80-1207 WATER-RESOURCES INVESTIGATIONS, COLLIER COUNTY, FLORIDA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS, COLLIER COUNTY, FLORIDA

OPEN-FILE REPORT 80-1207

Prepared in cooperation with the

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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By Howard Klein

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Tallahassee, Florida

1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) units and abbreviation of units

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785.0	cubic meters (m^3)
	Flow	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
cubic foot per second (ft^3/s)	0.2832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)

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National Geodetic Vertical Datum of 1929 (NGVD of 1929).--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." The datum was derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific coasts.

WATER-RESOURCES INVESTIGATIONS,

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ABSTRACT

Water-resources investigations in Collier County, Florida, began in the early 1950's and were concerned with availability of ground-water supplies and the problem of saltwater intrusion in the Naples area on the Gulf of Mexico coast. With the advent of canal drainage and land reclamation further inland, investigations were begun to evaluate the effects of major canal systems on the water resources and the environment. High on the list of investigative needs at the present time (1980) are the: (1) delineation of extent, thickness, and characteristics of the shallow aquifer which is the principal source of potable ground water; (2) delineation of areas of poor quality ground water in the shallow aquifer and determination of sources of that poor quality; (3) establishment of countywide network of data-collection stations for ground-water levels, canal discharge, water quality, and saltwater intrusion; and (4) determination of the relation between canals and the shallow aquifer.

INTRODUCTION

Collier County, in southwest Florida (fig. 1), was brought under the jurisdiction of the South Florida Water Management District (SFWMD) in 1977. SFWMD is assigned the responsibility of management of the water resources, and one of its functions is to allocate water to users by issuing permits. To insure that the water resources are properly protected and put to best use, SFWMD must have sufficient geologic and hydrologic data upon which to base its decisions before it issues permits. The purpose of this report is to summarize the availability of information related to SFWMD's area of responsibility in Collier County and to outline some of the deficiencies in data-collection and investigative programs.

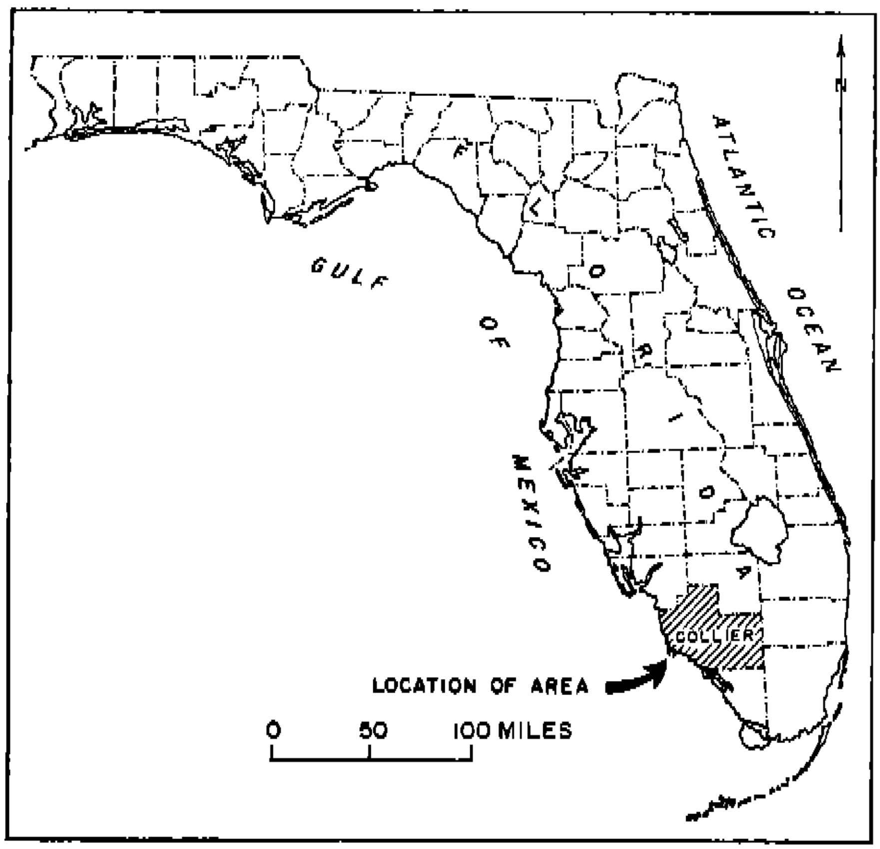

Figure 1.—Location of Collier County

SUMMARY OF ACTIVITIES

Most of the early geologic and hydrologic data for Collier County were obtained by the U.S. Geological Survey in a cooperative program with the city of Naples begun in 1951. The data were related to the expansion of the water-supply system for Naples and to the problem of saltwater intrusion. Work included exploratory drilling to determine the areal extent, depth, and character of the shallow aquifer. Observation wells were installed to delineate and monitor saltwater intrusion from the Gulf of Mexico and Naples Bay and to determine the effect of pumping municipal wells on water levels. Seasonal monitoring of water levels and saltwater intrusion has continued in the Naples area. Maps have been prepared which show annual wet and dry season water levels and saltwater conditions in the coastal part of the shallow aquifer.

Hydrologic investigations in the perennially wet area inland from Naples began in 1958 in cooperation with the Collier County Board of Commissioners, after the Golden Gate Canal system was started and the Golden Gate Estates was platted for land sales and development. A network of observation wells was installed inland as the construction of canals progressed. Discharge stations were established on the Cocohatchee River Canal, Henderson Creek Canal, and Golden Gate Canal (fig. 2) to determine their freshwater outflows to the ocean. The effects of those outflows on groundwater levels were monitored by an expanded network of observation wells. When the Fahka Union Canal, southeast of Naples, was completed in 1969, additional discharge and water-level data were collected. Small quantities of water-quality data were obtained concurrently with the ground- and surface-water measurements.

One of the indices of hydrologic conditions in south Florida is the rate of surface-water flow to the south through the Tamiami Canal outlets (29 small bridges) along the reach between 40-Mile Bend and Monroe Station (fig. 3). This flow is considered an index because the area upgradient is virtually pristine; since 1939 flow records have been collected in cooperation with the Corps of Engineers, National Park Service, and SFWMD. In addition records of flow south through outlets (19 bridges) between Monroe Station and Carnestown (fig. 3) have been obtained in cooperation with the National Park Service since 1960.

Hydrologic investigations of specific problems or areas resulted in reports on: (1) Naples and vicinity (Klein, 1954); (2) northwest Collier County (Sherwood and Klein, 1961); (3) Immokalee area (McCoy, 1967); (4) Big Cypress Swamp (Klein and others, 1970); (5) western Collier County (McCoy, 1972); (6) a review of Collier County hydrogeology (McCoy, 1962); (7) land use in Collier County (Armbruster, 1972); and (8) shallow aquifer of Collier County (Klein, 1972). These investigations ranged in scope from the intensive study in Naples to a reconnaissance in Big Cypress Swamp.

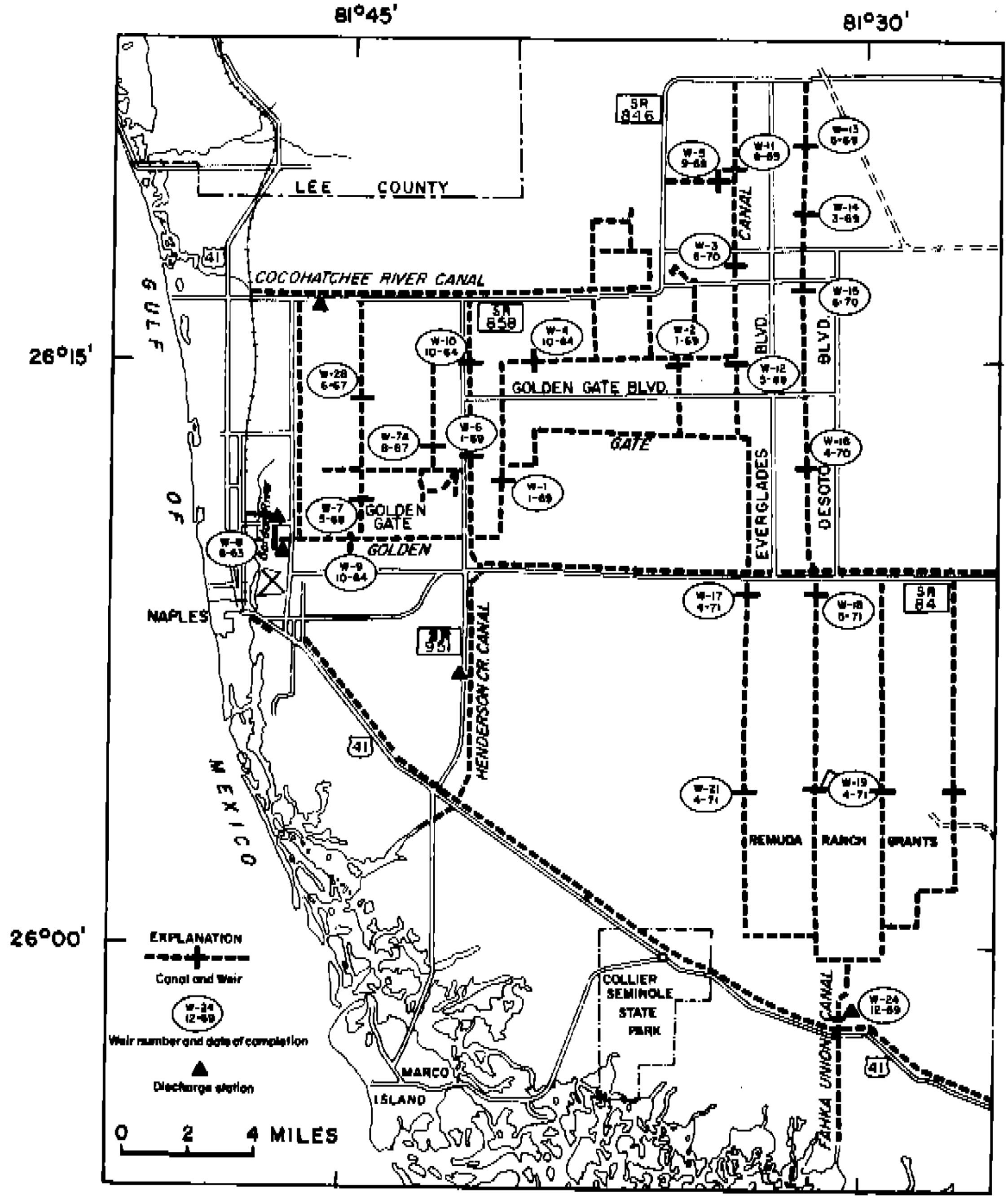

Figure 2.--West Collier County showing location of canals, weirs, and discharge stations (from McCoy, 1972, fig. 5)

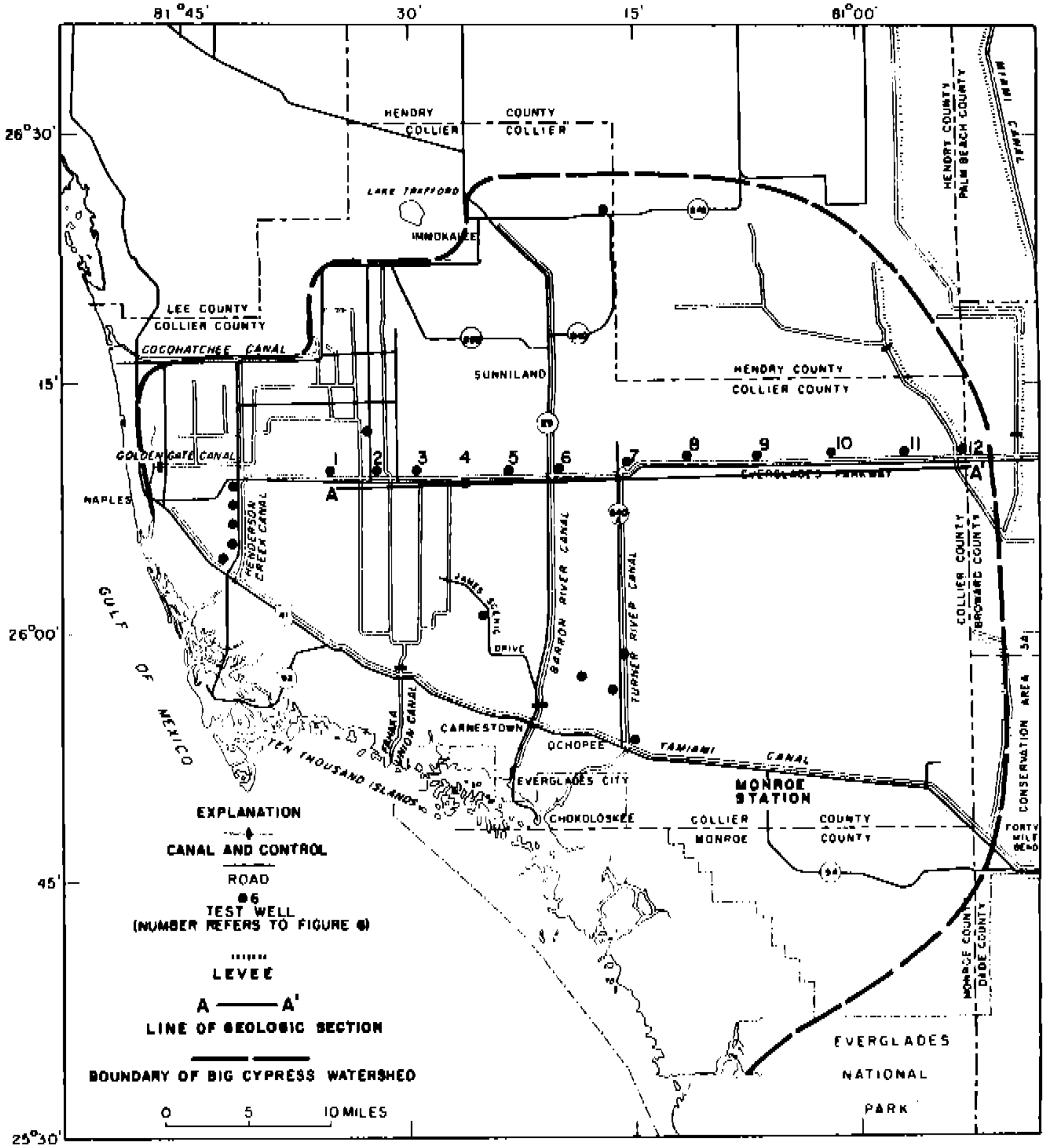

Figure 3.—Collier County showing location of selected test wells (from Klein, 1972, fig. 1)

Ongoing investigations include continuation of monitoring water levels and saltwater intrusion in Naples, monitoring ground-water levels and surface-water outflows within most of the county, monitoring ground-water quality in solid-waste landfills in Immokalee and east of Naples, and exploratory geologic and hydrologic work east of Naples in conjunction with the expansion of the Naples well-field system to inland parts of the county. Continuation of these cooperative investigations is anticipated. All investigations will be coordinated with those planned by SFWMD to avoid duplication and insure adequate overall coverage of the county.

DESCRIPTION OF AREA

The land surface of Collier County is virtually flat. Elevations are highest, 40 to 45 feet above sea level, in the vicinity of Immokalee (fig. 3). The slope is generally south. Land elevation within the Big Cypress Swamp (fig. 4) is generally less than 15 feet. Naples is on a coastal sandy ridge that has a maximum elevation of nearly 20 feet. The west and north parts of the county are covered by more than 10 feet of sand. The central and east parts, the Big Cypress Swamp (fig. 4), are primarily limestone at or a few feet below the surface.

Klein and others (1970, fig. 1) subdivided the Big Cypress Swamp watershed (most of Collier County) into three areas: (1) the relatively small northeast part that drains surface water into Water Conservation Area 3A of SFWMD; (2) the large undeveloped central part that drains south by sheet flow into Everglades National Park; and (3) the west part that has been extensively drained by the Golden Gate and Fahka Union Canal systems and has been developed with scattered housing and increased agriculture. Drainage of the central part of the county has been accelerated by the Barron River and Turner River Canals (McCoy, 1962, fig. 5). The flow of the Barron River Canal is seasonally regulated by stop-log controls. The flow in the Golden Gate and Fahka Union Canal systems is controlled at several points by weirs (fig. 2) which step up the water levels inland from the coast, thereby minimizing overdrainage of ground water. The north part of the county, sandy Flatlands (fig. 4), is primarily vegetable farms and citrus acreage. Agricultural areas are increasing in the sandy areas immediately east and southeast of Naples.

Population increases mainly along the Gulf coast. It is less rapid in the area immediately east of Naples and in the adjoining Golden Gate Estates area, but is expected to increase.

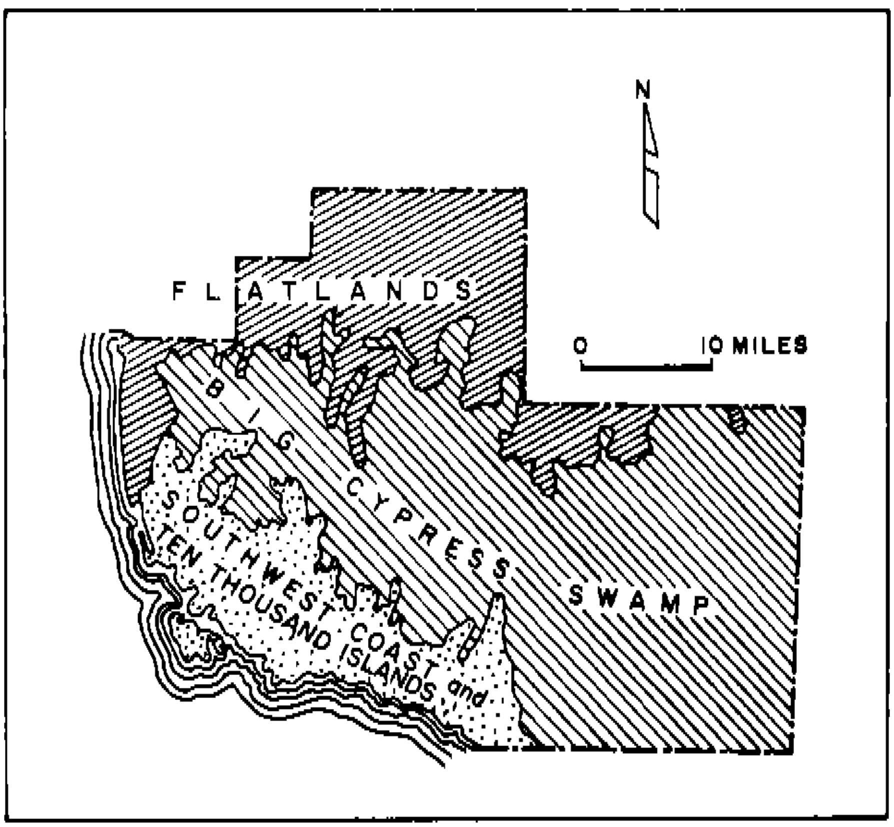

Figure 4.—Physiographic regions in Collier County (from McCoy, 1962, fig. 4)

HYDROGEOLOGIC SUMMARY

Ground water is available from two primary sources in Collier County: the artesian water-bearing zones at depths exceeding 200 feet, and the shallow nonartesian or locally confined aquifer that extends from the land surface to a maximum depth of about 150 feet. These two sources are separated by materials of low permeability, mostly clay. The upper artesian zones, which may be equivalent to freshwater zones ranging in depth from 75 to 200 feet in western Lee County (Boggess and others, 1977, p. 8), have furnished water to Everglades City on the south coast for many years (McCoy, 1962, p. 22; Meyer, 1971, p. 69; Deju and Miller, 1974, p. 72). However, the water quality in Everglades City does not meet the standard for public supplies.

The shallow aquifer is the source of potable water in most of Collier County and for the expanding municipal water system along the Gulf coast.

Floridan Aquifer System

Parker and others (1955, p. 188-189) applied the name, Floridan aquifer, to the principal artesian aquifer in Florida. Meyer (1971, p. 69) indicated that the Floridan aquifer in south Florida is composed of several artesian zones to comprise an aquifer system. This system underlies all of Collier County; the top is almost everywhere less than 400 feet below sea level (McCoy, 1962, p. 18). It is composed mostly of limestone and dolomite with a thickness of more than 2,000 feet. The several water-bearing zones are separated by rock of low permeability which accounts for the different water levels, and in some cases, different water quality for each zone. The upper zones are of lower yield and usually contain water of less salinity than the lower zones. Generally water from the Floridan aquifer in Collier County is too highly mineralized for most uses.

The potentiometric surface of the upper water-bearing zones of the Floridan aquifer system slopes southwest as indicated in figure 5 (McCoy, 1962). In 1960 water levels in northern Collier County were more than 55 feet above sea level, and along the coast between Marco Island and Naples about 25 feet. Healy's (1975) map of the potentiometric surface for 1974 indicates little or no change in levels during the 14-year interval.

Everglades City, on the south coast, has been served for many years by artesian wells which produce less than 50 gal/min per well from a relatively fresh zone between 375 and 500 feet deep (Meyer, 1971, p. 69). Increasing the withdrawal rate of the wells probably would induce upward migration of saltwater, causing a salinity increase of the supply.

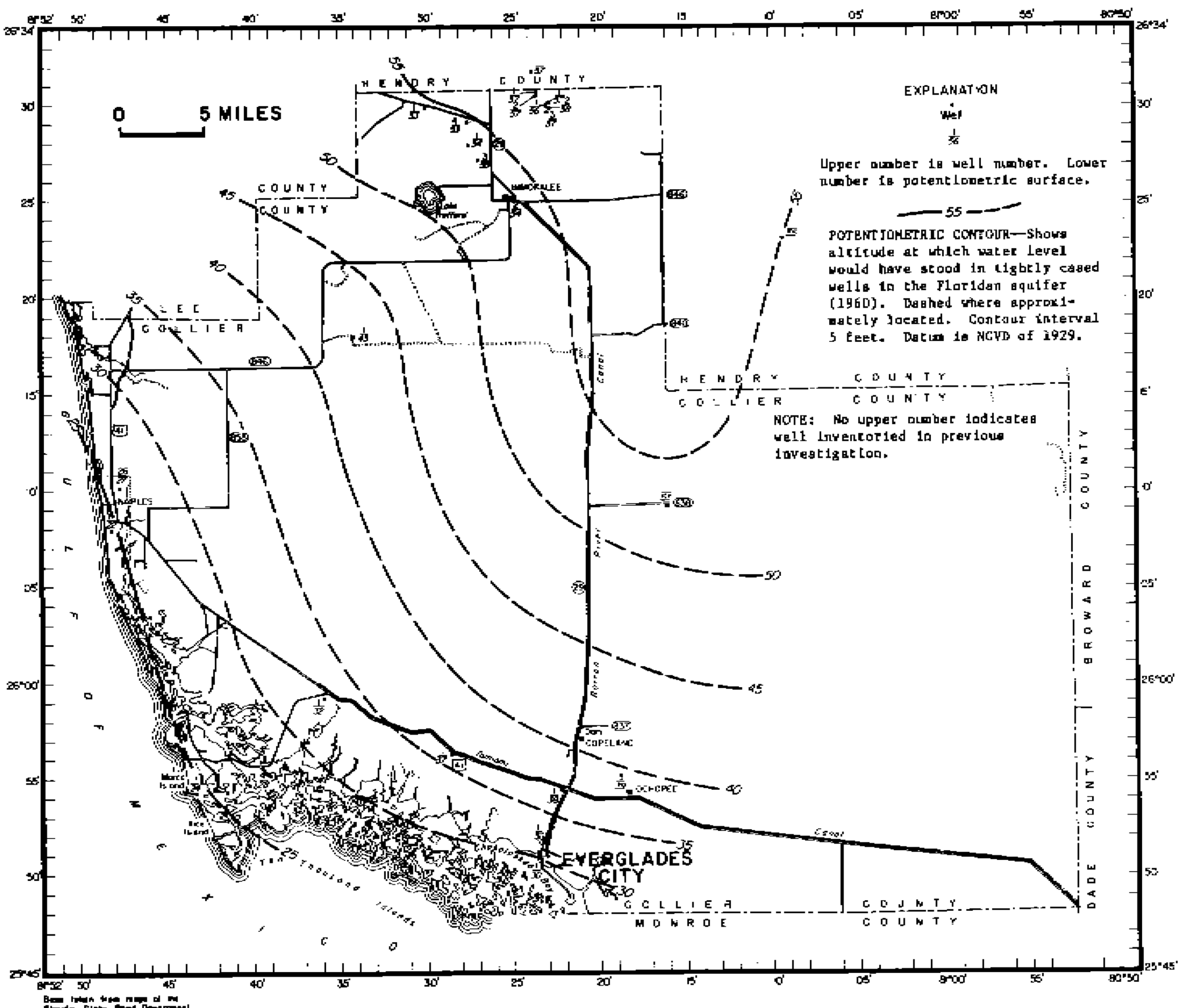

Figure 5.--Potentiometric surface of the Floridan aquifer in Collier County, 1960 (from McCoy, 1962, fig. 9)

Most of the artesian wells in Collier County are in the vicinity of Immokalee where depths usually exceed 600 feet. Six-inch wells produce more than 300 gal/min. Wells were used for irrigation. As water use increased, the artesian water became increasingly salty, and use was curtailed. The chloride concentration of the artesian water in the Immokalee area exceeds 1,000 milligrams per liter (mg/L).

Shallow Aquifer

The shallow aquifer, the principal source of freshwater in Collier County, is composed of shelly limestone and shelly, marly sand. It is nonartesian but may be locally confined. The aquifer extends from the land surface to a depth of about 130 feet near the Gulf coast, thins to the east, and wedges out near the Dade County boundary (McCoy, 1962, p. 24). In the central, east, and south parts of the county, the aquifer is primarily limestone. In the coastal ridge area, the aquifer is composed of sand 40 to 50 feet deep which is underlain by permeable limestone. The highly permeable sections in the county are composed of limestone which contains solution openings and large shells. An indication of the approximate thickness of the limestone along the Everglades Parkway is shown in figure 6 (Klein, 1972). The test wells in the section probably did not penetrate the full thickness of the aquifer. The yield to those test wells that penetrated thick sections of limestone exceeded 500 gal/min.

Test drilling and well inventory data show that a marked change in composition of the shallow aquifer occurs in the vicinity of Immokalee. The materials are primarily marl and medium to coarse sand. No limestones are noted in the upper 100 feet of sediments (McCoy, 1962, p. 24). Domestic and industrial supply wells range in depth from about 20 feet to more than 150 feet. Shallow wells tap sand and thin beds of quartz gravel, and require screens. Deep wells tap limestone of relatively low permeability, and pumping from wells causes large water-level drawdowns.

The shallow aquifer, along the west coast, is the source of all municipal water supplies for Naples and vicinity. McCoy (1962, p. 26) indicated that silt and shelly marl 30 to 40 feet deep within the shallow aquifer locally impedes the circulation of ground water between the surface sands and the deeper limestones in the Naples well-field area. Inland from Naples, a layer of hard, dense limestone of low permeability at or immediately below the surface locally retards the infiltration of rainfall. During times of heavy rainfall sheet flow occurs toward the nearest canals.

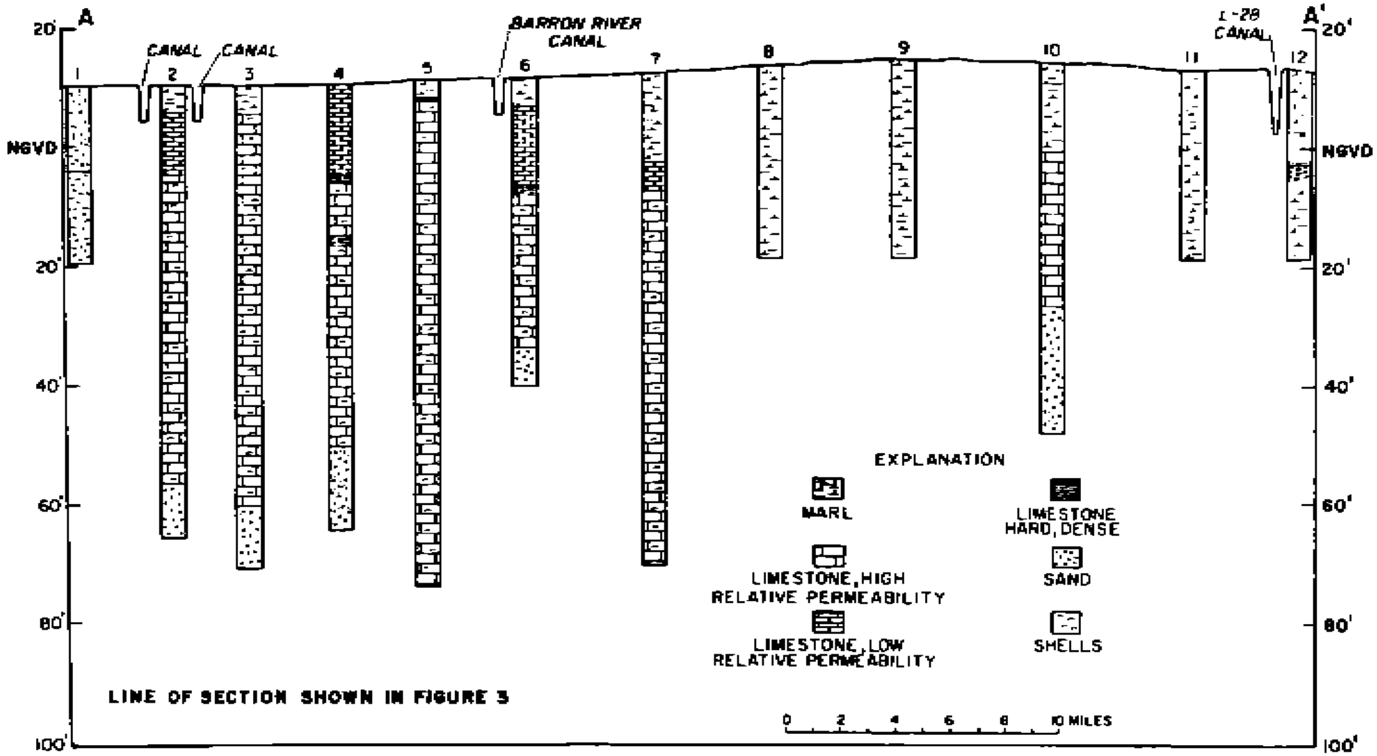

Figure 6.—Geologic section along Everglades Parkway
(from Klein, 1972, fig. 2)

Information on the hydraulic characteristics of the shallow aquifer is available chiefly in the west part of the county, where development of ground water supplies has been greatest. Tests by Klein (1954, p. 47), and Sherwood and Klein (1961, p. 39) show that the transmissivity in Naples ranges from 10,700 ft^2/d (80,000 gal/d/ft) to 24,800 ft^2/d (185,000 gal/d/ft), and the storage coefficient ranges from 0.0014 to 0.0004. The storage coefficient suggests partial aquifer confinement. McCoy (1962, p. 41) computed an average transmissivity of 8,000 ft^2/d (60,000 gal/d/ft) and an average storage coefficient of 0.00025 from tests in an agricultural area, 5 miles northwest of Immokalee. Klein and others (1964, p. 54) indicated a transmissivity of nearly 134,000 ft^2/d (1,000,000 gal/d/ft) in limestone of the Tamiami Formation at the Collier-Hendry County boundary east of Immokalee. Analyses of specific-capacity tests on wells along the Everglades Parkway and east of Naples indicated transmissivities ranging from 67,000 ft^2/d to 107,000 ft^2/d (500,000 to 800,000 gal/d/ft) (McCoy, 1972, p. 22).

The shallow aquifer is recharged primarily by local rainfall during the rainy season. After the start of the rainy season in May or June, water levels in the shallow aquifer in the east half of the county rise until the aquifer fills and sheet flow to the south occurs. Inundation prevails through February or March of the dry season. By May water levels have usually declined to their annual lows, and most of the interior area is dry except for the major sloughs and strands. Figure 7 shows the elevations and configuration of the unusually low water table in early May 1971 (Klein, 1972). The contours indicate that ground-water flow was southwest and south under hydraulic gradients that ranged from 0.6 to 0.9 ft/mi.

Similar seasonal fluctuations of the water table occurred in the west half of the county during precanal years. However, since the canals were dug, runoff has accelerated, inundated areas are no longer widespread, and periods of inundation are short. Figure 8 shows the declining trend of water levels from 1960-78 in northwest Collier County and the increase in the range of annual fluctuations.

HYDROLOGIC CHANGES

Hydrologic changes in Collier County have resulted from: (1) rapidly expanding urbanization and the coincident increasing municipal ground-water demands along the Gulf coast; (2) land-reclamation practices of digging canals in the west and west-central parts of the county; and (3) increased irrigation in the north and west parts of the county.

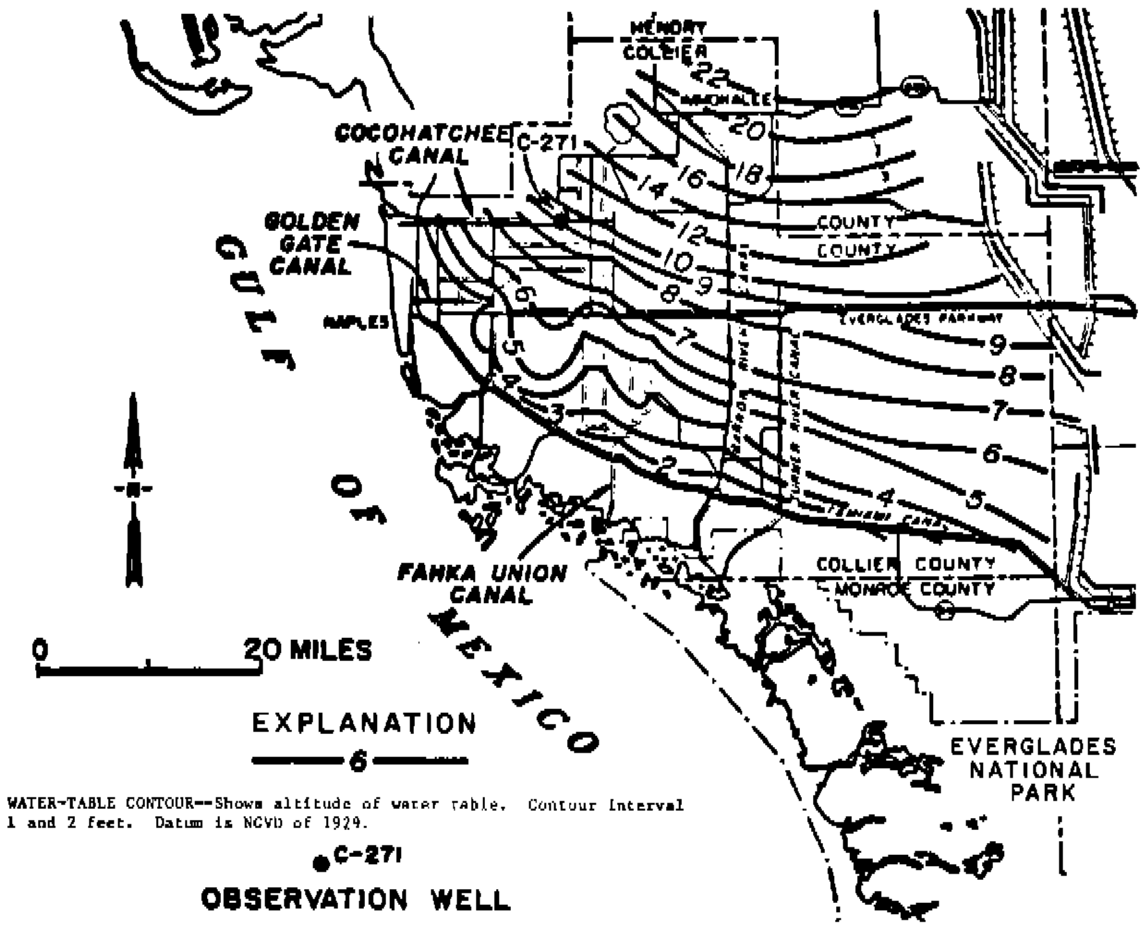

Figure 7.--Water-level contours at the end of the 1970-71 dry season in Collier County (from Klein, 1972, fig. 5)

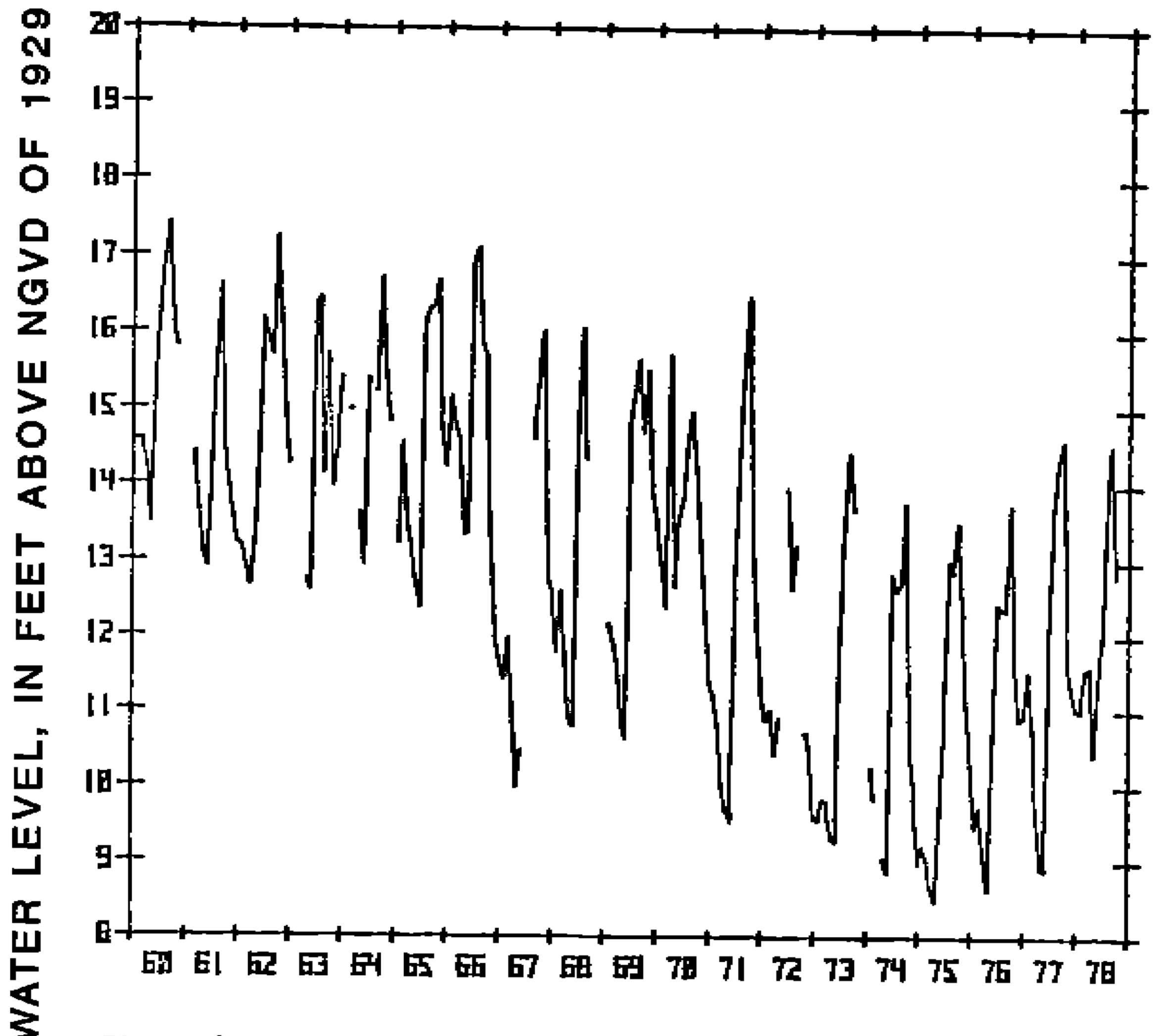

Figure 8.—Hydrograph of well C-271, northeast of Naples, 1960-78

Effects of Pumping

During early urbanization Naples was served by a well field composed of 22 small-diameter wells in the south part of the city; total withdrawal rate in 1952 was less than 1 Mgal/d. The effect of pumping these wells is shown in figure 9. The wells were 60 to 90 feet deep, and the lowest water level in the area affected by pumping was 2 feet below sea level in the north part of the field. Accelerated water demands resulted in the northward expansion of the municipal well field. Figure 10 shows the increase in annual pumpage from 1947-78. The rate of change has been most pronounced during 1970-75. During June 1979 the maximum pumpage was 15 Mgal/d.

Water-level contour maps have been prepared for the Naples well-field area from the early 1950's to 1978. Typical dry season water-level conditions are shown in figures 11 and 12 (McCoy, 1975). Figure 11 shows water levels in the lower zone of the shallow aquifer in May 1974, caused by pumping 12 Mgal/d from municipal wells which are bottomed in limestone 60 feet deep or more. The drawdown in the north is caused by pumping for irrigation. The contour pattern indicates that the effect of pumping extends to the coast, and the hydraulic gradient on the west side is inland from the Gulf.

The contour pattern for the lower zone is contrasted with that of the water table (shallow zone) shown in figure 12 for the same date. The effect of pumping is not apparent on the water-table map. However, because of the large difference in water levels, downward leakage was occurring through the intermediate zone of low permeability in most of the area. In the center of the area, the difference in water levels between the two zones was 17 feet. During 1965-77 the trend of water levels in the lower zone, near the center of the well field, is shown in the hydrograph of well C-391 (fig. 13).

Consultants for Naples have indicated that the capacity of the well field is limited by the threat of saltwater intrusion from the Gulf, and that withdrawals of more than 20 Mgal/d would cause intrusion (McCoy, 1972, p. 28). Migration of poor quality ground water that is inland from Naples could also be a threat to the well field, if withdrawals continue to increase. Naples is developing a new well field about 15 miles inland, within the Big Cypress Swamp, to satisfy increasing municipal demands.

Irrigation of citrus and truck crops is primarily by ground water from the lower part of the shallow aquifer. Some irrigation is from canals which are dug into the shallow aquifer. Most irrigation is in the north part of the county, in the area immediately east of Naples, and in the area southeast of Naples.

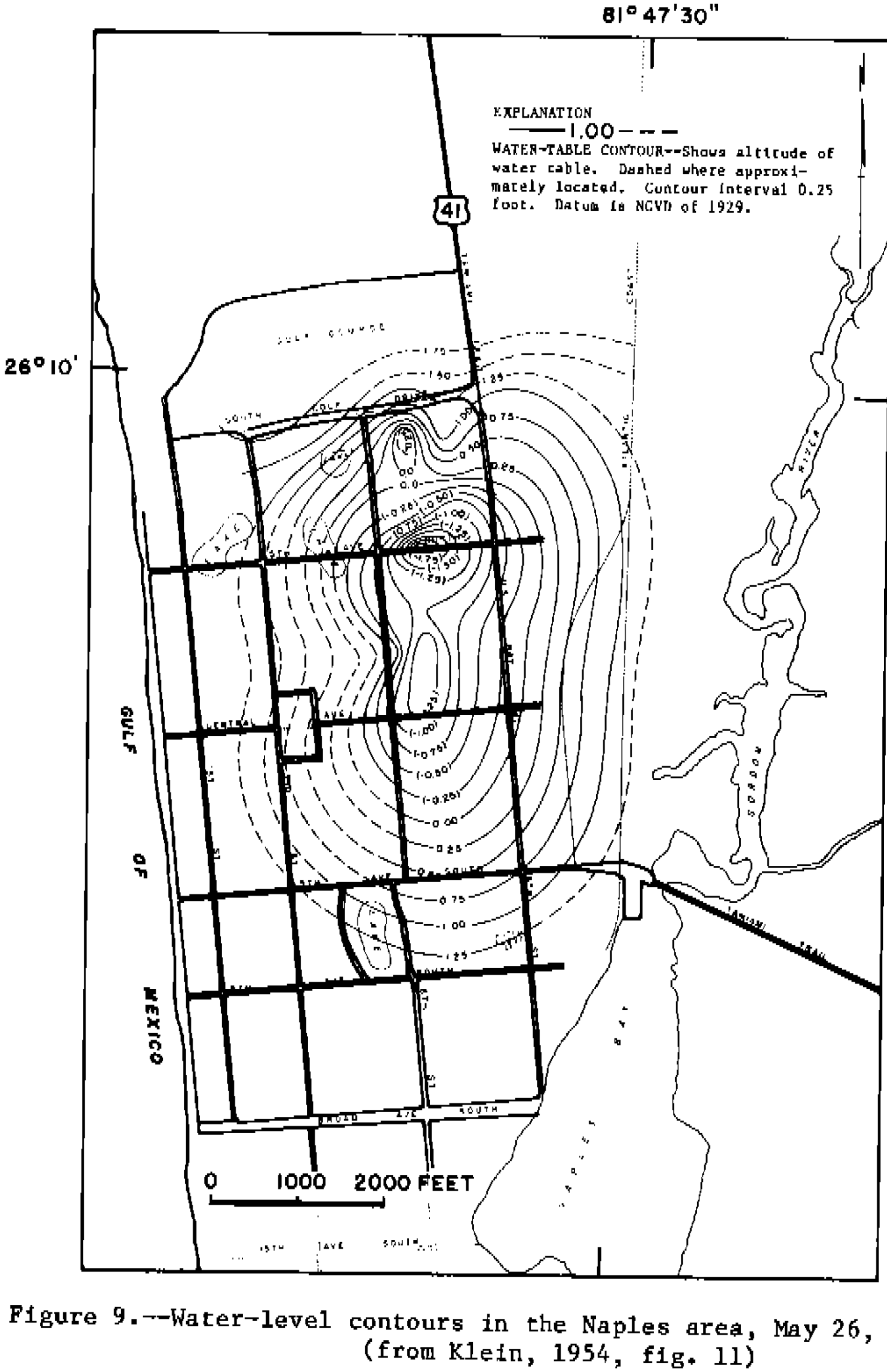

Figure 9.--Water-level contours in the Naples area, May 26, 1952 (from Klein, 1954, fig. 11)

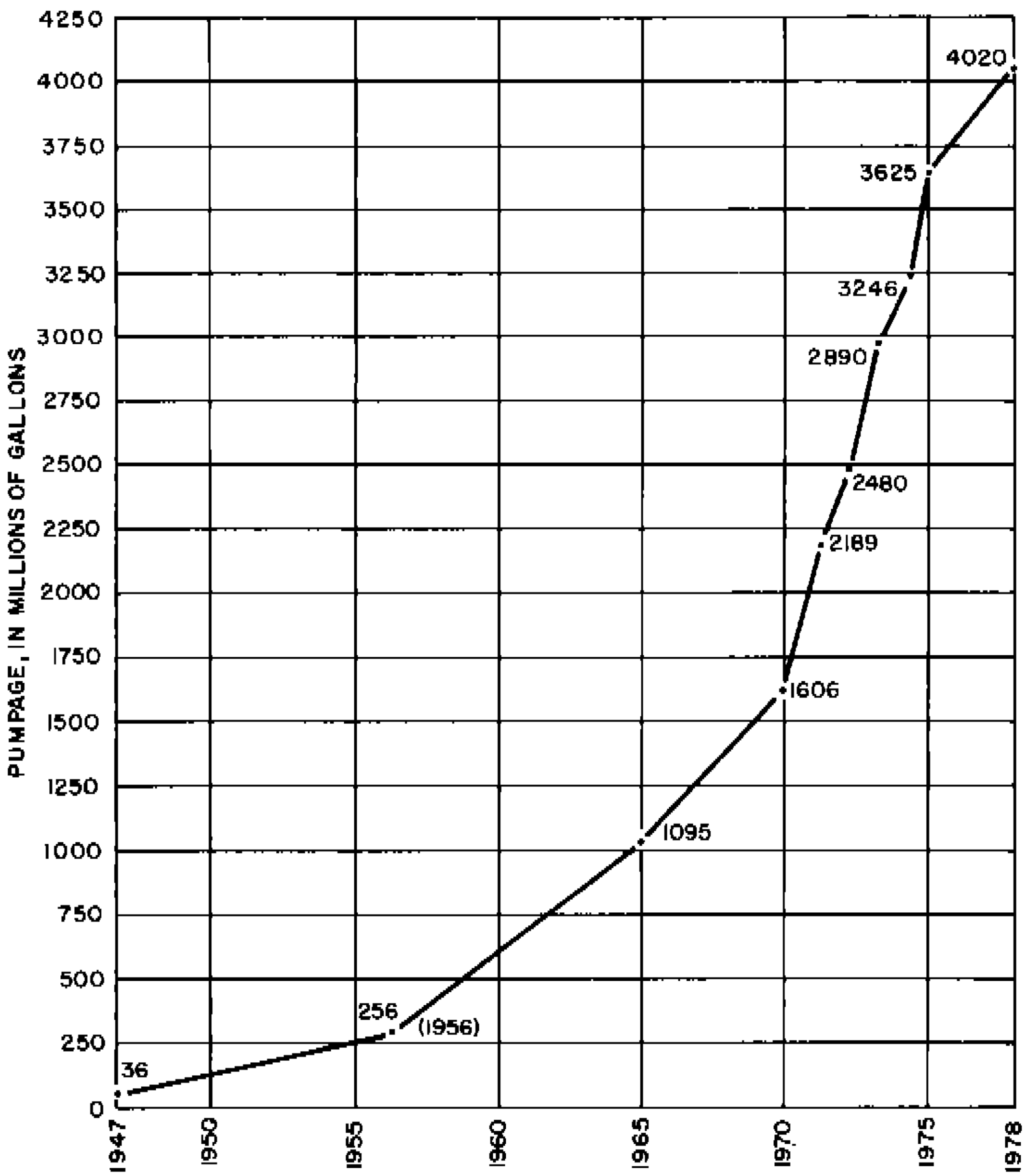

Figure 10.--Annual pumpage from Naples municipal wells, 1947-78

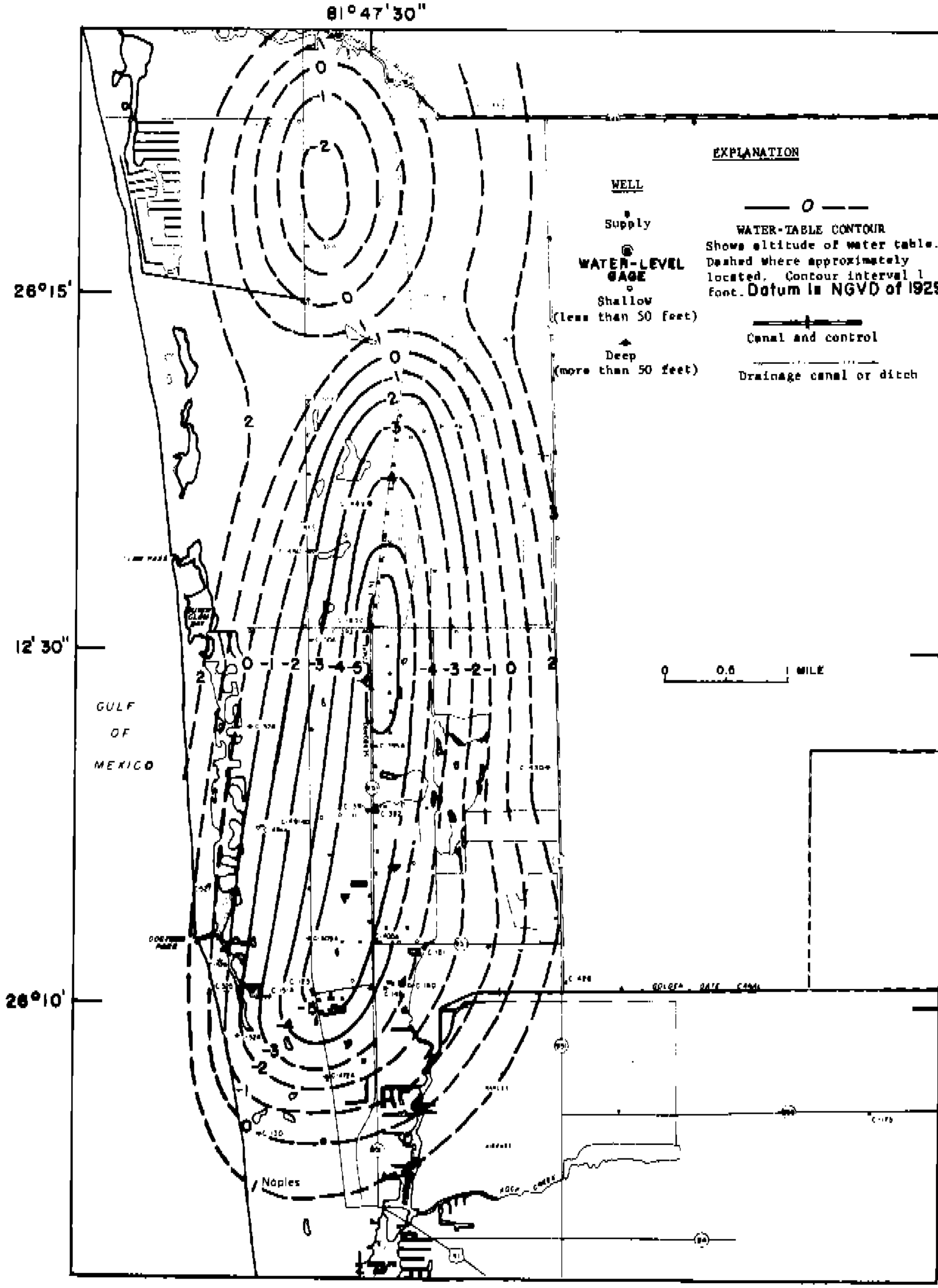

Figure 11.--Water-level contours for the lower zone in Naples and vicinity, May 7, 1974 (from McCoy, 1975, fig. 6)

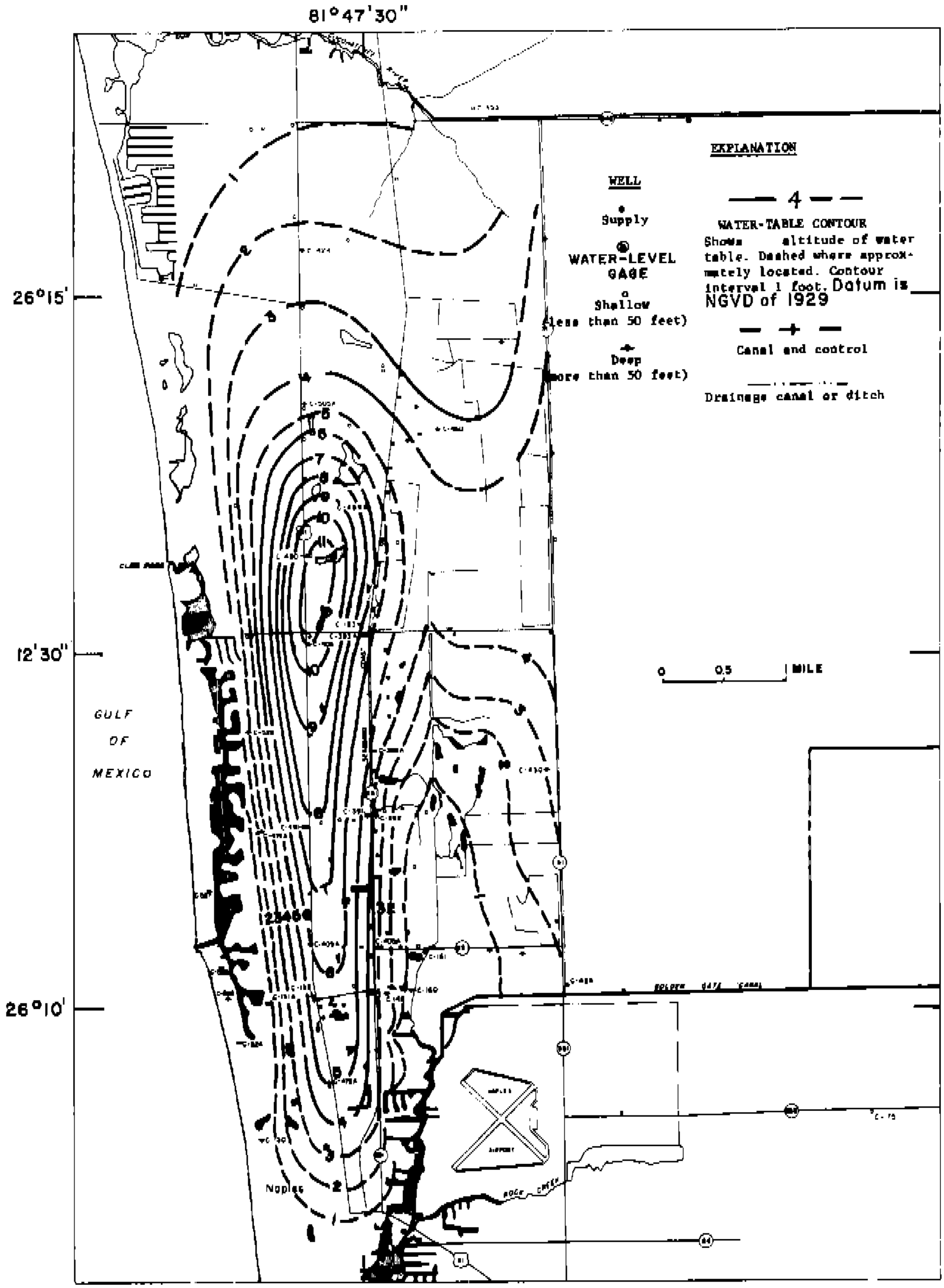

Figure 12.--Water-table contours (shallow zone) in Naples and vicinity, May 7, 1974 (from McCoy, 1975, fig. 5)

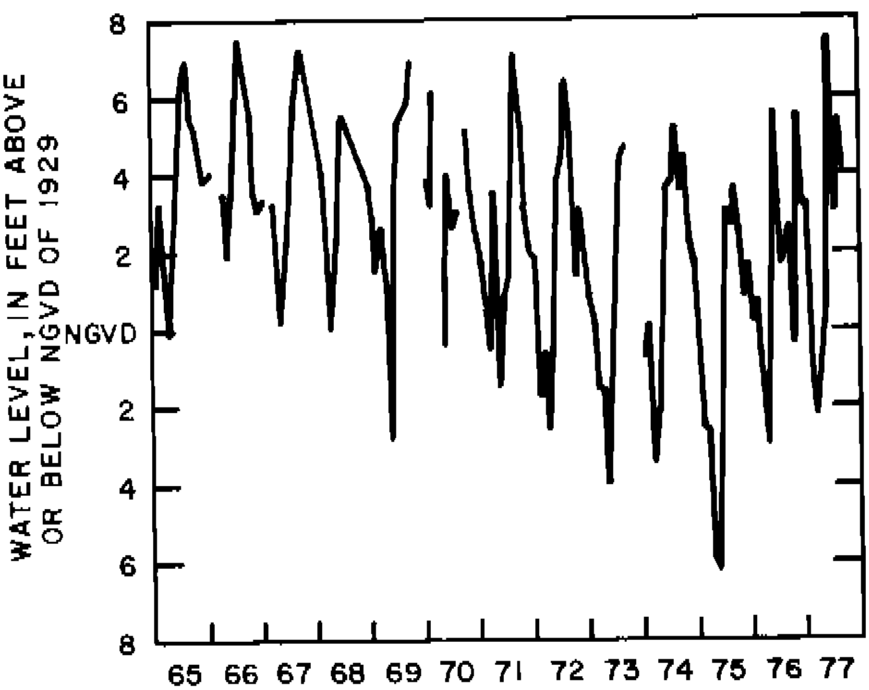

Figure 13.--Hydrograph of well C-391 in the Naples well field, 1965-77

Truck crops are irrigated during the dry season, but no persistent, year-to-year lowering of water levels occurs because the shallow aquifer is replenished during each rainy season. Citrus irrigation is primarily during the dry season, and as needed during the rainy season.

Effects of Canals

Canals have greatly accelerated the drainage of large parts of west and central Collier County. The east part has remained virtually in its natural state. The first canal to drain to the Gulf was the Barron River Canal which was dug from Everglades City northward through Immokalee before the 1930's (fig. 3). The flow of the Barron River Canal is regulated by stop-log control structures at seven sites. The average discharge for the 26-year record (1952-78) is 101 ft^3/s; the maximum discharge is 292 ft^3/s. Drainage of central Collier County was further modified by the digging of the Turner River Canal in the late 1950's. The Turner River Canal is uncontrolled.

Canal drainage of the west part of Collier County began in the early 1960's, with the digging of the Cocohatchee River Canal from Naples eastward into the Big Cypress Swamp, Henderson Creek Canal northward, and Golden Gate Canal northeast from Naples to the Big Cypress Swamp. Following are average and maximum discharges for these canals as of 1978:

Canal	Discharge (ft^3/s) Average	Discharge (ft^3/s) Maximum	Length of record (years)
Cocohatchee River	30	542	10
Henderson Creek	25	353	10
Golden Gate	332	3,460	14

The Cocohatchee River and Henderson Creek Canals are shallow, and though uncontrolled, their discharge is relatively small compared to the Golden Gate Canal. The Golden Gate Canal is deeper, wider, longer, and probably traverses more permeable limestone than the other canals. Therefore, with its tributaries, it can pick up large quantities of ground water from the shallow aquifer, in addition to draining surface water over a larger area. The Golden Gate Canal flow is regulated by a weir near its outlet to the Gordon River and by several additional upstream weirs (fig. 2) which step up the water levels inland and minimize overdrainage of the aquifer. Since the beginning of water control in the Golden Gate area, water levels have been lowered 2 to 4 feet (Klein and others, 1970, p. 72), and annual inundation greatly reduced in area and duration.

Construction of the Fahka Union Canal system, southeast of Naples, began in the late 1960's and was completed in the early 1970's. The 8-year (1971-78) record of discharge over the weir at U.S. Highway 41 indicates that the average flow is 248 ft^3/s, and the maximum is 3,200 ft^3/s. Upstream weirs minimize overdrainage similar to weirs in the Golden Gate Canal. To date (1980) little development has occurred in the Fahka Union Canal basin.

The total average discharge of the canals flowing south and west to the Gulf is about 735 ft^3/s or 475 Mgal/d. This flow is about equivalent to the total municipal water used in Dade, Broward, and Palm Beach Counties during the late 1970's.

Saltwater Intrusion and Water Quality

Saltwater intrusion into the shallow aquifer is a perennial problem, particularly in Naples, where annual increases in municipal withdrawals are causing incremental decline of low water levels nearly every dry season. McCoy (1962, p. 54, and fig. 27, p. 46) indicated that the Naples area is vulnerable to saltwater contamination from the Gulf, Naples Bay, Gordon River, and salty ground water at depths in the aquifer east and north of Naples. A possible source of the contamination in the area east of Naples is artesian water from the Floridan aquifer which may leak upward under high pressure, where the confining materials are thin or slightly permeable, or through open well bores or corroded casings of artesian wells (Sproul and others, 1972). Periodic analyses of the chloride concentration of water from monitor wells in the vicinity of the Naples well field suggest slight inland migration of saltwater along the Gulf and Gordon River during long rainless periods when municipal pumping is maximum.

Only a small amount of ground-water quality information is available in Collier County. Most of the data are for Naples and vicinity, for the area of mineralized water east of Naples, and for an area farther inland that is being explored and developed as the future source of Naples water supply. In areas not contaminated by salty water, the shallow ground water is a hard bicarbonate type. Wells 60 to 75 feet deep in Naples yield water that contains less than 40 mg/L of chloride, less than 250 mg/L of dissolved solids, and 200 to 220 mg/L of bicarbonate.

The ground water, east of Naples, is generally fresh within the upper 30 to 40 feet of the shallow aquifer, but the quality deteriorates with depth (McCoy, 1962, figs. 13, 14, 15). The areal extent of this poor ground water quality is not known. McCoy (1962, p. 56) suggests two sources of contamination: (1) unflushed connate water; and (2) upward leakage from the deeper artesian aquifer. Freshwater is available in the area from shallow wells by skimming at low pumping rates.

INVESTIGATION NEEDS

Water-supply and environmental problems in Collier County and lower southwest Florida are similar to those of the lower east coast. The problems are related to the effects of drainage and rapid urban expansion, changes in land use, increases in demands for water, and increased generation and disposal of solid and liquid wastes.

Saltwater intrusion is a problem for Naples. It is likely that the threat will continue if withdrawals from existing facilities increase and will then probably intensify during years of subnormal rainfall and long, dry seasons. The well field along the coastal area will probably remain the primary source of water for the Naples municipal system, until supplies in the interior are developed. Also, the ground-water quality along the coast is superior to that in the interior.

The adequacy of the network of saltwater monitoring wells which flanks the Naples well field can be improved with additional wells and replacement of wells that have been destroyed. Ideally monitor wells on the Gulf side of Naples would be so constructed as to permit the collection of water samples from the bottom of the shallow aquifer (120-130 feet), from depths equivalent to those of the Naples supply wells (70-80 feet), and from the shallow permeable zone (25-35 feet). Monitor wells should bracket the position of water containing 500 mg/L of chloride near the base of the aquifer. Seasonal sampling and measurements would indicate the extent and direction of saltwater movement. Analyses of water for chloride from the shallow zone would indicate if the intrusion in that zone is discrete from that in deeper zones of the aquifer. Periodic water-level measurements in sets of deep and shallow wells would indicate the vertical and horizontal head relations within the aquifer adjacent to the Gulf. Similar siting of monitor wells along the east side of Naples would delineate the west boundary of the poor quality water and the vertical head relations.

The extent of saltwater intrusion along the south coastal area of the county needs delineation, particularly in the area of the Barron River and Turner River Canals and the area southeast of Naples. McCoy (1962, p. 44) showed that the artesian water serving Everglades City has been increasing in chloride content. Continued deterioration of quality may force that community to seek another source, perhaps shallow ground water north of U.S. Highway 41, in the vicinity of Florida Highway 29. Delineation of the freshwater-saltwater interface there would aid in site selection for shallow wells.

Scattered housing subdivisions and agriculture utilize increasing quantities of shallow ground water between Naples and the Henderson Creek Canal. The inland extent of saltwater intrusion could be delineated by a series of monitor wells constructed at proper depths and locations. The depths and locations could be determined, in part, by an inventory of existing supply wells in the area.

Information on the areal extent and depth of the bottom of the shallow aquifer and its geologic and hydrologic characteristics is necessary to develop an effective program for monitoring the ground-water resource. Data on yield of wells, general geology, delineation of permeable zones, aquifer thickness, water quality, and water levels can be obtained by well inventory and exploratory core drilling. At the time of inventory and drilling, ground-water samples can be obtained for conductance and chloride to determine possible areas of inferior water quality.

McCoy (1962, p. 55) indicated that water in the shallow aquifer is highly mineralized north of Naples, near the Cocohatchee River, and in an area up to 10 miles inland from the coast. The inland occurrence of poor water quality may be due to inadequate flushing of shallow ground water, caused partly by dense, nearly impermeable limestones at shallow depths, which retard infiltration of rainfall (McCoy, 1962, p. 56). Since this zone lies between the Naples well field on the west and the proposed location for future municipal supplies, poor quality water may flow to those areas of withdrawal. Therefore, it is important that the areal and subsurface extent of the poor quality water be delineated and its origin determined.

Seasonal monitoring of wells will determine if drainage of the area by the Golden Gate Canal has increased water circulation sufficiently to enhance the ground-water quality. However, if upward leakage of artesian water through thin confining beds or old artesian wells is the cause of the poor water quality in the shallow aquifer, then the lowered levels caused by drainage could result in increased upward leakage of artesian water.

The network of hydrologic data-collection stations can be expanded at the time of exploratory drilling. The network should consist of wells for water-level measurements, with some wells equipped with recording gages, in both the upper and lower parts of the shallow aquifer and in the Floridan aquifer. Countywide coverage would enable preparation of water-level contour maps from which directions of ground-water flow can be determined. The existing network of data-collection stations shown in figures 14, 15, and 15a includes wells for water-level measurements and water-quality sampling, and canal stations for stage, discharge, and water-quality data.

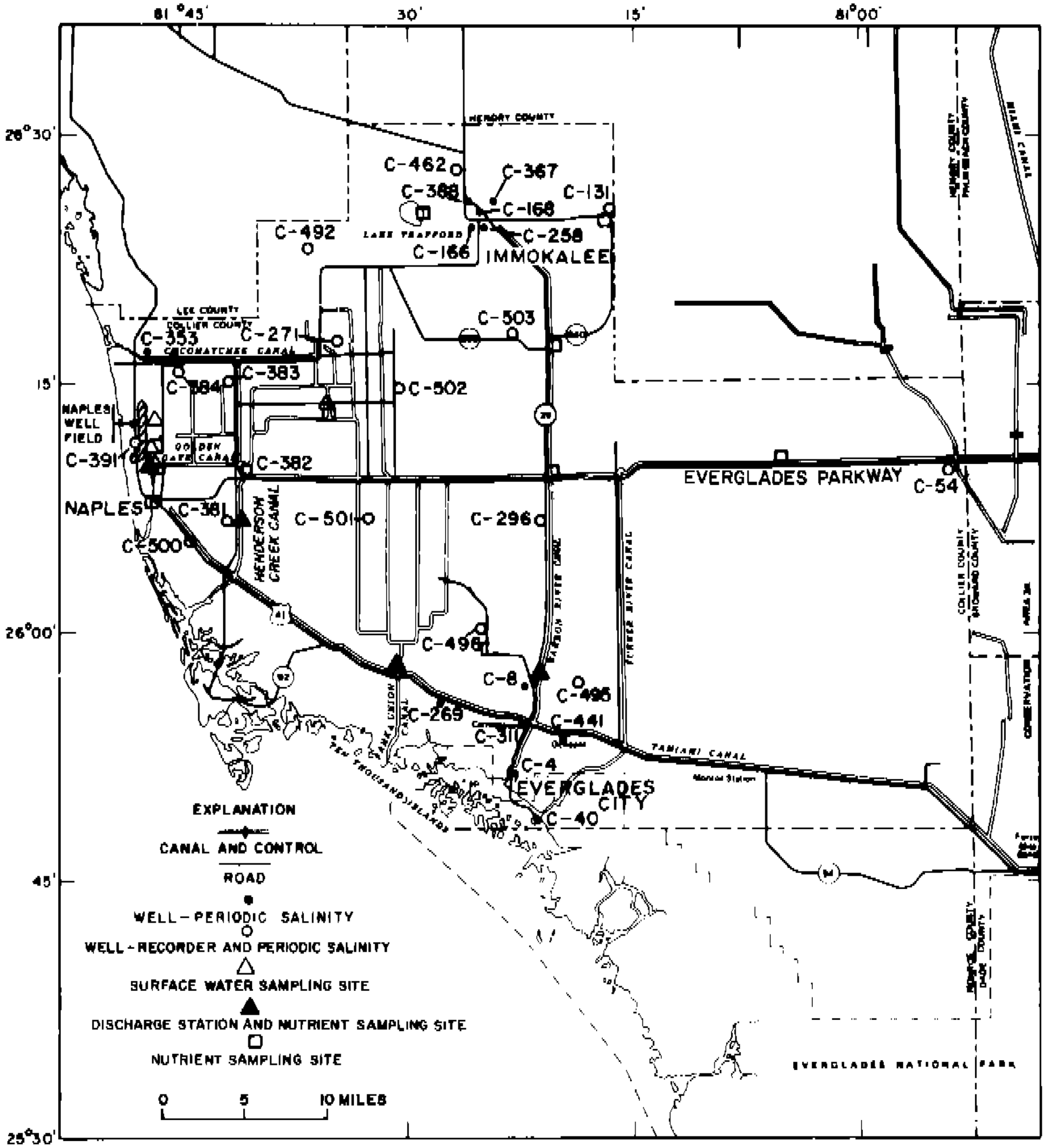

Figure 14.--Location of data-collection stations in Collier County

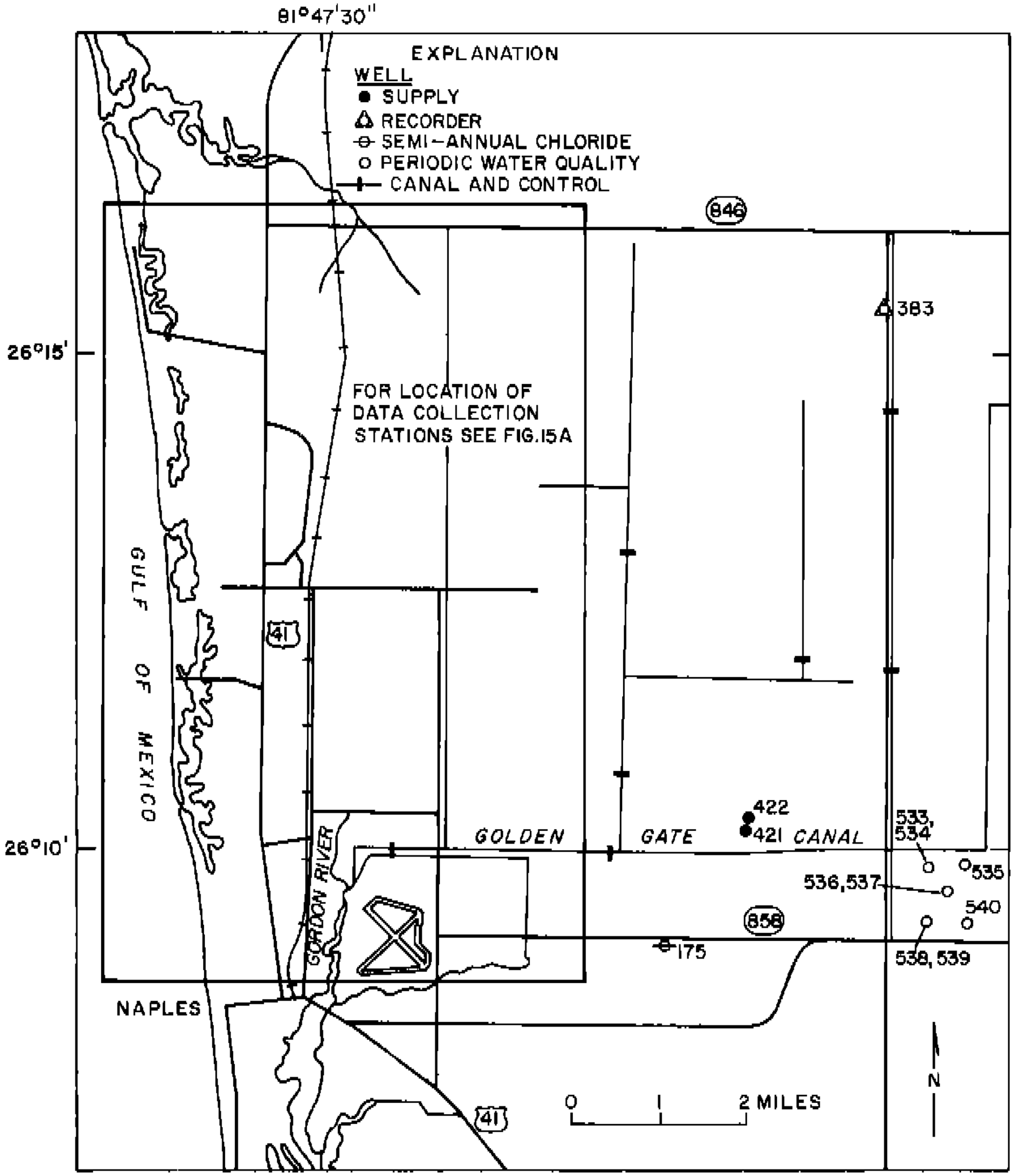

Figure 15.--Location of data-collection stations in Naples and vicinity

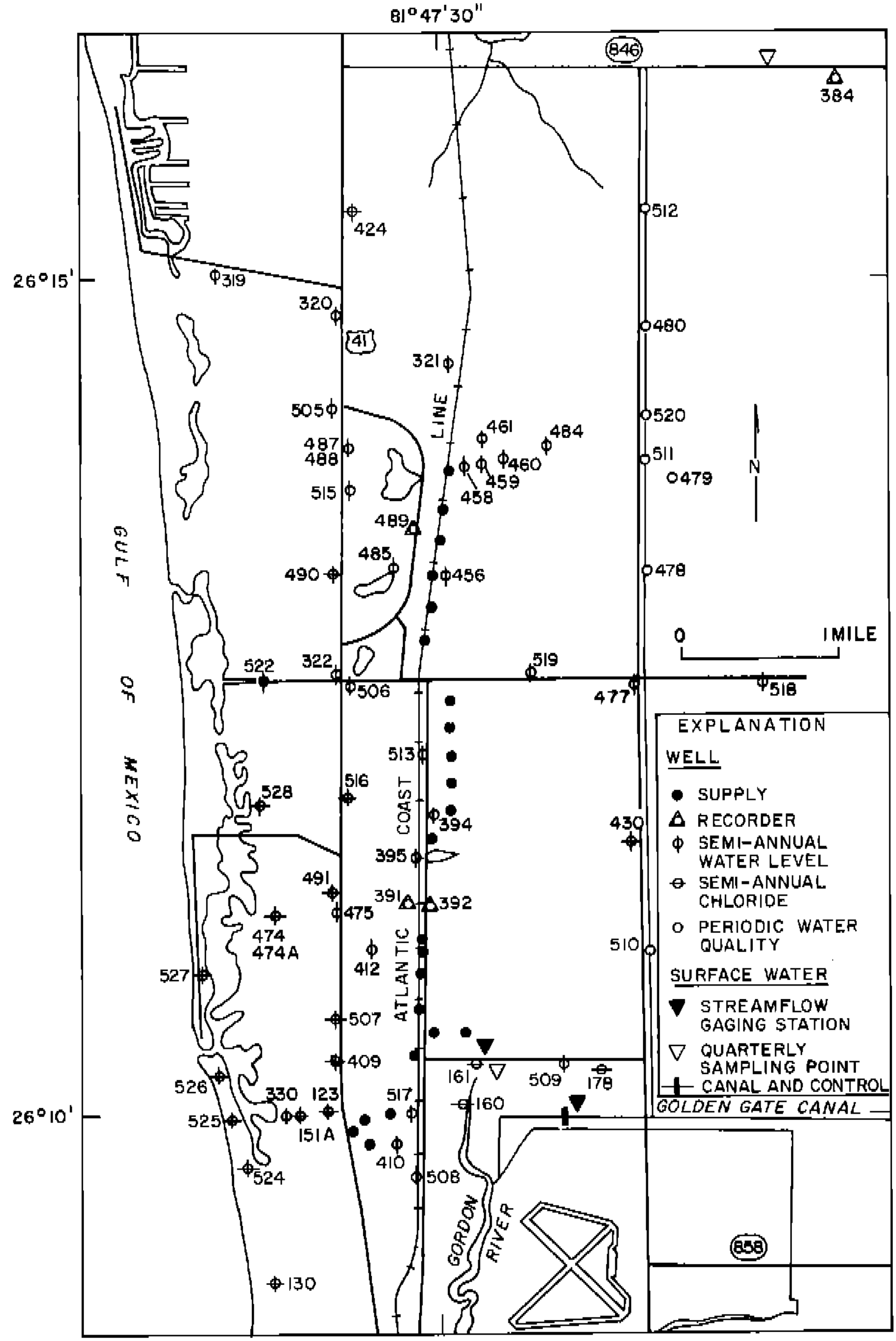

Figure 15a.--Location of data-collection stations in Naples well-field area

Drainage by the Golden Gate and Fahka Union Canal systems has lowered water levels and has decreased the area and period of inundation in much of west Collier County. A series of streamflow measurements in different reaches of canals within these systems would indicate the contributions or losses of water along those reaches. This could be related to change in relative permeability of the shallow aquifer within the affected basin area. Measurements of water levels in shallow and deep wells in lines perpendicular to the canals along the selected reaches would furnish hydraulic gradient data which could be used to indicate transmissivity. Such values are needed as input if predictive modeling of the shallow aquifer is planned.

In recent years SFWMD (April 1979, p. 7) has denoted that the Naples Bay and Fahka Union Bay estuarine areas have received quantities of freshwater that exceeded amounts that they received formerly, and that restoration of original flow would have beneficial effects on water supplies and the environment. Investigations are needed to determine the effects that reduced discharges to the ocean may produce within those basins. SFWMD also indicated that the consequences of restoring predrainage conditions in the Golden Gate and Fahka Union Canal basins may affect the established rights of some landowners. Digital models would be useful to determine the rise in water levels in interior areas that might result if elevations of selected weirs in the canals were increased. A series of such models would aid in establishing a range in canal water levels that might be generally acceptable from the standpoints of environmental preservation and urban development requirements.

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