UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

SOME ASPECTS OF THE AVAILABILITY OF WATER FROM THE EVERGLADES TO THE EVERGLADES NATIONAL PARK, FLORIDA

by

J. H. Hartwell

U.S. Geological Survey

OPEN-FILE REPORT

70007

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
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ABSTRACT

Much of the natural overland flow to the Everglades National Park entered Shark River Slough. The Slough is at the lower end of the Kissimmee-Lake Okeechobee-Everglades drainage basin whose upper tributaries are to the north near Orlando, Florida. Under natural conditions water from Lake Okeechobee generally overspilled to the Everglades at a stage of about 17 to 18 feet mean sea level. Beginning about 1882 the natural pattern of flow in the Everglades was changed gradually by construction of drainage canals. Major construction of levees, canals, pump stations and control structures occurred in the period from about 1906 to 1963.

Two 12-year periods, 1940-51 and 1952-63, were selected by which to compare rainfall and runoff. The first period was a time of virtually no change in water control works. The second period was a time of progressive construction of control works. Rainfall in the first period was generally less than in the second. Outflow from Lake Okeechobee to the Everglades in the first period (5.4 million acre-feet) was more than in the second (1.5 million acre-feet). Contrarily, flow to Shark River Slough increased from 2.4 in the first period to 5.1 million acre-feet in the second.

Runoff eastward to the sea from the major canals during the first period was more than during the second period. This reduction in runoff of fresh water to the sea was in part a result of completion of the levee system east of the three conservation areas in 1953. This levee system intercepts water that formerly flowed eastward and routes it southward through the Everglades to Shark River Slough. Also, other new drainage and water control works along the coastal ridge and better water management by the Central and Southern Florida Flood Control District played a part in this reduction.

It is concluded that part of the increase in flow to Shark River Slough was caused both by the increased rainfall and the reduction in flow to the sea through the coastal canals.

INTRODUCTION

The well being of the biologic communities of the Everglades National Park depends upon the seasonal distribution of water. Historically, this water came from rainfall over the park and from uninterrupted overland flow from the north. The overland flow is now controlled by a series of levees, which form conservation areas, and by control works that regulate the flow.

Questions have arisen as to the effect of the levees, conservation areas and associated water control works on the overland flow of water to the Everglades National Park. In order to provide some measure of the change in runoff, two 12-year periods, 1940-1951 and 1952-1963, were selected to compare rainfall and runoff. The first 12 years (1940-1951) was considered to be a period of no change in water control works. The second, equal period (1952-63) embraced a time span during which control works were progressively being built. The available hydrologic data were insufficient to adequately account for all water movements within the system. As a background, a brief description of the pristine drainage conditions in south Florida and of those man-made water control works that directly affect overland flow from the north into the park are portrayed. Accordingly, hydrologic data were selected which encompassed the 24-year period in order that a comparative, though not necessarily a precise, index of change could be portrayed.

One of the objectives of the program in cooperation with the National Park Service is to analyze the hydrology of Everglades National Park to define historical water conditions. This report was prepared to meet part of that objective.

NATURAL DRAINAGE CONDITIONS

Under natural drainage conditions, the region that now comprises the Kissimmee River, Lake Okeechobee, and the Everglades was a single drainage system (Parker and others, 1955). This 9,000 square-mile area is about 200 miles in length from the headwaters near Orlando southward to the Gulf of Mexico. The average width is about 45 miles.

The elongated shape of this drainage area and the normally erratic rainfall distribution indicate that the duration and magnitude of water flow, at a given time, varied from place to place in the basin. It is probable that in this extensive area events of flood and drought occurred concurrently. At some locations in the drainage basin, complete cessation of overland flow probably occurred and persisted for either brief or extended periods, while in other places, moderate to heavy flows occurred. In general, however, the flow was southward from the upper end of the Kissimmee drainage to the coastal marshes at the southern tip of Florida (see figure 1). The boundaries of the physiographic regions shown in figure 1 can only be generally defined. The Everglades National Park is at the lower end of this drainage area.

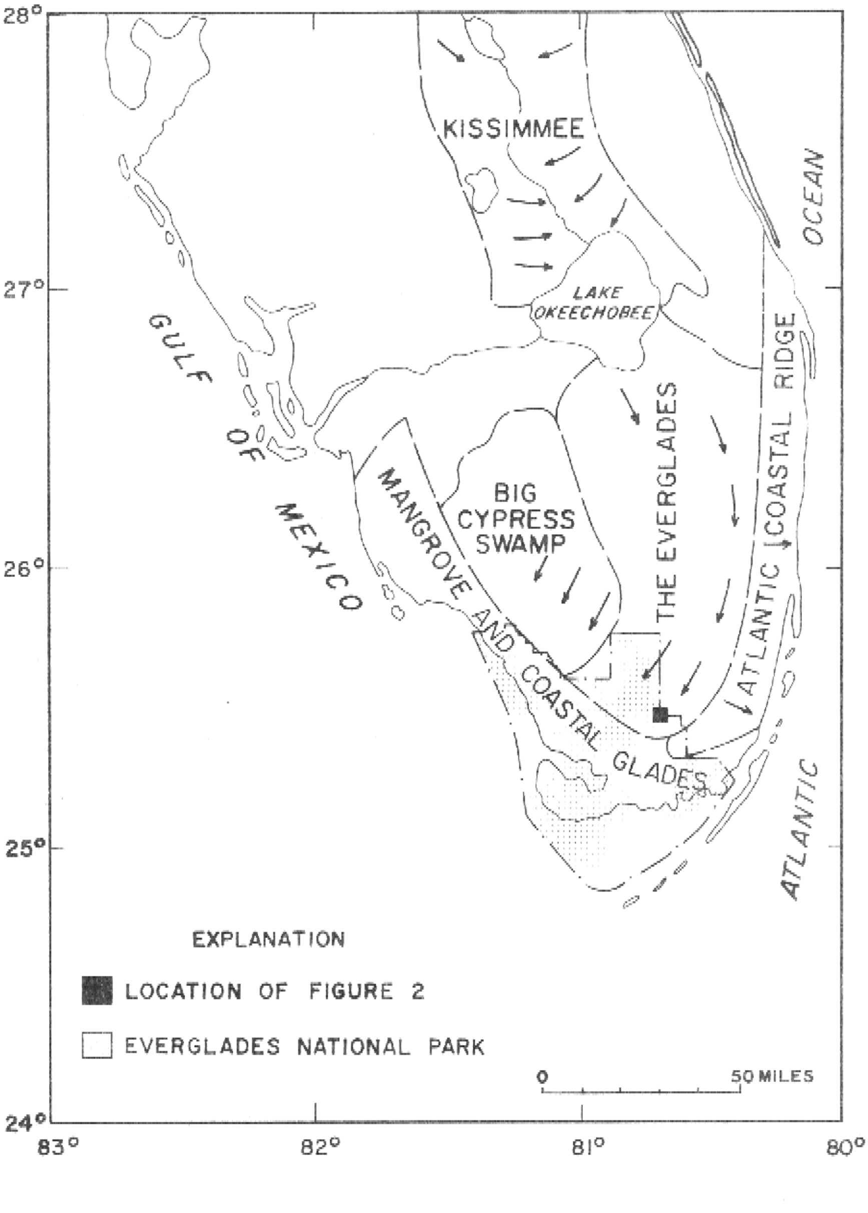


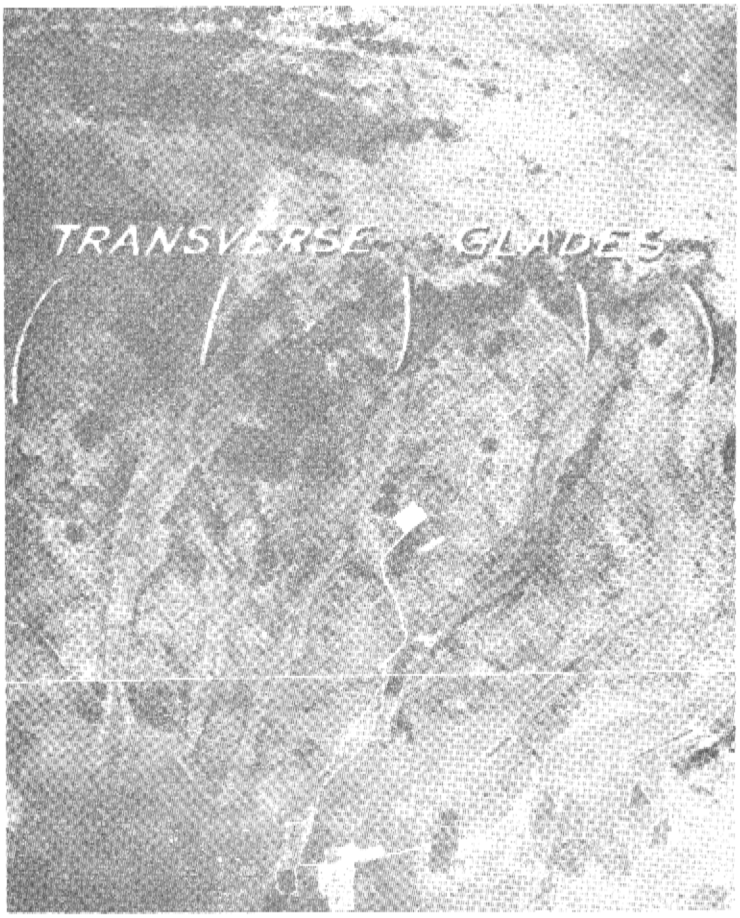
Figure 1. Map delineating the physiographic regions and the general directions of predrainage overland flow in south Florida.

Certain features of the natural drainage system in the Everglades permit generalization of the probable early water condition, even though hydrologic records are virtually nonexistent. Under natural drainage conditions, Lake Okeechobee acted as a temporary storage area of the southward flow of water from the Kissimmee River and other smaller tributaries. At a lake stage of about 15 feet above msl (mean sea level), spillage cocurred at a few isolated points along the southern shoreline of the Lake (Parker and others, 1955). General overflow occurred at 17 to 18 feet above msl, and the water flowed slowly, almost imperceptibly, southward through the dense grassy vegetation of the Everglades. The entire Everglades became inundated as a result of excessive rainfall and overflow from Lake Okeechobee.

In the reach from Lake Okeechobee to the Tamiami Canal, the average slope of the ground surface is about 0.15 foot (less than 2 inches) per mile. Essentially, the water surface in this stretch of the Everglades closely parallels the ground surface. Movement of water was and is slow because of the flat water slope and the additional retardation of flow by the relatively dense vegetation. The water slope does not remain constant under all conditions, however, and usually the greater the water depth, the steeper the slope and the faster the velocity of the water. In general, the velocity of flow in the Everglades ranges from less than 0.005 fps (foot per second) to about 0.1 fps.

Although predrainage estimates of flow in the Everglades have been made, none are considered to be reliable. The highest calendar year discharge that has been measured by the U. S. Geological Survey in the reach along the Tamiami Canal from Levee 30 to Monroe, 18 to 58 miles west of Miami, was 1.7 million acre-feet in 1960. Predrainage estimates of discharge have been considerably greater than the 1960 discharge.

One interesting physical feature of the drainage is the transverse glades. These glades cross the Atlantic Coastal Ridge in an east-west direction at many locations. They are shallow sloughs that permitted water to discharge from the Everglades to the sea, as indicated by figure 1, especially during wet periods. Transverse glades are illustrated by figure 2, a photograph of a part of Long Pine Key, 6 miles west of the main entrance to Everglades National Park. The transverse glades in figure 2 are oriented north-south, whereas most transverse glades, as indicated by the arrows on figure 1, are oriented east-west. Topographic maps indicate that the elevation of the ground in these transverse glades is lower than the adjacent land on either side of their water courses, but the lowest transverse glade elevation is somewhat higher than the ground level of the proximate Everglades. The fact that the sloughs are identifiable flow channels indicates that recurrent flows took place. When water discharged through these transverse glades, the concurrent depth of water in the Everglades was much deeper than that in the transverse glades. High water discharge,



Approximate scale: 1 inch equals 5,000 feet.

Figure 2.--Aerial photograph identifying transverse glades on Long Pine Key in Everglades National Park, 1964.

represented by the greater depth of water in the Everglades in predrainage times, could have formed the transverse glades by fluvial erosion. This physiographic evidence, coupled with the knowledge of water slopes, indicates that the southward flow of water in the Everglades was, at times in the past, greater than those observed since the beginning of the collection of continuous hydrologic records in 1939. No comparison of the water depth in the transverse glades today can be made with depths under natural conditions,as most transverse glades now are the sites of canals.

DRAINAGE CHANGES

Many water-control works have been constructed in central and southern Florida that have modified the natural flow in the Everglades. In this report, it is not intended to document construction of all canal and control works that have altered the flow in the Everglades, but rather to mention only those that caused major changes in the flow patterns to Everglades National Park. The first change in drainage was the construction of a 17-mile long canal from Lake Flirt (non-existent today), just east of La Belle, to Lake Hicpochee. This canal was constructed during the period July 1882 to January 1883 to connect the upper tributaries of the Caloosahatchee River with Lake Okeechobee for the purpose of providing water transportation from Fort Myers to Kissimmee. This canal also served as an outflow channel to drain water from Lake Okeechobee to the Gulf of Mexico. Owing to the small size of the canal and to shoal and vegetation constrictions, the discharge capacity of this canal was probably less than 5 percent of the present day Caloosahatchee Canal (inferred from Heilprin, 1887).

The completion, in 1912, of the North New River Canal from Lake Okeechobee to the head of the New River created a major interruption of natural flow to the south by collecting and diverting the water eastward that flowed southward. The Miami Canal, which was dug at about the same time, created an additional eastward diversion. Despite these diversions, some of the water from the Lake Okeechobee area continued to flow southward during periods of high water. Unfortunately, no records of water movement that might have been made in those early years are known to be available, except for several miscellaneous discharge measurements made by the U.S. Geological Survey in 1913.

Between the mid-1910's and prior to the start of construction on works of the Central and Southern Florida Flood Control Project in 1950, several other canals and levees were built. Foremost of these were the Lake Okeechobee levees, the St. Lucie Canal, dredging to increase the discharge capacity of the Caloosahatchee Canal, and the construction of several canals through the Atlantic Coastal Ridge. Most of these works were designed to prevent flooding and to provide local drainage. The Tamiami Trail (today's U.S. Highway 41), opened in April 1928, was constructed from borrow material excavated from land parallel and adjacent to the north shoulder of the roadway. This continuous borrow excavation,extending below the water table,created the Tamiami Canal. The Canal acted as a collector of overland flow from the north and conveyed the water to the nearest bridge or culvert under the Tamiami Train through which the water resumed flow southward. These bridges or culverts were placed less than a mile apart. At present, in the study area, the reach of the canal where the flow is eastward rather than southward is east of Levee 30, see figure 3.

Many control works have been completed thus far, under the Central and Southern Florida Flood Control Project. Of significance to the control of water that naturally flowed into Everglades National Park was the completion of the structures around Conservation Area No. 3. The progress of construction of water-control works in the vicinity of Conservation Area No. 3 is shown in figure 3. The date at the top of each of the six illustrations refers to the year(s) during which the labelled structures were completed. For those works that were not inclusive in the designated year(s), the year of completion is shown in parentheses. Figure 3 shows that the construction of the Central and Southern Florida Flood Control Project began in 1952. It can be seen that by the end of 1963 Conservation Area No. 3 was almost completely enclosed by levees and that several pumps and gated structures were in place to move water to and from the area. The S-12 structures at the south end of Conservation Area No. 3 were completed in 1962 and these structures control the flow of water from the conservation area to Everglades National Park.

ANALYSIS OF HYDROLOGIC INFORMATION

The Geological Survey started to monitor water flow continuously in south Florida in late 1939. Records of daily discharge have been acquired at several locations in canals since the inception of the Survey's cooperative investigations of water resources. Concurrently, the U.S. Weather Bureau and other water oriented agencies and individuals have gathered records of rainfall and discharge.

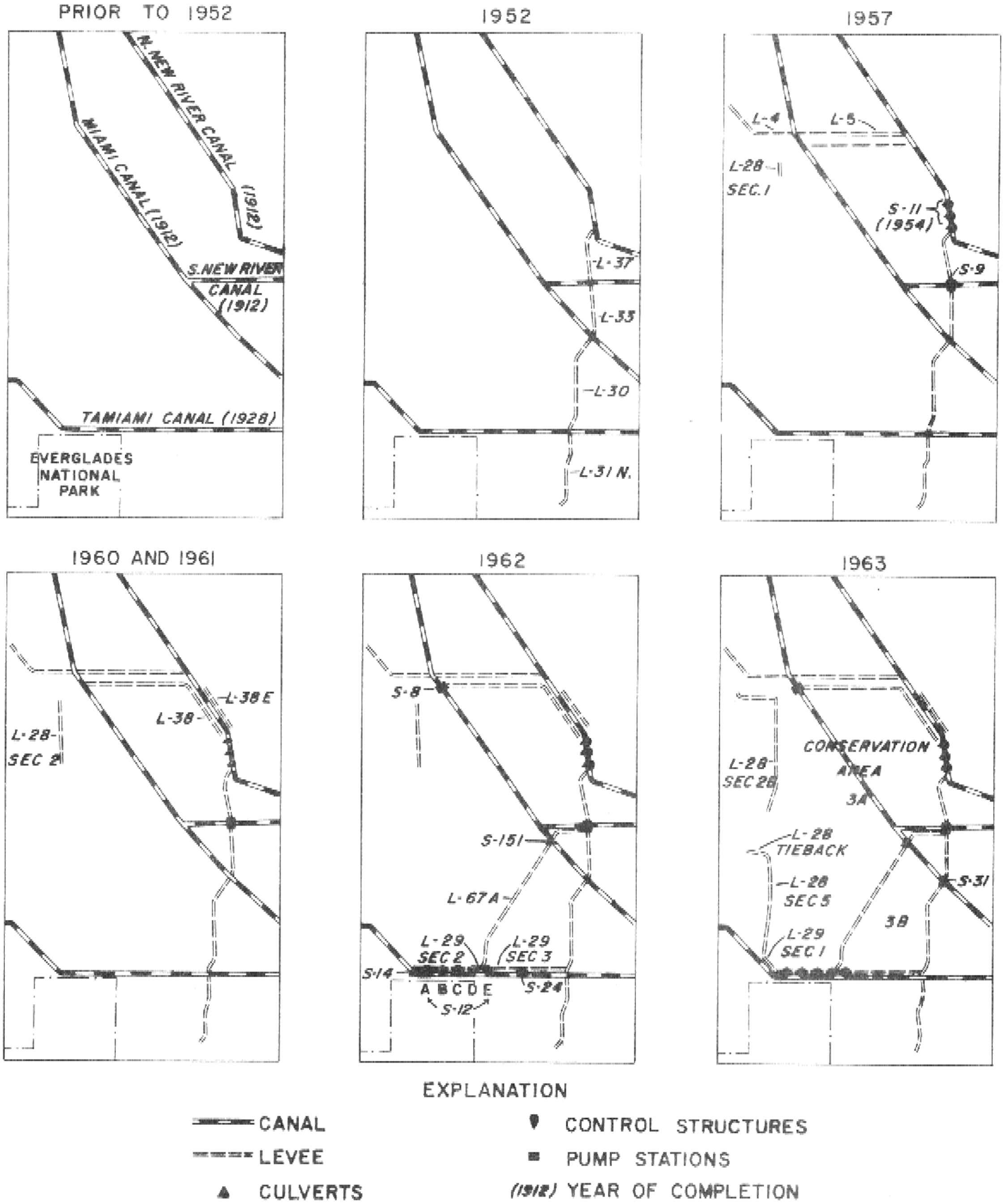


Figure 3.--Maps showing progress of construction of water-control works that formed Conservation Area No. 3.

The following analysis of rainfall and runoff is based on data from hydrologic stations having continuous record from 1940 to 1963. For comparison, the data are separated into two 12-year periods. Twelve-year periodswere selected because continuous discharge data were available for only 12 years prior to the beginning of construction. A period of similar length after construction began was chosen to have equal periods for comparison.

Total rainfall and average seasonal variability for each 12-year period are shown in figure 4 for the four major physiographic regions of south Florida. The rainfall stations listed on figure 4 were selected because they had continuous records for the 24-year period of evaluation and because of their geographic distribution. The two 12-year mean rainfall values for each region are not intended as quantitative measures of runoff, but rather as indices of the total water available for both runoff and evaporation. In the Kissimmee, Everglades, and Big Cypress Swamp regions rainfall during the first period was appreciably less than during the second period. The annual regional rainfalls used in figure 4 are illustrated in figure 5. The dashed line on figure 5 represents the average for each 12-year period.

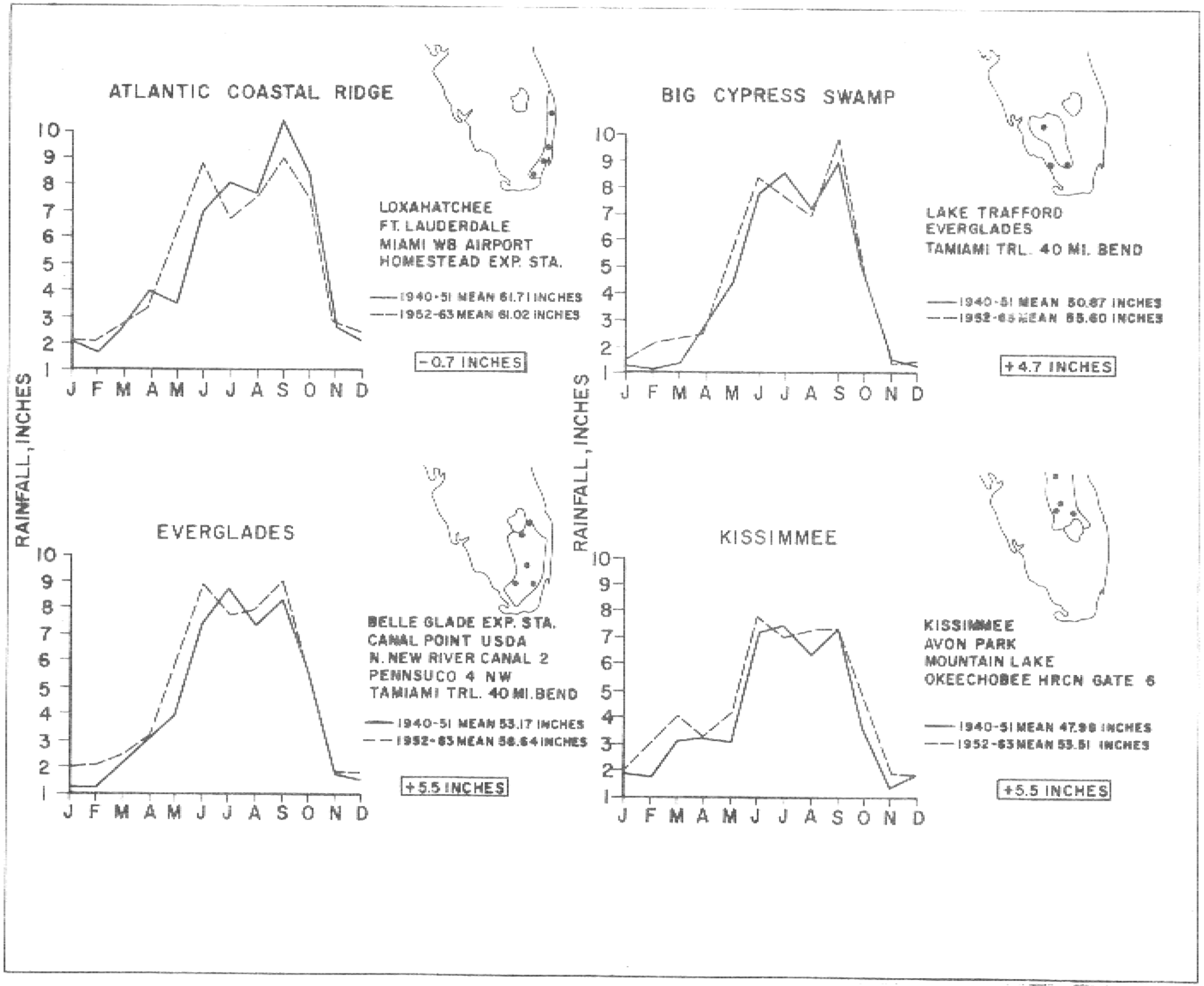


Figure 4. Average monthly rainfall for two 12-year periods in each of the four, major physiographic regions of south Florida. The number in the box is the average annual difference in the two periods. The listed rainfall stations are located by dots. Note that in all regions, except the Atlantic Coastal Ridge, the rainfall in the second period exceeds that of the first.

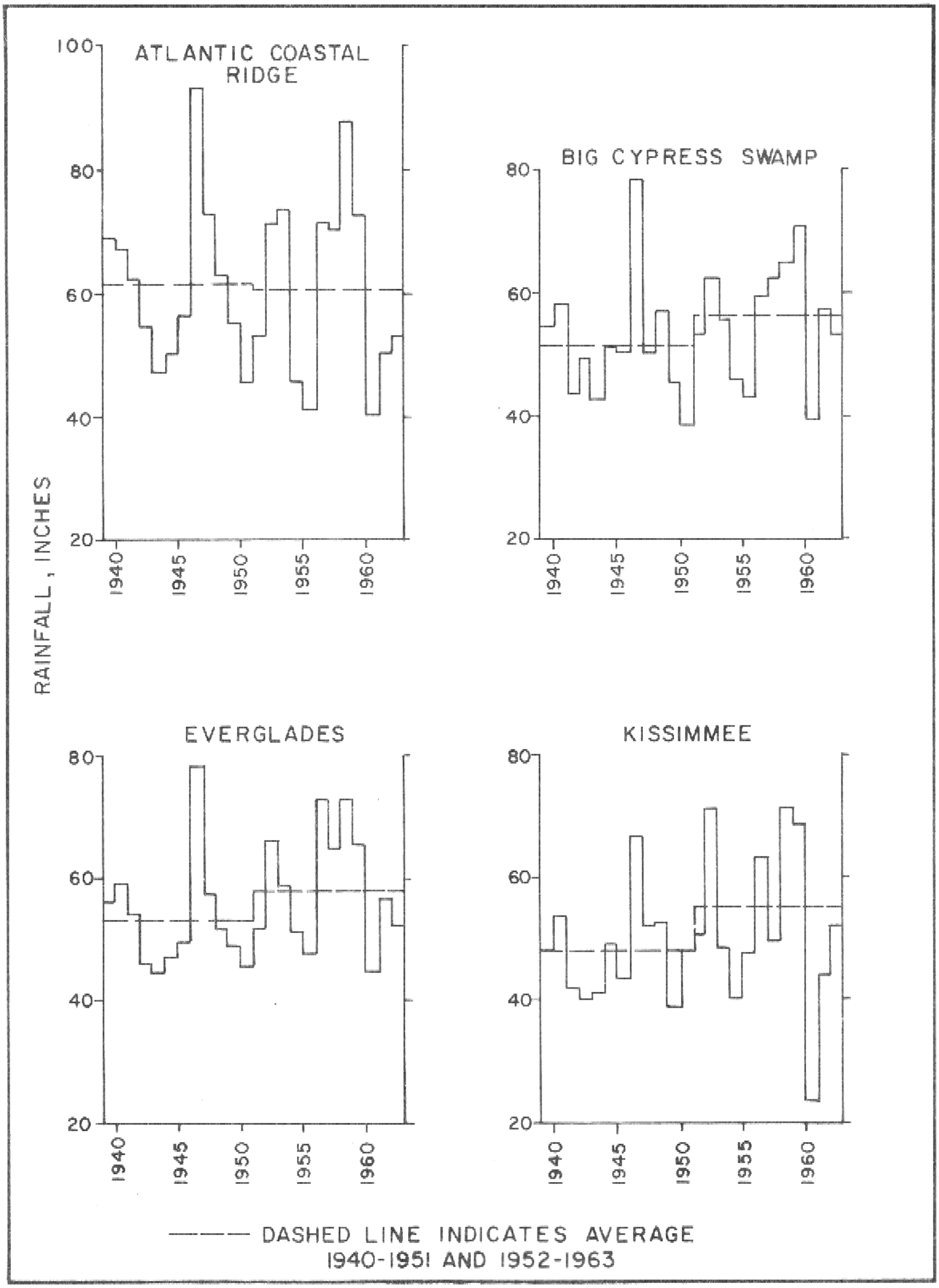


Figure 5. Annual rainfall for period 1940-63 in each of the four physiographic regions of figure 4.

Water in the Everglades comes from Lake Okeechobee and from rainfall on the area. An attempt was made to compute inflow-outflow relations for the Everglades for the two 12-year periods, but, owing to the incompleteness of some hydrologic information, the results were inconclusive. However, annual outflow from Lake Okeechobee to the Everglades, as a measure of available water, was found to be expressible in an equation as:

$$O_E = I_L + P_L - E_L + S_L - O_S - O_C$$

where O_E = Outlow to the Everglades

I_L = Inflow to Lake Okeechobee

P_L = Rainfall on the lake

E_L = Evaporation from the lake

S_L = Change in lake storage

O_S = Outflow through St. Lucie Canal

O_C = Outflow through Caloosahatchee Canal

By applying this equation, the net outflow was computed for each year in the period 1940 to 1963, and the results are presented in Table 1.

Table 1. Water movement to and from Lake Okeechobee

(thousands of acre-feet)

Calendar year	(O_E) Outflow to the Everglades	(I_L) Inflow to Lake Okeechobee 1/	($P_L - E_L$) Rainfall on and Evaporation from Lake Okeechobee 1/	(S_L) Change in storage of Lake Okeechobee 2/	(O_S) Outflow through St. Lucie Canal 3/	(O_C) Outflow through Caloosahatchee Canal
1940	-176	1,521	229	-400	1,004	522
1941	132	2,063	810	+220	1,527	1,434
1942	-696	1,897	451	-660	1,384	1,000
1943	989	1,133	-77	+130	175	22
1944	229	841	-117	-290	187	18
1945	2,289	2,317	203	+1,100	831	500
1946	339	1,251	261	-240	461	472
1947	1,937	3,818	1,357	+1,140	2,665	1,713
1948	-1,614	3,226	202	-860	2,389	1,793
1949	352	1,996	377	-200	885	936
1950	27	812	-112	-600	7	66
1951	1,614	1,779	277	+520	529	433
1940-51	5,422	22,654	3,861	-140	12,044	8,909
1952	609	1,691	229	+80	450	941
1953	618	3,722	459	+400	2,389	1,574
1954	-1,548	2,323	304	-740	1,468	1,967
1955	-298	711	64	-680	10	383
1956	197	653	-348	-80	7	21
1957	2,247	2,163	643	+1,200	855	904
1958	-1,291	1,850	620	-700	1,861	1,200
1959	796	3,680	703	+560	2,755	1,392
1960	516	5,005	472	+110	3,093	1,975
1961	-1,643	945	-410	-1,510	179	489
1962	1,884	607	141	+1,150	7	7
1963	-572	487	-106	-920	7	26
1952-63	1,518	23,837	2,771	-1,130	13,081	10,879

Note.--Negative figures of outflow indicate net movement from the Everglades to Lake Okeechobee.

1/ Estimated in part.

2/The negative sign indicates that there was less water in storage, by the amount shown, at the end of the year than at the beginning. The positive sign indicates more water was in storage at the end of the year.

3/Station relocated 23 miles downstream in October 1952; records considered comparable.

The values in Table 1 were compiled, for the most part, from records of the Geological Survey. The outflow to the Everglades (O_E) is the computed sum of the net discharge from Lake Okeechobee. This outflow is primarily into the Miami, North New River, Hillsboro, and West Palm Beach Canals, but some outflow was into the many ungaged culverts on the southern perimeter of the lake. The inflow (I_L) is the sum of the measured discharge from the Kissimmee River, Fisheating Creek, Taylor Creek, and estimated inflow from the ungaged areas adjacent to Lake Okeechobee. The change in lake storage from year to year was computed from records published by the Geological Survey. The figures for rainfall minus evaporation were compiled from U. S. Weather Bureau records and reports of the U. S. Army Corps of Engineers. Evaporation from the lake varies slightly from year to year and averages about 1.4 million acre-feet or about 3.5 feet of water depth over the normal area of the lake, according to the Corps of Engineers (1967). The Corps (1967) also reports that an average of about 4.0 feet of rain falls on the lake annually. This annual rainfall is somewhat less than that which falls on the surrounding area, but the smaller amount can be generally attributed to the presence of less cloud cover over the lake. The outflows through the St. Lucie and Caloosahatchee Canals are from records furnished by the Corps of Engineers and published by the U. S. Geological Survey.

The yearly outflow from Lake Okechobee to the Everglades, as listed in Table 1, is illustrated in figure 6. In 3 of the 12 years during the

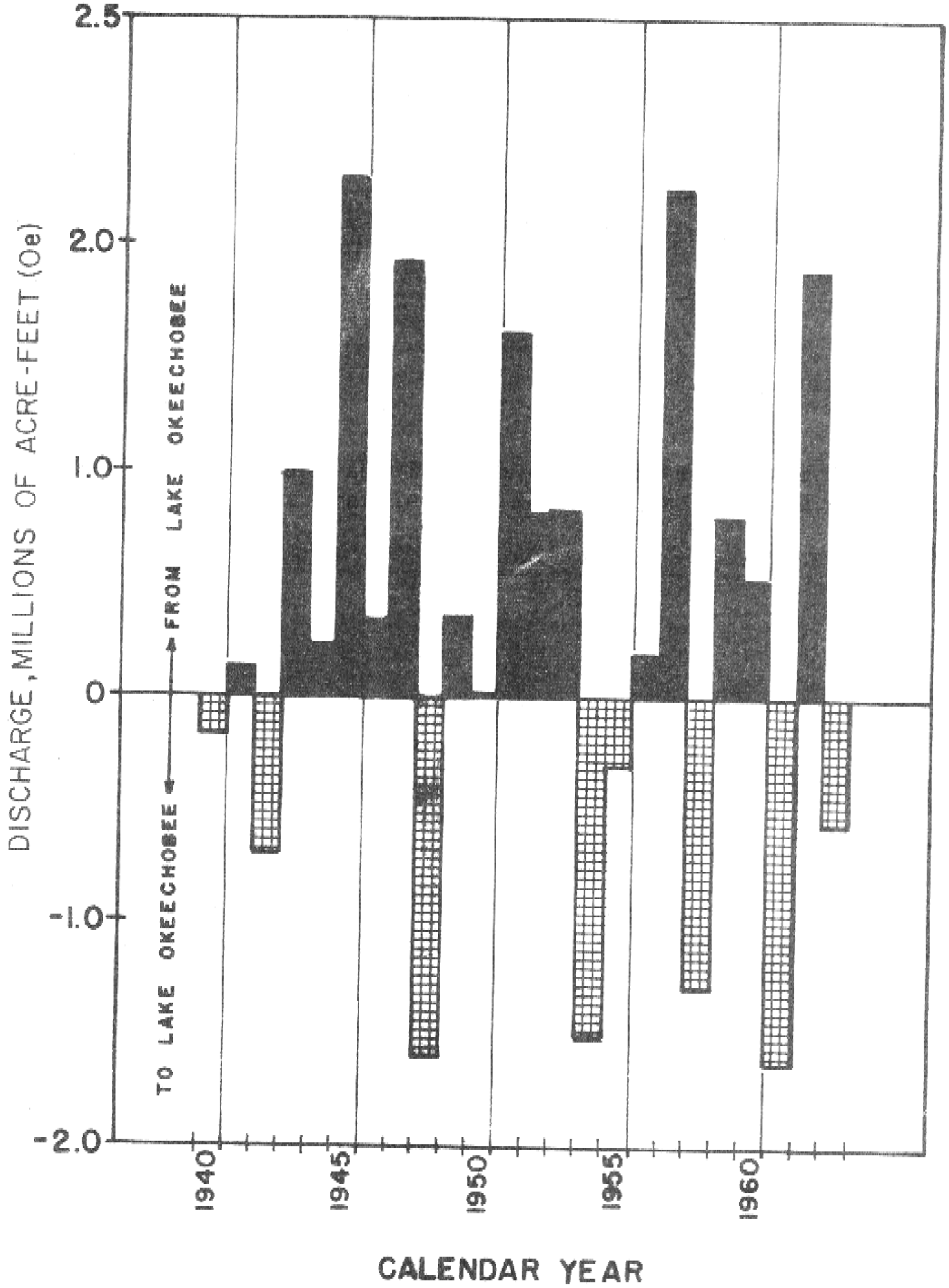


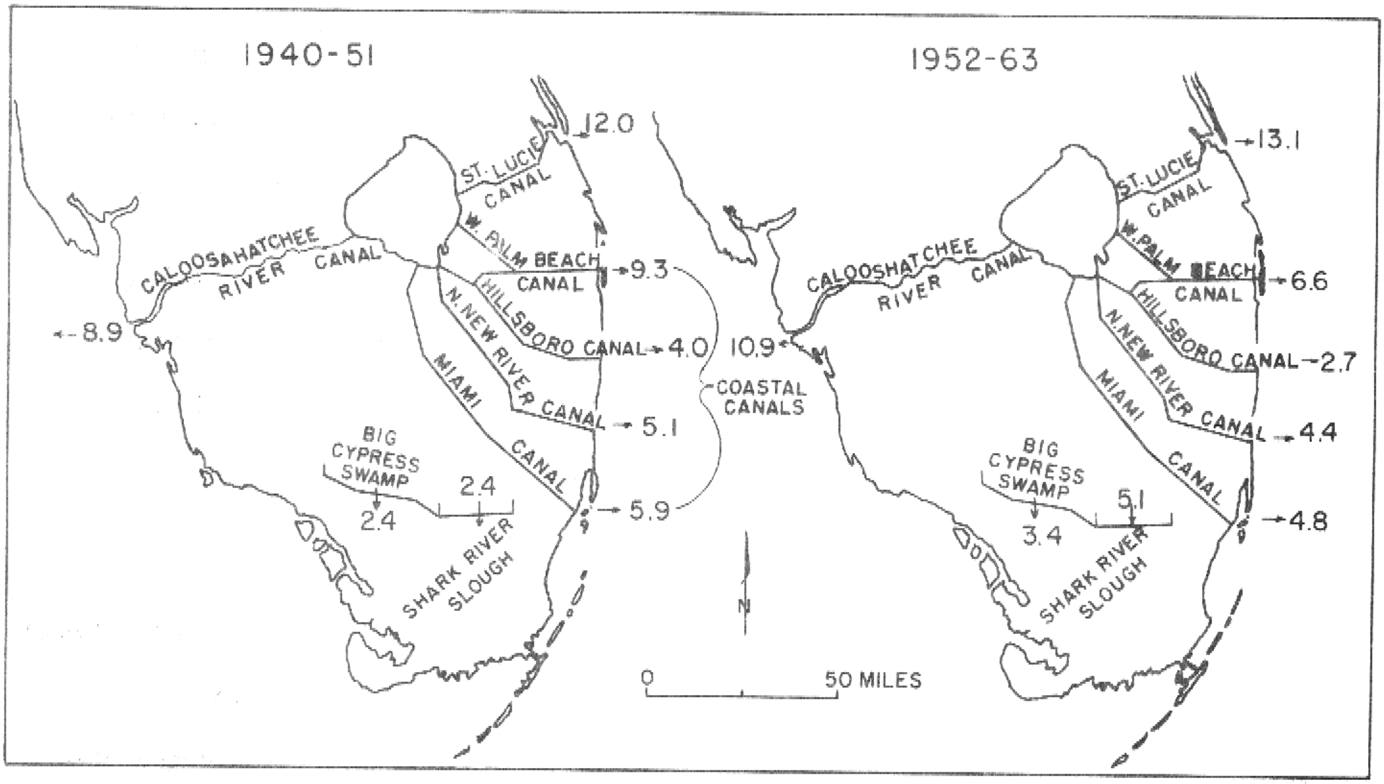
Figure 6.--Graph showing the yearly outflow from Lake Okeechobee to the Everglades. Net flow is reversed in some years.

period 1940-1951, the net flow was toward the lake, as compared with 5 years during 1952-63. In Table 1 and figure 6, the values of outflow (O_E) from Lake Okeechobee that are prefaced by a negative sign indicate that the net flow was reversed, that is, from the Everglades to Lake Okeechobee.

Of significance is the net cumulative amounts of discharge from Lake Okeechobee to the Everglades for each of the two 12-year periods. During the first period 1940-51 the net outflow was 5,422,000 acre-feet. During the second 12-year period 1,518,000 acre-feet was directed toward the Everglades or about 30 percent of the flow of the first period.

Another factor in the hydrologic analysis in south Florida is the discharge to the sea through the major coastal canals: the West Palm Beach, the Hillsboro, the North New River, and the Miami. These flows, shown schematically in figure 7, represent a major part of the runoff to the sea during the two 12-year periods. The summarization shows that the total runoff to the sea through the coastal canals was less during the second 12-year period than during the first. The reduction in runoff of 5.8 million acre-feet in the designated coastal canals more than offset the increase of 3.1 million acre-feet of runoff to the sea through the St. Lucie and Caloosahatchee Canals.

There are several possible reasons for the differences in coastal canal runoff in the two 12-year periods. The decreased runoff for 1952-63, as compared with the earlier period, 1940-51, may be due in part to the slight



CHANNEL	DISCHARGE, MILLIONS OF ACRE-FEET		
	1940-51	1952-63	DIFFERENCE
CALOOSAHATCHEE CANAL	8.9	10.9	+2.0
ST. LUCIE CANAL	12.0	13.1	+1.1
SUB TOTAL	20.9	24.3	+3.1
COASTAL CANALS	24.3	18.5	-5.8
TOTAL TO THE SEA	45.2	42.5	-2.7
TO SHARK RIVER SLOUGH	2.4	5.1	+2.7
FROM BIG CYPRESS SWAMP	2.4	3.4	+1.0

Figure 7. Comparison of discharges in south Florida for two 12-year periods.

decrease in rainfall on the coastal ridge (fig. 4). Another factor is the improvement and construction of several additional canals through the coastal ridge in southeast Florida during the period 1952-63, which intercepted some of the runoff that previously drained through the designated coastal canals. Also, better control of flow in the coastal canals as a result of the levee systems to the east of the three conservation areas and other new control works of the Central and Southern Florida Flood Control Project were significant factors in the reduced runoff.

Other, 12-year discharges shown on figure 7 are those from the Big Cypress Swamp and those into the Shark River Slough. This overland runoff enters the Everglades National Park at the park's northern boundary. The values for the Big Cypress Swamp were computed from records of the Geological Survey's gaging station, Tamiami Canal outlets, 40-mile bend to Monroe, Fla. The discharges into Shark River Slough were computed from a summation of records for the gaging station; (1) Tamiami Canal outlets, levee 30 to levee 67A, near Miami, Fla., and (2) a major portion of the flow for Tamiami Canal outlets, levee 67A to 40-mile, near Miami, Fla. A more detailed description can be found in a report by Hartwell (1963).

The seasonal discharge to the sea for the two 12-year periods is shown in figure 8. Depicted are the dry season and wet season flows, the dry season extending from November to April and the wet season from May to October. The dry season discharge comprised 46 percent of the total outflow

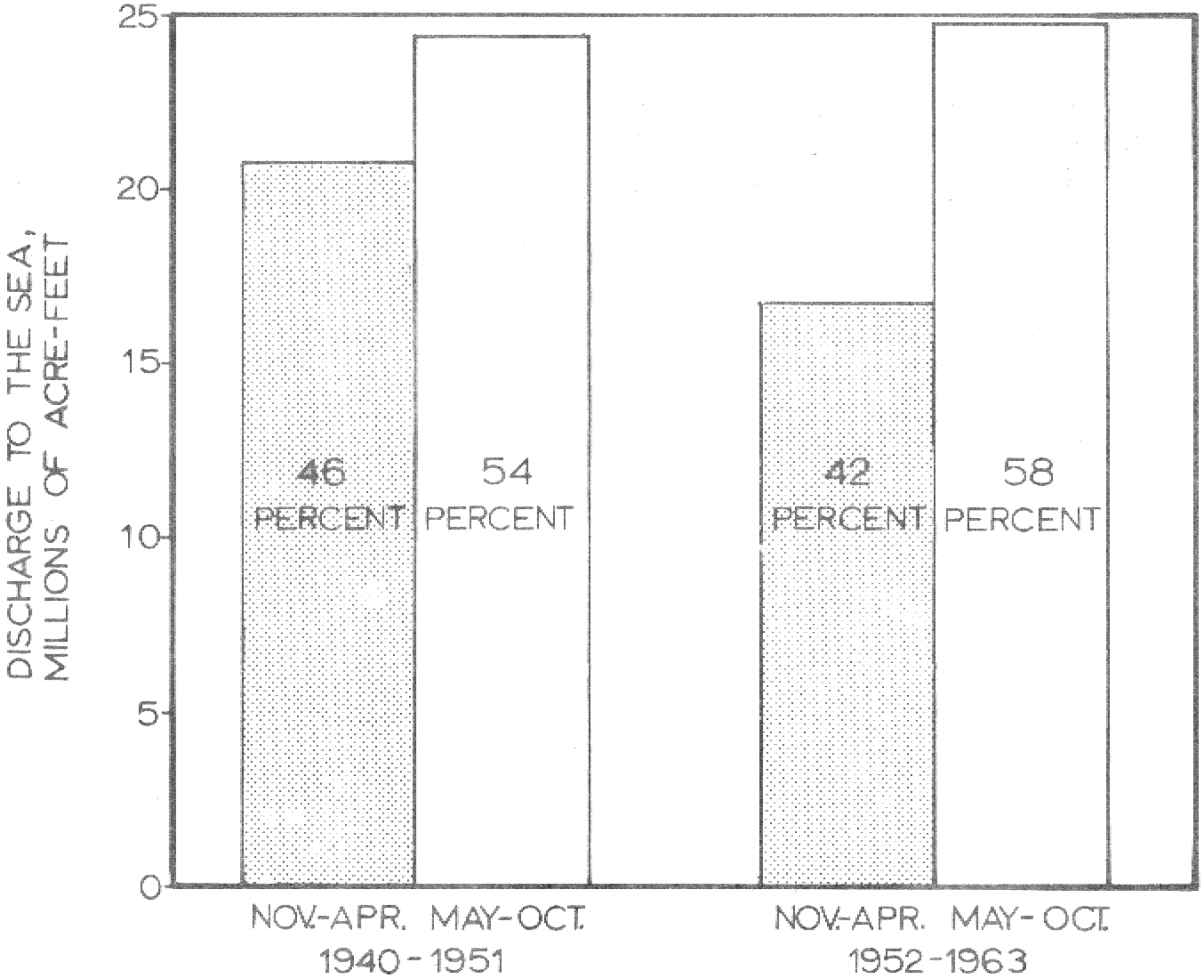


Figure 8. Distribution of discharge to the sea in the dry and wet seasons through the six canals shown in figure 7. Shaded part represents the dry season.

during the period 1940-51 and 42 percent in the latter period. A more detailed distribution of wet and dry season flows is shown in figure 9. It can be seen that during many years, the dry season discharge was greater than the wet season discharge in some of the canals. The dry season flow through the St. Lucie and Caloosahatchee Canals reflects the effort to maintain the water level in Lake Okeechobee within the limits of a regulation schedule.

As interpreted from the 12-year averages, see Table 1, the outflow from Lake Okeechobee to the Everglades during the second period (1952-63) was about one-third that during the first period. On the other hand, the average flow across the Tamiami Trail to Shark River Slough during the second period was more than double that of the first period. This indicates that the increased flows to Shark River Slough resulted from factors other than outflow from Lake Okeechobee.

Figure 10 depicts the cumulative discharge from Lake Okeechobee to the Everglades and that through the Tamiami Canal outlets to Shark River Slough

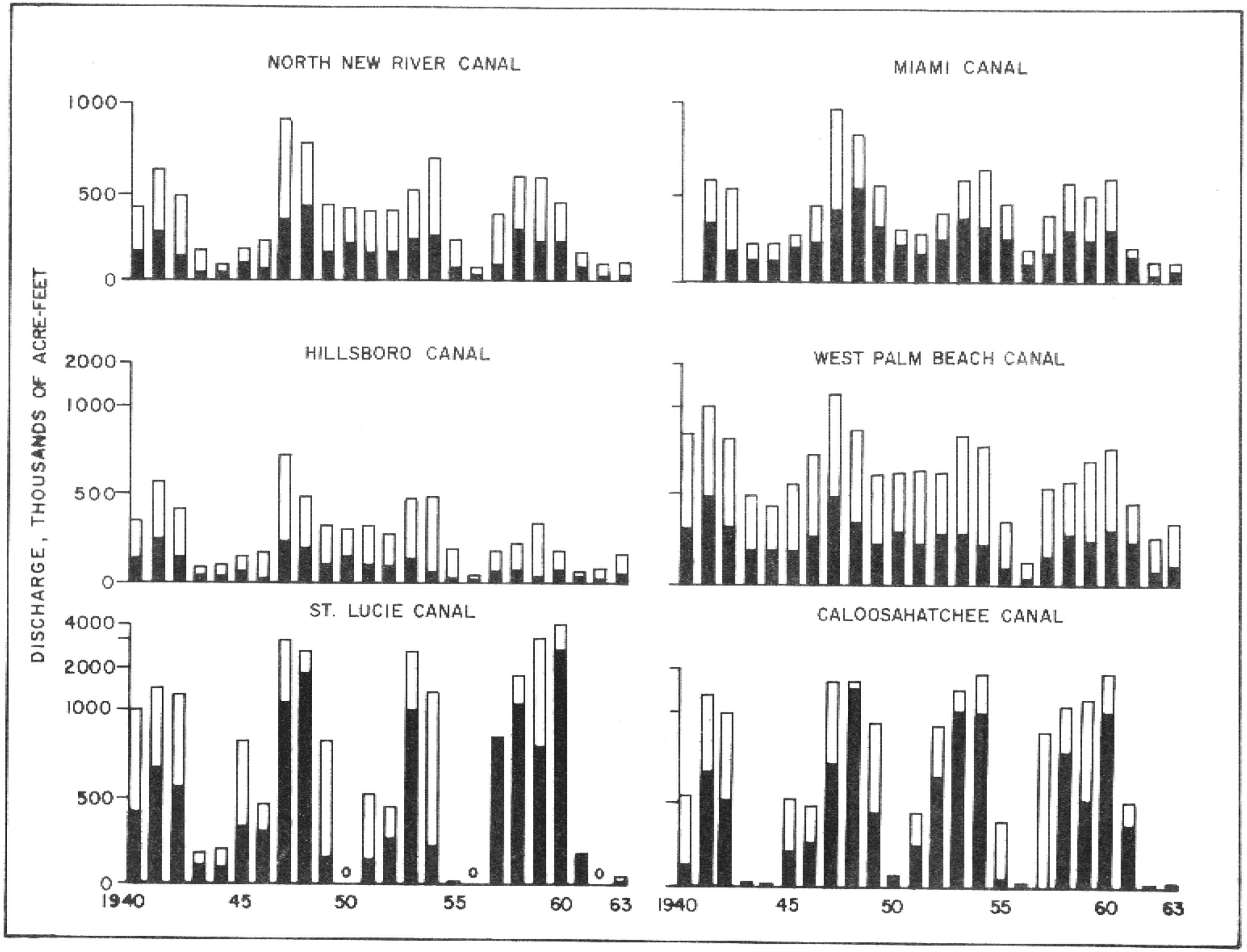


Figure 9. Annual discharges to the sea through six major canals in south Florida. The black part represents the discharge in the dry season (November through April) when, on the average, less than 20 percent of the annual rainfall occurs.

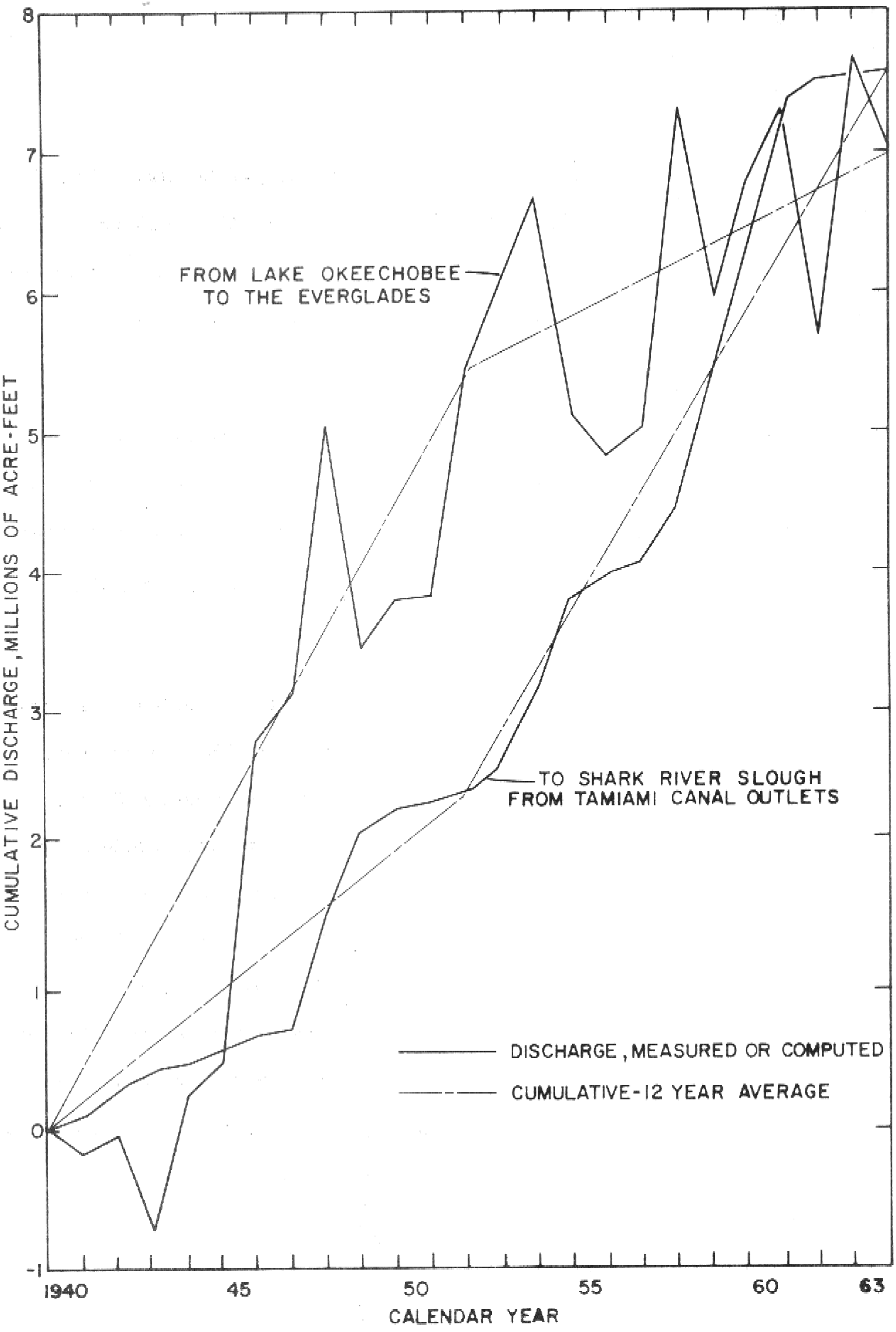


Figure 10. Cumulative water movement between Lake Okeechobee and the Everglades and that through the Tamiami Canal outlets to Shark River Slough, 1940-63.

from 1940 to 1963. The graph indicates a trend of increased flow to Shark River Slough and decreased flow from Lake Okeechobee to the Everglades. These trends indicate that the increase in flow to Shark River Slough was probably the result of an increase in rainfall and a reduction in runoff to the sea through the coastal canals.

Records of rainfall were analyzed to determine the significance of the increased rainfall in the second period,as depicted in figure 4. The rainfall values listed in Table 2 are the average of the following "index" stations: North New River Canal 2 (Pump Station 7), Pennsuco 4 N.W., and Tamiami Trail 40-Mile Bend.

These stations were selected as indexes because their period of record extends through 1940-63 and,more importantly,because of their geographic distribution in relation to Conservation Area No. 3. The average of the rainfall at the three stations in either 12-year period is not presented as an actual amount of rainfall on the entire conservation area, but is used to compare general rainfall amounts received during the two periods. From Table 2, the aggregate 12-year rainfall for the period 1952-63 was 85.86 inches greater than in the period 1940-51. This would represent an average increase of 7.2 inches annually in the second 12-year period. For comparison, such an increase is approximately 30 percent larger than the 5.5 inch average computed for the entire Everglades region,as shown in figure 4.

Table 2. Average yearly rainfall on Conservation Area No. 3

Year	Rainfall (inches)	Year	Rainfall (inches)
1940	59.57	1952	51.62
1941	57.28	1953	67.51
1942	53.45	1954	59.98
1943	49.88	1955	52.66
1944	45.49	1956	51.85
1945	46.55	1957	73.84
1946	41.62	1958	65.69
1947	76.94	1959	74.02
1948	58.83	1960	67.60
1949	52.59	1961	44.00
1950	54.96	1962	55.77
1951	39.13	1963	57.61
Total	636.29	Total	722.15
1940-51 Average	53.02	1952-63 Average	60.18

The U. S. Corps of Engineers (1968) made an analysis of the rainfall on the same general area for the two 12-year periods, beginning in 1940 and 1952. Records of differing lengths from nine stations for the first 12-year period were compared with records of differing lengths from 16 stations for the second 12-year period. The Corps of Engineers, written communication (1969), found that rainfall during the second 12-year period was greater than the first but only by 1.87 inches per year. In the Corps report (1968, Appendix 1, page C-32), they concluded that "Comparison of two 12-year periods beginning in 1940 and 1952 shows that rainfall during the two periods was essentially equal." For this report, it was decided that the three index stations provided a more valid comparison of the two 12-year periods,for they were the only representative stations with observations for the full, 24-year period.

The effect of an increase in yearly rainfall of 7.2 inches would be an addition of 4.2 million acre-feet of water to Conservation Area No. 3 (A and B) in the second 12-year period. As shown on figure 7, flow into Shark River Slough during this period was 5.1 million acre feet, 2.7 million acre-feet more than it was during the earlier period. The difference of 1.5 million acre-feet between rainfall on Conservation Area 3 and runoff from Conservation Area No. 3 during the second 12-year period can be attributed largely to evapotranspiration losses, for the yearly evapotranspiration exceeds 40 inches in most years (Parker and others,1955). As the evapotranspiration probably amounted to more than 1.5 million acre-feet, a part of the increased flow to Shark River Slough resulted, at times, from a southward diversion caused by the completion, in 1952, of levees 37, 33, 30, and 31N, as shown on figure 3.

The levee system east of the three conservation areas intercepts water that formerly flowed eastward and routes this water southward through the Everglades toward the Shark River Slough. This water formerly discharged to the Atlantic Ocean through the major coastal canals. As shown in figure 7, flow to the sea was 5.8 million acre-feet less in the second 12-year period than in the first, and some of the increase in flow to Shark River Slough probably was the result of the reduction inflow to the sea.

A similar rainfall-runoff comparison for the Big Cypress Swamp area shows that an annual increase in rainfall of 4.7 inches in the second period resulted in a 1.0 million acre-feet increase in runoff. Although rainfall-runoff comparisons are, at best, inferences, an increase in discharge for both the Big Cypress Swamp and to Shark River Slough reflects the increase in rainfall in the second 12-year period. It is therefore concluded that the increased discharge to Shark River Slough during the period 1952-63 resulted from both the increase in rainfall on Conservation Area No. 3 and the reduction in flow to the sea.

SUMMARY AND CONCLUSIONS

Hydrologic information was evaluated to determine the source of water in south Florida that flowed from the north into Everglades National Park. In particular, consideration was given to overland flow of water to the park.

A comparison was made of discharges at several locations for two, 12-year periods, 1940-51 and 1952-63. The first period was prior to the construction of water control works for the Central and Southern Florida Project. The second period covered the time during which control works were progessively being built. Discharge from Lake Okeechobee to the Everglades was 5.4 million acre-feet for the period 1940-51 and 1.5 million acre-feet during 1952-63. In spite of the reduction in flow from Lake Okeechobee to the Everglades in the second period, the flow to the Everglades National Park into the Shark River Slough was 2.7 million acre-feet greater in the second period than during the first period. An increase in rainfall on Conservation No. 3 in the period 1952-63 probably contributed significantly to the increased discharge to Shark River Slough, but some of the increase in discharge apparently resulted from new control works of the Central and Southern Florida Project,which reduced flow to the sea through the coastal canals.

REFERENCES

Hartwell, J. H., Klein H., and Joyner B.F., 1963, Preliminary evaluation of hydrologic sitatuion in Everglades National Park, U. S. Geol. Survey open-file report, 25 p.

Heilprin, A., 1887, Explorations on the west coast of Florida and in the Okeechobee wilderness, Warner Free Institute of Science of Philadelphia, p. 34-51.

Parker, G. G., Ferguson, G. E., Love, S. K., and others, Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami area: U. S. Geol. Survey Water-Supply Paper 1255, 965 p.

U.S. Army Corps of Engineers, 1967, Monthly report of operations Lake Okeechobee, 12 p.

U. S. Army Corps of Engineers, 1968, Survey-Review Report on Central and Southern Florida Project water resources for Central and Southern Florida, 75 p.

U. S. Geological Survey, 1913, Surface water supply of the U. S., pt. 2, south Atlantic slope and eastern Gulf of Mexico basins, WSP 352, 84 p.

U. S. Weather Bureau, Climatological data 1940-63.