Floridan and the nonartesian aquifers but most is via the Floridan aquifer. Water percolates downward from the overlying nonartesian aquifer to the Floridan aquifer or enters exposed portions of the Floridan aquifer.

Movement of ground water in the Floridan aquifer is generally outward in all directions from the southeastern part of the area. However, the areas contributing to the aquifer (p. 80) show that the predominant directions of ground-water movement are east and west. The ground-water divides in the aquifer shift slightly in response to demands in each contributing area. Most of the surface area that potentially would contribute recharge to the Floridan aquifer in Green Swamp lies within the Withlacoochee River basin. The distribution of ground-water outflow originating in each surface basin is shown in the tables on pages 116 and 117.

CULTURE AND DEVELOPMENT

The Green Swamp area is sparsely populated except for a few small towns and communities on the ridges along the border and along State Highway 33.

Most of the land is in large tracts owned by private individuals or corporations. The only large tract of public land in the area is the Withlacoochee State Forest, part of which is within the boundaries of the Green Swamp area in Sumter, Hernando, and Pasco counties.

The principal industry is agriculture. Much of the upland area has been cleared and planted in citrus groves. Other upland areas have been cleared and are used for cattle raising. Very little of the land is cultivated. The low swampland is unsuitable for agriculture because of poor drainage. In spite of the many miles of ditches, drainage is still inadequate. Even in the cleared areas that are suitable for agriculture, few attempts have been made to reclaim the many small, round, cypress swamps that dot the area.

Cypress lumbering was once an important industry in the western part of the area, particularly in the Withlacoochee River Swamp where there were extensive stands of trees. The first access roads to penetrate the interior of the swamp were trails and tram roads built for cypress lumbering. Timber and pulpwood are now produced from the pine flatwoods interspersed among the swamps.

There is some development of the mineral resources of the area for the commercial market. Extensive phosphate deposits in Polk County lie just south of the Green Swamp area. Some phosphate is mined within the area but the amount is only a small percentage of that produced in southern Polk and eastern Hillsborough counties. Limerock, used in road construction and agriculture, is mined in the northwestern part of the area. Deposits of sand, suitable for building uses, are mined in many places in the eastern part of the area.

CLIMATE

The location of the Green Swamp area, well south in the Temperate Zone, and its proximity to large bodies of warm water produce a warm humid climate. Precipitation and temperature, the principal climatic elements that influence the hydrology of the Green Swamp area, are described separately.

PRECIPITATION

The study of precipitation in central Florida can be restricted to rainfall only, because snow and hail are virtually unknown. The normal or long-term average annual rainfall of the Green Swamp area is 52.7 inches. This normal is computed by the Thiessen method of weighting long-term rainfall records at each of the following U. S. Weather Bureau stations in or near the project area: Clermont 6 miles south, Lake Alfred Experiment Station, Lakeland, and St. Leo (figs. 2 and 5).

The average rainfall for the station at St. Leo, west of the area, is slightly higher than that for the other three stations which are located farther inland. The average rainfall at the four stations ranges from a minimum of 50.1 inches at the Clermont station to a maximum of 56.4 inches at the St. Leo station. In view of the small deviation of these extreme values from the mean, the weighted average rainfall of 52.7 inches for the area of investigation appears to be reasonably accurate.

The amount of rainfall on the area varies seasonally. About 60 percent of the annual total rainfall occurs during the wet season from June through September. In the spring and early summer, local thunderstorms of high intensity and short duration sweep over the area. Showers occur almost daily, or perhaps several times a day, during June and July. Heavier and more prolonged rainfalls occur generally in August and September and are often intensified by tropical storms that occasionally reach hurricane proportions. On the other hand, there are periods of a month or more with little or no rainfall. Periods of below average rainfall usually occur during the winter season from November to February.

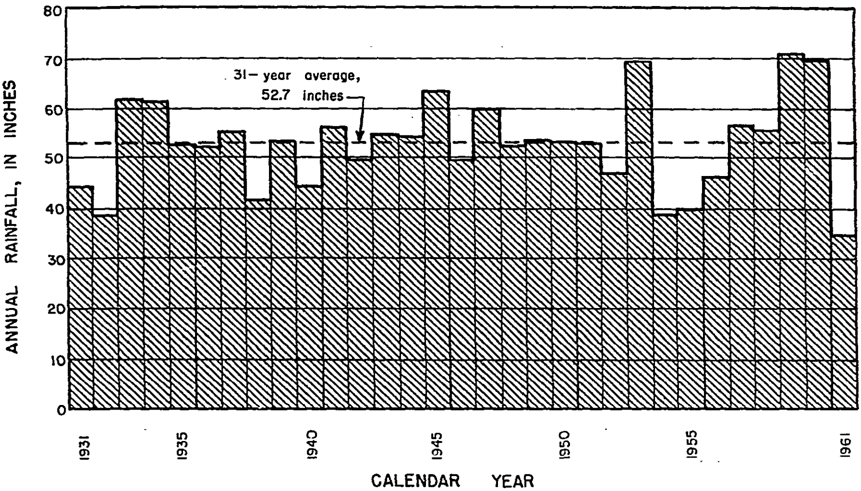
During wet years the annual rainfall is about twice that of dry years. The annual and the mean monthly rainfalls for the years 1931-1961 are shown by bar graphs in figure 6. The maximum annual rainfall during this 31-year period was 70.9 inches in 1959 and the minimum was 34.7 inches in 1961. Both occurred during the period of the investigation. It is a fortunate circumstance that the full range of hydrologic conditions was experienced during the investigation.

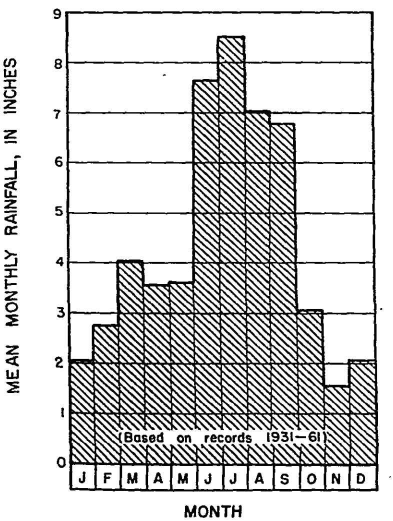
TEMPERATURE

A knowledge of temperature variations in central Florida is pertinent to a study of its water resources because of the dominant influence of temperature on rates of water losses by evaporation and transpiration.

The mean monthly temperature in the Green Swamp area ranges from 61° F. for January to 82° F. for August. The lowest temperature recorded during the 69-year period of record at the Clermont station was 18° F. and the highest was 104° F. Daily temperatures recorded at the U. S. Weather Bureau stations show that all parts of the area have essentially the same temperature, ranging no more than 2 to 3° F.

Killing frosts occur infrequently in this area, and damage to vegetation, although severe from the standpoint of agriculture, seldom is great enough to affect the hydrologic factors pertinent to water supplies.





Rainfall of Green Swamp area computed from U. S. Weather Bureau records at four stations, weighted by Thiessen method as follows:

Station	Percentage
Clermont 6S	37
Lake Alfred Exp. Sta.	22
Lakeland	11
St. Leo	30
	100

Figure 6. Graphs showing annual and mean monthly rainfall of Green Swamp area.

Water loss from a drainage basin is the difference between the average rainfall over the basin and the runoff from the basin for a given period (Williams, 1940, p. 3). In humid regions, where there is sufficient water to satisfy the demands of vegetation, the mean annual water loss is principally a function of temperature (Langbein, 1949, p. 7). The relation between mean annual temperature and mean annual water loss under such conditions is shown in figure 7, which is taken from U. S. Geological Survey Circular 52. For the Green Swamp area where the mean annual temperature is 72° F., the annual water loss would be 48 inches according to this figure.

ENVIRONMENTAL FACTORS AFFECTING THE QUALITY OF WATER

The quality of water in the Green Swamp area reflects the solubility of the material which the water contacts and its biologic environment, both of which are natural influences. Surface water is usually lower in mineral content than ground water because of low solubility of materials on the surface of the ground and short time of contact of water with the materials.

The quality of the surface water (lakes, streams, and swamps) depends mostly on the composition of the precipitation and the

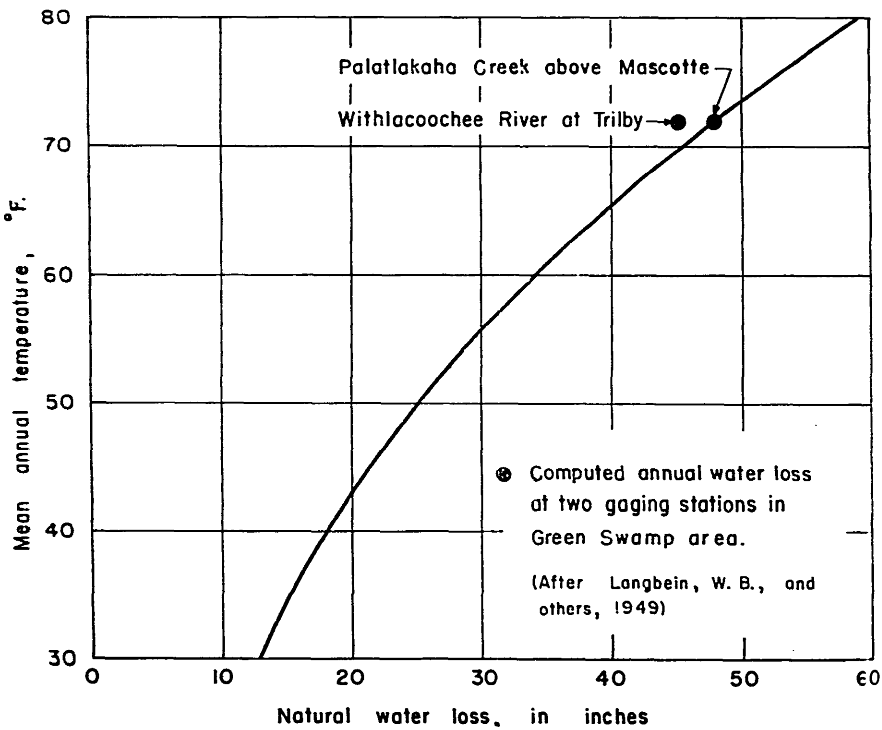


Figure 7. Relation of annual water loss to temperature in humid areas.

biologic environment. Generally, the mineral content of water in streams varies inversely with discharge. Surface waters are usually highly colored and acidic. Sodium and chloride, although in very low concentrations, are the principal dissolved mineral constituents and may be present as a result of wind and rain-borne salts from the ocean.

The quality of ground water in the Green Swamp area generally meets the requirements for most municipal, industrial, domestic, and agricultural uses. Ground water of lowest mineral content occurs along the eastern and western boundaries of the area and is lowest near the lakes. Ground water of highest mineral content occurs in the central part of the Green Swamp. The principal dissolved mineral constituents are calcium and bicarbonate which are products of limestone solution. Relatively high concentrations of calcium in the water cause hardness which is probably the most objectionable characteristic of the ground water in the Green Swamp area.

GEOLOGY[1]

Topographically, the surface of the Green Swamp area resembles a basin, or trough, opening to the north. However, geologically, the Green Swamp is part of an eroded, faulted anticline. The oldest formations are exposed along the axis of the anticline and eroded remnants of younger formations rim the flanks and present a basin-like feature.

The Green Swamp area is underlain by several hundred feet of limestone and dolomite that have been periodically exposed to solution-weathering and erosion. The surface is mantled with a varying thickness of clastic material (sand and clay) that was deposited in fluctuating shallow seas. No attempt has been made to differentiate the formations within the clastic material because of its complexity and the lack of data.

The upper part of the clastic sediments, composed of clayey sands, forms a distinct hydrologic unit, commonly referred to as the nonartesian aquifer. The basal portion of the clastic sediments, composed mostly of clay and some interbedded limestone (secondary artesian aquifer), is less permeable than the overlying,

[1]The classification and nomenclature of the rock units conform to the usage of the Florida Geological Survey and also with those of the U. S. Geological Survey, except for the Fort Preston Formation (?), the Tampa Formation, and the Ocala Group and its subdivisions.

clayey sands or the underlying porous limestone. The solution-riddled limestone formations, which underlie the clay deposits, comprise the Floridan aquifer, the principal source of artesian ground water in the State. Where present, the clay forms an aquiclude which retards the rate of water movement between the aquifers.

The principal artesian aquifer was first described by Stringfield (1936) and later named the Floridan aquifer by Parker (1955). According to Parker, the Floridan aquifer includes those limestone formations ranging in age from the middle Eocene (Lake City Limestone) to perhaps early and middle Miocene (Hawthorn Formation). In the Green Swamp area the following formations comprise the Floridan aquifer (from youngest to oldest); the Suwanee Limestone; the Ocala Group which includes the Crystal River, Williston, and Inglis Formations; and the Avon Park Limestone. The base of the aquifer is considered to be near the base of the Avon Park limestone at the first occurrence of gypsum because the presence of gypsum probably indicates poor circulation of ground water.

FORMATIONS

The formations that underlie the Green Swamp area are presented in table 4. Generalized geologic cross sections, shown in figure 8 were prepared based on data from wells located along lines A-A', B-B' and C-C'.

UNDIFFERENTIATED CLASTIC DEPOSITS

Undifferentiated clastic deposits, ranging from late Miocene to Recent in age, underlie the Green Swamp area except in the western part where Tertiary limestones are exposed at the surface. The deposits consist primarily of clayey sand or sandy clay. The following lithologic sequence (from youngest to oldest) is indicated: (1) fine quartz sand (surficial sand) with varying amounts of clay and organic material; (2) variegated (red-orange-tan) fine to coarse quartz sand with little clay; (3) white fine to very coarse quartz sand with varying amounts of white-green kaolinitic or montmorillonitic clay; and (4) white silty quartz sand with varying amounts of mica flakes.

Generally, the deposits range from 100 to 200 feet in thickness beneath the ridges that rim the Green Swamp area; however, they are thin or absent in the western part and tend to become more

TABLE 4. Geologic formations and their water-bearing characteristics in Green Swamp area and vicinity.

System	Series		Formation (after F.G.S.)	Formations used in this report	Approximate range of thickness (feet)	Lithology	Aquifer	Water-bearing characteristics
Quaternary	Recent		Recent Deposits	Undifferentiated Clastic Deposits	0-200	Light-colored clayey sands grading into sandy clays	Non-artesian	Generally poor source in the central part of the area. A fair source in the ridge areas.
	Pliocene		Terrace Sands					
Tertiary	Pleistocene		Citronelle Formation					
	Miocene	Upper	Fort Preston Formation (?)					
		Middle	Hawthorn Formation	Undifferentiated Clay	0- 60	Dark-colored phosphatic clay with limestone lenses	Secondary artesian	Generally very poor except in the Lakeland area where interbedded limestones are a fair source.
		Lower	Tampa Formation					
	Oligocene		Suwannee Limestone	Suwannee Limestone	0- 80	Hard, white-yellow limestone	Floridan	Generally good to excellent. The best source is the dolomitic Avon Park Limestone. Evaporite (selenite) deposits near the base of the Avon Park Limestone is considered to be the base of the aquifer.
	Eocene	Upper	Ocala Group: Crystal River Formation	Crystal River Formation	0-120	Soft, gray, limestone		
			Ocala Group: Williston Formation	Williston Formation	0- 40	Hard, tan limestone		
			Ocala Group: Inglis Formation	Inglis Formation	0- 50	Hard, tan limestone		
		Middle	Avon Park Limestone	Avon Park Limestone	800-1,000	Soft to hard, white-brown, dolomitic limestone		

clayey where they thin over the crest of the anticline (fig. 8, A-A'). The deposits appear to increase in coarseness from the interior of the Green Swamp area eastward to the Lake Wales Ridge. Much of these deposits occur as cavity fill in the underlying limestones especially in the ridge areas.

The undifferentiated clastic deposits form the nonartesian aquifer in the area. Generally, the deposits in the western part of the Green Swamp area are thin or absent, low in permeability and porosity; and therefore, they are of minor significance as an aquifer.

UNDIFFERENTIATED CLAY

Undifferentiated clays of Miocene age underlie most of the area, except in the western part, and contain varying amounts of quartz, phosphatic sand, and interbedded limestone. The following general lithologic sequence (from younger to older) is indicated: (1) light gray-tan-blue-green, montmorillonitic clay with varying amounts of quartz, phosphatic sand, and interbedded limestone; (2) dark gray-green-blue phosphatic, silty clay with varying amounts of quartz pebbles, silt and mica flakes.

The light-colored clay with interbedded limestone is part of the Hawthorn Formation of early and middle Miocene age. Generally, its occurrence is limited to the southeastern part of the Green Swamp area. It thickens eastward and southward and forms a secondary artesian aquifer which is a significant source of artesian water outside of the Green Swamp area. The dark, silty clay is probably equivalent to the Tampa Formation of early Miocene age (Carr, 1959). Generally, its occurrence is limited to the eastern part of the Green Swamp area where it forms an aquiclude.

SUWANNEE LIMESTONE

The Suwannee Limestone (Cooke and Mansfield, 1936) of Oligocene age is a white dense fossiliferous limestone. It is present in the southern and western parts of the Green Swamp area and crops out along the Withlacoochee River near Polk-Sumter-Pasco County line. The formation thickens southward in Polk and Hillsborough counties and westward in Pasco County. Many of the springs along the upper Hillsborough River flow from exposures of Suwannee Limestone. The Suwannee Limestone overlies the Crystal River Formation and it is overlain by either undifferentiated clay or undifferentiated clastic deposits.

OCALA GROUP

The Ocala Group (Puri, 1957) includes three limestone formations of late Eocene age. The subdivisions of the Ocala Group (from youngest to oldest) are the Crystal River, the Williston, and the Inglis Formations.

CRYSTAL RIVER FORMATION

The Crystal River Formation is primarily a coquina of large foraminifers and crops out in an area extending from northern Polk County through the southern end of Sumter County and into eastern Hernando County. It ranges from 50 to 120 feet in thickness, except in the eastern part of the area where it is absent. In the central part of the area, the formation contains many sand-filled cavities.

WILLISTON FORMATION

The Williston Formation is a tan-cream, medium to hard limestone containing abundant micro-fossils. The formation is slightly coarser than the underlying Inglis Formation but generally finer than the overlying Crystal River Formation. In most of the area, the Williston Formation ranges from 20 to 40 feet in thickness. It is thin or absent along the eastern boundary of the area.

INGLIS FORMATION

The Inglis Formation is generally a white-tan, hard, fossiliferous limestone. The texture of the formation appears to be finer than that of the Crystal River and Williston Formations. In most of the area, the Inglis Formation is about 50 feet thick. It is thin or absent along the eastern boundary of the Green Swamp area.

AVON PARK LIMESTONE

The Avon Park Limestone (Applin and Applin, 1944) of late middle Eocene age was the deepest formation penetrated by test drilling. The formation is nearest the surface on an upthrown fault block along the eastern side of the area (fig. 8, A-A'). The formation is found at considerable depth in the area south and southwest of Green Swamp. The top of the formation is characterized by a distinct color change from tan to brown limestone and by abundant cone-shaped foraminifers. The formation is a brown, dolomitic, porous limestone. Selenite (gypsum) near the base of the formation probably forms the bottom of the Floridan aquifer. The Avon Park Limestone is highly permeable and is the main source of water for most of the high-capacity wells in the area. Figure 9 shows the configuration of the top of the Avon Park Limestone. The map shows the northwest-southwest trend of the faulted anticline.

STRUCTURE

The Peninsular arch (Applin, 1951), a buried anticlinal structure of Paleozoic sediments, trends generally north-northwestward and its main axis is located east of the Green Swamp area. A flexure, developed on the western flank of the Peninsular arch in the Tertiary limestones, is called the Ocala Uplift. The Green Swamp area is located at the southern end of the Ocala Uplift (figs. 8 and 9).

Vernon (1951) dated the Ocala Uplift as post-Oligocene in age. Faults in the Green Swamp area complicate the definition of the geology and the hydrology. The main area of faulting occurs along the Lake Wales Ridge. Faulting in this area was described by Vernon (1951, p. 56) and named The Kissimmee Faulted Flexure. The cross sections in figure 8 show vertical displacement along fault zones.

The faults are probably post-Oligocene. Subsequent movement along fault zones may have occurred over a long period of time, the later movements being associated primarily with subsidence and sinkhole collapse along the solution-widened zones.

Figure 9 shows a structural map based on the top of the Avon Park Limestone. The contour lines generally define the shape of the anticline with associated faults. The linearity of ridges on the anticline suggests that other faults exist in the area.

Faulting probably could affect the hydrology of the Green Swamp in the following ways:

(1) Joints or faults within the Floridan aquifer, widened by solution, could cause zones of high permeability, or could cause zones of low permeability when filled with clastic materials.

(2) Displacement along the faults could position formations of different lithology (hence permeability) one against the other,

breaking the hydraulic continuity and producing barriers that retard water movement.

(3) Faults cutting confining beds could increase ground-water circulation between aquifers.

HYDROLOGY

The water supply of the earth, whether it is on the surface or below the ground, has its origin in precipitation. Of the precipitation that reaches the ground, part is returned to the atmosphere by evapotranspiration; part remains above ground and is stored temporarily in lakes, ponds, and swamps, or moves to the sea as streamflow; and part percolates into the ground, some to replenish the soil moisture and some to enter the zone of saturation and recharge the ground-water aquifers. Ground water moves in the aquifers under the influence of gravity, towards areas of discharge such as streams, lakes, springs, wells and the oceans.

WITHLACOOCHEE RIVER BASIN

DESCRIPTION OF BASIN

The Withlacoochee River drains 82 percent of the Green Swamp area. The total drainage area at stations 42 and 43 at the western boundary is 740 square miles, all of which is within the project area except for 45 square miles of lakes and hills west of U. S. Highway 301 and south of U. S. Highway 98 near Dade City.

Most of the general topographic and drainage features of the Green Swamp area, described in preceding sections of this report, apply to the Withlacoochee River basin in particular. The following description of the basin refers specifically to this stream system.

The Withlacoochee River heads in a group of lakes and swamps in the north-central part of Polk County in the vicinity of Polk City and the town of Lake Alfred (see fig. 5). Lakes Van and Juliana, the uppermost of these headwater lakes, drain into Lake Mattie. Surface drainage from Lake Mattie spills through a wide shallow marsh along the northeastern shoreline and flows northward through a series of interconnected shallow swamps and ditches to the northern boundary of Polk County. This is generally considered to be the major headwater channel of the Withlacoochee River. Other headwater tributaries originate in the marshes between Lakes Mattie and Lowery and flow generally northward between the confining ridges. These channels join near the northern boundary of Polk County and flow westward to form the Withlacoochee River.

West of State Highway 33 the tributaries of the Withlacoochee River are not confined by the ridges that are prominent in the area east of the highway. These tributaries have developed basins that are generally more fan-shaped than those in the eastern part.

Pony Creek, which flows northwestward, is the first of the large tributaries entering the Withlacoochee River west of the Seaboard Air Line Railroad. Pony Creek heads in a swamp east of Lake Helene near Polk City. Lake Helene has no surface outlet except at extremely high stages when it overflows into the Pony Creek basin.

Grass Creek, the next large tributary, empties into the Withlacoochee River about one mile downstream from Pony Creek. Grass Creek heads in a group of small lakes in the vicinity of Polk City, the largest of which is Lake Agnes. The outlet from Lake Agnes is a ditch leading from the northern end of the lake and connecting with the network of canals and ditches that carry the water northwestward through the swamp. Several other tributaries flow into Grass Creek as it crosses the swamp.

Gator Creek empties into the Withlacoochee River at the Polk-Pasco County line. This is the largest tributary upstream from the diffluence of the Withlacoochee River to the Hillsborough River. Gator Creek heads in several small swamps northeast of Lakeland and flows northwestward through a network of swamp channel and ditches.

From the point of diffluence to the Hillsborough River, the channel of the Withlacoochee River turns abruptly to the north and continues northwestward to the western boundary of the Green Swamp area at U . S. Highway 301.

About 14 miles downstream from the point of diffluence, a major canal draining several lakes and swamps east of Dade City empties into the river from the west. This canal also carries the drainage from an area of hills and lakes west of Dade City and the effluent from citrus concentrate plants at Dade City.

One of the larger tributaries entering the Withlacoochee River from the east is formed by the confluence of Devils Creek and Gator Hole Slough. Devils Creek heads in a swamp about 2½ miles east of the Sumter-Pasco County line. At high stages some water from the Withlacoochee River moves through a gap in a low ridge into Devils Creek. This water returns to the Withlacoochee River farther downstream.

Gator Hole Slough heads just east of the Seaboard Air Line Railroad and flows westward through an unimproved swamp channel, entering the eastern boundary of the Withlacoochee State Forest about 3 miles west of the railroad. It continues within the boundaries of the Forest to its confluence with Devils Creek which empties into the Withlacoochee River 2½ miles farther west.

The Little Withlacoochee River, the largest tributary of the Withlacoochee River, heads near State Highway 33 in Lake County and flows westerly. Bay Root Slough is the headwater tributary of the Little Withlacoochee River. This stream carries the drainage from several lakes and swamps east of the Seaboard Air Line Railroad and flows northwestward to the Lake-Sumter County line at the eastern boundary of the Withlacoochee State Forest. The river channel within the Forest is wide and shallow and contains dense growths of cypress trees. The channel has been allowed to remain in its natural swampy condition to store as much water as possible, rather than to remove the water by improved drainage, as a precautionary measure against fire damages to the valuable cypress and pine trees in the Forest. The Little Withlacoochee River emerges from the Forest near the Sumter-Hernando County line, where it is joined on the north by a major canal. This canal drains a swampy area between the Forest and State Highway 50. The river continues westward through the swamp to the crossing of State Highway 50 where it turns and flows northwestward toward U. S. Highway 301. Another canal joins the river about a quarter of a mile upstream from U. S. Highway 301. This canal heads near Webster, flows southward about 1½ miles, then turns westward to Big Gant Lake and then to the Little Withlacoochee River. The Little Withlacoochee River continues westward and empties into the Withlacoochee River 3 miles downstream from U. S. Highway 301.

STREAMFLOW

Streamflow data for gaging stations in the Withlacoochee River basin during the data-collection phase of the investigation are summarized in table 5.

Flow-duration curves for five gaging stations in the Withlacoochee River basin are given in figure 10. Records for only the Trilby gaging station are continuous for the 31½-year period, 1931-62. The curves for the other four stations in the basin have been adjusted from their individual short-term records to the 31½-year base period.

TABLE 5. Streamflow data for Withlacoochee River basin gaging stations in Green Swamp area (see figure 5 for station locations)

Station number	Station	Drainage area (sq.mi.)	Calendar year	Discharge in cfs Maximum	Discharge in cfs Minimum	Discharge in cfs Mean	Runoff in inches
36	Withlacoochee River near Eva	130	[a]1958	...	0	.	....
			1959	836	14	240	25.97
			1960	2,160	6.5	233	24.41
			1961	107	0	12.2	1.27
			[a]1962	....	0	....	....
38	Pony Creek near Polk City	9.5	[a]1960	234	...	....	....
			1961	6.3	0	.55	.79
			[a]1962	....	0	....	....
39	Withlacoochee-Hillsborough overflow near Richland	....	[a]1958	....	0	....	....
			1959	....	0	[b]144	....
			1960	1,880	0	[b]146	....
			1961	20	0	.32	....
			[a]1962	....	0	....	....
40	Withlacoochee River near Dade City		1959	2,740	....	....	....
			1960	5,900	....	....	....
			1961	302	[c].53	....	....
			[a]1962	....	0	....	....
41	Pasco Packing Co. canal at Dade City	....	1957-62	[c]75.6	[c]4.97	....	....
42	Withlacoochee River at Trilby	580	1958	2,600	48	364	....
			1959	2,960	109	1,157	[d]30.45
			1960	6,920	158	[illegible]	[d]31.80
			1961	372	28	115	[d]2.70
			[a]1962	....	26		....
			1931-61	8,840	8.6	406	....
43	Little Withlacoochee River at Rerdell	160	[a]1958	..	2.9	....	....
			1959	1,940	30	342	28.98
			1960	3,400	8.8	324	27.48
			1961	106	0	9.12	.77
			[a]1962	....	0	....	....

[a]Records for part of year.
[b]Partly estimated.
[c]Maximum or minimum measured; probably not the extreme.
[d]Adjusted for diversion to Hillsborough River basin.

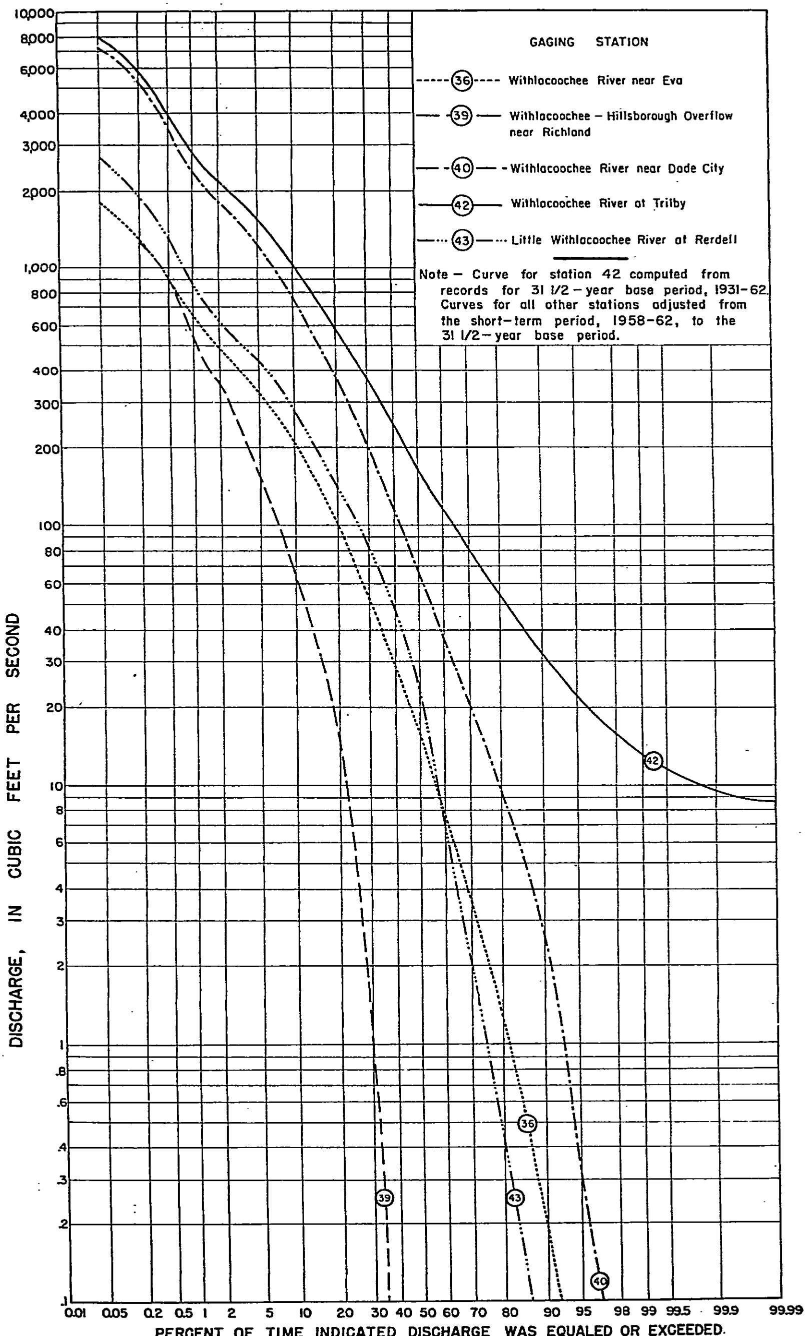


Figure 10. Flow-duration curves for Withlacoochee River basin, 1931-62.

The flow-duration curves indicate the percentage of time that specified discharges were equaled or exceeded during the period of record. These may be considered probability curves used to estimate the percent of time a specified discharge will be equaled or exceeded in the future. The use of flow-duration curves to indicate the future pattern of flow from a basin is valid only if the climatic conditions remain the same and the amount and distribution of runoff from the basin is not significantly changed by man.

The flow-duration curve for Withlacoochee River at Trilby (station 42) may be only an approximate representation of duration of future low flows because of the progressive increases in ground-water inflow by pumpage above the gaging station. However, the flow-duration curves for the other four stations shown in figure 10 may be considered probability curves and used to estimate the percent of time that a specified discharge will be equaled or exceeded in the future.

During a period of extremely low flow on May 23-25, 1961, streamflow was measured and water samples for chemical analysis were collected at several sites on the Withlacoochee River. The results of this low-flow investigation are shown on the map in figure 11.

The base flow of the Withlacoochee River near Dade City (station 40) represents the natural drainage from 390 square miles because no surface flow is diverted to the Hillsborough River basin through the overflow channel, C-9. Since about 1941 or 1942, the effluent from citrus processing plants at Dade City has been drained into the Withlacoochee River by way of the Pasco Packing Company canal. The water used by these plants is pumped from deep wells. Measurements at station 41 of the effluent from the Pasco Packing Company canal during 1958-62, ranged from 5 cfs, when the plant was at minimum operation, to about 76 cfs at peak operation during the citrus packing season. Inflow to the river from this plant and others at Dade City produces higher discharge below station 40 east of Dade City than would be derived from the natural yield of the basin. During dry periods, the effluent at Dade City greatly exceeds the base flow of the Withlacoochee River (see fig. 11).

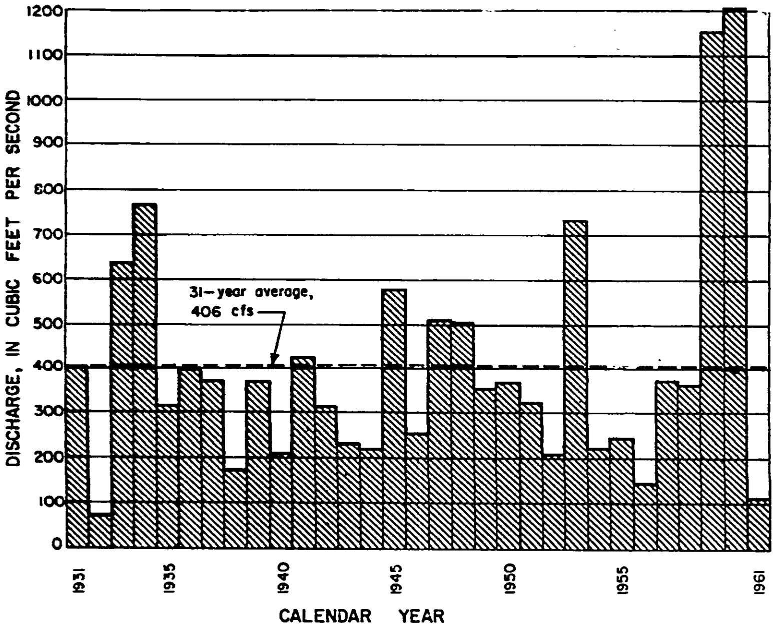
The drainage area above Trilby (station 42) comprises two-thirds of the Green Swamp area and the record collected at this station is a good index of the long-term variations of surface runoff from the entire area except at low flow.

The discharge at the Trilby gaging station does not represent the natural runoff from the Withlacoochee River basin because of the high-water flow diverted from the basin to the Hillsborough River by the Withlacoochee-Hillsborough overflow channel (C-9) and the effluent into the river from the citrus concentrate plants at Dade City. When the Withlacoochee River reaches a stage of about 78.5 feet above msl at the overflow channel, part of its flow is diverted into the Hillsborough River. At high stages more than a fourth of the flow from the upper Withlacoochee River is diverted through this channel. Computations of basin runoff for either the Withlacoochee or the Hillsborough Rivers must be adjusted for the amount of discharge from one basin to the other. Percentagewise, the plant effluent into the basin is small except when the discharge in the Withlacoochee River is extremely low and the plant is at peak operation.

The annual and mean monthly discharges at the Trilby gaging station are shown by the bar graphs in figure 12. The general relation between rainfall and streamflow is evident from figures 6 and 12. During the wet years of 1959 and 1960, annual rainfall over the Green Swamp area was 70.9 inches and 69.5 inches, respectively. The annual mean discharge at the Trilby gaging station was 1,157 cfs for 1959 and 1,209 cfs for 1960. The higher runoff for 1960 was probably the result of a carry-over from the high rainfall of 1959.

The maximum discharge of record at the Trilby station was 8,840 cfs on June 21, 1934. Flood-frequency studies by Pride (1958) indicate that the recurrence interval of a flood at this magnitude is more than 100 years. The peak discharge of the flood of March 1960 was 6,920 cfs and was the third highest flood of record. The recurrence interval of a flood of this magnitude is about 40 years.

The drought of 1954-56 was the most severe dry period of record, considering its 3-year duration and yearly deficiencies. Annual rainfall on the basin above the Trilby station for 1954-56 was 39.9, 40.2, and 46.2 inches per year, respectively. The prolonged period of low rainfall resulted in low discharges at the Trilby station during each of the 3 years. The lowest annual mean discharge at the Trilby station was 75.4 cfs for 1932, a year in which the total rainfall amounted to 39.6 inches. The total annual rainfall on the basin in 1961 amounted to only 35.2 inches and was the minimum for any year of record. Effluent from citrus concentrate plants, derived from ground-water sources, accounted for the higher annual mean discharges for 1954-56 and 1961 than that for 1932.



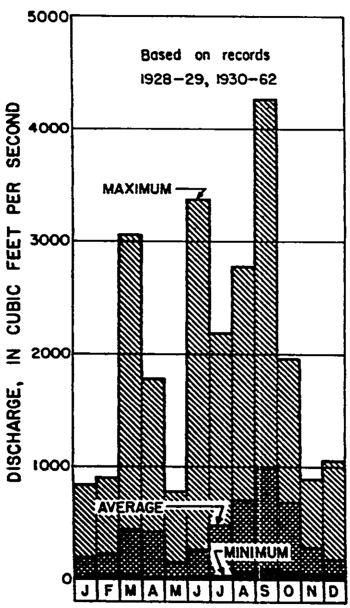


Figure 12. Graphs showing annual and mean monthly discharge of Withlacoochee River at Trilby.

The graph of mean monthly discharge for the Withlacoochee River at Trilby (fig. 12) shows that runoff from the basin is lowest for the months of November through June. The season of highest runoff is the 4-month period, July through October. During these months, 58 percent of the runoff from the basin occurs.

CHEMICAL CHARACTERISTICS OF SURFACE WATER

Waters of the Withlacoochee River in the eastern part of the Green Swamp area are very low in mineral content (figure 13 a, b) acidic, and usually highly colored. Chloride is the principal dissolved mineral constituent. The low mineral content is due to the insolubility of the surface sands. The acidic condition of the water in the southern area is probably due to decomposition of organic matter and subsequent release of carbon dioxide and humic acids to the water. The pH of surface water in this area ranged from 4.0 to 5.9 units. The presence of chloride as the principal dissolved mineral constituent may be due to rain and wind-borne salt from the coastal area. The chloride concentration is usually less than 12 ppm. High color is caused by organic matter in the water. The color ranged from 90 to 600 units and was higher than 250 units most of the time.

The chemical characteristics of water in the Withlacoochee River near Eva (station 36) indicate no inflows from the Floridan aquifer to the stream. Between Eva and Dade City (station 40) the mineral content is higher during periods of low flow but is essentially the same as that above Eva during periods of high flow. The highest mineral content observed in this reach of the river was 302 ppm (see fig. 11). This high mineral content was present in the river just above the mouth of Gator Creek and is about the same as the mineral content of the water from the Floridan aquifer in this area. The hardness of the water at this point was 254 ppm and the color, 15 units. The principal dissolved mineral constituents were calcium and bicarbonate.

During periods of low flow, the chemical characteristics of the water in the Withlacoochee River between Dade City (station 40) and Trilby (station 42) are similar to those of the water from the Pasco Packing Company Canal at Dade City. The source of water in this canal is from wells penetrating the Floridan aquifer. The mineral content of water in the canal ranged from 182 to 190 ppm. The color of water in the canal is low (usually less than 10 units), and the principal dissolved mineral constituents are calcium and

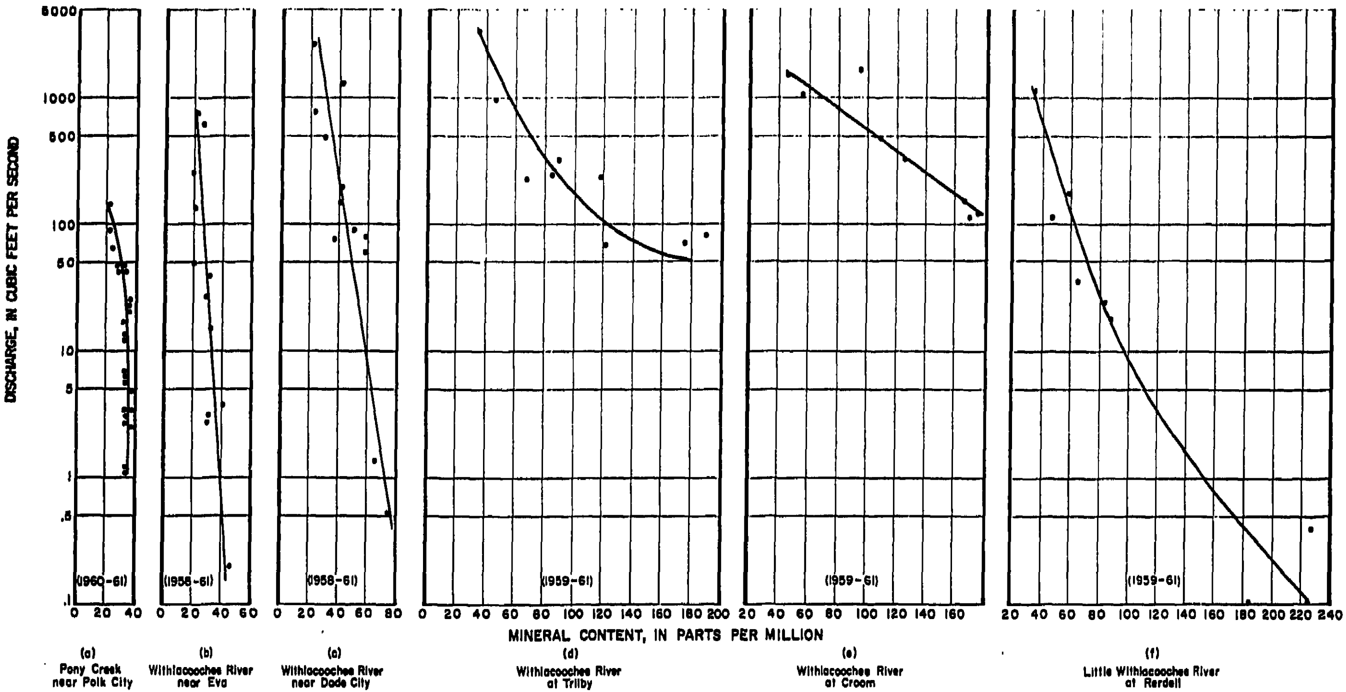


Figure 13. Relation of mineral content to discharge at gaging stations in the Withlacoochee River basin.

bicarbonate. Additional ground-water inflow in this reach of the river is indicated. The chemical characteristics of this inflow indicate that it was derived from the Floridan aquifer.

Gator Hole Slough, a tributary to the Withlacoochee River downstream from Dade City, was sampled at high flow. The water was low in mineral content and contained sodium and chloride as the principal dissolved mineral constituents. The color was 180 units.

Data were collected during the period of low flow (May 23-25, 1961) to determine the quantity and mineral content of the ground-water inflow in the reach of the Withlacoochee River between the stations near Lacoochee and Trilby (see fig. 11). The mineral content of the ground-water inflow from the Floridan aquifer into this reach of the Withlacoochee River was computed using the load equation (Hem, 1959):

$$Q_1C_1 + Q_2C_2 = Q_3C_3$$

where, Q is the discharge in cfs
C is the mineral content in ppm
Q_1C_1 is the instantaneous load near Lacoochee
Q_2C_2 is the instantaneous load between data-Collection stations
Q_3C_3 is the instantaneous load at Trilby

The inflow (Q_2) was determined to be 12.2 cfs by subtracting the discharge near Lacoochee from that at Trilby. The mineral content (C_2) of the inflow was then computed to be 260 ppm which is approximately equal to that of water in the Floridan aquifer in this area.

The mineral content of water in the Withlacoochee River at Croom (station 44) was less than that at Trilby (station 42) or that at Rerdell (station 43). The difference between the sum of the discharges at Trilby and Rerdell and that at Croom on May 25, 1961, was 38.9 cfs (see fig. 11). Based on the load equation, the mineral content of the inflows between the stations would be 148 ppm. Similar computations of data during other periods show the mineral content of the ground-water inflows in this area to range from 148 to 174 ppm. The computed mineral content indicates that the inflow between stations was probably a composite of surface water and ground-water inflows.

The mineral content of the water in the Little Withlacoochee River is shown in figure 13f. The color was usually above 100 units during periods of high flow. The principal mineral constituents during periods of low flow were calcium and bicarbonate, the water was very hard (204 ppm), and the color was low (15 units). These overall chemical characteristics during low flow indicate inflow from the Floridan aquifer. The mineral content of water of the Withlacoochee River at Croom (station 44) varied from 176 ppm during low flow to 45 ppm during a period of high flow (fig. 13e). The color ranged from 10 units at low flow to 120 units at high flow. The water was soft (34 ppm) during high flow and hard (144 ppm) during low flow.

Data collected at Lake Helene during April 1962 show that the water was low in mineral content (51 ppm); the temperature ranged from 76°F. at the surface to 68°F. at the deepest point in the lake (25 feet); dissolved oxygen ranged from 7.5 ppm at the top to 3.8 ppm at the bottom; and the pH ranged from 6.0 units at the top to 5.3 units at the bottom.

The waters of Lake Mattie and Little Lake Agnes were low in mineral content and slightly colored. These lakes are similar in chemical characteristics to those of Lake Helene. The mineral content of water in the three lakes is about the same as that of water in the nonartesian aquifer.

OKLAWAHA RIVER BASIN

DESCRIPTION OF BASIN

Palatlakaha Creek is the major headwater stream of the Oklawaha River. Figure 14 shows a flow diagram of the upper Oklawaha River system and the names of the various segments of the water course.

Lake Lowery, the largest of a group of lakes located near Haines City is the headwaters of the Palatlakaha Creek basin. Most of the drainage from Lake Lowery is to the north into Green Swamp Run through a culvert in the old Haines City-Polk City road. At extremely high lake stages the road is inundated.

The Palatlakaha Creek basin is confined by parallel sand ridges that extend from Lake Lowery northward almost to Lake Louisa. Between Lake Lowery and the Polk-Lake County line the drainage course is called Green Swamp Run. The stream channels in this water course are not deeply incised, and drainage is through wide shallow swamps.

Big and Little creeks drain the basin between the Polk-Lake County line and Lake Louisa. Big Creek is a continuation of Green Swamp Run. The stream channels for both Big and Little creeks have more definitely incised valleys and the flood plain swamps are not as wide as those for Green Swamp Run.

The Big Creek basin is confined along its eastern boundary by the Lake Wales Ridge. However, along the boundary between Big

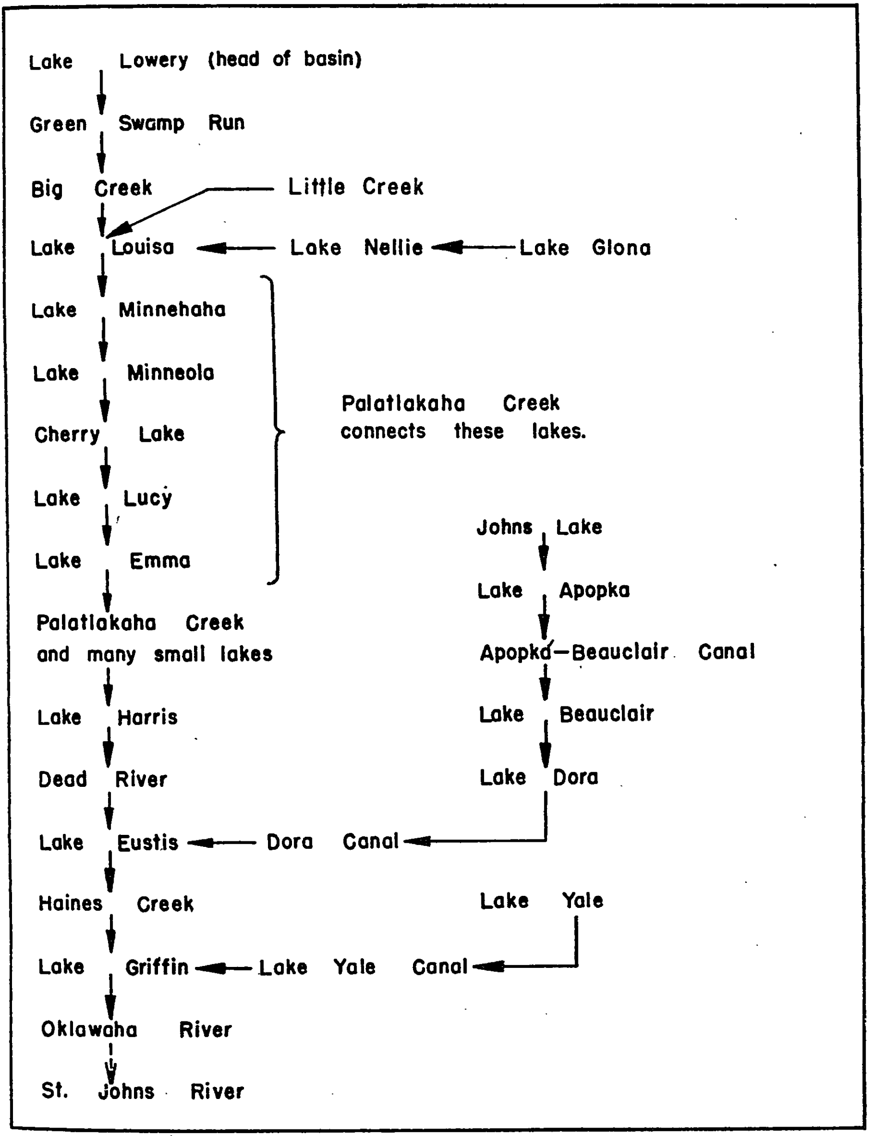


Figure 14. Flow diagram of the upper Oklawaha River.

and Little creeks, the ridge is broken by swamps in several places and the two basins are interconnected. Big Creek, including Green Swamp Run, drains an area of about 70 square miles. The basin, from Haines City to Lake Louisa, is about 25 miles long and from 2 to 4 miles wide. The swamp channel ranges in elevation from about 130 feet near Lake Lowery to about 100 feet near Lake Louisa.

Little Creek drains an area in Lake County west of Big Creek and empties into Lake Louisa. The western boundary of the Little Creek basin is fairly well defined by low ridges. However, in a few places the ridges are broken by saddles. The exchange of surface drainage between Little Creek and the Withlacoochee River through the saddles in the western boundary appears to be negligible.

The southern boundary of the Little Creek basin is not well defined. The probable boundary is along an old road that extends from State Highway 33 to U. S. Highway 27 about a mile or two north of the Lake-Polk County line. Much of the drainage from the area that was formerly drained by Little Creek has been diverted into the Withlacoochee River by interceptor canals. These canals are located near the Polk-Lake County line. However, some water from its former basin still drains into Little Creek through natural swamp channels that were not closed when the interceptor canals were dug. The present (1962) drainage area for Little Creek, as outlined in figure 5, is about 15 square miles during dry periods. During wet periods, water flows into the basin through the openings in the road along the southern boundary of Lake County.

Lake Louisa is the uppermost of a chain of large lakes in the upper Palatlakaha Creek system. Lake Minnehaha, Lake Minneola, and Cherry Lake are next in order below Lake Louisa. These lakes are connected by the wide, deep channel of Palatlakaha Creek. In addition to draining these lakes, Palatlakaha Creek also drains an area of smaller lakes and upland marshes westward to State Highway 33. This area affords storage facilities for large quantities of water.

During the latter part of 1956, an earthen dam with two radial gates was built at the outlet of Cherry Lake to maintain the stages of the waterway and lakes upstream during prolonged periods of dry weather. The water surface from the upper pool at this dam to Lake Louisa is essentially level except during periods of high discharge. During the maximum discharge period in 1960, the stage of Lake Louisa was about 1.6 feet higher than that of the upper pool at Cherry Lake outlet. The fall between Lakes Louisa and Minnehaha was 0.4 foot during this period.

The channel below Cherry Lake has been improved by a canal leading into Lake Lucy and Lake Emma. Palatlakaha Creek follows a more definite channel with steep gradient from Lake Emma to its mouth at Lake Harris. The fall in this reach is about 32 feet in 12 miles.

STREAMFLOW

Streamflow data for gaging stations in the Palatlakaha Creek basin during the data-collection phase of the investigation are summarized in table 6.

The flow-duration curve for Big Creek near Clermont (station 3), adjusted from the short-term period to the 31½-year period, 1931-62, is shown in figure 15. Long-term records for the Withlacoochee River at Trilby (station 42) were used for the adjustment because discharges at other long-term downstream stations on the Oklawaha River are partly regulated by water-control structures.

Streamflow of the headwaters of the Palatlakaha Creek upstream from Lake Louisa is unregulated. Since 1956, the flow below Lake Louisa has been regulated by a water-control structure at the outlet of Cherry Lake. During periods of low rainfall, most of the drainage from the 160-square mile basin above Cherry Lake Outlet is stored in the chain of large lakes and marshes between Lake Louisa and Cherry Lake.

Comparison of peak discharges during floods in March 1960 and September 1960 in Big Creek, Little Creek, and the upper Withlacoochee River shows the effect of the interconnections between the Little Creek and the Withlacoochee River basins. The peak discharge for the March 1960 flood in Big Creek at station 3 was 628 cfs. The discharge in Little Creek measured at station 6 near the peak of this flood was 801 cfs. The higher discharge from the smaller drainage area of Little Creek indicates that most of the flow was draining from the Withlacoochee basin into Little Creek through saddles in the drainage divide.

The peak discharge during the flood of September 1960 for Big Creek at station 3 was 691 cfs. The concurrent flood peak for Little Creek at station 5 was 400 cfs. The flood peak for Withlacoochee River near Eva (station 36) was 2,160 cfs in March 1960 and 1,290

TABLE 6. Streamflow data for Palatlakaha Creek basin stations in Green Swamp area (see figure 5 for station locations)

Station Number	Station	Drainage area (sq. mi.)	Calendar year	Discharge in cfs: Maximum	Discharge in cfs: Minimum	Discharge in cfs: Mean	Runoff in inches
2	Green Swamp Run near Loughman	33	[a]1959	[b]54	0	....	....
			[a]1961-62	....	0	....	....
3	Big Creek near Clermont	68	[a]1958	....	.4	....	....
			1959	283	18	112	22.37
			1960	691	22	142	28.39
			1961	64	.1	12.2	2.42
			[a]1962	....	0	....	....
5	Little Creek at Coopers Ranch near Clermont	10	1961	18	0	1.27	....
			[a]1962	....	0	....	....
6	Little Creek near Clermont	15	[a]1958	....	[b].65	....	....
			1959	[b]210	[b]3.92	[c]58	....
			1960	[b]801	0	[c]51	....
7	Lake Glona Outlet near Clermont	8.4	[a]1960-62	110	0	....	....
11	Palatlakaha Creek at Cherry Lake Outlet near Groveland	160	1958	304	0	78.4	6.65
			1959	370	11	224	18.98
			1960	584	36	251	21.40
			1961	162	0	23.7	2.00
			[a]1962	....	0	....	....
12	Palatlakaha Creek near Mascotte	180	1945-56	458	.2	....	....

[a]Records for part of year.
[b]Maximum or minimum measured; probably not the extreme.
[c]Estimated.

cfs in September 1960. Little Creek serves as an outlet for much of the flood drainage from the upper Withlacoochee River basin.

CHEMICAL CHARACTERISTICS OF SURFACE WATER

Waters of Big and Little Creeks have chemical characteristics similar to those of the Withlacoochee River upstream from State Highway 33 in that they have very low mineral content and are highly colored. Figure 16a shows that the mineral content of water in Big Creek ranges from 19 to 61 ppm. Figure 16b shows that the mineral content of water in Little Creek ranges from 18 to 31 ppm. Color of water in Big Creek ranges from 65 to 240 units and that of Little Creek ranges from 150 to 300 units. Both streams usually contain sodium and chloride as their principal dissolved mineral constituents.

Waters of the two streams differ in chemical characteristics in that water of Big Creek is more mineralized, usually less colored, and the pH is higher than that of Little Creek. The higher mineral content of water in Big Creek is due mostly to higher concentrations of calcium and bicarbonate.

HILLSBOROUGH RIVER BASIN

RELATION TO GREEN SWAMP AREA

The Withlacoochee-Hillsborough overflow channel (C-9, fig. 5), previously described with the Withlacoochee River basin, is one of the major drainage outlets from Green Swamp during high flows and is generally considered to be the head of the Hillsborough River. The overflow channel as it leaves the Withlacoochee River is about a mile wide. The road fill and bridge of U. S. Highway 98 crosses the channel about 1 mile downstream from the Withlacoochee River. The entire flow is confined by the road fill to the bridge opening which is 200 feet wide.

White (1958, p.19-24) presents evidence to support an assumption that the Withlacoochee-Hillsborough overflow channel was formerly the main channel of the Hillsborough River and that the Withlacoochee River was once the headwaters of the Hillsborough River. Field studies made in the area in 1962 by Altschuler and Meyer indicate that the Withlacoochee-Hillsborough River overflow was formed prior to natural divergence of the headwaters of the Hillsborough River to the Withlacoochee River and that the divergence may be related to uplift in the area.

From the bridge on U. S. Highway 98, the Hillsborough River flows generally southwestward through Pasco and Hillsborough counties and empties into Hillsborough Bay 53½ miles downstream.

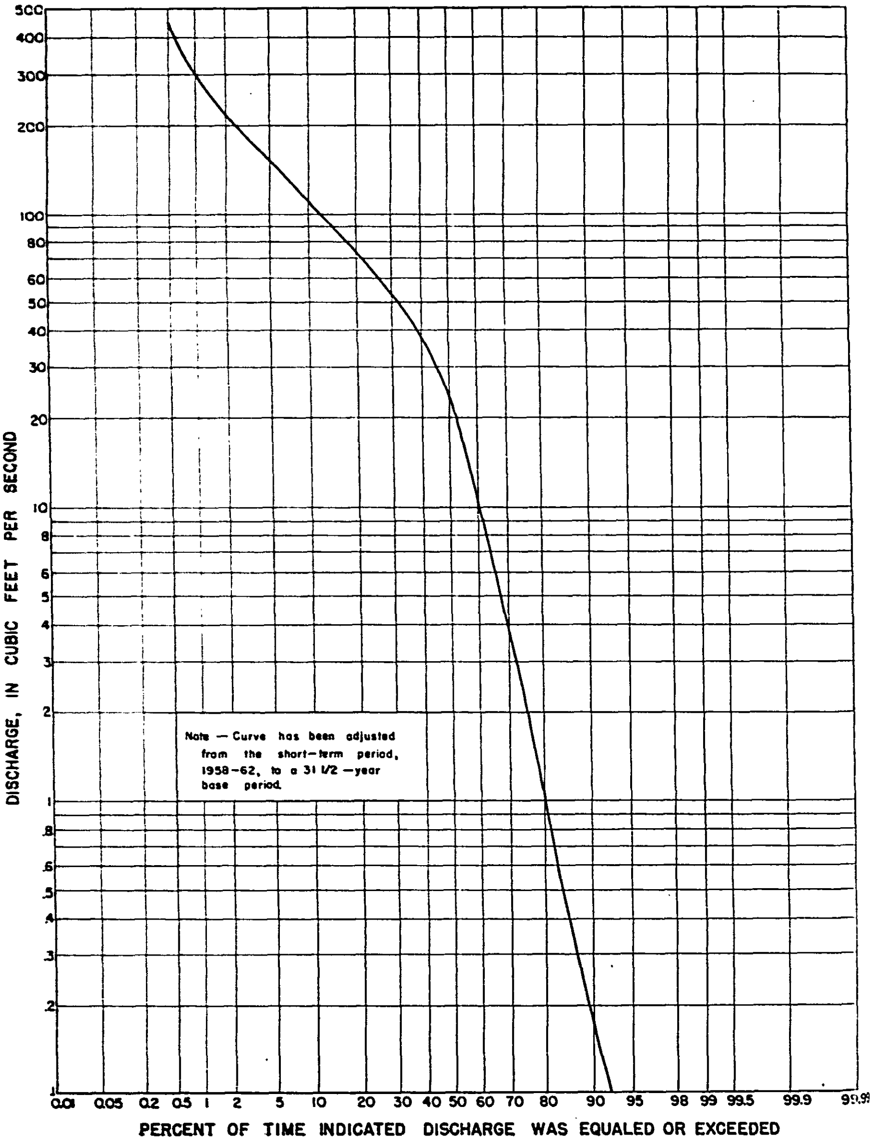


Figure 15. Flow-duration curve for Big Creek near Clermont, 1931-62.

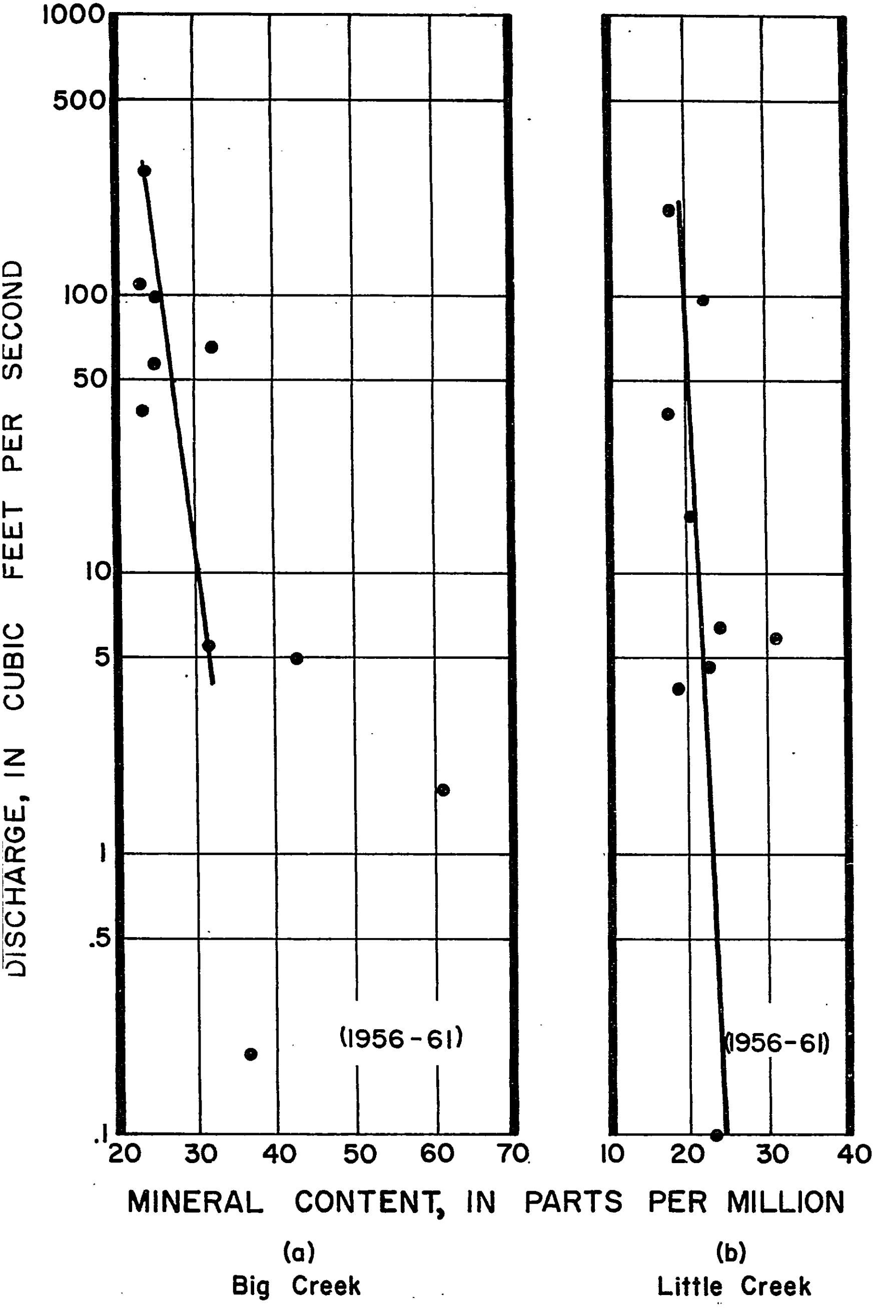


Figure 16. Relation of mineral content to discharge at gaging stations in upper Palatlakaha Creek basin.

The lower 15 to 18 miles of the river passes through the City of Tampa. The city water supply is a reservoir created by a dam in the river 10.2 miles upstream from the mouth. Tampa is vulnerable to damages from floods in the Hillsborough River because of extensive development of property in the flood plain.

STREAMFLOW

A summary of streamflow data for the gaging station on Withlacoochee-Hillsborough overflow (station 39) is shown in table 5. The flow-duration curve is shown in figure 10. No flow occurs in the channel at this point about 65 per cent of the time.

Crystal Springs flows into the Hillsborough River in southern Pasco County near the Pasco-Hillsborough County line. The average flow of Crystal Springs (station 31) is 62 cfs, ranging from 20.3 cfs to 147 cfs. Downstream from Crystal Springs the base flow of Hillsborough River is well sustained. The flow of Hillsborough River near Zephyrhills (station 33), which includes flow from Blackwater Creek, is reported to be 71 cfs or more for 90 percent of the time (Menke, 1961, p. 29).

CHEMICAL CHARACTERISTICS OF SURFACE WATER

The chemical characteristics of water of the Hillsborough River upstream from Crystal Springs are similar to those of the Withlacoochee River between Eva and Dade City although the mineral content is somewhat higher.

The water of the Hillsborough River at the Withlacoochee-Hillsborough overflow contained calcium and bicarbonate as the principal dissolved mineral constituents. The water contained color that ranged from 80 to 150 units. The mineral content ranged from 41 to 121 ppm.

The water of Crystal Springs had a mineral content of about 170 ppm, was clear, and contained calcium and bicarbonate as the principal dissolved minerals. The water was hard and alkaline.

During the periods of low flow, the chemical characteristics of the water of the Hillsborough River near Zephyrhills (below Crystal Springs) are essentially the same as those of water of Crystal Springs. Figure 17 shows the relation of the mineral content to discharge. During periods of high flow the mineral content of water is low. A more detailed discussion of the chemical character of the water of the Hillsborough River is given in a report by Menke (1961, p. 28-36).

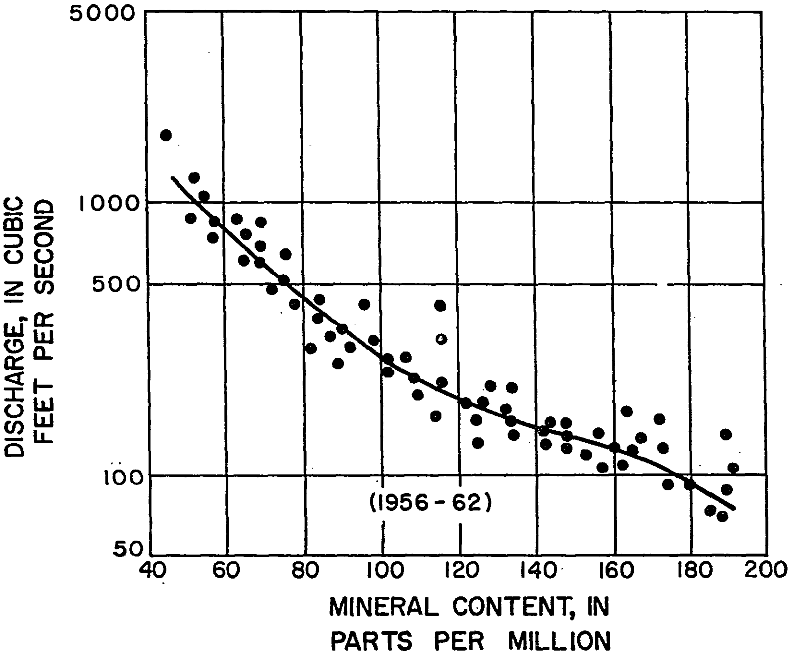


Figure 17. Relation of mineral content to discharge, Hillsborough River near Zephyrhills.

KISSIMMEE RIVER BASIN

RELATION TO GREEN SWAMP AREA

The eastern boundary of the Green Swamp area is U. S. Highway 27 atop the Lake Wales Ridge. This is generally the surface drainage divide between Palatlakaha Creek in the St. Johns River basin and headwater tributaries of the Kissimmee River.

The surface drainage from only 5 square miles of the Green Swamp area flows eastward into the Kissimmee River basin. Piezometric maps in figures 35 and 36 indicate ground-water movement eastward from the Green Swamp area into the Kissimmee River basin.

STREAMFLOW

Horse Creek is one of the Kissimmee River tributaries adjacent to Green Swamp. Streamflow records of Horse Creek at Davenport (station 19) were collected to study the base flow that is derived from ground water. The drainage area at the gaging station is 22.8 square miles. The maximum discharge during 2 years of data collection was 358 cfs and the minimum was 0.5 cfs. Runoff characteristics of the Horse Creek basin are compared with those of the Pony Creek basin in a following section of this report.

CHEMICAL CHARACTERISTICS OF SURFACE WATER

Data concerning the chemical characteristics of water in the Kissimmee River basin were collected from Horse Creek and Reedy Creek.

Water of Horse Creek is more mineralized than water in the upper Withlacoochee River. Figure 18 shows the general relation of mineral content to discharge. The mineral content from July to November 1960 ranged from 22 to 64 ppm (from daily conductivity records). Calcium and bicarbonate were the principal dissolved mineral constituents. The surface materials in the Horse Creek basin are sands and clays, which are essentially insoluble in water, and therefore the calcium bicarbonate type water in Horse Creek is probably due to seepage from the Floridan aquifer. The following

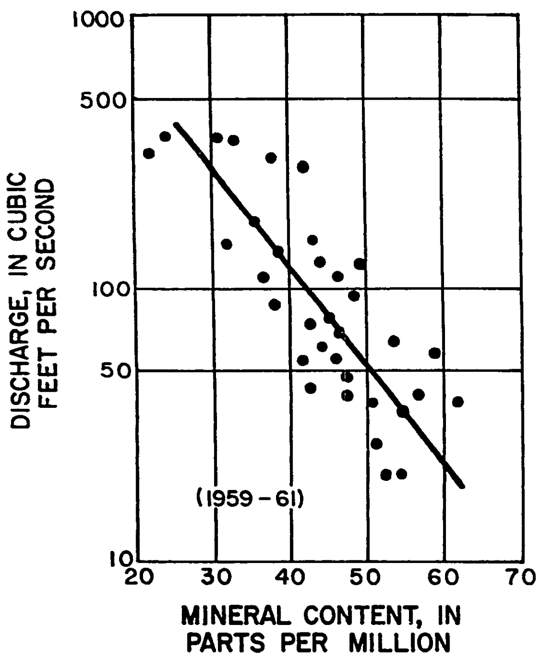


Figure 18. Relation of mineral content to discharge, Horse Creek at Davenport.

equations were used to determine the approximate amount of seepage from the aquifer:

$$Q_1 + Q_2 = Q$$
$$33Q_1 + 167Q_2 = CQ$$

where, Q_1 is the component of discharge from nonartesian aquifer and from direct runoff

Q_2 is the component of discharge from Floridan aquifer

Q is total discharge of Horse Creek

C is mineral content of water of Horse Creek

33 is average mineral content of ppm of typical water from nonartesian and from direct runoff

167 is average mineral content in ppm of typical water from the Floridan aquifer.

Based on the computation, seepage from the Floridan aquifer averaged about 6 cfs for the 4 complete months of daily conductivity records.

Color of water in Horse Creek ranged from 60 to 160 units and the pH ranged from 6.4 to 7.4 units.

Mineral content of water from Reedy Creek during a wet period in 1959 was 33 ppm, the color 80 units, and the pH 6.0 units.

PEACE RIVER BASIN

RELATION TO GREEN SWAMP AREA

The Peace River basin lies immediately to the south of the designated boundary for the Green Swamp area. Before construction of levees, highway and railroad fills, ditches and other drainage improvements, Lake Lowery and the surrounding marsh apparently drained southward into Peace River as well as northward to the Palatlakaha Creek and the Withlacoochee River basins. Under present conditions, the surface runoff from only 7 square miles of the Green Swamp area drains southward into the Peace River basin. This small area includes Gum Lake and its marsh outlet and Lake Alfred. The headwaters of the Peace River basin lie immediately south of the highest artesian water levels in the southeastern part of the Green Swamp area. Piezometric maps in figures 35 and 36 indicate ground-water movement southward to the Peace River basin.

STREAMFLOW

During the flood of September 1960, caused by Hurricane Donna, Lake Lowery reached a maximum stage of 133.32 feet above mean sea level. During this flood, a road fill between a marsh in the Withlacoochee River headwaters and Gum Lake marsh washed out and an undetermined amount of water flowed southward into the Peace River basin through an opening 12 feet wide (C-4, fig. 5).

The flow at Gum Lake marsh outlet (station 22) includes the drainage from 4.2 square miles in the Gum Lake basin plus that diverted from the Withlacoochee River basin through opening C-4. During the flood of September 1960, the peak discharge was not determined but most of this flood discharge was from the Withlacoochee River basin. The 3′ x 8′ box culvert and a section of the highway at the gaging station were overtopped. The flood peak reached a stage of 132.0 feet above mean sea level, as determined from high water marks at the gage. During periods of low rainfall there is no flow in this channel. For the period May 1961 to June 1962, the channel was dry. The average discharge at station 22 was 0.55 cfs in 1961. There was no flow from Lake Alfred during the period April 1961 to June 1962. The total surface outflow from the Green Swamp area to the Peace River basin is negligible except during flood periods.

DIVERSIONS AND INTERCONNECTION OF BASINS

Although surface drainage from the Green Swamp area follows rather definite routes and although the drainage divides are generally determined by the topographic features, there are several places where the basins are interconnected and water is diverted from one basin to another. Some of these points of diversion have been mentioned under the foregoing discussion of the individual drainage basins. The hydrologic importance of these interconnections, which are integral parts of the drainage systems, is shown in the following discussion.

The arrows on the map in figure 5 locate and show the direction of flow through many of the saddles in the drainage divides. The interconnections that are shown on the map are the most important ones disclosed by the investigation, but they by no means include all such points in the small subbasins where there are no definite drainage divides.

One of the major diversionary channels is the Withlacoochee-Hillsborough overflow in southeastern Pasco County (C-9, fig. 5).

This diversion was discussed in detail under sections describing the Withlacoochee River and Hillsborough River basins.

Other major interconnections of basins are near the Polk-Lake County line (C-3) in the eastern part of the Green Swamp area. The sand ridges in this area are dismembered by a transverse network of swamps that connect the Withlacoochee River and Little Creek basins. The alignment of the swamps and the relative widths of the flood plains shown on aerial photographs indicate that, in the former natural state, water carried to this area from the south was discharged by either of three different routes—Big Creek, Little Creek, or Withlacoochee River. The evidence indicates that most of the drainage from the southeastern area ran off via Big and Little creeks.

Beginning about 1948 and continuing progressively each year, extensive land reclamation by property owners has considerably altered the pattern of drainage in the eastern area. These physical changes, which were made for the development of the area, apparently changed the proportion of the water that drained by the three routes. Based entirely on the present pattern of drainage canals and without any factual data on the streamflow from the upper basins prior to the development of the area, it appears that the most significant change has been a decrease in the area drained by Little Creek and an increase in the area drained by the Withlacoochee River.

Major canals near the Polk-Lake County line were dug about 1948 and 1949 and appear to have intercepted the greater part of the flow from an area of about 60 square miles that was formerly the headwaters of the Little Creek basin. This area is roughly 18 miles long and 3 to 4 miles wide. It extends from the present southern divide of the Little Creek basin southward almost to the town of Lake Alfred. The greater part of the water from this area now drains to the Withlacoochee River. However, as discussed in the description of the Palatlakaha Creek basin, some flow still enters the Little Creek basin from its former headwaters. The changes in the drainage system predate streamflow records in the headwater basins. Therefore, the change in proportion of drainage between the two basins and the increased effectiveness of the drainage system may be inferred only on the basis of long-term streamflow records at downstream gaging stations. The runoff under present conditions, as compared with the runoff that occurred during the earlier years, is discussed under the heading "Effects of Man-Made Changes" in the following section.

A levee now fills a saddle in the drainage divide between Green Swamp Run and the Withlacoochee River in northeastern Polk County south of the Polk-Lake County line (fig. 5). Prior to the construction of the levee (about 1956 or 1957), drainage from Green Swamp Run divided into flow westward into the Little Creek basin (now the Withlacoochee River basin) and flow northward into Big Creek basin.

Lake Lowery and swamps in the upper Withlacoochee River basin are connected by a natural saddle (C-1) in the confining ridge northwest of the lake. This saddle is 200 to 300 feet wide and is one point at which flow may be diverted between the Palatlakaha Creek and Withlacoochee River basins. At high stages the two basins are interconnected at this point. Apparently water may flow through this saddle in either direction, depending on the distribution of rainfall and the relative water levels in the basins.

There are four interconnections (C-2) between Big and Little creeks. These openings, all in Lake County, are small and their net exchange of water is probably negligible in comparison with the total flow from the basin.

Other places, shown on the map in figure 5, where basins are interconnected are: (C-4) between the Withlacoochee River headwaters and Peace River headwaters; (C-5, C-6, C-7) between Lake Mattie, Withlacoochee River, and Pony Creek; and (C-8) between the Withlacoochee River and Devils Creek. Many of these interconnections act as equalizing channels through which water may flow in either direction, depending on relative water levels in connected basins.

EFFECTS OF MAN-MADE CHANGES

Many of the physical changes that have been made on the land surface through man's efforts have already been described. The most extensive developments of the area have occurred in recent years, but the first changes in the hydrologic characteristics undoubtedly occurred several years ago when logging trails and tramroads were built and much of the native timber was cleared from the area. The early developments of the area cannot be evaluated as they predate the period of data collection, but they probably had only minor effects on the hydrology.

Changes in the drainage characteristics of the Green Swamp area can be detected by comparing the hydrologic data for years before drainage developments with the data collected since major developments have been made. Long-term records of rainfall and streamflow in the upper Palatlakaha Creek (stations 11 and 12) and Withlacoochee River (station 42) have been used to detect changes or trends in the pattern of discharge from the upper Palatlakaha Creek basin since 1946.

Double-mass curves of cumulative measured runoff and cumulative computed runoff have been plotted to provide a means of examining the records of streamflow from the area of investigation to detect changes that may have occurred (Searcy and Hardison, 1960). The variables used in preparing the curves shown in figure 19 are the values of cumulative computed runoff, taken from the precipitation-runoff relations in the figures on pages 97 and 99 and cumulative measured runoff at each of the two gaging stations.

The rainfall pattern is not affected by the progressive changes in the drainage system in the Green Swamp area. The theoretical or computed runoff based on rainfall is taken from an average curve for several years of record. Any change in slope in the double-mass curves of figure 19 would reflect progressive man-made changes in runoff.

Figure 19a is the double-mass curve for the Withlacoochee River basin above the Trilby gaging station. Straight lines are drawn to average several points that show definite trends. These lines change in slope between 1942 and 1943, between 1945 and 1946, and between 1953 and 1954. The two changes in slope in the 1940's indicate changes in the runoff pattern but the authors have no knowledge of the causes of such changes. Minor deviations of the plotted yearly values of runoff are probably caused by variations of rainfall distribution and intensity during the year and are not necessarily indications of changes in the long-term trends. Yearly values of runoff for 1954-61 define an average line with less slope than that for any previous period. This change in slope indicates that a higher rate of runoff from the basin occurred during 1954-61 than that indicated from the same rainfall pattern of previous years.

Figure 19b is the double-mass curve for the upper Palatlakaha Creek basin. The figures of annual runoff were adjusted for changes in storage in lakes. For the period 1946-49, the curve takes the general direction as shown by the straight line. However, after 1949, a definite break occurs in the slope of the average line indicating less runoff from the area.

Figure 19c has been plotted to show the cumulative runoff from the combined Withlacoochee River and Palatlakaha Creek basins. The average line defining this curve has the same slope for the entire period, 1946-61. This indicates that there has been no significant change in runoff from the combined basins.

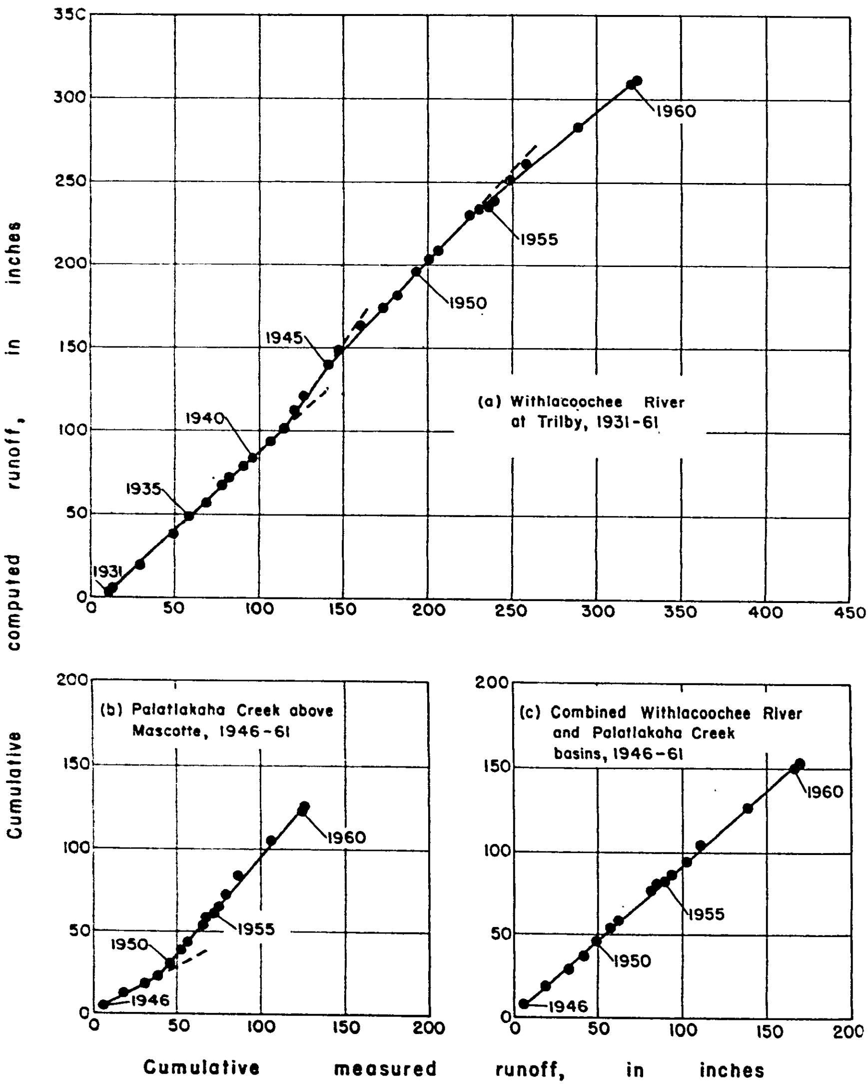


Figure 19. Double-mass curves of measured runoff versus computed runoff, Withlacoochee River and Palatlakaha Creek basins.

The explanation for the significant decrease in runoff from the Palatlakaha Creek basin is a decrease in the size of the drainage area. Such a change in the headwaters of Little Creek, a tributary to Palatlakaha Creek, occurred during the period 1948-49 and has been discussed earlier in this report. This change has resulted in the diversion of part of the flow from the Little Creek basin into the Withlacoochee River basin. The gain to the Withlacoochee River basin is not as obvious as the loss from the Palatlakaha Creek basin because of the difference in size of the drainage basins.

GROUND-WATER ACCRETIONS TO STREAMFLOW IN HORSE AND PONY CREEK BASINS

Stream flow consists of direct surface runoff and ground-water runoff or base flow. Surface runoff is rainfall that drains directly into the stream channel during and after a storm. Ground-water runoff is rainfall that infiltrates to the ground and then discharges into a stream channel. In well-drained basins surface runoff ceases a few days after the occurrence of rainfall, and streamflow is then derived entirely from ground-water runoff. Surface contributions to streamflow continue for longer periods in basins containing lakes, swamps, or other surface storage features.

Daily streamflow records were collected for the period June 1960 to June 1962 for Horse Creek at Davenport (station 19) and Pony Creek near Polk City (station 38). The runoff of these two streams probably represents the maximum variation in runoff of streams in the Green Swamp area. Horse Creek and Pony Creek basins have generally similar characteristics of geology and rainfall, but the two basins are situated differently with respect to the piezometric high. The basin slope of Horse Creek is higher than that of Pony Creek. Pony Creek basin above gaging station 38 is entirely atop the piezometric high. Horse Creek above gaging station 19 lies adjacent to the southeastern boundary of the Green Swamp area (fig. 5) and downslope from the piezometric high (fig. 35) in an area of artesian flow as indicated by hydrographs in figure 23.

Graphs of monthly rainfall and runoff in inches for the Horse and Pony creeks basins for July 1960 to June 1962 are shown in figures 20 and 21. Base flows, expressed in inches of runoff from the two basins, were estimated for the low runoff period from November 1960 to June 1962. Base-flow recession curves were developed and used as a partial basis for separation of the

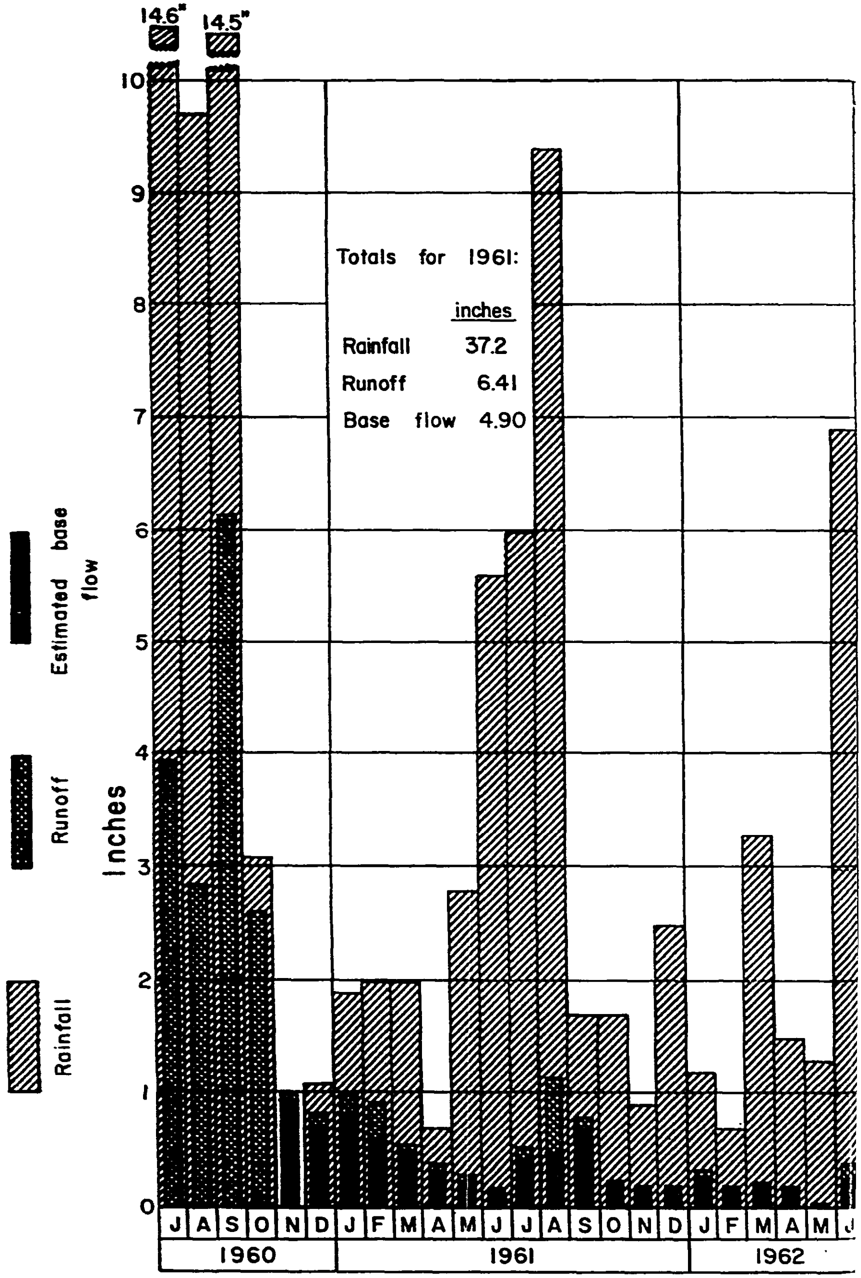


Figure 20. Graphs of monthly rainfall and runoff for July 1960 to June 1962 and estimated base flows for November 1960 to June 1962, Horse Creek at Davenport.

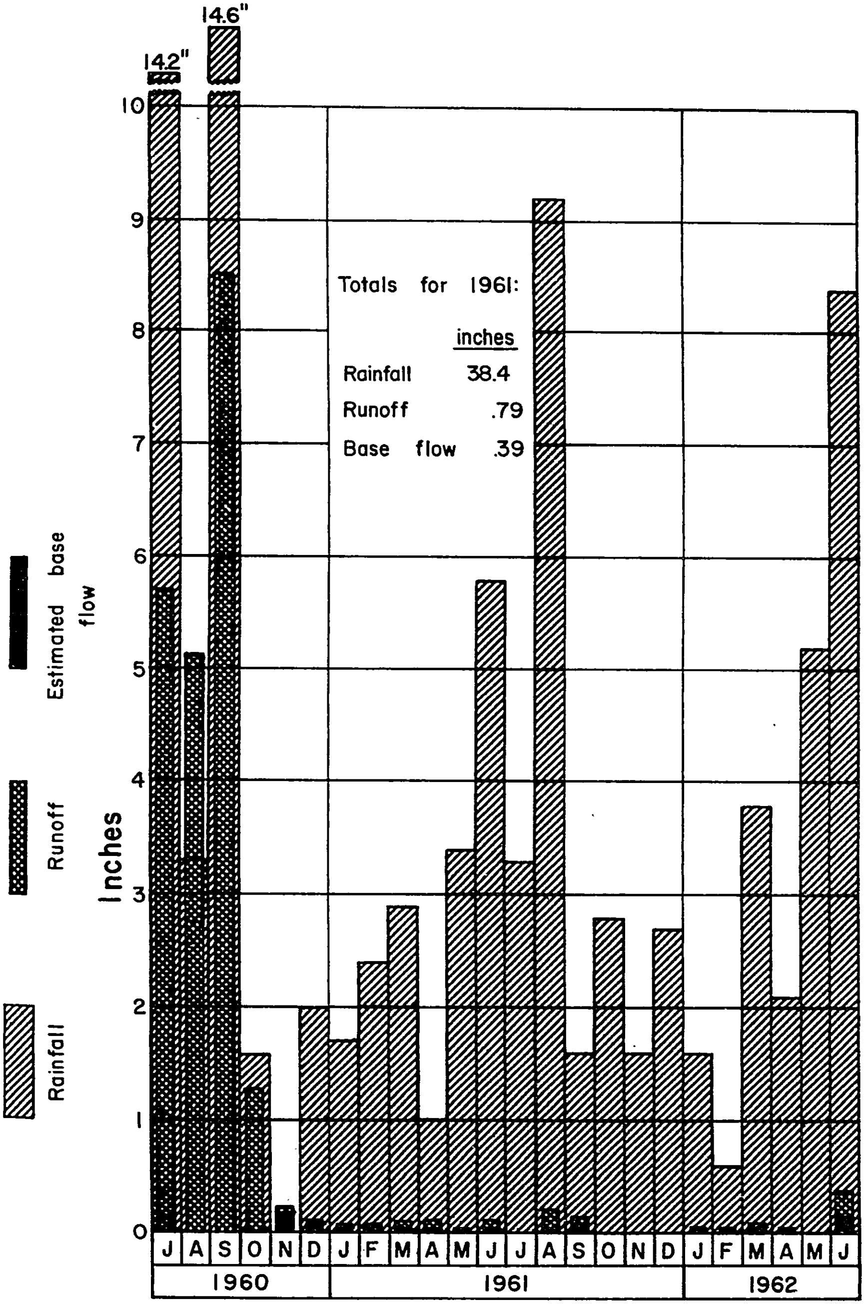


Figure 21. Graphs of monthly rainfall and runoff for July 1960 to June 1962 and estimated base flows for November 1960 to June 1962, Pony Creek near Polk City.

streamflow into the two component, base flow and direct runoff. The methods of separating streamflow into its components of base flow and direct runoff are hypothetical and the results are generally subject to some limitations. During months of high runoff, July to October 1960, streamflow was mostly from direct runoff and base flows could not be estimated with any degree of reliability.

Monthly values of rainfall and runoff for Horse Creek and Pony Creek are summarized in table 7. Direct runoff was computed as the difference between total runoff and base flow. For the months of July, August, and September 1960, the average rainfall on the Horse Creek basin was 38.8 inches and the runoff was 13.0 inches. For the same period, the rainfall on the Pony Creek basin was 32.1 inches and the runoff was 19.4 inches. The greater runoff from Pony Creek resulted from less rainfall than that which occurred in the Horse Creek basin. This was probably caused by high ground-water levels in the Pony Creek basin and lack of storage capacity in the nonartesian aquifer as indicated by comparison of the hydrographs of wells in the basins (see fig. 23, well 810-136-2; and fig. 27, well 813-149-2).

Comparison of the data for the year 1961 for the two stations in table 7 shows that Horse Creek received 37.2 inches of rainfall and Pony Creek received 38.4 inches. However, the runoff from the Horse Creek basin was 6.41 inches as compared to 0.79 inch from Pony Creek. The base flow or ground-water runoff for Horse Creek was 4.90 inches which was 76 percent of the total runoff. The base flow of Pony Creek was 0.40 inch which was 51 percent of the total runoff. Most of the additional runoff for Horse Creek in 1961 was probably gained by ground-water inflow. Base flow of the stream was sustained even during prolonged periods of little rainfall. On the other hand, Pony Creek basin is on top of the piezometric high and the stream received no ground-water flow during prolonged periods of low rainfall in 1961 and 1962.

Flow-duration curves based on the 2 years of record for Horse Creek and Pony Creek are shown in figure 22. A comparison of the runoff characteristics for the two basins may be made from these curves. The curves have not been adjusted to a long-term base period, and therefore should not be used to estimate future long-term patterns.

AQUIFERS

Aquifers are classified as either nonartesian or artesian. Nonartesian aquifers are unconfined, and their water surface (the

TABLE 7. Monthly water budgets for Horse Creek and Pony Creek basins, 1960-62

Month	Horse Creek at Davenport (Station 19)						Pony Creek near Polk City (Station 38)					
	Precipitation (inches)	Precipitation minus runoff (inches)	Runoff (inches)	Direct runoff (inches)	Base flow (inches)	Base flow Pencentage of runoff	Precipitation (inches)	Precipitation minus runoff (inches)	Runoff (inches)	Direct runoff (inches)	Base flow (inches)	Base flow Pencentage of runoff
1960												
July	14.6		3.98	—	—	—	14.2		5.71	—	—	—
August	9.7		2.86	—	—	—	3.3		5.14	—	—	—
September	14.5		6.16	—	—	—	14.6		8.52	—	—	—
October	3.1		2.64	—	—	—	1.6		1.26	—	—	—
November	.0		1.01	.06	.95	94	.0		.24	.05	.19	79
December	1.1		.84	.10	.74	88	2.0		.11	.03	.08	73
1961												
January	1.9		1.01	.20	.81	80	1.7		.07	.01	.06	86
February	2.0		.91	.17	.74	81	2.4		.08	.02	.06	75
March	2.0		.55	.04	.51	93	2.9		.10	.05	.05	50
April	.7		.38	.05	.33	87	1.0		.09	.05	.04	44
May	2.8		.30	.07	.23	77	3.4		.002	.00	.002	100
June	5.6		.18	.05	.13	72	5.8		.13	.08	.05	38
July	6.0		.53	.11	.42	79	3.3		.01	.001	.009	90
August	9.4		1.15	.67	.48	42	9.2		.20	.13	.07	35
September	1.7		.80	.11	.69	86	1.6		.11	.05	.06	54
October	1.7		.23	.02	.21	91	2.8		.00	.00	.00	—
November	.9		.18	.01	.17	94	1.6		.00	.00	.00	—
December	2.5		.19	.01	.18	95	2.7		.00	.00	.00	—
Year	37.2	30.8	6.41	1.51	4.90	76	38.4	37.6	.79	.39	.40	51
1962												
January	1.2		.32	.03	.29	91	1.6		.03	.01	.02	67
February	.7		.18	.01	.17	94	.6		.01	.00	.01	100
March	3.3		.22	.03	.19	86	3.8		.04	.02	.02	50
April	1.5		.17	.02	.15	88	2.1		.02	.00	.02	100
May	1.3		.03	.00	.03	100	5.2		.01	.008	.002	20
June	6.9		.38	.14	.24	63	8.4		.37	.22	.15	41

water table) is free to rise and fall. Artesian aquifers are saturated, confined or semi-confined, and their water surface is not free to rise and fall. The water in an artesian aquifer is under pressure (greater than atmospheric) which causes it to rise above the top of the aquifer. The level to which water will rise in tightly cased wells, penetrating an artesian aquifer, is called the piezometric surface.

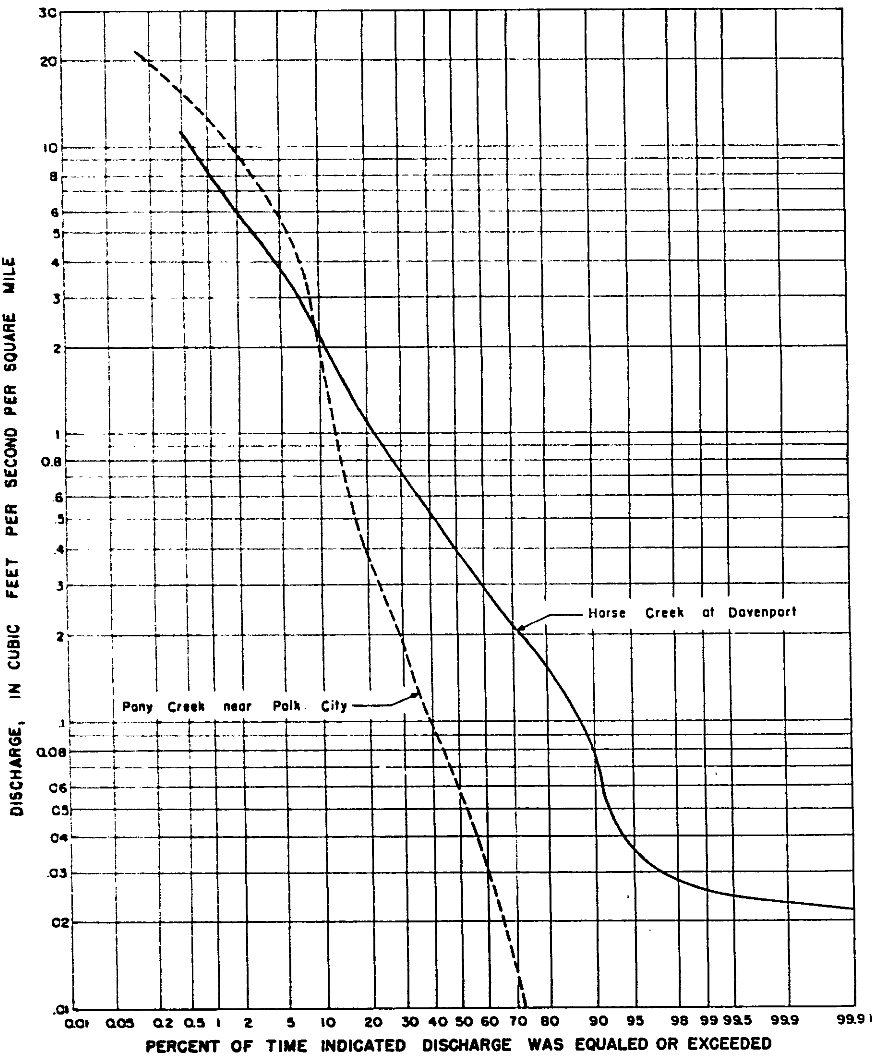


Figure 22. Flow-duration curves for Horse Creek at Davenport and Pony Creek near Polk City, 1960-62.

The principal importance of an aquifer is its ability to transmit and store water. The coefficients of permeability (P) and transmissibility (T) are measures of the capacity of an aquifer to transmit water. Permeability is usually determined by laboratory measurements of a minute part of the aquifer, whereas transmissibility usually determined in the field by aquifer tests, represents the average permeability for a localized area of the aquifer.

The coefficient of storage (S) is a measure of the capacity of an aquifer to store water. The coefficient of storage for artesian aquifers is usually determined by pumping tests and may range from about 0.00001 to 0.001. The coefficient of storage for nonartesian aquifers can be determined by pumping tests or laboratory methods and may range from about 0.05 to 0.30 and, for all practical purposes, equals the specific yield.

Coefficients of permeability were determined by laboratory analysis for samples from the nonartesian and artesian (Floridan) aquifers in the Green Swamp area (see tables 8 and 9). Aquifer tests were made at selected sites and the data were analyzed to determine coefficients of transmissibility using (1) the type curve

TABLE 8. Hydrologic analyses of disturbed sand samples from a test hole in Lake Parker near Lakeland

(Analyses by U. S. Geological Survey Hydrologic Laboratory, Denver, Colorado.)

Sample number	Depth below lake bottom (feet)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd/ft2)
1	5-7	37.1	36.3	75
2	11-12	34.0	33.4	40
3	15-16	35.0	34.6	50
4	20-23	32.7	32.1	80
5	24-26	34.2	34.0	20
6	27-28	35.2	38.4	60
7	35-37	36.9	35.8	90
8	44-45	36.2	34.5	150
9	50	32.2	31.0	95
10	55-56	39.7	37.3	180
11	60	44.8	43.9	110
12	70	45.4	41.7	115
13	73-77	43.2	39.0	40

TABLE 9. Hydrologic analyses of core samples from a well (805-154-8) near Lakeland
(Analyses by U. S. Geological Survey Hydrologic Laboratory, Denver, Colorado.)

Formation: AP, Avon Park Limestone; CR, Crystal River; I, Inglis; LC, Lake City Limestone; O, Oldsmar Limestone; S, Suwannee Limestone; W, Williston.

Specific yield: The pore space that drains by gravity.

Coefficient of permeability: Gallons per day at 60° F through cross section of 1 square foot under unit hydrologic gradient.

Sample number	Depth below land surface (feet)	Formation	Lithology	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd/ft^2) Horizontal	Vertical
1	71.8 to 72.4	S	Limestone, tan, fragmental, very soft	31.5	14.0	0.1	0.05
4	269 to 269.5	CR	Limestone, cream, chalky, coquina, soft	43.8	15.5	1.	.9
5	282.2 to 282.5	W	Limestone, tan, granular, hard	26.8	3.0	.2	.2
7	317.5 to 317.9	I	Limestone, cream, granular, hard	44.1	23.2	4	2
9	447.5 to 447.9	AP	Limestone, tan-gray, very dolomitic, very hard	18.3	10.8	.0006	.0001
11	519.5 to 519.8	AP	Limestone, brown, very dolomitic, very porous	30.3	19.0	11	12
14	1,001.9 to 1,002.5	AP	Limestone, white, very chalky, very soft	41.3	12.2	12[1]	.4
16	1,169.5 to 1,169.9	LC	Limestone, cream, chalky, soft with gypsum inclusions	35.1	21.6	19	15
17	1,386.3 to 1,386.6	LC	Limestone, tan, very dolomitic, hard	19.6	8.8	.004	.0003
19	1,476.8 to 1,477.3	O	Limestone, gray-brown, very dolomitic, with gypsum and anhydrite inclusion	15.4	.2	.02	.02

[1]Sample fractured at end of test. Permeability may be too high.

of the nonequilibrium formula (Theis, 1935), (2) the family of leaky aquifer curves (Cooper, 1963), or (3) a modified nonequilibrium formula (Jacob, 1950).

Semi-confining beds that impede the movement of ground water comprise what is commonly called an aquiclude. Ground water will move through an aquiclude under hydrostatic pressure. For instance, when the water table is higher than the piezometric surface of an artesian aquifer, the potential leakage is downward (recharge to the artesian aquifer) and vice versa. The rate at which ground water moves through the aquiclude depends on the vertical permeability and the hydraulic gradient across the aquiclude.

The aquifers of the Green Swamp area are discussed in order of occurrence from land surface downward: (1) the nonartesian aquifer; (2) the secondary artesian aquifer; and (3) the Floridan aquifer.

NONARTESIAN AQUIFER

DESCRIPTION OF THE AQUIFER

The nonartesian aquifer is composed of undifferentiated clastic deposits (table 4) which consist of fine-to-coarse-grained quartz sand with varying amounts of kaolinitic clay.

On the eastern side of the Green Swamp area (see fig. 8, A-A'), the aquifer ranges from about 50 to more than 100 feet in thickness. The permeability and specific yield is higher in the vicinity of the ridges than in the central and western areas. A relatively thin aquiclude, consisting of clay, forms the base of the aquifer.

On the western side of the Green Swamp area, the aquifer ranges in thickness from 0 to about 50 feet. An aquiclude consisting of sandy clay which thickens eastward and grades into the sand of the nonartesian aquifer forms the base.

RECHARGE AND DISCHARGE

Ground water in the nonartesian aquifer is recharged primarily by local rainfall. It is discharged by (1) evapotranspiration, (2) flow into streams and lakes, (3) downward leakage into the Floridan aquifer, and (4) outflow to areas of lower head outside of the Green Swamp area.

Most of the nonartesian ground water in the Green Swamp area is discharged by evapotranspiration because the water table is relatively close to the surface and surface drainage is poor. Evapotranspiration losses are least in the sandy ridge areas that rim the Green Swamp because the water table is farther beneath the ground than in the interior.

Ground water percolates downward from the nonartesian aquifer to recharge the underlying Floridan aquifer because the water table is usually at a higher elevation than the piezometric surface as shown by the hydrographs in figures 23-29 and the aquiclude (undifferentiated clay) between the aquifers is relatively thin (see fig. 8) and permeable. The coincidence of areas of high water table and of high piezometric head is evidence of leakage. The amount of ground water that percolates downward is equal to the net outflow of artesian water from the underlying Floridan aquifer. The quantity of ground water leaving the Polk piezometric high in the Green Swamp area, hence leakage from the nonartesian aquifer, is presented in the table on page 116.

Nonartesian ground water moves laterally to contribute to the surface runoff from the area. The direction of movement is generally governed by the topography. Therefore, ground-water divides in the nonartesian aquifer closely coincide with surface drainage divides shown in figure 5 except along the eastern boundary of the area where some nonartesian ground water flows laterally beneath the Lake Wales Ridge eastward to the Kissimmee River basin. The quantity of nonartesian ground water leaving the Green Swamp area by lateral seepage beneath the ridge was estimated to be insignificant in the water-budget analysis.

Fluctuations of the water table were recorded in several shallow wells and water-table lakes in and near the southern and eastern parts of the area, shown in figures 23-29. No data were obtained in the western part because the nonartesian aquifer is thin or absent. The hydrographs of wells in the nonartesian aquifer are presented with hydrographs of wells in the secondary artesian or Floridan aquifers to show the hydraulic relation between aquifers and the potential movement of water in a vertical direction.

No long-term records of water-table fluctuations are available within the Green Swamp area. However, records of water levels in a well located southeast of the Green Swamp area (810-136-2) show that the highest and lowest water levels since 1948 occurred during the period of investigation.

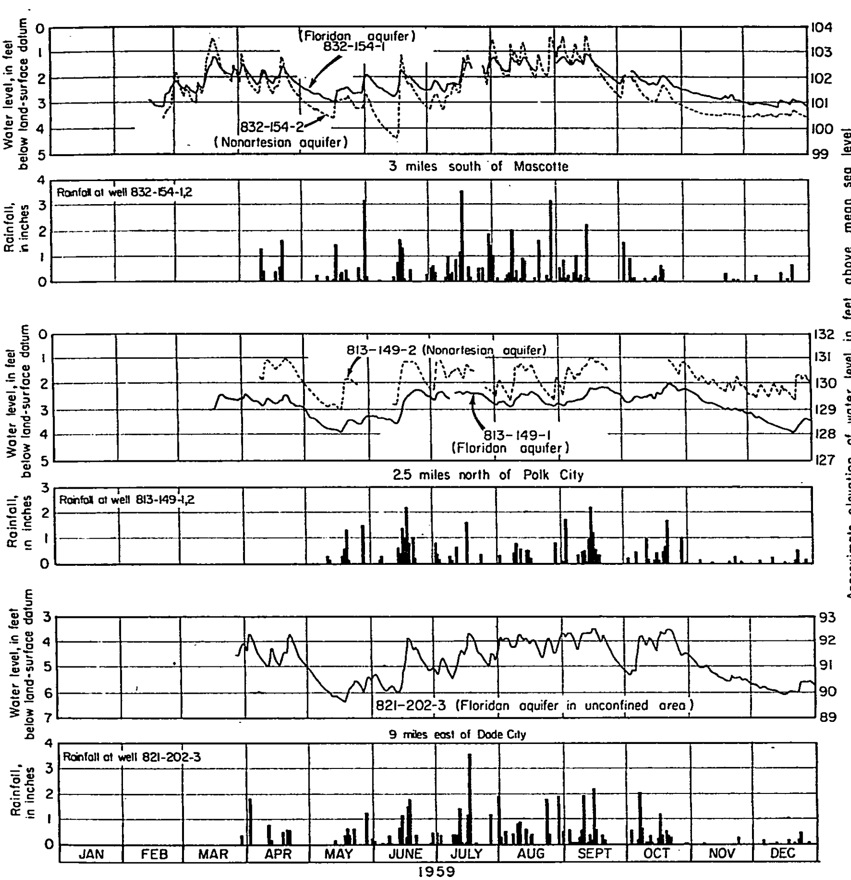


Figure 24. Hydrographs of water levels and rainfall at wells in the Green Swamp area, 1959.

Water levels in most wells in the Green Swamp area show rises in response to local daily rainfalls. Only wells 810-136-2 and 815-139-3, located in the sandy ridges east of the Green Swamp area, show no response to local daily rainfall. Apparently, this is due to the high retention of the thick section of sand through which the water must percolate to reach the water table.

Hydrographs of water levels in wells located in the central part of the Green Swamp area (figs. 27 and 28; wells 813-149-2, 813-150-2, 814-143-2, 822-149-2, 832-154-2) show that the water table declined less than 5 feet from a wet to a dry period (1959-62). During the wet years of 1959 and 1960, the water table remained near the surface and the aquifer afforded little capacity to store

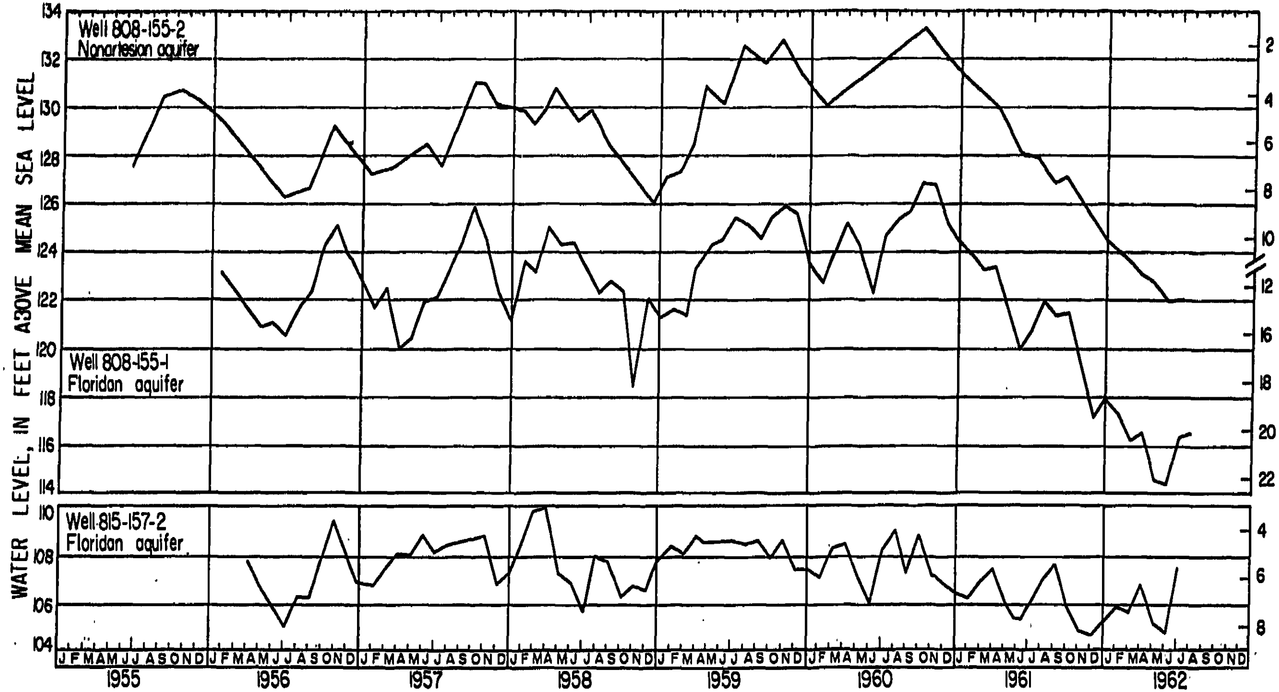


Figure 26. Hydrographs of water levels in Wells (808-155-1, 2) 4 miles north of Lakeland and in a well (815-157-2) 12 miles north of Lakeland.

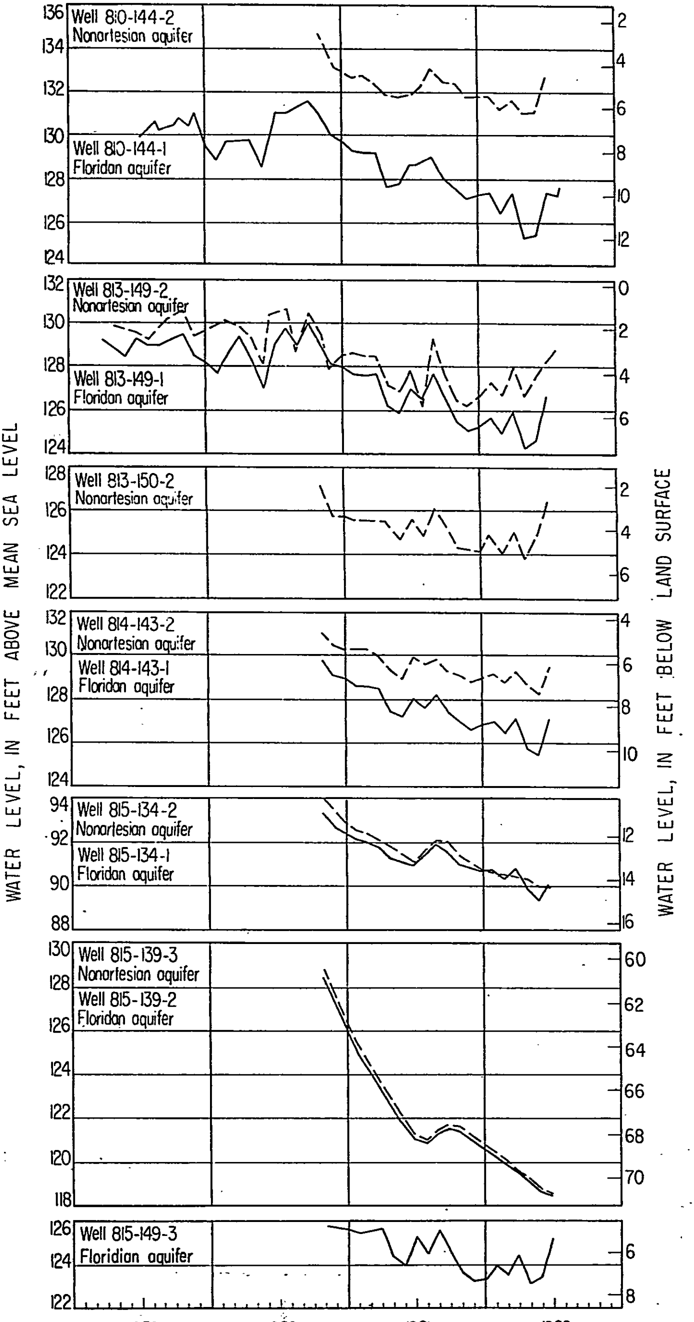


Figure 27. Hydrographs of water levels in wells (810-144-1, 2; 813-149-1, 2; 813-150-2; 814-143-1, 2; 815-149-3) in south-central Green Swamp and in wells (815-134-1, 2; 815-139-2, 3) about 9 miles north of Haines City.

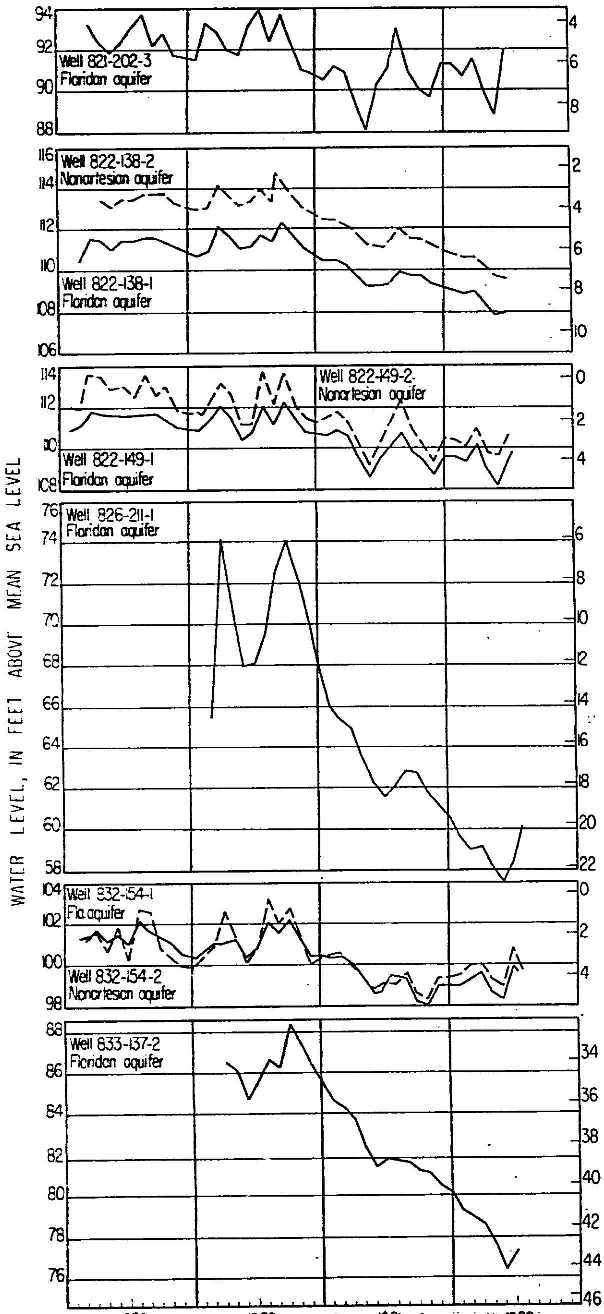


Figure 28. Hydrographs of water levels in wells (821-202-3; 822-149-1, 2; 832-154-1, 2) in north-central Green Swamp; in a well (826-211-1) 5 miles north of Dade City; in wells (822-138-1, 2) 17 miles north of Haines City; and in a well (833-137-2) 7 miles east of Clermont.

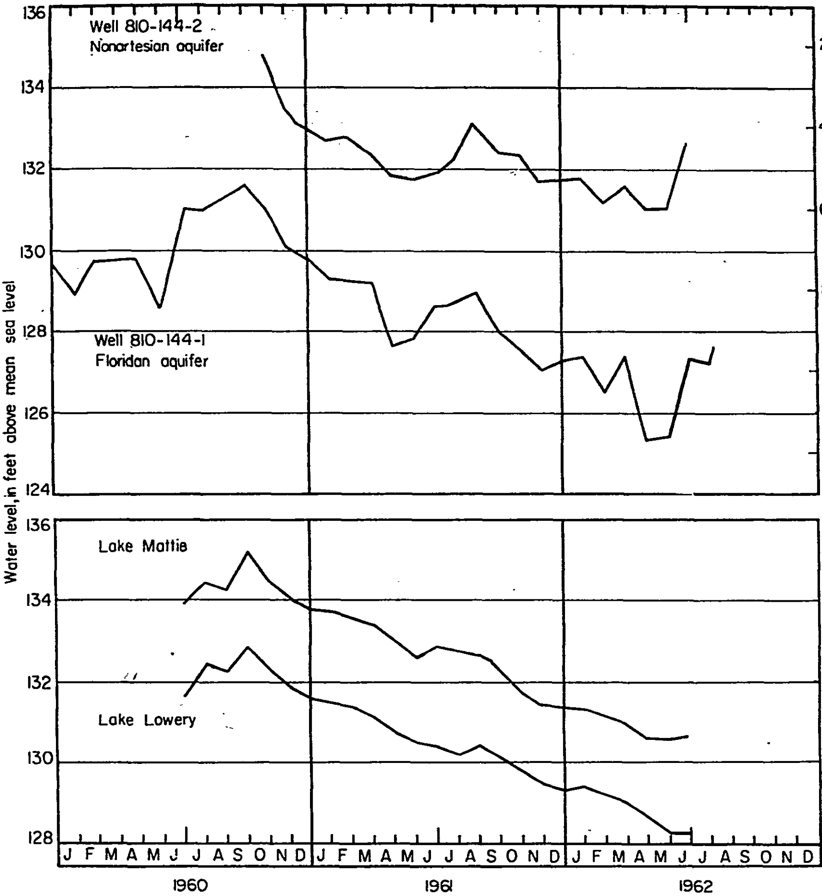


Figure 29. Hydrographs of water levels in wells 810-144-1, 2 and of Lake Lowery and Lake Mattie.

additional rainfall. Therefore, the runoff was high. Although the hydraulic gradient between the water table and the piezometric surface indicated that water moved downward most of the time, a reversal in direction was noted for dry periods.

Hydrographs of water levels in wells in the southwestern part of the Green Swamp area (fig. 25, well 805-155-1 and fig. 26, well 808-155-2) show that the water table fluctuated between 5 and 10 feet during the period 1959-62. The water table remained near the surface during the wet years of 1959 and 1960, and the aquifer afforded little capacity for storing rainfall. During the dry years of 1961 and 1962, the water table was progressively lowered by pumping from the Floridan aquifer south of the Green Swamp.

The area of greatest decline was in the vicinity of well 808-155-2 where the secondary artesian aquifer is absent. Large fluctuations of the water table in this area indicate good recharge to the Floridan aquifer and good hydraulic connection between the aquifers.

Hydrographs of water levels in wells east of the Green Swamp area (figs. 23, 27, and 28, wells 810-136-2, 815-134-2, 815-139-3, and 822-138-2) show that the water table fluctuated between 5 and 10 feet during the period 1959-62. The water table occurs at depths ranging from about 2 feet to more than 70 feet below land surface. The area has a potentially large capacity to store rainfall. Water moves downward from the nonartesian aquifer to the Floridan aquifer in the Lake Wales Ridge and moves upward in the valleys of Davenport and Reedy creeks. The best hydraulic connection between aquifers in the eastern part of the Green Swamp area probably occurs beneath the Lake Wales Ridge. This is indicated by almost identical fluctuations of water levels in wells 815-139-2, -3 (fig. 27).

Water levels in wells and sinkhole lakes, located in the southeastern part of the Green Swamp area, fluctuated about 5 feet (fig. 29). During wet periods, the water level is near or above land surface and water is stored in lakes and swamps. During dry periods, water levels decline due to lack of recharge and to pumping. Water levels in the nonartesian aquifer are generally higher than the piezometric surface indicating recharge to the Floridan aquifer.

HYDRAULICS OF THE NONARTESIAN AQUIFER

Permeability of a 3-foot section of the nonartesian aquifer was determined in a well (810-144-2) in southeastern Green Swamp and in a well (815-134-2) 5 miles east of Green Swamp by using the slug test method (Ferris, 1962). The field coefficients of permeability for the wells were determined to be about 50 gallons per day per square foot (gpd/ft^2) and about 40 gpd/ft^2, respectively. The results of laboratory tests of disturbed sand samples collected from a test hole in the bottom of Lake Parker near Lakeland (Stewart, 1959) ranged from 20 to 180 gpd/ft^2 (table 8). The permeability of the aquifer is probably lower in the interior of the Green Swamp area than in the surrounding ridges because of greater clay content.

The specific yield of the nonartesian aquifer was determined using a graphical analysis of rainfall and water-table fluctuations in wells located generally along the eastern and southern boundaries and in the interior. Continuous records of water-level fluctuations and rainfall were collected at each well site. The data were analyzed to select short periods during which all of the rainfall was assumed to reach the water table. One or two-day periods were selected when (1) antecedent conditions compensated for moisture requirements of the unsaturated material above the water table; (2) the water table was far enough below the ground to store all the rainfall and none left as runoff; and (3) the rainfall was of short duration, high intensity, and widespread. The rise in the water table is directly proportional to the depth of rainfall. The specific yield of the aquifer therefore is inversely proportional to the ratio of rise in the water table in inches to the depth of rainfall in inches.

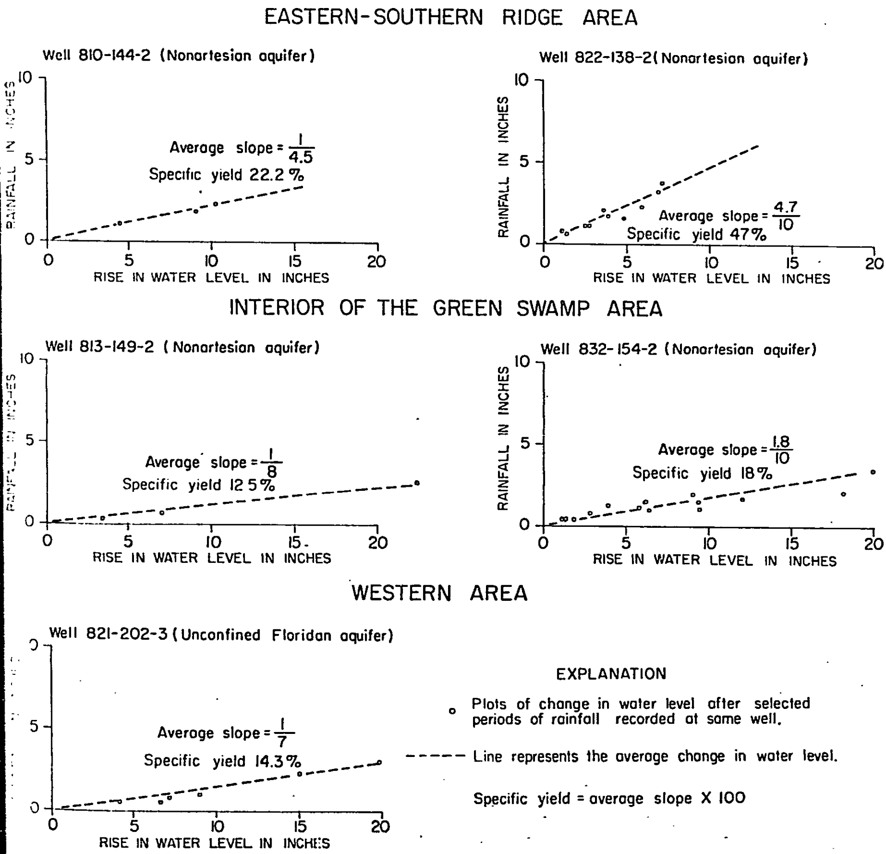


Figure 30. Graphical determination of specific yield.

The specific yield of the sand comprising the nonartesian aquifer ranged from 31.0 to 43.9 percent by laboratory analysis (table 8) and from 12.5 to 47 percent by analysis of water-level fluctuations caused by local rainfall, shown in figure 30.

The highest values (22.2 and 47 percent) are considered to be representative of the aquifer in the sandy ridges that surround the eastern and southern part of the Green Swamp area. The lower values (12.5 and 18 percent) are considered to be representative for the clayey sands in the central portion of the area.

CHEMICAL CHARACTERISTICS OF NONARTESIAN GROUND WATER

Water in the nonartesian aquifer in the eastern part of the Green Swamp area is less mineralized than that in the Floridan aquifer. The mineral content of water from the shallow wells in this area, ranging from 30 to 50 ppm, is due to the low solubility of the sand and clay which comprise the aquifer. The principal dissolved mineral constituents are sodium and chloride. The iron content ranged from 0.19 to 4.0 ppm. The 4.0 ppm in water from well 808-139-1 was the highest found in the Green Swamp area. The color of water from wells in the area was less than 15 units which is lower than that of surface water.

In the western part of the area, the nonartesian aquifer is almost nonexistent. The chemical characteristics of water in most shallow wells and in the Floridan aquifer are similar.

SECONDARY ARTESIAN AQUIFER

RELATION TO GREEN SWAMP AREA

The secondary artesian aquifer is composed of interbedded limestone in the undifferentiated clay (table 4). About 36 feet of the aquifer is present in well 810-144-1 in the southern part of the Green Swamp area. The aquifer thickens southward from the southern boundary of the area and is an important source of artesian water in southern Polk County. The aquifer pinches out northward and is absent in most of the Green Swamp area.

The aquifer is recharged by downward percolation of water from the overlying nonartesian aquifer and discharges principally by downward leakage to the Floridan aquifer.

Fluctuations of the piezometric surface of the secondary artesian aquifer were recorded in well 805-155-3 (fig. 25) and the surface is between the water table of the nonartesian aquifer and the piezometric surface of the Floridan aquifer. The clay beds separating the aquifers are leaky as indicated by the conformance of the fluctuations of the piezometric surfaces.

FLORIDAN AQUIFER

DESCRIPTION OF THE AQUIFER

The Floridan aquifer is the principal source of artesian ground water in Florida. In the Green Swamp area, the aquifer is exposed at the surface in the western and northwestern parts and occurs at depths ranging from 50 to more than 200 feet below land surface in the eastern part, shown in figure 31.

The Floridan aquifer is composed of marine limestones that have been exposed to erosion and solution weathering. The formations that comprise the aquifer in the Green Swamp area range in age from middle Eocene to Oligocene (table 4). The Geologic cross sections (fig. 8) show the limestone aquifer and the position of the overlying clastic material.

The top of the aquifer is highest (90 to 100 feet above msl) in the west-central part of the area as shown in figure 32. The base of the aquifer was determined by the first major occurrence of gypsum. Apparently, the gypsum fills the pores in the lower part of the Avon Park Limestone. The existing data indicate that the aquifer is about 1,000 feet thick in the central part of the area.

The transmissibility of the Floridan aquifer will vary depending primarily on the occurrence of solution features such as caverns, cavities, and pipes. The presence of dolomite in the limestone is an indication of solution activity. Dolomite zones and cavities generally occur in the Inglis Formation and the Avon Park Limestone which are highly permeable. Logs of numerous wells in the Green Swamp area indicate that a large percentage of the cavities in the aquifer contain sand which reduces the transmissibility. The low yields of some wells in the Lake Wales Ridge area are attributed to sand-filled and clay-filled caverns.

RECHARGE AND DISCHARGE

The Floridan aquifer in the Green Swamp area is recharged by rainfall that percolates downward from the surface of the ground either through the nonartesian aquifer and aquiclude or directly into the Floridan aquifer in outcrop areas. Water is discharged from the aquifer by (1) outflow to areas of lower piezometric head, (2) seepage and spring flow into the streams, (3) upward leakage to the nonartesian aquifer in areas of artesian flow, (4) evapotranspiration, or (5) pumpage.

Piezometric maps of the area were made from water-level measurements in about four hundred wells. These maps were analyzed to determine areas of recharge and discharge and the direction and rate of ground-water movement.

The first piezometric map of peninsular Florida was prepared by Stringfield (1936) and the latest, figure 33, was prepared by Healy (1961).

Ground water moves from high head to low head in a direction perpendicular to the contour lines. Piezometric mounds, referred to as "highs," usually indicate areas of recharge to the aquifer. Piezometric depressions or troughs, referred to as "lows," usually indicate areas of discharge from the aquifer. Recharge and discharge may take place anywhere from the high to the low where geologic and hydrologic conditions are favorable. Therefore, there is no one point of recharge nor one point of discharge. The difference in head between contour lines divided by the distance between them is the hydraulic gradient of the piezometric surface. The hydraulic gradient varies because of (1) unequal amounts of recharge or discharge, (2) differences in permeability within the aquifer, (3) differences in thickness of the aquifer, or (4) boundary conditions within the aquifer.

Ground water in the central part of the Florida Peninsula moves outward in all directions from an elongated piezometric high that extends approximately from central Lake County to southern Highlands County, generally referred to as the "Polk high," and from a smaller piezometric high in Pasco County, commonly referred to as the "Pasco high." The Green Swamp area occupies a relatively small part of the Polk high. The top of the Polk high occurs within the southeastern part of the Green Swamp area.

Ground-water drainage areas in the Floridan aquifer do not coincide with the surface-water drainage areas in the Green Swamp, shown in figure 34. The ground-water divides in the aquifer shift slightly in response to recharge and discharge. Therefore, the positions of the divides as shown in figure 34 were considered to be average for determining the size of the ground-water drainage areas that contribute outflow from the Green Swamp area toward the major surface drainage areas. Water in the Floridan aquifer moves generally from the southeastern part of the Green Swamp area eastward toward the Kissimmee River Basin; westward toward the Hillsborough and Withlacoochee River basins; southward toward the Peace and Alafia River basins; and northward toward the St. Johns River basin.

Figures 35 and 36 show the shape of the piezometric surface of the Floridan aquifer in the Green Swamp area and vicinity during a wet period (November 1959) and during a dry period (May 1962). Analysis of the maps shows the direction of movement of ground water did not change appreciably from wet to dry periods but the elevations of the piezometric surface declined. The decline was greatest along the southern and western borders and least in the interior of the Green Swamp area. Lows or troughs in the piezometric surface indicate that ground water discharges into Withlacoochee River through a spring at the mouth of Gator Creek and downstream from Dade City; into Hillsborough River at Crystal Springs; into Blackwater Creek; into Davenport and Reedy Creeks; and into Horse Creek. Closed depressions, such as those in the vicinity of Lakeland, indicate the effects of pumping.

Natural hydraulic gradients, indicated by the spacing of the contour lines in figures 35 and 36, are steep toward the Hillsborough River on the western side of Green Swamp and toward Reedy, Davenport, and Horse Creeks on the eastern side. The base flow of Hillsborough River below Crystal Springs is sustained by more than 50 cfs of ground-water inflow from the Floridan aquifer. The base flows of streams on the eastern side of the area are sustained by relatively small amounts of ground-water inflow from the Floridan aquifer. Obviously then, the steep gradient toward the east is caused by some factor other than a high rate of ground-water discharge. The geology along the eastern side of the Green Swamp area (see fig. 8, A-A') suggests that the steep eastward gradient is due to a barrier, or constriction in the aquifer, that was formed by natural grouting (sink-hole collapse and cavity-fill) along the fractures and joints in the limestone. Thus, the barrier effect decreases the ground-water outflow and a piezometric high is formed along the eastern side.

Figure 37 shows the decline in the piezometric surface from the wet period (1959-60) to the dry period (1962). Water levels declined least in the interior of the Green Swamp, in the Hillsborough River basin, and in the Kissimmee River basin (Davenport, Horse, and Reedy creeks). Water levels declined most along the southern (near Lakeland), western (near Dade City), and northeastern boundaries. Water levels declined about 5 feet in discharge areas (Hillsborough and Kissimmee River basins) because the ground-water discharge is relatively uniform regardless of seasonal variations in rainfall. Water levels declined less than 5 feet in the interior of the Green Swamp because there was little local pumpage and the rainfall during the dry period was about enough to balance the outflow; therefore, the aquifer remained relatively full.

The area surrounding the Green Swamp is more populated and developed and increased pumping during the dry period (1962) caused a greater decline in piezometric levels than would have occurred under natural conditions. If there had been no appreciable increase in pumping, the map could be used to detect areal changes in the hydraulic characteristics of the aquifer, particularly changes in permeability.

The northernmost extent of an area of heavy pumping for mining, industrial, municipal, and irrigational supplies is in the vicinity of Lakeland where the water levels declined about 20 feet. The drawdown is confined to the southern boundary of Green Swamp, suggesting that the area of the sinkhole-riddled ridges around southern Green Swamp is a recharge area. Water levels declined between 10 and 20 feet on the western side of Green Swamp in the vicinity of Dade City. This is considered to be an area of high permeability and good recharge. Water levels declined about 10 feet in the northeastern area which is also considered to be an area of high permeability and good recharge.

The general conclusion is that increase in discharge (natural or pumping) does not appreciably increase the lateral movement of ground water from the interior of Green Swamp but does affect the border areas.

HYDRAULICS OF THE FLORIDAN AQUIFER

Coefficients of horizontal and vertical permeability were determined for selected core samples of the limestones that comprise the Floridan aquifer. The samples were obtained from well 805-154-8, located just north of Lake Parker. The laboratory determinations are presented in table 9. The permeability values ranged from 0.0001 to 19 gpd/ft^2. The specific yields ranged from 0.2 to 23.2 percent. However, the specific yield determined in the laboratory represents that of the rock sample and not of the aquifer as confined.

Pumping tests were conducted in Green Swamp area and vicinity to determine coefficients of transmissibility (T) and storage (S) for the Floridan aquifer. The results of the tests are presented in table 10. Values of T ranged from about 20,000 gpd/ft to about 700,000 gpd/ft. The storage coefficients ranged from 0.013 to 0.0018 which means that for 1 foot change in head of the piezometric

TABLE 10. Pumping test data (Floridan aquifer)

Well number	Coefficient transmissibility gpd/ft)	Coefficient of storage	Coefficient of leakage (gpd/ft²/ft)	Aquifer penetration (nearest ten feet)	Average field coefficient of permeability (gpd/ft²)
(a) Determined by one or more observation wells					
807-154-4	[a,c]720,000	[a]0.0036	—	1,130	637
808-153-2	520,000	.0057	—	510	1,020
814-139-5	[b,c]680,000	.0018	—	350	1,940
814-139-5	[b,c]1,150,000	.012	0.042	350	3,280
816-135-2	120,000	.011	—	360	333
821-202-1	[c]22,000	.003	.022	130	169
828-154-2	293,000	.013	.036	260	1,130
(b) Determined by observations in the pumped well					
807-154-4	[b,c]1,150,000	—	—	1,130	1,020
810-144-1	110,000	—	—	340	324
813-149-1	40,000	—	—	140	286
813-201-1	62,000	—	—	240	258
814-139-5	[c]120,000	—	—	350	340
814-143-1	77,000	—	—	200	385
814-134-1	37,000	—	—	160	231
815-149-3	29,000	—	—	170	171
815-157-2	84,000	—	—	130	646
816-206-1	150,000	—	—	180	833
821-202-1	[c]22,000	—	—	130	169
822-138-1	26,000	—	—	230	113
822-149-1	32,000	—	—	130	246
826-211-1	300,000	—	—	190	1,580
827-158-1	57,000	—	—	160	356
832-154-1	28,000	—	—	100	280

[a]Average of two tests.
[b]Determined to be invalid. See pumping test analysis section.
[c]Analysed by Theis (1935) type curve and semilog method (Jacob, 1950).

surface, the aquifer releases or takes into storage 0.013 to 0.0013 foot of water per square foot of surface area of the aquifer.

A comparison of the results of laboratory tests with pumping tests indicate that the permeability of the Floridan aquifer is largely dependent upon the presence of solution holes (caverns, pipes, etc.) which, of course, are not represented in the small core samples.

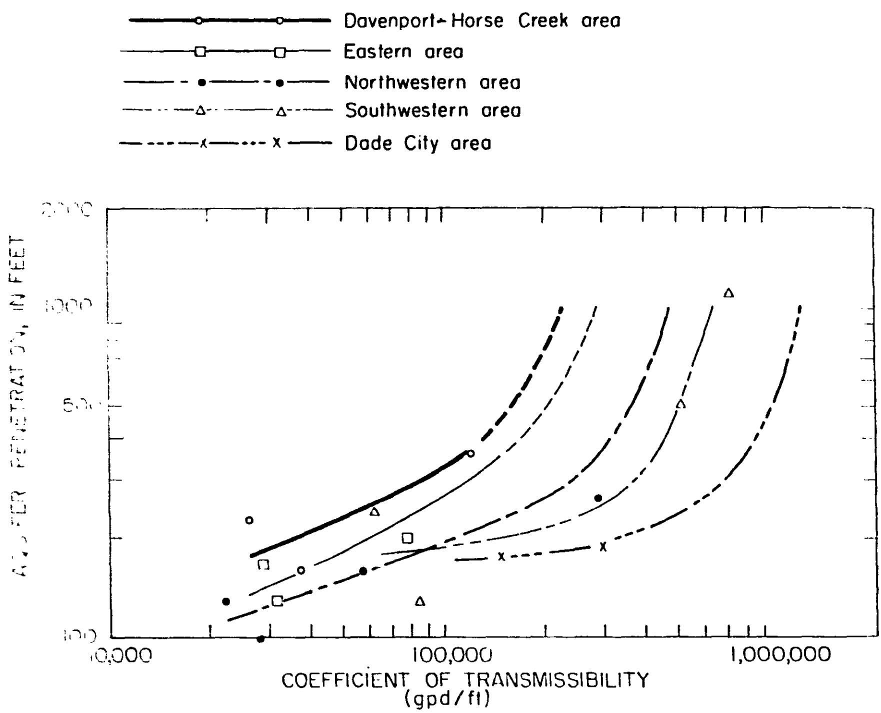


Figure 38. Graphs showing the relations between coefficient of transmissibility and depth of penetration in the Floridan aquifer.

The values of T for the pumping tests in table 10 were plotted against depth of aquifer penetration, as shown in figure 38. The wide range in values of T are caused by unequal penetration and by areal and vertical variations in permeability. Areal analysis of the data indicate that generally the eastern side (Davenport-Horse Creek area) of the Green Swamp area has a low value of T and the western side (Dade City) has a high value of T. Therefore, the test data were evaluated by location and depth of penetration.

The average field coefficients of permeability (P_f) table 10) were averaged for each area and then multiplied by the approximate thickness of the aquifer (1,000 feet) to estimate the coefficient of transmissibility (T_e) for each representative area. The data were analyzed for (1) the Davenport-Horse Creek area east of the Lake Wales Ridge; (2) the eastern area, which includes the general area between State Highway 33 and U.S. Highway 27; (3) the northwestern area, which includes the area west of State Highway 33 and north of the Withlacoochee River; (4) the southwestern area, which includes the area west of State Highway 33 and south of the Withlacoochee River; and (5) the Dade City area west of the Withlacoochee River. The results of the computations (expressed to the nearest hundred thousand gpd/ft) are presented in table 11. Computations of ground-water movement into or out of the area used in the water-budget analysis were based on the estimated coefficients of transmissibility shown in table 11.

TABLE 11. Estimates of transmissibility

Area	T_e (gpd/ft)
1. Davenport-Horse Creek	200,000
2. Eastern	300,000
3. Northwestern	500,000
4. Southwestern	600,000
5. Dade City	1,200,000

Barrier boundaries caused variations in the values of T in the vicinity of the Lake Wales Ridge. Observation wells 815-139-2 and 815-140-1 were used to observe the effects of drawdown and recovery caused by pumping well 814-139-5. Water level measurements were also made in the pumped well. The data were analyzed by the Theis method (1935), the family of leaky aquifer curves by Cooper (1936), and the Jacob method (1950). The data defined three curves, figure 39, with T values of 680,000 gpd/ft and 1,150,000 gpd/ft, for the observation wells and 120,000 gpd/ft for the pumped well. The wide variation in T probably indicates that the basic assumptions prerequisite for the analysis of the data do not apply and is probably caused by heterogeneity of the aquifer and existence of a barrier boundary. The test site is in a faulted area (see fig. 8, C-C'). Figure 40 shows the location of the wells with respect to sand-filled fractures in the underlying limestone along the Lake Wales Ridge. The variation in T values is probably caused by sand-filled fractures which act as barriers

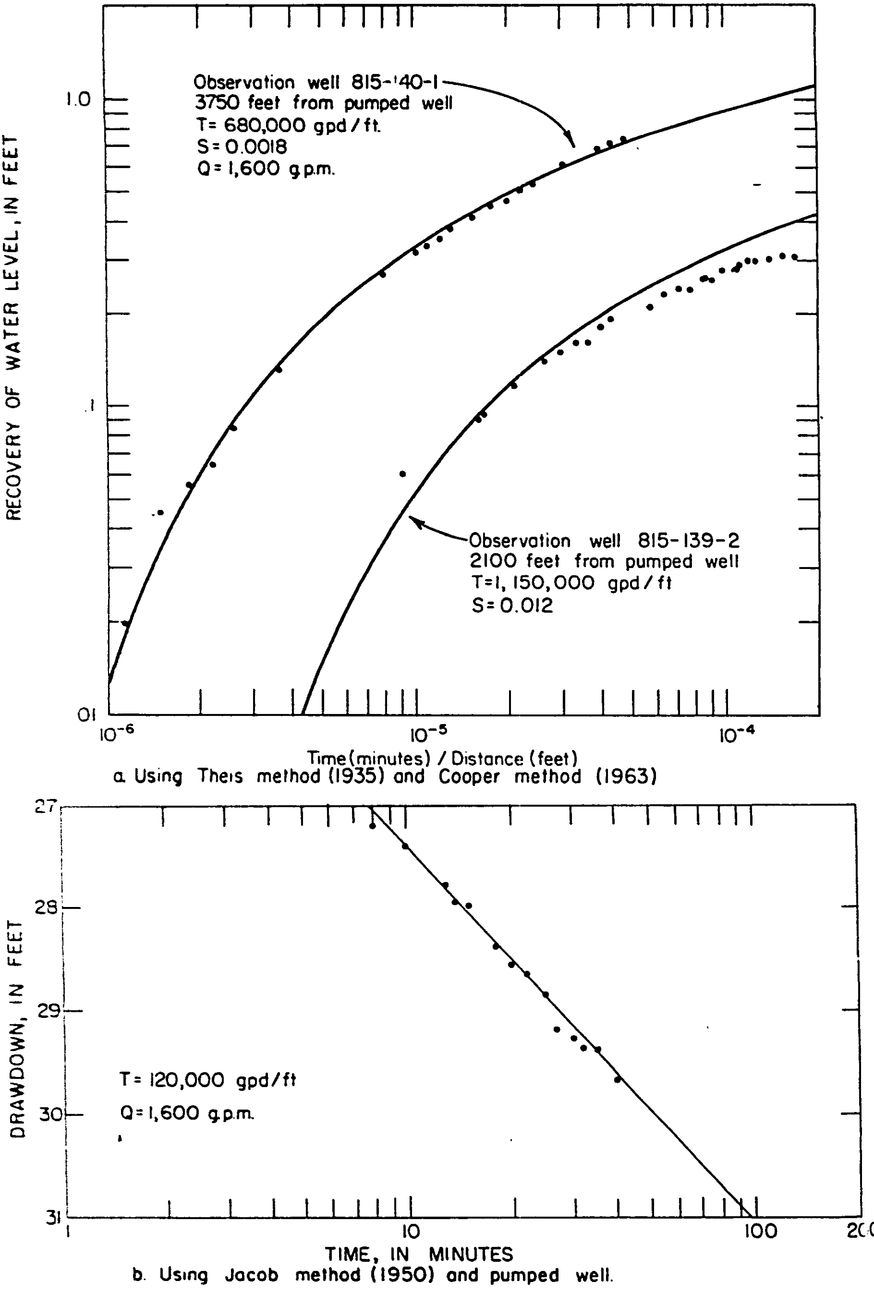


Figure 39. Graphs of pumping test at a well (814-139-5) about 9 miles north of Haines City.

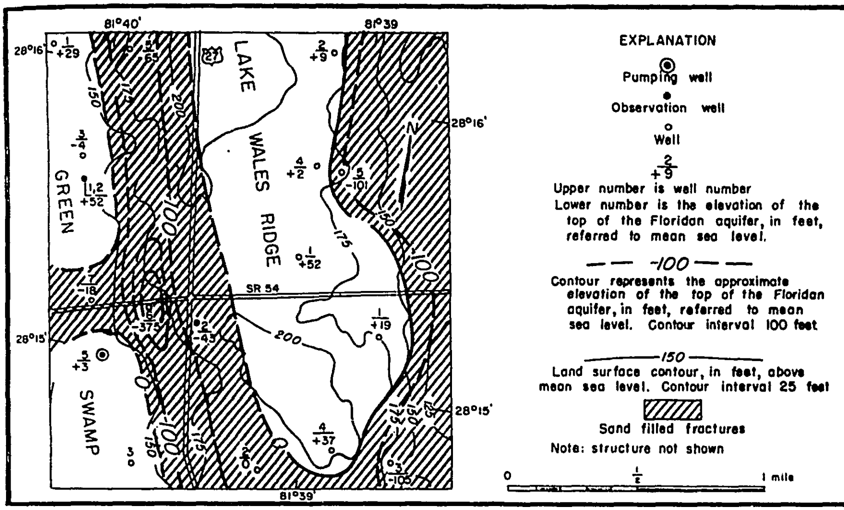


Figure 40. Map showing environment affecting pumping test at a well (814-139-5) about 9 miles north of Haines City.

between the pumped well and the two observation wells. The barriers decrease the drawdown in the observation wells giving erroneously high values of T. Probably the best value of T was obtained from data from the pumped well which is comparable to the results of a nearby test (see table 10, well 816-135-2).

CHEMICAL QUALITY OF WATER IN THE FLORIDAN AQUIFER

The quality of water in the Green Swamp area is good. The total mineral content is generally less than 350 ppm. Water containing a mineral content of less than 500 ppm is usable for most purposes. The water of the Floridan aquifer is more mineralized (100-400 ppm) than surface water or water from the nonartesian aquifer (20-50 ppm). The higher mineral content is caused by contact of water with materials that are more soluble. About 75 percent (by weight) of the mineral constituents dissolved in water of the Floridan aquifer are calcium and bicarbonate that cause the water to be hard and alkaline. Hardness, illustrated in figure 41, is one of the more undesirable characteristics. The water ranges from moderately hard in the eastern part of Green Swamp to very hard in the western part.

Figure 42 shows the iron content of water in the Floridan aquifer in the Green Swamp area. The highest concentrations of iron are found in the west-central part of the area. Iron greater than 0.20 ppm generally should be removed for most uses.

Other dissolved mineral constituents, including silica, potassium, sulfate, and chloride, occur in concentrations generally less than 10 ppm. Fluoride and nitrate are usually present in concentrations less than 1.0 ppm. The water is clear (color less than 5 units), the temperature ranges from 74 to 78°F., and the pH ranges from 6.8 to 8.6 units.

Water from a well (830-210-2) near the northwestern boundary had a sulfate concentration of 101 ppm. The high sulfate concentration is due to contact of water with gypsum. Samples of

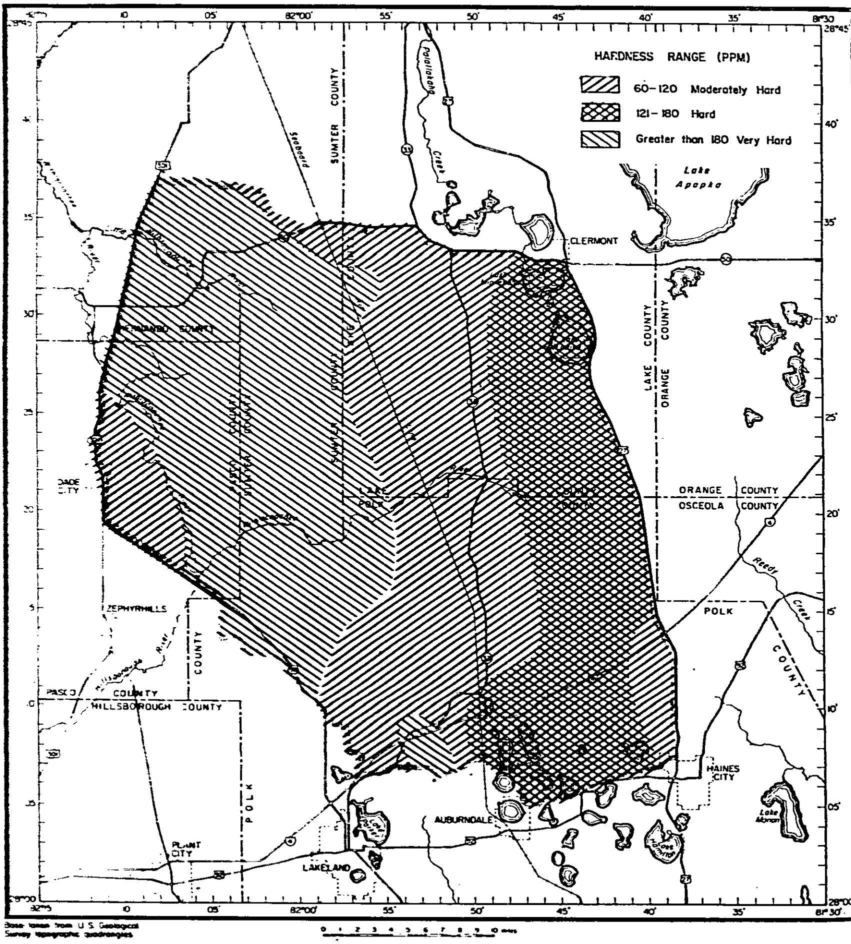


Figure 41. Hardness of water in the Floridan aquifer in the Green Swamp area.

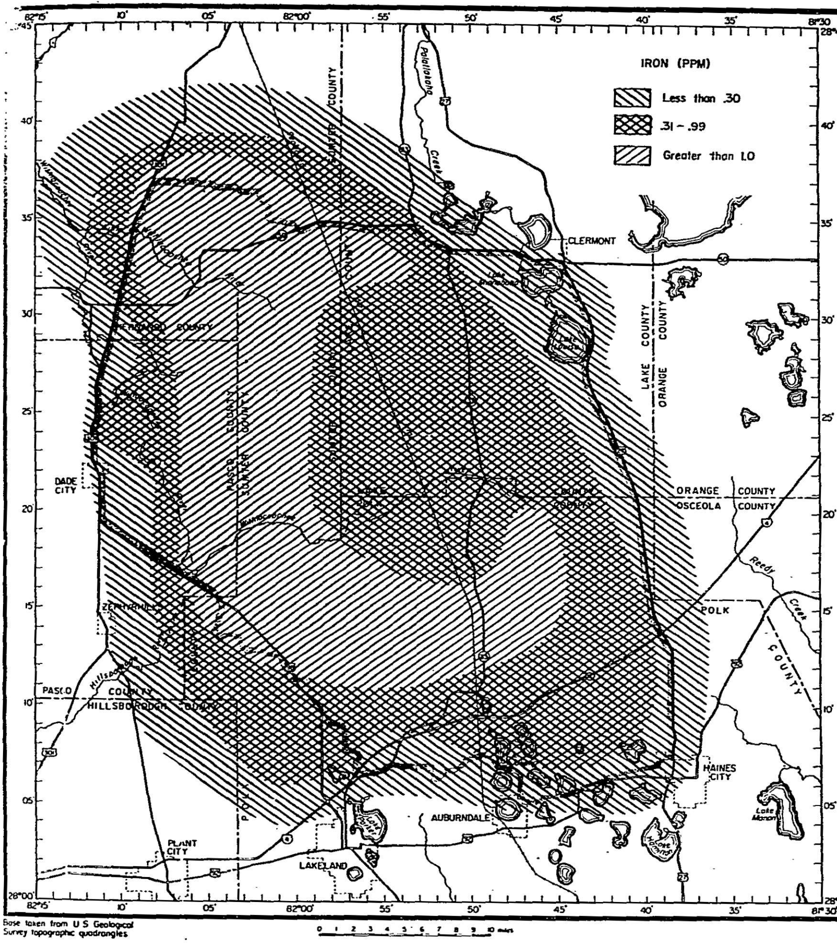


Figure 42. Iron content of water in the Floridan aquifer in Green Swamp area.

a well (810-144-1) located on the piezometric high were analyzed for trace elements, none of which were present in a concentration that would impair the usability for most purposes.

HYDROCHEMISTRY OF THE FLORIDAN AQUIFER IN CENTRAL FLORIDA

The chemistry of water in the Floridan aquifer can be used to gain a better understanding of the hydrology of the Green Swamp area and the recharge potential of the Green Swamp as compared to the rest of the central Florida area. The chemistry of the water in an aquifer depends on the chemical character of the water entering the aquifer, the chemical character of the rocks and water in the aquifer, and the time the water entering the aquifer is in contact with these rocks and water.

Water entering the aquifer in the Green Swamp area and in central Florida in general, is less mineralized than water already in the aquifer. Water is low in mineral content because the overlying sands and clays generally are less soluble than the limestone of the Floridan aquifer. Therefore, in recharge areas the mineral content should be lowest, other factors being equal. The mineral content of the water should increase as the water moves through the aquifer until it becomes saturated with calcium and bicarbonate. Using only the mineral content to indicate areas of recharge could be misleading because water entering the aquifer in some areas could be more highly charged with carbon dioxide than in other areas. High amounts of carbon dioxide in water dissolves more limestone than small amounts. In some coastal areas, the water in the aquifer already contains high concentrations of salt.

The percentage of limestone that was dissolved by the water in the aquifer in central Florida was calculated from measurements of alkalinity, pH, temperature, and mineral content (Back, 1963) and is shown in figure 43. Saturation values less than 100 percent indicate that the water could dissolve more limestone. Values of more than 100 percent indicate that the water is oversaturated and would therefore tend to precipitate limestone. Figure 43 shows undersaturated water occurs in the aquifer along the eastern and western boundaries of the Green Swamp and to the north. Water in recharge areas should be undersaturated and the percent of saturation should increase as the water moves away from the recharge area (Hem, 1961, p. C-15). If the recharge occurs only in the Green Swamp area, then the saturation values should be lowest in this area and should increase in all directions from the area. Figure 43 shows that the area of undersaturation includes much of central Florida and thus implies that recharge occurs over much of this area.

In the areas of undersaturation, caverns or fissures can be enlarged by limestone solution several hundred feet below the water table (Back, 1963). High rates of water movement through these caverns and fissures could account for the occurrence of undersaturated water at these depths. The time and area of contact of water with the limestone in these openings would be minimized.

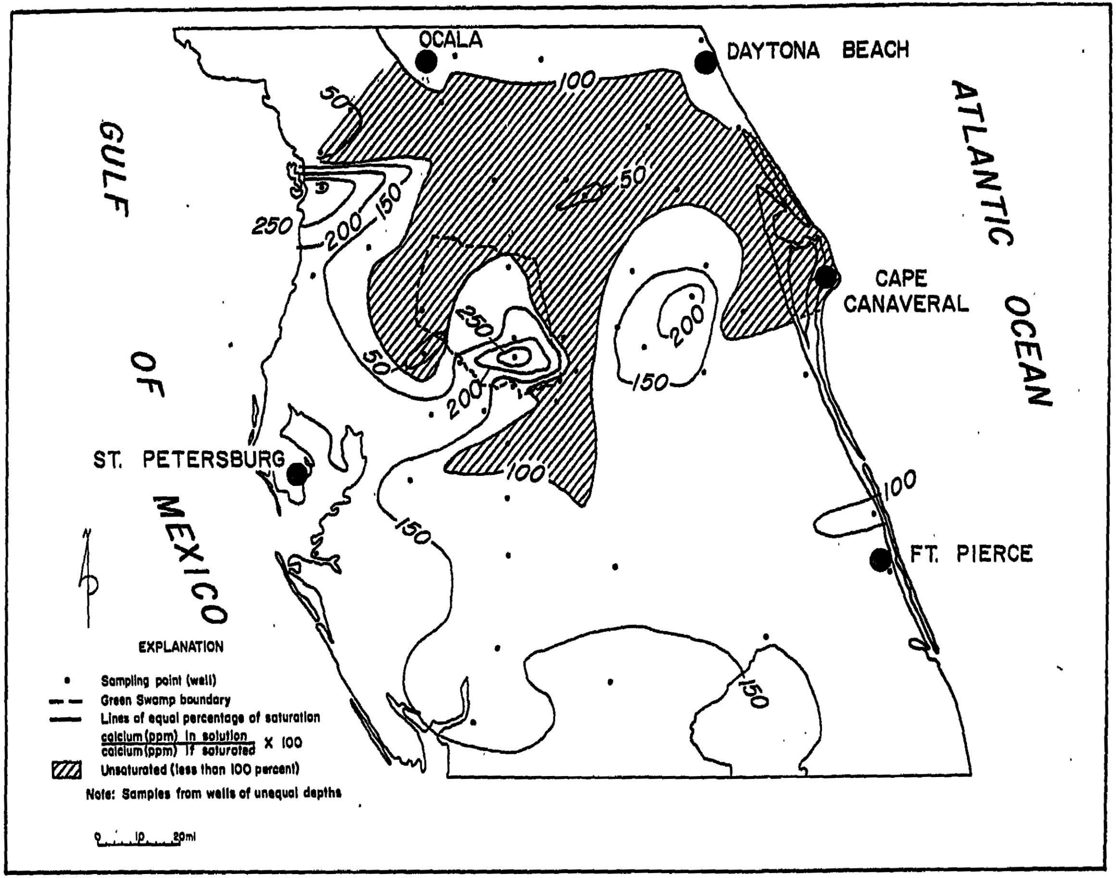


Figure 43. Map of central Florida showing the percentage of calcium carbonate saturation of water in the Floridan aquifer.

The presence of highly mineralized water in the Floridan aquifer may also be used to indicate the direction of movement of water. Assuming that at some time much of the aquifer of central Florida contained salt water, then the area in which the water now contains little or no salt (chloride), would be better flushed with fresh water than areas containing high amounts. The chloride content is generally higher at shallow depths near the coast than in the interior, shown in figure 44. However, water of low chloride content is present several hundred feet deep in local areas near the coast. Data from a few scattered deep wells indicate that fresh water extends to about 1,500 feet below sea level in much of the interior of central Florida from Marion County to Highlands County. Figure 44 and other data from the deep wells indicate that salt water has been flushed from the aquifer in much of the interior. Therefore, the total mineral content of the water in the Floridan aquifer in the interior of Florida is due to solution of limestone and not due to mixing with salt water. If recharge occurred only in the Green Swamp area, then the concentration gradient should increase in all directions from that area. Figure 45 shows that the concentration gradients do not increase immediately away from the Green Swamp but instead show a decrease over much of central Florida. The areas of low mineral content and areas of undersaturation generally coincide (figs. 43 and 45). This supports the implication that recharge is not confined to the Green Swamp area.

ANALYSIS OF THE HYDROLOGIC SYSTEM

The Green Swamp area is considered to be a self-sustaining hydrologic unit because most of its water supply is derived from rain that falls directly on the area. Water is imported from outside the area only in the vicinity of Dade City (see figs. 5, 11, 35, 36). Inflows in the vicinity of Dade City affect only the lower reaches of the Withlacoochee River.

The amounts of water in the various parts of the hydrologic system and losses of water as the result of natural processes, are evaluated for the Green Swamp area.

RAINFALL, RUNOFF, AND WATER LOSS

Runoff is the residual of precipitation after all the demands of nature have been met. These demands taken collectively are called water loss. A simple definition for water loss is: Water loss equals precipitation minus runoff adjusted for change in storage and for

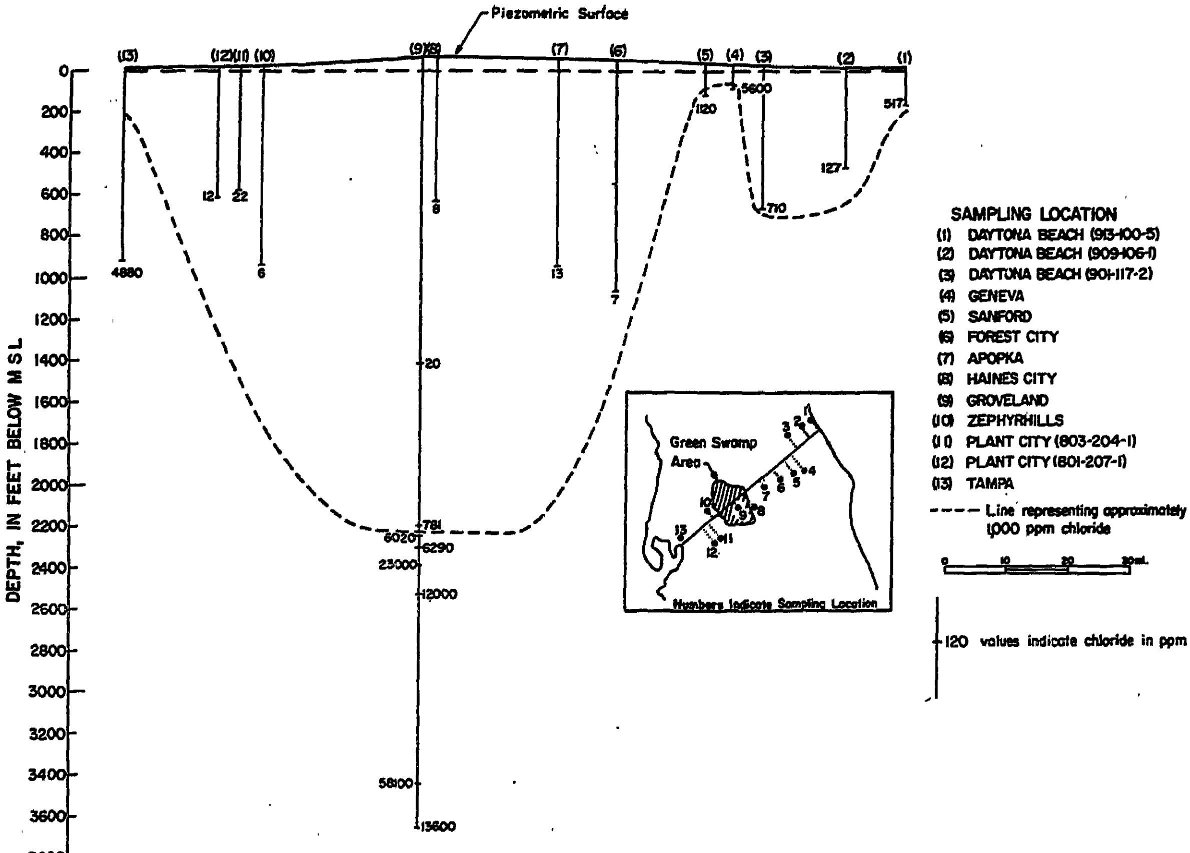


Figure 44. Vertical distribution of chloride content of water in wells across central Florida.

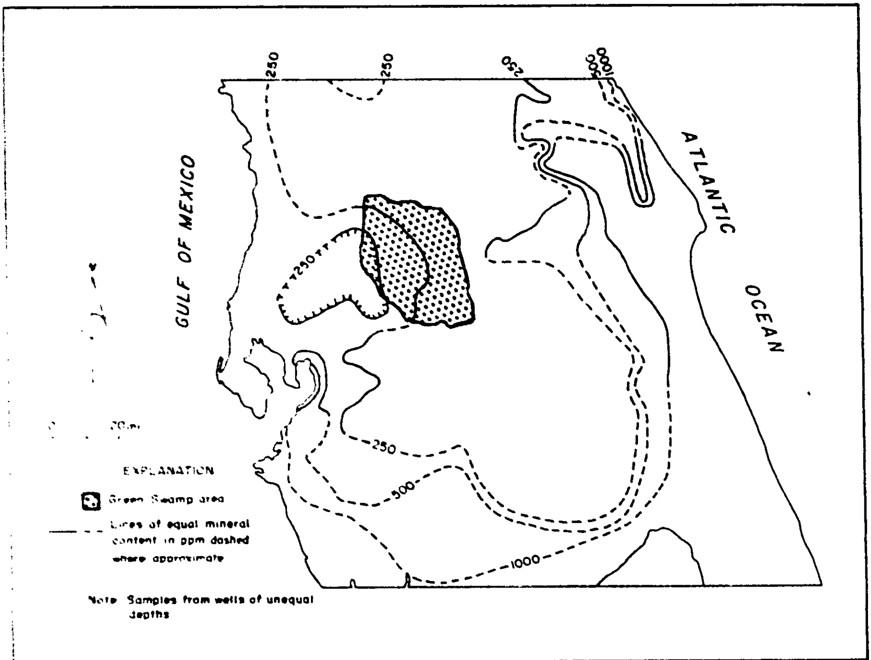


Figure 45. Map of central Florida showing mineral content of water in the Floridan aquifer.

seepage into and out of the basin. The basic concept is that water loss is equal to evapotranspiration; that is, water that returns to the atmosphere and thus is no longer available for use. As used in this report, water loss is not adjusted for seepage into or out of the basin. Thus, the equation for water loss is:

$$L = P_e - R \pm \Delta S$$

where, L is water loss
P_e is effective precipitation
R is streamflow
ΔS is change in storage both surface and underground

Use of an effective precipitation (Searcy and Hardison, 1960) is one way of making allowance for the variable amount of water carried over from year to year as ground water storage in the basin. Effective precipitation (P_e), as commonly used, is that part of the precipitation (P_o) for the current year and the part of the precipitation (P_1) for the preceding year that furnished the runoff for the current year, or

$$P_e = aP_o + bP_1$$

The coefficients a and b are determined by statistical correlation.

Long-term annual records of rainfall and runoff for the Withlacoochee River and Palatlakaha Creek basins have been used to determine the variations in water loss in the Green Swamp area. Areal variations in water loss are caused by: (1) climatic factors, the most important of which are rainfall, temperature, humidity, and wind; (2) drainage basin characteristics, which include size, shape, surface slope, the amount of water area, seepage as related to the surface and sub-surface geology, and the condition and type of vegetative cover; and (3) storage underground and in natural lakes, ponds, swamps, and artificial reservoirs. The effective annual precipitation determined for the Withlacoochee River basin above Trilby and for the Palatlakaha Creek basin above Mascotte is

$$P_e = 0.8P_o + 0.2P_1$$

The annual water-loss curve for Withlacoochee River at Trilby is shown in figure 46. The $P_e = L$ line (dashed line) in figure 46 represents the theoretical limit of water loss which would occur if the loss equaled the precipitation and none ran off as streamflow. The average water-loss curve is shown by the solid line which was drawn to average the annual figures of effective precipitation and loss($P_e - R$) for the basin. The departures of the yearly data from the average curve may be caused in part by changes in storage and seepage and in part by differences in the distribution of precipitation within the year. No adjustment is made for these factors in the water-loss equation for Withlacoochee River at Trilby and they thus affect the apparent evapotranspiration.

An effective annual precipitation of about 32 inches, indicated by the point where the downward extension of the curve coincides with the $P_e = L$ relation, is the most probable yearly amount below which little significant runoff would occur. Under some conditions of intensity and distribution of precipitation, there could be runoff with less than 32 inches of precipitation.

As shown by the curve in figure 46, the average water loss increases with the precipitation until it becomes nearly a constant for higher values of precipitation. This is about the maximum loss that would occur regardless of the amount of precipitation and is called the potential natural water loss for the basin. The potential

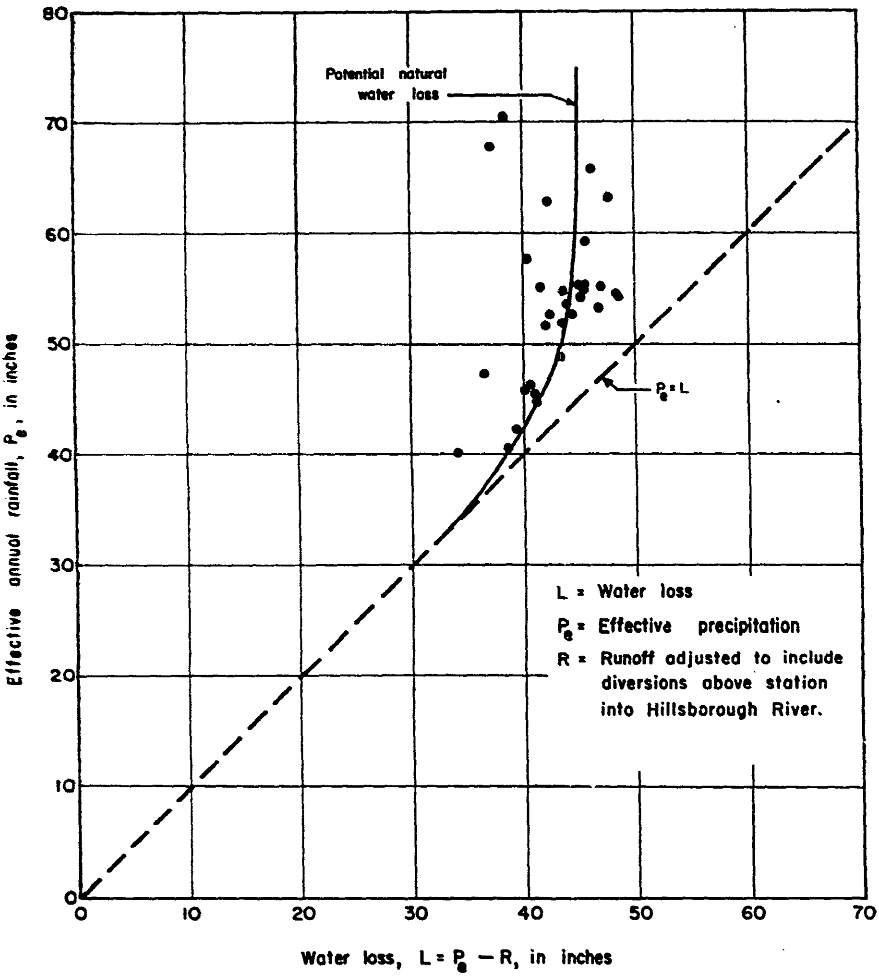


Figure 46. Relation of effective annual rainfall and annual water loss, Withlacoochee River at Trilby, 1931-61.

natural water loss for the Withlacoochee River at Trilby is shown to be 45 inches. This figure compares favorably with the 48 inches of average water loss shown for 72°F., the mean annual temperature for the area, in figure 7.

Figure 47 shows the plotted yearly figures of rainfall and runoff for the Trilby station and an average curve. The average curve was determined by using the curve in figure 46 and plotting the departures of the potential water-loss curve from the limiting curve ($P_e = L$).

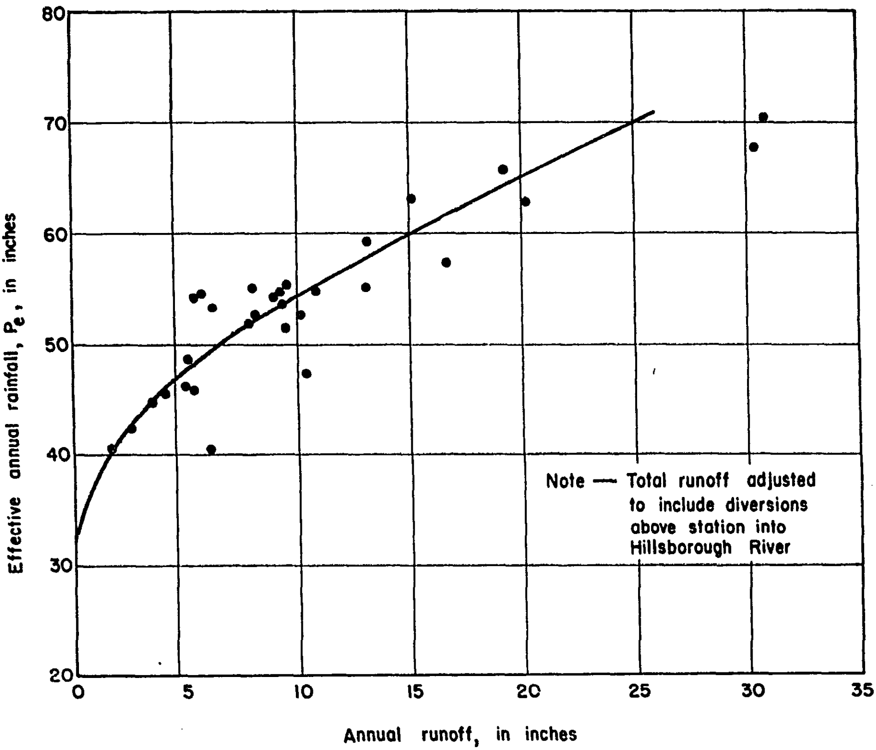


Figure 47. Relation of effective annual rainfall and annual runoff, Withlacoochee River at Trilby, 1931-61.

The runoff from the upper Palatakaha Creek basin has been measured since 1945 (stations 11 and 12 in table 1). The water-loss curve for the upper Palatlakaha Creek basin is shown in figure 48. Runoff was adjusted for annual changes in storage in the many lakes and swamps in the basin. No allowance was made for change in underground storage or for seepage into or out of the basin.

The water-loss curves shown in figures 46 and 48 indicate that, for a year in which rainfall was 32 inches or less, the natural losses would nearly equal the rainfall and little or no runoff would occur from either the Withlacoochee River or the Palatlakaha Creek basins in the Green Swamp area.

As shown in figure 48, the potential natural water loss for the upper Palatlakaha Creek basin is 48 inches which is the same as the annual water loss shown for 72°F. in figure 7. Figure 49 shows the relation of the effective annual rainfall and runoff for the upper Palatlakaha Creek basin.

The potential natural water loss, indicated by this analysis for each basin, includes both evapotranspiration and ground-water outflow. Further analyses show that about 2 inches more ground

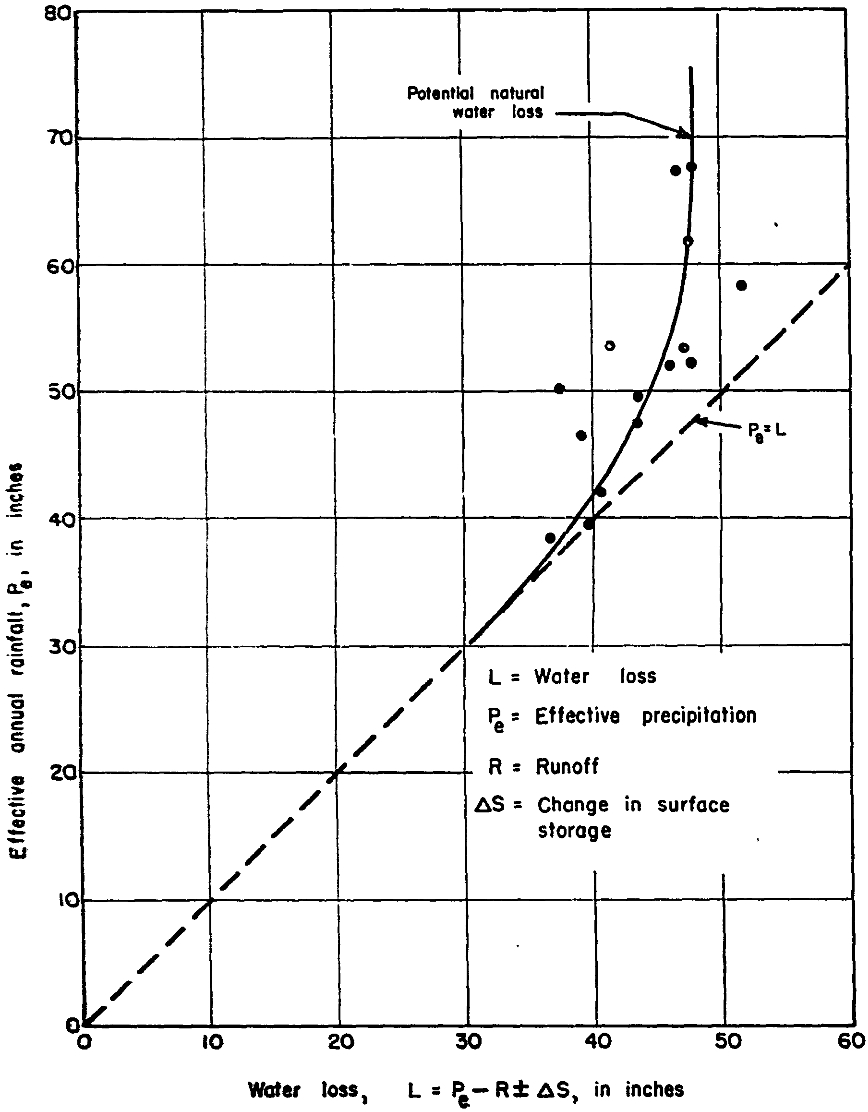


Figure 48. Relation of effective annual rainfall and annual water loss, Palatlakaha Creek above Mascotte, 1946-61.

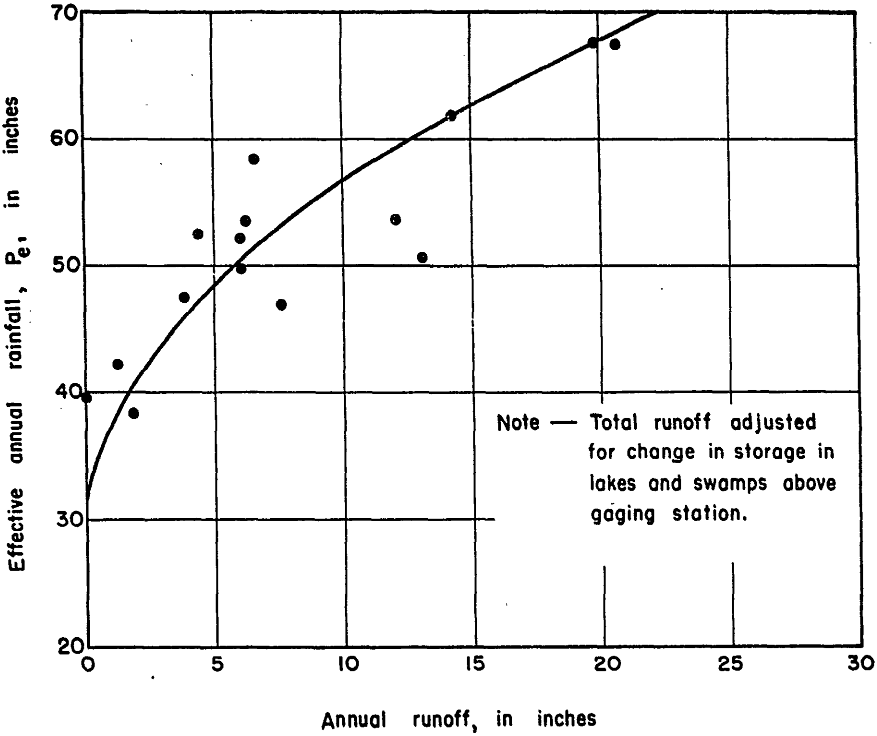


Figure 49. Relation of effective annual rainfall and annual runoff, Palatlakaha Creek above Mascotte, 1946-61.

water flows from eastern basins than from western basins (table 14). The gain in streamflow by ground-water pumpage at Dade City reduces the apparent water loss in the Withlacoochee River basin above Trilby. The many large lakes and swamps in the upper Palatlakaha Creek basin afford the opportunity for high evapotranspiration losses. The differences in ground-water inflows and outflows in the Palatlakaha Creek and Withlacoochee River basins and the increased evapotranspiration losses from the large lakes and swamps could easily account for the 3 inches more potential natural loss from the Palatlakaha Creek basin.

WATER-BUDGET STUDIES

A water budget is a quantitive statement of the balance between the total water gains and losses of a basin or area for a period of time. The budget considers all waters, surface and subsurface, entering and leaving or stored within a basin. Water entering a basin is equated to that leaving the basin, plus or minus changes in basin storage.

The budget equation was the basis of the expression for determining the water-loss equation in the foregoing discussion of rainfall, runoff, and water loss. The water-budget equation may be expressed in greater detail as

$$P = R + ET + U + \Delta S_s + \Delta S_g$$

where: P is precipitation
R is streamflow
ET is evapotranspiration
U is ground-water outflow
ΔS_s is change in surface-water storage (+ for net gain; — for net loss)
ΔS_g is change in ground-water storage (+ for net gain; — for net loss)

Precipitation (P) and streamflow (R) are factors of the budget equation that can be measured directly. The other factors are not measured directly but are derived from observed or deduced data. Ground-water outflow (U) in the Green Swamp area is the net amount of water that moves out of the basin by subsurface flow through both the nonartesian and Floridan aquifers.

The amount of water leaving the nonartesian aquifer by horizontal underflow is an insignificant factor in the budget where the water-table divides coincide with the surface-water divides. In the Green Swamp area, the divides on the eastern boundary do not coincide and a small quantity of water leaves the area via the nonartesian aquifer.

The amount of water leaving the area via the Floridan aquifer was estimated by using the hydraulic coefficients of the aquifer and piezometric maps.

The gain or loss of water by storage changes (ΔS_s and ΔS_g) in an area such as the Green Swamp may be a significant quantity for short periods. However, by using selected long-term periods, the effects of storage changes are minimized. The change in surface-water storage (ΔS_s) is indicated by change in stage of lakes, stream channels, and swamps in a basin. In this analysis, the open water surfaces were considered to be a small percentage of the total drainage area, and estimates for storage changes in the nonartesian aquifer were used for an overall storage change including ΔS_s.

The change in ground-water storage (ΔS_g) is the net change in ground-water stage multiplied by the specific yield for (or storage coefficient) of the aquifer for a given period of time. Separate analyses were made for both the nonartesian and the Floridan aquifers.

Evapotranspiration (ET) cannot be measured directly for large areas such as the Green Swamp, but may be approximated by balancing the water-budget equation and determining the residual quantity. The other quantities of water loss are small in proportion to the quantity lost by evapotranspiration. Therefore, the residual quantity in the equation reasonably represents the evapotranspiration loss.

EVAPORATION AND WATER BUDGET OF LAKE HELENE

Most of the precipitation that falls on an area is dissipated through the natural processes of evaporation and transpiration. Because evaporation plays such an important role in the hydrologic cycle, much effort was expended to measure it directly at Lake Helene instead of calculating it as a residual in the storage equation.

Harbeck (1962) describes a practical method for measuring the evaporation from an open-water surface utilizing the mass-transfer theory. A report by the U. S. Geological Survey (1954), and one by Harbeck and others (1958), may be consulted for additional information on the method.

The mass-transfer method provides a technique for measuring the evaporation and for determining the seepage from a lake, two factors of the water budget that are generally determined indirectly or estimated. The change in volume resulting from evaporation on the water surface of a lake is computed by use of an empirical equation based on measurements of the evaporative capacity of the air. The water-budget equation is then balanced to account for volume changes from rainfall, surface inflow and outflow, evaporation, seepage, and other consumptive losses.

Evaporation computed by applying a coefficient to measured evaporation from a pan may be subject to considerable error, particularly for periods of less than a year. The annual average Class-A pan coefficient for central Florida has been estimated by Kohler and others (1959, pl. 3) to be about 77 percent. The monthly evaporation-pan coefficients vary more widely and with a greater range of probable error than the annual coefficients. There is, therefore, the need to supplement pan records with direct measurements of evaporation.

Evaporation from Lake Helene was measured in 1962 by use of the mass-transfer method. Lake Helene is located about 1 mile southeast of Polk City on top of the piezometric high (see figs. 5 and 35). The lake has no surface inlet and no surface outlet except at extremely high stages, and in 1962 its surface area ranged from 56.6 to 51.2 acres. It is nearly devoid of vegetative growth; consequently, transpiration losses are negligible. A map of Lake Helene showing depth contours is given in figure 50. The depth-contour map for Lake Helene is taken from a report by Kenner (1964): This map shows the locations of the water-stage and rainfall recorder and the raft in mid-lake supporting an anemometer and a water-surface temperature recorder.

Figure 51 is the hydrograph of the daily stage of Lake Helene from March 31, 1961, to December 31, 1962. The evaporation station was established December 13, 1961. Computations of the evaporation data for the 1962 calendar year have been summarized and used to help define the annual water budget.

Pumpage of water from Lake Helene to irrigate the surrounding citrus groves contributes to water loss from the lake. A pumping station capable of pumping 1,800 gallons per minute was installed in 1962 and operated intermittently during the year. The volume changes due to pumpage from the lake were computed from the recorded changes in stage and stage-volume relations. These computations were verified by records of the approximate periods of pumpage and the rated capacity of the pump.

Nearly all the gains of water in the lake were derived from rain that fell directly on the water surface. The lake stage increased approximately the same amount as the recorded depths of rainfall during light to moderate rain storms. However, during a few heavy rain storms the lake stage increased slightly more than the depth of rain, indicating runoff from land. The increase in lake stage during these periods is equivalent to the total gain for rain falling directly on the lake and from runoff. Net seepage to or from the lake caused a gain in volume at times and a loss at other times.

The water-budget equation for Lake Helene may be expressed as follows:

$$\Delta V = P + R + Se - E - Pu$$

where:

ΔV is change in lake volume (+ for increase; — for decrease)

P is precipitation on lake

R is runoff from land

Se is seepage (+ for net gain; — for net loss)

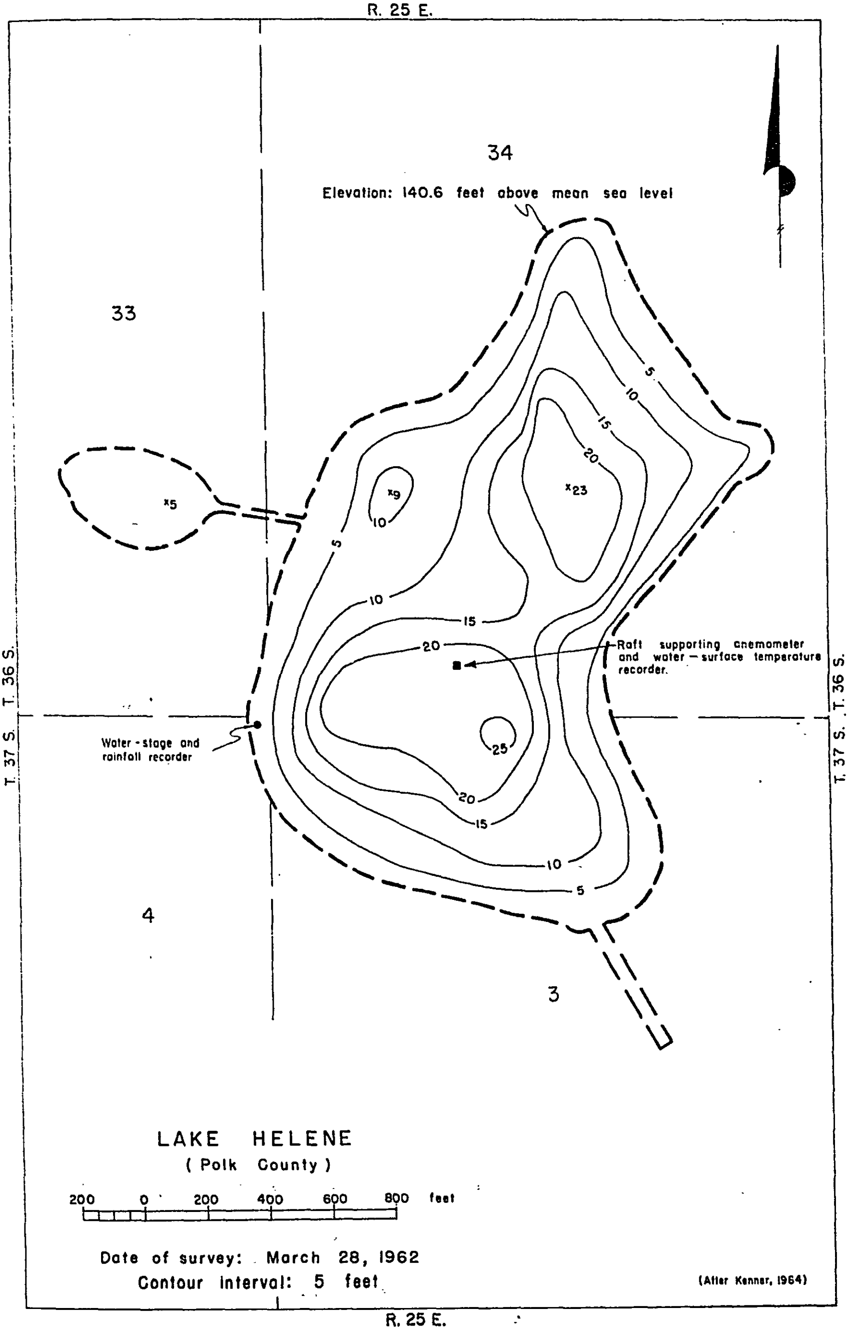


Figure 50. Map of Lake Helene showing depth contours and locations of data-collection equipment.

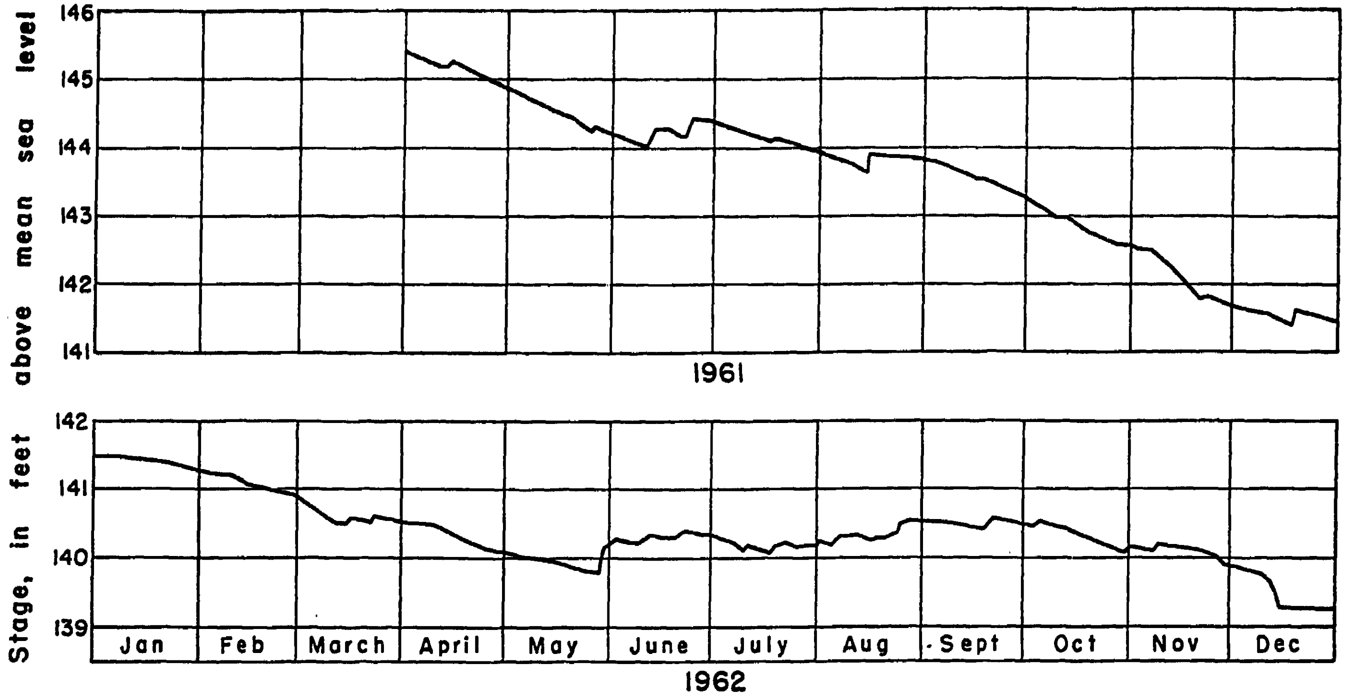


Figure 51. Hydrograph of daily stage for Lake Helene, 1961-62.

E is evaporation from lake
Pu is pumpage from lake

The monthly water budget for Lake Helene for 1962 is shown in table 12. The total loss from evaporation was 53.10 inches as shown in column 12. Seepage to or from the lake was variable as shown by the monthly amounts in columns 10 and 11. Net seepage for the year was 6.64 inches from the lake.

The items of inflow and of outflow for Lake Helene were determined independently. Computed values of change in volume (column 16) are the algebraic sums of the items of inflow and items of outflow for each month. These values compare closely with the observed values of change in storage shown in column 17.

Average annual lake evaporation in this part of central Florida for a 10-year period (1946-55) has been estimated to be about 49 inches (Kohler and others, 1959, pl. 2). Evaporation losses from Lake Helene for 1962 exceeded Kohler's estimate, based on a 10-year average, by about 4 inches. Records from several evaporation pan stations show that evaporation amounts are generally higher during dry years. Thus, the measured evaporation from Lake Helene during 1962, a dry year, may be higher than for an average year.

COMPARISON OF EASTERN AND WESTERN BASINS

Geology and topography, the two predominant factors affecting the water budget of the Green Swamp area, are somewhat different in the eastern and in the western parts of the area. The effects of these factors on the components of the water budgets have been determined by the selection of representative basins in each part for defining the budget equation.

The drainage basins east of State Highway 33 are interconnected by swamp channels (see fig. 5) and flood runoff from each basin may not be representative of that originating within the basin. However, the sum of the discharges measured at Big Creek at station 3, Little Creek at station 5, and Withlacoochee River at station 36 represents approximately the natural streamflow from the combined drainage basin of 208 square miles. Small amounts of water may be exchanged with other basins at interconnecting points designated as C-4, C-5, C-6, and C-7 in figure 5. The amount and duration of flow through these openings are considered to be insignificant in comparison with the total amounts measured at the three gaging stations. In the following analysis of the water

TABLE 12. Monthly water budget for Lake Helene near Polk City, 1962

Month 1962	Lake stage at beginning of month	Average surface area (acres)	Change in stage during month		Items of inflow: Precipitation (P)		Items of inflow: Runoff from land (R)		Items of inflow: Seepage (Se)		Items of outflow: Evaporation (E)		Items of outflow: Pumpage (Pu)		Change in volume (ΔV)	
			(ft)	(in)	(in)	(ac-ft)	(in)	(ac-ft)	(in)	(ac-ft)	(in)	(ac-ft)	(in)	(ac-ft)	Computed (ac-ft)	Observed (ac-ft)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Jan.	141.464	56.2	−0.182	−2.18	1.28	5.99	0.11	0.52	−0.93	−4.36	2.83	13.25			−11.1	−10.2
Feb.	141.282	55.6	− .378	−4.54	.34	1.58			−1.68	−7.78	2.98	13.81			−20.0	−21.0
Mar.	140.904	54.7	− .359	−4.31	3.48	15.86			−2.17	−9.89	5.61	25.57	0.22	1.00	−20.6	−19.6
Apr.	140.545	53.8	− .435	5.22	1.69	7.58			− .90	−4.04	5.46	24.48			−20.9	−23.4
May	140.110	53.3	+ .070	+ .84	7.29	32.38	1.38	6.13	−2.17	−9.64	5.59	24.83			+ 4.0	+ 3.7
June	140.180	53.6	+ .160	+1.92	6.67	29.79	.44	1.97	− .30	−1.34	4.48	20.01	.50	2.23	+ 8.2	+ 8.6
July	140.340	53.7	− .088	−1.06	5.75	25.73	.36	1.61	− .31	−1.39	5.69	25.46	1.34	6.00	− 5.5	− 4.7
Aug.	140.252	53.9	+ .308	+3.70	6.52	29.29	.98	4.40	+ .62	+2.78	4.44	19.94			+16.5	+16.6
Sept.	140.560	54.2	− .062	− .74	2.99	13.50	.06	.27	+ .90	+4.06	4.97	22.45			− 4.6	− 3.4
Oct.	140.498	53.8	− .332	−3.98	1.98	8.88	.27	1.21	− .31	−1.39	4.96	22.24	1.01	4.53	−18.1	−17.9
Nov.	140.166	53.0	− .286	−3.43	1.40	6.18	.19	.84	+ .30	+1.32	3.62	15.99	1.65	7.20	−14.9	−15.2
Dec.	139.880	52.2	− .648	−7.78	.24	1.04			+ .31	+1.35	2.47	10.74	5.76	25.06	−33.4	−33.8
Jan.	139.232															
Year					39.63	177.80	3.79	16.95	−6.64	−30.32	53.10	238.82	10.48	46.11	−120.4	−120.3

Computed change in volume = Precipitation + runoff + seepage − evaporation − pumpage.
Observed change in volume = change in stage during month X average surface area.

budget the combined basins east of State Highway 33 are referred to as eastern basins.

Runoff of the Little Withlacoochee River at Rerdell (station 43) is representative of the natural drainage in the western part of the Green Swamp area. Streamflow at the gaging station is derived from rainfall on the Little Withlacoochee River basin. The drainage area at station 43 is 160 square miles.

Water budget analyses were made for the eastern and western basins. Figure 52 shows the daily streamflow from these basins for the calendar years 1959-61. Streamflows, ground-water levels, and lake levels were nearly the same at the beginning and end of the year both in 1959 and 1960. Although these were the 2 wettest years of at least 60 years of record in central Florida, the indicated year-end storage changes were small and insignificant.

The year 1961 was one of the driest of record, and the annual runoff was low. Stream discharges were less and water levels, as indicated at representative ground-water observation wells and lake gages, were generally 1 to 3 feet lower at the end of 1961 than at the beginning. The surface runoff from the eastern basins in 1961 was 1.7 inches and that from the Little Withlacoochee River basin was 0.8 inch.

Ground-water outflow from the Floridan aquifer in the eastern and western basins was computed using the piezometric maps (figs. 35 and 36). The piezometric surfaces shown by the map for November 1959 (fig. 35) and the map for May 1962 (fig. 36) represent the flow conditions and the probable range in the rates of ground-water movement during wet and dry periods, respectively. The piezometric surface representing flow conditions for the year 1961 was assumed to be the average between that shown by maps for November 1959 and May 1962.

The western part of the Green Swamp area, as represented by the Little Withlacoochee River Basin received more rainfall each of the 3 years than did the eastern part of the area. Runoff from the eastern basins was almost as much as that from the Little Withlacoochee River basin in 1959 and 1960 even though the rainfall was 3.4 inches less in 1959 and 5.6 inches less in 1960. In 1961, a dry year, 0.9 inch more runoff occurred from the eastern basins than that from the Little Withlacoochee River basin although the yearly rainfall was 0.9 inch less.

Where and when the ground-water and surface-water divides coincide, some ground water from the nonartesian aquifer discharges from a basin as the base flow of the stream draining the basin. The divides do not coincide along the eastern boundary of the Green Swamp area because little or no water reaches the water table beneath the ridge. During dry periods, the water-table divide is located about 3 miles west of U. S. Highway 27, and nonartesian ground water moves laterally beneath the Lake Wales Ridge from the St. Johns River basin to the Kissimmee River basin. During seasonally wet periods, however, there is sufficient downward seepage through the ridge sediments to build up a temporary ground-water divide beneath the Lake Wales Ridge. This low wet-season divide recedes rapidly and the hydraulic gradient is resumed from the Green Swamp eastward to the chain of lakes, swamps, and streams which lie at the base of the eastern side of the Lake Wales Ridge. Ground water moves eastward in the nonartesian aquifer beneath the ridge along a 25-mile stretch from Haines City almost to Clermont. Data from wells drilled on each side of the ridge indicate that the nonartesian aquifer is about 100 feet thick. Hydraulic gradients to the east in the nonartesian aquifer, measured across the ridge at 10 locations, averaged 6.6 feet per mile. The coefficient of permeability of the nonartesian aquifer beneath the ridge probably ranges from 20 to 180 gpd/ft^2 on the basis of data shown in table 8. Using an assumed coefficient of 200 gpd ft.^{2}, the computed ground-water discharge from the nonartesian aquifer in the eastern area was about 5 cfs in 1961. This discharge from the 208 square-mile area is equivalent to 0.3 inch, an insignificant budget factor.

The ground-water outflow from the basins through the Floridan aquifer was computed as follows: (1) the drainage basin map (fig. 5) was overlain by the piezometric maps and streamlines were drawn to intersect and subdivide the boundary of each selected basin into numerous flow sections, shown in figure 53; (2) the hydraulic gradient (I), computed from the map, was multiplied by the length of the flow section, also scaled from the map, to obtain a flow factor for each flow section; (3) the discharge through each section was computed by multiplying the flow factor by the coefficient of transmissibility; (4) the sum of discharges through all flow sections around the boundary represents the net ground-water discharge from the basin. The total discharge was computed in units of million gallons per day (mgd) and converted to cubic feet per second (cfs); (5) ground-water discharge from a drainage basin was expressed in terms of outflow in inches for the basin so that it could be compared readily with rainfall and surface runoff.

The net ground-water outflow (U) thus computed from the Floridan aquifer for the eastern and western basins for November 1959 and May 1962 are presented in table 13. About 80 percent of the outflow from the western area originated from rainfall within the basin; the remaining 20 percent was inflow from the eastern basin. All outflow from the eastern area originated from rainfall within the basin. More than half of the total amount of ground water leaving the eastern basin flows to the Kissimmee River basin. The mean annual ground-water outflows from the eastern and western basins for the years 1959 and 1960 are assumed to be the same as those shown in table 13 for November 1959. The mean annual values for 1961 are assumed to be averages between the values for the two periods in table 13. Mean annual ground-water outflows thus computed for the 3 years are summarized in table 14.

Annual changes in the amount of ground water in storage in the nonartesian aquifer were determined for the period 1959-61. The net change in storage for the years 1959 and 1960 is negligible. However, the net loss in water from storage during 1961 amounted to about 7.4 inches in the eastern basin and about 2 inches in the western basin. These storage losses add to precipitation as a source of supply in the water-budget equation.

Coefficients of storage of the artesian Floridan aquifer are small (table 10). Therefore, changes in ground-water storage during the period 1959-60 were insignificant quantities. During 1961, the net decrease of the piezometric surface was about 2 feet, which is equivalent to a loss of about 0.2 inch of water from the basins. This is an insignificant budget factor. Thus, change in storage shown in table 14 was computed for only the nonartesian aquifer.

Comparative results of the annual water-budget for the eastern and western basins are summarized in table 14.

OUTFLOW FROM GREEN SWAMP AREA

The total surface runoff from 818 square miles, which includes most (94 percent) of the Green Swamp area, was measured at each of the five major outlets. Listed in table 15 are the mean monthly discharges determined at each of these outlets from the beginning of the investigation in July 1958 to June 1962.

Table 15 shows the distribution of total discharge from month to month as well as that from the individual streams draining from the area. The effects of wet and dry years on the amount and

TABLE 13. Ground-water outflow from the Floridan aquifer for eastern and western basins

Basin	Basin Area (Sq mi)	Coefficient of transmissibility (gpd/ft)	Ground-water outflow, November 1959			[b]Ground-water outflow, May 1962		
			(mgd)	(cfs)	[a]Inches per year	(mgd)	(cfs)	[a]Inches per year
Eastern	208	300,000	49.9	77.2	5.0	51.1	79.1	5.2
Western	160	500,000	21.2	32.8	2.8	25.8	39.9	3.4

[a]Assuming computed outflow is mean annual discharge.
[b]Increased outflow during dry period due to increased pumping near the boundaries.

TABLE 14. Comparison of budget factors for eastern and western basins.

Year	Eastern Basins (Big Creek, Little Creek and Upper Withlachoochee River, 208 sq. mi.)					Western Basin (Little Withlacoochee River, 160 sq. mi.)				
	Items of supply (inches)		Items of disposal (inches)			Items of supply (inches)		Items of disposal (inches)		
	Precipitation (P)	Change in storage (ΔS)	Runoff by streamflow (R)	[a]Ground-water outflow (U)	Evapotranspiration (ET)	Precipitation (P)	Change in storage (ΔS)	Runoff by streamflow (R)	[a]Ground-water outflow (U)	Evapotranspiration (ET)
1959	71.8	*	27.3	5.0	39.5	75.2	*	29.0	2.8	43.4
1960	69.4	*	27.9	5.0	36.5	75.0	*	27.5	2.8	44.7
1961	38.2	−7.4	1.7	5.1	38.8	39.1	−2.0	.8	3.1	37.2
3-year average	59.8	−2.5	19.0	5.0	38.3	63.1	− .7	19.1	2.9	41.8

Note.—$ET = P - \Delta S - R - U$

*Negligible

[a]Ground-water outflow for 1959 and 1960 assumed to be same as that for November 1959 and that for 1961 assumed to be the average for the two periods (table 13).

TABLE 15. Surface-water outflow from Green Swamp area, July 1958 to June 1962

Month	Mean discharge in cubic feet per second						Cfs per sq. mile	Runoff in inches
	Sta. No. 8 Big Creek near Clermont (Drainage area, 68 sq. mi.	Sta. No. 5, 6, Little Creek near Clermont (Drainage area, 10 sq. mi.	Sta. No. 30 Withlacoochee-Hillsborough overflow near Richland ----	Sta. No. 42 Withlacoochee River at Trilby Drainage area, 580 sq. mi.	Sta. No. 43 Little Withlacoochee River at Rerdell (Drainage area, 160 sq. mi.)	Total of all outlets (Drainage area, 818 sq. mi.)		
1958								
July	....	----	....	173	----	----	----	—
August	4.1	----	0	227	114	----	----	—
September	6.9	----	0	76.5	23.9	----	----	—
October	20.7	----	0	55.1	12.5	----	----	—
November	33.2	----	0	98.9	35.4	----	----	—
December	11.8	----	*10	75.3	21.1	----	----	—
1959								
January	62.9	*50	*90	600	182	984.9	1.20	1.38
February	81.6	*15	*4	384	99.9	534.5	.653	.68
March	128	*115	*350	1,457	760	2,810	3.44	3.97
April	168	*105	*250	1,742	459	2,724	3.33	3.72
May	72.2	*40	*30	790	122	1,054.2	1.29	1.49
June	63.8	*65	*220	915	178	1,441.8	1.76	1.96
July	205	*90	*270	1,921	488	2,974	3.64	4.20
August	152	*75	*160	1,461	622	2,470	3.01	3.47
September	133	*60	*210	1,942	701	3,046	3.72	4.15
October	152	*45	*100	1,409	308	2,014	2.46	2.84
November	112	*25	*20	890	117	1,164	1.42	1.58
December	58.6	*5	0	322	41.3	426.9	.522	.60
Year	112	*58	*144	1,157	342	1,804	2.21	30.04
Percent of total	6.2	3.2	7.9	63.8	18.9	100		

1960								
January	48.5	*3	0	258	28.5	333	.407	.47
February	58.7	*10	*5	332	99.8	500.5	.612	.66
March	268	*210	*490	3,049	1,045	5,062	6.19	7.14
April	200	*75	*70	1,785	408	2,538	3.10	3.46
May	62.3	*7	.1	403	51.2	523.6	.640	.74
June	37.3	6.5	0	212	39.6	295.4	.361	.40
July	54.5	32.2	104	724	186	1,100.7	1.35	1.56
August	190	53.6	372	2,777	695	4,087.6	5.00	5.76
September	418	141	521	2,322	707	4,104	5.02	5.60
October	238	56.4	177	1,941	488	2,900.4	3.55	4.09
November	97.3	12.4	1.8	438	81.5	631.0	.771	.86
December	44.4	2.9	0	205	29.1	281.4	.344	.40
Year	142	51	146	1,209	324	1,868	2.28	31.14
Percent of total	7.6	2.7	7.8	64.6	17.3	100		
1961								
January	35.5	2.9	0	190	27.5	264.9	.324	.37
February	47.1	9.6	.5	245	60.6	362.8	.444	.46
March	28.6	2.7	0	158	15.0	204.3	.250	.29
April	7.5	.8	0	123	1.8	133.1	.163	.18
May	.4	0	0	83.7	.4	84.5	.103	.12
June	1.7	0	0	63.8	.1	65.6	.080	.09
July	2.5	0	0	71.5	.6	74.6	.091	.10
August	6.8	0	1.8	106	1.8	116.4	.142	.16
September	10.1	0	1.5	217	4.5	233.1	.285	.32
October	2.4	0	0	42.9	.2	45.5	.056	.06
November	3.2	0	0	34.5	.5	38.2	.047	.05
December	2.8	0	0	41.8	.5	45.1	.055	.06
Year	12.2	1.3	.3	115	9.1	139	.170	2.26
Percent of total	8.9	.9	.2	83.4	6.6	100		
1962								
January	4.1	0	0	83.2	1.6	88.9	.109	.13
February	2.1	0	0	70.9	2.0	75.0	.092	.10
March	3.6	.1	0	53.0	.9	57.6	.070	.08
April	1.2	0	0	42.3	.4	43.9	.054	.06
May	.1	0	0	55.5	0	55.6	.068	.08
June	.2	0	8.4	135	.4	144.0	.176	.20

*Estimated on basis of discharge measurements at monthly intervals and records for other stations.

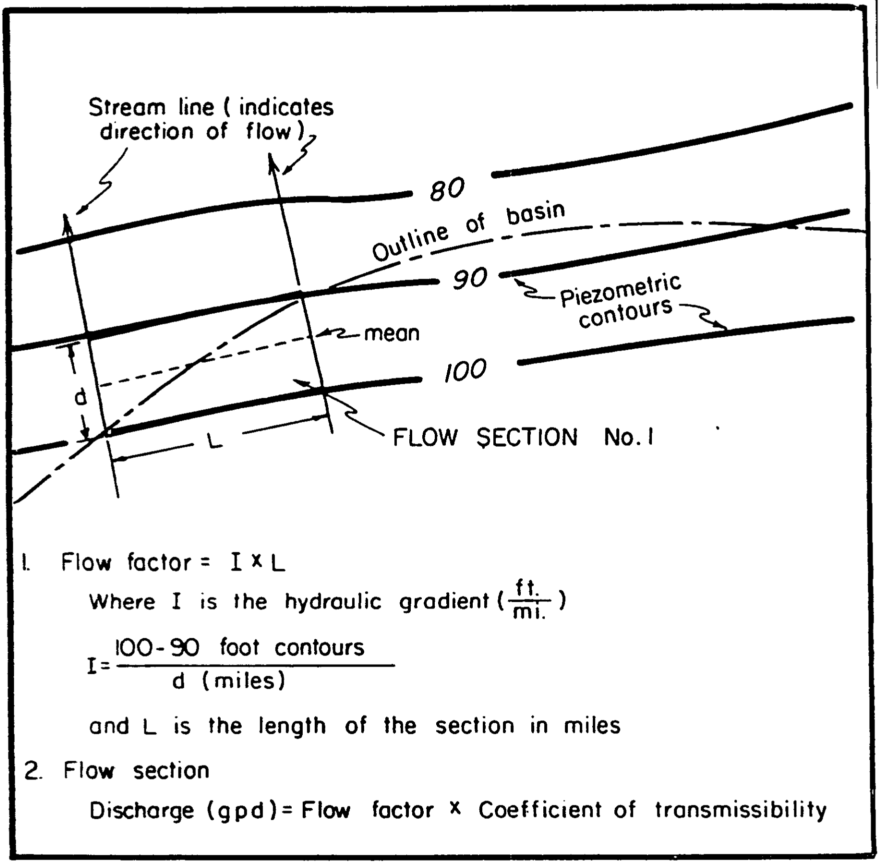


Figure 53. Sketch showing analysis of a flow section.

distribution of runoff from the area are shown in this table. The years 1959 and 1960 were the wettest of record and 1961 and 1962 were the driest.

The discharges given in table 15 indicate that Little Creek and Withlacoochee-Hillsborough overflow carry significant amounts of water from the area only in wet years. During 1961, Little Creek carried only 0.9 percent and the Withlacoochee-Hillsborough overflow carried only 0.2 percent of the total surface outflow from the area. Both channels were dry during most months in 1961 and 1962.

Ground-water outflow (U) from the Polk high was also computed using the flow net method of analysis of the piezometric surfaces of November 1959 (fig. 35) and May 1962 (fig. 36). These computations exclude the ground-water inflow from the Pasco high to the Green Swamp area in the vicinity of Dade City.

Outflows from each major basin were computed using ground-water areas enclosed by the divides as shown in figure 34. The distribution of the outflows from the Polk high to the major drainage basins is shown in table 16.

Most of the natural outflow is contributed to the Kissimmee and Withlacoochee River basins. Increased pumping for mining, irrigation, and municipal supplies in the southern part of the area (from Lakeland to Haines City) during the dry period caused about 50 percent increase in outflow to the Peace and Alafia River basins. Significant changes in outflow in the dry period also were experienced in the Withlacoochee and St. Johns River basins. The decrease in outflow to the Kissimmee River basin and the corresponding increase to the Peace River Basin were caused by slight shifting of the ground-water divides. The ground-water outflow in 1959 is considered to be more representative of natural outflow.

Net ground-water outflow (U) from the Green Swamp area was computed using the same method as used for the eastern and western areas. The total outflow via the nonartesian aquifer was determined to be an insignificant quantity (0.08 inch per year). The total outflow via the Floridan aquifer was computed along the boundary of the 870 square-mile area.

The net ground-water outflow from the Floridan aquifer during November 1959 and May 1962, adjusted to equivalent amounts of runoff in inches per year, are presented in table 17. The estimated mean annual ground-water outflows interpolated for 1959, 1960, and 1961, on the basis of yearly totals in table 17, are presented in table 18.

The net change in ground-water storage in both the nonartesian and Floridan aquifers for 1959 and 1960 are considered to be negligible. However, water levels in both aquifers declined significantly in 1961. The average net decline of water levels in the nonartesian aquifer in 1961 was equivalent to about 4.3 inches of water over the Green Swamp area. The average net decline of the piezometric surface of the Floridan aquifer in 1961 was equivalent to an insignificant change in storage (0.2 to 0.3 inch) because of artesian storage coefficients.

Rainfall, surface-water outflow (table 15), ground-water outflow (table 17), and changes in ground-water storage are combined in

TABLE 16. Ground-water outflow from the Polk piezometric high in Green Swamp area

Basin receiving ground-water drainage from Green Swamp area	Ground-water contributing area (sq. mi.)	Coefficient of transmissibility (gpd/ft)	Outflow from the Floridan aquifer November 1959, a period of high water levels			[a]Outflow from the Floridan aquifer, May 1962, a period of low water levels		
			(mgd)	(cfs)	Percent of total	(mgd)	(cfs)	Percent of total
St. Johns River (Palatlakaha Creek)	100	300,000	13.5	20.9	12	24.7	38.2	15
Kissimmee River	75	300,000	31.6	48.9	27	25.7	39.7	15
Peace River	60	600,000	18.1	28.0	15	39.1	60.5	23
Alafia River	5	600,000	3.0	4.6	3	15.1	23.3	9
Hillsborough River	230	600,000	12.7	19.6	11	9.8	15.2	6
Withlacoochee River (excluding 45 sq. mi. area in vicinity of Dade City)	355	500,000	38.0	58.8	32	52.6	81.4	32
Total	825		116.9	180.8	100	167.0	258.3	100

Assuming that the computed outflow is the mean annual discharge:
Ground-water for a wet year would be 3.0 inches.
Ground-water outflow for a dry year would be 4.2 inches.
[a]Increased outflow during dry period due to increased pumping near the boundaries.

TABLE 17. Ground-water outflow from Green Swamp area

Basin receiving ground-water drainage from Green Swamp area	Ground-water contributing area (sq mi)	Coefficient of transmissibility (gpd/ft)	Outflow from the Floridan aquifer, November 1959, a period of high water levels			[b]Outflow from the Floridan aquifer, May 1962 a period of low water levels		
			(mgd)	(cfs)	[a]Inches per year	(mgd)	(cfs)	[a]Inches per year
St. Johns River (Palatlakaha Creek)	100	300,000	13.5	20.9	2.8	24.7	38.2	5.2
Kissimmee River	75	300,000	31.6	48.9	8.8	25.7	39.8	7.2
Peace River	60	600,000	18.1	28.0	6.3	39.1	60.5	13.7
Alafia River	5	600,000	3.0	4.6	12.5	15.1	23.3	62.2
Hillsborough River	230	600,000	12.7	19.6	1.2	9.8	15.2	.9
Withlacoochee River	400	(500,000 [c](1,200,000	[d]−6.2	[d]−9.6	[d]−.3	[d]−5.1	[d]−7.9	[d]−.3
Total	870		72.7	112.4	1.8	109.3	169.1	2.6

[a]Assuming computed outflow is mean annual discharge.
[b]Increased outflow during dry period due to increased pumping near the boundaries.
[c]Transmissibility of 500,000 gpd/ft used east of Withlacoochee River and 1,200,000 used west.
[d]Net minus outflow is result of greater inflow from Pasco high.

the water-budget analysis of the Green Swamp area for the period 1959-61. Yearly summaries of the budget factors are presented in table 18.

Surface runoff is directly dependent on rainfall and varies through a wide range as shown by comparison of the wet years of 1959 and 1960 with the dry year of 1961. On the other hand, the ground-water outflow from the area varied little from the wet to dry years. Though the difference is small, the ground-water outflow was more during the dry year than during either wet year. The increase in ground-water outflow during 1961 was caused primarily by increased pumpage from the Floridan aquifer in the area along the southern and western boundaries of the Green Swamp area. The net loss in ground-water storage during 1961 also was greatest along the boundaries reflecting the drawdown effects caused by the pumpage.

The 3-year average evapotranspiration loss was 36.8 inches from the Green Swamp area as shown in table 18. Evaporation from Lake Helene in 1962 amounted to 53.1 inches (table 12). Comparison of these values indicates that exposure of the water surface by impoundment in reservoirs would increase the evaporation loss by about 16 inches per year per unit area in the Green Swamp. Other studies indicate that the increased evaporation loss would be less than 16 inches. Estimates by Kohler and others (1959) indicate that the average annual lake evaporation in central Florida is 49 inches. From table 14 the evapotranspiration loss for two representative basins averaged about 40 inches for the 3-year period. Based

TABLE 18. Summary of water-budget factors in Green Swamp area, 1959-61

Year	Items of supply (inches)		Items of disposal (inches)		
	Precipitation (P)	Change in storage (ΔS)	Runoff by Streamflow (R)	[a]Ground-water outflow (U)	Evapotranspiration (ET))
1959	70.9	*	30.0	1.8	39.1
1960	69.5	*	31.1	1.8	36.6
1961	34.7	—4.3	2.3	2.2	34.5
3-year average	58.4	—1.4	21.1	1.9	36.8

Note. $ET = P - \Delta S - R - U$

*Negligible

[a]Ground-water outflow for 1959 and 1960 assumed to be same as for November 1959 and that for 1961 assumed to be the average for two periods (table 17).

on these values the increased evaporation loss would be about 9 inches.

EVALUATION OF PROPOSED PLAN OF WATER CONTROL

A comprehensive plan of improvements proposed by the U. S. Corps of Engineers (1961) provides for diversion canals and flood-control conservation reservoirs in the Green Swamp area, and in the upper Oklawaha, Peace, Hillsborough, and Withlacoochee River basins, shown in figure 54. Green Swamp Reservoir, largest of those included in the plan of improvement, would be located in the Withlocoochee River basin near the center of Green Swamp. The proposed Green Swamp Reservoir would provide for a total of 460,000 acre-feet of storage (134,000 acre-feet at conservation pool level of 100 feet above msl and 326,000 acre-feet above the conservation pool for flood control at level of 107 feet above msl). The surface area of the flood-control pool would be about 61,000 acres.

The Southeastern Conservation Area (Johnson, 1961), also designated the Lowery-Mattie Conservation Area (Corps of Engineers, 1961), would be located in the southeast corner of the Green Swamp area. This proposed water-conservation area would cover about 46 square miles in three pools and provide for maximum storage of about 72,000 acre-feet at pool levels ranging from 133.0 to 134.5 feet above msl.

Also within the Green Swamp area and included in the comprehensive plan of improvement are the Little Withlacoochee Reservoir, the Upper Hillsborough Reservoir, Big Creek upper and lower diversion canals, and Lowery Canal.

REDUCTION OF FLOOD PEAKS IN THE HILLSBOROUGH RIVER

The annual runoff to the Hillsborough River basin through the Withlacoochee-Hillsborough overflow was 104,000 acre-feet for 1959 and 106,000 acre-feet in 1960. The flood-control pool of the proposed Green Swamp Reservoir is capable of impounding the total annual runoff contributed by the Green Swamp to the Hillsborough River basin. For the purpose of computing the effectiveness of the proposed Green Swamp Reservoir in reducing flood peaks of the Hillsborough River at Tampa, the flood of March 1960 has been taken as a typical case. The maximum extent that the total Green Swamp area could reduce floods in the Hillsborough River would be by the impoundment of all the discharge that drains through the Withlacoochee-Hillsborough overflow channel at station 39.

Hydrographs of mean daily discharge for Withlacoochee-Hillsborough overflow, Hillsborough River near Zephyrhills, and Hillsborough River near Tampa for the flood of March 1960 are shown in figure 55. The hydrographs were plotted using mean daily discharges at the gaging stations. The discharge at the Tampa station was slightly regulated by the waterworks dam but the effect is not apparent on the mean daily values of discharge. The peak discharge at the Zephyrhills station, which is 2 miles downstream from Blackwater Creek, occurred on March 18, the same day as the peak from Blackwater Creek. The peak discharge at Withlacoochee-Hillsborough overflow occurred on March 19 while

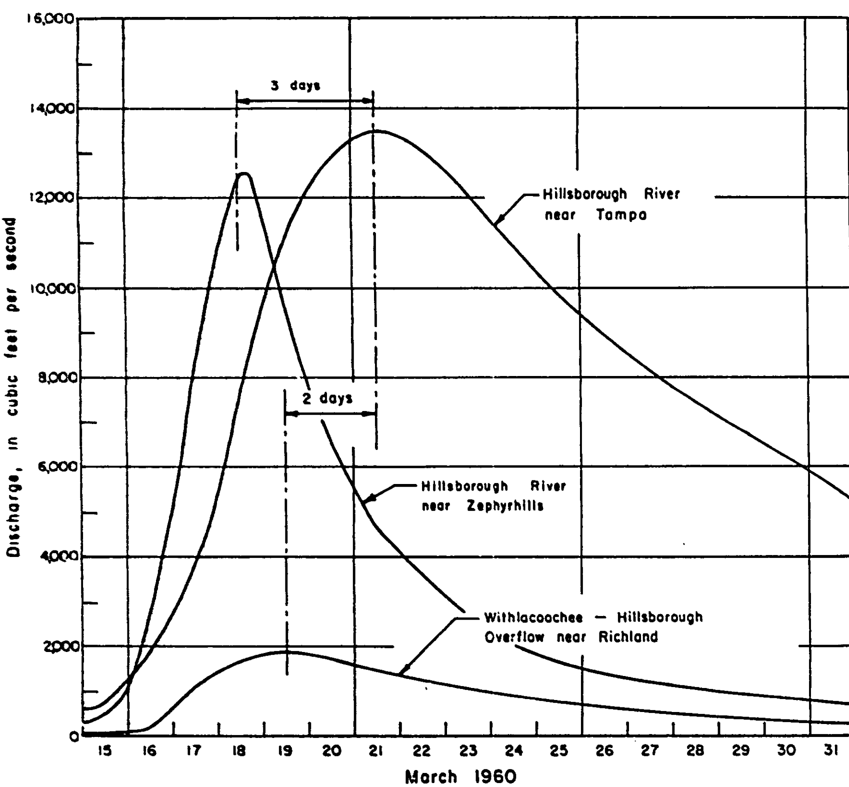


Figure 55. Hydrographs of mean daily discharge for three Hillsborough River gaging stations, flood of March 1960.

the peak for Hillsborough River near Tampa was on March 21. The flood peak at the Tampa station occurred about two days later than that at the Withlacoochee-Hillsborough overflow and about 3 days later than that at the Zephyrhills station.

The gaging station near Tampa is in the upper pool at the waterworks dam. In March 1960, the stage of the upper pool was regulated between narrow limits by tainter gates and flashboards. A stage-discharge relation was defined at 22nd Street, 0.5 mile downstream from the dam, by measurements made during the floods of 1959 and 1960. Mean daily discharges for the gaging station at the dam were used with the stage-discharge relation to compute the stage hydrograph for 22nd Street as shown in figure 56.

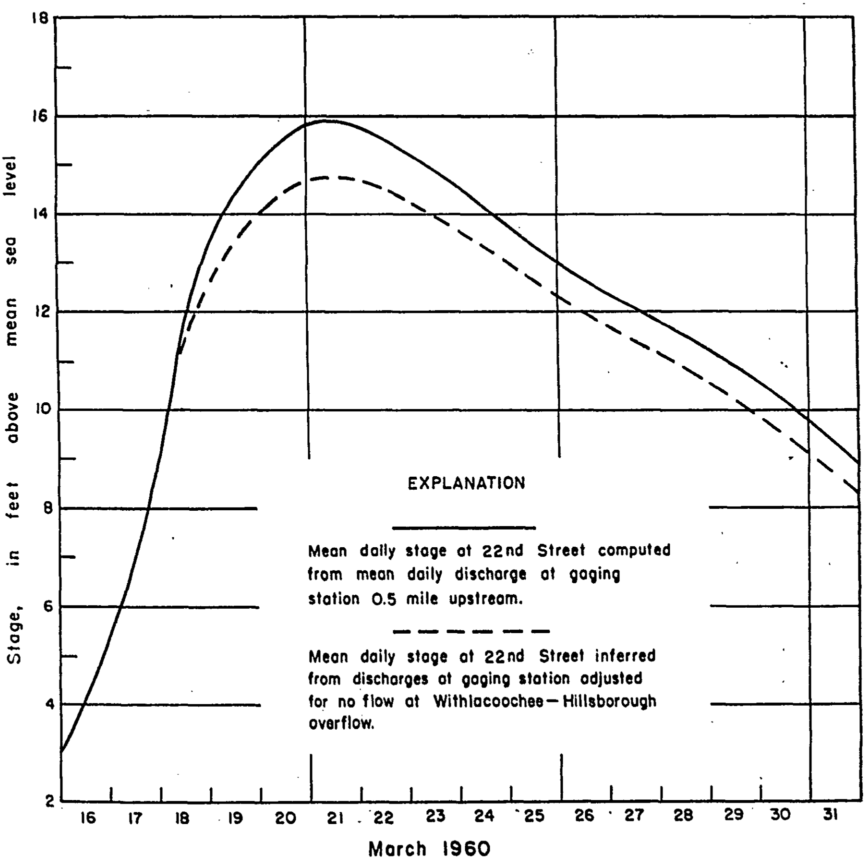


Figure 56. Hydrographs of computed mean daily stage of Hillsborough River at 22nd Street, Tampa, flood of March 1960.

Mean daily discharges for Withlacoochee-Hillsborough overflow were subtracted from the mean daily discharges for the Tampa station two days later to synthesize the effective discharge that would have occurred at the Tampa station if all the flow from Green Swamp to the Hillsborough River had been impounded. This adjusted discharge was used to compute the inferred stage hydrograph for 22nd Street shown by the broken line in figure 56. The difference between the two hydrographs on March 21 was 1.2 feet which indicates the maximum reduction in crest stage at 22nd Street that would have occurred if the total flow from Green Swamp to the Hillsborough River had been impounded. Similar computations of the theoretical flood reduction at 22nd Street by complete impoundment of the flow from Green Swamp were made for the September 1960 flood. This flood crest would have been reduced by about 1 foot, approximately the same as that of the March flood.

Other reservoirs and channel changes proposed for the Hillsborough River basin (Corps of Engineers, 1961) would further reduce the flood peaks at Tampa.

REDUCTION OF FLOOD PEAKS IN THE WITHLACOOCHEE RIVER

The effect on the lower Withlacoochee River by storage of flood discharge in the proposed reservoirs in Green Swamp was also estimated on the basis of the March 1960 flood. Table A-1 of the Corps of Engineers Comprehensive Report (1961) shows that the total drainage area of the Withlacoochee River above Green Swamp Reservoir is 328 square miles, and that above the Upper Hillsborough Reservoir is 66 square miles or a total of 394 square miles above the Trilby gaging station. Figure 57 shows the relation between runoff in acre-feet and drainage area for the Withlacoochee River basin for the flood period March 16 to April 20, 1960. From this relation, the indicated flood runoff from a drainage area of 394 square miles was about 200,000 acre-feet during the March flood. The allocated flood storage capacity of Green Swamp Reservoir is 326,000 acre-feet. Assuming that the flood-control pool would be empty at the beginning of the flood period, the entire volume of runoff from the basin above the reservoir could be impounded for a flood greater than that of March 1960. This would be equivalent to reducing the effective drainage area for uncontrolled flood runoff above the Trilby gaging station to about 186 square miles (580

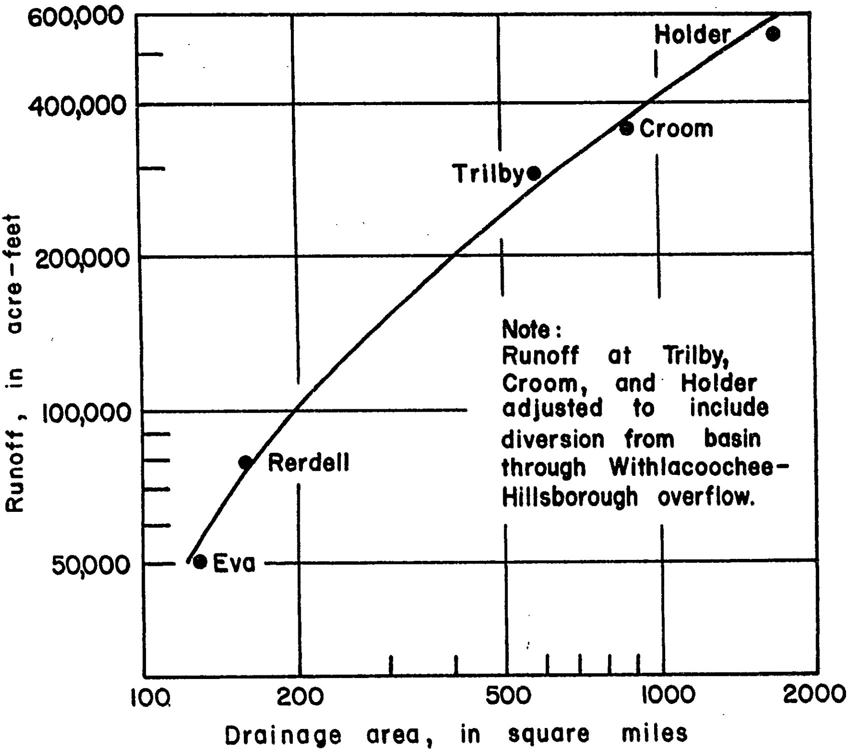


Figure 57. Relation between basin runoff and drainage area for Withlacoochee River, March 16 to April 20, 1960.

square miles at gaging station minus 394 square miles above the two reservoirs).

Peak discharges for the flood of March 1960 have been plotted against drainage areas at gaging stations in the Withlacoochee River basin as shown in figure 58. The peak discharge at Withlacoochee-Hillsborough overflow was 1,880 cfs. From the relation in figure 58, the drainage area that would produce a peak discharge of 1,880 cfs for the March flood would be 100 square miles. Effective drainage areas for the gaging stations downstream from Withlacooche-Hillsborough overflow have been computed by subtracting 100 square miles from the measured drainage areas of each. The curve shown by the broken line in figure 58 represents the theoretical relation of drainage areas to flood peaks that would have prevailed if no flood discharge had been diverted from the basin.

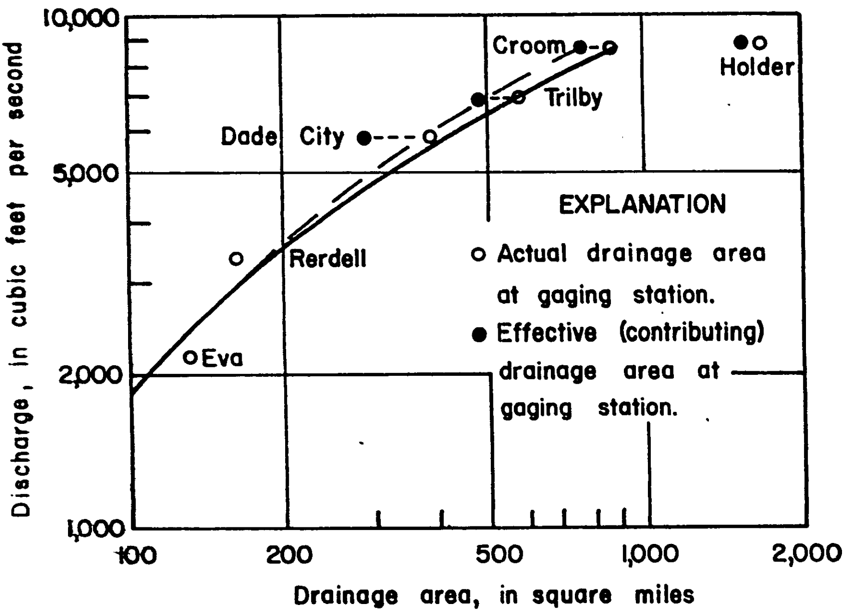


Figure 58. Relation between peak discharge and drainage area for Withlacoochee River, flood of March 1960.

From the curve represented by the broken line in figure 58, the peak discharge from a 186 square-mile drainage area would be 3,400 cfs. This discharge at the Trilby gaging station would occur at gage height 15.4 feet, which is 4.0 feet lower than the crest stage of March 1960.

Flood stages at the Croom station would be further reduced by storage in Little Withlacoochee Reservoir (drainage area, 86 square miles). The total reduction in crest stage for a flood equivalent to that of March 1960 would be 1.7 feet at this station.

The reduction in crest stage by flood storage in reservoirs proposed in Green Swamp would continue to decrease at points further downstream on the Withlacoochee River. At the crossing of State Highway 200 at the Holder station, reduction of crest stage by storage in Green Swamp would be small. However, the Jumper Creek Reservoir would provide additional storage for flood control in the lower Withlacoochee River basin.

EFFECTS OF WATER IMPOUNDMENT IN GREEN SWAMP RESERVOIR ON GROUND-WATER LEVELS

Comparison of figures 31 and 54 show that the proposed Green Swamp Reservoir is underlain at shallow depth by the Floridan aquifer. A reconnaissance of the area indicated that limestone of the aquifer crops out for about 6 miles along the north-south portion of the proposed levee. The head created by the reservoir will cause additional amounts of water to move through the aquifer beneath the levee.

The principal factors controlling the underseepage are the horizontal and vertical permeabilities of the materials beneath the reservoir and the percentage of the reservoir area immediately underlain by the Floridan aquifer.

Aquifer tests in adjacent areas indicate that the coefficient of transmissibility varies considerably from point to point. The coefficient of transmissibility in the reservoir area is estimated to range from 125,000 gpd/ft to 500,000 gpd/ft. Significant amounts of underseepage will probably occur along about 14 miles of the north-south portion of the proposed levee because the predominant direction of water movement is from the east to the west. Underseepage will be greatest in the channel of the Withlacoochee River because the channel is well incised into the aquifer.

The hydraulic gradients scaled from the piezometric maps (figs. 35 and 36) were used to compute the existing wet and dry period flow of ground water beneath the area of the proposed levee. During the wet period (1959), the average elevation of the piezometric surface beneath the 14-mile length of proposed levee was about 95 feet, the average hydraulic gradient across the proposed levee was about 2 feet per mile, and the estimated mean daily underflow ranged from about 5 to 20 cfs. During the dry period (1962), the average elevation of the piezometric surface beneath the 14-mile length of proposed levee was about 89 feet, the average hydraulic gradient across the proposed levee was about 2.6 feet per mile, and the estimated mean daily underflow ranged from about 10 to 30 cfs.

In order to estimate future underflow it was assumed that the amount of water that seeps into the limestone will raise the piezometric surface to the same level as that of the conservation pool (100 ft). If the impoundment occurred during a wet period, then the piezometric surface would rise from 95 to 100 feet, the gradient would increase from 2 to 7 feet per mile, and the estimated mean daily underflow would range from about 20 to 80 cfs. If the impoundment occurred during a dry period, then the piezometric surface would rise from 89 to 100 feet, the gradient would increase from 2.6 to 13.6 feet per mile, and the estimated mean daily underflow would range from about 40 to 150 cfs.

Seepage and evaporative losses from the shallow reservoir indicate that the amount of water that would be available for release during dry periods such as that in 1962 would probably be small. The position of the reservoir with respect to contributing recharge to the heavily pumped portions of the Floridan aquifer is poor. However, benefits derived from the reservoir would be increased base flow of the upper Withlacoochee and Hillsborough rivers and reduction of flood crests.

EFFECTS OF WATER IMPOUNDMENT IN SOUTHEASTERN CONSERVATION AREA ON GROUND-WATER LEVELS

The primary purpose of a plan for water impoundment in the Southeastern Conservation Area (Johnson, 1961), also designated the Lowery-Mattie Conservation Area (Corps of Engineers, 1961), is to maintain and to increase recharge to the Floridan aquifer. The three pools that would comprise the Southeastern Conservation Area proposed by Johnson would cover about 46 square miles, with pool levels ranging from 133 to 134.5 feet above msl. The pools would overlie an area of high piezometric levels in the Floridan aquifer. In this area, water normally seeps downward from the nonartesian aquifer through a bed of clay (aquiclude) into the underlying Floridan aquifer. Here, the water level in the nonartesian aquifer and in surface-water bodies are above the piezometric surface of the Floridan aquifer. The difference in levels is caused by relative differences in the permeabilities of the nonartesian aquifer, of the Floridan aquifer, and of the aquiclude. The rate of seepage through the aquiclude is directly proportional to the difference between the water levels; therefore, raising the water table or lowering the piezometric surface will increase the rate of seepage.

In order to evaluate the importance of the three conservation pools, a comparison was made of seepage rates during wet and dry periods in the vicinity of Lake Lowery with seepage rates that would occur had the pools been at the proposed levels. The average vertical permeability of the aquiclude was estimated and used as the basis of computations of seepage rates for existing hydraulic gradients and for future hydraulic gradients. The vertical permeability computed from the movement of 5 inches of water a year through the 15 feet of aquiclude with a head difference of 2 feet is about 0.003 gpd/ft^2.

During a wet period (November 1959), the average yearly seepage from the eastern part of the area was determined to be about 5 inches (table 14) when the level of Lake Lowery was about 134 feet and the piezometric surface was about 132 feet. During a dry period (May 1962), the indicated yearly seepage from Lake Lowery was about 21 inches when the level of Lake Lowery was about 128 feet and the piezometric surface was about 120 feet. If during May 1962 the water level in the Lowery pool had been maintained at about 133 feet, the resulting gradient (13 feet) would cause a yearly seepage rate of about 34 inches which is 60 percent greater than that computed for May 1962.

The piezometric surface will decline progressively in response to increased pumping in the populated and industrialized areas south of Green Swamp (see fig. 37). Therefore, maintaining high water levels in the southeastern part of the Green Swamp area will make additional water available for future recharge.

SIGNIFICANCE OF THE HYDROLOGY OF THE AREA

The Green Swamp area is unique because it is a headwaters area for five major rivers and for part of the Floridan aquifer. The proximity of the headwaters of the streams and their interconnections by swamps at relatively high elevation suggest that the area can be used effectively for flood control and water conservation. Because of the high piezometric surface, Stringfield (1936) and others have inferred that high rates of recharge for the Floridan aquifer occur on the Polk high in the Green Swamp area and that ground water flows outward in all directions from the area. In order to meet the demands of present and future water-use and for flood prevention, a water-management plan was proposed to utilize the Green Swamp area for impoundment of flood waters and for increasing the amount of recharge to the Floridan aquifer. Thus, the significance of the hydrology of this area in relation to central Florida has been appraised on the basis of the findings of this investigation.

In general, with other water-budget factors being equal, surface runoff would be low in areas where high rates of ground-water recharge occur. Therefore, comparison of streamflow from two areas, similar in other respects, would indicate the relative amount of water recharged to the aquifers.

Table 7 shows that the total surface runoff during July, August, and September 1960 from Pony Creek, a basin located on the Polk piezometric high, was about 6 inches more than that from Horse Creek, a basin located downslope from the Polk high, although the rainfall on the Pony Creek basin was about 7 inches less. This indicates a smaller ground-water storage capacity in the Pony Creek basin than in the Horse Creek basin. Table 14 shows that during the years 1959-61 surface runoff from the eastern basins, which include the Polk high, was nearly the same as that from the western basin although the rainfall was less. The conclusion derived from comparing the data shown in Table 14 is that the rate of ground-water recharge on the Polk high is about the same as that in an area downslope from the Polk high.

Ground-water outflow from the Green Swamp area is almost entirely via the Floridan aquifer. The net outflow over a significant period of time is approximately equivalent to the average amount of recharge to the aquifer during the period if there were no appreciable change in ground-water storage. Table 14 shows that the outflow is about 5 inches per year from the eastern part of the Green Swamp area and about 3 inches per year from the western part. Therefore, this infers that the eastern part contributes about 2 inches more recharge to the Floridan aquifer. The net ground-water outflow from the Polk piezometric high (table 16) was estimated to range from 181 to 258 cfs or about 3 to 4.2 inches per year. Part of the outflow discharges into streams and swamps in the western part of the Green Swamp area so that the net amount that leaves as ground-water outflow probably ranges from 112 to 169 cfs, or about 1.8 to 2.6 inches per year (table 17).

Mineral content and calcium carbonate saturation with respect to calcite in water in the Floridan aquifer implies that recharge is about the same in the Green Swamp area as in other parts of central Florida. The presence of low mineral content in water in the interior of central Florida and high mineral content in water toward the coasts (figs. 44 and 45) suggests a general movement of water from the interior to the coasts. A comparison of the degree (percentage) of calcium carbonate saturation of water with respect to calcite in the Floridan aquifer throughout central Florida shows that under-saturation occurs throughout much of central Florida (fig. 43). Hem (1961, p. C-15) states that the degree of saturation should be lowest in recharge areas, and should increase as water moves through the aquifer.

It would appear then that factors other than high recharge rates contribute to the causes of the Polk high. It can be inferred from geologic and hydrologic data that a relation exists between the water movement and structural deformation in the Green Swamp area. This is indicated at the surface by the parallel linearity of ridges and surface drainage systems, and in the subsurface by the presence of an anticline and related faults. Also of importance is the relation between structural deformation and subsequent solutional deformation indicated by the parallel linearity of sinkhole lakes.

High piezometric levels in the southeastern part of the Green Swamp area are believed to be the result of a relatively slow rate of ground-water outflow which is probably caused by sand-filled fractures, caverns, and sinkholes. These act as a natural grout which decreases the transmissibility of the aquifer. Although the coefficient of transmissibility of the Floridan aquifer is generally high, it is variable, ranging from about 200,000 to 1,200,000 gpd/ft (table 11). The lower value applies to the eastern part of the Green Swamp area where the piezometric high exists.

Flood-control and conservation reservoirs proposed for the Green Swamp area would provide a partial solution to the flood problems in the lower Hillsborough River and lower Withlacoochee River basins. Total impoundment in the Green Swamp area of a flood equal to that of March 1960 would reduce the flood crest of the Hillsborough River at Tampa by about 1 foot. Impoundment of the March 1960 flood in reservoirs proposed for the Green Swamp area would have reduced the flood crest of the Withlacoochee River at the Trilby gaging station by about 4 feet and at the Croom gaging station by about 1.7 feet. Reservoirs in the Green Swamp area would be less effective in reducing flood stages further downstream on the Withlacoochee River.

Impoundment of floodwaters in the Green Swamp reservoirs would probably have little effect on net ground-water outflow from the Green Swamp area but would increase base flows downstream from the reservoirs.

Impoundment of flood waters in the Southeastern Conservation Area would increase the rate of seepage to the Floridan aquifer. The rate of seepage would be more significant during dry periods when the piezometric surface is lowered by pumping in the developed areas south of the Green Swamp. Therefore, water storage in this area at the beginning of a dry period would become more important as the demand for water increases.

Further drainage of the area could change the proportional amounts of water disposed of by the various routes. The time of concentration of water in stream channels would be decreased. More water would be moved from the areas as streamflow. Water would remain on the land surface for shorter periods and therefore evapotranspiration would be decreased. Certainly if the water-table in the whole area were lowered, this would effectively lower the piezometric surface and decrease ground-water outflow from the area. However, at present, the central and western parts of the area are downgradient from the piezometric high and generally are poorly drained both on the surface and subsurface. The area is generally wet and runoff is high after intense rainfall because the aquifers are always nearly full and the rate of ground-water movement from the area is slow.

Although water management in the Green Swamp area would not be the sole solution to the water problems in central Florida, Green Swamp is hydrologically important and must be considered in any overall plan of water management.

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GLOSSARY

Anticline. An upfold or arch of rock strata, dipping in opposite directions from an axis.

Aquiclude. A formation which, although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring.

Aquifer. A formation, group of formations, or part of a formation that will yield water in usable amounts.

Artesian ground water. Water that is under pressure sufficient to cause it to rise above the top of the aquifer in which it occurs.

Base flow. The discharge entering stream channels from ground water.

Clastic. Pertaining to fragmental material derived from pre-existing rocks transported mechanically into its place of deposition, for example, sand and clay.

Coefficient of permeability. The rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot under a unit hydraulic gradient at a temperature of 60° F.

Coefficient of storage. The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In artesian aquifers it is related to the compressibility of the material comprising the aquifer and of the water. In non-artesian aquifers it is primarily related to gravity drainage and is approximately equal to specific yield.

Coefficient of transmissibility. The rate of flow of water, in gallons per day, at the prevailing water temperature through each vertical strip of the aquifer 1 foot wide having a height equal to the thickness of the aquifer and under a unit hydraulic gradient.

Color. The color of water is due only to materials in solution. Color is determined by comparison with standard colored disks that are calibrated in units according to the platinum-cobalt scale.

Confining bed. A bed which, because of its position and its impermeability or low permeability relative to that of the aquifer, gives the water in the aquifer either an artesian or subnormal head.

Confluence. The meeting or junction of two or more streams.

Diffluence. Flowing apart. A term used to describe a stream which branches in a downstream direction.

Direct surface runoff. The runoff entering stream channels promptly after rainfall.

Discharge. Flowing or issuing out. Also used to designate the volume of water flowing past a cross section of a stream in a unit of time.

Double-mass curve. A plot of the cumulative values of one variable versus the cumulative values of another.

Drainage area. The size of a drainage basin usually expressed in square miles.

Drainage basin. An area enclosed by a topographic divide such that direct surface runoff from precipitation normally would drain by gravity into the river basin.

Drainage divide. The boundary line, along a topographic ridge, separating two adjacent drainage basins.

Drainage system. A surface stream or a body of impounded surface water, together with all surface streams and bodies of impounded surface water that are tributary to it.

Effective precipitation. A weighted average of current and antecedent precipitation that is "effective" in correlating with runoff.

Evaporation. The process by which water becomes vapor at a temperature below the boiling point, including vaporization from free water surfaces and from land surfaces.

Evapotranspiration. Evaporation plus transpiration.

Fault. A fracture or fracture zone along which there has been displacement of rock material on the two sides relative to one another parallel to the fracture.

Ground water. That part of the subsurface water that is in the zone of saturation.

Hydraulic conveyance. The water-carrying capacity of a stream channel.

Hydraulic gradient. As applied to an aquifer, it is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction.

Hydrograph. A graph showing stage, flow, velocity, or other property of water with respect to time.

Infiltration. See seepage.

Instantaneous load. The quantity of dissolved material carried by a stream at the point and time indicated.

Marine. Of or belonging to or caused by the sea.

Mineral content. A summation of the individual values, in parts per million, of the determined dissolved chemical constituent in the water.

Nonartesian ground water. Water in an aquifer that is unconfined.

Parts per million (ppm). A unit weight of a chemical constituent dissolved in a million unit weights of water.

Percolation. The movement of water by gravity through the pores in a rock or soil, excluding the movement through large openings such as caverns.

pH. An index of the acidity of water. A value of 7 is neutral. Values above 7 indicate alkalinity—values below 7, acidity

Piezometric surface. The level to which water will rise in tightly cased wells that penetrate a given aquifer.

Potential natural water loss. The maximum water loss that could occur naturally in a basin with optimum or full moisture supply and native vegetation.

Recharge (of ground water). Intake. The processes by which water is absorbed and is added to the zone of saturation. Also used to designate the quantity of water that is added to the zone of saturation.

Retention. The part of storm rainfall which is intercepted, stored, or delayed, and thus fails to reach the concentration point by either surface or subsurface routes during the time period under consideration.

Runoff. That part of the precipitation that appears in surface streams, having reached the stream channel by either surface or subsurface routes.

Runoff in inches. The depth to which an area would be covered if all the runoff from it in a given period were uniformly distributed on its surfaces.

Seepage (infiltration). Percolation of water through the earth's crust, or through the walls of large openings in it, such as caves or artificial excavations.

Specific conductance. Specific conductance is the measure of the capacity of water to conduct an electric current. It varies with the concentration and degree of ionization of the different constituents in solution. It may be used to estimate the mineral content but does not indicate the nature of, or the relative amounts of, the various mineral constituents.

Specific yield. The ratio of the volume of water that will drain from the saturated material of the aquifer to the volume of the material, expressed in percent.

Streamflow. The actual discharge of surface streams. It includes runoff modified by artificial causes.

Surface water. Water that occurs above the surface of the ground.

Time of concentration. The time required for the water to flow from the farthest point on the watershed to a gaging station or to another specified point.

Transpiration. The process by which water vapor escapes from a living plant and enters the atmosphere.

Water loss. The difference between the average precipitation over a drainage basin and the runoff adjusted for changes in storage and for interbasin movement of ground water. The basic concept is that water loss is equal to evapotranspiration; that is, water that returns to the atmosphere and thus is no longer available for use in the area. However, as used in this report, the term applies to differences between measured inflow and outflow even where part of the difference may be seepage.

Zone of saturation. The zone in which the permeable rocks are saturated with water under pressure equal to or greater than atmospheric.

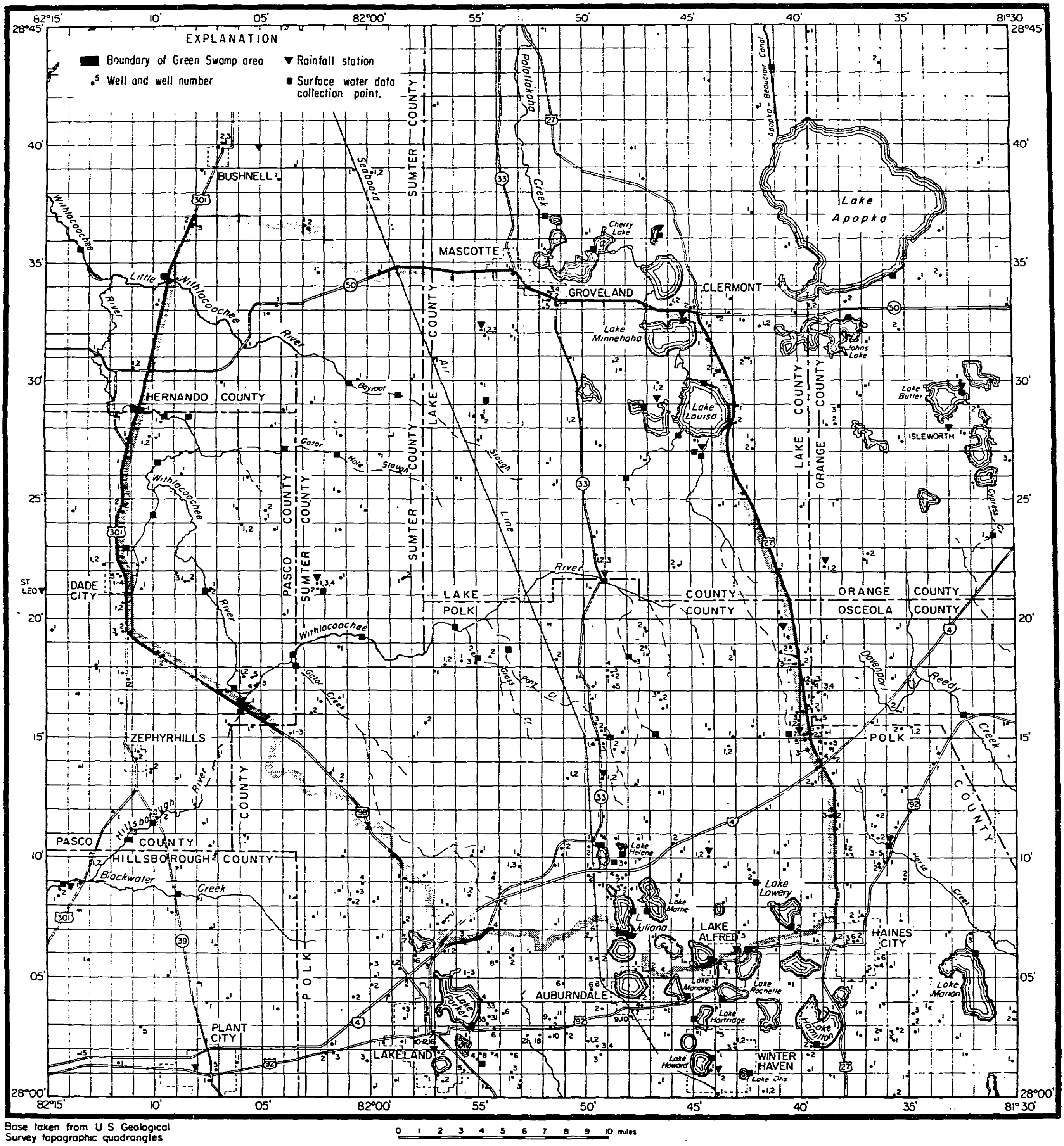

Figure 2. Map showing data-collection points in Green Swamp area.

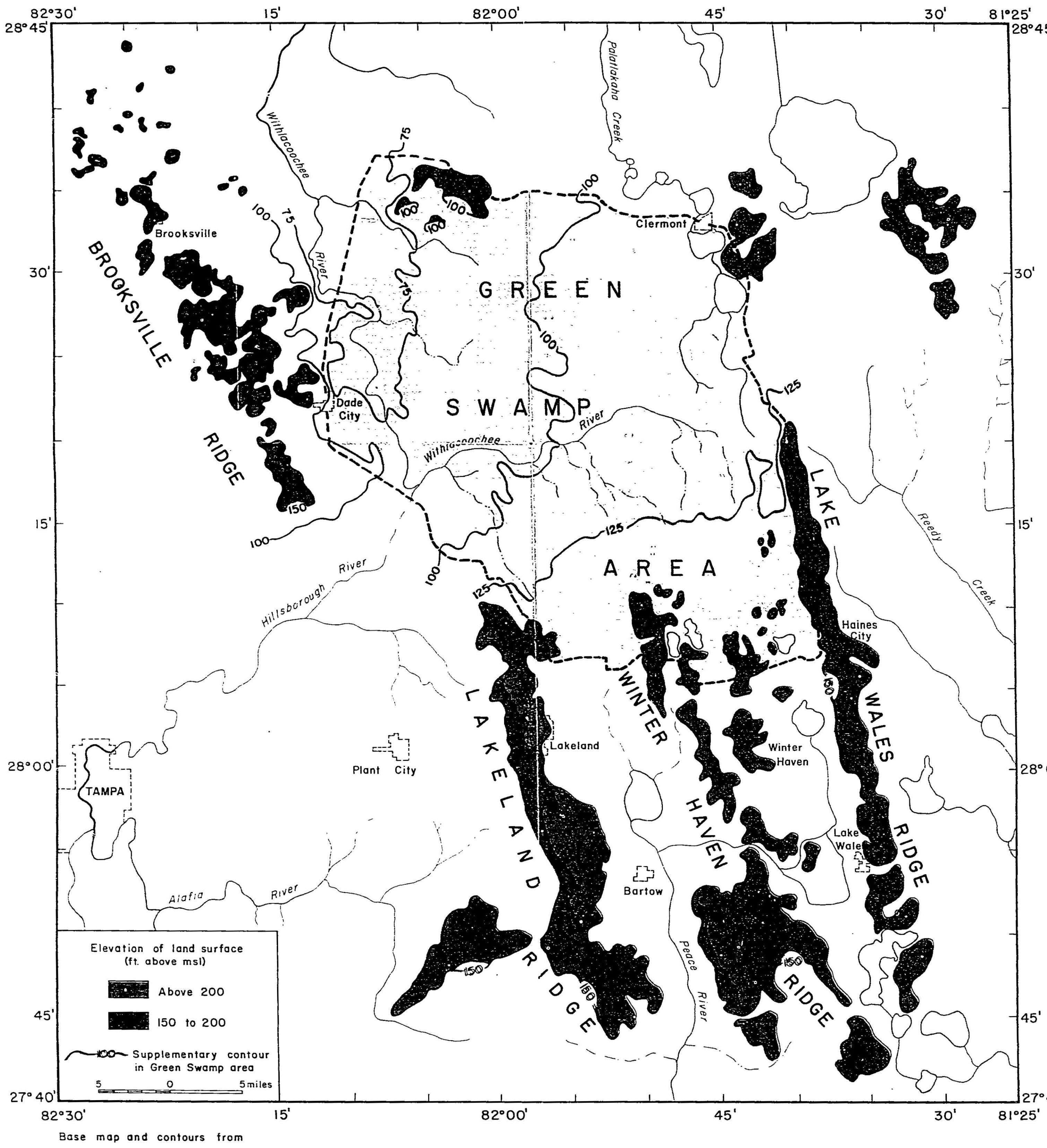

Figure 4. Map showing topography of central Florida and its relation to Green Swamp area.

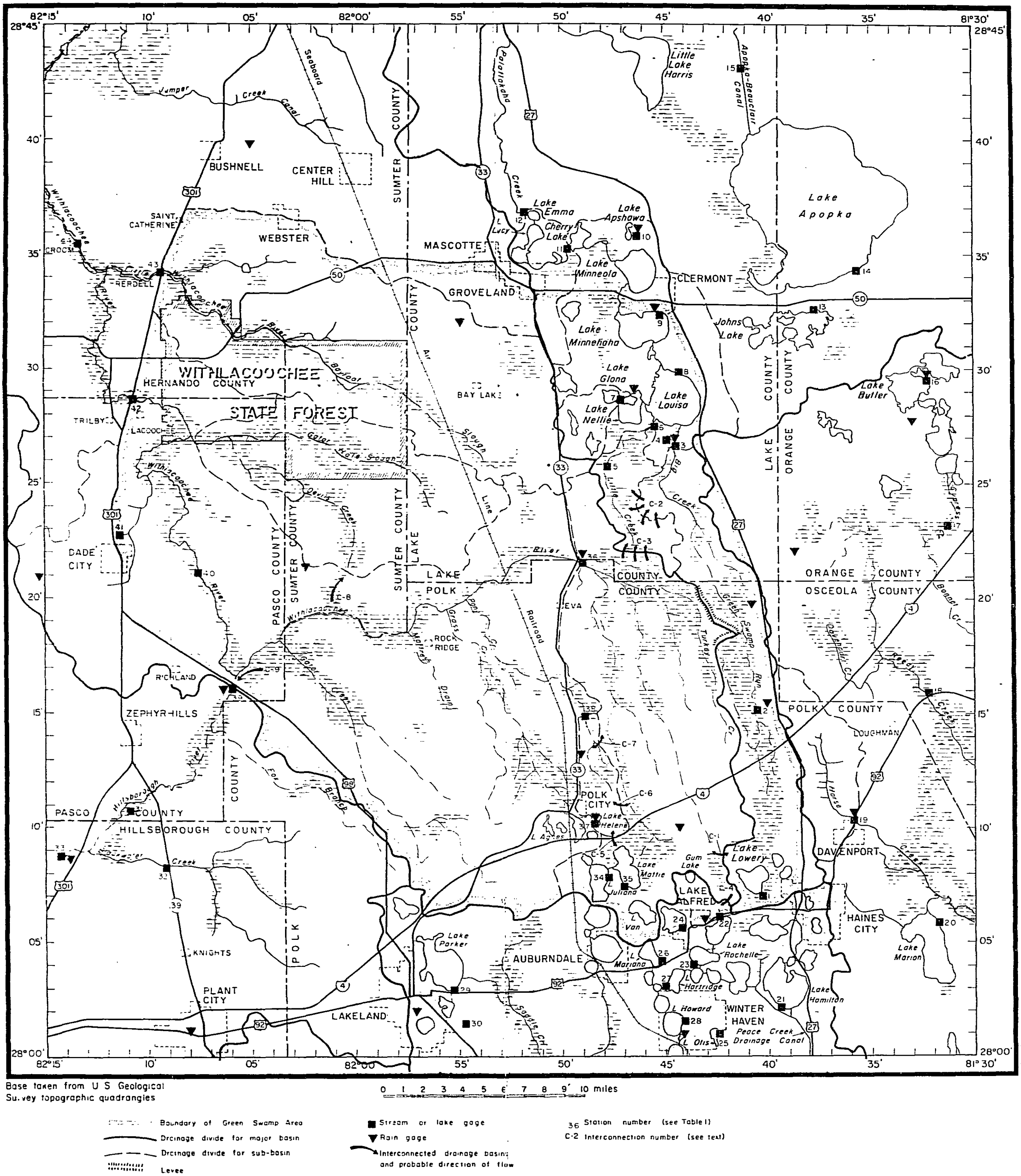

Figure 5. Map showing surface-water drainage features of Green Swamp area.

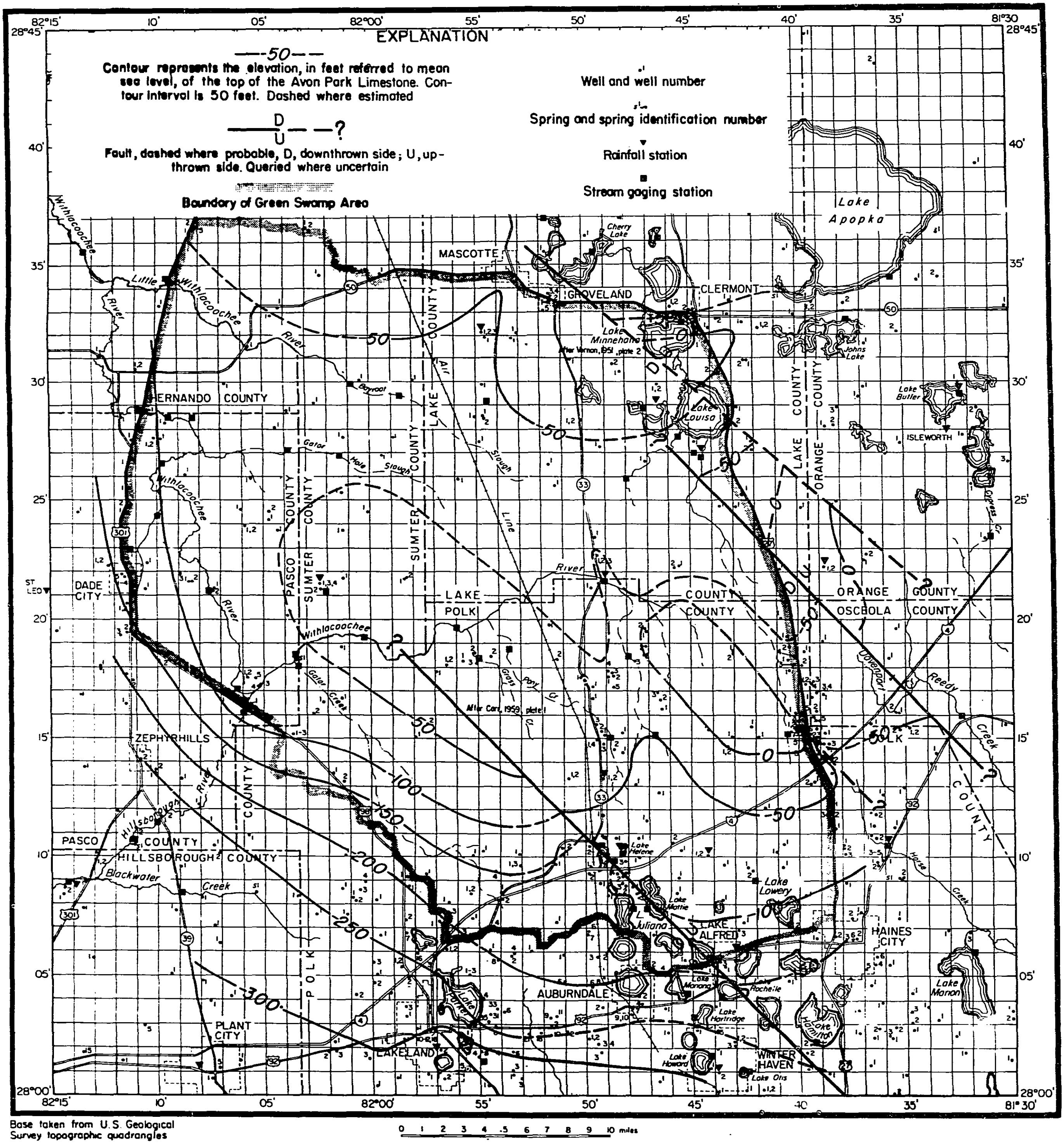

Figure 9. Map showing contours on top of the Avon Park Limestone.

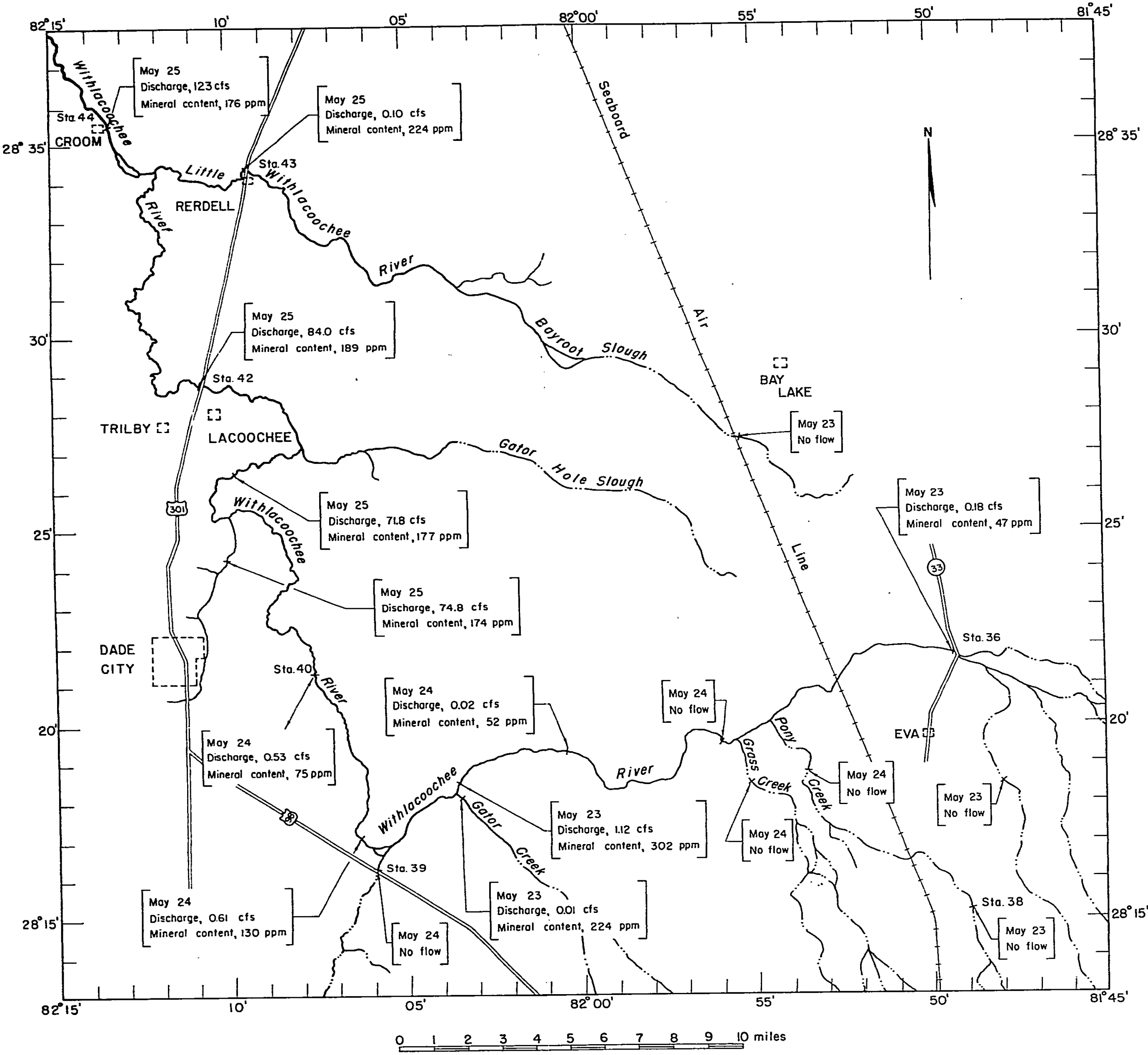

Figure 11. Map showing results of low-flow investigation of Withlacoochee River, May 23-25, 1961.

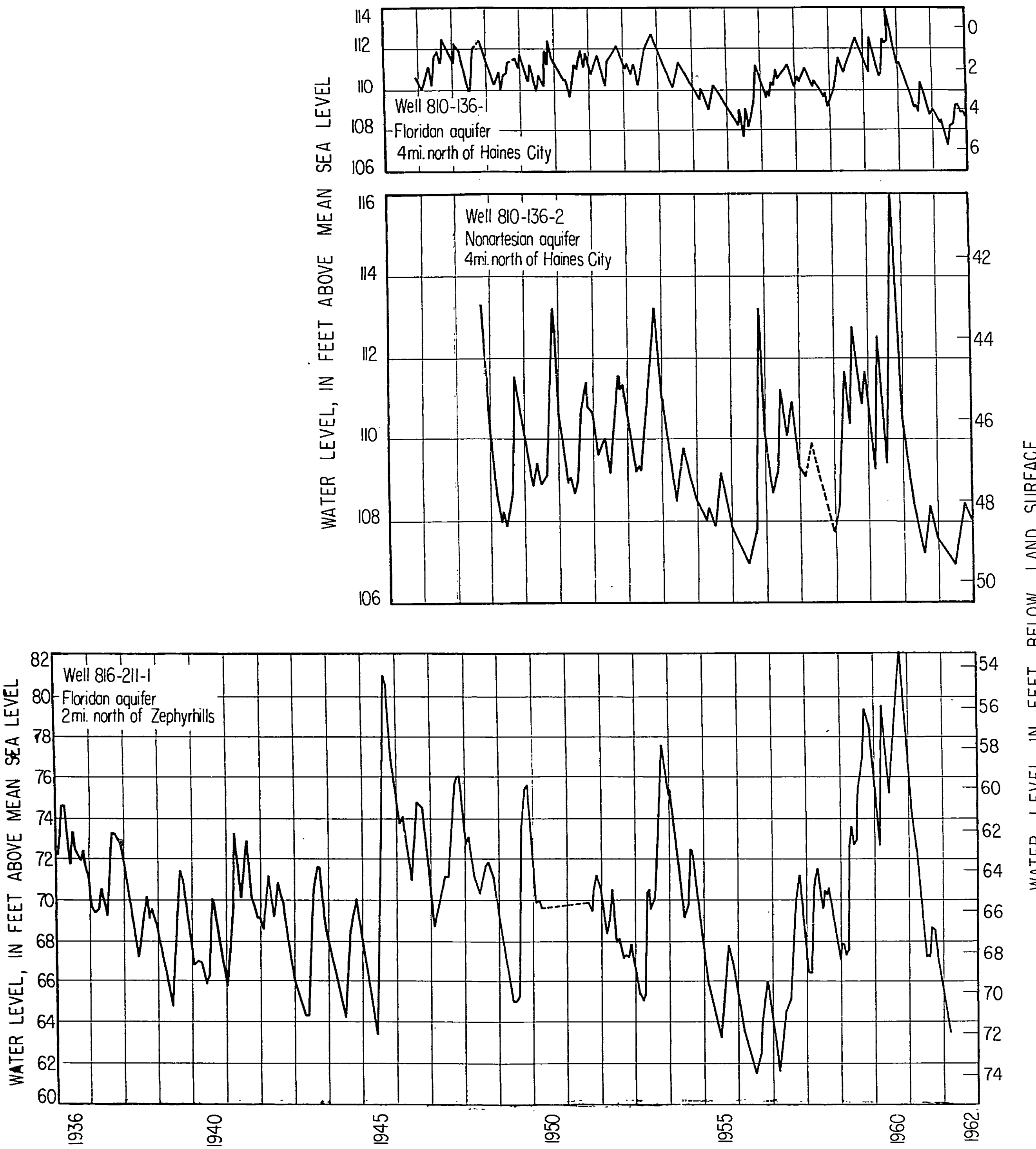

Figure 23. Hydrographs of long-term records of ground-water levels near the Green Swamp area.

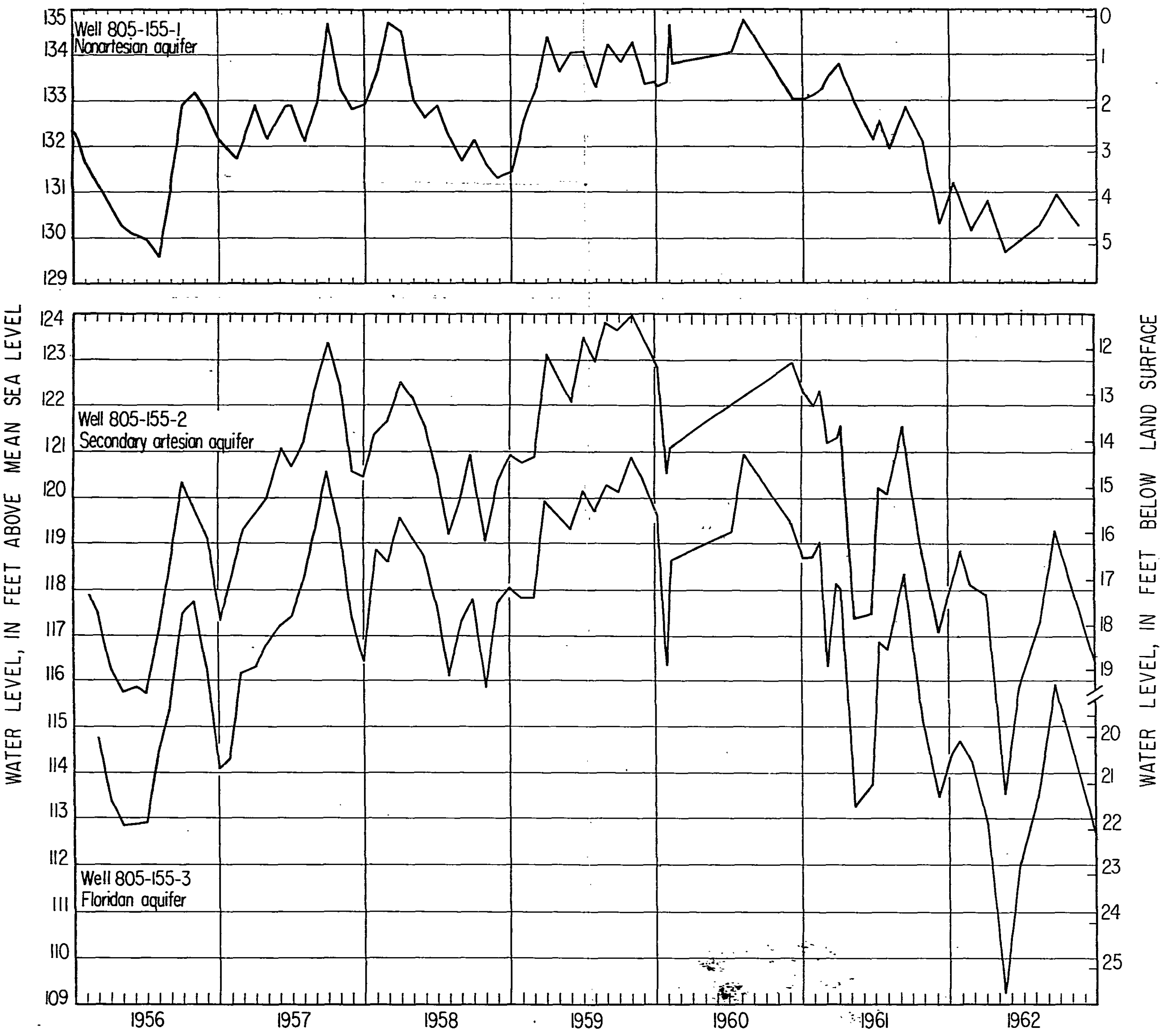

Figure 25. Hydrographs of water levels in wells (805-155-1, 2, and 3) near Lakeland.

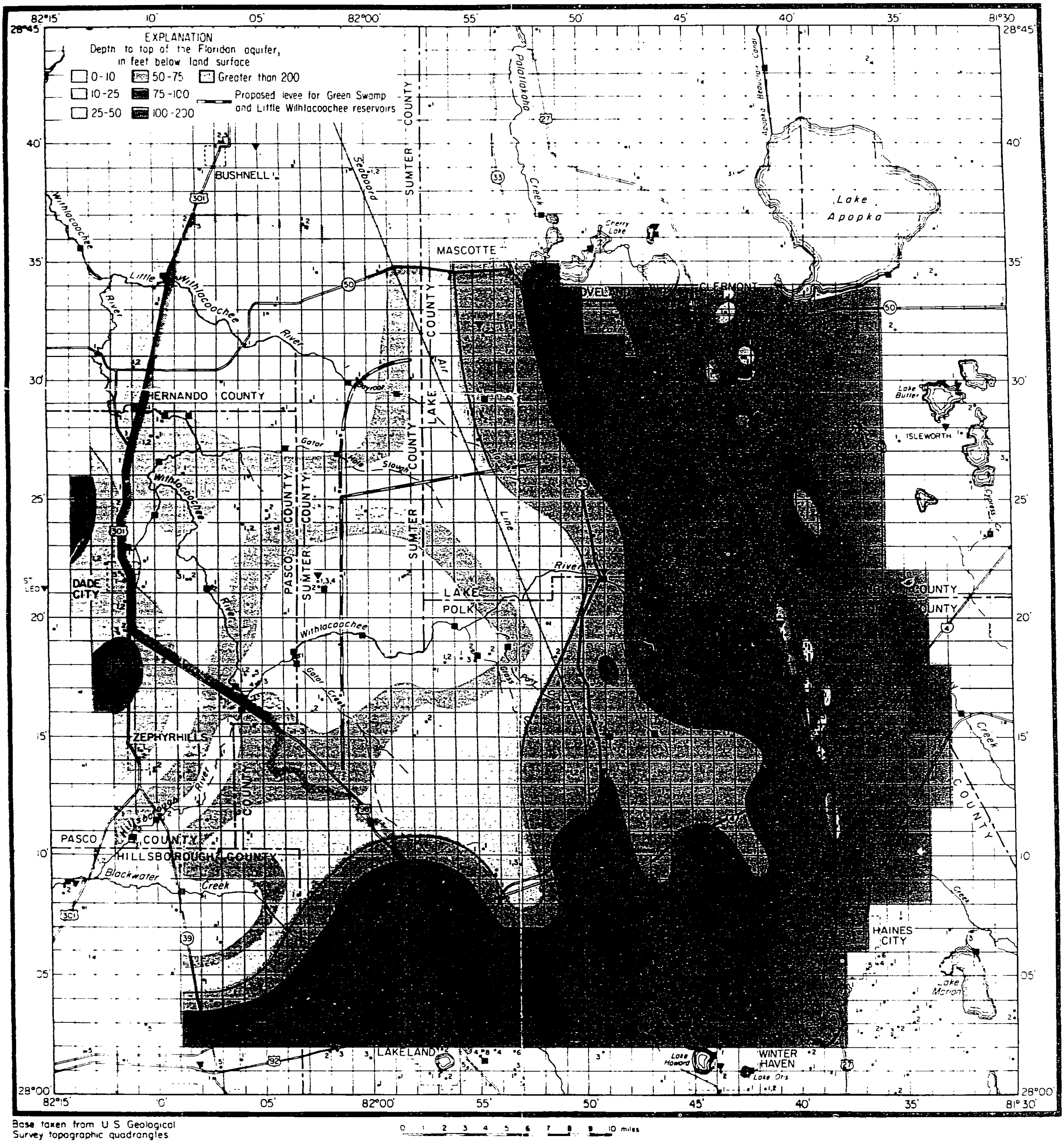

Figure 31. Map of Green Swamp area showing depths to the top of the Floridan aquifer.

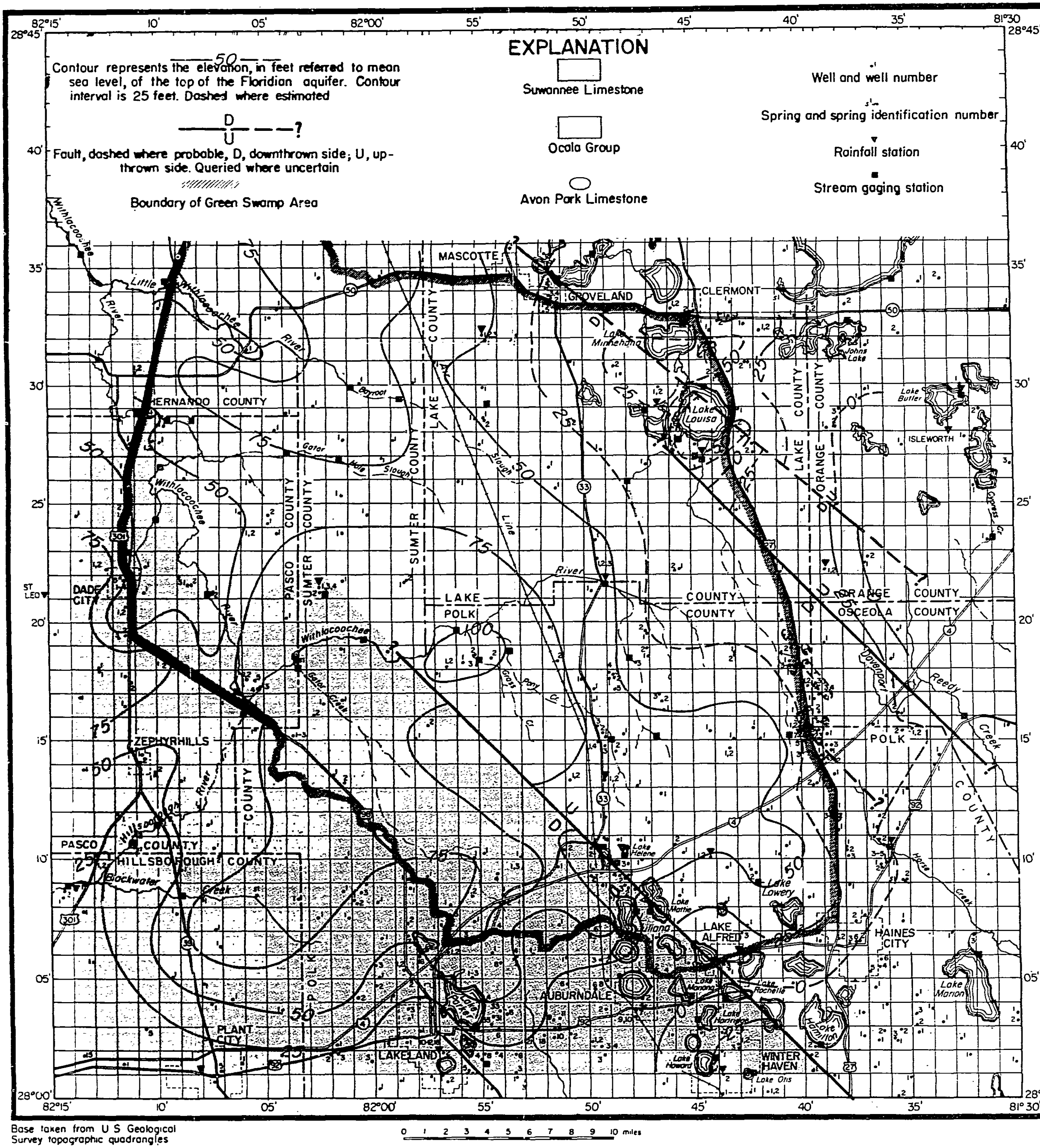

Figure 32. Map of Green Swamp area showing the limestone formations that comprise the top of the Floridan aquifer and contours on its upper surface.

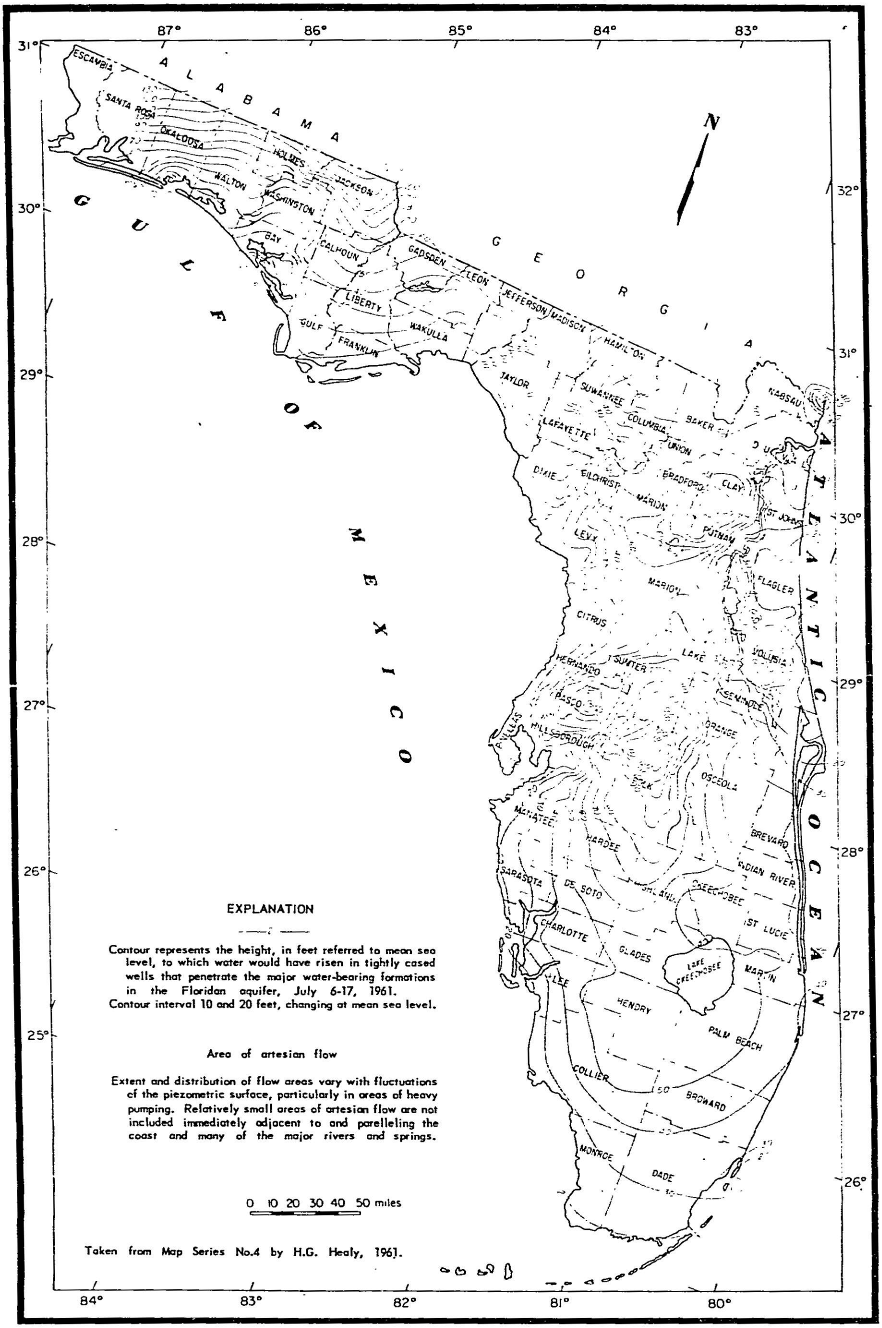

Figure 33. Map of Florida showing contours on the pizometric surface of the Floridan aquifer, 1961.

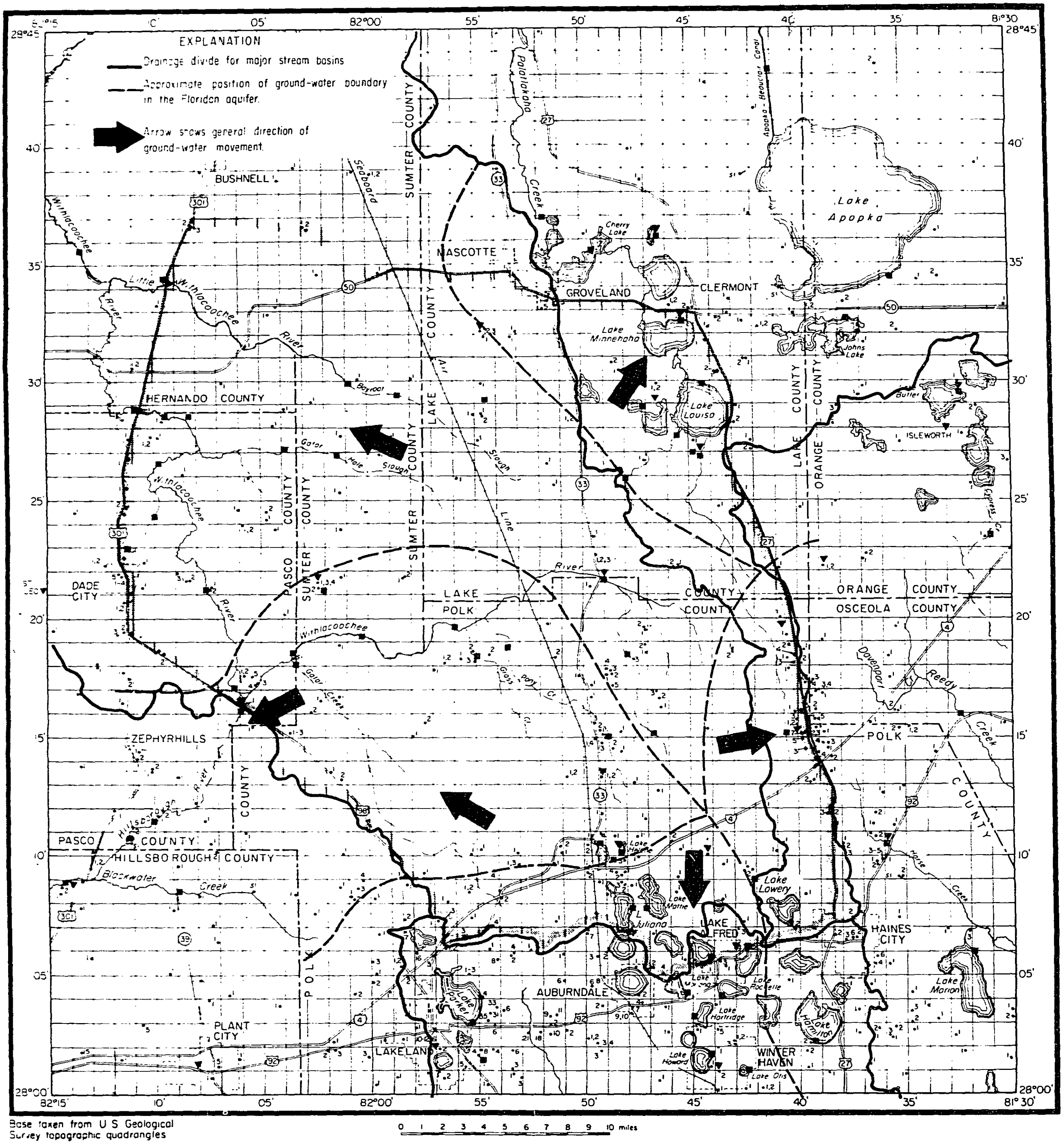

Figure 34. Map showing major surface drainage areas and their ground-water contributing areas in the Floridan aquifer.

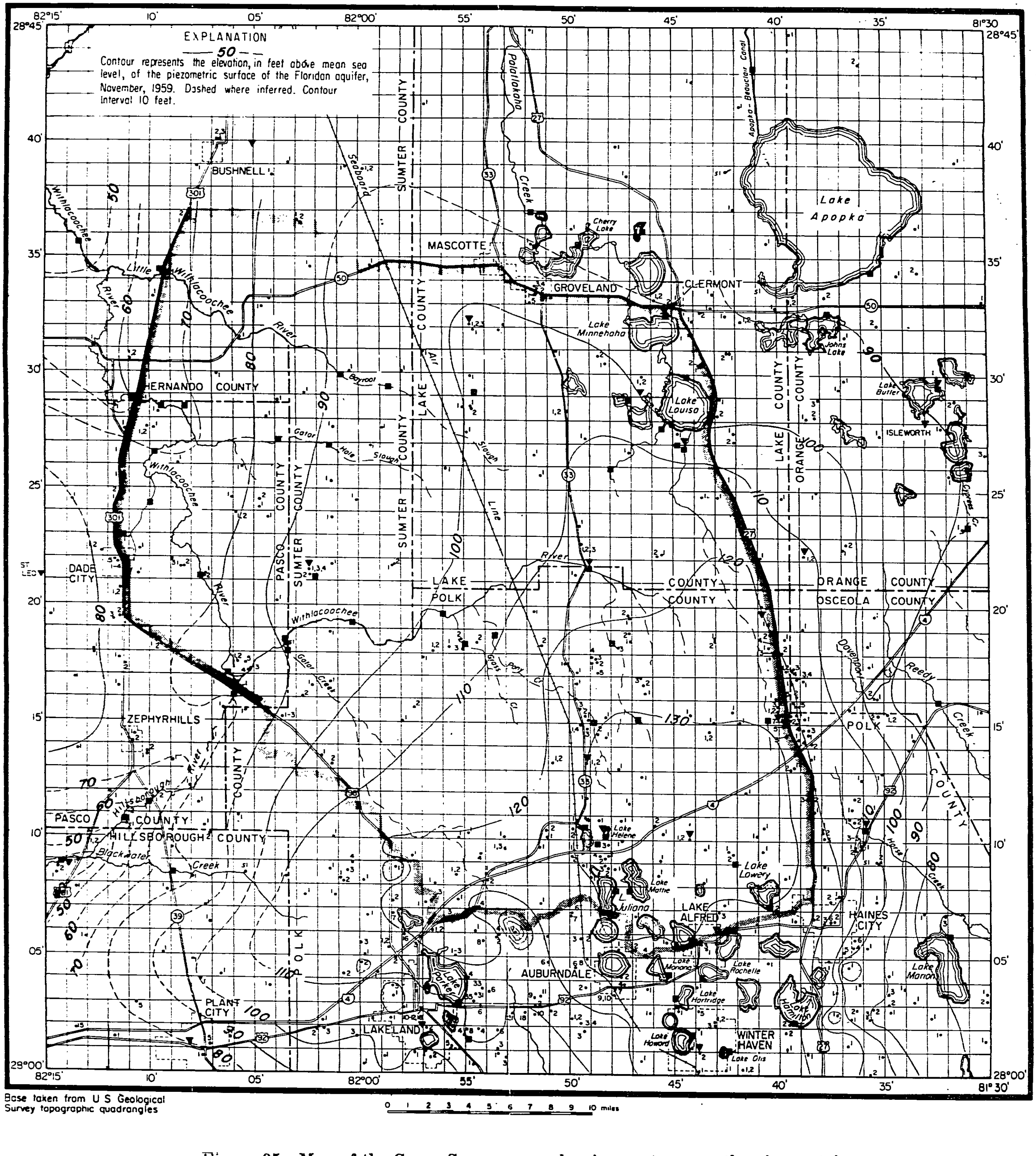

Figure 35. Map of the Green Swamp area showing contours on the piezometric surface of the Floridan aquifer during a wet period, November 1959.

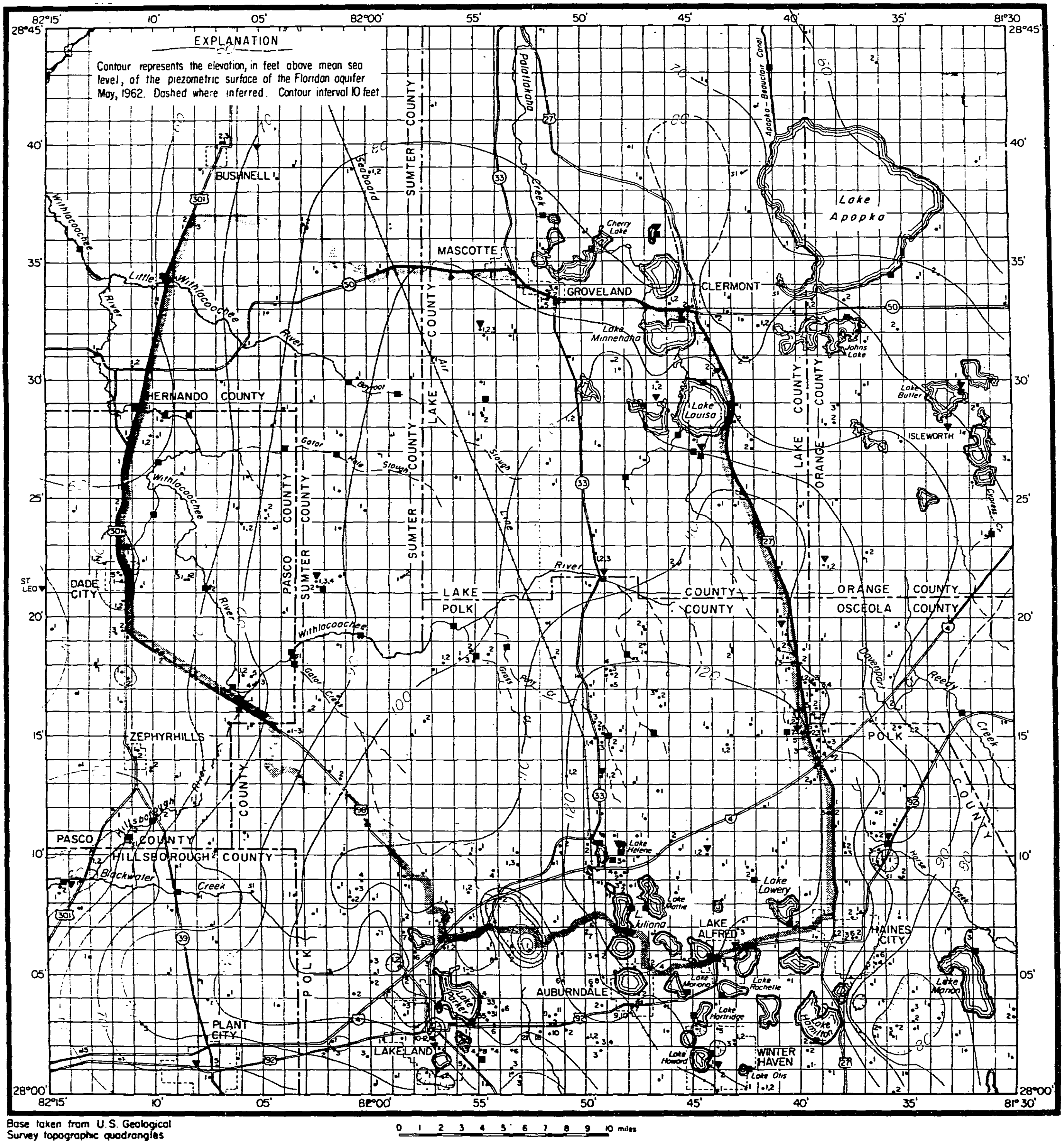

Figure 36. Map of the Green Swamp area showing contours on the piezometric surface of the Floridan aquifer during a dry period, May 1962.

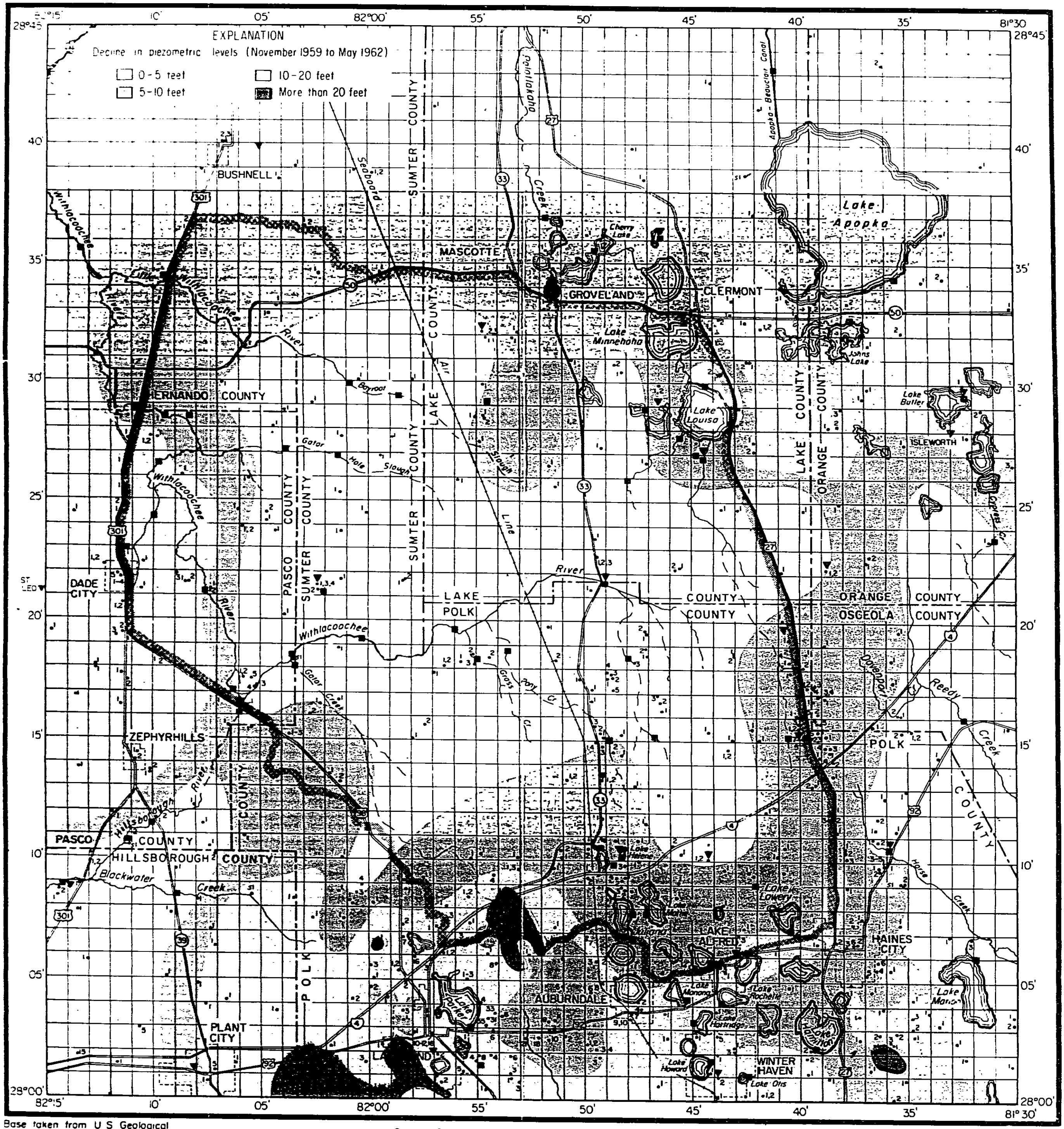

Figure 37. Map showing decline in piezometric surface of the Floridan aquifer, November 1959 to May 1962.

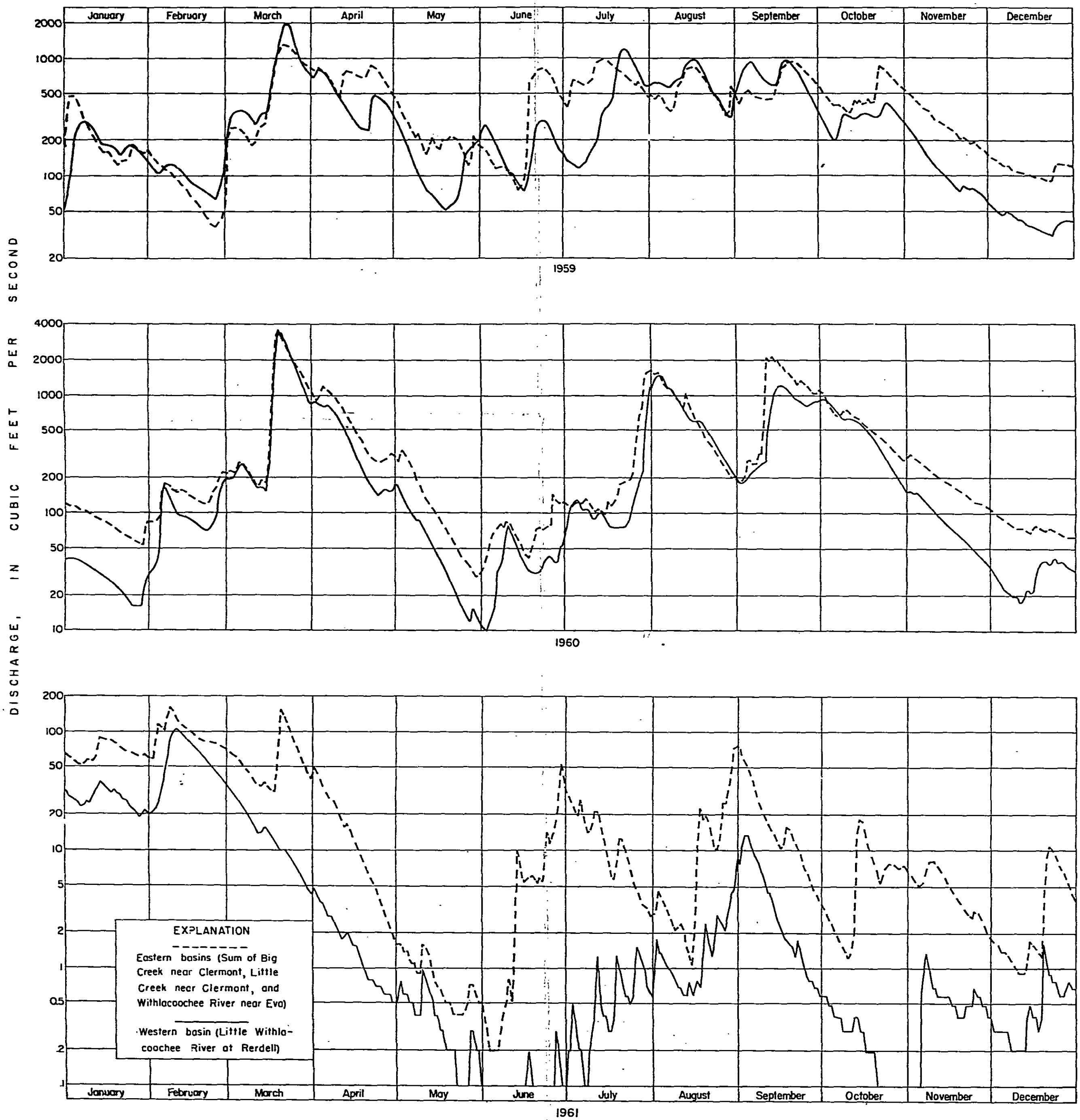

Figure 52. Hydrographs of streamflow from eastern and western basins in Green Swamp area, 1959-61.