UNITED STATES
DEPARTMENT OF THE INTERIOR
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ANNOTATED BIBLIOGRAPHY OF THE GEOLOGY AND HYDROLOGY OF THE SURFICIAL AQUIFERS IN DADE, BROWARD, AND PALM BEACH COUNTIES, FLORIDA

By Carmen R. Causaras

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JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

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

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ABSTRACT

Bibliographic citations and abstracts from 147 hydrologic and geologic investigations of the surficial aquifers of southeast Florida are listed in this annotated bibliography. The citations are listed alphabetically by the senior author's name.

INTRODUCTION

In 1979 the U.S. Geological Survey, in cooperation with the South Florida Water Management District, began a comprehensive investigation to assess the hydraulic, geologic, and water-quality characteristics of the surficial aquifers of southeast Florida. As part of this investigation, a literature search was made to identify previous studies that provide information and background hydrologic and geologic data on the surficial aquifers in Dade, Broward, and Palm Beach Counties.

Citations, annotations, and references for the reports are arranged alphabetically by author (senior author's name in cases of multiple authorship). In designated instances, all or part of the author's abstract or introduction is used in preference to an annotation written specifically for this summary. Geologic terminology is as it appears in the original source, and its use herein does not constitute acceptance by the U.S. Geological Survey.

BIBLIOGRAPHY

Appel, C. A., 1973, Electrical-analog model study of a hydrologic system in southeast Florida: U.S. Geological Survey open-file report FL-73004.

"The hydrologic system of southeast Florida consists of the Biscayne aquifer, a system of levees and canals, and related water-control facilities. Because the canals cut into the highly permeable aquifer, the aquifer and canals form a hydraulically connected system. Thus, manipulation of water levels in a canal influences levels in the aquifer and conversely, pumping from the aquifer affects conditions in nearby canals.

"An electrical analog model of the aquifer-canal system was built. This model will be useful to determine the effects of alternative water management plans that would be impractical to essay by field investigation. Electrical stresses are imposed on the model approximately analogous to real stresses observed in the field for one month in 1962. Adjustments were made to the model, particularly to the electrical components used to simulate the hydraulic connection between the aquifer and canals so that the relation between model results and observed conditions was acceptable. Criteria used for this comparison are the net water-level changes over the one-month period and changes in canal flow.

"The analog model is used to estimate future water needs for southeast Dade County during the typically dry season, November through May. The canal network modeled includes major existing and planned canals. The results provide an estimate of the water that will be needed to satisfy anticipated demand for public supply, irrigation, and evapotranspiration for 90 percent of the years, using canal water levels specified as optimum by management agencies." (Quoted from author's abstract.)

Appel, C. A., and Klein, Howard, 1969, Hydrogeologic data related to establishment of a pumping station in the Everglades National Park, Florida: U.S. Geological Survey open-file report FL-69010.

"In order to alleviate the effects of prolonged drought on the plant and animal life in the northeastern part of the Everglades National Park, Florida, the National Park Service considered the possibility of pumping ground water from a collection gallery to replenish deficient water in the Shark River Slough area. Design criteria called for a sustained yield of 100 cfs (cubic feet per second) from a 4,000-foot gallery for as long as 100 days, with a resultant drawdown not to exceed 8 feet in the gallery.

"Results of tests along the northeastern boundary of the Park showed that the proposed gallery would yield only about 10 percent of the required rate. Results from an alternate site, from 10 to 14 miles to the south, indicated that a gallery there would have to be at least 20,000 feet long to yield 100 cfs." (Quoted from authors' abstract.)

Bearden, H. W., 1973, Hydrologic data for 1971, Broward County, Florida: U.S. Geological Survey open-file report FL-73016.

"This report is the first of an annual series that will describe the hydrologic conditions in Broward County, Florida. The general hydrologic conditions in Broward County for the 1971 water year (October 1, 1970, to September 30, 1971) are portrayed by graphically comparing long periods of record from rainfall, ground-water, surface-water, and water-quality stations with records from these stations for the 1971 water year. Major changes in hydrologic conditions in any year generally are a direct result of the amount and distribution of rainfall during that year. Major areal changes in conditions which may be permanent, result from construction of canals for drainage, establishment of controls on canals, withdrawals, and other such actions." (Quoted from author's introduction.)

Bearden, H. W., 1974a, Hydrologic data for 1972, Broward County, Florida: U.S. Geological Survey open-file report FL-74005.

"This report is the second of an annual series presenting hydrologic data in Broward County, Florida. The hydrologic data in Broward County for the 1972 water year are compared with long periods of records from rainfall, ground-water, surface-water, and water-quality stations." (Quoted from author's introduction.)

Bearden, H. W., 1974b, Ground-water resources of the Hollywood area, Florida: Florida Bureau of Geology Report of Investigations no. 77.

"Population in the Hollywood area increased more than 200 percent from 1960 to 1970 (35,237 to 106,873) and the growth in population is expected to continue. This explosion in population is the source of most of the area's water problems.

"Fresh water for all purposes in Hollywood is derived from the highly permeable Biscayne aquifer. The aquifer is composed chiefly of permeable beds of limestone, sandstone, and sand that extend from land surface to a depth of about 200 feet.

"Water levels in the aquifer fluctuate chiefly in response to rainfall, the major source of recharge. The water table slopes gently from the west and averages about 1.0 foot higher in the western part of the city than in the eastern part. The configuration of the water table is greatly influenced by Hollywood Canal and the ocean. Because the permeability of the aquifer is high, the effect of pumping of wells is dispersed over a large area and drawdowns are about 0.1 foot.

"Salt-water intrusion from Hollywood Canal is the chief threat to the ground-water supply in Hollywood. When discharge is low, the chloride concentration of water in the canal has reached levels greater than 10,000 milligrams per liter. Salt water has been detected in the aquifer at depth within 0.1 mile of the municipal wells.

"Results of test drilling and water quality analyses indicate that ground water of good quality is available in the western part of the Hollywood area. Because the transmissivity of the Biscayne aquifer is high, with proper planning additional quantities of water can be obtained without affecting water levels significantly in existing wells." (Quoted from author's abstract.)

Bearden, H. W., 1974c, Hydrologic data for 1973, Broward County, Florida: U.S. Geological Survey open-file report FL-74028.

"This report, the third of an annual series presenting hydrologic data in Broward County, Florida, includes hydrologic data for the 1973 water year. In it these data are compared with long-term records from rainfall, ground-water, surface-water, and water-quality stations." (Quoted from author's introduction.)

Bearden, H. W., 1975, Hydrologic data for 1974, Broward County, Florida: U.S. Geological Survey open-file report FL-75006.

"This report, the fourth of an annual series presenting hydrologic data in Broward County, Florida, includes hydrologic data for the 1974 water year. In it these data are compared with long-term records from rainfall, ground-water, surface-water, and water-quality stations." (Quoted from author's introduction.)

Beaven, T. R., 1979, Hydrologic conditions in Broward County, Florida, 1976: U.S. Geological Survey Open-File Report 79-1258.

This report, the sixth of an annual series presenting hydrologic data in Broward County, Florida, includes hydrologic data for the 1976 water year. In it these data are compared with long-term records from rainfall, ground-water, surface-water, and water-quality stations.

Beaven, T. R., and McPherson, B. F., 1978, Quality of the water in borrow ponds near a major highway interchange, Dade County, Florida, October-November, 1977: U.S. Geological Survey Open-File Report 78-1029.

"Water, bottom sediment, and aquatic plants were sampled from ponds near a major south Florida highway interchange to document concentrations of selected constituents in an aquatic environment near heavy vehicular traffic. Generally, concentrations of constituents were within the range expected in an uncontaminated environment in south Florida. However, concentrations did exceed south Florida background levels or Environmental Protection Agency criteria in a few cases. Two trace elements--chromium (20 micrograms per liter) in ponded surface water and lead (500 micrograms per gram) in bottom sediment--exceeded background levels. Concentrations of dieldrin (22 micrograms per kilogram) and polychlorinated biphenyls (53 micrograms per kilogram) also exceed background levels in bottom sediment. The concentration of phenol (23 micrograms per liter) in ground water exceeded Environmental Protection Agency quality criteria by 22 micrograms per liter, but was within the background range for south Florida. Ten metals were detected in the cattail or algal samples, but only iron, manganese, and zinc were in higher concentrations than those in the bottom sediment." (Quoted from authors' abstract.)

Benson, M. A., and Gardner, R. A., 1974, The 1971 drought in south Florida and its effect on the hydrologic system: U.S. Geological Survey Water-Resources Investigations 12-74.

"The 1971 dry season rainfall in south Florida was low enough that the public media and concerned public officials unanimously characterized the event as a severe drought.

"Rainfall over all of south Florida during the 1970 wet season and the 1970-71 dry season was less than 85 percent of normal, as was the 1971 wet season on the heavily populated southeast coast of Florida. Rainfall during the dry season ranged from 20 to 63 percent of normal and recurrence intervals for dry season rainfall of this magnitude ranged from 100 years to several hundred years.

"Canal flow and ground-water levels reflected the drought conditions but in most cases did not set record lows. No permanent undesirable effects occurred as a result of the drought." (Quoted from authors' abstract.)

Broward, R. H., and Parker, G. G., 1945, Saltwater encroachment in limestone at Silver Bluff, Miami, Florida: Economic Geology, v. 40, no. 4.

This report discusses the saltwater encroachment problem in the Silver Bluff area with relation to the Ghyben-Herzberg Theory.

Buchanan, T. J., and Hartwell, J. H., 1972, Analysis of water-level data for Everglades National Park, Florida: U.S. Geological Survey open-file report FL-72004.

"Stage-duration curves were developed for five gaging stations in Everglades National Park, Florida. Four of the five curves show similar characteristics with an increase in the slope when the water level is below land surface. Monthly stage-duration curves, developed for one of the stations, reflect the seasonal trends of the water level.

"Recession curves were prepared for the same five stations. These curves represent the average water-level decline during periods of little or no rainfall. They show the decline in level at the end of 10, 30, and 60 days for any given initial stage. A family of curves was also prepared to give the recession from various initial stages for any period up to 60 days." (Quoted from authors' abstract.)

Buchanan, T. J., and Klein, Howard, 1976, Effects of water management on fresh-water discharge to Biscayne Bay: University of Miami Sea Grant Special Report no. 5; Biscayne Bay Symposium I, Key Biscayne, Florida, 1976, Proceedings.

"Prior to development in southeast Florida, fresh water discharge to Biscayne Bay consisted of flow through natural drainageways, overland flow, and coastal underseepage from the Biscayne aquifer. Through the years, the characteristics of the fresh-water flow have changed from natural, sporadic, short bursts of rainy-season flow through the low drainageways and prolonged dry-season coastal underseepage, to regulated discharge through drainage canals and decreased periods of coastal underseepage.

"The fresh-water flow to Biscayne Bay has been significantly reduced in quantity and in time, due to extensive flood and water-control measures and water-management practices instituted after the extensive flooding of 1947. By the end of 1962, surface flows could be fully controlled in the Everglades by a system of levees and canals, water-conservation areas, pumps, and flow regulation structures. Thus, since 1953 annual fresh-water flow to Biscayne Bay has been reduced by about 20 percent and the duration of storm-water runoff has also been reduced. Flood control measures in south Dade County have altered the pattern of fresh-water flow to the Bay. Ground-water level recession rates in south Dade County are twice as rapid as they were before the implementation of flood control measures there. This means that the Bay receives fresh-water runoff for only about half as long after a storm as it did previously.

"Implementation of planned water-management practices would result in further reduction of fresh-water runoff to the Bay. Further changes in south Biscayne Bay could be expected if urbanization in south Dade County approaches the density of that of Miami and vicinity." (Quoted from authors' abstract.)

Cooke, C. W., 1945, Geology of Florida: Florida Geological Survey Geological Bulletin no. 29.

Following publication of the original "Geology of Florida," by C. W. Cooke and Stuart Mossom, 1929, many deep boreholes were drilled in search of petroleum. Consequently, subsurface formations ranging in age from Recent to Triassic were penetrated. The faunal studies conducted by various scientists, including C. W. Cooke, brought new insight into the stratigraphic relationships of the outcropping formations, and also recognition of several new stratigraphic units.

All the data accumulated from the boreholes, and the newly formed stratigraphic concepts were incorporated in this report which discusses general aspects of the formations found in Florida. The stratigraphic features discussed are: origin of the name, general characteristics, thickness, areal distribution, and stratigraphic relationships of the formations. Also included are fauna and flora typical of each formation followed by the location of the wells that penetrate each formation.

Cordes, E. H., and Gardner, R. A., 1976, Analog model simulations for secondary canal controls and forward pumping in water-management schemes in southeast Florida: U.S. Geological Survey Water-Resources Investigations 76-93.

"The analog model of the Biscayne aquifer of southeast Florida was used to approximate the effects of two proposed water-management schemes. One involved adding a secondary control structure in a major canal which is controlled near the coast. In the model the controls were operated in accordance with canal water level both above and below the secondary control. Although the model could not differentiate between control openings of 1 foot or 5 feet (0.3 metre or 1.5 metres), it showed that the secondary control is a viable method of conserving ground water.

"The second scheme involved pumping ground water ('forward pumping') from the Biscayne aquifer in inland areas during the dry season to: (1) augment canal flows toward the coast to sustain ground-water levels there, and (2) generate additional ground-water storage space for recharge in the wet season. Several sites on the model were programed for forward pumping wells and the storage change was noted as a percentage of the ground-water withdrawal." (Quoted from authors' abstract.)

Cross, W. P., and Love, S. K., 1942, Ground water in southeastern Florida: American Water Works Association Journal, v. 34, no. 4.

The surficial materials in southeastern Florida consist of oolitic limestone and unconsolidated sand, muck, and marl. Highly permeable beds of sandstone, sandy limestone, and sand are found directly underneath these surficial materials.

Very large quantities of ground water available for use were found in the coastal area. Because of the uncontrolled canals; however, the coastal area is threatened by salt-water encroachment.

The composition of the uncontaminated ground water in the coastal area is fairly uniform. The concentrations of total dissolved solids range from 250 to 300 mg/L (milligram per liter), and the total hardness, expressed as calcium carbonate, ranges from 225 to 275 mg/L. Dissolved mineral matter consists largely of calcium and bicarbonate.

Fischer, J. N., 1978, Evaluation of the high permeability zone of the shallow aquifer, Palm Beach County, Florida, in hydrogeology of south-central Florida: West Palm Beach, Florida, 22nd, Field Conference 1978: Southeastern Geological Society Publication no. 20.

The areal extent, thickness, lithology, and hydrologic characteristics of the high-permeability zone were determined from analyses of driller's logs, surface resistivity, and borehole geophysical data. An aquifer test was conducted, and the data were analyzed by using the modified Hantush method for leaky aquifers.

Freiberger, H. J., 1972, Nutrient survey of surface waters in southern Florida during a wet and dry season, September 1970 and March 1971: U.S. Geological Survey open-file report FL-72008.

"A mass nutrient survey of southern Florida surface waters was made in September 1970, during a period of generally high water, and again in March 1971, during a period of low water. Water samples were analyzed by automated chemical techniques for total ortho plus acid-hydrolyzable phosphorus ($P-PO_4$), ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N).

"Phosphorus ($P-PO_4$) concentration averaged about 0.50 mg/1 (milligram per liter) during the wet season; the average concentration was slightly higher during the dry season. At many sites sampled during the wet and dry seasons, less than 0.01 mg/1 of phosphorus was found. At one site in Broward County near a point of sewage outfall, the concentration was 45 mg/1 during the dry season. Ammonia was the most prevalent form of nitrogen detected. Concentrations of NH_3-N ranged from less than 0.01 to 14 mg/1 in the wet season and from less than 0.01 to 25 mg/1 in the dry season. Ammonia nitrogen concentrations averaged about 0.55 mg/1 in the wet season and about 0.50 mg/1 in the dry season. Throughout the study area, nitrite and nitrate concentrations were generally low in both wet and dry seasons. Nitrite ranged from less than 0.01 to 0.70 mg/1 NO_2-N during the wet season and slightly lower in the dry season. Most nitrate concentrations were below 0.20 mg/1 NO_3-N during the wet and dry seasons." (Quoted from author's abstract.)

Freiberger, H. J., 1973, Effects of backpumping from South New River Canal at pump station S-9 on quality of water in Water Conservation Area 3, Broward County, Florida: U.S. Geological Survey open-file report FL-73026.

"The quality of water in Water-Conservation Area 3 is affected by backpumping from the South New River Canal at pump station S-9, as indicated by marked decreases in dissolved oxygen and increases in ammonia nitrogen in the canals of the conservation area. Decreases in dissolved oxygen immediately above S-9 of as much as 5.8 mg/1 (milligrams per liter) were recorded after backpumping, and effects in the canals of the conservation area were detected as far as 3 miles from S-9. Increases in ammonia immediately above S-9 of as much as 0.26 mg/1 were recorded after backpumping. The low dissolved oxygen, as low as 0.20 mg/1, and the high ammonia, an average of 0.38 mg/1 (NH_3-N), in South New River Canal below S-9 result from the large ground-water contribution that occurs with backpumping. The areal extent and period of degradation in Water Conservation Area 3 from backpumping is dependent mainly on the amount of flow released from Water Conservation Area 2, which dilutes and flushes backpumped water.

"Concentrations of potential contaminants including toxic metals, pesticides, and nutrients, especially phosphorus, are relatively low in the area of South New River Canal affected by backpumping. Concentrations are higher in the eastern urban part of the canal, but transport westward is prevented by the S-13A water-control structure. As a result, most of the water presently backpumped is uncontaminated with these pollutants.

"Salt-water intrusion from Hollywood Canal is the chief threat to the ground-water supply in Hollywood. When discharge is low, the chloride concentration of water in the canal has reached levels greater than 10,000 milligrams per liter. Salt water has been detected in the aquifer at depth within 0.1 mile of the municipal wells.

"Results of test drilling and water quality analyses indicate that ground water of good quality is available in the western part of the Hollywood area. Because the transmissivity of the Biscayne aquifer is high, with proper planning additional quantities of water can be obtained without affecting water level significantly in existing wells." (Quoted from author s abstract.)

Freiberger, H. J., and McPherson, B. F., 1972, Water quality at Miami International Airport, Miami, Florida, 1971-72: U.S. Geological Survey open-file report FL-72023.

"The quality of water, sediment, and biota was determined at four sites in canals and drainage ditches at Miami International Airport (MIA) during high- and low-water periods and during summer and winter 1971-72. Concentrations of common ions, such as calcium, sodium, chloride, and magnesium, tended to be above average for fresh water because of periodic salt-water intrusion. Nitrogen, phosphorus, and pesticides were in higher concentrations than typical for undisturbed areas of south Florida, but not higher than usual for the urban coastal area, so it is not known to what extent these chemicals are attributable to surrounding urbanization. Heavy metals, oil and grease, and PCB's (polychlorinated biphenyls) were the best indicators of the effects of MIA on water quality. Concentrations of the above were quite variable; high values for each were recorded and were probably associated with recent discharges from industrial sources. Arsenic, lead, iron, and chromium all exceeded, in one or more samples, the U.S. Public Health Service's recommended upper limits for metals in water. Only iron normally exceeds these standards in the natural waters of south Florida. PCB's were detected in most samples and were in concentrations up to 1,000 micrograms per kilogram in fish. In addition to pesticides and PCB's, another group of persistent chlorinated compounds, PCN's (polychlorinated naphthalenes) were detected in water, sediment, and fish. This is the first known detection of these compounds in the environment." (Quoted from authors' abstract.)

Gallatin, M. H., and others, 1947, Soil survey, Dade County, Florida: U.S. Department of Agriculture, Series 1947, no. 4.

The soil types of Dade County, Florida are described along with a discussion on "*** how the soil can be used, how it responds to treatment, what care it needs, and what yields may be expected." (Quoted from authors' abstract.)

Galliher, C. F., and Hull, J. E., 1969, Hydrologic conditions during 1967 in Dade County, Florida: U.S. Geological Survey open-file report FL-69001.

"This report is the second in a series designed to describe the annual hydrologic conditions in Dade County, Florida. A quantitative picture of the general hydrologic conditions which prevailed in Dade County for the 1967 water year (October 1, 1966 to September 30, 1967) is summarized by use of tables, graphs, and maps." (Quoted from authors' introduction.)

Goolsby, D. A., Mattraw, H. C., Lamonds, A. G., Maddy, D. V., and Rollo, J. R., 1976, Analysis of historical water-quality data and description of plan for sampling network in central and southern Florida: U.S. Geological Survey Water-Resources Investigations 76-52.

"This report presents the results of an analysis of historical water-quality data collected by the U.S. Geological Survey (USGS) from approximately 130 sites on streams, canals, and lakes in central and southern Florida and suggests a plan for a revised water-quality network in the area. The water-quality data analyzed were separated into the following six broad categories: (1) major inorganic chemical constituents, (2) daily measurements of specific conductance and temperature, (3) nutrients, (4) trace metals, (5) insecticides and (6) organic carbon and BOD." (Quoted from authors' summary.)

Grantham, R. G., and Sherwood, C. B., 1968, Chemical quality of waters of Broward County, Florida: Florida Bureau of Geology Report of Investigations no. 51.

"The chemical quality of the abundant surface and ground-water resources of Broward County is generally good. However, natural and man-made problems of water quality are accented by the mushrooming need for water and changes in the hydrology of the area caused by rapid urbanization.

"Water of good chemical quality for municipal and domestic supplies in Broward County is obtained from the highly productive Biscayne aquifer, which is part of an interconnected ground and surface-water system. The water is calcium bicarbonate in type and ranges from hard to very hard, and from neutral to slightly alkaline. The prime objectionable constituents in the water are iron in the southern part of the county, and chloride near the coast and in the lower part of the Biscayne aquifer in the inland areas.

"Large quantities of water are available in the artesian Floridan aquifer at depths below 900 feet, but the water is salty and of limited use. The Floridan aquifer is used for the disposal of sewage effluent at one location.

"Surface water in the area is generally good but variable in chemical quality. During the rainy season the mineral content of the water in canals is diluted by surface runoff; however, during the dry season the mineral content of the canal water increases because of the increase in the percentage of ground water in the canals and the drainage from swampy inland areas. Large quantities of surface water are used for irrigation in inland areas and for replenishment to coastal parts of the aquifer for municipal supplies and to prevent salt-water intrusion.

"The water in parts of Broward County is contaminated by salt-water intrusion and by various wastes such as sewage effluent. The use of the controlled canal system for disposal of waste materials poses a potential problem during periods of little or no flow. Chemical weed killers applied on the land, as well as detergents, have been detected in the ground water indicating movement of waste through the ground. As urbanization and industrial growth continue, problems of waste disposal will become more acute and will require stricter control." (Quoted from authors' abstract.)

Hardee, Jack, Miller, R. A., and Mattraw, H. C., Jr., 1978, Storm-water runoff data for a highway area, Broward County, Florida: U.S. Geological Survey Open-File Report 78-612.

"Rainfall, stormwater discharge, and water-quality data for both rainfall and runoff are summarized for a highway area near Pompano Beach, Florida. Loads for 20 water-quality constituents were computed for the runoff from 41 storms between April 1975, and July 1977. The basin of 58.3 acres contains a 3,000-ft segment of highway and is 36 percent impervious." (Quoted from authors' abstract.)

Hardee, Jack, Miller, R. A., and Mattraw, H. C., Jr., 1979, Storm-water runoff data for a multi-family residential area, Dade County, Florida: U.S. Geological Survey Open-File Report 79-1295.

"Rainfall, stormwater discharge, and water-quality data for a multifamily residential area in Dade County, Florida, are summarized in this report. Loads for 19 water-quality constituents were computed for runoff from 16 storms from May 1977 through June 1978. The 14.7 acre basin contains apartment buildings with adjacent parking lots. The total surface area consists of 70.7 percent impervious material." (Quoted from authors' abstract.)

Hartwell, J. H., 1970, Some aspects of the availability of water from the Everglades to the Everglades National Park, Florida: U.S. Geological Survey open-file report FL-70007.

"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 South 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 by the increased rainfall and the reduction in flow to the sea through the coastal canals." (Quoted from author's abstract.)

Hartwell, J. H., Klein, Howard, and Joyner, B. F., 1964, Preliminary evaluation of hydrologic situation in Everglades National Park, Florida: U.S. Geological Survey open-file report FL-64002.

"Historically, flow from the north replenished the Everglades National Park's water supply during rainless periods. The completion, in December 1962, of Levee 29 and its appurtenant control structures has obstructed overland flow to the Shark River Slough -- the major drainageway through the park.

"In May 1962, near the end of a prolonged drought, the water levels in some areas of the park were below sea level. These depressed water levels were caused by the high rate of evapotranspiration, which in the south was estimated to be 1,580 acre-feet per day from an area of about 275 square miles. Extreme drought conditions were conducive to salt-water incursion from Florida Bay and the Gulf of Mexico. They also caused an increase in the calcium carbonate concentration in fresh water areas.

"Discharge relations, from data obtained prior to completion of effective control works, showed that releases from the Levee 29 control structures should range from 21 to 1,020 cfs to duplicate average monthly water levels that occurred in the park during the 10-year period prior to December 1962. The average yearly release should be 250,000 acre-feet." (Quoted from authors' abstract.)

Healy, H. G., 1977, Public water supplies of selected municipalities in Florida, 1975: U.S. Geological Survey Water-Resources Investigations 77-53.

"This report summarizes the water-use information obtained from 169 municipalities and five county water systems in Florida and the data presented are current to December 1975." (Quoted from author's purpose and scope.)

Higer, A. L., and Kolipinski, M. C., 1967, Monthly analysis of water conditions in Everglades National Park, January 1967: U.S. Geological Survey unpublished data. Available for inspection at the U.S. Geological Survey, Miami, Florida.

The results of the monthly chemical analysis of the estuaries are given.

Hoffmeister, J. E., Stockman, K. W., and Multer, H. G., 1967, Miami Limestone of Florida and its recent Bahamian counterpart: The Geological Society of America Bulletin, v. 78.

"The Miami Oolite, named by Sanford for the oolitic limestone of Pleistocene age which covers a large part of the southern tip of Florida, has been found to consist of two separate units, an upper unit, herein designated the oolitic facies and a lower unit, called here the bryozoan facies. In this paper the two units are combined as the Miami Limestone, a formation name which may seem more appropriate than the Miami Oolite. The bryozoan facies, the dominant constituents of which are massive compound colonies of the cheilostone bryozoan Schizoporella floridana Osburn surrounded by oolids and pellets, covers the greater part of Dade County and extends in places into adjoining counties--a total area of about 2,000 square

miles. It averages 10 feet in thickness in southeastern Florida and thins to 1 foot or so westward to the Gulf of Mexico. It is the surface rock of the southern Everglades and is one of the most extensive bryozoan limestones in the country. In southestern Florida it is covered by an elongated mound of cross-bedded oolitic limestone, the upper unit or oolitic facies. This is the rock of the southern end of the Atlantic Coastal Ridge, with a maximum thickness of 15 feet under the Ridge summit thinning westward toward the low-lying Everglades as it encroaches over the bryozoan facies.

"Interest in the origin of the two units has been heightened recently by the recognition of similar deposits that are being actively produced in a nearby area. Immediately east of Miami on the western edge of the Great Bahama Bank, strung im a north-south line, are the islands of Bimini, Cat Cay, Sandy Cay, etc., the region described by Newell and others (1959). East of the Cays and parallel to them, a large underwater mound of unstable oolite is forming, and east of the mound in the shallow lagoon, massive, tubular bryozoans (Schizoporella floridana Osburn) are growing. The oolite from the mound is slowly encroachng over the bryozoan beds. The bathymetric and ecologic conditions now extant im this area are probably similar to those which existed during the Pleistocene to form the units of the Miami Limestone.

"The eastern slope of the unstable oolite mound of the Cat Cay and Sandy Cay area is cut by tidal channels which run normal to the direction of the mound itself. Narrow valleys, similar to these channels, can be found in the indurated rock of the oolitic facies of the Atlantic Coastal Ridge. The valleys probably had their origin as channels produced by tidal currents at the time the oolitic mound of the Ridge was in an unstable condition. It is also believed that the shape and orientation of the Lower Keys of Florida originated in a similar fashion." (Quoted from authors' abstract.)

Hoy, N. D., and Schroeder, M. C., 1952, Age of subsurface "Tamiami" Formation rear Miami, Florida: The Journal of Geology, v. 60, no. 3.

The Tamiami Formation of Parker and Cooke, 1944, was correlated in core borings obtained from test wells west of Miami, Florida. Fresh-water limestone was encountered in the rock assigned to the Tamiami Formation. The absence of fresh-water beds in the Pliocene of the Atlantic Coastal Plain and the Caloosahatchee Marl, and the presence of these fresh-water beds suggests that the major part of the rock heretofore assigned to the Tamiami Formation is not Pliocene but is the Pleistocene equivalent, in part, to the Fort Thompson Formation. It also suggests that the Tamiami of Parker and Cooke should thus be restricted to the lower basal portion of the highly permeable aquifer below the lowest fresh-water bed, and that the major part of the aquifer is a highly permeable and greatly thickened southward extension of the Fort Thompson Formation.

Hull, J. E., 1972, Hydrologic conditions during 1970 in Dade County, Florida: U.S. Geological Survey open-file report FL-72006.

"This report is the fifth in a series describing the annual hydrologic conditions in Dade County, Florida. The general hydrologic conditions in Dade County for the 1970 water year (October 1, 1969 to September 30, 1970) are summarized in tables, graphs, and maps." (Quoted from author's introduction.)

Hull, J. E., 1975, Summary of hydrologic data collected during 1974 in Dade County, Florida: U.S. Geological Survey open-file report FL-75012.

"This report is ninth in a series documenting the annual hydrologic conditions in Dade County, Florida. The hydrologic conditions in Dade County for the 1974 water year (October 1, 1973 to September 30, 1974) except for rainfall are summarized in tables, graphs, and maps." (Quoted from author's introduction.)

Hull, J. E., 1978, Summary of hydrologic data collected during 1976 in Dade County, Florida: U.S. Geological Survey Open-File Report 78-883.

"During 1976 rainfall was 1.58 inches below the long-term average. Ground-water levels ranged from 0.4 foot above to 0.5 foot below average. The highest and lowest ground-water levels for the year were both 1 foot below their long-term averages. In the Hialeah-Miami Springs area, water levels in wells near the centers of the heaviest pumping ranged from 8.0 to 9.5 feet below msl (mean sea level, 1929); and in the Southwest well-field area, ground-water levels near the centers of pumping ranged from 2.0 feet above to 3.0 feet below msl." (Quoted from author's abstract.)

Hull, J. E., 1979, Summary of hydrologic data collected during 1977 in Dade County, Florida: U.S. Geological Survey Open-File Report 79-514.

"During 1977 rainfall was 1.52 inches above the long-term average. Ground-water levels ranged from 0.3 foot above to 0.1 foot below average. The highest and lowest ground-water levels for the year were 1 foot below and 1 foot above their long-term average. In the Hialeah-Miami Springs area, water levels in wells near the centers of the heaviest pumping ranged from 7.2 to 11.9 feet below mean sea level, 1929; and in the Southwest well-field area, ground-water levels near the centers of pumping ranged from 1.0 foot above to 1.5 feet below mean sea level.

"In 1977 the combined average daily discharge from nine major streams and canals that flow eastward into tidal waters was 1,712 cubic feet per second, 46 cubic feet per second above the combined average daily flow for 1976. The combined average daily flow through the Tamiami Canal outlets was 582 cubic feet per second, 201 cubic feet per second above that of 1976.

"The 1977 position of the salt front in the coastal part of the Biscayne aquifer was about the same as in 1976, except south from Homestead Air Force Base to S-18C where the salt front had encroached farther inland." (Quoted from author's abstract.)

Hull, J. E., and Beaven, T. R., 1977, Summary of hydrologic data collected during 1975 in Dade County, Florida: U.S. Geological Survey Open-File Report 77-803.

"This report is the tenth in a series documenting the annual hydrologic conditions in Dade County, Florida. The hydrologic conditions for the 1975 water year (October 1, 1974 to September 30, 1975) are summarized in tables, graphs, and maps." (Quoted from authors' introduction.)

Hull, J. E., and Galliher, C. F., 1969, Hydrologic conditions during 1966 in Dade County, Florida: U.S. Geological Survey open-file report FL-69002.

"This report is the first in a series designed to describe the annual hydrologic conditions in Dade County, Fla. A quantitative picture of the general hydrologic conditions which prevailed in Dade County for the period under consideration is summarized by use of tables, graphs, and maps." (Quoted from authors' introduction.)

Hull, J. E., and Galliher, C. F., 1970, Hydrologic data during 1968 in Dade County, Florida: U.S. Geological Survey open-file report FL-70002.

"This report is the third in a series describing the annual hydrologic conditions in Dade County, Florida. The general hydrologic conditions in Dade County for the 1968 water year (October 1, 1967 to September 30, 1968) are summarized in tables, graphs, and maps." (Quoted from authors' introduction.)

Hull, J. E., and McKenzie, D. J., 1974, Summary of hydrologic data collected during 1973 in Dade County, Florida: U.S. Geological Survey open-file report FL-74029.

"This report is eighth in a series documenting the annual hydrologic conditions in Dade County, Florida. The general hydrologic data in Dade County for the 1973 water year (October 1, 1972 to September 30, 1973) are summarized in tables, graphs, and maps." (Quoted from authors' introduction.)

Hull, J. E., McKenzie, D. J., and Meyer, F. W., 1973, Summary of hydrologic data collected during 1972 in Dade County, Florida: U.S. Geological Survey open-file report FL-73032.

"This report is seventh in a series documenting the annual hydrologic conditions in Dade County, Florida. The general hydrologic data in Dade County for the 1972 water year (October 1, 1971 to September 30, 1972) are summarized in tables, graphs, and maps." (Quoted from authors' introduction.)

Hull, J. E., and Meyer, F. W., 1973, Salinity studies in East Glades agricultural area, southeastern Dade County, Florida: Florida Bureau of Geology Report of Investigations no. 66.

"Saline soils in the East Glades Agricultural area are caused chiefly by brackish ground water moving upward from the water table during dry periods. Brackish ground water is caused by infiltration of salt water from nearby coast-normal canals and by inland movement of salt water through the deep parts of the Biscayne aquifer during droughts. The soils most prone to salt accumulation generally occur within the area affected by sea water intrusion. The outlook for the East Glades is for no improvement in saline soil problems unless land use changes significantly, permitting maintenance of higher water levels along the coast to halt the inland movement of sea water." (Quoted from authors' abstract.)

Hull, J. E., and Wimberly, E. T., 1972, Hydrologic conditions in Dade County, Florida: U.S. Geological Survey open-file report FL-72024.

"This report is the sixth in a series describing the annual hydrologic conditions in Dade County, Florida. The general hydrologic conditions in Dade County for the 1971 water year (October 1, 1970 to September 30, 1971) are summarized in tables, graphs, and maps." (Quoted from authors' introduction.)

Hunter, M. E., 1978, What is the Caloosahatchee Marl?: Coastal Petroleum Company: Hydrology of south-central Florida: West Palm Beach, Florida, 22nd, Field Conference, 1978: Southeastern Geological Society Publication no. 20.

This paper outlines the current stratigraphic terminology, discusses the major boundary problems, and suggests for discussion a stratigraphic column that recognizes destruction or flooding of surface outcrops.

Irwin, G. A., and Healy, H. G., 1978, Chemical and physical quality of selected public water supplies in Florida, August-September 1976: U.S. Geological Survey Water-Resources Investigations 78-21.

"During August-September 1976 the U.S. Geological Survey, in cooperation with the Florida Department of Environmental Regulation, made a water-quality sampling reconnaissance of 127 treated and untreated public water supplies in Florida. The purpose of the reconnaissance was to determine background concentrations of nitrate, fluoride, turbidity, selected trace elements, and pesticides which have maximum contaminant levels established in the National Interim Primary Drinking Water Regulations (Public Law 93-523).

"Results of this sampling reconnaissance indicated that, with few exceptions, virtually all major public water supplies in Florida are of high quality and meet the standards set forth in the National Interim Primary Drinking Water Regulations. Occasionally the concentrations of fluoride, turbidity, cadmium, chromium, and lead approximated, equaled, or exceeded maximum contaminant levels with exceedences occurring very infrequently. The pesticides, 2,4-D and silvex, were detected in some public supplies throughout the State and were particularly common in surface water. Although pesticides were not detected in concentrations approaching the maximum levels established in the regulations, their presence does signal that the activities of man are beginning to affect some public water supplies." (Quoted from authors' abstract.)

Jackson, D. F., and Maurrasse, Florentin, 1976, Man-made lakes of Dade County, friends or foes? an environmental assessment: Florida International University, Miami, Florida.

"This report is a review of the two principal problems associated with man-made lakes, the effects they have on water quality and on water quantity." (Quoted from authors' overview.)

Klein, Howard, 1957, Interim report on saltwater encroachment in Dade County, Florida: Florida Geological Survey Information Circular no. 9.

"***one of the chief causes of the encroachment of salt water in the underlying rocks in the Miami area is the system of uncontrolled or inadequately controlled tidal drainage canals. It has been shown that water-control structures, properly placed, have retarded encroachment and, in some places, have caused the salt water to retreat seaward. In some canals, however, the controls have been placed too far upstream to be effective in retarding or preventing encroachment. The effects of uncontrolled tidal canals between Biscayne Bay and the coastal ridge would be the same as if arms of the Bay extended to the ridge; the salty ground water would occur farther inland over a broad front." (Quoted from author's summary.)

Klein, Howard, 1965, Probable effect of Canal 111 on salt-water encroachment, southern Dade County, Florida: U.S. Geological Survey open-file report FL-65002.

"The effect of an uncontrolled sea-level canal such as Canal III will be to accelerate runoff of fresh water and to lower adjacent water levels when water levels are high. When water levels are low, the sea water that moves into the canal will recharge the Biscayne aquifer into which the canal is incised. Inland movement of the salt front also may limit the development of water-supply facilities in the vicinity.

"Spring and storm tides will inundate the area south of the canal and may affect the biota in that part of the Everglades National Park.

"A salinity-control structure on the canal near its mouth would reduce but not necessarily prevent wastage of fresh water to the sea and would reduce but not prevent salt water from moving inland." (Quoted from author's summary.)

Klein, Howard, 1970, Preliminary evaluation of availability of potable water on Elliot Key, Dade County, Florida: U.S. Geological Survey open-file report FL-70010.

"Facilities available to the general public will include swimming, boating, fishing, camping, hiking, and other recreational activities. A supply of fresh water will be required. This report describes the results of a reconnaissance on the availability of potable ground water in Elliot Key." (Quoted from author's introduction.)

Klein, Howard, 1976, Simulations of water-level drawdowns in proposed well-field areas, Dade County, Florida: U.S. Geological Survey Open-File Report 76-651.

"Electrical analog model simulations of hydraulic conditions in the Biscayne aquifer were made at proposed inland well-field sites in Dade County. Simulated drawdowns of water levels after 7 months of continuous pumping at 50, 100, and 150 million gallons per day (2.2, 4.4, and 6.6 cubic meters per second) were obtained at each site. Simulataneous pumping of each of the sites at 50 million gallons per day (2.2 cubic meters per second) showed that after 7 months pumping there would be interference between proposed well fields." (Quoted from author's abstract.)

Klein, Howard, Armbruster, J. T., McPherson, B. F., and Freiberger, H. J., 1975, Water and the south Florida environment: U.S. Geological Survey Water-Resources Investigations 24-75.

As part of the major investigation on the ecology, this report describes "*** the surface-water and ground-water resources of south Florida that was assigned to the Geological Survey. The quantity and quality of surface water and ground water and their interrelation with estuarine and marine waters are here considered. Also considered are the problems, present or future, related to the hydrologic environment that involve human, animal, and plant life. Changes taking place, apparent trends, and projections for the future are also considered, as well as alternatives for water management." (Quoted from authors' introduction.)

Klein, Howard, Schneider, W. J., McPherson, B. F., and Buchanan, T. J., 1970, Some hydrologic and biologic aspects of the Big Cypress Swamp drainage area, southern Florida: U.S. Geological Survey open-file report FL-70003.

"Water, a principal resource of the Big Cypress, governs the ecology and influences the patterns of land development. Abundant but seasonal rainfall and flow natural drainage allow water to collect in ponds each year over as much as 90 percent of the undeveloped area for as long as 4 months. During the dry season, water in ponds and sloughs covers about 10 percent of the land. A shallow aquifer presently supplies most water for municipal use and irrigation. It extends from the land surface to a depth of about 130 feet in Naples, to about 60 feet near Sunniland, and wedges out near the east edge of the Big Cypress." (Quoted from authors' summary.)

Klein, Howard, and Sherwood, C. B., 1961, Hydrologic conditions in the vicinity of Levee 30, northern Dade County, Florida: Florida Geological Survey Report of Investigations 24, Part I.

"Thin layers of dense limestone of low permeability that occur near the top of the Biscayne aquifer in the vicinity of the north end of Levee 30 in Dade County, Florida are of hydrologic importance because they retard the downward infiltration of ponded water in Conservation Area no. 3. This retarding effect frequently results in high head differentials across the levee. Tests made in a small area adjacent to Levee 30 indicate that the coefficient of transmissibility of the aquifer is 3,600,000 gpd (gallons per day) per foot, and the coefficient of vertical permeability of the dense limestones is 13 gpd per square foot. If ground-water flow beneath the levee is laminar, the total inflow to the Levee 30 Canal from Conservation Area No. 3 will be about 350 mgd (million gallons per day), or 540 cfs (cubic feet per second), per mile length of levee when the head difference across the levee is 10 feet." (Quoted from authors' abstract.)

Kohout, F. A., 1960a, Cyclic flow of salt water in the Biscayne aquifer of southeastern Florida: Journal of Geophysical Research, v. 65, no. 7.

Cyclic flow is caused by progressive dilution of saltwater flowing inland from the sea to where horizontal flow ceases, after which it moves upward and returns to the sea. The cyclic flow acts as a deterrent to the invasion of saltwater because of return to the sea of a part of the inland flow.

Kohout, F. A., 1960b, Flow pattern of fresh water and salt water in the Biscayne aquifer of the Miami area, Florida: International Association of Scientific Hydrology Publication 52.

The movements of fresh and saltwater in the Biscayne aquifer of the Miami area, Florida is shown by a flow net that was constructed from horizontal gradients derived from a low-head equipotential diagram.

Kohout, F. A., 1961, The flow of fresh water and salt water in the Biscayne aquifer of the Miami area, Florida: in Sea water in coastal aquifers: U.S. Geological Survey Water-Supply Paper 1613-C.

"Investigations in the coastal part of the Biscayne aquifer, a highly productive aquifer of limestone and sand in the Miami area, Florida, show that the salt-water front is dynamically stable as much as 8 miles seaward of the position computed according to the Ghyben-Herzberg principle. This discrepancy results, at least in

part, from the fact that the salt water in the Biscayne aquifer is not static, as explanations of the dynamic balance commonly assume. Cross sections showing lines of equal fresh-water potential indicate that during periods of heavy recharge, the fresh water head is high enough to cause the fresh water, the salt water, and the zone of diffusion between them to move seaward. When the fresh-water head is low, salt water in the lower part of the aquifer intrudes inland, but some of the diluted sea water in the zone of diffusion continues to flow seaward. Thus, salt water circulates inland from the floor of the sea through the lower part of the aquifer becoming progressively diluted with fresh water to a line along which there is no horizontal component of flow, after which it moves upward and returns to the sea.

"This cyclic flow is demonstrated by a flow net which is constructed by the use of horizontal gradients determined from the low-head equipotential diagram. The flow net shows that about seven-eighths of the total discharge at the shoreline originates as fresh water in inland parts of the aquifer. The remaining one-eigth represents a return of sea water entering the aquifer through the floor of the sea." (Quoted from author's abstract.)

Kohout, F. A., and Hartwell, J. H., 1967, Hydrologic effects of Area B flood control plan on urbanization of Dade County, Florida: Florida Geological Survey Report of Investigations 47.

"Swampy low land (Area B) that fringes the Everglades west of Metropolitan Miami, Florida (Area A) probably will be urbanized in the future. Area B will be protected from flooding by huge pumps that will pump water westward from Area B over a levee system into Conservation Area 3B. The total capacity of the pumps will be about 13,400 cubic feet per second which is sufficient to lower water levels 2 inches per day in the 203 square miles of Area B. As this capacity is about equal to the highest gravity-flow discharge to the ocean through existing canals of the Miami area, a great potential will exist, not only for control of floods, but also beneficial control and management of a major segment of the water resources in southeastern Florida.

"An evaluation of flow in the Miami River during a low-water period indicates that Conservation Area 3B contributes 33 percent of the total discharge, Area B 26 percent, and Area A 41 percent. After implementation of the Area B plan, contributions from Area A will continue to flow seaward, whereas contributions from Area B and Conservation Area 3B, which now unavoidably are wasted to the ocean in a high-water period will be pumped westward into storage in the conservation area.

"A steady-state electric-analog study was made for the 1961 Area B plan. Maps of the results showed that the water-level pattern would be radically changed if water-control dams were installed to isolate the levee borrow canal from the intakes of the pump stations. Without the control dams, the lowest steady-state water levels would occur at the western side of Area B and underseepage from Conservation Area 3B would be maximum. However, if dams were installed, the highest water levels would occur at the western side of Area B and underseepage would be minimized. Partial openings of the control dams probably would produce advantageous compromise solutions between the two-modeled extremes.

"Estimates of population growth indicate that water use in the Miami area may amount to 1.4 billion gallons per day in 1995. This water use is equivalent to 2,170 cfs (cubic feet per second), almost twice the yearly mean discharge of 1,280 cfs that flowed into the ocean from six major Miami area canals during the dry period June 1962 to May 1963. A rate 1.4 bgd for a year's time is equivalent to the total surface runoff (about 10.5 inches of water) from an area extending 28 miles westward from the coast and 100 miles southward from Lake Okeechobee into Everglades National Park. As other coastal cities and Everglades National Park will require a share of water from this same area, improved water-management techniques are needed to insure a continuing supply of fresh water for southeastern Florida. In consideration of continually growing water needs, the Area B plan should be conceived as a water conservation as well as a flood control plan." (Quoted from authors' abstract.)

Kohout, F. A., and Hoy, N. D., 1963, Some aspects of sampling salty ground water in coastal aquifers: Ground Water, Journal of the National Water Well Association, v. 1, no. 1.

"Investigations of the fluctuations of chloride content in wells that tap the zone of diffusion between fresh and salt water show that the salty well water behaves erratically when the well is pumped. Frequently, a static distribution of chloride content that ranges from less than 1,000 ppm at the top to more than 10,000 ppm at the bottom is present in the open-hole part of a well. When the well is pumped, the discharge water tends to come from the upper part of the open hole because less energy is expended by removal of low-density water from this region than by removal of high-water density water from the lower part of the open hole. Where the permeability of strata in the deep part of the open hole is greater than that in the shallow part, the tendency for natural selection of the less dense, shallow water is suppressed, and pratically all the water in the blend comes from the deep part.

"As a result of this complex interrelation of hydraulics, distribution and density of the salt water, and permeability, the depth at which the pumped water enters the well bore is indeterminate. This deficiency leads to the use of multiple-depth-bottle, windshield-wiper, and electrical-conductivity sampling techniques for collection of data used in constructing maps and cross sections that show the areal-depth relations of salt water in the Biscayne aquifer of the Miami area, Florida." (Quoted from authors' abstract.)

Kohout, F. A., and Klein, Howard, 1967, Effect of pulse recharge on the zone of diffusion in the Biscayne aquifer: International Association of Scientific Hydrology, Publication no. 72.

"In the Biscayne aquifer of the Miami area, Florida, two factors contribute to dynamic stabilization of the salt front at a position as much as eight miles seaward of that computed according to the Ghyben-Herzberg principle.

"Equipotential lines in terms of equivalent fresh-water head in wells show that when the fresh-water head is low, sea water flows inland from the floor of the sea into the zone of diffusion in the deep part of the aquifer and thence upward and back to the sea through the upper part of the aquifer. This cyclic flow limits the extent to which sea water invades the aquifer because of the steady return to the sea of part of the inland flow.

"During periods of heavy rainfall large quantities of fresh water are placed in storage below sea level as high salinity water in the deep part of the aquifer is driven seaward under steep seaward hydraulic gradient. The distortion of the zone of diffusion from such a heavy pulse of recharge, and the return to normal, is demonstrated by biweekly mappings of the isochlor pattern subsequent to a 13-inch rainfall. Diagrams showing the pattern of flow for both expulsion and intrusion are constructed from the gradients for the horizontal component of flow determined from fresh-water equipotential diagrams. The flow diagrams indicate that the forceful expulsion of salt water after heavy rains results in more efficient recharge than discharge because fresh water is injected into storage by seaward flow throughout the full aquifer thickness, whereas during the subsequent intrusion or cyclic-flow phase, fresh water is discharged at the shoreline under comparatively small hydraulic gradient through only about one third of the aquifer thickness." (Quoted from authors' abstract.)

Kohout, F. A., and Leach, S. D., 1964, Salt-water movement caused by control-dam operation in the Snake Creek Canal, Miami, Florida: Florida Geological Survey, Report of Investigations no. 24.

"Movement of salt water in the Biscayne aquifer and the Snake Creek Canal was investigated to establish criteria for operation of the salinity-control dam in the canal. All four gates of the dam were opened for 3 days during a special test in March 1961. Although salt water oscillated landward and seaward a distance of 2 miles from the control in response to tide, the salinity of the ground water near the canal did not change greatly during this time. Salt water trapped in the canal by closing the dam at high tide moved landward as a density current at a rate of about 900 feet per hour and began to flow into a connected deep rock pit. A flushing operation removed salt water from the canal but the salt water in the rock pit remained. During subsequent months, wind and tide action caused upward dispersion of salt into the uppermost water of the rock pit, and the trapped salt water was gradually removed by seaward discharge through the canal.

"Some of the salt water trapped in the canal moved into the aquifer. This salty water was traced by sampling fully cased wells of different depths and distances from the canal. Some of the salty water was retrieved by drainage from the aquifer when the gates were partially opened 2 months after entrapment. Because of its relatively great density some of the salt water moved downward in the aquifer and was not retrieved.

"The data show the negative effects of trapping salt water, and also that the control can be closed gradually without trapping salt water. If the total opening of the control is distributed uniformly among the four partially closed gates, the increased velocity of the fresh water as it flows under the submerged sluice gates, will impede upstream movement of salt water at the bottom of the control. Calculations indicate that salt water probably will not move upstream in the canal if a head of 0.3 foot is maintained between upstream and downstream sides of the control at the time of minimum head differential, about 2 hours before high tide." (Quoted from authors' abstract.)

Kolipinski, M. C., and Higer, A. L., 1969, Some aspects of the effects of the quantity and quality of water on biological communities in Everglades National Park: U.S. Geological Survey open-file report FL-69007.

"Hydrobiological investigations in Everglades National Park are summarized under four main topics: (1) vegetative changes, (2) population dynamics of animals, (3) repopulation of small aquatic animals after droughts, and (4) water-quality characteristics.

"Changes of vegetation in Shark River Slough from 1940 to 1964, as determined from analysis of aerial photographs, showed a decrease in acreage of wet prairie communities and an increase in sawgrass marshes and woody vegetation. The apparent reasons for the changes are shortened wet periods, increase in fires, and loss of soil.

"A long-range program of quantitative sampling of small fishes and aquatic invertebrates in Shark River Slough began in 1965. Preliminary findings indicate that long wet periods result (1) in an abundance of small aquatic animals, and (2) the successful formation of wading bird rookeries.

"The recovery of aquatic populations after drought depends on duration and extent to which the aquatic habitats dry. Animal burrows were shown to serve as survival holes for small fishes during droughts of short duration.

"The chemical constituents of the surface waters in Everglades National Park compare favorably with other naturally occurring waters in the United States that support a mixed fish fauna. Dissolved oxygen during periods of low water in alligator holes decreases to below 2 mg/l (milligrams per liter) during most of each 24-hour period, causing a mortality of susceptible fishes, such as the centrachids.

"An average of 0.02 ug/l (micrograms per liter) of DDT+DDD+DDE was found in the surface waters of the park. Several aquatic plants and animals exhibited biological magnification of insecticides. For example, mosquitofish contained 700 ug/kg (micrograms per kilogram) of the DDT family which is 4 orders of magnitude greater than that found in the waters." (Quoted from authors' abstract.)

Land, L. F., 1975, Effects of lowering interior canal stages on salt water intrusion into the shallow aquifer in southeast Palm Beach County, Florida: U.S. Geological Survey Open-File Report 75-74.

"Land in southeast Palm Beach County is undergoing a large-scale change in use, from agricultural to residential. To accommodate residential use, a proposal has been made by developers to the Board of the Lake Worth Drainage District to lower the canal stages in the interior part of the area undergoing change. This report documents one of the possible effects of such lowering. Of particular interest to the Board was whether the lower canal stages would cause an increase in salt-water intrusion into the shallow aquifer along the coast." (Quoted from author's abstract.)

Land, L. F., 1977, Ground-water resources of the Riviera Beach area, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations 77-47.

"The principal source of freshwater that has been developed in the Riviera Beach area is the so-called shallow aquifer, which is composed of sand, shells, sandstone, limestone, marl, and occasionally clay strata. Often a stratum contains mixtures of two or more of these materials and occasionally they are cemented. The aquifer ranges in thickness from approximately 300 feet at Lake Worth to less than 175 feet in the interior. The major water-bearing zone usually consists of cemented layers of sand and shells, about 100 feet thick, in the lower part of the aquifer.

"The quality of water in the shallow aquifer is generally suitable for municipal use except for an area along C-17 Canal where the dissolved solids concentration exceeds 500 milligrams per liter.

"The primary source of recharge to the shallow aquifer is rainfall. Discharge is mainly by evapotranspiration. Other discharges include seepage into drainage canals and Lake Worth, and pumpage.

"The configuration of the water table is greatly influenced by Lake Worth, C-17 Canal, West Palm Beach water catchment area, rainfall, and municipal pumpage.

"The major threat to development of water supplies, and possibly to the continuation of a current withdrawal rate of over 5 million gallons per day, is seawater intrusion. The municipal supply wells are almost 1 mile inland from the source of the seawater (Lake Worth), but the combined effects of increased pumpage, reduced recharge resulting from increased land development, and below normal rainfall, have caused seawater to advance inland in the aquifer. Additional supplies could be developed to the west, away from the threat of seawater intrusion." (Quoted from author's abstract.)

Land, L. F., Rodis, H. G., and Schneider, J. J., 1973, Appraisal of the water resources of eastern Palm Beach County, Florida: Florida Bureau of Geology Report of Investigations no. 67.

"Ground water from the shallow aquifer, a hydrologic unit comprised of the Biscayne, Pamlico and Anastasia Formations, underlies the entire area and is the principal source of water for most uses. The top of the Floridan aquifer, a limestone under high artesian pressure, underlies the area at depths ranging from 800 to 1,000 feet below land surface but the water is too brackish or salty for most uses.

"Specific capacities of municipal wells range from about 10 to more than 350 gallons per minute per foot of drawdown. Municipal pumping averaged about 75 million gallons per day during 1970. West Palm Beach is the only community which uses surface water for municipal supply.

"The differences between average annual rainfall and potential evaporation in eastern Palm Beach County is 8 to 14 inches per year. The annual rainy season extends from May to October when the eastern part of the county receives more than 40 inches of annual rainfall. Despite the periodic surpluses, several municipal well fields are beset with problems of salt-water intrusion caused by increasing pumpage during droughts.

"Total dissolved solids of the fresh water in the shallow aquifer system ranges from 200 to 300 mg/l (milligram per liter) in the coastal ridge to more than 500 mg/l in the western areas.

"In the surface water system, the water containing the least amount of dissolved solids, generally less than 200 mg/l, occurs in Canal 18 and Canal M immediately downstream from the Loxahatchee Slough. The inorganic nitrogen concentration of this water is less than 0.15 mg/l. The most seriously contaminated water is in Canal 17 where the coliform bacteria count often exceeds 50,000 colonies per 100 ml (milliliters) and inorganic nitrogen concentration usually exceeds 2 mg/l. The dissolved-solid content of the surface water is less than that of ground water.

"Water in the shallow aquifer is slightly contaminated at shallow depths in the immediate vicinity of the Cross State Solid Waste Disposal Area. The contaminants probably stay near the water table and are filtered out by the sand." (Quoted from authors' abstract.)

Leach, S. D., and Grantham, R. G., 1966, Salt-water study of the Miami River and its tributaries, Dade County, Florida: Florida Geological Survey Report of Investigations no. 45.

"The Miami River has the largest discharge of all rivers in southeastern Florida, and serves as the outlet for the Miami and the Tamiami Canals. The widening and deepening of the Miami River and the construction of the Miami and Tamiami Canals have been beneficial in flood control but have increased the threat of salt-water encroachment. The primary purpose of the investigation is to present a study of the salt-water movement in the Miami River and Canal and its effect on the fresh-water supply of the area." (Quoted from authors' introduction.)

Leach, S. D., Klein, Howard, and Hampton, E. R., 1972, Hydrologic effects of waste control and management of southeastern Florida: Florida Bureau of Geology Report of Investigations no. 60.

"Although the results of several water-related investigations have been published, the total hydrologic effects of drainage and reclamation have not been clearly portrayed. The purpose of this report is to describe and evaluate from the mass of hydrologic information the effects that man's activities have had on the hydrology of southeast Florida. Analysis of the data collected, together with an evaluation of the effects of water management provide answers to such questions as:

1. What gross effects have the works of the C&SFFCD had on the hyrologic regimen of southeast Florida?

2. What are the climatic conditions in the southeast Florida area today, and how do they compare with conditions in the past?

3. Will the present and proposed flood-control system be adequate to prevent flooding and to halt sea-water intrusion into the Biscayne aquifer in coastal areas and to provide water to meet the demands of the growing population and other demands?

"In the process of answering the above questions, the history of the construction of C&SFFCD works was compiled, the seepage beneath various levees was determined, a generalized water budget was estimated for the conservation areas, and projection of water needs by the year 2000 have been made." (Quoted from authors' purpose and scope.)

Leach, S. D., and Sherwood, C. B., 1963, Hydrologic studies in the Snake Creek Canal area, Dade County, Florida: Florida Geological Survey Report of Investigations no. 24, Part 3.

"Snake Creek Canal was constructed primarily to drain parts of northern Dade County and southern Broward County, Florida. During dry periods, however, it conveys water from the Everglades seaward to replenish coastal sections of the Biscayne aquifer. A salinity-control structure at the mouth of the canal prevents the upstream movement of salt water and helps to maintain upstream water levels high enough to prevent salt-water encroachment into the aquifer. These hydraulic effects are made possible because of the high permeability of the aquifer and the excellent interconnection between the canal and the aquifer.

"Hydrologic tests made March 25-26, 1961, on the flow system indicate that an inflow of 36 cfs (cubic feet per second) from Area B was required in the canal to maintain a water level of 2.7 feet above msl (mean sea level) at the control structure. This water is used to recharge the aquifer in the coastal ridge.

"Future well fields of Metropolitan Dade County will withdraw as much as 200 mgd (million gallons per day) from the Biscayne aquifer in the western part of the Snake Creek Canal area. These large quantities of water will be derived chiefly by infiltration from the canal system and will greatly increase the amount of water needed to maintain desired levels near the coast. During drought periods this quantity could amount to more than four times the natural losses from the system." (Quoted from authors' abstract.)

Lee, C-H., and Cheng, R. T-S., 1974, On seawater encroachment in coastal aquifers: Water Resources Research, v. 10, no. 5.

"The seawater encroachment in a coastal aquifer is studied by means of a mathematical model. In some aquifers the dispersion amalgamates the encroaching seawater and the discharging freshwater to produce an extensive zone of diffusion. The coupled nonlinear conservation equations of mass and of salt are formulated and solved by the finite element method with the aids of iteration and underrelaxation. The numerical procedure is verified by comparing solutions with known results in the literature. In this study the seawater encroachment in the Biscayne aquifer at Cutler area, Florida, is modeled; the numerical results are in good qualitative agreement with the field data obtained by Kohout." (Quoted from authors' abstract.)

Leighty, R. G., Henderson, J. R., and others, 1958, Soil survey (detailed-reconnaissance) of Dade County, Florida: U.S. Department of Agriculture, Soil Survey Series 1947, no. 4.

"This report is about the soils of Dade County, Florida. It contains a description of each kind of soil and tells how the soil can be used, how it responds to treatment, what care it needs, and what yields you can expect. Maps accompanying the report show the location and extent of each soil. If you want to know how the soils were formed and how they are classified, some information on these subjects is given in a technical section, Morphology, Genesis, and Classification of Soils." (Quoted from authors' abstract.)

Love, S. K., 1944, Cation exchange in ground water contamination with sea water near Miami, Florida: American Geophysical Union Transactions of 1944, Part VI.

"In connection with studies of the chemical character of ground-water in areas along the coast in and near Miami where the ground-water is contaminated with sea-water, it was found that the composition of the contaminated water differed considerably from the composition of simple mixtures of ground-water and sea-water. Differences in the composition of salty ground-water in southern Florida have also been observed by SANFORD [see 1 of "References" at end of paper] and STRINGFIELD [2]. It appears that the observed differences in the Miami Area can be explained as the result of cation-exchange." (Quoted from author's text.)

Mattraw, H. C., Hull, J. E., and Klein, Howard, 1978, Ground-water quality near the Northwest 58th Street solid-waste disposal facility, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations 78-45.

"The Northwest 58th Street solid-waste disposal facility, 3 miles (4.8 kilometers) west of a major Dade County municipal water-supply well field, overlays the Biscayne aquifer, a permeable, solution-riddled limestone which transmits leachates eastward at a calculated rate of 2.9 feet per day (0.9 meter per day). The disposal facility has operated since 1952. A multi-depth ground-water sampling program between August 1973 and July 1975 identified the leachate characteristics and the conservative components which most readily have migrated downgradient.

"A discrete, identifiable leachate plume has been recognized under and downgradient from the waste disposal facility. Production of leachate from the disposal area depends on seasonal rainfall patterns. This causes some variability in concentration strength and location of the observed plume. Concentrations of sodium, chloride, ammonia, and dissolved solids decreased with depth beneath the disposal area and downgradient in response to an advective and convective dispersion. Downgradient, leachates were also diluted by the infiltration of rainfall into the aquifer. At a distance of about one-half mile (0.8 kilometer) downgradient, the rate of contribution of leachate from the source to the leading edge of the plume was about equal to the rate of loss of leachate from the leading edge of the plume by diffusion and dilution during the period covered by the nine samplings. Heavy metals, pesticides, and most other water-quality constituents are filtered, adsorbed by aquifer materials, or are precipitated near the disposal area." (Quoted from authors' abstract.)

McCoy, H. J., 1973, Effects of the Feeder Canal on the water resources of the Ft. Lauderdale prospect well field: U.S. Geological Survey open-file report FL-73019.

"Ever-increasing water demands of the rapidly growing Fort Lauderdale, Florida, area have required water managers to use expedient means for not only increasing the amount of fresh water available for use but also for protecting the fresh-water source itself from salt-water contamination. A Feeder Canal was dredged to increase recharge to the Biscayne aquifer in the vicinity of the Prospect well field. Fresh water is conveyed into the Feeder Canal from the perimeter canals of an inland water-conservation area by way of Middle River Canal (C-13). The Feeder Canal runs from the controlled reach of the Middle River Canal, along the south part of the Prospect well field, then back into the tidal reach of the Middle River Canal. Flow in the lower reach of the Feeder Canal is regulated by a control structure near Powerline Road.

"Comparison of water-level contour maps of the well-field area before and after dredging of the Feeder Canal indicates that the canal has raised water levels in the southwest part of the well-field area. During the latter part of the 1970-71 drought, the canal probably contributed about 3 million gallons of water a day to the Biscayne aquifer.

"Channel improvements in the Feeder Canal, between Middle River Canal and the conservation area's perimeter canal, and raised stages in the Middle River Canal will doubtless increase flow in the Feeder Canal. Data collected after these modifications have been made will indicate how much water will be required to overcome losses by evaporation and seepage to the tidal reach of Middle River Canal and still recharge the aquifer along the entire reach of the Feeder Canal." (Quoted from author's abstract.)

McCoy, H. J., and Hardee, Jack, 1970, Ground water resources of the lower Hillsboro Canal area, southeastern Florida: Florida Bureau of Geology Report of Investigations no. 55.

"The lower Hillsboro Canal area of this report occupies about 60 square miles of Palm Beach and Broward counties in southeastern Florida. All potable ground water in the lower Hillsboro Canal area is obtained from the Biscayne aquifer. The aquifer extends from the land surface to a depth of about 400 feet and is composed of sand, sandy limestone, shells, and indurated calcareous sand. Municipal well fields of Deerfield Beach and Boca Raton and most of the domestic, irrigation, and industrial wells obtain adequate water supplies from permeable limestone 90 to 130 feet below land surface. Rainfall in the area and induced infiltration from controlled canals provide the recharge to the aquifer.

"Sea-water intrusion, although a constant threat, has not advanced inland enough to contaminate either municipal well field. Intrusion from the El Rio Canal toward the Boca Raton well field appears to be stabilized, though further intrusion is a distinct possibility if fresh water levels are further lowered in the area. Data collection stations are maintained to monitor changes of the salt-water front in the aquifer.

"Large quantities of water can be withdrawn from the interior part of the area without the attendant threat of salt-water intrusion. Hydraulic characteristics of the aquifer are similar throughout the area and high year-round water levels in the interior afford a potential source of immediate and long-term recharge to the aquifer underlying the coastal ridge.

"The lower Hillsboro Canal area is still experiencing rapid growth with resultant demands for larger quantities of potable water. Although potable water is abundant, continuous observation and evaluation of changes in the hydrology of the area should be maintained to protect and efficiently manage the water resources of the area." (Quoted from authors' abstract.)

McCoy, H. J., and Sherwood, C. B., 1968, Water in Broward County, Florida: Florida Bureau of Geology Map Series 29. Scale is approximately 3 1/2 miles to an inch.

"The purpose of this report is to present a general picture of the water resources of Broward County, the regional and local water management facilities designated to alleviate present and future water problems, and the methods used for obtaining large municipal water supplies. Selected data are shown to aid in understanding the hydrologic system and the natural and man-made factors that affect the quantity, quality, and movement of water within the system." (Quoted from authors' introduction.)

McPherson, B. F., 1969, Preliminary determinations of hydrobiological and chemical conditions in the vicinity of the proposed jetport and other airports in south Florida, July 1969: U.S. Geological Survey open-file report FL-70004.

Surface water samples were collected at 21 stations during April, July, and October to November, 1969. This report gives the results of the first set of sampling done in April, 1969.

McPherson, B. F., 1970, Water quality at the Dade-Collier Training and Transition Airport, Miami International Airport, and Cottonmouth Camp - Everglades National Park, in November, 1969: U.S. Geological Survey open-file report FL-70011.

"Water quality was determined at three areas in south Florida in November 1969 to portray conditions at a commercial jetport (Miami International Airport), and in a natural environment (Cottonmouth Camp in Everglades National Park) and a transitional environment (Dade-Collier Training and Transition Airport). Water in canals near Miami International Airport generally contained higher concentrations of nitrogen, phosphorus, organic carbon, trace elements and heavy metals, and lower concentrations of dissolved oxygen than waters at the Training and Transition Airport and at Cottonmouth Camp. Concentrations of chromium, lead, and oil in surface water at Miami International Airport exceeded the limits established in 1969 by the Federal Water Quality Administration for interstate waters of Florida; concentrations were below these limits in the other areas. Sediment at Miami International Airport was heavily coated with oil and grease (23 percent) at station 5, and contained a relatively high concentration of 85.2 µg/kg (micrograms per kilogram) of the DDT family (DDT, DDE, DDD) at station 1. Sediment at other stations in the three areas contained less than 3.0 percent oil and grease and less than 4.2 µg/kg of the DDT family. Nutrient concentrations in sediment were highest at a natural pond near Cottonmouth Camp (station 11) and lowest in a newly excavated borrow pit (station 9) at the Training and Transition Airport." (Quoted from author's abstract.)

McPherson, B. F., 1973a, Water quality in the conservation areas of the Central and Southern Florida Flood Control District, 1970-72: U.S. Geological Survey open-file report FL-73014.

"Selected chemical indicators of water quality in and near the conservation areas in southern FLorida in 1970-72 varied with location and season. Dissolved solids generally were highest in the north and northeast where averages ranged from 471 to 641 mg/l (milligrams per liter), and lowest in the south and west where averages ranged from 172 to 387 mg/l. Pesticides showed a similar distribution trend. The DDT family (the most commonly detected pesticide) averaged, 192 µg/kg (micrograms per kilograms) in bottom sediments in the north of the areas compared with 13.8 µg/kg in the south. DDT averaged 723 µg/kg in centrarchid fish (bass and sunfish) at the north end of Area 1, 264 µg/kg at the south end of Area 1, 230 µg/kg in Area 2, and 56 µg/kg in Area 3. Dieldrin (5.7 to 130 µg/kg) and toxaphene (2,200 to 5,000 µg/kg) were also in high concentrations in fish at the north end of Area 1 and in Area 2. Concentrations of polychlorinated biphenyls (PCB's) were highest (1,300 and 1,900 µg/kg) in bottom sediment at two stations in Area 2. Concentrations of nitrogen and phosphorus varied more with

season or water level than with location. They were highest in June 1971, at the end of a drought; average values were 2.6 mg/l inorganic N (compared with 0.13 to 0.48 mg/l at other times), 4.0 mg/l organic N (compared with 0.8 to 2.5 mg/l at other times), and 0.05 mg/l as P (compared with 0.01 to 0.04 mg/l at other times)." (Quoted from author's abstract.)

McPherson, B. F., 1973b, Vegetation in relation to water depth in Conservation Area 3, Florida: U.S. Geological Survey open-file report FL-73025.

"Five vegetative bench mark stations that represent different water depths and periods of inundation were established in Conservation Area 3A, and vegetative models, transects, and biomass estimates were made. The vegetative models include trees and brush, dense emergent vegetation, and sparse emergent vegetation. In the southeastern part of the Conservation Area, where the water is deep, areas of sparse emergent vegetation are predominantly slough with periphyton, spike rush (Eleocharis cellulosa), bladderwort (Utricularia sp.), water hyssop (Bacopa caroliniana), white water lily (Nymphaea odorata) and Eleocharis elongata. At the shallower northern stations, areas of wet prairie increase and maidencane (Panicum hermitomon) and beak rush (Rhynchospora tracyi) are common in the slough and prairies.

"Biomass of slough vegetation generally decreased with lower water level both at a given station and between stations; it ranged from 16,340 grams (wet weight) per square meter at a water depth of 0.8 meter to less than 200 grams at 0.1 meter." (Quoted from author's abstract.)

McPherson, B. F., Hendrix, G. Y., Klein, Howard, and Tyus, H. M., 1976, The environment of south Florida, a summary report: U.S. Geological Survey Professional Paper 1011.

"The South Florida Environmental Study identified and described the natural ecosystems of south Florida as they functioned before man began to have major impacts on these systems. Where remnants of natural systems still function as before, they were measured and described.

"The study also encompassed the agricultural and urban developments of south Florida and their impacts on the ecosystems. Man is a natural component of the system and, like all living components, seeks to attain some degree of balance or equilibrium with the rest of the system." (Quoted from authors' preface.)

Meyer, F. W., 1972, Preliminary evaluation of infiltration from the Miami Canal to well fields in Miami Springs-Hialeah area, Dade County, Florida: U.S. Geological Survey open-file report FL-72027.

"Infiltration from controlled canals minimizes the depth and extent of the cone of depression about the well fields in the Miami Springs-Hialeah area and prevents sea-water intrusion. In the 1940's the controlled canals contributed 78 to 100 percent of the dry-season pumpage. Average pumpage has increased from 67 to 92 million gallons per day during 1961-71 without significantly affecting the quality of well-field water. Water demands since 1961 have caused the cone of depression to expand beyond the limits of the recharging canals; therefore, the percentage of dry-season contribution from the canals has decreased. In April 1971, the cone of depression expanded southward and caused deep salty ground water in the vicinity of the Tamiami Canal to move northward beneath the airport toward the well fields, forcing a reduction in pumpage. A temporary dam was installed in the Tamiami Canal in September 1971 as a stopgap measure to minimize the threat of sea-water intrusion." (Quoted from author's abstract.)

Meyer, F. W., 1974, Availability of ground water for the U.S. Navy well field near Florida City, Dade County, Florida: U.S. Geological Survey open-file report FL-74014.

"The purpose of this report is to indicate the effects that a 12 mgd increase in Navy well-field pumpage will have on local water levels and on the zone of sea-water intrusion in southeast Dade County." (Quoted from author's purpose and scope.)

Meyer, F. W., and Hull, J. E., 1967a, Hydrologic conditions in the Canal 111 area, Florida, April 17, 1967: U.S. Geological Survey open-file report FL-67005.

"This report is a summary of data collected on July 11, 1967 and is the first in a series of monthly reports that began April 17, 1967. The data are presented in the form of graphs and maps designed to present a 'birds eye' view of the water level and salinity conditions observed on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967b, Hydrologic conditions in the Canal 111 area, May 8, 1967: U.S. Geological Survey open-file report FL-67006.

"This report is a summary of data collected on May 8, 1967 and is the second in a series of monthly reports that began April 17, 1967. The data are presented in the forms of graphs and maps designed to present a 'birds eye' view of the water level and salinity conditions observed on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967c, Hydrologic conditions in the Canal 111 area, June 5, 1967: U.S. Geological Survey open-file report FL-67007.

"This report is a summary of hydrologic data collected in the Canal 111 area on June 5, 1967 and is the third in a series of monthly reports that began April 17, 1967. The data are presented in the form of graphs and maps designed to present a 'birds eye' view of the water-level and salinity conditions observed on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967d, Hydrologic conditions in the Canal 111 area, July 11, 1967: U.S. Geological Survey open-file report FL-67008.

"This report is a summary of data collected on July 11, 1967 and is the fourth in a series of monthly reports that began April 17, 1967. The data are presented in the forms of graphs and maps designed to present a 'birds eye' view of the water level and salinity conditions observed on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967e, Hydrologic conditions in the Canal 111 area, August 8, 1967: U.S. Geological Survey open-file report FL-67009.

"This report is a summary of data collected on August 8, 1967, and is the fifth in a series of monthly reports that began April 17, 1967. The data are presented in the form of graphs and maps designed to present a 'birds eye' view of the water level and salinity conditions observed on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967f, Hydrologic conditions in the Canal 111 area, October 10, 1967: U.S. Geological Survey open-file report FL-67010.

"The report is a summary of data collected on August 8 and October 11, 1967 and is the sixth in a series of reports that began April 17, 1967. The data, in the form of graphs and maps, present a 'birds eye' view of the water level and salinity conditions on a particular date." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1967g, Hydrologic conditions in the Canal 111 area, December 5, 1967: U.S. Geological Survey open-file report FL-67011.

"The report is a summary of data collected on October 10 and December 5, 1967 and is the seventh in a series of reports that began April 17, 1967. The data, in the form of graphs and maps, present a 'birds eye' view of the water level and salinity conditions." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1968a, Hydrologic conditions in the Canal 111 area, December 6, 1967 - February 1, 1968: U.S. Geological Survey open-file report FL-68011.

"This report summarizes the hydrologic data collected in the Canal 111 area between December 5, 1967 and February 1, 1968 and is the eighth in a series of reports that began April 17, 1967. The data, in the form of graphs and maps, present a comprehensive picture of water level and chlorinity conditions." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1968b, Hydrologic conditions in the Canal 111 area, February 2, 1968 - April 15, 1968: U.S. Geological Survey open-file report FL-68012.

"This report summarizes the hydrologic data collected in the Canal 111 area between February 2, 1968 and April 15, 1968 and is the ninth in a series of reports that began April 17, 1967. The data, in the form of graphs and maps, present a comprehensive picture of water level and chlorinity conditions." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1968c, Hydrologic conditions in the Canal 111 area, April 16 - June 11, 1968: U.S. Geological Survey open-file report FL-68013.

"This report summarizes the hydrologic data collected in the Canal 111 area between April 15, 1968 and June 11, 1968 and is the tenth in a series of reports that began April 17, 1967. The data in the form of graphs and maps present a comprehensive picture of water level and of chloride concentrations in the waters." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1968d, Hydrologic conditions in the Canal 111 area, June 12 - August 21, 1968: U.S. Geological Survey open-file report FL-68014.

"This report summarizes the hydrologic data collected in the Canal 111 area between June 12, 1968 and August 21, 1968 and is the eleventh in a series of reports that began April 17, 1967. The data in the form of graphs and maps present a comprehensive picture of water levels and of chloride concentrations in the waters." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1968e, Hydrologic conditions in the Canal 111 area, August 22 - October 15, 1968: U.S. Geological Survey open-file report FL-68015.

"This report summarizes the hydrologic data collected in the Canal 111 area between August 22, 1968 and October 15, 1968, and is the twelfth in a series of reports that began April 17, 1967. The data in the form of graphs and maps present a comprehensive picture of water levels and of chloride concentrations in the waters." (Quoted from authors' abstract.)

Meyer, F. W., and Hull, J. E., 1968f, Hydrologic conditions in the Canal 111 area, October 16 - December 19, 1968: U.S. Geological Survey open-file report FL-68016.

"This report summarizes the hydrologic data collected in the Canal 111 area between October 16, 1968 and December 19, 1968, and is the thirteenth in a series of reports that began April 17, 1967. The data in the form of graphs and maps present a comprehensive picture of water levels and of chloride concentrations in the waters." (Quoted from authors' introduction.)

Meyer, F. W., and Hull, J. E., 1969, Hydrologic conditions in the Canal 111 area, December 20, 1968 - February 13, 1969: U.S. Geological Survey open-file report FL-69012.

"This report summarizes the hydrologic data collected in the Canal 111 area between December 20, 1968 and February 13, 1969 and is the fourteenth in a series of reports that began April 17, 1967. The data in the form of graphs and maps present a comprehensive picture of water levels and of chloride concentrations in the waters." (Quoted from authors' introduction.)

Miller, R. A., 1979, Characteristics of four urbanized basins in south Florida: U.S. Geological Survey Open-File Report 79-694.

"Physical characteristics of four urbanized basins in south Florida are presented. Land use of the four basins are low-density residential, highway, commercial, and high-density residential. Maps of each basin include a photomosaic, a sewerage map, a drainage map, and an impervious-area map. Tabular data include pervious and impervious areas; sewer data, such as pipe diameter, length, and slope; and inlet elevations. General descriptions of the soil cover and type, vegetation, streets, gutters, and curbs are also provided." (Quoted from author's abstract.)

Miller, R. A., Mattraw, H. C., and Hardee, Jack, 1979, Stormwater runoff data for a commercial area, Broward County, Florida: U.S. Geological Survey Open-File Report 79-982.

"Rainfall, stormwater discharge, and water-quality data for rainfall and runoff are summarized for a commerical area in Fort Lauderdale, Florida. Loads for 20 water-quality constituents were computed for runoff from 31 storms between May 1975 and June 1977. The basin of 20.4 acres contains a shopping center with adjacent parking, and is 97.9 percent impervious." (Quoted from authors' abstract.)

Miller, W. L., 1975, Nutrient concentrations of surface waters for southern Florida, September 1970 to April 1975: U.S. Geological Survey open-file report FL-75010.

"Inorganic nitrogen and phosphorus in the surface waters of southern Florida were measured synoptically by the U.S. Geological Survey during wet (June - October) and dry (November - May) seasons nine times between September 1970 and April 1975. The number of sites sampled ranged between 175 in 1970 and 500 in 1975, with a total of 2,367 samples collected and analyzed since the inception of the program. Samples were collected from canals, rivers, lakes, coastal bays, marshes, and swamps. The data are shown on a series of maps which indicate the locations of sampling sites and the nutrient concentrations. Each nutrient species is shown separately on maps prepared using data collected during the surveys. The analytical data are presented with no discussion of variation in concentration of the several parameters in either space or time. No statistical analysis has been given the data, nor has the significance of given nutrient concentration been cited. The accumulated data of nine nutrient surveys are presented to facilitate storage of and reference to the data." (Quoted from author's abstract.)

Miller, W. L., 1978, Effects of bottom sediments on infiltration from the Miami and tributary canals to the Biscayne aquifer, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations 78-36.

"Infiltration from the Miami Canal and its tributaries is a major source of recharge to the Biscayne aquifer in the Miami Springs-Hialeah well-field area. In the late 1940's when average pumpage was less than 50 million gallons per day, canal infiltration contributed an estimated 80 to 100 percent of the dry season pumpage. Between 1970 and 1973, average daily pumpage increased 18 percent tut the canal infiltration capacity decreased 6 percent. In May 1973, about 50 percent of the well field's peak pumpage of 120 million gallons per day was attributed to canal infiltration. Steadily increasing withdrawals have caused deepening and broadening of the well field's cone of depression thereby increasing the threat of saltwater intrusion during dry, peak demand periods.

"Canal water levels were consistently higher than the water table in 1973. Canal-bottom sediments impede downward infiltration from the canals. Filtration through bottom sediments reduces concentrations of coliform bacteria, pesticides, PCB's, metals, and suspended materials. Filtration by the sandy upper part of the aquifer further reduces concentrations of these constituents as infiltrating water moves toward the pumping zone. The quantitative effects on ground-water quality resulting from the removal of the canal-bottom sediments cannot be adequately predicted from present data." (Quoted from author's abstract.)

Orth, P. G., 1975, Nutrient fluctuations in groundwater under an agricultural area, Dade County, Florida: Soil and Crop Science Society of Florida Proceedings, v. 35.

An investigation was initiated to determine the concentrations of plant nutrients in the ground water and the effect that agriculture might have on these concentrations.

The results indicate that agriculture is not responsible for any permanent build-up of nutrients in the ground water of southwest Dade County, and temporary increases are not a threatening problem.

Parker, G. G., 1945, Saltwater encroachment in southern Florida: Journal of the American Water Works Association, v. 37, no. 6.

This report discusses the occurrence and principles of saltwater encroachment in the Miami coastal area. Although the local geology is somewhat different, these principles are believed to be applicable to other coastal areas of Florida.

Parker, G. G., 1951, Geologic and hydrologic factors in the perennial yield of the Biscayne aquifer: Journal American Water Works Association, v. 43, no. 10.

This report presents a general overall view of the geology and hydrology basic to understanding the water supply development in the Miami area. The factors of perennial yield that are applicable to the local aquifer are also discussed in this presentation.

Parker, G. G., and Cooke, C. W., 1944, Late Cenozoic geology of southern Florida, with a discussion of ground water: Florida Geological Survey Bulletin 27.

This report discusses the formations of southern Florida and their geologic and hydrologic characteristics in the order of deposition by the transgressive and regressive sea.

Parker, G. G., Ferguson, G. E., and Love, S. K., 1944, Interim report on the investigation of water resources in southeasern Florida with special reference to the Miami area in Dade County: Florida Geological Survey Report of Investigations no. 4.

Geologic, hydrologic, and chemical data were obtained in order to determine: "***the areal extent of the water-bearing formations; the capacity of these formations to transmit and yield water; the area and rate of recharge and discharge; the quantity and quality of water in the different parts of the water-bearing rocks; the source and approximate rate of movement of saltwater at all depths in the water-bearing rocks; factors controlling salt-water encroachment; the height of the water table and the direction of flow of ground water at different times of the year; the stage and discharge of the canals throughout the years; and the period when canals drained the nearby land areas and when they fed water to these areas; and the approximate quantities of water involved." (Quoted from authors' introduction.)

Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida: U.S. Geological Survey Water-Supply Paper 1255.

A comprehensive study of the water resources of southeastern Florida was made by the collection and interpretation of geologic, hydrologic, and climatic data. Special emphasis was placed on the geology and geomorphology of southern Florida because of their importance in the occurrence and movement of both surface and groundwater.

Lithologic logs, geologic cross-sections, water-quality data, and various types of contour maps are published in this report.

Parker, G. G., and Stringfield, V. T., 1950, Effects of earthquakes, trains, tides, winds, and atmospheric pressure changes on water in the geologic formations of southern Florida: Economic Geology, v. 45, no. 5.

Water-level measurements in wells are essential in determining basic hydrologic factors. These water-level readings may be misleading because in addition to changes in recharge and discharge they respond to changes in tides, atmospheric pressure, winds, earthquakes, and passing trains. Usually, both artesian and non-artesian aquifers are known to react differently to these forces, but in some areas the local geologic conditions in non-artesian aquifers may cause water-level fluctuations normally found only in artesian wells.

Perkins, R. D., 1977, Depositional framework of Pleistocene rocks in south Florida, Part II; in Quaternary Sedimentation In South Florida: The Geological Society of America, Memoir 147.

"Detailed stratigraphic analysis of the Pleistocene of south Florida, based on 56 measured sections, indicates that these deposits are divisible into five marine units separated by regional discontinuity surfaces. Marine units are correlated with eustatic high sea-level stands and discontinuity surfaces with subaerial exposure during low stands. Discontinuity surfaces are often found to be intraformational when related to format stratigraphic designations presently in use. The Fort Thompson and Anastasia Formations contain four such surfaces, the Key Largo Limestone contains two, and the Miami Limestone contains one. When considered in detail, discontinuity surfaces in south Florida are found to vary in the amount of time they represent and the degree to which they are developed and preserved.

"***Each stratigraphic unit is analyzed from the following viewpoints: (1) role of pre-unit topography, (2) isopach patterns, (3) lithofacies patterns, (4) ecologic facies patterns, and (5) interpretation of depositional environments." (Quoted from author's abstract.)

Pitt, W. A. J., Mattraw, H. C., and Klein, Howard, 1975, Groundwater quality in selected areas serviced by septic tanks, Dade County, Florida: U.S. Geological Survey Open-File Report 75-607.

"An investigation of ground water in five selected areas serviced by septic tanks in Dade County, Florida was conducted. Analyses of ground water from base-line water-quality wells in inland areas remote from urban development indicated that the ground water is naturally high in organic nitrogen, ammonia, organic carbon and chemical oxygen demand. Some enrichment of ground water

with sodium provided a possible key to differentiating septic-tank effluent from other urban ground-water contaminant sources. High ammonia nitrogen, phosphorus, and the repetitive detection of fecal coliform bacteria were characteristic of two 10-foot monitor wells that consistently indicated the presence of septic-tank effluent in ground water. Dispersion, dilution, and various chemical processes have presumably prevented accumulation of septic-tank effluent at depths greater than 20 ft, as indicated by the 65 types of water analyses used in the investigation. Fecal coliform bacteria were present on one or two occasions in many monitor wells but the highest concentration, 1,600 colonies/100 ml, was related to storm-water infiltration rather than septic-tank discharge.

"Areal variations in the composition and the hydraulic conductivity of the sand and limestone aquifer had the most noticeable influence on the overall ground-water quality. The ground water in the more permeable limestone in south Dade County near Homestead contained low concentrations of septic-tank related constituents, but higher concentrations of dissolved sulfate and nitrate. The ground water in north Dade County, where the aquifer is less permeable, contained the highest dissolved iron, manganese, COD, and organic carbon." (Quoted from authors' abstract).

Pitt, W. A. J., Jr., and Meyer, F. W., 1976, Ground-water quality at the site of a proposed deep-well injection system for treated wastewater, West Palm Beach, Florida: U.S. Geological Survey Open-File Report 76-91.

"The U.S. Geological Survey collected scientific and technical information before, during, and after construction of a deep test well at the location of a future regional waste-water treatment plant to be built for the city of West Palm Beach, Florida. Data from the test well will be used by the city in the design of a proposed deep-well injection system for disposal of effluent from the treatment plant. Shallow wells in the vicinity of the drilling site were inventoried and sampled to provide a data base for detecting changes in ground water quality during construction and later operation of the deep wells. In addition, 16 small-diameter monitor wells, ranging in depth from 10 to 162 feet, were drilled at the test site. During the drilling of the deep test well, water samples were collected weekly from the 16 monitor wells for determination of chloride content and specific conductance. Evidence of small spills of salt water were found in monitor wells ranging in depth from 10 to 40 feet. Efforts to remove the salt water from the shallow unconfined aquifer by pumping were undertaken by the drilling contractor at the request of the city of West Palm Beach. The affected area is small and there has been a reduction of chloride concentration." (Quoted from authors' abstract.)

Rodis, H. G., 1973, Encroaching saltwater in northeast Palm Beach County, Florida: Florida Bureau of Geology Map Series 59. Scales vary.

This report consists of diagrams describing the causes of saltwater intrusion and possible solutions to the problem.

Rosendahl, P. C., and Rose, P. W., 1979, Profile water quality standards: Everglades National Park: U.S. National Park Service.

"Water quality criteria were developed for delivery waters to Everglades National Park. The park receives a minimum of 12.34 m^3/sec (315,000 acre-ft/yr) of water from controlled sources external to its boundary. These waters often originate from areas that are or potentially are impacted from urban and agricultural developments. When, in 1970, the U.S. Congress guaranteed minimum water deliveries to Everglades National Park, it also required that these waters be of good quality." (Quoted from authors' abstract.)

Rosenstiel, D. H., and Lewis, 1971, An ecological study of south Biscayne Bay and Card Sound, Florida appendix-chemistry: University of Miami School of Marine and Atmospheric Sciences.

Four chemical appendixes are presented in this paper. Appendix I consists of tabulated chemical data from the ecological study of south Biscayne Bay and Card Sound. Appendix II consists of chemical and hydrologic data obtained from the area of thermal discharge adjacent to the Florida Power and Light's Turkey Point Generating Plant in Lower Biscayne Bay. Appendix III discusses the use of the Perkin Elmer HGA-70 heated graphite atomizer for use in selected volatalization. Appendix IV discusses the observations and relationship to observations made of the water temperatures of the thermal plume.

Russell, G. M., Hanson, C. E., and Pitt, W. A. J., Jr., 1978, Water quality in the Old Plantation Water Control District, Broward County, Florida - Progress Report, July 1976 - June 1977: U.S. Geological Survey Open-File Report 78-411.

"Water quality in the Old Plantation Water Control District in Broward County, Florida has been affected by effluent from sewage-treatment plants, agriculture, and storm-water runoff. Effect of the effluent from sewage-treatment plants on water quality was evident at 3 sites where concentrations of nutrients and bacteria in the Broward County canals exceeded state standards of 2,400 colonies per 100 milliliters for total coliform bacteria, and where at 2 of the 3 sites the fecal coliform/fecal streptococcus ratios indicated possible human contamination. The effect of agriculture on

water quality was evident where relatively high levels of chlorinated hydrocarbon insecticides had concentrated in the bottom sediments of the canals. For example, DDD reached levels of 330 micrograms per kilogram at site 3. The effects of storm-water runoff on water quality were detected during the wet season when concentrations of several trace elements increased. For example, zinc averaged 30 micrograms per milliliter in the wet season compared with 20 micrograms per milliliter during the dry season." (Quoted from authors' abstract.)

Russo, T. N., 1974, Indicators of organic contamination in Plantation canal, Broward County, Florida, 1971-72: Florida Bureau of Geology Report of Investigations 70.

This report documents "*** the water-quality characteristics of a contaminated controlled canal. The report demonstrates the value of the physical, chemical and biological properties of the bottom sediments in providing an overall picture of the long-term effects of contamination." (Quoted from author's purpose and scope.)

Russo, T. N., and McQuivey, R. S., 1975, Simulation of DO and BOD, Plantation Canal, Broward County, Florida with an evaluation of a stream-quality routing model for use in south Florida: U.S. Geological Survey Water-Resources Investigations 59-75.

"A mathematical model; QUAL-I, developed by the Texas Water Development Board, was evaluated as a management tool in predicting the spatial and temporal distribution of dissolved oxygen and biochemical oxygen demand in Plantation Canal. Predictions based on the QUAL-I model, which was verified only against midday summer-flow conditions, showed that improvement of quality of inflows from sewage treatment plants and use of at least 130 cubic feet per second (3.7 cubic metres per second) of dilution water would improve water quality in the canal significantly.

"The model was not fully amenable to use on Plantation Canal because: (1) it did not consider photosynthetic production, nitrification, and benthic oxygen demand as sources and sinks of oxygen; (2) the model assumption of complete mixing, transport, and steady state were not met; and (3) the data base was inadequate because it consisted of only one set of data for each case. However, it was felt that meaningful results could be obtained for some sets of conditions." (Quoted from authors' abstract.)

Schneider, J. J., 1969, Tidal relations in the south Biscayne Bay area, Dade County, Florida: U.S. Geological Survey open-file report FL-69008.

"Development of the waterfront lands of southeast Dade County depends upon the construction of sea walls (bulkheads) and filling of the lowlying land. To assist Dade County officials in planning the development of the area, an investigation was made to determine the elevation of mean high water and tidal patterns in the south Biscayne Bay area. The results of the investigation are based on records collected from ten tide gages during the period July 1, 1967 through June 30, 1968. Prior records from most of the gages were available for correlation. The elevation of mean high water was 1.5 feet in central Biscayne Bay and 0.9 foot in the lower bays. The mean tidal range was 2.0 feet in central Biscayne Bay and 0.5 foot in the lower bays. The difference between mean half tide and mean water levels was found to be negligible at all stations. The time lag for high and low tides, referred to Miami Beach, was approximately one hour in Biscayne Bay and 6 hours at Manatee Bay." (Quoted from author's abstract.)

Schneider, J. J., 1970, Tidal relations along the intracoastal waterway, Broward County, Florida: U.S. Geological Survey open-file report FL-70006.

"One of the most intensely developed urban areas in the Nation borders the Intracoastal Waterway in Broward County. An investigation was made to assist County officials in establishing the elevation of mean high water and tidal patterns along the waterway. The results of the investigation are based on records collected from five tide gates, during the period March 1, 1968 through February 28, 1969. Along the waterway, mean high water was approximately 1.5 feet above mean sea level. The mean tidal range in the waterway at Hollywood was 0.6 foot less than the tidal range of the ocean at Miami Beach. The difference between mean half tide and mean water level was negligible at all stations. The average time difference for high and low tides, referred to Miami Beach, ranged from zero at Port Everglades to plus one hour and 40 minutes at Hollywood." (Quoted from author's abstract.)

Schneider, J. J., 1973, Tidal relations along the intracoastal waterway, Palm Beach County, Florida: U.S. Geological Survey open-file report FL-73021.

"From September 1, 1971 through August 31, 1972, mean high water along the Intracoastal Waterway in Palm Beach County ranged from 1.71 to 1.87 feet above mean sea level, datum of 1929. The mean tidal range varied from 2.33 to 2.69 feet. The difference between half tide and mean sea level varied between -0.01 foot at

Delray Beach to +0.05 foot at Juno Beach with a zero variation at Southern Blvd. and Blue Heron Blvd. The average time difference for high tides referred to Miami Beach, ranged from plus 20 minutes at Riviera Beach to plus 1 hour and 50 minutes at Delray Beach." (Quoted from author's abstract.)

Schneider, J. J., 1976, Geologic data from test drilling in Palm Beach County, Florida, since 1970: U.S. Geological Survey Open-File Report 76-713.

"Test hole data that may be used to determine the type and character of the subsurface materials and the thickness and areal extent of the shallow aquifer are presented. Lithologic logs from 66 test wells and geophysical logs from 54 test wells are contained in this report." (Quoted from author's abstract.)

Schroeder, M. C., 1953, Stratigraphy of the outcropping formations in southern Florida; in carbonate deposits in south Florida: 8th field trip guidebook: Southeastern Geological Society.

A generalized description of the geologic characteristics and stratigraphic relationship of the outcropping formations of south Florida is discussed and supplemented by generalized geologic cross-sections showing the lithology of the Lake Flint Marl, Fort Thompson Formation, Caloosahatchee Marl, and the Anastasia Formation.

Schroeder, M. C., Klein, Howard, and Hoy, N. D., 1958, Biscayne aquifer of Dade and Broward counties, Florida: Florida Geological Survey Report of Investigations no. 17.

"The Biscayne aquifer is the only source of fresh ground water in Dade and Broward counties, Florida. Composed of highly permeable limestone and sand mainly of Pleistocene age, the aquifer supplies large quantities of water, of excellent quality except for hardness, for municipal, industrial, and irrigational use. The aquifer attains its maximum thickness in the Atlantic coastal areas and wedges out in western Dade and Broward Counties.

"Water-table conditions prevail in the Biscayne aquifer, and the water table fluctuates with variations in rainfall, evapotranspiration, and pumping. High ground-water levels occur during the fall months and low levels during spring and early summer. The highest water levels of record occurred in October 1947, when intense rainfall accompanying a hurricane flooded large areas throughout the two counties. Major discharge from the aquifer occurs by natural outflow and evapotranspiration. The average daily pumpage from the Biscayne aquifer in 1950 is estimated to have been 130 million gallons.

"Permeability tests show that the limestone of the Biscayne aquifer rank among the most productive aquifers ever investigated by the U.S. Geological Survey.

"Salt-water encroachment in the aquifer has taken place in coastal areas of southeastern Florida. The greatest inland advance of salt-water intrusion has occurred as tongues along tidal drainage canals and rivers." (Quoted from authors' abstract.)

Schroeder, M. C., Milliken, D. L., and Love, S. K., 1954, Water resources of Palm Beach County, Florida: Florida Bureau of Geology Report of Investigations no. 13.

"The principal source of ground water in Palm Beach County is the water-table aquifer, which ranges in thickness from 60 to 300 feet and is composed of the surface sands and the permeable limestone and shell beds underlying them. About 8,000 million gallons was withdrawn from this aquifer by wells in 1951. The capability of the water-table formations to transmit water to wells differs greatly from place to place in the county, but large quantities of shallow ground water are available in most parts of the county. The aquifer discharges large quantities of water into canals that annually discharge about five times as much water into the ocean as they receive from Lake Okeechobee. Principal recharge of the aquifer is by local rainfall which averages about 60 inches a year." (Quoted from authors' abstract.)

Scott, W. B., 1976, Hydraulic conductivity and water quality of the shallow aquifer, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations 76-119.

"Subsurface geophysical and lithologic logs were correlated with aquifer tests and laboratory test data to estimate the hydraulic conductivity of selected zones of the shallow aquifer. These zones are, in order of decreasing hydraulic conductivity, Z-1, Z-2, and Z-3. The hydraulic conductivity of the shallow aquifer is estimated to range from 1 to 130 feet per day (0.3 to 40 meters per day), based on lithology and physical properties. The yield of wells penetrating this aquifer ranges from 100 to more than 1,000 gallons per minute (6 to 60 liters per second).

"Zone Z-4 represents the upper part of the numerous confining layers which separate the underlying Floridan artesian aquifer from the non-artesian shallow aquifer. Its hydraulic conductivity generally is less than 1 ft/day (0.3 meter per day). The yield of wells penetrating this zone is less than 100 gal/min (6 liters per second)." (Quoted from author's abstract.)

Scott, W. B., Land, L. F., and Rodis, H. G., 1977, Saltwater intrusion in the shallow aquifer in Palm Beach and Martin Counties, Florida: U.S. Geological Survey Water-Resources Investigation 76-135.

"The withdrawal of large quantities of fresh ground water in the vicinity of the coast has reduced or locally reversed the natural seaward hydraulic gradient and, in places, allowed saltwater to advance landward in the aquifer, displacing freshwater. This landward advance is termed saltwater intrusion. The purpose of this report is to show the position of the saltwater front in eight urban areas adjacent to the coast. The saltwater front, as shown on the profiles, is based on a chloride concentration of 250 mg/L which is recommended as a limit for water that is considered potable (NAS and NAE, 1973). The chloride concentration of native freshwater almost always is less than 50 mg/L in the coastal aquifer." (Quoted from authors' introduction.)

Sherwood, C. B., 1959, Ground-water resources of the Oakland Park area of eastern Broward County, Florida: Florida Geological Survey Report of Investigations no. 20.

"The Biscayne aquifer is the source of all fresh ground water in the Oakland Park area of eastern Broward County, Florida. This aquifer extends from the land surface to more than 215 feet below mean sea level and is composed chiefly of sandy marine limestone, calcareous sandstone, and beds of fine to medium quartz sand. The aquifer differs from place to place, but, in general, most of the layers of limestone and sandstone occur at depths below 60 feet. The permeability of the aquifer increases with depth.***

"Chemical analyses of ground-water samples indicate a hard limestone water that is suitable, naturally or with treatment, for most ordinary uses. Periodic determinations of chloride content of the ground water show that some salt-water encroachment has occurred in areas near the coast and in the Middle River basin." (Quoted from author's abstract.)

Sherwood, C. B., and Klein, Howard, 1963, Surface and ground water relation in a highly permeable environment: U.S. Geological Survey, extract of Report of Investigations 63, 1963, International Association of Scientific Hydrology.

"Major problems of flooding, drought, and salt-water encroachment occur in the mushrooming urbanized area of southeastern Florida because of the unequal distribution of rainfall and the highly integrated nature of the surface and ground-water flow system. However, hydrologic studies in the vicinity of levees and controlled canals of the massive regional flood-control system and in municipal well fields, show that the excellent interconnection

between canals and the aquifer facilitate effective management of the water resources. The regulation of stages and flows in the network of controlled canals, which connect large inland conservation areas to the coast, provides gravity drainage of flood waters to the sea and fresh water for recharge by infiltration to the highly permeable Biscayne aquifer for municipal supplies and the control of salt-water encroachment during droughts.

"Levee underseepage is appreciable at the south end of the system where limestone is near the surface; however, it is retarded somewhat by thin beds of marl and dense limestone of low vertical permeability. Seaward losses of fresh water, incurred in the prevention of salt-water encroachment, constitute a relatively minor part of the overall freshwater potential of the area. The losses will be greatly exceeded by municipal well-field withdrawals when maximum urbanization occurs. Careful monitoring of drawdowns in well-field areas and of the inland extent of the salt front as well as predictions of the effects of proposed changes in the flow system are essential to the complete management of this regional water resource." (Quoted from authors' abstract.)

Sherwood, C. B., and Leach, S. D., 1962, Hydrologic studies of the Snapper Creek Canal area, Dade County, Florida: Florida Geological Survey Report of Investigations no. 24.

"The Snapper Creek Canal drains the southernmost part of the Greater Miami area and a part of the lower Everglades in Dade County, Florida. The canal and a control structure near Biscayne Bay are part of a water-control system designed to provide maximum drainage during flood periods and to maintain water levels high enough to retard salt-water encroachment during dry periods.

"The area is underlain by highly permeable limestone and sand of the Biscayne aquifer. Because of the high permeability, there is excellent hydraulic interconnection between the canal and the aquifer, and inflow to or losses from the canal occur rapidly in response to changes in canal levels. When the control structure is closed, canal levels along the lower reach are generally higher than ground-water levels and appreciable losses from the canal occur by underflow toward the bay. Except under very low water conditions, these losses are balanced by ground-water inflow from the western part of the coastal ridge. When extreme drought conditions prevail, it is estimated that about 50 cfs (cubic feet per second) will be needed in the canal to balance the losses that will occur if a water level of 2.75 feet above msl (mean sea level) is maintained in the canal at the control structure. During prolonged droughts a large part of the water withdrawn by the nearby city of Miami well fields will be derived from infiltration from the canal. This loss could amount to more than twice as much as the natural losses from the system." (Quoted from authors' abstract.)

Sherwood, C. B., McCoy, H. S., and Galliher, C. F., 1973, Water resources of Broward County, Florida: Florida Bureau of Geology Report of Investigations no. 65.

"The purpose of this report is to describe the water resources and water problems of Broward County and to evaluate the present and future potential of the resources. The water resources are portrayed by description of ground and surface-water flow systems; hydrologic characteristics of the principal aquifers, primary canals, and water conservation areas; and a summary of water-quality and water-use data." (Quoted from authors' purpose and scope.)

Swayze, L. J., 1979, Water-level contour map of the Alexander Orr and Southwest well-field areas, Dade County, Florida, October 12, 1978: U.S. Geological Survey Open-File Report 79-1266, scale 1:24,000.

Map showing water-level contours of Alexander Orr and Southwest well-field areas in Dade County, Florida.

Tarver, G. R., 1964, Hydrology of the Biscayne aquifer in the Pompano Beach area, Broward County, Florida: Florida Bureau of Geology Report of Investigation no. 36.

The ground-water investigation of the Biscayne aquifer in Pompano Beach area consisted of the following: "(1) an inventory of wells, (2) installation of two automatic water-level recording gages, (3) installation of shallow wells for water-level observations, (4) drilling of four deep test wells to determine the character of the sediments and the quality of the water in the Biscayne aquifer, (5) leveling to refer measuring points to mean sea level altitudes, (6) periodic water-level measurements, (7) periodic determination of the chloride content of water from wells and bodies of surface water, and (8) pumping tests to determine the water transmitting and storing properties of the aquifer." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1959, Survey-review report on South Dade County - Central and Southern Florida Project; south Dade County.

"This report reviews the Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes *** with respect to flood- and water-control problems in the portion of South Dade County described in chapter II. Field investigations for this report included meteorologic, geologic, hydrographic, and economic surveys of the area. Available data developed in connection with

design memorandum studies on the Central and Southern Florida Project were reviewed and brought up to date, and material submitted by local interests was given careful consideration. General inspections were made to determine the area subject to flooding." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1960, Survey-review report on Central and Southern Florida Project; Part I agriculture and conservation areas supplement 33 -- general design memorandum, Conservation Area No. 3.

"This report presents hydrologic and hydraulic data and determines a plan of improvement for Conservation Area No. 3. The principal factors affecting the plan of improvement are the amount of storage required in the pool for low-water regulation; control of seepage through porous rock under some levees; location and capacity of structures needed to control water levels in the pool and on adjacent areas; and the alinement and grade of the levees needed to protect adjacent areas from flooding or to retain water for use during dry periods." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1961a, Survey-review report on Central and Southern Florida Project; Cutler drain area project.

"This report reviews the Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes *** with respect to flood- and water-control problems in the area***. Field investigations for this report included meteorologic, geologic, hydrographic, and economic surveys of the area. Available data developed in connection with design memorandum studies on the Central and Southern Florida Project were reviewed and brought up to date, and material submitted by local interests was given careful consideration. General inspections were made to determine the area subject to flooding." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1961b, Survey-review report on Central and Southern Florida Project; Greater Miami area (area B).

"This report reviews the Comprehensive Report for Central and Southern Florida with respect to the sparsely developed portion of the Greater Miami area (Area B) lying between the developed area (Area A) and Conservation Area no. 3, all in Dade County, Fla. (Those area designations were arbitrarily chosen for convenience of reference in lieu of better descriptive regional names). *** Field

investigations for this current report included meteorologic, hydrographic, and economic surveys of the area. Available field data on subsurface explorations and topography developed in connection with design memorandum studies on the Central and Southern Florida Project were also used. General inspections were made to determine the area subject to flooding." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1963, Survey-review report on Central and Southern Florida Project, southwest Dade County (mimeographed report).

"This report reviews the Comprehensive Report on Central and Southern Florida with respect to the sparsely developed portion of central Dade County, Fla., lying between the alinement of Levee 31(N) of the project under review and the boundaries of Everglades National Park, all lying south of Tamiami Canal.

"Field investigations for this current report include meteorologic, hydrologic, and economic surveys of the area. Available field data on subsurface explorations, topography, and underground seepage characteristics developed in connection with design memorandum studies on the Central and Southern Florida Project were also used. General inspections were made to determine the area subject to flooding and the suitability of the land for agricultural and other types of development." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1968a, Survey-review report on Central and Southern Florida Project; water resources for central and southern Florida, appendix I.

"This report reviews the Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes *** with respect to flood- and water-control problems in the area ***. Field investigations for this report included meteorologic, geologic, hydrographic, and economic surveys of the area. Available data developed in connection with design memorandum studies on the Central and Southern Florida Project were reviewed and brought up to date, and material submitted by local interests was given careful consideration. General inspections were made to determine the area subject to flooding." (Quoted from author's purpose and scope.)

U.S. Army Corps of Engineers, 1968b, Survey-review report on Central and Southern Florida Project; water resources for central and southern Florida, main report.

This report reviews the water resources for central and southern Florida. It includes geologic, hydrologic, and soil data.

U.S. Federal Water Quality Administration, 1970, Pollution of the waters of Dade County, Florida.

"This report discusses the effects on water quality of the numerous waste sources discharging into the canals, coastal waters and ocean in and adjacent to Dade County. The necessary actions required to alleviate the problem are also discussed. Data for this report were furnished by the Florida State Air and Water Pollution Control Board, and additional data were collected by the Federal Water Quality Administration, Lower Florida Estuary Study." (Quoted from author's introduction.)

U.S. Geological Survey, 1973, Land use and land cover, 1973, West Palm Beach, Florida: U.S. Geological Survey Land Use Series Map L-85, scale 1:250,000.

A map portraying the land use of Palm Beach Counties, including the following sections: Urban or built up land, agricultural land, rangeland, forest land, water, wetland, barren land, tundra, and perennial snow or ice.

U.S. Geological Survey, 1976, Water resources data for Florida, water year 1975 -- volume 2: Southern Florida: U.S. Geological Survey Water Data Report FL-75-2.

"Water resources data for the 1975 water year for south Florida consist of records of stage, discharge, and water quality of streams; elevation and water quality of lakes and reservoirs; water-levels and water quality of wells; and discharge and water quality of springs. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating state and federal agencies in Florida." (Quoted from author's introduction.)

U.S. Geological Survey, 1977, Water resources data for Florida, water year 1976 -- volume 2: U.S. Geological Survey Water-Data Report FL-76-2.

"Water resources data for the 1976 water year for south Florida consist of records of stage, discharge, and water quality of streams; elevation and water quality of lakes and reservoirs; water-levels and water quality of wells; and discharge and water quality of springs. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating state and federal agencies in Florida." (Quoted from author's introduction.)

U.S. Geological Survey, 1978, Water resources data for Florida, water year 1977 -- volume 2B: southern Florida: U.S. Geological Survey Water-Data Report FL-77-2B.

"Water resources data for the 1977 water year for south Florida consist of records of stage, discharge, and water quality of streams; elevation and water quality of lakes and reservoirs; water-levels and water quality of wells; and discharge and water quality of springs. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating state and federal agencies in Florida." (Quoted from author's introduction.)

Vorhis, R. C., 1948, geology and ground water of the Fort Lauderdale area: Florida Geological Survey Report of Investigations no. 6.

The geology and ground water of Fort Lauderdale was interpreted from the following geologic and hydrologic data: "(1) Areal extent and vertical distribution of water-bearing formations (aquifers); (2) Hydrologic and lithologic characteristics of these aquifers; (3) Quality of water at various depths in aquifers; (4) Present extent of and probable future salt-water enroachment; (5) Elevation and shape of the water table in the well-field area at various times of the year; (6) Effect on the water table of pumping from wells, as shown by the mapped cone of depression around the well field; (7) Effect on the water table or drainage ditches and other developments; and (8) Average height of water table at various places in the area." (Quoted from author's introduction.)

Waller, B. G., 1976, Analysis of selected benthic communities in the Florida Everglades with reference to their physical and chemical environment: U.S. Geological Survey Water-Resources Investigations 76-28.

"Species diversity and numbers of benthic macroinvertebrates were determined at 12 sites, both canals and marshes, in the Everglades of south Florida. The values calculated are used to indicate long-term trends in water quality and variations between study areas.

"Species diversity at all sites was generally in a range indicative of degraded water quality. The number of organisms per square metre of bottom surface was highly variable ranging from 43 to 8,200 organisms.