INTRODUCTION

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AREA OF INVESTIGATION

The afore-mentioned water-resources and geologic investigations cover most of southern Florida in a general way. However, it is those parts of southeastern Florida considered to be a present or future source of water supply for Dade County and the cities of Miami, Miami Beach, and Coral Gables that is the principal area of investigation covered by this report. It includes most of Dade County, the Everglades, Lake Okeechobee, and parts of Kissimmee River basin and Big Cypress Swamp (see fig. 1).

Investigations of surface-water supply were most intensive in Kissimmee River basin, around Lake Okeechobee, and along the drainage canals because the well-defined surface channels were limited mostly to those areas. Likewise, the investigations of ground-water supplies, with their attendant geologic studies, were concentrated in the Miami area where the promising Biscayne aquifer was found early in the investigation to be of prime importance.

As a result of the war emergency, water-resources investigations (including comprehensive geologic studies) were made in other areas in southern Florida extending along the Atlantic Coastal Ridge from Cocoa on the north to Key West on the south and along the Gulf coast north to and beyond Sarasota. The cooperative studies with the cities of Fort Pierce, Lake Worth, Delray Beach, Fort Lauderdale, Dania, and Fort Myers were of considerable help in filling in local details of the investigation.

PURPOSE OF THE INVESTIGATION

The rapid increase in population of southern Florida during the past two decades has been phenomenal. As a concomitant of this large population growth there has been increased usage of the natural resources of the area, and various attempts have been made to develop these resources.

The result has been a radical change in the natural hydrologic balance; some changes, which were not anticipated, have had deleterious effects. To study these changes, present conditions, and possible future changes, the U. S. Geological Survey, in cooperation with the cities of Miami, Miami Beach, Coral Gables, and Dade County, began an investigation of the water resources of southeastern Florida in the fall of 1939 (some records of stage and discharge of streams were started in 1930). Particular emphasis was placed on the geology and ground water of the Miami area.

Table 1.— *Population of 12 counties in area of investigation*

[From United States Census and Florida State Census]

County	1890	1900	1910	1920	1930	1935 State census	1940	1945 State census	1950
Broward (Created in 1915 from Dade and Palm Beach)				5,135	20,094	23,042	39,794	50,442	83,933
Collier (Created in 1923 from Lee)					2,883	4,790	5,102	4,957	6,488
Dade (Created in 1836)	861	4,955	11,933	42,753	142,955	180,998	267,739	315,138	495,084
Glades (Created in 1921 from DeSoto)					2,762	2,673	2,745	2,281	2,199
Hendry (Created in 1923 from Lee)					3,492	3,711	5,237	5,066	6,051
Highlands (Created in 1921 from DeSoto)					9,192	10,912	9,246	16,224	13,636
Lee (Created in 1887 from Monroe)	1,414	3,071	6,294	9,540	14,900	16,351	17,488	23,593	23,404
Martin (Created in 1925 from St Lucie and Palm Beach)					5,111	5,214	6,295	6,094	7,807
Monroe (Created in 1824)	18,786	18,006	21,563	19,550	13,624	13,354	14,078	19,018	29,957
Okeechobee (Created in 1917 from Osceola, Palm Beach, St. Lucie)				2,132	4,129	3,484	3,000	2,919	3,454
Palm Beach (Created in 1909 from Dade)			5,577	18,654	51,781	53,194	79,989	112,311	114,688
St. Lucie (1905 recreated)			4,057	7,886	7,057	9,044	11,871	12,958	20,180
Total of the 12 counties	21,061	26,032	49,424	105,650	277,980	326,767	462,584	571,001	806,881
State of Florida	391,442	528,542	752,619	968,470	1,468,211	1,606,842	1,897,414	2,250,061	2,771,305
Proportion of the 12 counties to the State total, in percent	5.4	4.9	6.6	10.9	18.9	20.3	24.4	25.4	29.1
Metropolitan Miami area		1,681	5,471	30,215	126,588	154,411	218,000	254,154	[1]458,647

[1]Metropolitan Miami area has grown at expense of rural areas.

Prior to the entrance of the United States into World War II, the coastal ridge was principally a resort area, with agricultural, commercial, and business interests of only secondary importance; very little manufacturing was done. However, war-time activities created a tremendous stimulus to air, rail, and water transportation, and to agriculture, business, and commerce. Light manufacturing, shipbuilding and repairing, and service industries became important. As a result of these activities the once marked seasonal fluctuation of the population has noticeably diminished.

West of the coastal ridge, and on the southern end of the ridge beyond South Miami, the principal development is agriculture; on the higher limestone areas, citrus fruits, avocados, mangoes, guavas, and other subtropical fruits are grown. The lower lands of the coastal marshes and the Everglades produce truck vegetables and sugarcane.

The principal soils of the Everglades are organic (peats and mucks) and cover 1,900,000 acres (Jones, 1948, p. 63) of which about 100,000 acres (Allison, 1939, p. 37) was intensively cultivated in 1939. Under the stimulus of World War II, low-water conditions for several years, and the refinancing of Everglades Drainage District, this acreage was about doubled by 1946. The largest development is in the northern part of the Everglades where the soil is thickest (about 8 feet) and where water control can be most effectively practiced. The important crops are sugarcane and truck vegetables; ramie, a fiber plant, shows promise of becoming a valuable crop in the Everglades organic soils, and the fattening of beef cattle is becoming increasingly important.

PROBLEMS RESULTING FROM DEVELOPMENT

Among the most serious problems resulting from the development of southern Florida are those that arose in part, at least, from the superimposed hydrologic effects of the drainage canals, first constructed about the turn of the century in the interest of reclamation of the Everglades. The construction of the drainage canals has lowered the average water level several feet, not only in the Everglades but also in the coastal ridge. As a result, during times of drought the organic soils dry out almost to the water table, which may fall several feet below the land surface (see figs. 127a and 152); in places beneath the coastal ridge the water table may even fall below sea level, especially during a protracted drought (see figs. 42 and 45).

Among the effects of this network of drainage canals on the land, crops, and wildlife of the Everglades have been the following:

1. Shrinkage, compaction, oxidation, burning, and general subsidence of the organic soils. This loss is reported by Jones (1948, p.

79) to be much as 5 feet over extensive areas of the cultivated organic soils; the soil has disappeared in some areas where it was thin.

2. Development of shallow "subsidence valleys" along each major canal extending laterally for 3 to 4 miles (Evans and Allison, 1942, p. 34-46).

3. Increase in damage due to frosts, which formerly had been held in check by the large body of water in the Everglades (Clayton, Neller, and Allison, 1942, p. 5).

4. Reduction of much of the original capacity of the canals, owing to loss of vertical section. This condition results from lowering of the land surface; sedimentation of the canal bottoms; slumping of canal banks especially in sand cuts; and blocking by water weeds (such as water hyacinths), fallen trees, and other debris.

5. Cessation of deposition of the organic material that has built the peat and muck soils.

6. Changed ecologic conditions seriously affecting wildlife of the drained areas. This has brought about the migration of some species and the extinction, or near extinction, of others—one of these is the Everglades kite, now almost extinct because of the drainage of the swamps and the destruction of a certain species of fresh-water snails upon which the kite feeds solely (O'Reilly, 1940, p. 129 131-134).

Water problems have become of prime importance. Among these are:

1. The development and protection from salt-water contamination of adequate perennial water supplies for the populous cities and agricultural areas along the coast. It was noted in 1940 that the consumption was about 50 mgd during the winter season for the communities from West Palm Beach to Key West, and that Miami consumed a maximum the previous year of about 33 mgd. It was estimated that in 1946, because of the greatly increased population, approximately 50 percent more water was used. In Miami alone, monthly consumption during the last 6 months of 1946 averaged 56 mgd; this is 171 percent of the monthly consumption for the same period in 1940.

2. Unregulated flow in the canals during droughts, which allows salty water to move inland in and along the canals (even beyond the coastal ridge in some places), thus contaminating the fresh ground water in adjacent areas. Salty water was observed 11 miles inland in the Miami Canal in 1939.

3. Changing the naturally established equilibrium that had existed between fresh- and salt-water bodies, by a lowering of the fresh-water head in the Biscayne aquifer, which brought about general encroachment of salt water at depth in the aquifer all along the coastal strip. In the Silver Bluff area of Miami this salt-water movement extended inland for a distance of more than 2 miles from Biscayne Bay in 1946.

4. Regulation of the water level in Lake Okeechobee and the canals leading oceanward from it. The St. Lucie and Caloosahatchee Canals form links of the cross-state waterway between Stuart and Fort Myers, on which the Federal Government maintains navigation. The lake is usually held at levels between 12.6 and 15.6 feet above mean sea level, U. S. Coast and Geodetic Survey datum, or 14 and 17 feet, Okeechobee datum. This regulation has been deemed necessary in order to supply adequate water for transportation and, at the same time, to maintain the lake level at a point low enough to prevent hurricane waves from overtopping the flood levee and inundating the adjacent lands. In normal years such control is not difficult, but following a prolonged drought, or a series of exceedingly wet months, it is much more difficult. Regulation to meet the needs of navigation alone would not be too difficult, but the additional consideration of agricultural needs complicates the regulation considerably.

5. Shortage of water for irrigation, municipal supplies, and all other needs in drought periods. Distribution of rainfall is uneven, and means have not been found to store excess water in wet periods.

6. Overloading of the main canals because of added drainage works that facilitate rapid runoff.

7. Flooding of urban developments that have been built in natural floodways during extended periods of low water levels.

SCOPE OF THE INVESTIGATION

The general scope and objectives of the investigations by the U. S. Geological Survey were largely determined during conferences with representatives of cooperating agencies prior to the beginning of work in the fall of 1939. The local motivating interest was the need for one or more sources of water supply sufficient for present and future municipal needs of the metropolitan area of Miami and for agricultural and industrial purposes of Dade County. These interests were stimulated by the loss to salt-water encroachment of two former well fields of the city of Miami and thousands of private well supplies along the coast of Dade County, and by the recurring threats to the principal existing source of municipal supply. Accordingly, U. S. Geological Survey activities throughout the period

of study have included the investigation of factors pertinent to an evaluation of all significant sources of water supply that could possibly be utilized by the residents of the cooperating county and municipalities.

As originally planned however, this cooperative program with the above objectives was only a part of a broader concurrent activity by other Federal and State agencies and was known as The Southeastern Florida Joint Investigation. This investigation, initially sponsored and coordinated by the National Resources Planning Board in cooperation with the Florida State Planning Board, also included work programs for the Soil Conservation Service, the Bureau of Agricultural Economics, and the Fish and Wildlife Service. The Corps of Engineers agreed to supply data from its files as needed by the other agencies during the period of investigation. The main objective of the joint investigation was a general study of the natural resources of southeastern Florida for the benefit of future development in the area.

Prior to the termination of its activities on April 1, 1941, the National Resources Planning Board, cooperating with the Florida State Planning Board, coordinated the operations of the several participating agencies through its local representative, Stanley B. Wright. Therefore, although the Southeastern Florida Joint Investigation did not continue as such beyond this date, the several agencies have continued to work together in the interests of greatest benefit to the citizens of the area.

It was recognized that an evaluation of possible development of water supply would require the collection of basic geologic, hydrologic, hydraulic, and chemical data over a wide area in southern Florida. For example, the study of existing and possible future ground-water sources in Dade County necessarily included an investigation of the rock structure, not only in the immediate vicinity but over most of southern Florida, to determine and evaluate basic geologic controls and general characteristics of recharge and ground-water movement. Likewise, studies of possible surface-water sources necessarily included the evaluation of such fairly distant supplies as Kissimmee River and Lake Okeechobee, the nature of recharge to and discharge from the lake, and the hydraulic and geologic characteristics of all major waterways in the Everglades and the coastal ridge. Determinations of chemical quality of water were made of samples from all water sources investigated.

This report therefore is a compilation of basic information relating to the quantity, chemical quality, and availability of the water resources, and the method of utilization most practicable for development by the cooperating county and municipalities. Most of the data were collected from field observations and research in

geology and hydrology made during the period of investigation, beginning in the fall of 1939 and extending through the fall of 1946. Considerable additional data were collected either by the U. S. Geological Survey during other programs of observation, including war-service-connected work, or furnished by other interested parties. A minor amount of information collected by the Survey as late as 1950 has been incorporated into the report.

No attempt is made herein to recommend or specify the details of development of any water supply, because this is not within the Survey's authorized activities. Instead, it is intended that the report should serve as a comprehensive and convenient reference for those charged with the responsibility of both developing and protecting water supplies and for those who use or control water in significant quantities. The data are such as to be useful not only in municipal water-supply development but also in all developments in the southern Florida area that are in any way dependent upon or affected by water.

PREVIOUS INVESTIGATIONS

Information concerning the geology and water resources of southern Florida is contained in numerous published and unpublished reports. Prior to the present investigation no intensive study of the water resources of southern Florida had been made; Matson and Sanford's 1913 report and Stringfield's 1933 and 1936 reports are among the most important contributions. Significant reports are included in the selected bibliography which appears at the end of this report.