STATE OF FLORIDA

STATE BOARD OF CONSERVATION

DIVISION OF GEOLOGY

FLORIDA GEOLOGICAL SURVEY

Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 31

GROUND-WATER RESOURCES OF COLLIER COUNTY, FLORIDA

By

H. J. McCoy

U.S. Geological Survey

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with
COLLIER COUNTY
the
CITY OF NAPLES
and the
FLORIDA GEOLOGICAL SURVEY

Tallahassee

1962

FLORIDA STATE BOARD
OF
CONSERVATION

LETTER OF TRANSMITTAL

Florida Geological Survey

TALLAHASSEE

August 8, 1962

Honorable Farris Bryant, *Chairman*
Florida State Board of Conservation
Tallahassee, Florida

Dear Governor Bryant:

The Division of Geology is publishing, as Florida Geological Survey Report of Investigations No. 31, a report on the ground-water resources of Collier County, prepared by Mr. H. J. McCoy, geologist with the U. S. Geological Survey, in cooperation with the City of Naples, Collier County, and this department.

The report recognizes two major aquifers as the source of ground water in Collier County. The lower aquifer is highly mineralized, but contains usable water, and the more shallow aquifer is the source of large supplies, which are utilized by municipalities and domestic users. Adequate supplies of fresh water are present in the Naples area and by proper planning, these can be developed in an orderly manner and salt water encroachment can be prevented.

Respectfully yours,

Robert O. Vernon
Director and State Geologist

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CONTENTS

ILLUSTRATIONS

Table		Page
1	Average monthly temperature at Naples and Everglades, the average monthly rainfall at Naples, Everglades, Lake Trafford, and Miles City	6
2	Chemical analyses of water from selected wells that penetrate the Floridan aquifer in Collier County	45
3	Chemical analyses of water from selected wells that penetrate the shallow aquifer in Collier County	47
4	Chloride content in parts per million, from selected wells in northwestern Collier County	48
5	Well records in Collier County, Florida	66

GROUND-WATER RESOURCES OF COLLIER COUNTY, FLORIDA

By
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ABSTRACT

Two major aquifers are the sources of ground-water supplies in Collier County.[1] The lower is the Floridan aquifer, and wells penetrating it throughout most of the county will flow. Except in the town of Everglades, where it yields water containing about 300 ppm (parts per million) of chloride, the Floridan aquifer produces water too highly mineralized for most purposes. The main producing zones of the Floridan aquifer in Collier County are the permeable limestones of the Tampa Formation, of Early Miocene Age, and those in the lower part of the Hawthorn Formation, of Middle Miocene Age. The fine sand and clay section in the upper part of the Hawthorn Formation confines the Floridan aquifer. The top of the aquifer is generally about 400 feet below the land surface.

The chief source of fresh ground water in Collier County is an extensive shallow aquifer which extends from the land surface to a depth of about 130 feet in the northwestern part of the county, to a depth of about 90 feet in the southern part, and to a depth of about 60 feet in the central and northeastern parts. The aquifer thins to a featheredge along the eastern county boundary.

The permeable zones of the shallow aquifer are the Pamlico Sand and solution-riddled limestones of the Anastasia Formation, of Pleistocene Age, and the Tamiami Formation of Late Miocene Age. Semi-confining layers of marl impede the vertical movement of water within the aquifer.

The shallow ground water in the southern coastal areas contains very high concentrations of chloride as a result of sea-water encroachment. The shallow water in the Naples area is of good quality, containing about 250 ppm of dissolved solids. This is due in part to a high fresh-water head adjacent to the coast and the resultant flushing of ground water. In the areas inland from Naples the ground water contains greater concentrations of chlorides and dissolved solids, which are due to residual

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[1] The classification and nomenclature of the rock units conform to the usage of the Florida Geological Survey and also, except for the Tampa Formation and the Ocala Group and its subdivisions, to that of the U.S. Geological Survey, which regards the Tampa as the Tampa Limestone and the Ocala Group as two formations, the Ocala Limestone and the Inglis Limestone. The Ocala Group as used by the Florida Geological Survey includes the Crystal River, Williston, and Inglis Formations.

sea water and lack of flushing of the shallow aquifer. In the Immokalee area, water from the shallow aquifer is potable but its quality varies considerably with different well depths.

The coefficient of transmissibility of the shallow aquifer in the Naples area ranges from 92,000 gpd (gallons per day) per foot to 180,000 gpd per foot and the coefficient of storage ranges from 0.001 to 0.004. In the vicinity of Immokalee the coefficient of transmissibility is about 60,000 gpd per foot and the coefficient of storage is 0.0002.

Adequate supplies of fresh ground water are available in Naples and vicinity, and these can be developed in an orderly manner to prevent salt-water encroachment. Controlled drainage of inland areas can provide fresh water to replenish ground-water supplies of coastal areas as urbanization expands.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

Since 1950 the population of the coastal areas of Collier County, Florida (fig. 1), has increased rapidly. With this increase has come the need for additional quantities of potable water. Recognizing this, the Collier County Board of Commissioners, in cooperation with the city of Naples, requested the U.S. Geological Survey to investigate the ground-water resources of the county. Such an investigation was begun in November 1959 by the Geological Survey in cooperation with Collier County. An appreciable part of the data was obtained during a continuing cooperative program begun in 1951 with the city of Naples.

The investigation included the following phases: (1) assembling and evaluating existing basic data; (2) obtaining data related to the availability and movement of ground water; (3) determining the hydrologic and geologic characteristics of the subsurface materials; (4) determining the chemical quality of ground water; and (5) preparing a report of the results of the investigation.

The investigation was under the general supervision of Philip E. LaMoreaux, former chief of the Ground Water Branch of the Geological Survey, Washington, D. C., and under the immediate supervision of M. I. Rorabaugh, district engineer, Tallahassee, and Howard Klein, geologist, U.S. Geological Survey, Miami, Florida.

PREVIOUS INVESTIGATIONS

Two reports, "Ground-Water Resources of the Naples Area, Collier County, Florida" in 1954 and "Ground-Water Resources of Northwest Collier County, Florida" in 1961, summarize the geologic and hydrologic

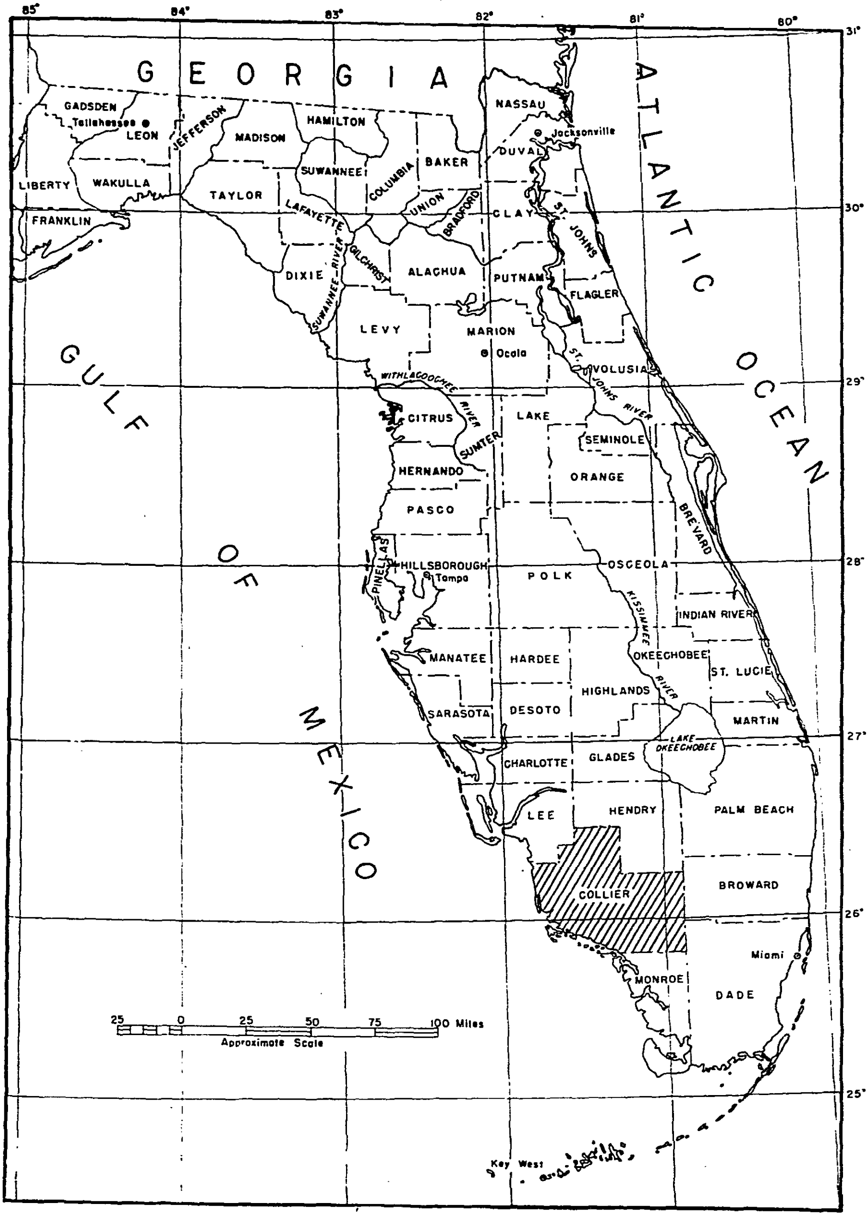

Figure 1. Florida Peninsula showing location of Collier County.

conditions in northwestern Collier County. The U.S. Geological Survey maintains water-level recording gages in the city of Naples well-field area, in eastern Collier County near the Broward County boundary, and east of Immokalee at the Hendry County boundary. Significant parts of the 1954 and 1960 reports are incorporated in this report because they pertain to the overall development of water resources in northwestern Collier County.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on longitude and latitude coordinates. As shown in figure 2, Collier County has been divided into quadrangles by a grid of 1-minute parallels (of latitude) and 1-minute meridians (of longitude). The well numbers were assigned by their locations within the grid system. Each number consists of three parts; the first part is the last degree digit and the 2-minute digits of latitude, on the south side of the 1-minute quadrangle; the second part is the last degree digit and the 2-minute digits of longitude on the east side of the quadrangle; the third part is the order in which the well was inventoried within the quadrangle. The first degree digit of north latitude and west longitude is omitted because all wells have the same digit. For example, well 609-147-17 designates the 17th well inventoried in the quadrangle bounded by latitude 26°09′ on the south and longitude 81°47′ on the east.

ACKNOWLEDGMENTS

Appreciation is expressed to Mr. W. H. Turner, Collier County engineer, for his cooperation and courtesy throughout the investigation; to Mr. W. F. Savidge, Naples Water Plant superintendent, for his cooperation and information concerning ground-water use and proposed well-field locations for the municipal water supply in and around Naples; to the Collier Development Corporation for its cooperation in permitting access to many unused wells on its properties; and to the residents of Collier County for furnishing information about their wells. Thanks are extended to the following well drillers of the area for information on the subsurface geology and the depth, construction, and yield of wells: Mr. Albert Miller of Fort Myers, Mr. James Whatley of Immokalee, and Mr. Carl May of Naples.

GEOGRAPHY

GENERAL FEATURES

Collier County comprises 2,032 square miles in the southwestern part of the Florida Peninsula (fig. 1.) Its population has increased from 6,488

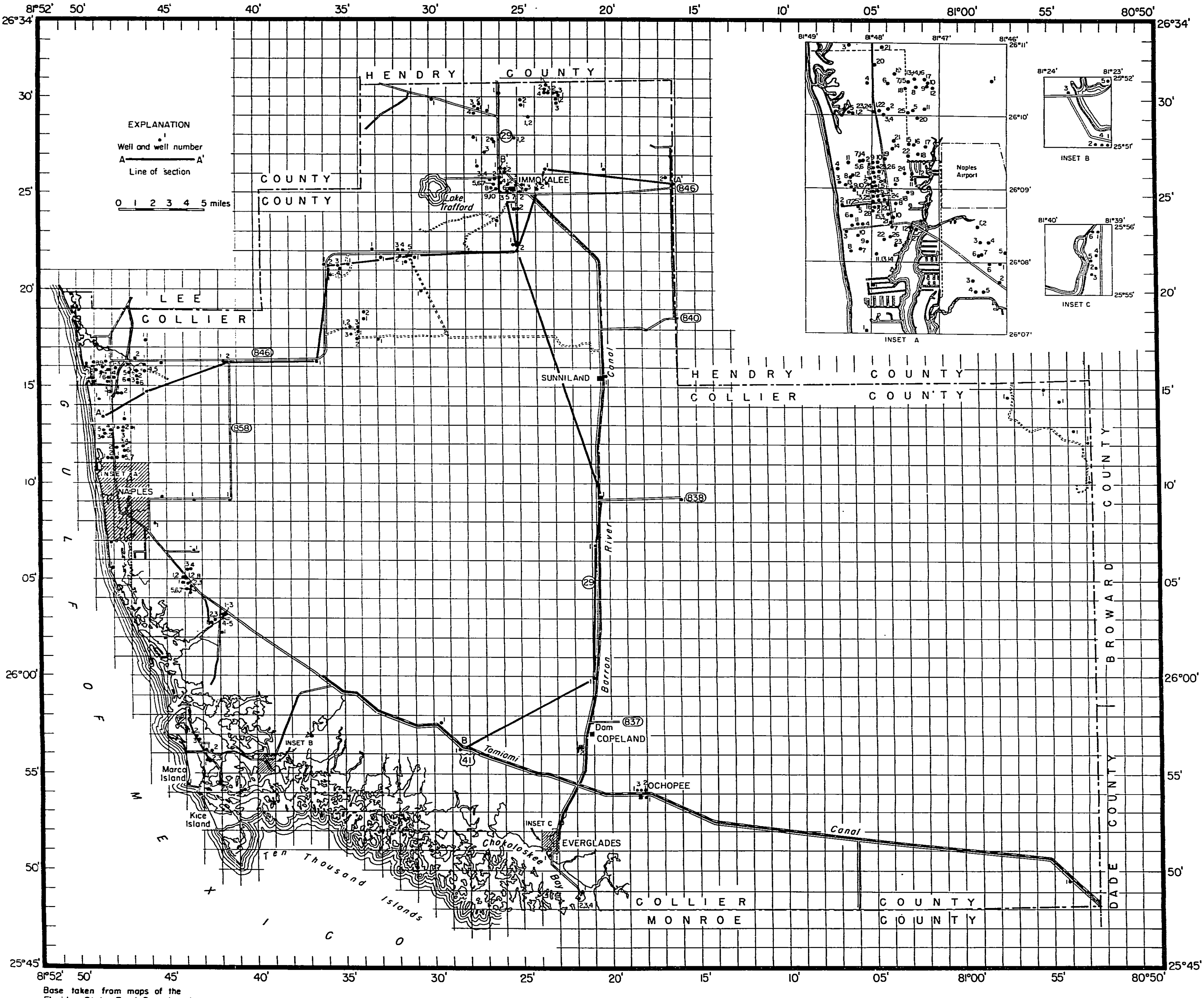

Figure 2. Collier County showing location of wells and geologic sections A-A' and B-B'

in 1950 to 15,753 in 1960, more than half of which is in the three principal towns. Naples (fig. 2) has a population of 4,650, and its suburbs to the north and east increase this figure to more than 9,000. During each winter season a large number of tourists visit this coastal area. Immokalee has a population of 4,800, which is increased periodically by the influx of migrant farm laborers. The town of Everglades has decreased in population from 800 in 1950 to 550 in 1960.

The principal occupation of the county is truck farming. The most important crops are tomatoes, cucumbers, peppers, and watermelons. Cattle raising is carried on also. Tourism is important to the economy of the area, particularly the coastal towns of Naples and Everglades. Oil production adds considerably to the economy, as the only producing oil field in Florida is located at Sunniland in central Collier County (fig. 2). Quarrying of limestone for road and building materials is also a sizable industry.

There are three major roads in Collier County (fig. 2); the Tamiami Trail (U.S. Highway 41) is the main arterial road through the county. State Highway 29 connects Everglades with Immokalee and Immokalee with northern towns; and State Highway 846 connects Naples with Immokalee and Immokalee with eastern towns. There are several unimproved roads, but a large part of the interior of the county can be reached only by specially equipped vehicles.

CLIMATE

The climate of Collier County is humid subtropical but temperatures are moderated by winds from the Gulf of Mexico and the Atlantic Ocean. Table 1 shows temperature and rainfall averages at weather stations within the county. The average annual temperature for coastal Collier County is approximately 75°F. The warmest months are usually July and August. The humidity is high but frequent afternoon thundershowers prevent extremely high temperatures.

Rainfall records from the Naples, Everglades, and Lake Trafford stations show that there is not a significant variation in the average annual rainfall throughout much of the county, but that large differences do occur during a single year. During the very wet year of 1959 the Miles City station recorded 88.76 inches of rainfall, the greatest yearly rainfall of record in the county, whereas the station at Everglades recorded 64.29 inches. That year also established a new high for Naples, where 72.50 inches was recorded. Several dry years occurred during which less than 35 inches fell.

TABLE 1. Average Monthly Temperature at Naples and Everglades, and Average Monthly Rainfall at Naples, Everglades, Lake Trafford, and Miles City

Month	Temperature (°F)*		Rainfall (inches)†			
	Naples	Everglades	Naples	Everglades	Lake Trafford	Miles City
January	65.9	67.0	1.50	1.58	1.48	2.83
February	67.3	67.5	1.49	1.43	1.93	2.53
March	72.1	70.4	2.28	2.21	2.83	4.41
April	74.1	73.9	2.54	2.63	2.79	3.39
May	77.3	77.5	4.15	4.63	5.02	8.15
June	81.3	81.0	7.81	8.87	6.29	9.64
July	82.7	82.2	8.65	8.40	7.94	10.29
August	83.3	82.9	7.97	7.27	6.87	8.54
September	82.3	82.1	9.93	9.75	8.99	9.46
October	77.4	78.2	5.77	4.24	6.19	7.16
November	71.9	72.1	1.51	1.24	1.28	1.38
December	67.3	68.2	1.27	1.35	2.05	2.32
Yearly average	75.1	75.2	54.84	53.78	53.86	74.06

* Period of record, U.S. Weather Bureau, Naples, 1942-60; Everglades, 1926–60.
† Period of record, U.S. Weather Bureau, Naples, 1943-60; Everglades, 1926-60; Lake Trafford, 1951-60; and Miles City, 1957-60.

PHYSIOGRAPHY AND DRAINAGE

Collier County lies within the Atlantic Coastal Plain physiographic province (Meinzer, 1923, pl. 28). It is part of the Terraced Coastal Lowlands physiographic region of Florida as subdivided by Puri and Vernon (1959, p. 7, fig. 3).

The Terraced Coastal Lowlands were formed during the interglacial stages of the Pleistocene Epoch, when sea level was much higher than it is today and Florida was nearly covered by the ocean. When the sea remained relatively stationary for a long period, current and wave action developed relatively flat surfaces on the ocean floor. During the glacial stages the sea retreated and the flat surfaces emerged as marine terraces which had gentle seaward dips. Wave action at the inland margin of the sea would generally cut a scarp or bench into the abutting landmass, leaving a well-defined shoreline when the sea retreated. In many places, however, either wave-cut benches were not formed or they were masked by later deposition or the growth of vegetation.

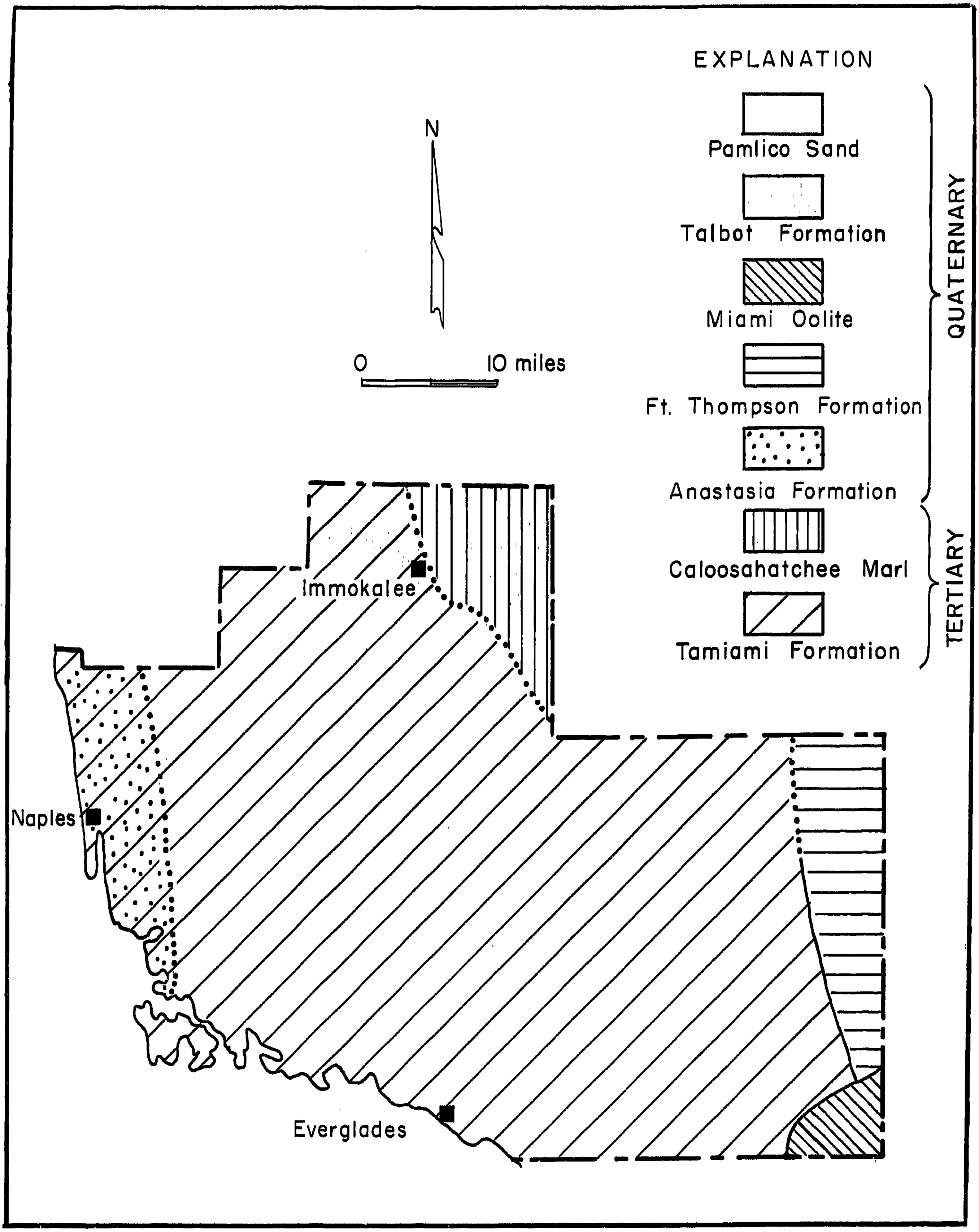

Figure 3. Collier County showing the geology exclusive of organic soils.

Cooke (1945, p. 245-248; 273-311) recognized seven terraces representing seven stands of the sea during Pleistocene time. Of these terraces only the lowest two are within the surface altitudes of Collier County: the Pamlico terrace at 25 feet above msl (mean sea level) and the Talbot terrace at 25-42 feet above msl. Parker and Cooke (1944, p.24) included a still lower shoreline, called Silver Bluff terrace, which is recognizable along Biscayne Bay in Miami, Florida, where it cuts into the rock at an altitude of 5 feet.

The writer was unable to distinguish any field evidence of the ancient shorelines in Collier County. However, from aerial photographs and topographic maps, a part of the Pamlico shoreline can be traced which correlates with that of Parker and Cooke (1944, pl. 14). Parker and Cooke (p. 26) indicated that during Pamlico time, while most of south Florida was covered by the sea, an island existed south of the Caloosahatchee River. This island was probably a remnant of the Talbot terrace which stood between 25 and 42 feet above sea level. As can be seen in figure 3, only a small part of the island extended into Collier County. This island was referred to as Immokalee Island by Parker, et al., (1955, p. 139).

During the last glacial stage of the Pleistocene, the sea retreated to about 25 feet below its present level and left many parallel beach ridges and bars in southern Florida. Sand was transported southward beyond Everglades and Marco Island and dunes were formed. Sand dunes are the foundations of many of the islands in the Ten Thousand Islands area, and the top of one dune on Marco Island stands 52 feet above sea level, the highest land point in Collier County (Parker and Cooke, 1944, p. 26).

Davis (1943, fig. 1) divided Collier County into three physiographic regions: the Flatlands, the Big Cypress Swamp, and the Southwest Coast and Ten Thousand Islands (fig. 4). The Flatlands region contains a great number of marshes and swamps, cypress stands, and open-water depressions. These include the Corkscrew Marsh, Lake Trafford, and the Okaloacoochee Slough (fig. 5). Numerous embayments, lagoons, creeks, and rivers occur in this region along the Gulf of Mexico. The Big Cypress Swamp covers the flat, poorly drained central and eastern parts of the county and is characterized by swamps containing large cypress trees, islands of pine forests, and wet marl prairies. Most of the region is less than 15 feet above sea level. The Southwest Coast and Ten Thousand Islands has many tidal streams, bays, lagoons, and thousands of shoal-water islands. Much of the area is covered by mangrove swamps and salt-water marshes.

Drainage in Collier County is sluggish, because of the general flat topography, and is mainly through the interconnected sloughs (fig. 5).

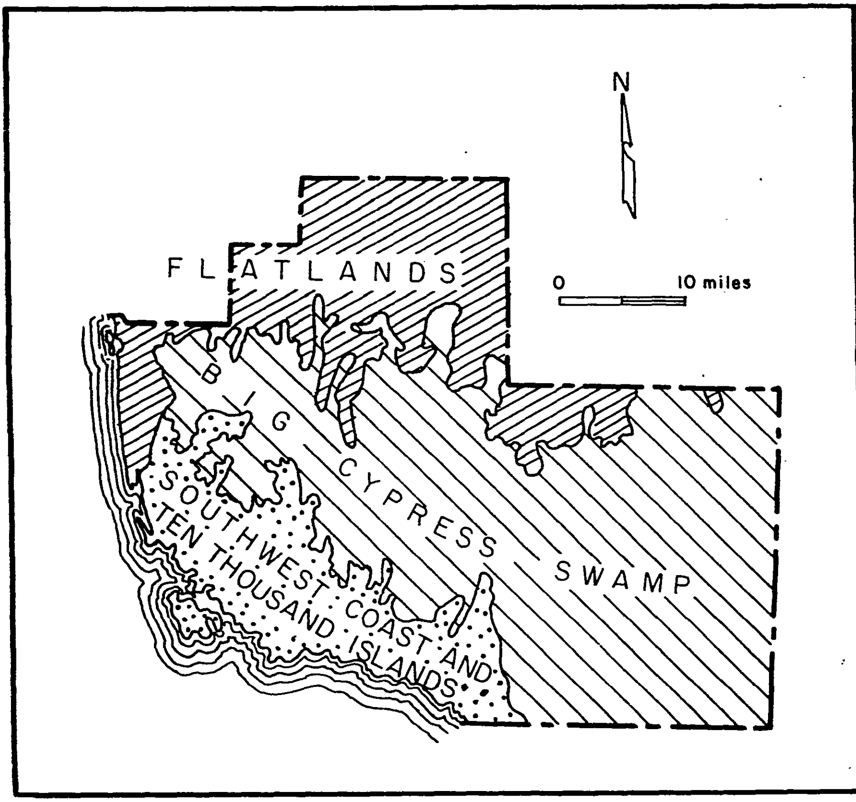

Figure 4. Physiographic regions of Collier County.

There are many creeks and rivers along the coastline, but they do not extend great distances inland. The principal drainage channels are the Gordon River at Naples, the Barron River at Everglades, the Turner River east of Everglades, and the Cocohatchee River in the northwestern part of the county. Major canal construction has extended the drainage of the Cocohatchee and Barron rivers considerable distances inland.

The digging of several major canals has altered the natural drainage to some extent. The canal adjacent to the Tamiami Trail (U.S. Highway 41) acts chiefly to collect southward runoff from the Big Cypress Swamp and distribute the water to the nearest outlets beneath the highway. It has little effect on drainage except in areas where it joins streams that discharge to the gulf, such as the Barron and Turner rivers. The recently constructed borrow canals adjacent to State Highways 858 and 846

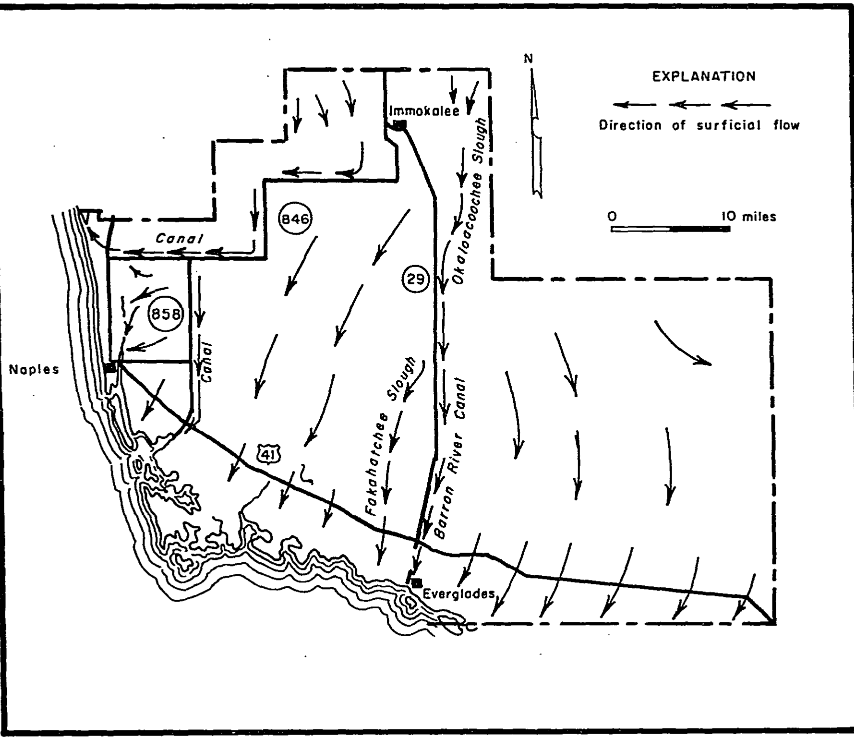

Figure 5. Surficial flow in Collier County.

constitute the beginning of a program of drainage and development in northwestern Collier County. The canal adjacent to State Highway 846 connects with the Cocohatchee River and extends more than 12 miles inland into frequently flooded areas, where land-surface elevations in places exceed 15 feet.

The Barron River Canal probably diverts a sizable amount of water from the Fakawatchee Swamp. Drainage in eastern and west-central Collier County is so poor that the area remains flooded for long periods after the end of each rainy season.

Deep Lake, one of five sinkhole lakes in southern Florida (Parker and Cooke, 1944, p. 44) is just east of State Highway 29, and about 14 miles north of Everglades (fig. 2). It has vertical or overhanging sides to depths ranging from 35 to 50 feet, below which it slopes gradually to its deepest point of 95 feet. It resulted from underground solution and collapse of limestone.

GEOLOGY

GENERAL STATEMENT

The peninsula of Florida is an emerged part of a large extension of the ancient continental landmass. The extension is called the Floridian Plateau (Vaughan, 1910). The core of this plateau is formed of igneous and metamorphic rocks known as the basement complex. Sedimentary rocks overlying the core range in thickness from about 4,000 feet near the center of the peninsula to more than 12,000 feet in Collier County (Parker and Cooke, 1944, p. 18). The predominant materials in this county to a depth of about 700 feet are sand, limestone, and clay; below 700 feet the rocks are chiefly limestone and dolomite.

The only producing oil field in Florida is located in Collier County, near Sunniland (fig. 2). Oil was discovered at a depth of 11,626 feet, where it is trapped in structural folds within the sediments of Trinity Age in the Lower Cretaceous Series. The discovery well was completed on September, 26, 1943, but was later abandoned. Additional wells were drilled and the field is still producing. Oil-exploration wells drilled in Collier County furnish valuable information for the study of the deep structures and stratigraphy of southern Florida.

Rocks of Miocene Age and younger are the only materials in Collier County that will yield water suitable for irrigation, municipal, or domestic purposes. Older rocks of Oligocene and Eocene Age yield large quantities of water to deep flowing wells, but the water is too highly mineralized for ordinary uses. Therefore, only those formations that yield water of fair to good quality or in usable quantities will be described here in detail.

MIOCENE SERIES

TAMPA FORMATION

Cooke (1945, p. 111-115) defined the Tampa Formation as the Lower Miocene sandy limestones that overlie the Suwannee Limestone of Oligocene Age and grade upward into the younger Hawthorn Formation. In Collier County, the Tampa Formation is represented primarily by a sandy limestone or a calcareous sandstone. The sand is predominantly quartz and occurs in pockets or thin beds, or is disseminated in the limestone matrix. In well cuttings, the limestone varies from a dirty buff color to a very light color. Some phosphatic material is associated with the Tampa Formation in Collier County.

In oil-exploratory wells in the central part of the county, the Tampa Formation is approximately 200 feet thick. In one well, near Sunniland, the top of the Tampa Formation was reached at a depth of 411 feet. In well 609-115-1, 5 miles east of Miles City, the Tampa Formation was penetrated in the interval between 400 and 578 feet below land surface. In well 556-128-1 on the southern mainland and well 554-143-1 on Marco Island, the Tampa Formation was reached at depths of 376 and 350 feet, respectively. Several flowing wells in the Naples area probably are of sufficient depth to penetrate the Tampa Formation, but no record of the well cuttings is available. The 300-foot test well 616-141-2, 8½ miles northeast of Naples, did not reach the Tampa Formation (fig. 6).

In Collier County, the limestones of the Tampa Formation probably are the chief source of the water yielded by flowing wells which penetrate the upper part of the Floridan aquifer, the principal artesian system that underlies Florida (Parker, 1951, p. 831).

HAWTHORN FORMATION

The Middle Miocene Hawthorn Formation in Collier County overlies the Tampa Formation and underlies the Tamiami Formation of Late Miocene Age. It is composed predominantly of clay but it contains also stringers or lenses of sand and gravel and thin layers of limestone and shells. The limestones generally occur near the bottom of the formation.

The clay and sandy clay in the formation are relatively impermeable. In places they resemble commercial modeling clay. Because of the characteristic low permeability of the clay, the Hawthorn Formation forms the main part of the confining section that caps the Floridan aquifer.

The boundary between the green clay of the Hawthorn Formation and the gray-green silty, sandy clays of the overlying Tamiami Formation is very difficult, if not impossible, to determine from fossils. Lithologic differences cannot be used to differentiate because there appears to be a gradational zone between the Hawthorn Formation and the Tamiami Formation (figs. 6, 7). However, it is estimated by the author that the Hawthorn Formation in Collier County ranges in thickness from about 250 to 300 feet, and that the top of the formation ranges in depth from less than 100 feet in the Sunniland-Immokalee area to more than 200 feet along the western coastal areas. Figure 7 shows the subsurface lithology along line B-B′ in figure 2.

Parker, et al., (1955, p. 84) stated that artesian wells penetrating limestones in the lower part of the Hawthorn Formation in coastal Collier County have water levels that correspond with those of deeper wells. This indicates that the lower limestones of the Hawthorn Formation are interconnected with the main body of limestones of the Floridan aquifer and they may be considered the top of the aquifer. However, some of these wells probably extend into the Tampa Formation in order that adequate yield may be obtained.

Information obtained by Klein (1954, p. 22) has shown that soft limestones in the Hawthorn Formation at depths of 200 to 250 feet in the Naples area yield low to moderate quantities of water. Wells tapping these beds have water levels considerably lower than those of deeper wells, and the contained water is more saline than water from the Floridan aquifer. These relatively shallow limestones probably constitute a separate artesian system.

TAMIAMI FORMATION

The Tamiami Formation as defined by Parker (1955, p. 85) includes all the Upper Miocene deposits in southern Florida. It underlies nearly all of Collier County (fig. 3), and in the southern and eastern parts of the county it is exposed at the surface or is covered by a thin veneer of younger deposits. Parker (1955, p. 85) indicated that the formation has a maximum thickness of about 150 feet in southern Florida. The exact thicknesses of the formation were not determined from test wells in Collier County because Tamiami sediments are gradational with the older Hawthorn sediments. Schroeder and Klein (1954, p. 4) suggested a thickness of about 50 feet for the Tamiami Formation at Sunniland.

The Tamiami Formation is composed predominantly of tan to light gray sandy and silty clay and shell marls. The lower part of the formation is chiefly shelly, fine sand and greenish clayey marls. These materials are of low permeability and constitute the upper part of the confining beds of the Floridan aquifer.

The upper part of the Tamiami Formation throughout most of Collier County is composed of relatively thin, solution-riddled, highly permeable and very fossiliferous limestone. This limestone member appears to wedge out a few miles west, south, and east of Immokalee, and according to Schroeder and Klein (1954, p. 4) it does not occur near the Dade-Broward County boundary. In well 625-116-1 (fig. 6), 9 miles east of Immokalee at the Hendry County boundary, the limestone was penetrated at a depth of 22 feet and was more than 32 feet thick. The shallow depth of the wells immediately east of Immokalee indicates that the member is thinning to the west. In the vicinity of Naples, the top of the limestones of the Tamiami Formation ranges from about 25 to 55 feet below the land surface. In southern and southeastern Collier County, it is exposed at the surface or is overlain by a thin veneer of younger materials.

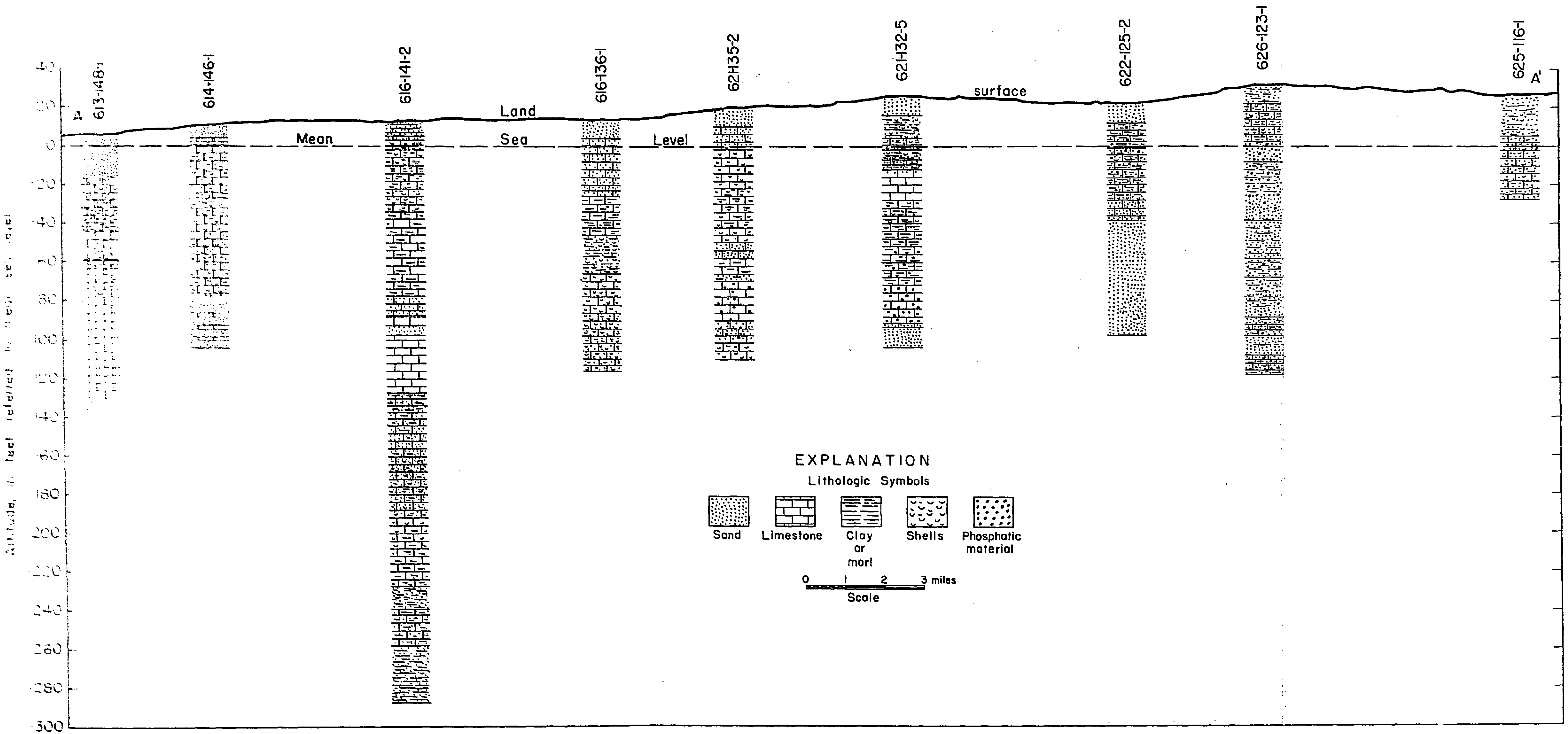

Figure 6. Lithologic cross section along line A-A' in figure 2.

It is exposed in canals and ditches, and is quarried extensively along U.S. Highway 41 in the southern part of the county and along State Highway 29, principally in the vicinity of Sunniland. In the quarried areas the limestone is characterized by the large echinoid *Encope macrophora tamiamiensis.*

The Tamiami Formation is probably unconformable with overlying younger sediments. Schroeder and Klein (1954, p. 4) described the surface of the formation in the eastern part of the county as undulating and dissected. They indicated also that the dissection occurred prior to Pliocene deposition and possibly again during the Pleistocene.

The limestone of the Tamiami Formation forms the principal shallow aquifer in Collier County. Its high permeability and widespread occurrence indicate its great importance in the development of large water supplies in the county.

PLIOCENE SERIES

CALOOSAHATCHEE MARL

The Caloosahatchee Marl is predominantly a grayish green silty, sandy, shell marl with interbedded layers of sand, silt, clay, and marl (Parker, et al., 1955, p. 89). The formation rests unconformably on the Tamiami Formation in the eastern part of Collier County (fig. 3). In well 625-116-1, 9 miles east of Immokalee, 18 feet of gray sandy, shelly marl was penetrated (fig. 6) which may represent the Caloosahatchee Marl. It overlies solution-riddled limestone of the Tamiami Formation.

The generally low permeability of the Caloosahatchee Marl causes wells drawing water from it to have low yields.

PLEISTOCENE AND RECENT SERIES

ANASTASIA FORMATION

The Anastasia Formation represents the marine deposits of pre-Pamlico Age of the Pleistocene Series in Collier County. Parker, et al., (1955, pl. 4) indicated that the Anastasia Formation occurs in a band about 5 to 6 miles wide along the west coast of Collier County (fig. 3). At its type locality, Anastasia Island near St. Augustine, the Anastasia Formation is a coquinoid limestone. In Collier County, however, it appears as a light cream to light gray sandy limestone and tan shelly, sandy marl containing many *Chione cancellata.*

Although the Anastasia Formation is present only in a small part of Collier County (fig. 3), it causes much difficulty in well drilling. Many small-diameter wells have been abandoned or restricted to shallow depths because drillers could not penetrate a hard, dense limestone in the formation.

The Anastasia Formation is exposed along the canal banks on the north side of State Highway 846. Two miles east of the intersection of State Highway 846 and U.S. Highway 41, the hard limestone of the formation is very near the land surface and dips toward the Gulf of Mexico. In well 613-148-1, the formation is 22 feet below land surface and is probably about 15 feet thick (fig. 6).

The Anastasia Formation probably overlies the Tamiami Formation unconformably in most areas of the county. In the southern part of Collier County along U.S. Highway 41 and in the Sunniland quarries, very thin beds of hard tan limestone or sandstone, which contain abundant *Chione cancellata,* overlie and fill depressions of the old eroded surface of the Tamiami Formation. Parker, et al., (1955, p. 85) assigned this limestone to be Anastasia Formation.

Limestones of the Anastasia Formation are generally permeable and where they are thick, as at Naples, they form an important part of the shallow aquifer.

FORT THOMPSON FORMATION

The Fort Thompson Formation is composed of alternating marine and fresh-water deposits. The deposits consist of sand, marl, shell marl, sandstone, and limestone of fresh-water and marine origin which were deposited during one or several of the glacial stages of the Pleistocene (Klein, 1954, p. 13). Any sequence of fresh-water and marine beds, or fresh-water beds alone, older than Recent fresh-water deposits is considered as representing the Fort Thompson Formation of Pleistocene Age. (See Schroeder and Klein, 1954, p. 5; Parker, et al., 1955, p. 90-99.)

The Fort Thompson Formation occurs in the eastern part of Collier County (fig. 3) where it rests unconformably on the Tamiami Formation. Test drilling indicated that along the eastern boundary of the county the Fort Thompson Formation ranges in thickness from 3 to 9 feet (Schroeder and Klein, 1954).

Klein (1954, p. 12-13) described a zone of fresh-water gastropods overlying the Anastasia Formation in Naples. This zone may represent or be equivalent to the uppermost zone of the Fort Thompson Formation.

MIAMI OOLITE

The southeast corner of Collier County is covered by the Miami Oolite, a gray, porous, oolitic limestone (fig. 3). The contact between the Miami Oolite and the underlying Tamiami Formation can be seen

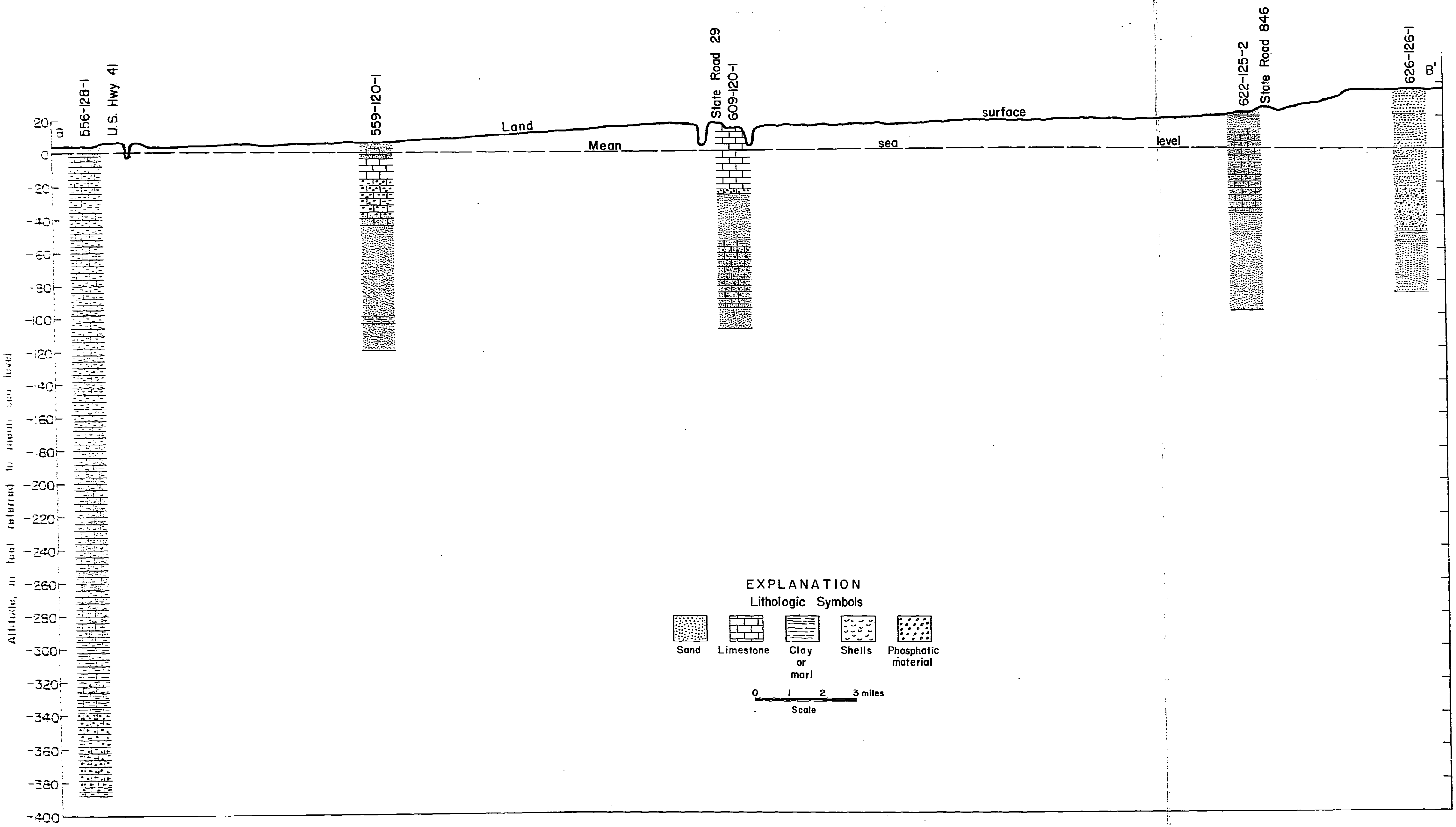

Figure 7. Lithologic cross section along line B-B′ in figure 2.

in canal banks along U.S. Highway 41 a few miles west of the Dade County boundary. The Miami Oolite in Collier County probably does not exceed 5 feet in thickness, but it thickens eastward in Dade County, where it forms an integral part of the Biscayne aquifer.

PLEISTOCENE TERRACES AND RECENT DEPOSITS

As discussed in the section on physiography, marine terraces were formed by fluctuations of the sea level during interglacial stages of the Pleistocene. When the ancient sea stood 42 feet above present sea level, the Talbot terrace was formed. It is present in Collier County only in the northern part, where its deposits blanket Immokalee Island (fig. 3). Deposits of the Talbot terrace are characterized by very fine to coarse quartz sand and some silt or clay. The sands of the Talbot Formation yield ample water to many shallow sand-point wells in the vicinity of Immokalee.

The Pamlico Sand was deposited when the sea covered all the land area of Collier County, which was less than 25 feet above present sea level (fig. 3). In Collier County the Pamlico Sand is composed of fine to medium quartz. The base of this sand is 10 to 15 feet below msl in the Naples area where it immediately overlies the Anastasia Formation. The uppermost material is white or light gray medium grained quartz sand, which grades downward to a highly colored rust brown fine grained quartz sand. The color is apparently caused by the vertical migration of organic materials in percolating ground water (Klein, 1954, p. 13). In the interior areas of Collier County, the Pamlico Sand forms a thin blanket over the Tamiami Formation or the thin, hard limestone layer of the Anastasia Formation (fig. 6). After the close of Pamlico time the terrace surface was altered by winds to form dunes. These dunes are greatly emphasized on Marco Island but are less noticeable along the upper west coast of the county. The Pamlico Sand forms the top unit of the shallow aquifer in Collier County.

Recent deposits are composed chiefly of organic materials, derived from decayed vegetation, mixed with the terrace deposits. Thin accumulations of peat and muck occur also in the Big Cypress Swamp where they are mixed locally, in depressions, with marly and sandy materials.

TEST-WELL DRILLING

Twelve test wells were drilled in Collier County during the first year of the investigation. The wells ranged in depth from 123 to 700 feet below the land surface. The locations of the test wells were determined by the amount and distribution of geologic, hydrologic, and quality-of-water information obtained during the well inventory phase of the investigation. The test wells were therefore drilled in areas where information was scarce or nonexistent.

Samples of the materials penetrated by the test wells were taken at 5-foot intervals whenever possible. When a layer of permeable rock was penetrated, a water sample was pumped from that layer. In thick permeable zones water samples were pumped at 10-foot intervals. When material of low permeability was penetrated and its water yield was small, water samples were collected from that depth by use of the bailer. Several water samples from highly permeable zones were collected for complete chemical analysis; all the water samples were analyzed for chloride content.

Water-level measurements were made during the drilling of each test well. An analysis of these water levels indicates differences in pressure head within a given aquifer or between aquifers. When a permeable zone was pumped, the yield of the well was estimated at that depth and water-level measurements were made after pumping stopped to determine the rate of recovery of the water level. The rate of recovery is a factor in determining the relative permeability of the tested zone.

One test well, 5 miles east of Miles City, penetrated the Floridan aquifer. This well was drilled to furnish data on the occurrence of relatively fresh water in the aquifer in the southern part of the county.

During the period 1957-58, several exploratory wells were drilled in the vicinity of Naples in cooperation with the city of Naples. These wells were drilled to determine areas that might be developed as sources of additional water for municipal supply, and to determine the extent of salt-water encroachment from the Gulf of Mexico. They are also used as water-level observation wells and are sampled at regular intervals to determine changes in the salt content of the water.

Rock cuttings and water samples were collected during the drilling of six privately owned wells. The logs of 18 wells are given in table 5.

GROUND WATER

PRINCIPLES OF OCCURRENCE

Ground water composes one part of the earth's water-circulating system known as the hydrologic cycle. In this cycle water is taken from the earth's surface into the atmosphere by evaporation. It condenses and returns to the surface as precipitation. When it falls on land areas the water moves downward under gravitational forces, seeking to fill all the pore spaces of the host rock or soil. The portion of material that is filled with water is called the zone of saturation. The pore spaces of the material overlying the saturated zone are filled with water and air and this material is called the zone of aeration. Water in the zone of saturation is known as ground water; water in the zone of aeration is referred to as vadose water (Meinzer, 1923, p. 29-32; 38-39; 76-83). The direction of movement of vadose water is generally downward because of gravity.

Ground water occurs in permeable geologic formations called aquifers. If water in the aquifer is unconfined, the upper surface of the zone of saturation is under atmospheric pressure and is called the water table. The direction of movement of ground water is controlled by the slope of the water table.

Confined aquifers, also called artesian aquifers, occur where ground water is confined by relatively impermeable formations and is under pressure greater than atmospheric. The direction of movement of ground water in an artesian aquifer is from points of high pressure to points of low pressure. Water in a well penetrating a nonartesian aquifer will rise no higher than the water table, whereas water in a well penetrating an artesian aquifer will rise above the bottom of the confining formation to a height determined by the hydrostatic pressure of the aquifer. The height to which water will rise in tightly cased wells penetrating an artesian aquifer is called the piezometric or pressure surface. If the piezometric surface is above land surface, the water will flow from the well.

Unconfined or nonartesian aquifers are replenished by the downward infiltration of rainfall, or downward seepage from lakes and rivers. This replenishment, or recharge, generally occurs throughout the extent of the aquifer. Confined or artesian aquifers can receive recharge only in areas where the confining bed is absent, breached, or somewhat permeable, and the recharge water has a greater head than the water in the artesian aquifer.

FLORIDAN AQUIFER

Most of Florida is underlain by thick sections of permeable limestones of Miocene and pre-Miocene Ages. These limestones form an extensive artesian aquifer from which most of the large ground-water supplies for the central and northern parts of Florida are obtained. Stringfield (1936, p. 125-132, 146) described the aquifer and mapped the piezometric surface in 1933 and 1934. The name "Floridan aquifer" was introduced by Parker, et al., (1955, p. 189) to include all parts of the thick permeable section of limestones of Middle and Late Eocene Age and Oligocene Age, which constitute a single hydrologic unit, and the

Tampa Formation and permeable parts of the Hawthorn Formation which form the top of the aquifer and which are in hydrologic contact with the rest of the aquifer. The Floridan aquifer is confined by relatively impermeable limestone layers in the Hawthorn Formation and by the overlying clay and silt beds of the Hawthorn and Tamiami Formations.

The Floridan aquifer underlies all of Collier County. It slopes very gently in a southerly direction in the county, and the top of the aquifer is almost everywhere less than 400 feet below msl. The thickness of the Floridan aquifer in Collier County is not known, but several wells 2,000 feet deep do not completely penetrate it. It yields large amounts of water to wells by natural flow, but the water is usually so highly mineralized that its use is limited.

The yield and pressure of the artesian water in the Floridan aquifer vary with depth. Well 609-115-1, 5 miles east of Miles City, receives water from two zones within the aquifer. The casing of the well is so constructed that the two zones are independent of one another. The upper part of the well is cased to 312 feet below the land surface and has an open hole from 312 to 485 feet. The lower part of the well is cased from land surface to 587 feet below the land surface and has an open hole from 587 to 700 feet. Although each of the open-hole zones yielded about the same quantity of water, there was a significant difference in their pressures. On May 26, 1961, the water level of the shallow zone was 30 feet above msl, whereas that of the deep zone was 52 feet above msl. The magnitude of the head differential indicates that the material between the two open-hole intervals is of relatively low permeability and that the zones may be separate artesian systems.

Two wells in Goodland (fig. 2) also show differences in pressure resulting from differences in depth. Well 555-139-2 is 540 feet deep and has 179 feet of open hole. Well 555-139-5 is 342 feet deep and has 22 feet of open hole. Their water pressures are respectively 33 and 26 feet above msl.

In the Naples area, isolated lenses or stringers of limestone and shells within the thick confining section of the Hawthorn Formation have sufficient permeability to yield moderate quantities of water to relatively shallow artesian wells. However, these units are not of great importance because their yield to wells is small and the quality of the water is no better than that from the Floridan aquifer.

PIEZOMETRIC SURFACE

The piezometric surface of the Floridan aquifer is an imaginary surface representing the pressure head of the confined water and is the

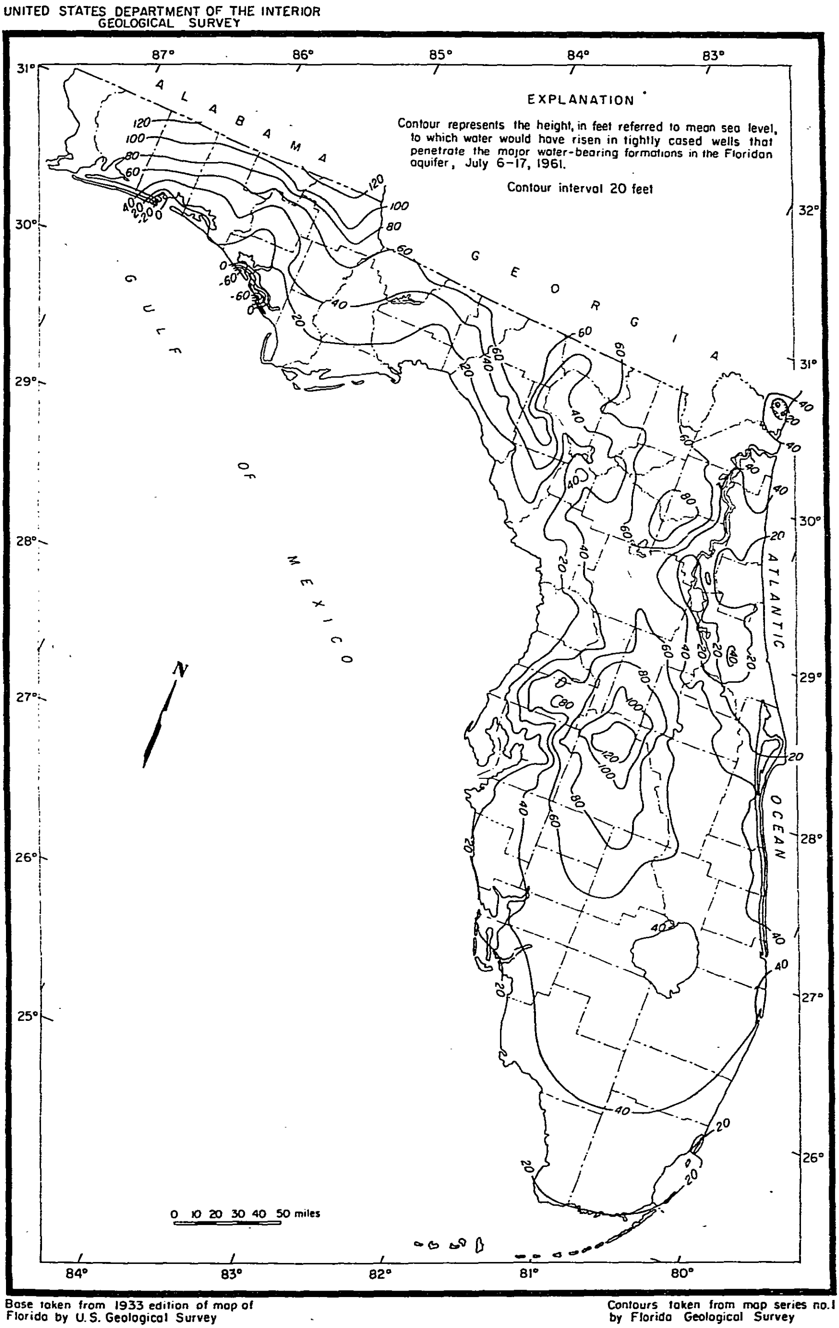

Figure 8. The piezometric surface of the Floridan aquifer, July 6-17, 1961.

height to which water will rise in tightly cased wells that penetrate the aquifer. The configuration of the piezometric surface of the Floridan aquifer in peninsular Florida is shown by the contour lines in figure 8.

The piezometric surface of the Floridan aquifer in Collier County ranges from 22 feet above msl at Naples to 58 feet above msl in the northern part of the county, north of Immokalee. It is higher than the land surface in all parts of the county except the high sand dunes on Marco Island. The piezometric surface slopes in a southwesterly direction to the Gulf of Mexico (fig. 9). Ground water in the Floridan aquifer moves downgradient from areas of high artesian pressure to areas of low artesian pressure along flow lines which are perpendicular to the contour lines. Therefore, the flow of ground water in the Floridan aquifer in Collier County is generally to the southwest. The distortion of the regional pattern of the piezometric surface in the area north of Immokalee is the result of discharge of several flowing wells in that area.

In figure 9, the slope of the piezometric surface in the coastal and adjacent areas is fairly steep, indicating discharge from the aquifer in offshore areas. The average slope in the downgradient areas is about 1 foot per mile; in upgradient areas it decreases and averages about half a foot per mile. The relatively equal spacing between contour lines suggests that all the observation wells, measured for pressure readings used in the preparation of figure 9, penetrate the Floridan aquifer.

RECHARGE AND DISCHARGE

The Floridan aquifer is replenished where the aquifer is at or near the land surface, or where the altitude of the recharge water is higher than the piezometric surface and the confining bed is thin, breached, or relatively permeable. These areas are known as recharge areas. The principal recharge area for central and southern Florida is Polk County and vicinity, where the piezometric surface of the aquifer is highest, as shown in figure 8. In some areas of Polk County, leaky confining beds overlie the Floridan aquifer (Stewart, 1959, p. 55), and recharge water under high head can infiltrate vertically from shallow water-bearing materials to the Floridan aquifer which contains water under a lower head.

The water level in the Floridan aquifer in Polk County and vicinity is at a higher altitude than it is in the surrounding areas. The water in the aquifer moves downgradient, perpendicular to the contour lines, to points of discharge, principally springs and wells. Discharge by upward leakage through the confining beds probably occurs in downgradient

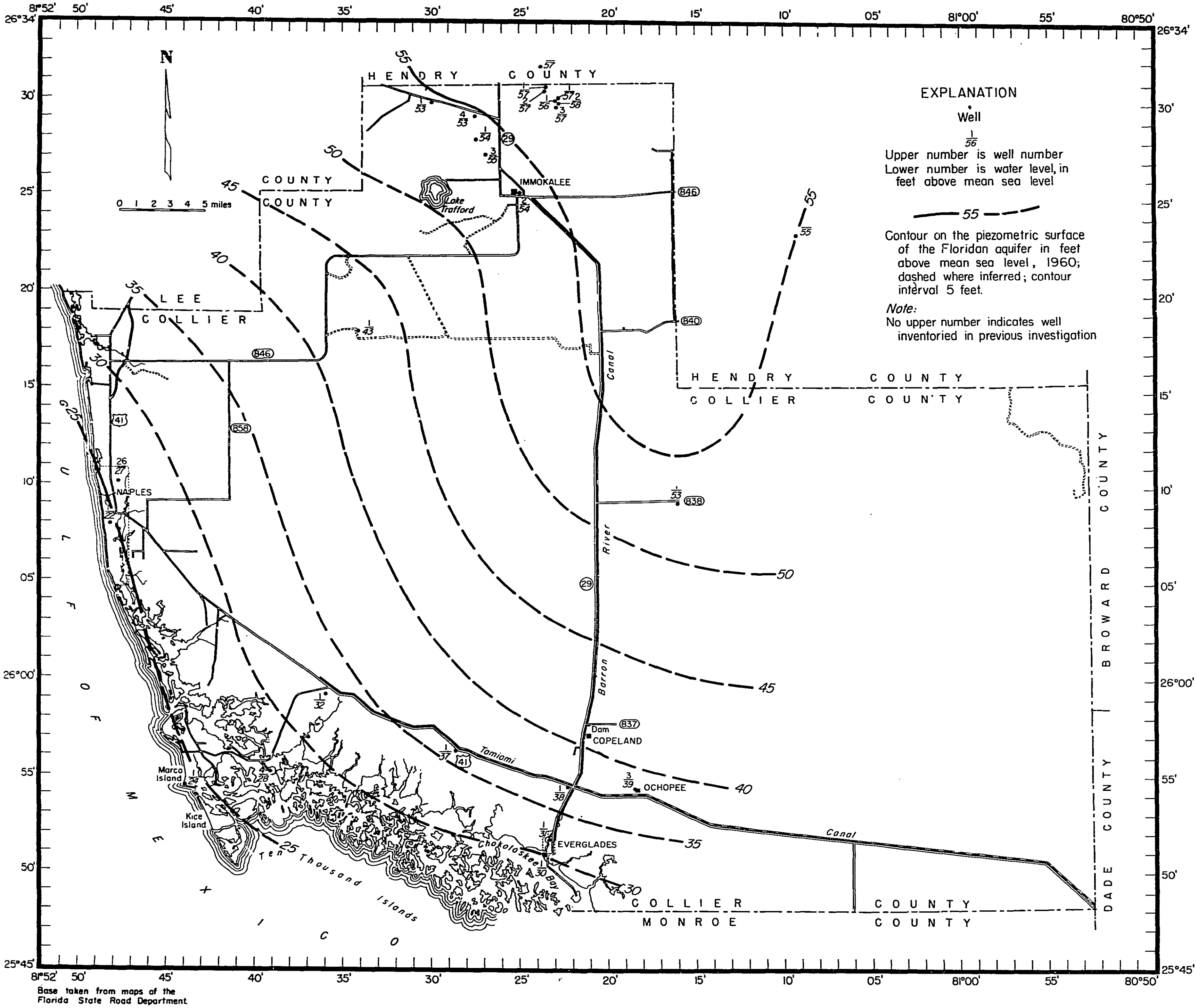

Figure 9. Piezometric surface of the Floridan aquifer in Collier County, 1960.

areas where the piezometric surface is higher than the water level of the shallow materials.

Water is discharged from the aquifer in Collier County by about 50 flowing wells. There probably are others which have been capped and abandoned for many years. The casings of abandoned wells deteriorate and considerable leakage takes place in the subsurface through them.

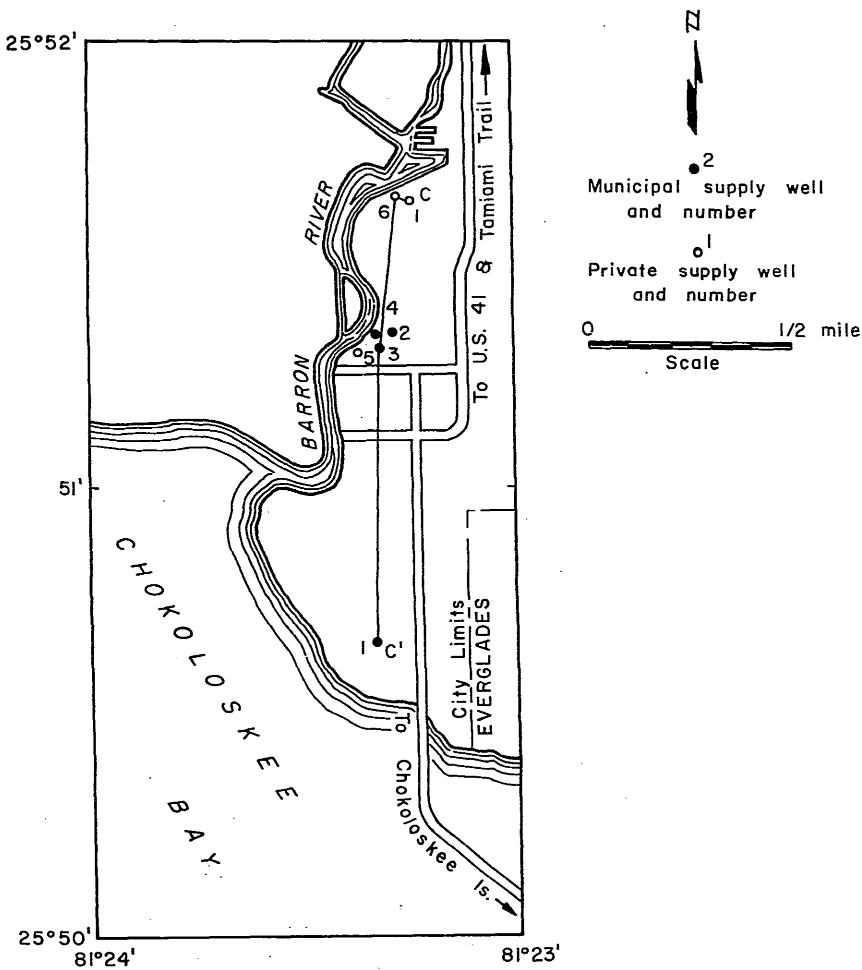

Figure 10. Map of Everglades showing location of wells and cross section along line C-C′.

The Floridan aquifer probably crops out on the ocean floor at a considerable distance from the coast of Collier County. Because the artesian pressure at the coast is high, 22 to 25 feet above msl, considerable offshore discharge from the aquifer can be expected through submarine springs.

As there is a large upward pressure gradient within the Floridan aquifer, shown by water-level measurements in the test well east of Miles City, water can be continuously discharged from the lower zones through open well bores into shallow zones. This movement of water can be extremely important in wells containing long intervals of open hole, especially where the lower zones contain very highly mineralized water.

AVAILABILITY AND USE OF GROUND WATER

Ground water from the Floridan aquifer is available by natural flow to wells throughout Collier County except on the high sand dunes of Marco Island. However, its use is greatly limited because of its relatively high mineral content. Generally, the water is too salty for most purposes but it is used as a supplemental supply in irrigation systems.

About 40 percent of the flowing artesian wells in Collier County are in the Immokalee area (fig. 2). Most of these wells were originally used for irrigation but many have been abandoned or are used only as an auxiliary supply. Several deep wells in the Naples area are used to maintain lake levels and supply irrigation water. One artesian well in downtown Naples was used for many years as a fire-protection well.

The town of Everglades obtains its water supply from four flowing artesian wells which penetrate the Floridan aquifer (fig. 10). It is the only place in southern Florida where the quality of the water from the Floridan aquifer approaches the standards of the U.S. Public Health Service for drinking water. Usually, wells penetrating the aquifer in the area south of Lake Okeechobee yield water with a chloride content near or greater than 1,000 ppm.

During the period 1927-29, four wells were drilled in the town of Everglades to furnish the municipal supply. Well 551-123-1 was drilled in the northern part of the town but was abandoned because of the poor quality of the water. Wells 551-123-2, 3, and 4 were drilled approximately half a mile south of well 551-123-1. The three wells in this field form a triangle about 150 feet long on each side. In 1935, well 550-123-1 was drilled about half a mile south of the well field. A year later, wells 551-123-2 and 3 were deepened to increase their yield. In 1961, water supplies for the town were furnished by wells 551-123-2 and 3, and wells 551-123-4 and 550-123-1 were reserved for emergencies.

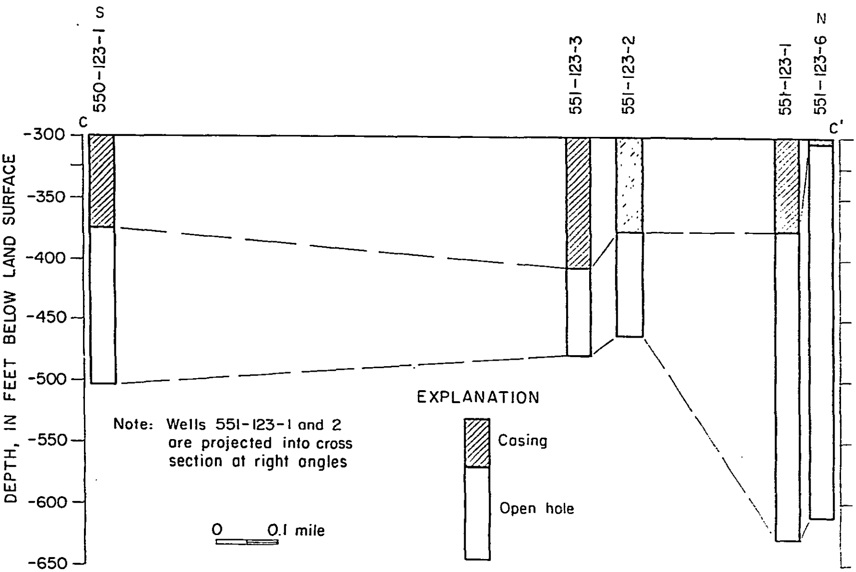

Figure 11. Cross section along line C-C′ in figure 10, showing amount of open hole in wells.

Figure 11 is a cross section in Everglades. The casing bottoms and total depths of the wells have been presented to show the differences in construction. Lack of detailed information prohibits determining the reasons for the differences in amount of open hole in wells relatively close together.

In four wells, a formation described by the drillers as a water rock or water shale was reached at a depth of about 380 feet. The presence of this stratum is probably the reason that the casings in most of the wells end above this depth. Wells 551-123-2 and 3 were drilled until caving halted the operation. No explanation is given for the depths of the other wells. After setting the casing, the driller probably continued to make open hole until the desired yield was obtained. This supposition is somewhat supported by the fact that all the wells mentioned above, except 550-123-1, have been deepened, indicating that the initial flow had decreased or had become inadequate to supply the demand.

Wells 554-122-1 and 556-128-1 are respectively 4 miles north and 7 miles northwest of Everglades (fig. 2). Both are flowing artesian wells and yield water of the same salinity. The total depth of well 556-128-1 is unknown, but it is probably no greater than that of the wells in the

Everglades well field. Well 556-128-1 reached the dark green dense clay of the Hawthorn Formation at a depth of 292 feet, and a light gray limestone in the Floridan aquifer at 376 feet. The well was drilled to a total depth of 392 feet. The materials penetrated in well 556-128-1 correlate very closely to those in well 551-123-6. Well 551-123-6 reached the green clay at a depth of 275 feet and the limestone at 371 feet. The salinity of the water from well 551-123-6 for the interval 371-414 feet was considerably higher than that from well 556-128-1.

SHALLOW AQUIFER

The shallow aquifer is the principal source of fresh water in Collier County. It is composed of the Pleistocene terrace sands, the Anastasia Formation, and the upper permeable limestones of the Tamiami Formation. The lower parts of the Tamiami Formation, together with the impermeable sections of the Hawthorn Formation constitute the confining layer for the Floridan aquifer.

The shallow aquifer has a maximum thickness of about 130 feet in western Collier County, where the Pamlico Sand, the Anastasia Formation, and limestones of the Tamiami Formation are all present and are fairly well interconnected. It thins eastward to a thickness of about 60 feet near Sunniland, and wedges out near the Dade County boundary, where the shallow materials are composed of marls and fine sand. In southern Collier County, the shallow aquifer is composed entirely of solution-riddled, highly permeable limestone of the Tamiami Formation which extends to a depth of at least 90 feet below the land surface.

Test drilling and data on the depth and yield of existing wells in the Immokalee area indicate a marked change in the lithology of the shallow aquifer in that area. The subsurface materials in the vicinity of Immokalee are chiefly clastic sediments ranging from marls to very coarse sands. No limestones of appreciable thickness or permeability were penetrated within the upper 100 feet of the section. Several beds or lenses of coarse quartz sand occur in this upper section which would probably yield large quantities of water to screened wells; however, most of the wells of high yield penetrate limestones and shell beds at depths of 200 feet or more. These deeper limestones may be interconnected with the shallow aquifer.

The thick section of clastics may be part of a frontal edge of a large delta, which, according to Bishop (1956, p. 26), extended southward through Highlands County (on the north) during the Miocene Epoch. To the east and west of the Immokalee area the clastic sediments grade into

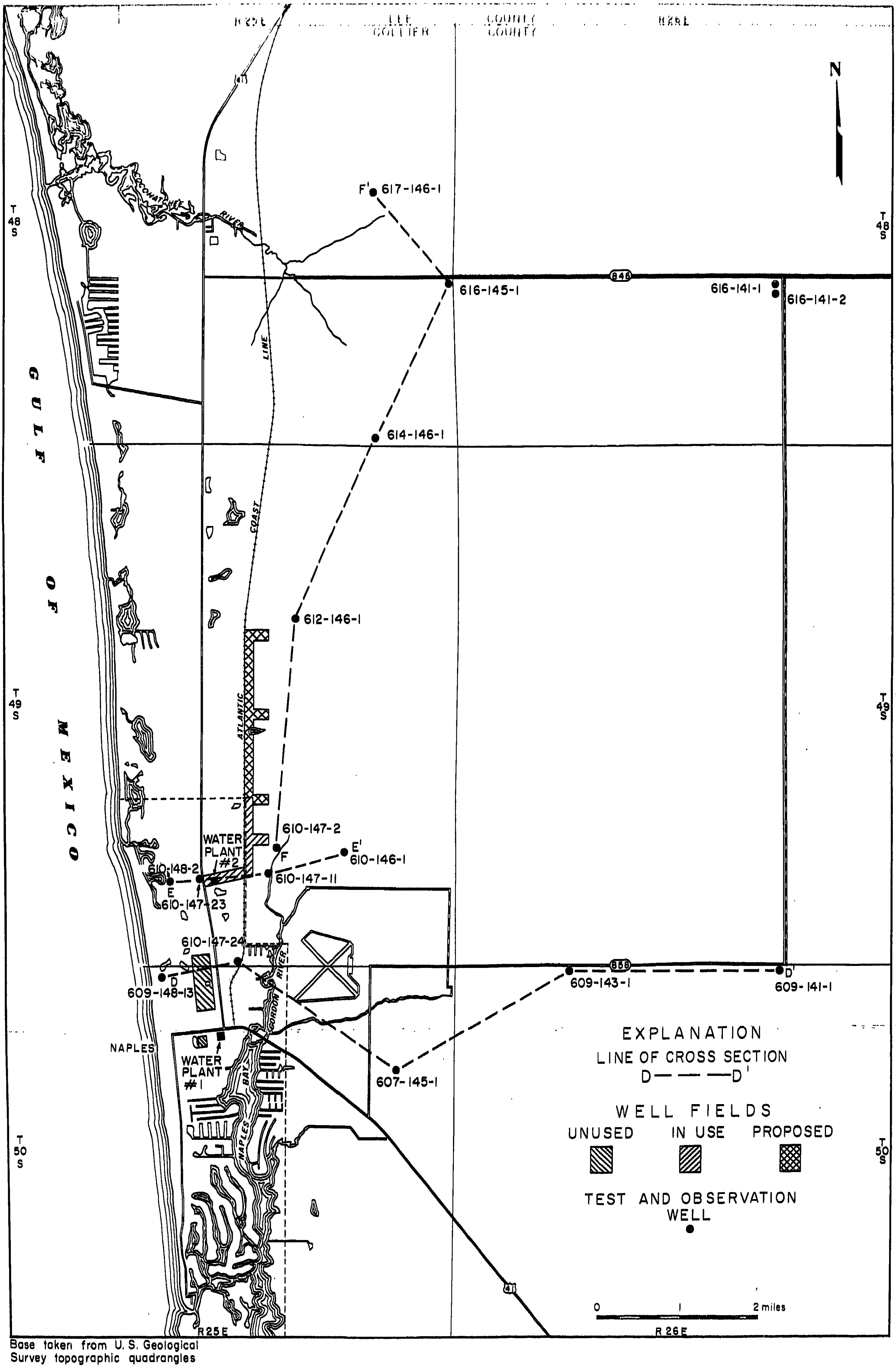

Figure 12. Northwestern Collier County showing locations of the Naples municipal well fields and geologic cross sections along lines D-D', E-E', and F-F'.

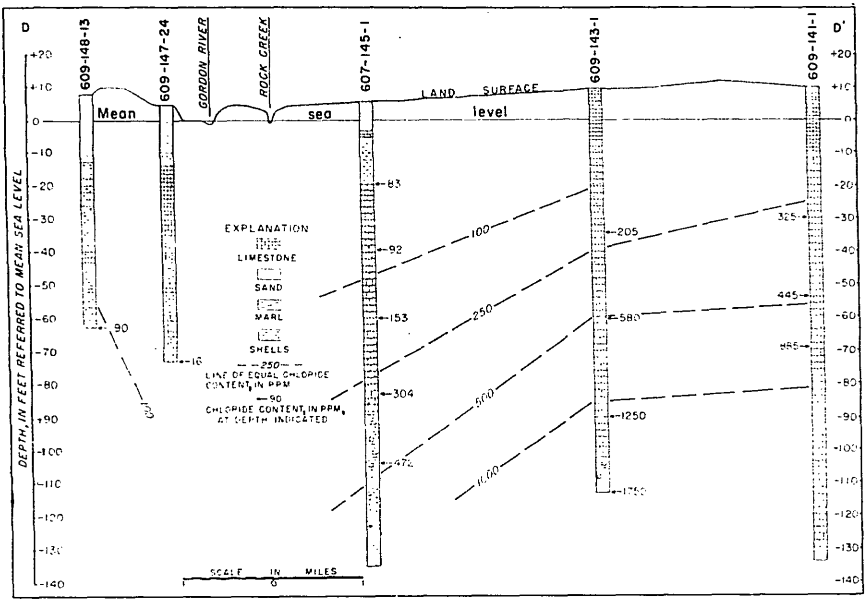

Figure 13. Geologic cross section and chloride content of water along line D-D' in figure 12.

permeable marine limestones which yield large quantities of water to open-hole wells.

The shallow aquifer supplies large amounts of water for irrigation throughout the county. The Pleistocene sands yield small amounts of fresh water to very shallow wells on Marco Island.

During 1957-59, several exploratory wells were drilled east and northeast of Naples in connection with the expansion of water facilities for Naples (fig. 12). Figures 13, 14 and 15 show the lithology of the shallow aquifer along the three cross-sectional lines indicated in figure 12. The cross sections show that east of Naples the aquifer is compared almost entirely of limestone. Northeast of Naples the aquifer becomes thinner and the limestone is interbedded with sand and marl. The Pamlico Sand (uppermost part of the aquifer), which is about 15 to 20 feet thick in Naples, thins rapidly eastward.

RECHARGE AND DISCHARGE

The shallow aquifer is recharged principally by local rainfall that percolates downward to the zone of saturation. During periods of high

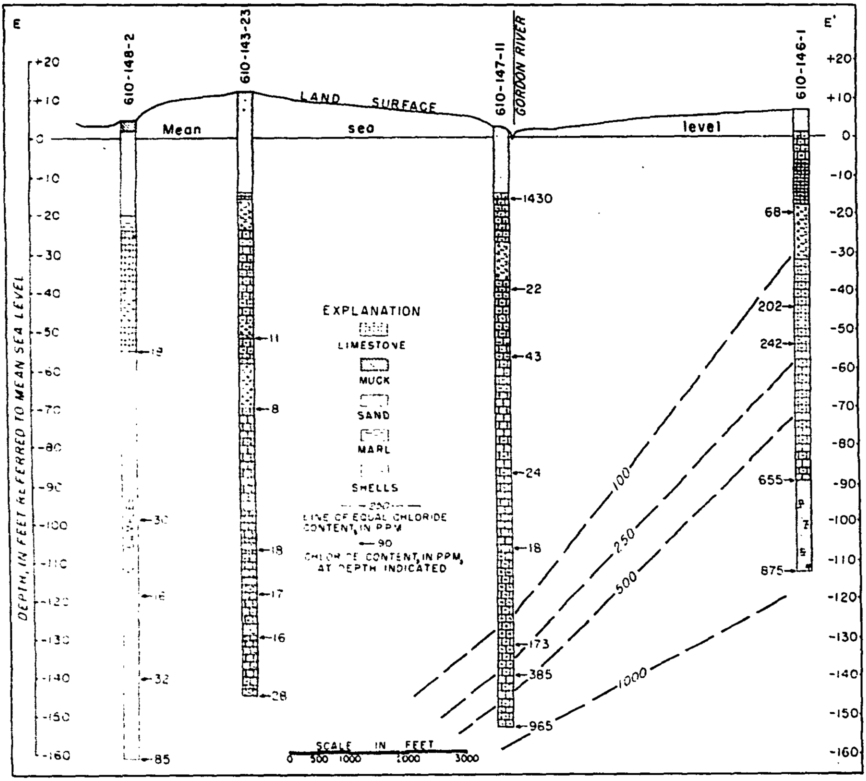

Figure 14. Geologic cross section and chloride content of water along line E-E' in figure 12.

water levels it is possible that canals and streams would afford some recharge to the aquifer for a short time. Where impermeable layers are present at or near the land surface, recharge by rainfall is restricted and much potential recharge is lost by sheet flow to the streams, sloughs, canals, and Gulf of Mexico.

In the Naples area, a confining bed of silt and marl occurs within the shallow aquifer and impedes the downward infiltration of ground water. Materials above the confining bed readily soak up and store a large amount of rainfall. In much of the area northeast of Naples, a layer of very hard, dense limestone of low permeability occurs at or immediately below the land surface. The low permeability greatly decreases the amount of downward infiltration to the aquifer, and as a result much of the water in this area drains off as overland flow and does not recharge the aquifer.

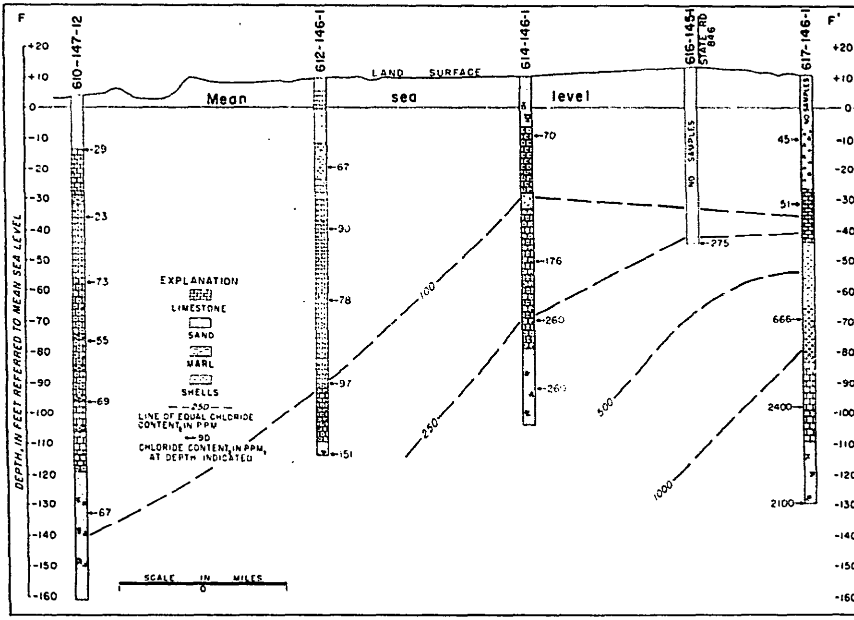

Figure 15. Geologic cross section and chloride content of water along line F-F' in figure 12.

Figures 16 and 17 show the effect of rainfall on water levels in observation wells penetrating the shallow aquifer in the county.

Well 610-147-14 (fig. 16) is in the Naples well field and is affected by pumping. However, the altitude of the plotted daily highs correlates closely with rainfall recorded at Naples. The graph of pumpage from the well field shows that pumping magnifies the fluctuations, especially during dry periods when pumping is increased.

Water levels in wells 617-134-3 and 625-116-1 are compared to rainfall recorded at Lake Trafford (fig. 17). Well 617-134-3 is about 10 miles southwest and well 625-116-1 is about 13 miles east of Lake Trafford. Time lapses of several days can be noted between rains recorded and rises in water levels. Some rains show little if any effect, indicating that probably no rain fell in the vicinity of the well. The same situation appears to be true for well 606-120-1 and Miles City (fig. 17). The hydrographs show that some areas remain flooded for a considerable time during the rainy season.

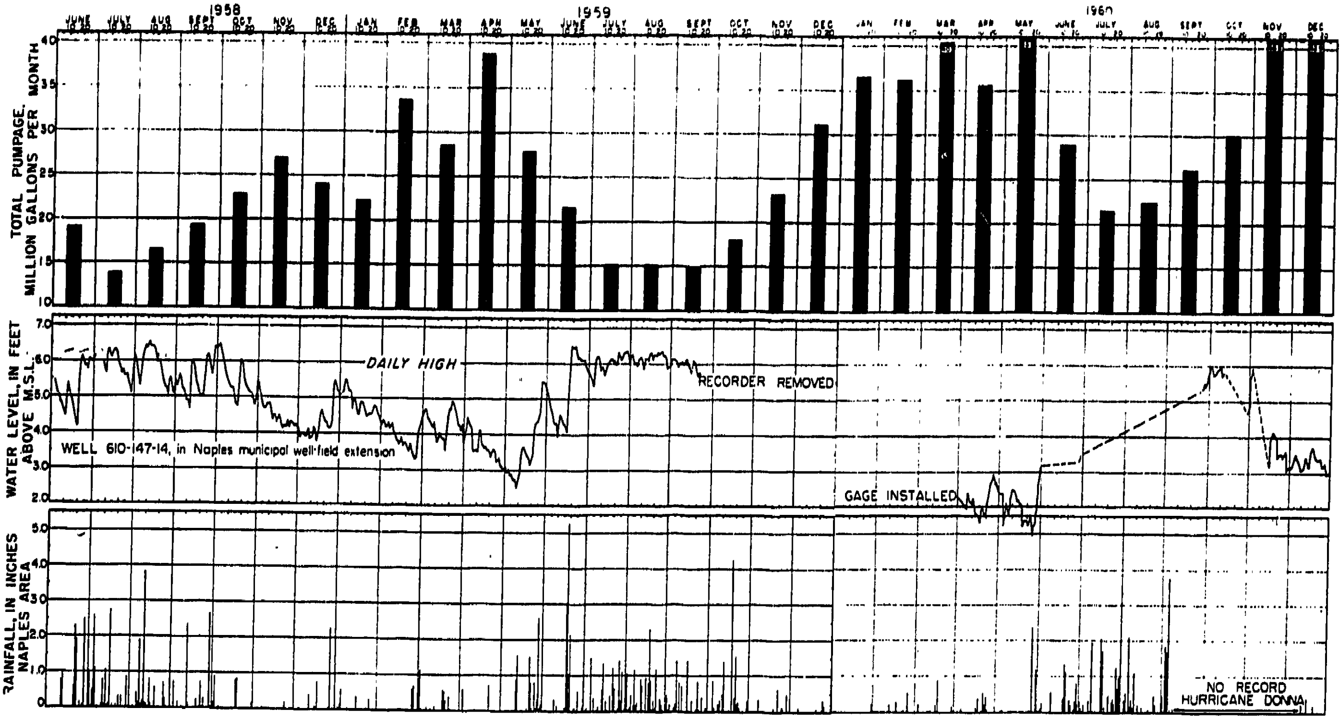

Figure 16. Hydrograph of well 610-147-14 showing daily high, monthly pumpage from Naples well field, and daily rainfall at Naples, June 1958-December 1960.

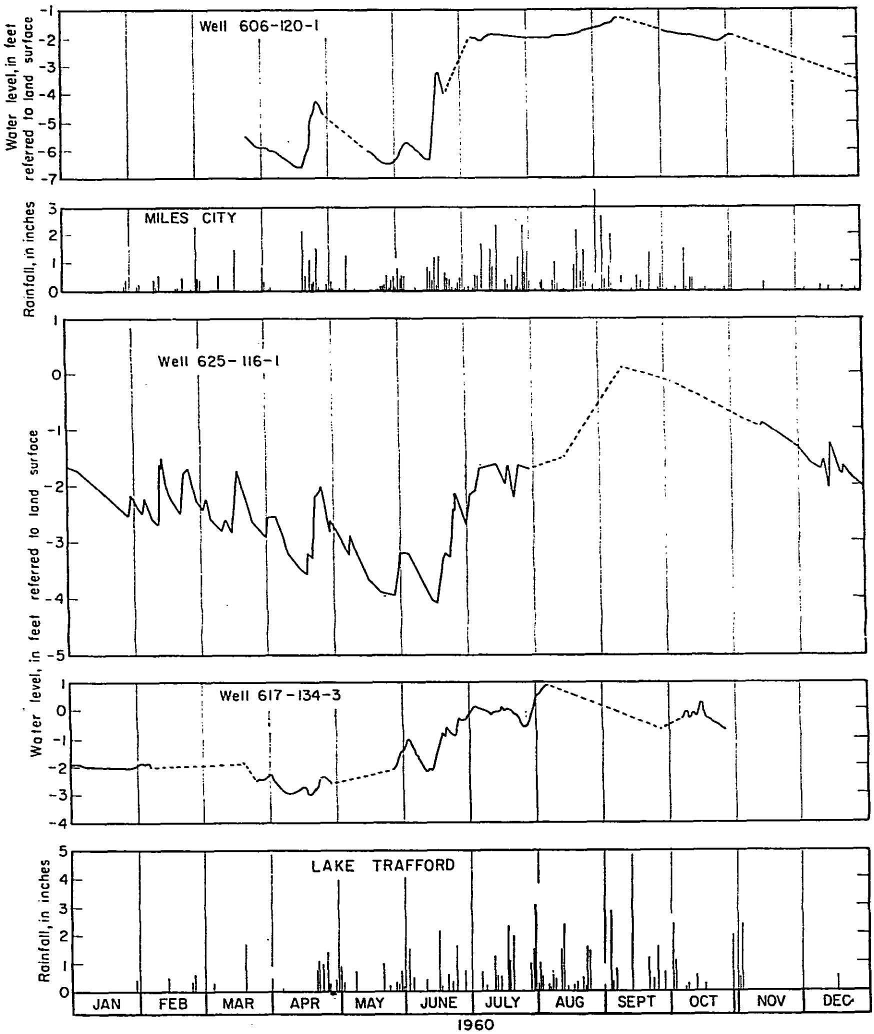

Figure 17. Hydrographs of wells 606-120-1, 625-116-1, and 617-134-3, and daily rainfall at Miles City and Lake Trafford, 1960.

Ground-water losses from the shallow aquifer occur by natural discharge into streams, drainage canals, and the Gulf of Mexico; by evapotranspiration; and by pumping from wells. Losses by natural discharge are greatest during periods of high rainfall, when ground-water levels are highest. Also, when ground-water levels are high many parts of the county are flooded, and as a result the rate of evaporation increases.

Transpiration by plants also account for large losses. Ground water discharged by natural processes far exceeds the amount discharged by pumping.

Ground-water use is greatest along the western coastal area and in the northern part of Collier County. In the coastal area the rapid spread of urbanization has increased the demand for municipal supplies (fig. 16). Several housing subdivisions are supplied by privately owned water systems. Also, hundreds of small-diameter wells in the area are used for lawn irrigation and individual household supplies where no municipal supplies are available.

In northern Collier County scores of large-diameter wells are used to irrigate truck crops. East of Immokalee wells yield as much as 1,000 gpm (gallons per minute), or more.

WATER-LEVEL FLUCTUATIONS

Fluctuations of the water table in the shallow aquifer reflect changes in the amount of ground water in storage in the aquifer. Fluctuations are caused by recharge by rainfall, and discharge by outflow from the aquifer, evapotranspiration, and pumping of wells. Water levels in wells near the coast are affected by gulf tides. Minor fluctuations in some areas result from variations in atmospheric pressure. Rainfall, evapotranspiration, and pumping are the most important factors in the fluctuation of water levels in the shallow aquifer in Collier County. The hydrographs in figures 16 and 17 show the fluctuations of water levels in different areas of Collier County.

Water levels in several wells in northwestern Collier County were measured to determine the altitude and configuration of the water table during periods of high and low rainfall. These wells tap the uppermost section of the aquifer. Figure 18 shows the approximate altitude and configuration of the water table in the Naples area on August 15, 1960, after a period of heavy rainfall. The configuration of the contours shows that the aquifer is recharged by local rainfall. The steep water-table gradient on the west side toward the gulf suggests that the sandy surface material is only moderately permeable and can therefore retain large amounts of ground water in storage. In general, the water table conforms to the topography of the area and the contours indicate that underflow is westward to the Gulf of Mexico, southward to Naples Bay and the Naples well field, and eastward to the Gordon River drainageway.

Figure 19 shows the configuration and altitude of the water table on March 29, 1960, after a period of deficient rainfall (Sherwood and Klein, 1960). The pattern is similar to that of August 15, 1960, but the altitude

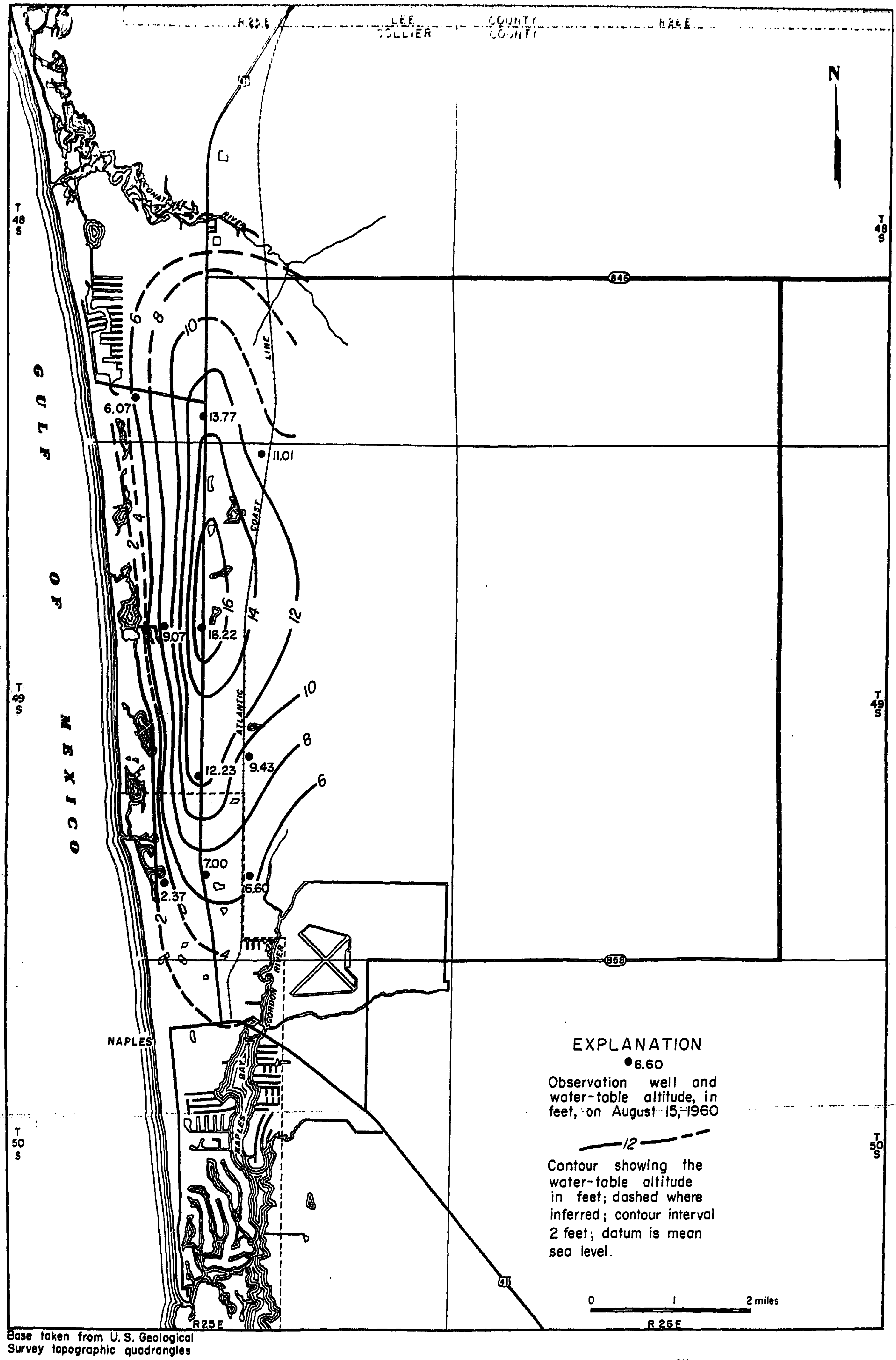

Figure 18. Water-level contour map of northwestern Collier County, August 15, 1960.

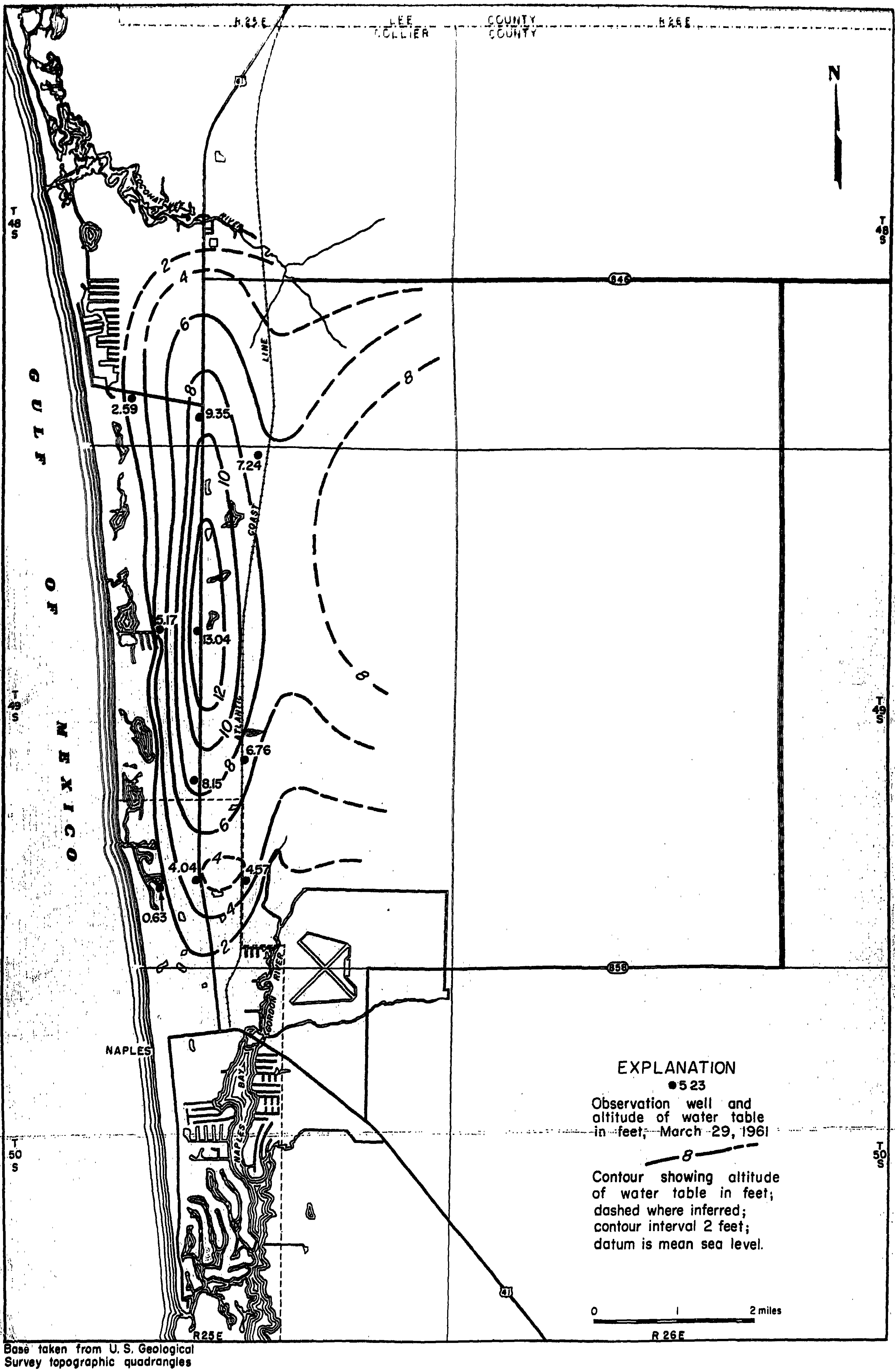

Figure 19. Water-level contour map of northwestern Collier County, March 29, 1960.

of the water surface is somewhat lower. Both contour maps show the effect of pumping in the municipal well field, which is indicated by a shallow water-table depression in the northeastern part of the city.

Water-level measurements made during the drilling of test wells and supply wells along the coastal area showed differences in head between the upper and lower parts of the aquifer. Along the central part of the ridge, the water levels in shallow wells (25-30 feet deep) ranged from 1 to 3 feet higher than the water levels in wells penetrating the deeper part of the aquifer (60-100 feet deep). Such head differential causes downward leakage of ground water. It is typical of the recharge areas, and the magnitude of the differential is related to the degree of confinement of the zone between the two parts of the aquifer. In the peripheral areas where discharge from the aquifer takes place, the head relationship is reversed; the water levels in deep wells range 1 to 2 feet higher than those in the shallow wells and upward leakage occurs. In the municipal well-field area, where wells 60 to 100 feet deep are heavily pumped, water levels in the upper part of the aquifer are substantially higher than those in the lower part and much of the ground water pumped is supplied by downward leakage in the area of the cone of depression.

The graphs in figure 16 show the relationship between pumpage, rainfall, and water-level fluctuations in well 610-147-14, in the Naples well field, for the period June 1958 - December 1960. Although the well penetrates the lower part of the aquifer, the response of the water level in the well to rainfall is rapid. Pumping is the major factor causing large declines in the vicinity of the well field; other fluctuations such as those caused by tides and variations in barometric pressure are minor.

AVAILABILITY AND USE OF GROUND WATER

The shallow aquifer is the prinicpal source of fresh ground water in the county except for the area in the vicinity of Everglades. The limestone of the Tamiami Formation is the chief water-bearing zone of the aquifer in most of the county. On Marco Island, the Pamlico Sand provides the only obtainable potable ground-water supply.

The shallow aquifer yields ground water at various depths depending on the location. In the west to west-central part of the county, it produces from a zone that ranges in depth from about 35 to 100 feet below the land surface; in the central part, from 20 to 90 feet; in the northern part, from shell beds and coarse sand lenses at various depths in the Pleistocene terrace and other sediments; in the southern part, from land surface to about 30 feet; and in the southeastern part, from about 20 to 25 feet.

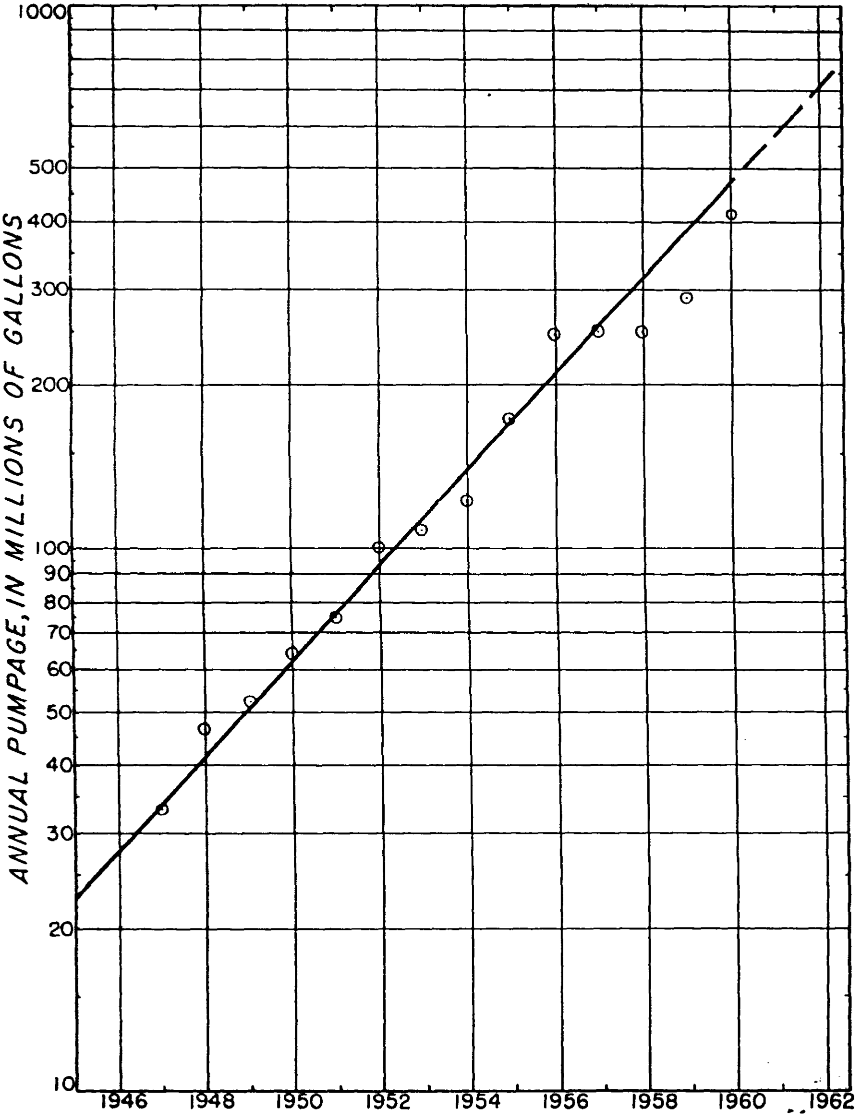

Figure 20. Graph showing annual pumpage from the Naples well fields, 1945-62.

Large quantities of ground water are obtained from the shallow aquifer in the farm belt which stretches from Immokalee southwestward to the Tamiami Trail (U.S. Highway 41) north of Naples. Irrigation wells near the western edge of the farm belt are generally about 60 to 70 feet deep, but farther inland their maximum depth is about 100 feet.

The small community of Copeland obtains its water supply from the limestone of the Tamiami Formation. Well 556-121-2, which supplies Copeland, was drilled to a depth of 30 feet in 1945. At that time the cypress lumber industry was near its peak and the population of Copeland was considerably greater than the 1960 population of 100 to 150. During 1945 the well was pumped at an average rate of 75,000 gpd, or an annual amount of 27.4 million gallons. The well was still in operation in 1961.

Before 1945, the municipal supply for Naples was obtained from one 6-inch and two 4-inch wells located in the southern part of the city, between Naples Bay and the Gulf of Mexico (fig. 12). These wells were closely spaced and were pumped heavily for short periods, which caused salt water to move inland and upward and thus contaminate the aquifer.

During 1945-46, a new well field was established north of the original well field. This field comprises 22 small-diameter wells (3- and 4-inch) spaced 400 feet apart. To dimish the effect of large drawdowns of the water levels, each well was pumped at a rate not to exceed 30 gpm. This control of withdrawals distributed the effect of pumping over a large area and reduced the hazard of salt-water encroachment. The annual pumpage from this well field increased from about 33 million gallons in 1947 to 122 million gallons in 1954.

The city officials proposed the establishment of a new permanent well field because of the constantly increasing demand for water (fig. 20), the high cost of pumping 22 wells, and the constant threat of salt-water encroachment from the Gulf of Mexico and the Gordon River into the field. Their objective was to establish a well field in the cypress swamp area east and north of the city; but no data were available as to the continuity of the aquifer and the quality of the ground water in that area. The city officials believed that a productive field in this area could furnish sufficient water for all the coastal ridge area of Collier County. A new well field was developed in 1954 in the northeastern part of the city (fig. 12), and further expansion of facilities would be inland. Water-treatment plant No. 2 was built at this field.

In 1958, three wells were drilled northeast of water plant No. 2 to supplement the supply from the well field. The layout of the present well field with the extension wells is shown in figure 21. Total pumpage from the well field and extension was 414 million gallons in 1960, more than 25 percent above the total for 1959.

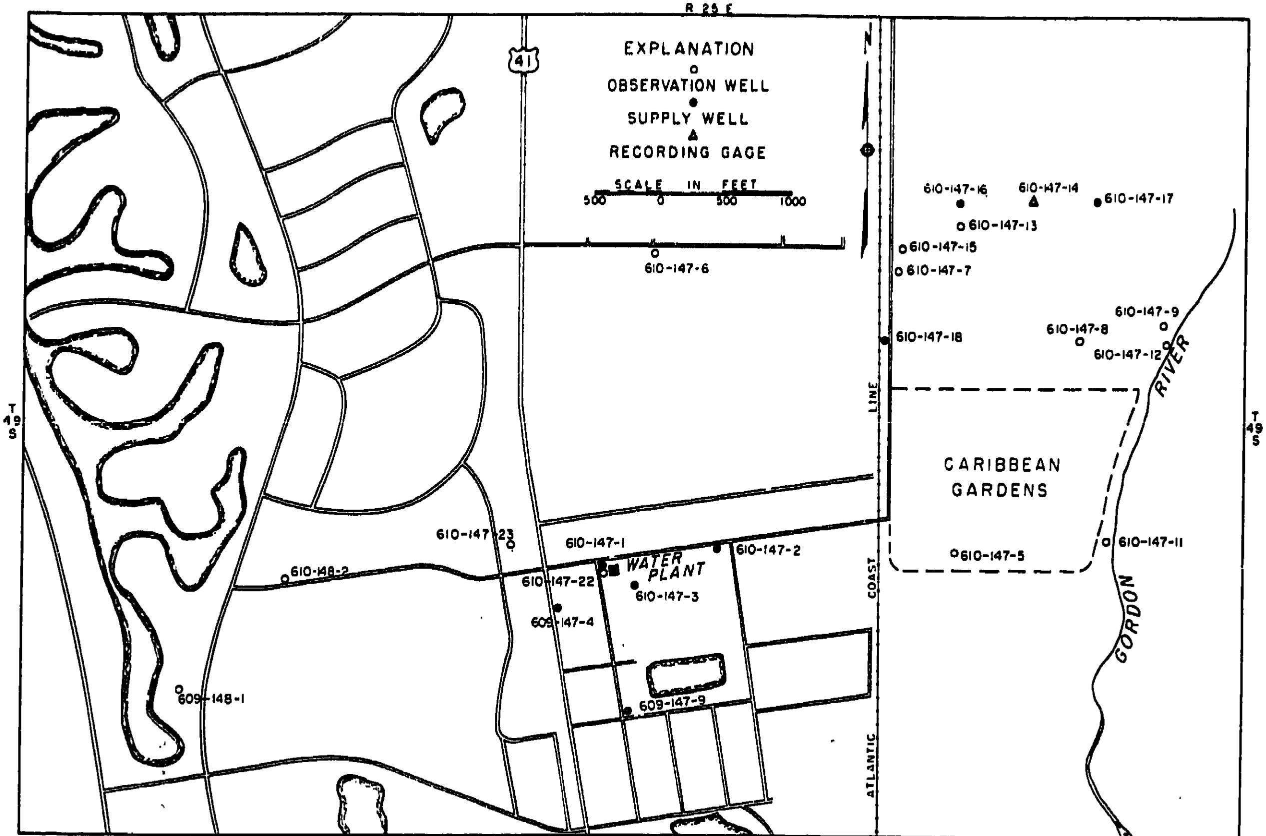

Figure 21. Naples well field area showing municipal supply wells and observation wells.

QUANTITATIVE STUDIES

HYDRAULICS OF AQUIFERS

When a well tapping a shallow aquifer begins to discharge, water is removed form the aquifer surrounding the well and the water level is lowered. The amount that the level is lowered at the well is called the drawdown. The decline of the water table near the discharging well is rapid and large but decreases rapidly outward from the well. An inverted cone, centered at the discharging well, defines the dewatered part of the aquifer and is referred to as the cone of depression or cone of influence. As the discharge continues at a constant rate, the cone spreads outward, thereby diverting more water to the well.

If recharge is available and a sufficient amount can be diverted toward the well to balance the withdrawal, the cone spreads no farther, and the shape of the cone will remain constant. Deepening of the cone will result if the discharge rate is increased or if another nearby well in the aquifer begins discharging. When pumping from the well ceases, the water level immediately starts to recover, rapidly at first, then at a slowly decreasing rate, to the static water level of the area.

The rate of drawdown and recovery in the vicinity of a well depends in part upon the transmissibility of the aquifer. In an aquifer of high transmissibility the drawdown is relatively small and the cone of depression is wide and shallow; in an aquifer of low transmissibility the drawdown is relatively great and the cone is narrow and deep.

Unlike the effect of withdrawal from a water-table well, where the result is a dewatering of the aquifer within the cone of depression, withdrawal from an artesian well results in a lowering of pressure at the well, and the effect, theoretically, is transmitted with the speed of sound throughout the aquifer. In an artesian aquifer, water is released from storage as a result of the compaction or squeezing of sediments when the artesian pressure is lowered, and as a result of the slight expansion of water itself. The basic principle of the cone of influence remains in effect for both types of aquifers, but the cone develops more rapidly in an artesian aquifer because the amount of water released from storage per unit area is much smaller than that resulting from dewatering an unconfined aquifer.

From data obtained by observing water levels in a pumped well and observation wells in the cone of influence, the coefficients of transmissibility and storage can be determined.

The coefficient of transmissibility is the capacity of an aquifer to transmit water. It is expressed as the quantity of water, in gallons per day, that will move through a vertical section of the aquifer 1 foot wide under a hydraulic gradient of 1 foot per foot (Theis, 1938, p. 892). The coefficient of storage is a measure of the capacity of an aquifer to store water and is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

In aquifers where leakage occurs through semiconfining beds, a leakage coefficient can be determined. The leakage coefficient (Hantush, 1956, p. 702) characterizes the ability of semiconfining beds above or below an aquifer to transmit water to the aquifer. It may be defined as the quantity of water that crosses a unit area at the interface between the main aquifer and its confining bed, if the difference between the head in the main aquifer and in the beds supplying the leakage is unit.

AQUIFER TESTS

Seven aquifer tests were made in or near Collier County prior to this investigation. Six of the tests were made in Naples in connection with well-field development, and one was made at the county boundary east of Immokalee. The first three tests were made in 1951-52 to determine the safe rate of pumping from the well field in the southern part of the city. From analyses of the water-level data obtained from these tests, a coefficient of transmissibility of 92,000 gpd per foot and a coefficient of storage of 0.001 were determined (Klein, 1954, p. 47).

Further studies in the area and a comparison of future water demands and the availability of water indicated that the municipal supplies would have to be extended northward where water levels were higher and where the threat of salt-water contamination was less. In 1954, water plant No. 2 (fig. 21) was built and the new well field was established (fig. 12).

Aquifer tests made by Sherwood and Klein (1961) in the new field indicated that the transmissibility of the aquifer increased northward, and in the proposed area of expansion (fig. 12) a coefficient of transmissibility of 185,000 gpd per foot was computed. The tests indicated that, although the upper part of the aquifer contained semiconfining layers, downward leakage was considerable when the well field was pumped. This leakage reduced drawdowns in the lower, pumped zone of the aquifer. The Gordon River, east of the well field was determined to be a source of replenishment at times when the field was pumped heavily.

Figure 22 shows the drawdowns in observation wells at the end of a 30-hour pumping test in the proposed area of development. The

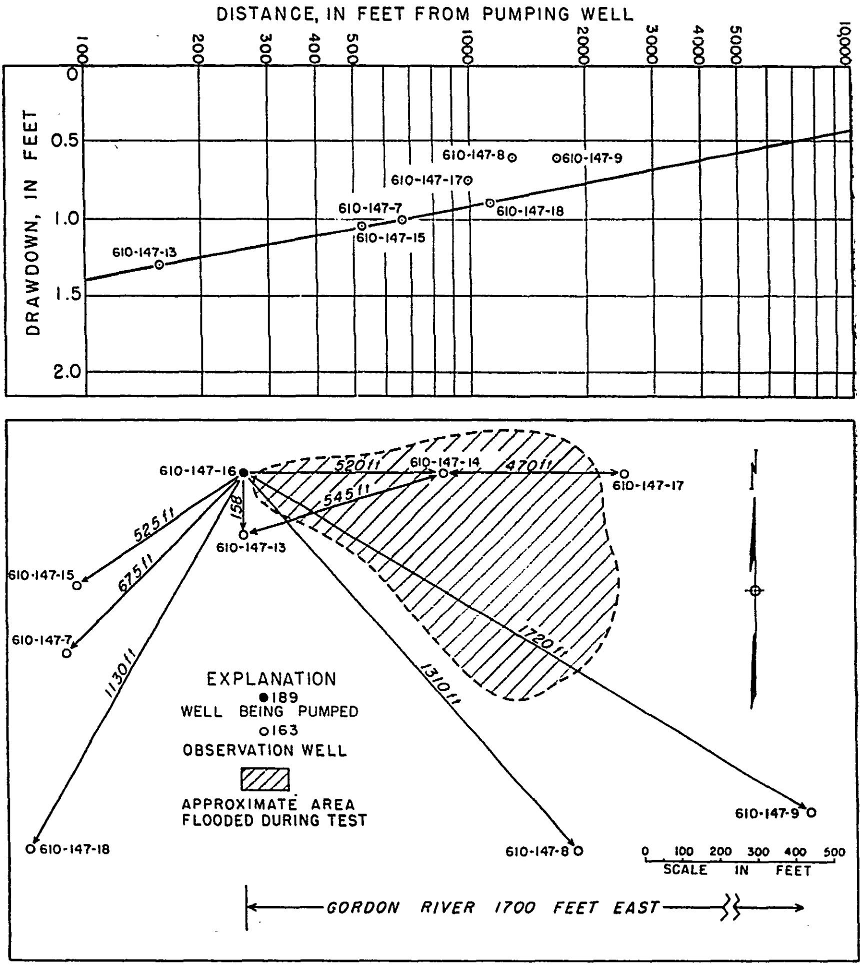

Figure 22. Graph showing drawdown in observation wells at the end of the 30-hour aquifer test, January 9-10, 1959, and sketch showing wells used in the test.

drawdowns in wells between the pumped well and the Gordon River were substantially less than in wells west of the pumped well. The coefficient of leakage computed for this test ranged from 0.001 to 0.008 gpd per square foot per foot of head difference. In general, the coefficient increased eastward.

In the ideal leaky-aquifer system (fig. 23) of Jacob (1946, p. 199) the water table in the nonartesian aquifer is maintained at a constant level

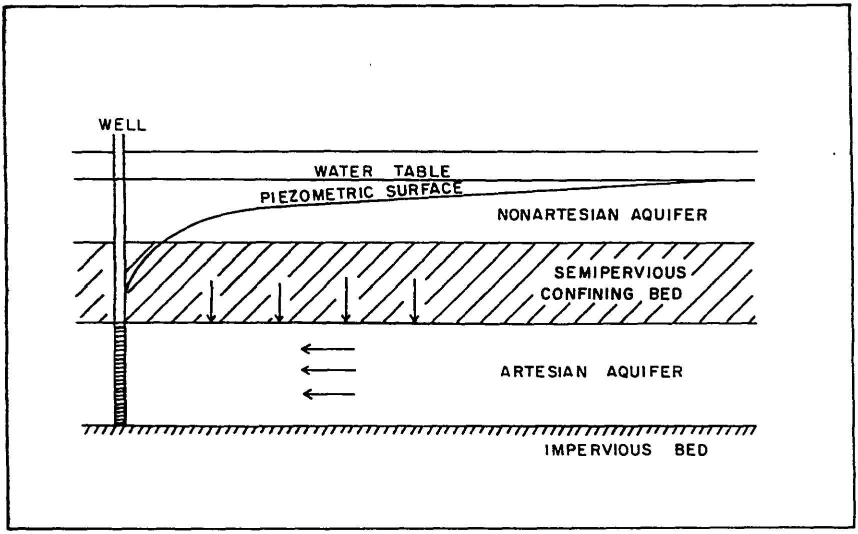

Figure 23. Idealized sketch showing flow in a leaky artesian aquifer system.

by recharge. Pumping from the artesian aquifer causes a cone of depression to form which expands until the amount of downward leakage equals the amount of water withdrawn. In the Naples area. however, the water table in the shallow sands of the upper zone is not maintained constant due to insufficient recharge; therefore, the rate of downward leakage to the pumped zone will decline and the cone of depression will continue to spread.

Figure 24 shows drawdown graphs of wells 610-147-9 and 610-147-15 during the aquifer test of January 1959 (fig. 22). The A curves represent the theoretical drawdown for artesian conditions with no recharge and were computed from the coefficients of transmissibility and storage determined from the aquifer tests. The B curves represent the theoretical drawdowns for nonartesian conditions with no recharge and after extended time. The B curves were computed with a coefficient of storage of 0.15 (characteristic of nonartesian aquifers) and a coefficient of transmissibility 10 percent higher than that determined from the test (to take into account the transmissibility of the upper zone). The water levels near the end of the test were constant, indicating leaky-aquifer conditions and downward leakage was keeping pace with discharge. The C curves are projections of the observed data and indicate the water level would remain constant if sufficient recharge was available. The D curves

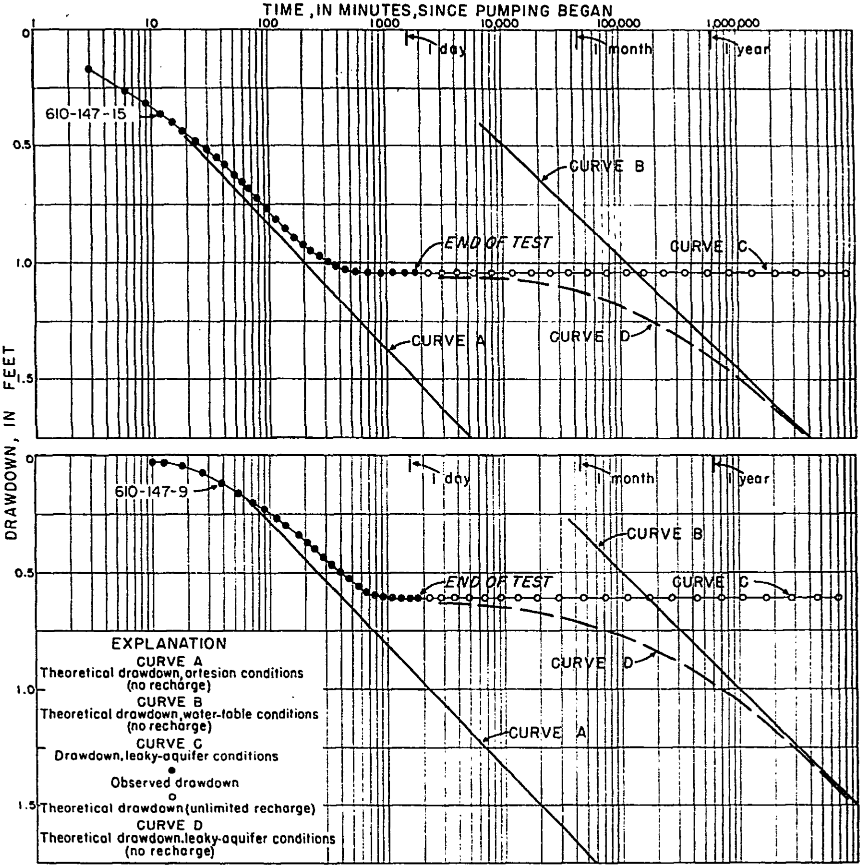

Figure 24. Graph showing drawdowns in wells 610-147-9 and 610-147-15 during aquifer test January 9-10, 1959, and theoretical drawdown for artesian, water-table, and leaky-aquifer conditions.

represent the theoretical drawdown in a leaky aquifer with no recharge and were computed from the coefficients of transmissibility and storage determined from the test.

The drawdown caused by longtime pumping is reflected at the water table, and is controlled by the coefficients of storage and transmissibility of the upper and lower zones, and the availability of replenishment.

Cities along the lower east coast of Florida have developed large water supplies by locating well fields near canals. These canals tap large water reserves in inland areas and are controlled near their outlets by salinity barriers (check dams). Water levels in the well fields are maintained by infiltration from the canals into the aquifer. Because of relatively high inland swamps draining toward the Gulf of Mexico and the hydraulic characteristics of the shallow aquifer, large water supplies can be obtained in northwestern Collier County by methods similar to those used in southeastern Florida.

In June 1958, a pumping test on wells in the shallow aquifer was made at the Collier County boundary, east of Immokalee (Klein, Litchtler, and Schroeder, written communication). Wells 625-116-1 and -2 were used as observation wells, and a large-diameter irrigation well just east of the county boundary was pumped at 1,300 gpm. Analyses of the data from the wells in Collier County indicated that the average coefficient of transmissibility was 910,000 gpd per foot, the average coefficient of storage was 0.00033 and the average coefficient of leakage was 0.000014 gpd per square foot per foot of vertical head.

The low permeability of the 15-foot layer of sandy clay that caps the aquifer in this area (fig. 7) is indicated by the small coefficient of leakage. The relatively low coefficient of storage indicates that artesian conditions prevail in the aquifer. The high transmissibility of the aquifer

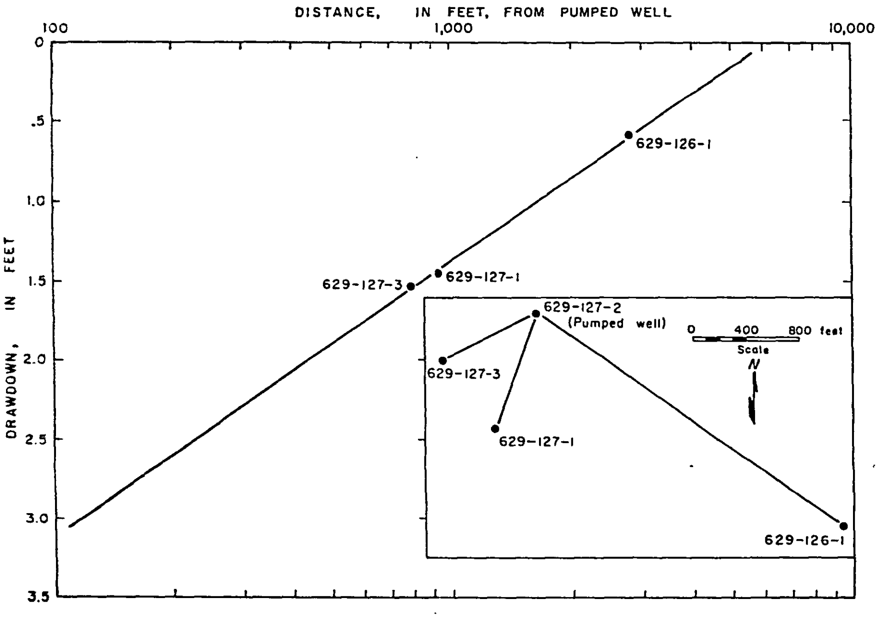

Figure 25. Sketch showing wells used in pumping test, April 8-10, 1960, and graph showing drawdown at the end of the 44-hour test.

and the large areal extent of the main limestone of the aquifer indicate that very large quantities of water probably are available east and southeast of Immokalee.

During April 8-10, 1960, a pumping test was made 5 miles northwest of Immokalee. Figure 25 is a sketch showing the locations of the observation wells and the pumped well used during the test and a graph of the drawdowns recorded at the end of the test.

Well 629-127-2 was pumped for 44 hours at 152 gpm. The water was discharged into an adjacent drainage ditch which conveyed it from the immediate area. Recording gages were installed on the three observation wells to obtain a complete record of the water-level fluctuations in the wells. The gages were in operation a week before the test to obtain background data on the natural fluctuations of the water level. These background records were used to adjust the recorded drawdowns obtained during the pumping period.

Figure 26 is a hydrograph of the uncorrected drawdown and recovery data from well 629-127-3. Pumping of an irrigation well 1.9 miles west of the test site started about 4 hours after the pumping test began; however, the effect of this pumping is not apparent on the drawdown curve of figure 26. The slight undulations on the hydrograph probably are caused by variations in atmospheric pressure and evapotranspiration.

The drawdown data were adjusted to correct for the fluctuations caused by factors other than pumping. Coefficients of transmissibility and storage computed from this test were 58,000 gpd per foot and 0.00024, respectively, at well 629-127-1 and 62,000 gpd per foot and 0.00026, respectively, at well 629-127-3. These values are considerably lower than those computed for the Naples area. The leakage coefficient at the Immokalee site was computed at 0.00073 gpd per square foot per foot of vertical head at well 629-127-1 and 0.00099 gpd per square foot per foot of vertical head at well 629-127-3. These values also are much lower than those computed for Naples and indicate more effective confining layers above the main producing zone of the aquifer in the area northwest of Immokalee. Therefore, in this area the main producing zone receives less recharge by downward leakage than the main producing zone in the Naples area. The low coefficients of storage in the area indicate that the main producing zone is under artesian conditions.

QUALITY OF WATER

Aquifers in Collier County contain very large supplies of ground water, but in many places the water is unsuitable for drinking as the result of the high concentrations of undesirable minerals.

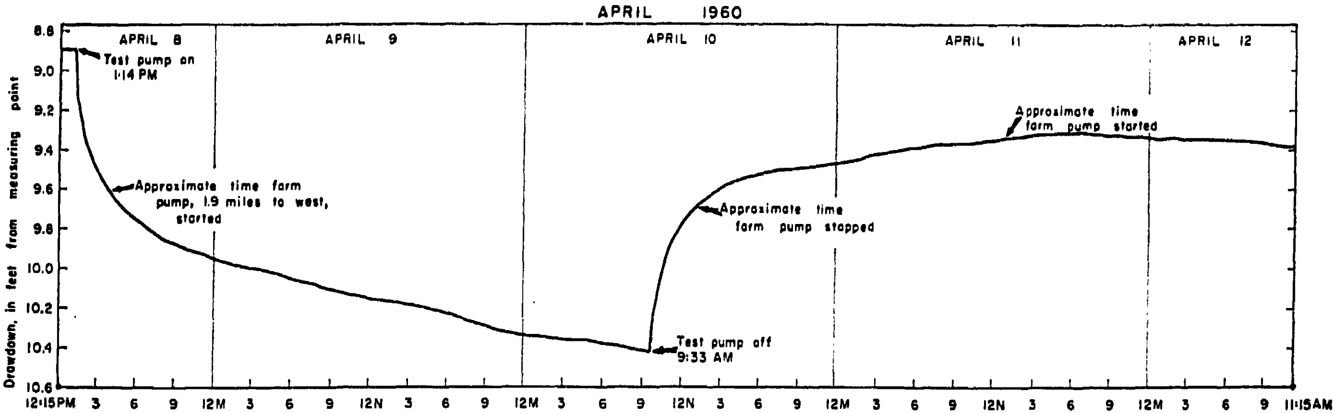

Figure 26. Drawdown and recovery of water level in well 629-127-3 showing effects of pumping test, April 8-10, 1960.

The amount and character of the chemical constituents in ground water are controlled for the most part by the composition of the rocks through which the water passes; the temperature and pressure of the water and the duration of contact with the rocks; and the amount of material in solution or suspension. However, salt-water encroachment can cause normally fresh ground water to become highly mineralized under certain conditions.

Most drinking-water supplies in the United States conform to standards established by the U.S. Public Health Service. Below are some of the more common constituents and the maximum limits recommended by the U.S. Public Health Service (1961).

Chloride	250 ppm
Dissolved solids, desirable	500 ppm
Dissolved solids, permitted	1,000 ppm
Iron, manganese, together	0.3 ppm

Iron in quantities greater than that listed above is objectionable because it imparts a disagreeable taste and it quickly discolors objects with which it comes into contact. Its presence in ground water is unpredictable as to both depth and location. Fortunately, iron can be removed easily by aeration and filtration.

The amount of dissolved solids indicates the degree of mineralization of ground water.

The words "salt water" as used in this report identify ground water containing large amounts of chloride. About 91 percent of the dissolved-solids content of sea water consists of chloride salts. Thus, determinations of the chloride content of ground water are generally a reliable indication of the extent to which normally fresh ground water has become contaminated with sea water.

Normal sea water has a chloride content of about 19,000 ppm. Some individuals can taste the salt in water having a chloride content of 500 ppm. If a salty taste is not noticed at this concentration, the water may have a "flat" taste. Most persons can detect salt in ground water having a chloride content of 750 ppm or more.

Hardness is a measure of the calcium and magnesium content of ground water and is customarily expressed as the equivalent of calcium carbonate. Water having a hardness of less than 60 ppm is rated as soft; of 60 to 120 ppm, as moderately hard; and of 120 to 200 ppm, as hard. Water having a hardness of more than 200 ppm ordinarily requires softening for most uses.

The pH indicates the acidity or alkalinity of the ground water. The pH scale ranges from 0 to 14, with 7 indicating neutral water. Values less than 7 denote increasing acidity, and those greater than 7 denote increasing alkalinity.

FLORIDAN AQUIFER

Except in the town of Everglades and vicinity, the Floridan aquifer in Collier County yields water undesirable for drinking. The chloride content of the water generally is more than 1,000 ppm. Table 2 gives the results of the chemical analysis of water samples from certain wells in the Floridan aquifer.

The high mineralization in the water from the Floridan aquifer is due to either, or to a combination, of the following factors: (1) Sea water that was trapped in the sediments at the time they were deposited on the floor of an ancient sea (connate or residual sea water); (2) sea water that entered the aquifer during interglacial stages of the Pleistocene Epoch, when most of Florida was covered by shallow seas; and (3) a recent salt-water encroachment of the Floridan aquifer. The aquifer has undergone flushing action, but considerable contaminants remain.

In the vicinity of the town of Everglades, the Floridan aquifer yields relatively fresh water. In 1960, the chloride content of the water from individual wells in the municipal well field ranged from 190 to 360 ppm, and the water from well 550-123-1, south of the field, contained 240 ppm. Following is a tabulation of the changes of chloride content of the water from three wells in Everglades (fig. 10, 11):

Date	Chloride content, in ppm		
	Well 550-123-1	Well 551-123-2	Well 551-123-3
Feb. 1949	-----	278	185
Aug. 1949	98	-----	-----
Apr. 1950	-----	282	186
Jan. 1951	-----	287	186
Sept. 1951	-----	285	192
Mar. 1952	99	295	195
Oct. 1952	95	-----	190
Aug. 1954	106	255	-----
Oct. 1959	240	350	-----
May 1960	-----	360	190

The relatively low chloride content of water from wells 550-123-1 and 551-123-3 indicates some of the water moving southward from the

TABLE 2. Chemical Analyses of Water from Selected Wells that Penetrate the Floridan Aquifer in Collier County
(All results are in parts per million except those for color, pH, and specific conductance)

Well number	Date sample collected	Depth (feet)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	Color	pH	Specific conductance (microhmos at 25°C)
550-123-1........	10- 5-35	503	9.5	0.06	20	26	229	....	366	197	106	....	800	155	....	....	....
551-123-6........	3-11-57	536	15	.01	63	76	567	20	276	212	900	0.7	2,070	470	0	7.7	3,480
554-118-3........	12- 3-56	446	17	.02	99	117	960	25	236	455	1,490	1.0	3,400	728	15	8.0	5,360
554-143-1........	4-28-59	402	12	.54	288	167	1,600	200	196	488	2,800	.5	6,010	504	0	7.9	8,910
556-128-1........	4- 8-59	302	19	1.6	54	44	245	1.5	316	96	310	1.1	947	316	0	8.0	1,660
609-115-1........	9-23-59	485	33	.22	68	93	725	37	414	372	985	1.2	2,570	552	2	7.4	4,320
630-126-1........	12-15-41	566	....	.01	108	99	433	....	180	302	820	....	....	677	5	....	....

recharge area (in central Florida) remains relatively uncontaminated throughout its course to the south end of the peninsula. This fresh-water zone may constitute only a very thin section of permeable limestone in the uppermost part of the aquifer.

The increase in chloride content in recent years may be due to the following: (1) Upward leakage of inferior water, under high pressure, through open well bores to zones of fresh water under lower pressure, during a long period of continued water use; (2) upward movement of inferior water resulting from large drawdowns caused by heavy industrial use of water from deep wells in an area about 2,000 feet north of the well field.

SHALLOW AQUIFER

Ground-water samples were collected at different depths during the drilling of test wells and from certain wells. The chemical analyses of the ground water in the shallow aquifer in Collier County are shown in table 3. Ground-water samples for the analysis of chloride content were taken from every well inventoried during the investigation. Water from the aquifer is generally potable and could be used without treatment; however, it is hard and softeners are used in many systems.

In areas southeast of Naples and near Copeland, residents use commercially bottled water for their drinking supply. This does not mean that individual water supplies cannot be treated to supply potable ground water, but rather the expense of treatment may exceed the cost of bottled water. Ground-water supplies are still used for purposes other than drinking.

Domestic ground-water supplies in the Immokalee area are obtained generally from permeable beds in the Hawthorn Formation. This is probably due to the fact that the water from the Hawthorn beds has less undesirable constituents such as iron and hardness. However, many wells penetrating shallow sand or shelly material in the aquifer yield ground water of good quality which does not require treatment.

The data from table 3 and the analyses reported by Klein (1954, p. 38-40) show that ground water from the shallow aquifer in the Naples area is relatively high in mineral content except along and immediately east of the coastal area. Figure 27 shows the approximate chloride content of water samples from wells and surface-water sampling points in northwestern Collier County. The complete results from the chloride sampling are shown in table 4.

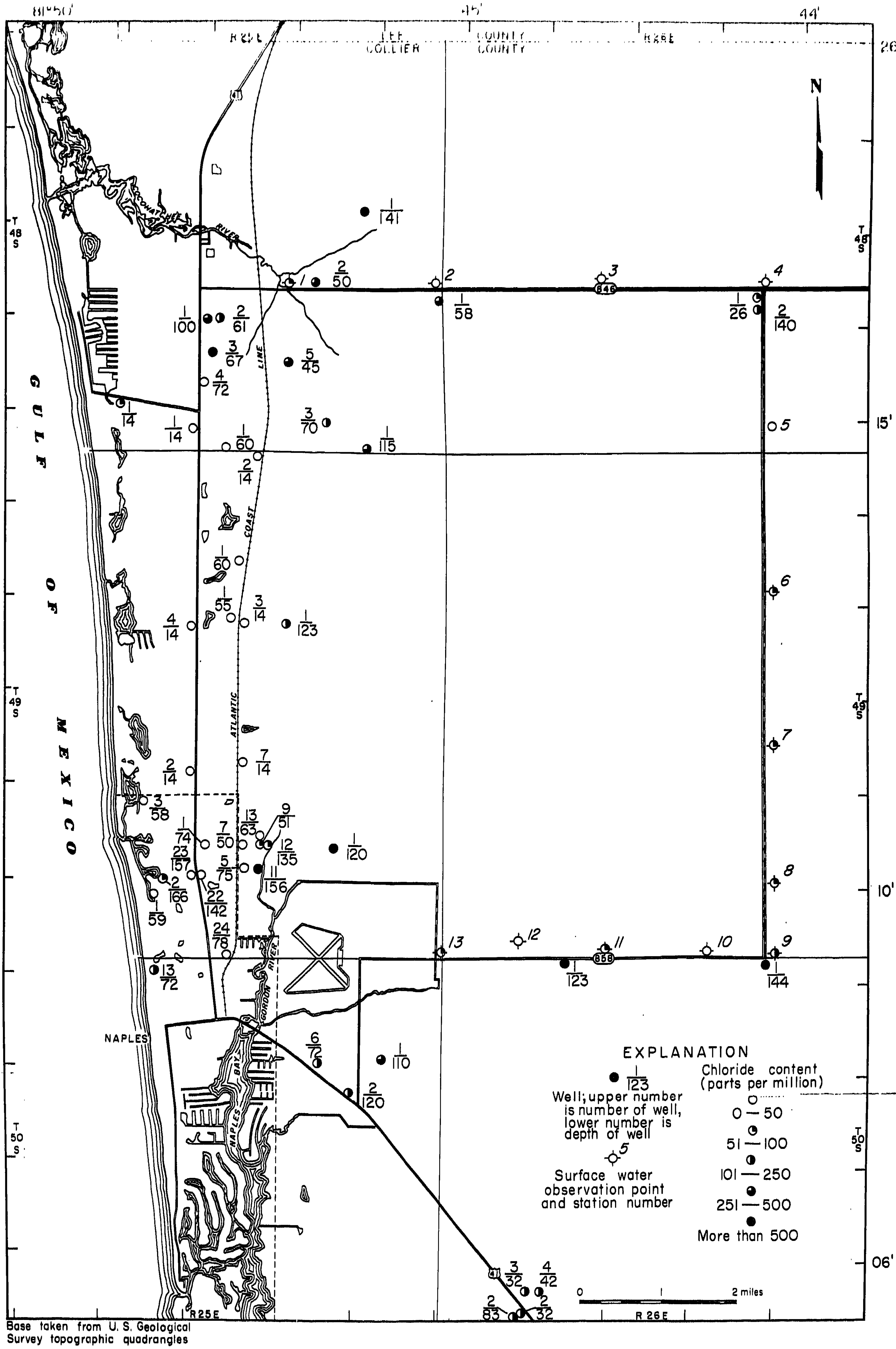

Figure 27. Northwestern Collier County showing chloride content of water from selected wells and surface-water observation points.

TABLE 3. Chemical Analyses of Water from Selected Wells that Penetrate the Shallow Aquifer in Collier County
(Results in parts per million except those for color, pH, and specific conductance)

Well number	Depth of sample below land surface (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
559-120-1	44	8-14-59	5.4	0.01	56	5.0	17	0.5	198	10	25	0.2	0.3	220	160	378	8.1	15
606-143-1	142	8-13-59	20	.02	140	15	75	3.0	374	11	180	.0	1.4	781	411	1,140	7.5	8
608-146-4	90	1-16-59	13	2.1	130	8.6	24	.0	386	4.0	48	.1	.0	492	360	747	8.0	0
608-147-22	40	1-11-52	....	....	....	....	49*	....	314	4.5	62	....	1.0	....	244	644	7.7	....
	70	1-14-52	11.0	.10	69	3	8.8	.6	218	4.5	15	.1	.5	241	184	368	7.8	45
609-115-1	28	9- 2-59	10	1.9	144	2.1	16	.3	466	.2	25	.3	.8	478	368	708	7.0	8
609-120-1	90	8-20-59	11	.00	54	7.7	12	.4	210	.0	15	.2	.1	207	166	364	7.5	5
609-141-1	41	7-16-58	17	.09	166	32	162	5.6	438	77	325	.2	1.5	1,000	731	1,720	7.3	20
609-143-1	44	7-17-58	12	.01	166	15	97	2.6	464	7.5	205	.3	.9	735	572	1,270	7.3	23
610-146-1	28	7-28-58	....	....	119	6.6	35	.7	....	10	68	....	....	....	324	753	....	....
	52	7-28-58	....	....	146	13	102	2.7	....	43	202	....	....	....	418	1,280	....	....
	96	7-28-58	....	....	214	36	315	4.4	....	178	655	....	....	....	682	2,790	....	....
610-147-13	63	3-19-58	11.0	.27	72	.1	9.0	.9	220	1	18	.1	.7	225	180	394	7.6	28
612-146-1	85	7-30-58	....	.03	103	8.0	46	2.3	....	10	92	....	....	....	290	766	....	....
612-148-2	75	1-22-58	....	.01	68	9	....	....	252	3	15	.5	....	229	208	....	7.5	18
616-131-1	110	8-10-59	23	.01	70	15	40	4.6	308	14	41	.4	.2	365	236	609	8.1	15
616-141-2	46	7-28-59	10	2.3	170	6.3	26	.2	520	4.4	46	.0	.3	599	474	911	7.1	68
	240	8- 3-59	20	.76	196	89	631	21	236	440	1,150	.1	1.0	2,660	1,517	4,530	....	5
616-145-1	58	7-20-58	24	1.0	134	29	162	7.2	418	122	275	.3	.1	960	565	1,640	7.3	17
621-135-2	92	7-24-59	25	.78	72	16	39	4.6	336	11	32	.0	.6	370	246	625	7.6	2
625-116-1	54	3-10-55	17	.36	114	16	50	2.6	451	.1	69	.3	2.0	534	353	876	7.3	75
625-124-1	282	5-16-58	30	.02	98	22	18	1.9	402	4.0	38	.2	.1	407	338	702	7.7	25

* Sodium, potassium as sodium (Na).

TABLE 4. Chloride Content, in Parts Per Million, from Selected Wells in Northwestern Collier County
(Depth of sample given in feet below land surface)

Well number	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride
605-143-2	32	1- 2-50	130	...	...	...	...	...	...	...	...	...
605-143-3	32	1- 2-50	174	...	...	...	...	...	...	...	...	...
605-143-4	42	1- 2-50	134	...	...	...	...	...	...	...	...	...
605-144-2	83	1- 2-50	172	...	...	...	...	...	...	...	...	...
607-145-1	25 46	11-17-58 11-17-58	83 92	66	11-17-58	153	92	11-17-58	304	110	11-18-58	472
607-146-2	120	1-16-59	119	...	...	...	...	...	...	...	...	...
608-146-6	72	1-16-50	127	...	...	...	...	...	...	...	...	...
609-141-1	41	7-14-58	325	64	7-14-58	445	144	7-16-58	885	...	...	...
609-143-1	44	7-17-58	205	70	7-17-58	580	123	7-17-58	1,750	...	7-17-58	1,250
609-147-24	78	5- 6-54	16	...	...	...	...	...	...	...	...	...
609-148-12	72	12-31-52 5-15-53 5- 6-54 2-28-55	168 181 168 169	... ...	3- 7-56 2-27-57 3-20-58	165 182 190	... ...	3-13-61 4-28-61 5- 2-61	158 156 170	... ...	5- 8-61 6- 6-61 7-14-61	186 166 162
610-146-1	28 52	7-28-58 7-28-58	68 202	61	7-28-58	242	96	7-28-58	655	120	7-29-58	875
610-147-5	75	2-28-55 3- 7-56 8- 5-58 5- 4-54	20 15 17 20	... ...	6- 8-59 12- 3-59 1- 6-60 3-29-60	26 16 15 24	... ...	8-15-60 3-13-61 4-28-61 5-19-61	34 22 34 36	... ...	6-16-61 7-14-61 8-11-61	30 28 30
610-147-6	32	3-14-56	15	74	3-14-56	13	...	...	...	...	...	...
610-147-7	50	7-29-56	18	...	...	...	...	...	...	...	...	...
610-147-9	51	3-25-58	59	...	1-19-59	59	...	...	...	...	...	...
610-147-11	20 44 60	8-20-57 8-20-57 8-20-57	1,430 22 43	90 110 141	8-20-57 8-20-57 8-20-57	24 18 385	156	8-21-57 5- 4-59 6- 8-59	965 352 340	... ...	12- 3-59 1- 6-60 3-29-60	615 470 1,020

610-147-12	17	8-21-57	29	61	8-21-57	73	100	8-22-57	69	....	3-26-58	72
	40	8-21-57	23	80	8-22-57	55	133	8-22-57	67			
610-147-13	16	3-19-58	18	24	3-19-58	19	63	3-19-58	18	....	....	....
610-147-22	142	3-29-60	20	....	4-26-61	50	....	5-18-61	38	....	7-14-61	34
	....	3-15-61	24	....	5- 2-61	26	....	6-16-61	32			
610-147-23	64	3- 7-52	11	157	3-14-56	28	....	3-29-60	14	....	5-19-61	46
	84	3- 7-52	8	....	3-20-58	25	....	8-15-61	24	....	6-16-61	39
	120	3-14-56	18	....	2-13-59	21	....	3-13-61	14	....	7-14-61	34
	130	3-14-56	17	....	3- 4-59	17	....	4-26-61	58	....	8-11-61	34
	140	3-14-56	16	....	12- 3-59	21						
610-148-1	33	8-16-56	22	59	8-16-56	25	....	....	....	....	....	....
610-148-2	60	8-16-56	18	166	5- 4-59	79	166	3-13-61	34	166	5-19-61	48
	123	3-20-58	16	166	6- 8-59	60	166	4-26-61	40	166	6-16-61	40
	145	3-20-58	32	166	3-20-60	44	166	5- 2-61	42	166	7-14-61	38
	166	3-20-58	85	166	8-15-60	68						
610-148-3	35	8-17-56	14	58	8-17-56	13	....	....	....	....	....	....
611-147-7	14	11-12-59	34	....	....	....	....	....	....	....	....	....
611-148-2	14	11-12-59	30	....	....	....	....	....	....	....	....	....
612-146-1	28	7-29-58	67	72	7-30-58	78	100	7-30-58	97	123	7-30-58	151
	48	7-29-58	90									
612-147-1	55	11-13-58	28	....	....	....	....	....	....	....	....	....
612-148-4	14	11-11-59	24	....	....	....	....	....	....	....	....	....
613-147-1	60	11-13-58	34	....	....	....	....	....	....	....	....	....
614-146-1	20	11-18-58	70	61	11-18-58	176	82	11-18-58	260	103	11-19-58	260
614-147-1	60	11-13-58	38	....	....	....	....	....	....	....	....	....
614-147-2	14	11-11-59	19	....	....	....	....	....	....	....	....	....
614-148-1	14	11-11-59	18	....	....	....	....	....	....	....	....	....
615-146-3	70	3-29-60	190	....	....	....	....	....	....	....	....	....
615-147-1	100	3-28-60	314	....	....	....	....	....	....	....	....	....
615-147-2	61	3-28-60	200	....	....	....	....	....	....	....	....	....
615-147-3	67	3-28-60	530	....	....	....	....	....	....	....	....	....

TABLE 4.—(Continued)

Well number	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride	Depth (feet)	Date	Chloride
015-147-4	72	3-20-60	10	....	....	....	....	....	....	....	....	....
015-147-5	45	3-20-60	200	....	....	....	....	....	....	....	....	....
015-148-1	14	11-11-59	51	....	....	....	....	....	....	....	....	....
016-141-1	26	7-18-58	87	....	....	....	....	....	....	....	....	....
016-141-2	25 46	7-20-59 7-20-59	28 46	99	7-20-59	72	140	7-20-59	146	240	8-3-59	1,150
016-145-1	58	7-20-58	275	....	....	....	....	....	....	....	....	....
016-146-2	50	3-23-60	200	....	....	....	....	....	....	....	....	....
017-146-1	20 44	11-21-58 11-24-58	45 51	80 82	12-21-58 12-21-58	644 666	109	12-21-58	2,400	141	12-21-58	2,100

Chemical analyses of water samples from wells along the coastal ridge indicate the presence of a hard limestone water that is suitable, for most uses, with or without chemical treatment. As ground water must seep through a considerable thickness of sand and rock to reach the producing zones in the aquifer, it is generally free of harmful bacteria and suspended material. However, it dissolves some of the rocks through which it moves and this action is aided by the presence of carbon dioxide which is absorbed by rainfall from the atmosphere and from organic material in the soil. Calcium and bicarbonate, from the solution on calcium carbonate in the limestone, are the principal ions in ground water in most of the coastal ridge area.

The high mineral content of the ground water east of the coastal strip is due primarily to constituents derived from sea water, in addition to the calcium and bicarbonate derived from the limestone in the aquifer. The chloride content of the water ranges from less than 100 ppm to more than 2,000 ppm and may come from three possible sources: (1) Direct movement inland from the sea and along tidal reaches of streams; (2) residual sea water left in the sediments at the time of deposition or during former invasions of the sea; and (3) upward movement of salty water from deeper artesian aquifers.

SALT-WATER CONTAMINATION

Under normal conditions, coastal aquifers discharge fresh ground water into the ocean at or seaward of the coastline. Large withdrawals of ground water from these aquifers can cause the seaward movement to decrease or reverse, thereby causing salt water to enter the aquifer and move inland to contaminate the wells. This phenomenon is called salt-water intrusion or salt-water encroachment.

Considerable study has been made of the phenomenon. The Ghyben-Herzberg theory assumed (1) that an interface exists between fresh and salt water due to the difference in their densities, (2) no flow is present in either the fresh- or salt-water zone, and (3) the water table slopes seaward. From these assumptions the following equation was developed:

$$Z = \frac{h_f}{Ps - Pf}$$

where Z = depth to salt water, in feet below mean sea level; h_f = height of fresh water, in feet above mean sea level; and Ps - Pf = the difference in densities of salt water and fresh water. If standard figures are inserted for the two densities, the equation becomes:

$$Z = 40\, h_f$$

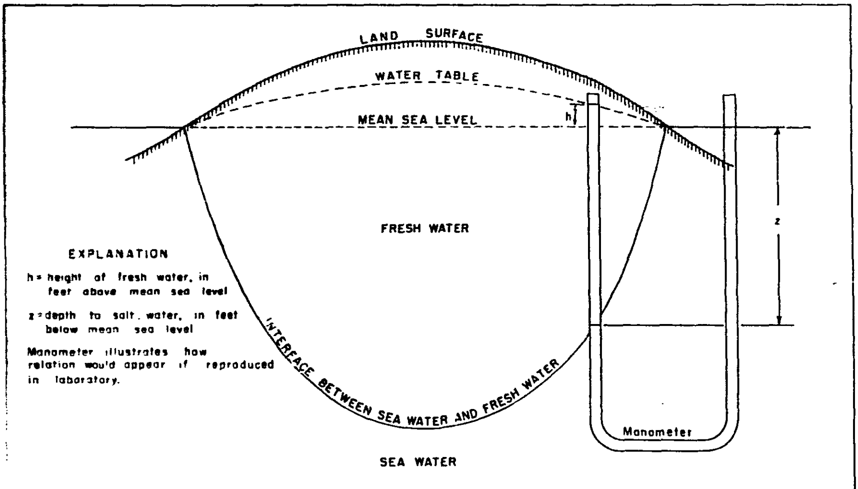

Figure 28. Idealized sketch of fresh-water and salt-water distribution in an unconfined coastal aquifer to illustrate the Ghyben-Herzberg relation.

According to this principle, for every foot of fresh ground-water head above mean sea level in coastal aquifers there will be 40 feet of fresh water below mean sea level (fig. 28).

However, this principle assumes that the fresh water is static and for this reason gives only approximately the position of the interface. An exact equation for determining the shape and position of the interface with a known rate of discharge of fresh water under one set of boundary conditions (fig. 29) has been devised by Glover (1959) for an analogous problem of free-surface gravity flow:

$$y^2 - \frac{2Q}{\gamma k} x - \frac{Q^2}{\gamma^2 k^2} = 0$$

x = distance measured horizontally landward from shoreline (feet).
y = distance measured vertically downward from sea level (feet).
Q = fresh-water flow per unit length of shoreline (square feet per second).
k = permeability of the strata carrying the fresh-water flow (feet per second).
γ = excess of the specific gravity of sea water over fresh water (dimensionless).

Figure 29 is a comparison of Glover's interface with that of Ghyben-Herzberg. Because the interface is in a hydrodynamic rather than a hydrostatic balance, it is farther seaward.

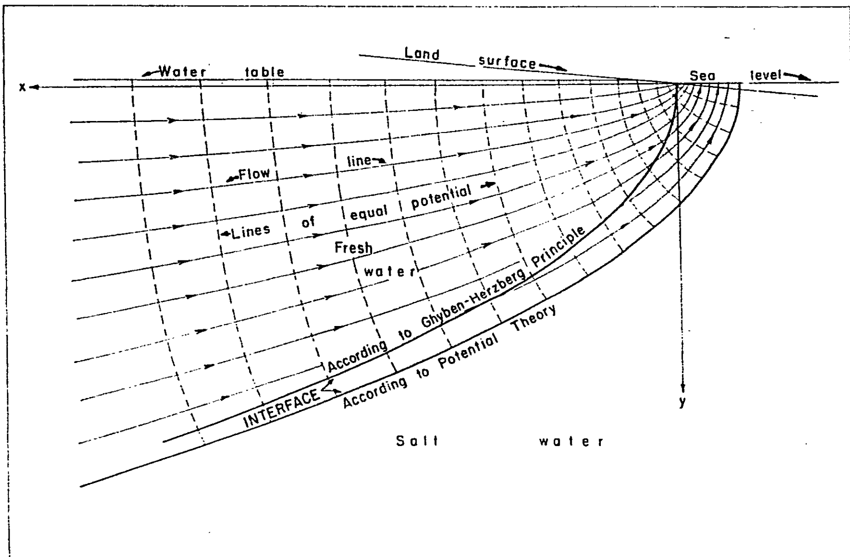

Figure 29. Sketch showing the fresh-water—salt-water interface according to the potential theory and the Ghyben-Herzberg principle.

Kohout (1960) showed, from field observations made at Miami, that the actual salt-water interface is farther seaward than is indicated by either principle in figure 29, not only because of seaward flow of the fresh ground water, but also because of the cyclic flow within the salt-water front. Cooper (1959) expressed the hypothesis of salt-water cyclic flow and referred to the salt-water—fresh-water contact not as an interface but as a zone of diffusion wherein salt water moves inland along the aquifer floor, moves upward into the zone of diffusion, and then returns to the sea.

From the above brief and general history of salt-water encroachment studies, it can be seen that the Ghyben-Herzberg relation will give the maximum extent that the salt-water front will move inland under a specific set of hydrologic conditions.

In Collier County, contamination of the ground water by salt-water encroachment has occurred chiefly in coastal areas adjacent to major streams and drainage canals that flow to the ocean. These waterways enhance the possibility of sea-water encroachment in two ways: (1) They lower ground-water levels, thereby reducing the fresh-water head opposing the inland movement of sea water; and (2) they provide access for sea water to move inland during dry periods.

RECENT AND RESIDUAL ENCROACHMENT

The Naples area is vulnerable to two types of salt-water contamination: (1) Sea water can move laterally inland directly from the Gulf of Mexico, Naples Bay, and the lower part of the Gordon River that is affected by tides; and (2) chemical analyses (table 3) indicate that salty water at depth east of Naples is probably residual sea water trapped during the deposition of the sediments or that it entered the sediments when the sea covered the Naples area during Pleistocene time.

Examples of both types of encroachment are shown by data collected during the drilling of well 610-147-11, east of the well-field extension and near the upper tidal reach of the Gordon River (fig. 14, 15). Chloride analyses of water samples taken from test well 610-147-11, as shown in figure 14, indicate that salt water from the Gordon River had infiltrated downward to a depth of about 25 feet below msl in the uppermost limestone bed of the aquifer. The salt-water contamination from the river was reported to have caused the loss of several rows of litchi trees near the river in the Caribbean Botanical Gardens (fig. 21).

Litholigic and chloride data from well 610-147-11 (fig. 14, sec. E-E′) show that the uppermost layer of limestone is underlain by 10 feet of marl which separates shallow water of high chloride content from deeper water of low chloride content. The difference in the quality of the water may be caused by either, or a combination, of the following factors: (1) The marl layer is sufficiently impermeable to form an effective seal between the upper and lower limestones; (2) well 610-147-11 is near the Gordon River, a discharge area, and the pressure head in the lower part of the aquifer is greater than it is in the shallow part, thus preventing the downward movement of salty water.

The high chloride content below 130 feet in well 610-147-11 indicates that salt water has moved inland beneath the Gordon River, presumably as a result of local lowering of the ground-water levels in the adjacent drainage area. The fluctuation of chloride content of water samples collected periodically from a depth of 156 feet below the land surface reflects the movement of the salt front deep in the aquifer in response to changes in ground-water levels (table 3). The low chloride content of the water at a depth of 135 feet in well 610-147-12 (table 4) indicates that in 1958 the deep salt wedge had not reached that well.

The extent of the salt-water encroachment at depth in the Cocohatchee River basin has not been determined because of the lack of deep observation wells near the lower reaches of the river. However, the presence of water containing 664 ppm of chloride at a depth of 60 feet and 2,400 ppm of chloride at a depth of 103 feet below the land surface in well 617-146-1 suggests the possibility of recent encroachment beneath canals that extend inland from the river. A determination of the origin of this high chloride content can be made by periodic sampling of the well and complete chemical analysis of the water.

Extensive encroachment from the sea has not occurred west of the well field, although water levels in the area are lowered by pumping in the well field and numerous canals extend inland from the gulf. However, inland movement of salt water is indicated by a fluctuation of chloride content of samples, taken periodically from March 1958 to July 1961, that ranged between 34 and 85 ppm at a depth of 166 feet in well 610-148-2.

Major encroachment probably is being retarded by the high ground-water levels (fig. 16, 18, 19). The hydrographs of wells 610-148-2 and 610-147-11 correlate closely; accordingly, the long-term hydrograph of well 610-147-11 (fig. 16) suggests that the water levels in well 610-148-2 probably averaged between 4 and 5 feet above sea level during the period 1958 through September 1959, a period of heavy rainfall and above normal ground-water levels. The head of fresh ground water above sea level would indicate that fresh water extends to the base of the aquifer at this point. Encroachment may be retarded also by beds of marl in the aquifer, which probably extend seaward under the gulf.

Although the encroachment of salt water toward the well field has been slight, the salt-water front near well 610-148-2 indicates that long-term lowering of ground-water levels caused by extension of the canal system or increased pumping during a long dry period might cause encroachment that would endanger the well field.

Because the chloride content of the water is an indicator of changes in mineral content, the data in figure 27 show that highly mineralized water occurs north of Naples near the Cocohatchee River and east of the coastal ridge as much as 10 miles inland from the coast. Comparison of water-level contour maps (fig. 18, 19) and the topography of the area indicates that ground-water levels east of the ridge range from 5 to 15 feet above sea level. The lines of equal chloride content in figures 13, 14, and 15 show that the chloride content of the ground water increases gradually with depth in the eastern part of the area, but rather sharply in material of low permeability near the bottom of the aquifer. The high water levels and the inland location of the Big Cypress area indicate that the high mineral content of the ground water in that area is not caused by the recent encroachment of sea water. The high mineral content of ground water in materials of low permeability in the lower part of the aquifer suggests that the source of contamination is connate salt water or upward leakage from the deeper artesian aquifer.

Ground water in the shallow aquifer along the southwestern and southern coast of Collier County is highly mineralized. The water levels in the area are not high enough to impede salt-water intrusion from the gulf.

Poor flushing of the ground water within the shallow aquifer probably accounts for the high mineralization of the ground water in the interior of the county. The lack of flushing is caused partly by dense beds of relatively impermeable limestones at shallow depths retarding the infiltration of rainfall. Poor flushing because of retarded rainfall infiltration is exhibited east of Naples where ground water from shallow depths has a high chloride content and surface water has a low chloride content. Also in this area, the water-table gradient is almost flat except adjacent to tidal streams and Naples Bay. The data obtained from wells 616-141-1 and 616-141-2 indicate drainage in the inland areas can improve the quality of the ground water in the shallow aquifer. Well 616-141-1 was drilled July 18, 1958 near a drainage canal which had been completed prior to that date. At a depth of 26 feet the chloride content of water from the well was 87 ppm. Well 616-141-2 was drilled July 29, 1959 about 100 yards east and the same distance from the canal. At a depth of 26 feet the chloride content of water from the well was 38 ppm, indicating that the construction of the canal had steepened the water-table gradient and caused considerable flushing during the 1-year period.

UPWARD LEAKAGE

Test-drilling information indicates that head differentials large enough to cause upward leakage do not exist in the shallow aquifer in the county except in the coastal ridge area in Naples. Moreover, in the central part of the county, the chloride content of the ground water is relatively low throughout the entire thickness of the aquifer, which indicates that contamination would not take place even if upward leakage did exist.

Data pertaining to the possibility of upward leakage of salt water from deep water-bearing strata were collected during the drilling of well 616-141-2 in the northwestern part and well 609-115-1 in the central part of the county. Well 616-141-2 was drilled to a depth of 300 feet in January 1959. The analyses of water samples collected at 46 feet and 240 feet below the land surface are given in table 3. Materials of very low permeability were penetrated between the base of the shallow aquifer (about 130 feet below the land surface) and a permeable bed at 230 to 240 feet below the land surface, from which the lower sample was taken.

Water levels measured as drilling progressed in the section of low permeability ranged from 5.4 to 14.8 feet below the land surface. Water levels in both the shallow aquifer and the lower permeable zone were less than 1 foot below the land surface. Water-level measurements in all zones were made under the same conditions. The extremely high mineral content of the lower sample from well 616-141-2 indicates a source for contamination of the shallow aquifer from below but the head differential between the two levels suggests that no upward flow was occurring.

Well 609-115-1 was drilled to a total depth of 700 feet in September 1959. When the well was 28 feet deep, the water level was 0.41 foot below the land surface and the chloride content was 25 ppm. When the well was 485 feet deep, the water level was 32 feet above the land surface and the chloride content was 985 ppm. This indicates that upward leakage can take place from the lower, more mineralized Floridan aquifer into the overlying shallow aquifer if the confining beds separating the two aquifers are thin. Leaky casing penetrating the Floridan aquifer also can permit upward leakage.

SUMMARY

The Floridan aquifer underlies all of Collier County and wells penetrating the aquifer flow except in the area of high dunes on Marco Island. However, except in the town of Everglades and vicinity, the ground water from the Floridan aquifer is highly mineralized and unsuitable for drinking. The Tampa Formation of late Miocene Age is the chief source of water for the Floridan aquifer in Collier County. The top of the aquifer is about 400 feet below the land surface.

The shallow aquifer is the principal source of fresh ground water in Collier County. It comprises the Pamlico Sand, Anastasia Formation, and permeable limestones of the Tamiami Formation. Marl beds of varying thicknesses in the upper portion of the aquifer restrict the vertical permeability in certain parts of the county. The shallow aquifer extends from the land surface to about 130 feet below in the northwestern part of Collier County, to about 90 feet in the southern part, and to about 60 feet in the central and northeastern parts. The aquifer thins to a featheredge along the Dade-Broward County boundary.

Ground water in the shallow aquifer in the Naples area is of good quality, containing about 250 ppm of dissolved solids. This is due in part to the high fresh-water head adjacent to the coast and the resultant flushing of ground water.

The ground water of the shallow aquifer in the same coastal communities in Collier County is unsuitable for drinking because of contamination by salt water. Ground water is available in the interior of the county but it is highly mineralized owing to poor flushing of the aquifer. High concentrations of chloride in the area east and northeast of Naples are due to poor flushing of the aquifer and to residual salt-water contamination.

The results of aquifer tests indicate that the shallow aquifer will produce large quantities of water with moderate drawdowns in water levels, especially in areas where surface water can recharge the aquifer. The topography, drainage pattern, and hydraulic characteristics of the shallow aquifer in northwestern Collier County indicate that supplies equal to present water needs can be developed along the eastern edge of the coastal ridge and the adjacent drainageway. Additional supplies can be developed from the same area by the use of infiltration in conjunction with the drainage of inland areas. Present and future well fields may be safeguarded from salt-control dams near the gulf in major streams.

A continuing appraisal of the quantity and quality of water in storage in northwestern Collier County will be needed for the maximum development of the area. The immediate need is for water-level and streamflow data for use in the design of a comprehensive water-control system.

Studies of flood-control and drainage systems in southeastern Florida have shown that, with proper location and operation of salinity controls and carefully planned overall drainage systems, large inland areas can be developed for urban or agricultural use without depletion of essential ground-water resources.

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WELL LOGS

WELL 554-143-1

Material	Depth, in feet below land surface
Beach sand, shell, and fill material	0 - 13
Sand, quartz, fine, shelly, last 3 feet containing greenish marl	13 - 33
Sand, quartz, fine; dark green marl, less shell than above	33 - 44
Limestone, gray to white, hard, shelly	44 - 58
Limestone, tan to white, ranging from soft to very soft; light tan-green marl streaks at 128 feet and 153 feet	58 - 193
Sand, quartz, fine to coarse, cemented with $CaCO_3$, quartz grains are well rounded; greenish marl	193 - 273
Clay, green, marly, sandy, some shell from above; clay becomes harder at 330 feet	273 - 343
Limestone, yellow, crystalline; phosphatic material; some clay	343 - 353
Limestone, white, shelly, phosphatic, marly; becomes softer at 373 feet	353 - 404

WELL 556-128-1

Material	Depth, in feet below land surface
Sand, quartz, marly	0 - 12
Limestone, gray to white, shelly, *Pecten* shells	12 - 162
Limestone, buff to gray; coarse, quartz sand; shell; marl	162 - 252
Limestone, buff to gray, shelly; green clay	252 - 262
Clay, marly, sandy, bluish gray, shell	262 - 292
Clay, dense, tight dark green, becoming sandy at 325 feet, phosphatic at 348 feet, and hard zone at 365	292 - 376
Limestone, light gray to dirty white, marly, phosphatic	376 - 392

Note: Well was drilled with rotary drill rig. Samples were washed free of drilling mud, thereby any sand or silt-size particles were removed.

WELL 559-120-1

Material	Depth, in feet below land surface
Sand, brown, organic, and limestone fill rock	0 - 10
Limestone, light tan to white, soft, permeable	10 - 44
Sand, quartz, fine to medium, brown; white limestone	44 - 50
Sand, quartz, fine to medium, brown	50 - 150
Sand, quartz, fine to medium, brown; green clay	105 - 126

WELL 606-143-1

Material	Depth, in feet below land surface
Limestone, light gray to buff, very hard, sandy, marly	0 - 20
Shell, hash, cream to buff, marly, soft	20 - 30
Limestone, light tan, shelly, phosphatic; permeable	30 - 60
Limestone, light gray, sandy, some shell, soft; hard zone at 100 feet	60 - 127
Limestone, light cream to dark gray, soft, sandy shelly	127 - 142

WELL 607-145-1

Material	Depth, in feet below land surface
Sand, quartz, surface	0 - 9
Marl, dark, hard	9 - 13
Sand, quartz, fine to medium, marly, very shelly	13 - 25
Limestone, white to dark gray, shelly sandy, permeable	25 - 92
Sand, quartz, very fine, gray to tan	92 - 115
Sand, quartz, very fine to medium, tan to green, phosphatic	115 - 141

WELL 609-115-1

Material	Depth, in feet below land surface
Sand, black, organic, marly, shelly	0 - 24
Sand, quartz, fine, shelly; small amount of limestone	24 - 56
Sand, quartz, buff to pink, phosphatic; fossiliferous limestone	56 - 66
Sand, quartz, very fine, shelly, phosphatic	66 - 76
Sand, quartz, fine to coarse, white to light gray phosphatic	76 - 112
Sand, quartz, very fine, phosphatic; green clay	112 - 132
Clay, green, tight; quartz sand, decreasing in lower part	132 - 158
Clay, gray-green, hard; very coarse, phosphatic, quartz sand; greenish material at 200 feet may be phosphatic, crystalline limestone or iron-bearing silica	158 - 238
Clay, gray-green, sandy, phosphatic, shelly	238 - 244
Shell, hash; quartz sand loosely cemented with $CaCO_3$; 3-foot thick layer of clay at 261 feet	244 - 290
Clay, bluish green, sandy, shelly, phosphatic	290 - 400
Limestone, light gray, friable or "rotten," shelly; abundance of shell hash at 425-435 feet	400 - 485
Limestone, very light gray to cream, sandy, phosphatic	485 - 530
Limestone, light gray, shelly, phosphatic, clayey	530 - 570
Clay, green, tight, shelly; light gray limestone	570 - 575
Limestone, light gray to white, phosphatic, clayey; varying amounts of shell with depth; very hard limestone zone 3-4 feet thick at 587 feet	575 - 700

WELL 609-120-1

Material	Depth, in feet below land surface
Limestone, light tan, very hard, fossiliferous; very hard	0 - 30
Limestone, white to light tan, shelly; pink coating on shells	30 - 38
Limestone, white, phosphatic	38 - 40
Sand quartz, very fine, white	40 - 72
Limestone, white to light gray phosphatic, sandy	72 - 103
Sand, quartz, silt-size to very coarse, clayey	103 - 122

WELL 613-148-1

Material	Depth, in feet below land surface
Sand, fine to medium, brown; organic material	0 - 22
Limestone, light gray, sandy, shelly, marly	22 - 44

Limestone, gray, sandy; greenish shelly clay; phosphatic nodules	44 - 48
Limestone, gray, shelly, sandy, phosphatic; permeable	48 - 72
Limestone, white, friable, granular; permeable	72 - 128
Limestone, light gray, sandy, some shell	128 - 136
Sand, quartz, fine to very fine, white	136 - 142

WELL 614-146-1

Material	*Depth, in feet below land surface*
Sand, quartz, yellow	0 - 4
Sand, quartz, fine, gray; indurated gray limestone	4 - 17
Limestone, gray, sandy, shelly, permeable	17 - 39
Sand, quartz, fine, dark gray, phosphatic, marly	39 - 44
Limestone, dark gray, sandy, shelly	44 - 85
Sand, quartz, medium, limy	85 - 115

WELL 616-131-1

Material	*Depth, in feet below land surface*
Sand, dark-brown, organic	0 - 10
Limestone, sandy, light tan to gray	10 - 20
Limestone, light gray, clay, sandy	20 - 40
Clay, green, soft; light gray limestone	40 - 60
Clay, green, soft, sandy, shelly	60 - 80
Limestone, light to dark gray, hard, shelly, phosphatic and sandy in lower part; very permeable	80 - 130

WELL 616-141-2

Material	*Depth, in feet below land surface*
Limestone fill rock and sand	0 - 10
Shell, hash, cream colored; limestone, marly	10 - 35
Limestone, light cream, shelly, phosphatic	35 - 46
Limestone, white to dark gray; light green clay in varying amounts	46 - 90
Limestone, gray, sandy; sand-filled cavity at 105 feet	90 - 150
Clay, gray-green, soft, sandy, phosphatic	150 - 160
Limestone, light cream, sandy, phosphatic	160 - 170
Limestone, very shelly, clayey, and phosphatic; clay increasing	170 - 220
Limestone, white and gray, clayey, phosphatic	220 - 240
Clay, green, sandy, phosphatic; gray limestone	240 - 270
Clay, green, sandy, hard	270 - 300

WELL 617-146-1

Material	*Depth, in feet below land surface*
Sand, quartz, dark, organic	0 - 1
Limestone, gray, fossiliferous, very hard, impermeable	1 - 23
Sand, quartz, medium, gray to white, shelly; dark gray to tan limestone	23 - 55
Clay, dark green	55 - 75
Marl, green, shelly limestone in lower part; permeable	75 - 94

Limestone, white; sandy in lower part; permeable	94 - 121
Sand, quartz, very fine, white phosphatic	121 - 141

WELL 621-135-2

Material	*Depth, in feet below land surface*
Fill material	0 - 10
Sand, quartz, medium, tan; gray limestone; shell in lower part	10 - 40
Clay, marly, shelly, greenish tan	40 - 60
Limestone, dark gray, shelly, becoming sandy in lower part	60 - 90
Sand, quartz, very fine, limy, clayey, phosphatic	90 - 95
Limestone, buff-colored, phosphatic, sandy, becoming shelly in last 7 feet; permeable	95 - 123

WELL 621-136-5

Material	*Depth, in feet below land surface*
Sand, quartz, fill material, and organic material	0 - 10
Shell, tan, hash, fill material	10 - 20
Limestone, light gray and shell hash	20 - 30
Limestone, light gray, sandy, marly, becoming harder and darker gray at bottom; permeable	30 - 55
Limestone, gray to white, with greenish gray clay, sand, and phosphatic material in lower part; permeable	55 - 118
Sand, quartz, very fine; white and gray limestone fragments	118 - 120
Sand, quartz, fine, white	120 - 130

WELL 622-125-2

Material	*Depth, in feet below land surface*
Sand, quartz, fine to medium, organic material	0 - 10
Sand, quartz, fine, gray, marly, phosphatic, clay in lower part	10 - 35
Marl, sandy, green, phosphatic	35 - 48
Limestone, white to gray; fine to medium quartz sand, abundance of white and black shell fragments	48 - 53
Sandstone, probably $CaCO_3$ cement	53 - 60
Sand, quartz, medium to coarse, becoming finer	60 - 120

WELL 625-123-3

Material	*Depth, in feet below land surface*
Surface sand, fill, and organic matter	0 - 10
Sand, quartz, fine, dirty white, becoming whiter with depth; marl, light brown, decreasing in amount with depth; phosphatic material in lower part	10 - 37
Sand, quartz, fine, gray	37 - 70
Sand, quartz, medium to coarse, gray, phosphatic material	70 - 80
Sand, quartz, medium, poorly consolidated, marly	80 - 90
Clay, greenish gray, sandy, marly, becomes green in lower part	90 - 110
Sand, quartz, coarse, marly; tightly cemented sandstone in lower part	110 - 129

Sand, quartz, medium, marly; semi-indurated gray limestone	129 - 145
Sand, quartz, coarse; phosphatic material; dark green soft clay in lower part	145 - 171
Clay, sandy, dark green; phosphatic material	171 - 175
Clay, sandy, light gray; white limestone	175 - 177
Limestone, white to buff, sandy, phosphatic material	177 - 190
Sand, quartz clear to gray, coarse; limestone fragments; phosphatic material	190 - 212
Clay, marly, light gray to green; fine to medium quartz sand; phosphatic material	212 - 303

WELL 626-123-1

Material	*Depth, in feet below land surface*
Sand, quartz, medium, brown, marly; organic material	0 - 10
Sand, quartz, medium, light brown, shelly, marly; becomes very shelly in lower part	10 - 30
Sand, quartz, very fine, gray, phosphatic	30 - 40
Sand, quartz, coarse, gray, clayey, phosphatic; contains corals; sand becomes pebble size in lower part	40 - 60
Sand, quartz, very fine, light gray, phosphatic; becomes coarser with dark green marl in lower part	60 - 100
Sand, quartz, coarse to pebble-size; sandstone; shell fragments; dark green marly clay	100 - 116
Sand, quartz, coarse to pebble-size; green marly clay	116 - 140
Sand, quartz, very fine, gray, marly, clayey, phosphatic	140 - 150

WELL 626-126-1

Material	*Depth, in feet below land surface*
Sand, quartz, fine to medium, white to gray	0 - 15
Sand, quartz, fine to very coarse, well rounded, white, becoming finer in lower part	15 - 41
Sand, quartz, fine, gray, with phosphatic material	41 - 50
Sand, quartz, coarse to very coarse, white well rounded; phosphatic material	50 - 73
Sand, quartz, gravel-size, white to gray; phosphatic material	73 - 85
Sand, quartz, fine to very fine, white to pink; green-blue clay; light brown to buff marl	85 - 95
Sand, quartz, fine, marly	95 - 123

TABLE 5. Well Records in Collier County, Florida

Aquifer: S, shallow aquifer; F, Floridan aquifer.

Remarks: W- is the Florida Geological Survey well number.

Use: PS, public supply; O, observation; D, domestic; T, test (if not noted in remarks section, it refers to a well drilled for water and earth samples); Ir, irrigation; S, stock; In, Industrial.

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
630-126-1	Humble Oil Co......	Mays Bros.........	1941	566	166	4½	F	Top of 4½-inch casing.	1.0	....	11.5	12-15-41	350	......	....	82	T	Oil exploratory
630-123-1	Atlantic Coast Line..	....	....	....	....	4	F	Top of 4-inch discharge pipe........	2.0	....	16.4	10- 9-59	150	825	10- 9-59	80	Ir	
-2	do...........	....	....	....	....	4	F	do............	1.7	....	16.0	10- 9-59	....	1,030	10- 9-59	80	Ir	
-3	J. Houghteling......	B. and D. Well Drillers..........	1950	56	48	3	S	Lower edge of 2½-inch elbow.............	1.5	....	- 6.45	8-13-52	....	......	....	....	Ir	
-4	do...........	do...........	1952	166	....	5	S	Top of 6-inch casing..	.5	....	- 7.48	8-13-52	....	17	8-13-50	77	Ir	
630-122-1	Atlantic Coast Line..	....	....	....	....	4	F	Land surface.........	.0	....	23.5	10- 9-59	150	1,100	10- 9-59	80.5	Ir	
-2	J. Houghteling......	B. and D. Well Drillers..........	1950	56	40	3	S	Top of 3-inch coupling...........	1.0	....	- 4.40	8-13-52	....	17	8-13-52	......	Ir	
-3	do...........	do...........	1952	55	....	6	S	Top of 6-inch casing..	1.3	....	- 4.61	8-13-52	....	....	....	......	Ir	
											- 4.74	10- 9-59						
629-120-1	....	J. H. Whatley......	....	660	....	6	F	Top of 6-inch discharge pipe........	2.0	....	21.8	10- 9-59	200	....	10- 9-59	80.4	Ir	
629-127-1	Collier Corp........	....	....	20	....	6	S	Top of 6-inch casing..	.0	....	-10.35	5- 8-59	....	48	5- 8-59	......	Ir	
-2	do..........	....	....	20	....	6	S	do............	1.0	....	- 9.39	5- 8-59	....	35	5- 8-59	......	Ir	
-3	do..........	....	....	....	....	....	S	....	....	....	....	....	....	....	....	......	Ir	
-4	....	J. M. Whatley......	....	1,119	....	6	F	Top of galvanized extension on discharge pipe	.7	....	11.7	10- 8-59	100	1,100	10- 8-59	84.5	Ir	Flowing wild

629-126-1	Collier Corp.			26		6	S	Top of 6-inch casing	.0		- 7.74	5- 8-59		83	5- 8-59		Ir	
629-124-1	Bud Fredricks	Miller Bros.		55		6	S						700	38	5- 7-59	75.5	Ir	
-2	do.	do.		55		6	S							48	5- 7-59		Ir	
629-122-1	Atlantic Land and Improvement Co.	J. M. Whatley	1958	702	304	6	F	Top of discharge pipe	1.3		20.0	10- 9-59	90	980	10- 9-59	79	Ir	
-2						4	F	do.	2.0		20.0	10- 9-59	100	1,120	10- 9-59	81	Ir	
-3						4	F	do.	1.0		24.0	10- 9-59		1,090	10- 9-59	81	Ir	
628-124-1	Bud Fredricks	Paul Dukes		45-55	30	6	S							138	5- 7-59	75	Ir	
-2	do.			800?		6	F	Land surface	.0	38	9.0	5- 7-59	50	520	5- 7-59	80	Ir	
627-127-1				750		4	F	Top of 4-inch discharge pipe	2.0		16.1	10- 8-59	15	1,120	10- 8-59	82.5	Ir	
627-126-1	University of Florida Agricultural Experiment Station	J. M. Whatley		184	168	2		Land surface	.0		-10.0	5- -56					Ir	
-2	do.	do.	1957	184		2								75	3-10-59		Ir	
-3		do.		682		6	F	Top of 6-inch elbow	1.6		19.2	10- 8-59	50	1,018	10- 8-59	83	Ir	
627-125-1	Stokes			39		4	S	Top of 4-inch casing	1.75		- 7.26	6- 2-59		62	6- 2-59		Ir	
-2	do.			35		4	S	Top of 4-inch unthreaded casing	.88		- 5.95	6- 2-59		36	6- 2-59		Ir	
626-127-1	Frank Corbett		1958	40	40	1½	S							28	3- 4-59		Ir	
626-126-1	USGS	Miller Bros.	1959	123	84	2	S	Top of 2-inch casing	1.1		- 5.2	6-23-59	55	26	6-23-59		T	
626-125-1	Kenneth Glidden			256		2								39	3-25-59		D	
-2	Knox Blount	Dave Buschmann	1957	230	210	2								10	3-25-59		D	
626-123-1	USGS	Miller Bros.	1959	153	144	2	S	Land surface	.0		- 4.34	7-12-59					T	
626-121-1	Collier Corp	Ray Messer	1953	33	23	6	S										Ir	
625-126-1	do.	Mays Bros.	1941	753	228	4½	F									81	T	Oil exploratory
-2	Tom Lynn	D. Buschmann	1957	227	200	1½		Land surface	.0		-18.0	8- -57	25	23	3- 4-59		D	
-3	R. M. Anderson	do.	1957	65	65	1¼	S							42	4- 5-59		D	
-4	do.	do.	1950	35	35	1¼	S							25	4- 5-59		D	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
625-126-5	H. E. McDaniel		1949	196		4								54	3-27-59		D	
-6	do.			220		4								17	3-27-59		D	
-7	J. G. Dupree	D. Buschmann	1957	130	125	1¼								61	3-27-59		D	
-8	Chas. Scott	O. B. Fowler	1955	42		2								38	3-27-59		D	
-9	L. H. Gross	D. Buschmann	1952	216	180	2								48	3-27-59		D	
-10	Lloyd Brown	J. M. Whatley	1959	242	210	2								50	3-27-59		D	
625-125-1	Collier County Board of Public Instruction	Fred's Barn	1958	250	193	4							500	27	3-13-59		PS	
-2	do.	J. M. Whatley	1957	187		4	S							48	3-13-59		PS	
-3	Immokalee Gas	do.		125	70	1¼	S						50	40	5-17-58		In	
-4	Mr. Shirling	D. Buschmann	1951	133		2	S							47	3-25-59		D	
-5	Mrs. Bethea	do.	1947	90		2	S							35	3-27-59		D	
-6	do.	do.	1954	120		3	S							79	3-27-59		D	
-7	do.	do.	1954	120		3	S							48	3-27-59		D	
625-124-1	Florida State Agriculture Marketing Board	J. M. Whatley	1956	292	208	6		Land surface			-13.5	4- -56	250				In	
-2	J. M. Whatley	do.		783		4	F	do.			19.0	3-25-59	100	1,040	3-25-59		In	
-3	Atlantic Coast Line		1910	590		6	F	Top of 6-inch casing	1.5		.0	10-22-40				78	In	
625-123-1	Collier Corp		1959	35	24	6	S										Ir	
-2	do.		1959	30	20	6	S										Ir	
-3	USGS	Miller Bros	1959	303	254	3	S	Land surface			-10.88	7- 8-59		38	7- 8-59		T	

625-116-1	do.	B. and D. Well Drillers	1952	54	22	6	S	Top of 6-inch casing	.0		- 2.77	6-11-52		66	6-11-59		T	
-2	Collier Corp.			51			S	Top casing	.5		- 2.26	6-17-58	500	70	6-17-58		Ir	
624-125-1	Collier County Board of Public Instruction	J. M. Whatley	1956	278	218	4		Land surface	.0		4.0	2- -56		26	3-16-59		PS	
-2	Florida Forest Service	D. Buschmann	1958	107	164	4	S	do.	.0		- 3.0	1956	100	24	3-13-59		D	
-3	Mrs. Carl McPhail		1954	100		2	S							68	3-27-59		D	
623-126-1	Collier Corp.			37		6	S	Top of 6-inch casing	.65		- 3.95	3-16-59		31	3-16-59		S	
622-133-1	Humble Oil Co.	Loffland Bros.	1949	12,210													T	Oil exploratory, W-2103
622-125-1	Don Lucas													20	3-16-59		D	
-2	USGS	Miller Bros.	1959	120	112	2	S							20	7-14-59		T	Chloride sample taken at 50-53 foot interval
621-135-1	Collier Corp.	do.		60		8	S	Top of 8-inch casing	.5		- 2.35	3-24-59		34	3-24-59		Ir	
-2	USGS	do.	1959	120	120	2	S	Top of 2-inch casing	.88		- 2.38	7-24-59		38	7-24-59		T	Chloride sample taken at 86-93 foot interval
-3	Sam Shaw					8		Top of 8-inch casing										
-4	do.					8		do.										
621-134-1	Collier Corp.			84		4	S	Top of 8-inch casing	.55		- 2.74	3-24-59		49	3-24-59		Ir	
621-132-1	do.			115		8	S	do.	.3		- 1.65	3-24-59		85	3-24-59		Ir	
621-131-1	do.			92		8	S	do.	.63		- 4.36	3-16-59		51	3-16-59		Ir	
-2	do.			112		8	S	do.	.5		- 3.07	3-17-59		111	3-17-59		Ir	
-3	do.			105		8	S	do.	.0		- 1.74	3-24-59		57	3-24-59		Ir	
-4	do.			105		8	S	do.										
-5	USGS	Miller Bros.	1959	130	123	2	S							44	7-21-59		T	
621-130-1	Collier County			82		8	S	Top of 8-inch casing	.0		- 3.42	3-17-59		48	3-17-59		Ir	
620-135-1	do.			63		8	S	do.	.0		- 1.74	3-23-59		55	3-23-59		Ir	
619-130-1	Humble Oil Co.	Dorris Ballew	1949	11,000		20											T	Oil exploratory, W-1885
618-134-1	Collier Corp.	J. M. Whatley		18		8	S	Top of 8-inch casing	.65		- 1.98	3-16-59		47	3-16-59		Ir	
-2	do.	do.		31		8	S	do.	.65		- 1.38	3-16-59		34	3-16-59		Ir	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
618-134-3	Tony Rosbough.....	Miller Bros.........	....	100	....	6	S	....	......	......	......	....	800	56	3-17-59	......	Ir	
618-133-1	do..	do..........	....	52	....	6	S	....	......	......	......	....	1,000	59	3-17-59	......	Ir	
-2	do..	do..	1958	25	....	6	S	....	......	......	......	....	800	37	3-17-59	......	Ir	
617-146-1	Collier Corp........	Carl May..........	1958	141	124	2	S	....	......	......	......	....	....	2,100	12-21-58	......	T	
617-134-1	Tony Rosbough.....	J. M. Whatley......	....	875	....	6	F	Land surface.........	......	......	25.0	6-12-61	250	785	3-16-59	......	Ir	
-2	do..	do..........	....	60	....	6	S	....	......	......	......	....	1,000	61	3-17-59	......	Ir	
-3	do..........	do..........	....	38	....	6	S	Top of 6-inch casing..	2.38	......	− 5.03	5- 6-59	....	71	4-22-59	......	Ir	Equipped with continuous water-level recorder
617-132-1	do..........	do..........	1958	30	....	6	S	do..........	......	......	......	....	800	43	3-17-59	......	Ir	
616-149-1	Mr. Baker..........	Chis Rivers.........	1958	50	....	2	S	....	......	......	......	....	....	36	12-29-59	......	D	
616-148-1	C. B. Lambertsons...	do..........	1956	38	....	2	S	....	......	......	......	....	....	43	1- 5-60	......	D	
616-147-1	6-L Farms..........	Miller Bros.........	1959	30	....	2	S	....	......	......	......	....	....	....	....	......	D	
616-146-1	John Pulling........	do..........	....	65	....	8	S	....	......	......	......	....	....	....	....	......	Ir	
-2	Palm River Estates..	Chis Rivers.........	1960	52	42	2	S	....	......	......	......	....	....	290	3- 2-60	......	Ir	
616-145-1	USGS.............	Carl May..........	1958	58	....	2	S	Top of 1¼-inch casing	3.2	......	......	....	....	275	7-20-58	......	T	

616-141-1	USGS	Carl May	1958	51	51	2	S							87	7-18-58		T	Casing broke at 21 feet
-2	do	Miller Bros	1959	300	232	2	H	Land surface	.0		- .59	8- 4-59		1,100	8- 3-59		T	Chloride sample taken at 230-240 feet interval
616-136-1	do	do	1959	130	125	2	S	do	.0		- .39	8-10-59	10	39	8-10-59		T	
615-149-1	Claude Grimm	Chiz Rivers	1955	60		2	S							194	12-29-59		D	
-2	Mr. Van Camp	do		40		2	S							458	12-29-59		D	
615-148-1	USGS	USGS	1959	11	9	1¼	S	Top of 1¼-inch casing	1.33	8.74	- 5.56 - 2.67	1- 5-60 8-15-60		51	11-11-59		O	
-2	C. L. Foster					2	S							35	12-29-59		D	
-3	Mrs. Downing	Chiz Rivers	1959	51	42	2	S							49	12-29-59		D	
-4	R. P. Boyd	do	1955	48		2	S							81	12-29-59		D	
-5	Myrtle E. Wilkens	do	1957	35		2	S							14	12-29-59		D	
-6	Mr. Kopen	Sweet		56		2	S							17	1- 5-60		D	
-7	M. A. Tropf			56		2	S							64	1- 5-60		D	
-8	Earl Craig	Chiz Rivers	1960	53		2	S							210	1- 5-60		D	
-9	do	do	1960	41		2	S							32	1- 5-60		D	
615-147-1	Ralph May	do	1959	100		8	S						1,000	314	3-28-60		Ir	
-2	do	Miller Bros	1959	61		8	S							200	3-28-60		Ir	
-3	do	do	1959	67		8	S							530	3-28-60		Ir	
-4	do	do	1959	72		8	S							19	3-29-60		Ir	
-5	6-L Farms	do	1959	45		8	S							200	3-29-60		Ir	
-6	do	do	1959			8											Ir	
615-146-1	do	do	1959	65		8	S										Ir	
-2	do	do	1959	65		8	S										Ir	
-3	do	do	1959	65		8	S							190	3-29-60		Ir	
-4	John Pulling	do	1959	65		8	S										Ir	
-5	do	do	1959	70		8	S										Ir	
-6	6-L Farms	do	1959	30		1½	S										Ir	
615-120-1	Collier Corp	C. E. Failing Co	1942	1,100		4½	F									82	T	Oil Exploratory
614-148-1	USGS	USGS	1959	11	9	1¼	S	Top of 1¼-inch casing	.5	15.70	- 6.35 - 1.92	3-29-60 8-15-60		18	11-11-59		O	
614-147-1	Doyle Hodges	Carl May	1958	65		2	S							38	11-13-59		D	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
614-147-2	USGS.............	USGS.............	1959	12	9	1¼	S	Top of 1¼-inch casing	0.35	11.56	− 4.32	3-29-60	....	19	11-11-59	......	O	
614-146-1	Collier Corp........	Carl May..........	1958	115	115	2	S	....	....	....	....	....	....	260	11-18-59	......	T	Chloride sample taken at a depth of 82 ft.
614-057-1	John S. Harris......	John S. Harris......	....	23	23	1¼	S	....	....	....	....	....	....	....	....	......	D	
614-055-1	do............	do............	....	11	11	1¼	S	....	....	....	....	....	....	....	....	......	S	
614-054-1	do............	do............	....	11	11	1¼	S	....	....	....	....	....	....	....	....	......	S	
613-148-1	Collier Corp........	Carl May..........	1960	135	128	2	S	Land surface.........	.0	....	− .54	8-10-60	....	35	8-10-60	......	T	
613-147-1	David Veenschoten..	....	....	....	....	....	....	....	....	....	....	....	....	34	11-13-58	......	D	
612-148-1	John Pulling........	....	1958	75	....	6	S	....	....	....	....	....	90	18	6- 4-59	......	PS	
-2	do............	....	1958	75	....	6	S	....	....	....	....	....	90	44	6- 4-59	......	PS	
-3	do............	....	1958	75	....	6	S	....	....	....	....	....	90	30	6- 4-59	......	PS	
-4	USGS.............	USGS.............	1959	11	9	1¼	S	Top of 1¼-inch casing	1.75	18.43	− 5.39 − 2.14	3-29-60 8-15-60	....	24	11-11-59	......	O	
-5	do............	do............	1959	11	9	1¼	S	do....	.5	10.88	− 5.71 − 1.80	3-29-60 8-15-60	....	....	....	......	O	
612-147-1	D. H. McBride......	Chis Rivers.........	1955	55	50	2	S	....	....	....	....	....	....	28	11-13-58	......	D	
-2	do............	do............	1955	49	49	2	S	....	....	....	....	....	....	60	11-13-58	......	D	

-3	USGS	USGS	1959	11	9	1¼	S	Top of 1¼-inch casing	.55	13.43	- 3.25 - 4.39	1- 5-60 3-29-60	...	56	11-11-59	...	O	Stolen
612-146-1	do.	Carl May	1958	123	106	2	S	...	...	...	...	...	...	150	7-29-58	...	T	
612-053-1	John S. Harris	do.	...	75	...	1¼	S	...	...	...	...	...	...	...	...	...	D	
612-052-1	do.	...	...	11	11	1¼	S	...	...	...	...	...	...	...	...	...	D	
611-148-1	USGS	USGS	1959	11	9	1¼	S	Top of 1¼-inch casing	1.5	15.33	- 6.25 - 6.99	12- 3-59 1- 5-60	...	835	11-12-59	...	O	Stolen
-2	do.	do.	1959	11	9	1¼	S	do.	.75	15.98	- 7.83 - 3.75	3-29-60 8-15-60	...	111	11-12-59	...	O	
611-147-1	P. H. Gadsden, Jr.	Bell Well Drilling	1958	65	...	2	S	...	...	...	...	...	...	34	6- 4-59	...	D	
-2	Mr. Conrad	Chiz Rivers	1952	45	...	2	S	...	...	...	...	...	...	46	6- 4-59	...	D	
-3	R. A. Walker	R. A. Walker	...	...	...	...	S	...	...	...	...	...	...	26	6- 4-59	...	D	
-4	Robert Burgan	Robert Burgan	...	...	...	...	S	...	...	...	...	...	...	88	6- 4-59	...	D	
-5	Hole-in-the-Wall Golf Course	Hartley's Water System	...	60	...	2	S	...	...	...	...	...	...	54	6- 8-59	...	PS	
-6	do.	do.	...	60	...	2	S	...	...	...	...	...	...	24	6- 8-59	...	PS	
-7	USGS	USGS	1959	11	9	2	S	Top of 1¼-inch casing	.75	11.26	- 4.39 - 1.83	3-20-60 8-15-60	...	34	11-12-60	...	O	Destroyed by SRD
610-148-1	Collier Corp.	Carl May	1956	54	51	2	S	Top of 2-inch casing	.8	...	- 2.16	8-16-56	75	25	8-16-56	...	T	
-2	do.	do.	1956	60	50	2	S	do.	.9	...	- 6.51	8-16-56	50	...	...	...	T	
				166	145	...	...	do.	1.7	8.55	- 9.87 - 5.47	4-28-61 8-15-60	... ...	40 68	4-28-61 8-15-60	...	O	
-3	do.	do.	1956	58	40	2	S	do.	.8	...	- 5.70	8-17-56	75	...	...	...	T	
-4	do.	do.	1956	60	50	2	S	do.	.4	...	-12.09	8-27-56	...	16	8-27-56	...	T	
-5	USGS	USGS	1959	11	9	1¼	S	Top of 1¼-inch casing	.85	5.44	- 5.03 - 3.04	4-26-61 8-11-61	... ...	60 ...	11-12-59 ...	... ...	O	
610-147-1	City of Naples	Carl May	1953	96	85	6	S	...	...	...	...	...	500	...	...	...	PS	
-2	do.	do.	1953	87	77	2	S	...	...	...	...	...	...	...	...	...	PS	
-3	do.	do.	1954	...	...	6	S	...	...	...	...	...	...	...	...	...	PS	
-4	do.	do.	1954	50	...	6	S	...	...	...	...	...	...	...	...	...	PS	
-5	Caribbean Gardens	do.	1954	70-75	...	6	S	...	...	...	...	...	...	24	8-11-61	...	PS	
-6	USGS	do.	1956	74	73	2	S	Land surface	.0	...	- 4.74	3-14-56	...	...	...	...	T	
-7	Mrs. Lawrence Tibbett	...	...	40	...	2	S	Top of 2-inch casing	3.18	...	...	...	...	...	...	...	Ir	
-8	do.	...	...	48	...	3	S	Top of 3-inch casing	.94	...	...	...	...	39	1-19-59	...	Ir	

Table 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Aquifer	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Elevation above mean sea level	Water level: Above or below (—) measuring point (feet)	Water level: Date of measurement	Yield: Gallons per minute	Chloride: Parts per million	Chloride: Date sampled	Temperature (°F)	Use	Remarks
610-147-9	Mrs. Lawrence Tibbett	......	......	42	......	3	S	Top of 3-inch casing	0.65	......	......	......	......	50	1-10-59	......	Ir	
-10	do.	......	......	......	......	3	S	......	......	......	......	......	......	......	......	......	Ir	Obstruction in well
-11	Caribbean Gardens	Carl May	1957	156	144	2	S	Top of 2-inch casing	1.75	4.87	- 5.58 - .61	3-20-60 8-15-61	......	1,020	3-20-60	......	Ir	
-12	Mrs. Lawrence Tibbett	do.	......	165	140	2	S	do.	......	......	......	......	......	......	......	......	......	Dynamited at 118 feet
-13	City of Naples	do.	......	63	20	6	S	......	......	......	......	......	500	20	3-10-58	......	Ir	
-14	Mrs. Lawrence Tibbett	......	......	51	8	......	S	......	......	......	......	......	......	......	......	......	Ir	
-15	do.	......	......	53	......	4	S	Top of 4-inch casing	.7	......	......	......	......	28	1-10-59	......	PS	
-16	City of Naples	......	1958	84	......	8	S	Top of 8-inch casing	.8	......	......	......	......	34	3- 9-59	......	PS	
-17	do.	......	1958	......	......	8	S	......	......	......	......	......	......	62	1-10-59	......	PS	
-18	do.	......	1958	96	......	6	S	Top of 6-inch casing	1.35	......	......	......	......	30	1-10-59	......	PS	
-19	Mr. G. H. Paske	Carl May	1955	60	......	2	S	......	......	......	......	......	......	34	6- 1-59	......	D	
-20	Carl Thurner	do.	1954	60	......	2	S	......	......	......	......	......	......	26	6- 5-55	......	D	
-21	W. G. Henson	do.	1956	64	......	2	S	......	......	......	......	......	......	62	6- 4-59	......	D	
-22	City of Naples	......	......	142	......	2	S	Top of 2-inch casing	1.0	11.01	-10.35 - 9.42	3-15-61 8-11-61	......	24	3-15-61	......	O	Affected by pumping
-23	do.	Miller Bros.	1952	157	97	2	S	do.	2.17	13.61	-15.21 - 9.92	4-26-61 8-11-61	......	58 34	4-26-61 8-11-61	......	O	
-24	USGS	USGS	1950	11	9	1¼	S	Top of 1¼-inch casing	1.0	11.33	- 7.6 - 5.27	4-26-61 8-11-61	......	80	11-12-61	......	O	
-25	do.	do.	1950	11	9	1¼	S	do.	1.0	9.42	- 4.82 - 3.67	3-15-61 8-11-61	......	70	3-15-61	......	O	
-26	Caribbean Gardens	Carl May	1961	350-400	1	6	F	Top of 4-inch discharge pipe	......	7.53	10.4	5-21-61	......	......	......	......	Ir	

610-146-1	City of Naples	Carl May	1958	120	90	2	S	...	...	...	...	...	...	375	7-23-58	...	T	
610-052-1	USGS	USGS	1951	9	8	6	S	Top of 6-inch casing	2.8	...	- 4.16	2- 9-51	...	...	...	...	O	Equipped with recorder
609-148-1	City of Naples	Joe Maharrey	1949	74	67	4	S	Top of 4-inch casing	1.5	...	-10.57	8- 7-51	25	16	8- 7-51	70	PS	
-2	do	do	1950	92	88	4	S	do	1.5	...	...	...	22	13	8- 7-51	78.5	PS	
-3	Lawrence Tibbett	Jeff Townsend	1950	65	60	2½	S	...	...	...	...	...	...	575	8- 8-51	82	Ir	
-4	Julius Fleishmann	do	1950	55	50	2	S	...	...	...	...	...	...	550	8- 8-51	83	Ir	
-5	Naples Beach Club Hotel	...	1930	50	...	6	S	Top of 6-inch casing	.9	...	- 6.06	8- 8-51	...	13	8- 8-51	80	Ir	
-6	do	...	1930	50	...	6	S	do	-1.1	...	- 6.41	8- 8-51	...	24	8- 8-51	...	Ir	
-7	do	...	1930	63	...	6	S	...	...	...	...	...	...	14	8- 8-51	...	Ir	
-8	B. W. Morris	Chiz Rivers	1950	46	...	3	S	...	...	...	...	...	...	58	8-22-51	81	Ir	
-9	W. T. Truesdale	Aubrey Cooper	1951	63	60	2	S	...	...	...	...	...	...	27	9-26-51	81	Ir	
-10	do	do	1951	83	78	2	S	...	...	...	...	...	...	110	9-26-51	81	Ir	
-11	USGS	Miller Bros	1952	78	62	2	S	Top of 2-inch casing	.6	...	- 7.80	1-18-52	...	14	1-18-52	...	O	
-12	Dreher	...	1951	40	...	1½	S	...	...	...	...	...	...	34	4-20-52	...	Ir	
-13	USGS	Miller Bros	1952	71	69	6	S	Top of 6-inch casing	2.4	...	- 7.46	4-28-61	...	156	4-28-61	...	O	
-14	Naples Beach Club Hotel	J. P. Maharrey	1952	90	82	8	S	...	...	...	- 4.20	8-11-61	...	186	8-11-61	...	Ir	
609-147-1	City of Naples	do	1951	63	...	4	S	Top of 4-inch casing	...	8.53	- 6.61	3-15-61	...	28	8- 7-51	70	PS	
-2	do	do	1951	63	...	4	S	...	...	...	...	...	...	17	8- 7-51	70	PS	
-3	do	do	1951	73	...	4	S	Top of 4-inch casing	...	9.44	- 7.50	3-15-61	...	28	8- 7-51	70.5	PS	
-4	do	do	1951	73	...	4	S	...	...	...	...	...	...	38	7-31-51	...	PS	
-5	do	do	1951	93	...	3	S	...	...	...	...	...	...	25	7-31-51	70.5	PS	
-6	do	do	1949	76	65	4	S	Top of 4-inch casing	1.5	...	-12.47	8- 7-51	...	12	8- 7-51	70	PS	
-7	do	do	1949	75	...	4	S	do	1.5	...	-11.80	8- 7-51	...	...	...	...	PS	
-8	do	do	1950	88	...	4	S	do	1.5	...	- 9.20	3-15-61	...	15	8-13-51	78.5	PS	
-9	do	do	1950	78	78	4	S	do	1.9	...	...	...	22	12	8- 7-51	70	PS	
-10	do	do	1950	70	70	4	S	do	1.5	...	...	...	...	12	8- 7-51	70	PS	
-11	John Pulling	Jenkins	1939	33	26	4	S	...	...	...	...	...	...	...	...	...	Ir	
-12	do	do	1939	33	...	4	S	...	...	...	...	...	...	...	...	...	Ir	
-13	Carver Negro School	J. P. Maharrey	1950	90	75	4	S	...	...	...	...	...	...	24	9-26-51	...	PS	
-14	W. R. Rosier	John Pulling	1951	63	60	1½	S	...	...	...	...	...	...	25	8- 8-51	82	D	
-15	J. G. Sample	...	1945	60	...	6	S	Bottom lip of 6-inch elbow	1.7	...	- 3.94	8- 8-51	...	...	...	...	Ir	
-16	do	Joe Maharrey	1945	52	...	6	S	do	1.1	...	- 3.28	8- 8-51	...	25	8- 8-51	...	Ir	
-17	do	...	1949	43	...	6	S	do	1.7	...	- 2.38	8- 8-51	...	41	8- 8-51	78	Ir	
-18	do	...	...	...	...	6	...	Bottom lip of 3-inch nipple on elbow	2.2	...	- 2.82	8- 8-51	...	...	...	...	Ir	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Aquifer	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Elevation above mean sea level	Water level: Above or below (—) measuring point (feet)	Water level: Date of measurement	Yield: Gallons per minute	Chloride: Parts per million	Chloride: Date sampled	Temperature (°F)	Use	Remarks
609-147-19	J. G. Sampl	......	1949	62	......	6	S	Top of 3-inch nipple on 6-inch casing....	0.7	......	- 7.21	8- 7-51	......	......	......	......	Ir	
-20	Neapolitan Enterprises............	Chis Rivers.........	1951	63	......	3	S	......	......	......	......	......	......	18	8- 8-51	78	PS Ir	Supplies 3 homes and a nursery
-21	R x Lehman........	......	1937	72	......	2	S	......	......	......	......	......	......	18	8- 9-51	80	D	
-22	J. G. Sample........	Joe Maharrey.......	1949	52	......	6	S	Bottom lip of 6-inch tee..............	.3	......	- 3.31	8-23-51	......	43	8-21-51	......	Ir	
-23	City of Naples......	do...........	1951	68	......	4	S	Top of 4-inch casing..	......	......	......	......	......	10	8-16-51	......	PS	
-24	do..........	Miller Bros.........	1952	78	63	2	S	Top of 2-inch casing..	2.0	......	- 4.84	1-10-52	......	16	1-10-52	......	O	
-25	do..........	do...........	1952	113	112	2	S	do............	1.7	......	-13.91	1-17-52	......	448	1-17-52	......	O	
-26	do..........	Bert Dudley........	1953	57	37	6	S	......	......	......	......	......	......	......	......	......	PS	
609-145-1	Naples Swamp Buggy Assn.......	......	1957	......	......	......	......	......	......	......	......	......	......	......	......	......	PS	
609-143-1	City of Naples......	C. W. May.........	1958	123	104	2	S	......	......	......	......	......	......	1,750	7-17-58	......	T	
609-141-1	do..........	do...........	1958	144	80	4	S	......	......	......	......	......	......	885	8-14-58	......	T	
609-120-1	USGS..............	Miller Bros.........	1959	122	82	2	S	......	......	......	......	......	......	15	8-20-59	......	T	
609-115-1	do..........	do...........	1959	485	312	4	F	Land surface.........	......	15	16	5-21-61	5	985	9-23-59	......	T	Single well constructed to perform as two wells of different depths
				700	587	2½	F	do..........	......	15	38	5-21-61	12	1,950	10- 8-59	......	......	

608-148-1	L. A. Orick	Chiz Rivers	1949	52		3	S							31	8-8-51	82	Ir	
-2	Ad Miller	Aubrey Cooper	1950	60		2	S							408	9-26-51	80	Ir	
-3	J. E. Turner	Jeff Townsend	1950	42		2	S							215	9-26-51	79	Ir	
-4	C. J. Summerall	C. J. Summerall	1949	42		1½	S							15	9-26-51		Ir	
-5	R. O. Clark	Aubrey Cooper	1950	42		2	S							14	9-26-51	82	Ir	
-6	Roy Brack	do.	1950	42		2	S							113	9-26-51	80	Ir	
-7	William Storter	Jeff Townsend	1949	45		1¼	S							442	9-26-51	79	Ir	
-8	H. M. McClaskey	Aubrey Cooper	1951	40		1½	S							242	4-29-52		Ir	
-9	H. C. Sherier	do.	1951	42		1½	S							17	4-29-52		Ir	
-10	L. F. Grimes	do.	1951	46		1½	S							115	4-29-52		Ir	
-11	R. L. Williams	J. P. Maharrey	1951			2	S							21			Ir	
608-147-1	C. L. Yonze		1940	110		3	S							22	7-31-46	78	PS	
-2	City of Naples	Joe Maharrey		73	66	3	S	Top of 3-inch casing	1.81					43	7-31-46		PS	
-3	do.	do.		73	64	4	S							43	8-7-51	79	PS	
-4	do.	do.		63		4	S							25	8-7-51	79	PS	
-5	do.	do.		73		4	S							41	8-7-51	78.5	PS	
-6	do.	do.		63		4	S							25	8-31-46	78	PS	
-7	Jack Prince		1930	27		1½	S							19	8-8-51	79	D	
-8	Naples Supply Co.	Joe Maharrey	1950	70		3	S							45	8-8-51	80	In	
-9	John Polling		1939	33		2	S							32	8-8-51	80	S	
-10	Trails End Motel		1951	75	70	4	S							30	8-8-51	79	Ir	
-11	City Ice and Fuel Co.		1930	73	70	3	S										In	
-12	Combs Fish Co.					1½	S							270	8-9-51	79	In	
-13	City Ice and Fuel Co.		1940	73		3	S							167	8-9-51	78	In	
-14	do.		1922			4	S	Top of 4-inch casing	.0		-3.78	8-9-51		200	8-9-51		In	
-15	City of Naples	Joe Maharrey	1941	66	60	3	S										O	
-16	do.	do.	1951	72	60	4	S							16	10-11-51		PS	
-17	do.	do.	1951	81	78	4	S							31	10-12-51		PS	
-18	do.	do.	1951	40	27	6	S							15	10-12-51		PS	
-19	do.	do.	1951	76	74	4	S							12	8-16-51		PS	
-20	Sea Shell Motel	Chiz Rivers		78	68	4	S							27	10-17-51		D	
-21	City of Naples	Joe Maharrey	1939	540	300	5	F	Top of 5-inch coupling	1.0		21.5	1-18-52		2,180	12-17-51		In	Fire well
-22	do.	Miller Bros.	1952	70	69	2	S	Top of 2-inch casing	1.6		-4.28	1-14-52		27	1-14-52		O	
-23	A. Dimeola	Chiz Rivers	1949	55		1½	S							145	3-11-52		D	
-24	City of Naples	B. Dudley	1953	33	27	6	S										PS	
-25	do.	do.	1952	22	19	4	S										PS	
-26	do.	do.	1952	69	52	4	S							49	5-25-53		PS	
-27	Clam Canning Plant			63		6	S									78	In	
-28	J. L. Kirk	Aubrey Cooper	1951	42		2	S							168	8-9-51	77	Ir	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
608-146-1	C. A. Newell		1953	63	60	2	S										D	
-2	do.		1953	73	72	2	S										D	
-3	John Townsend	Chiz Rivers					S							79	1-16-59		D	
-4	C. M. Townsend	do.		90		2	S						30	79	1-16-59		D	
-5	Rev. Walton			70	63	2	S						70	87	1-16-59		D	
-6	Aubrey Cooper	Aubrey Cooper		72	72	1½	S							127	1-16-59		D	
-7	do.	do.		54	54	2	S							54	1-16-59		D	
607-148-1	J. G. Sample	J. P. Maharrey	1952	325	300	6	F	Top of discharge pipe	0.0	4.0	18.0	5-21-61	1,000	2,040	2-11-52		Ir	Flowing well
607-147-1	V. L. Belding		1951	245	235	4	S							4,400	11-13-51		Ir	
607-146-1	Tom Hamilton	Carl May		102	95	2	S							80	1-16-59		D	
-2	Glades Motel	do.		120	105	2	S							119	1-16-59		PS	
-3	Roland Weeks	Chiz Rivers	1958	18	18	2	S							266	1-16-59		D	
-4	Thomas Weeks	Carl May	1955	43	43	2	S							296	1-16-59		D	
-5	Hampton	do.	1955	43	43	2	S										D	
-6	Dick Townsend	do.		70		2	S										D	
607-145-1	Collier Development Corp.	do.	1958	141	120	2	S							270	11-17-58		T	
606-148-1	W. B. Uihlein	Richards	1937	470		6	F							1,960	8- 9-51	78	Ir	
606-143-1	USGS	Miller Bros.	1959	142	105	2	S									80	T	

606-120-1	Collier Development Corp.			45		4	S								6-16-51		O	Equipped with recorder
605-148-1	A. Nystrom	Miller Bros.	1949	220	213	4								240	1-20-52		Ir	
605-144-1	John Seckford		1958	33		2	S							130	1- 2-59		D	
-2	Albert Anderson	Chiz Rivers	1956	83	30	2	S							172	1- 2-59		D	
605-143-1	Jack Cannon	do.	1957			2	S							92	1- 2-59		D	
-2	George Nemchik	do.	1957	32	32	2	S							130	1- 2-59		D	
-3	Travis Bickford	do.	1957	32		2	S							174	1- 2-59		D	
-4	R. O. Edwards	C. W. May	1958	42	38	2	S							134	1- 2-59		D	
604-144-1	Charles McCool	H. R. Snowball	1958	30	30	2	S							890	1- 2-59		D	Not used for drinking
604-143-1	William French	do.	1958	25	25	2	S							68	12-31-58		D	
-2	J. G. Breau	C. W. May	1954	32	32	2	S							82	12-31-58		D, Ir	
-3	do.	do.	1953	32	32	2	S										D, Ir	
-4	do.	do.	1954	22	22	4	S										Ir	
-5	do.	do.	1954	27	22	4	S							78	12-31-58		Ir	
-6	J. H. Gaunt	do.		20	20	6	S										Ir	
-7	do.	do.		30	30	6	S							88	12-31-58		Ir	
-8	Claude Hunter	H. R. Snowball	1958	34	34	2	S							56	1- 2-59		D	
603-141-1	L. L. Loach	C. W. May	1958	31	34	2	S	Top of 2-inch casing	.43		- 2.45	2-12-59		220	2-12-59		O	
-2	do.	do.	1958	34	34	2	S	do.	.2		- 2.33	2-12-59		314	2-12-59		O	
-3	do.	do.	1958	30	34	2	S	do.	.83		- 2.4	2-12-59		238	2-12-59		O	
-4	do.	do.	1958	30	34	2	S	do.	1.0		- 2.61	2-12-59		204	2-12-59		O	
-5	do.	do.	1958	28	34	4	S	Top of 4-inch casing	.97		- 2.87	2-12-59		156	2-12-59		O	
602-142-1	Barefoot Williams	Chiz Rivers	1954	16	11	2	S	Top of 2-inch tee	1.5		- 2.72	12-30-58		760	2-12-59		D	
-2	Carl Puchhas						F											Flowing well
-3	J. G. Breau	H. R. Snowball		27	27	2	S							424	12-30-58		Ir	
602-141-1	L. L. Loach	C. W. May	1958	42	38	2	S										O	Salty from 28 feet downward
559-120-1	USGS	Miller Bros.	1959	127	126	2	S	Top of 2-inch casing	.7		- 1.35	8-17-59		31	8-14-59		T	
558-143-1	G. L. Lowenstein	Kellog		*800-900		6	F	Top of 2-inch vertical tee	2.0	10±	14.5	10-28-40				76	D	*Exact depth of well unknown

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Aquifer	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Elevation above mean sea level	Water level: Above or below (—) measuring point (feet)	Water level: Date of measurement	Yield: Gallons per minute	Chloride: Parts per million	Chloride: Date sampled	Temperature (°F)	Use	Remarks
558-143-2	Marco Highlands, Inc.	Carl May	1957	53	48	2	S							17,200	9- 5-57		T	Chloride less than 40 ppm to depth of 20 feet
557-129-1	Collier Corp.	Humble Oil Co.	1952	300	7	5											T	Log in Collier County engineer's file
556-143-1																78		
-2	Barron Collier			12		2	S	Surface			− 9.0	10-28-40				76	D	
-3	Richard Brooks													35	5-11-59		D	
556-142-1	J. M. Barfield	Miller Bros.	1926	200-300		4	F?							2,550	10-28-40	78.5		Flowing
-2	Marco Island School			22		2	S						*	75	5-11-59		D	*200/day
556-128-1	L. G. Norris	J. M. Whatley	1959	392	300	4	F	Top of 4-inch casing	0.5	3	33.5	4-10-59	100	330	4- 8-59	78	D	Flowing
556-121-1	Lee Tidewater Cypress Co.	Humble Oil Co.		440			F	Top of 6-inch casing	1.5		32.0	7-25-46	Flow	2,310	7-25-46	75	A	
-2	do.		1945	30	15	3	S						50	27	7-25-46	77	D	
555-142-1	Collier Development Corp.			13		2	S	Top of curbing	1.2		−11.4	10-28-40				78	In	
-2	J. M. Barfield			22		1½	S							59	10-28-40		D	
-3	Naples Construction Co.		1959	20		1¼	S							23	5-11-59		In	

555-159-1	Collier Development Corp.	Libby and Freeman												1,700	12-21-49			Well never completed
-2	do.	Humble Oil Co.	1949	540	361	7	F	Top of 3-inch elbow	2.0	11±	19.2	12-21-49		4,000	12-21-49	80	Ir	
-3	Ken Fogstad		1946	13		2	S							80	12-21-49		D	Two wells in manifold 20 feet apart
-4	Collier Development Corp.	Libby and Freeman		351	345	6	F	Top of 6-inch valve flange	3.5	6±	21.3	6-20-50		3,800	6-20-50	79		Flowing
-5	H. F. Pettit	Paul Lawrence		342	320	3	F	Top of 1¼-inch valve	4.5	4±	17.5	6-20-50		2,250	6-20-50	78.2		do.
554-143-1	U.S. Air Force	J. M. Whatley and Miller Bros.	1959	404	351	8	F	Top of 8-inch casing	.0	6.0	18.0	4-27-59	500	2,700	4-27-59		In	Flowing
554-142-1	Mr. Kice	Miller				6								2,680	10-28-40			Abandoned—flowing
-2	Al Grossman	do.		376		4	F							2,590	1-10-47	77.5		Flowing
-3	City of Caxambas			7			S	12x12 foot curbing	.0	20±	- 4.7	10-28-40		70	10-28-40	77	PS	
554-140-1	G. B. Patrick		1939	16		3/4	S							37	10-28-40	80	D	
-2	do.		1937	12		1	S									81	D	
554-122-1	Collier Development Corp.						F	Land surface	.0	4	34.5	5-26-61		388	5-19-60		PS	Flowing
554-118-1	Ralph Brown	O. L. Norman	1939	450		6	F											Flowing
-2	do.	Frank Noyes	1939	450		3	F										In	do.
-3	K. G. Hey	Andersen	1939	446		3	F	Center of gage	3.5	5.0	34.0	10-29-40		1,450	10-29-40	72	D	do.
553-118-1	E. A. Griffin	E. A. Griffin	1945	14		2	S	Top of well	1.3		- 1.0	6- 4-46		4,800	11- 2-51		D, In	
551-123-1	Lee County Light & Power Co.	Maharrey and Norman	1936	628	376	6	F							1,650	9-13-48		In	
-2	City of Everglades	Miller	1927	463	377	6	F							190	5-19-60		PS	
-3	do.	Maharrey and Norman	1936	478	407	6	F							360	5-19-60		PS	
-4	do.			503	375	8	F							121	10-26-59		PS	
-5	do.			409		3	F							1,440	1935			
-6	do.	Miller Bros.	1957	612	304	8	F	Top of casing	2.4		15.4	10- -59	200	885	10- -59	78	In	
550-123-1	City of Everglades	Maharrey and Norman	1935	503	375	6	F	Surface	.0	4.0	26.0	6- -61		240	10-26-59		PS	

TABLE 5. (Continued)

Well number	Owner	Driller	Year completed	Depth of well (feet)	Casing		Aquifer	Measuring point			Water level		Yield	Chloride		Temperature (°F)	Use	Remarks
					Depth (feet)	Diameter (inches)		Description	Above or below land surface (feet)	Elevation above mean sea level	Above or below (—) measuring point (feet)	Date of measurement	Gallons per minute	Parts per million	Date sampled			
549-054-1	USED	USED		38													T	USED No. L-29-G Log on file in Collier County engineering office
548-121-1	G. Hamilton	Libby and Freeman	1949	484	436	5	F	Top of 5-inch casing	1.5		31.5	8-16-49	400	1,250	8-16-49		D	
-2	Ted Smallwood			456	417	5	F							700	8-18-49		D	
-3	do.	Libby and Freeman	1949	497		4	F							950	9-19-49		D	
-4	Collier County			430		6	F							400	2-20-57			