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STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
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DIVISION OF INTERIOR RESOURCES
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BUREAU OF GEOLOGY
Charles W. Hendry, Jr., *Chief*

Report of Investigation No. 69

THE SHALLOW FRESH–WATER SYSTEM OF SANIBEL ISLAND, LEE COUNTY, FLORIDA, WITH EMPHASIS ON THE SOURCES AND EFFECTS OF SALINE WATER

By
D. H. Boggess

Prepared by the
U. S. GEOLOGICAL SURVEY
in cooperation with
BUREAU OF GEOLOGY
DIVISION OF INTERIOR RESOURCES
FLORIDA DEPARTMENT OF NATURAL RESOURCES
and the
COUNTY COMMISSIONERS OF LEE COUNTY

TALLAHASSEE, FLORIDA

1974

LETTER OF TRANSMITTAL

Bureau of Geology
Tallahassee
February 27, 1974

Honorable Reubin O'D. Askew, *Chairman*
Department of Natural Resources
Tallahassee, Florida 32304

Dear Governor Askew:

The Department of Natural Resources, Bureau of Geology, is publishing as its Report of Investigation No. 69 the report entitled, "The Shallow Fresh-water System of Sanibel Island, Lee County, Florida, with Emphasis on the Sources and Effects of Saline Water," by D. H. Boggess of the U. S. Geological Survey.

Sanibel Island for many years has been a major tourist attraction. The resident population and the number of tourists visiting the island have increased greatly over the last decade and projections indicate a much greater increase in the future. Development of land on the island has generally paralleled the rapid development in other parts of Lee County. As a result of this rapid growth, numerous land and water-resource problems have occurred on the island.

The purpose of this report is to provide a generalized description of the geology and hydrology of the surficial sediments and the surface-water network which together form the shallow fresh-water system of the island.

Respectfully yours,

C. W. Hendry, Jr., *Chief*
Bureau of Geology

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THE SHALLOW FRESH–WATER SYSTEM OF SANIBEL ISLAND, LEE COUNTY, FLORIDA, WITH EMPHASIS ON THE SOURCES AND EFFECTS OF SALINE WATER

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D. H. Boggess

ABSTRACT

The Sanibel Island fresh-water system includes the water-table aquifer and the hydraulically connected surface network of streams, ponds, lakes, and canals in the interior of the island. The aquifer and surface-water network react similarly to recharge and discharge factors and generally form a hydrologic unit. Beneath the water-table aquifer, a shallow artesian aquifer with widely different characteristics, occurs at depths ranging from about 29 to 34 feet below land surface and probably extends to depths of more than 100 feet. A clay or marl stratum of variable thickness separates the aquifers and retards the movement of water between them. Other artesian aquifers occur at greater depths beneath the island.

The fluctuation of water levels in the water-table aquifer follows a seasonal pattern; levels are highest near the end of the wet season in September or October and lowest near the end of the dry season in May or June. The annual fluctuation of the water table ranged from about 1 to 3 feet in most parts of the island in 1972. Within the shallow artesian aquifer, water levels respond to the loading and unloading of tides in the Gulf of Mexico. The tidal efficiency of wells tapping this aquifer range from about 10 to 77 percent. The artesian pressure in the aquifer is related to the tide; therefore, lowest water levels occur during the winter months when mean tide levels are lower. It is estimated that water levels in the aquifer annually fluctuate over a range of about 3 feet.

Chloride concentrations in the water-table aquifer range from 12 to 23,200 milligrams per liter; concentrations are highest in or adjacent to the salt-marsh areas along the north half of the island. Generally the chloride concentration increases with increasing depth of penetration in the aquifer, although the rate of increase is variable. Periodic sampling of streams, lakes, ponds, and canals in the interior of the island indicates a range in the chloride concentration from about 500 to 16,100 miligrams per liter. Within the shallow artesian aquifer, the chloride concentrations range from 2,250 to 30,900 miligrams per liter; concentrations are highest under the north half of the island.

The sources of saline water or the mechanisms through which this water enters the interior fresh-water system include: direct inland flow through the

Sanibel River from adjacent tidal water bodies because of leakage or overtopping the control structures during high tides; inland movement throught the water-table aquifer when fresh-water levels are at or below mean sea level; upward leakage from the shallow artesian aquifer during low stages of the water table; discharge into the interior drainage system of water from the lower part of the water-table aquifer and from the shallow artesian aquifer during dewatering operations while excavating ponds, lakes, and canals; and discharge of water from wells or test holes which tap saline water zones in the deep artesian aquifers and which are improperly cased or sealed.

Most of the problems caused by intrusion of saline water into the interior fresh-water system can be resolved. The inland movement of saline water throught the Sanibel River from adjacent tidal water bodies could largely be averted if the control structures were modified to prevent their being topped by high tides. Dewatering of excavations should be restricted to those areas where no fresh water occurs within the water-table aquifer. Excavations should be limited to depths which will not improve the hydraulic connection between the water-table and shallow artesian aquifers. All wells or test holes which penetrate any of the artesian aquifers should be plugged with cement after serving their purpose.

INTRODUCTION

Sanibel Island for many years has been a major tourist attraction. The resident population and the number of tourists visiting the island have increased greatly over the last decade and projections indicate a much greater increase in the future. Development of land on the island has generally paralleled the rapid development in other parts of Lee County. As a result of this rapid growth, numerous land and water-resource problems have occurred on the island.

In June 1970, saline water was encountered in several parts of the interior drainage system. Although the sources of the intruding saline water were identified, it was evident that additional detailed information was needed for more effective management of the fresh water in the interior of the island.

In October 1970, the U. S. Geological Survey started a more detailed investigation of the geologic-hydrologic characteristics of the island. The investigation was made in cooperation with the Lee County Board of County Commissioners and the Florida Department of Natural Resources, Bureau of Geology.

PURPOSE AND SCOPE

The purpose of this report is to provide a generalized description of the geology and hydrology of the surficial sediments and the surface-water network which together form the shallow fresh-water system of the island. The ground-water part of the investigation is based on information obtained from numerous test holes, observation wells, and private wells. Information on the surface-water system was obtained from existing ponds, lakes, and canals and those under construction and the interior drainage system of the Sanibel River. Most of the ponds, lakes, and canals were excavated to obtain fill for increasing the altitude of adjacent land areas. The methods of excavation and the depth of penetration into the underlying sediments frequently cause the quality of the water in the excavation to deteriorate. Thus, greater emphasis is placed on these excavations in the report. Particular attention has been given to the identification of sources of saline water and the effects of the saline water on the fresh-water system on the island.

Originally, the investigation was restricted to an area of about 2 square miles near the east end of the island where basic elements of the hydrologic cycle could be investigated in detail. However, it was determined early in the investigation that surface runoff could not be measured accurately because of existing and proposed changes in the drainage system. Thus, the scope of the investigation was extended to provide greater, but less detailed, coverage beyond the 2-square-mile area.

ACKNOWLEDGMENTS

The author gratefully acknowledges the cooperation of residents of Sanibel Island, other land owners, and public and private firms for permitting construction of observation wells, measurement of water levels, collection of water samples, geophysical logs, and providing other essential geologic and hydrologic information. Several drilling firms provided drill cuttings and water samples from some of the deeper wells. Most of the geophysical logs from deeper wells on the island were provided by the Florida Department of Natural Resources.

Special thanks are given to Mr. Robert L. England for the volunteer operation of the rain gages on the island and providing the rainfall records used in this report.

The continued interest and support of the Lee County Board of County Commissioners and the Sanibel-Captiva Conservation Foundation, Incorporated is gratefully acknowledged.

PREVIOUS INVESTIGATIONS

The results of two investigations have added measurably to an understanding of the geology and hydrology of the island.

An investigation by Provost (1953) established the relation between fluctuations of ground-water and surface-water levels on the breeding cycle of the salt marsh mosquito. The investigation also provided valuable data on fluctuations of the water table resulting from cyclic recharge in discharge. The report served as a basis for the present water-control system which has been a major factor in reducing the mosquito population.

The study by Missimer (1972), conducted concurrently and utilizing some of the subsurface data collected during the investigation described herein provides a rational hypothesis concerning the origin and depositional history of Sanibel Island. Missimer also provides a summary of earlier investigations which mentioned some facet of the island's geology and hydrology as part of more generalized studies.

LOCATION AND DESCRIPTION OF THE AREA

Sanibel Island is one of a series of offshore barrier islands bordering on the Gulf of Mexico along the west coast of Florida. Unlike most other islands in this chain which generally parallel the mainland, Sanibel Island forms an arc, one end of which points eastward toward the mainland and the other northwestward. The 18-square-mile island is along the coast of Lee County as shown on figure 1.

Most of the north half of the island bordering on Pine Island Sound consists of mangrove swamps and other low lying areas subject to tidal flooding. A large part of this area is in the J. N. "Ding" Darling National Wildlife Refuge (fig. 2).

Beach ridge remnants in the upland interior of the island (along State Road 867) are 4 to 7 feet above mean sea level and form a barrier to the movement of surface water. The beach ridges parallel to the present shoreline of the Gulf of Mexico similarly form a hydrologic boundary on the south side of the island. Between these upland areas, the land generally slopes toward an interior lowland, commonly referred to as the "Sanibel Slough."

Within the slough a central drainageway consisting of natural and improved channels runs along most of the length of the island. This shallow, narrow stream which flows only occasionally, is referred to as the "Sanibel River" by local residents. This name is used throughout this report to identify the main channel of the interior drainageway.

Numerous ponds, lakes, and canals have been excavated throughout the island, primarily to obtain fill to increase the altitude of adjacent land areas for development. An extensive network of shallow drainageways has been excavated both in the interior and in the salt-marsh areas for mosquito control.

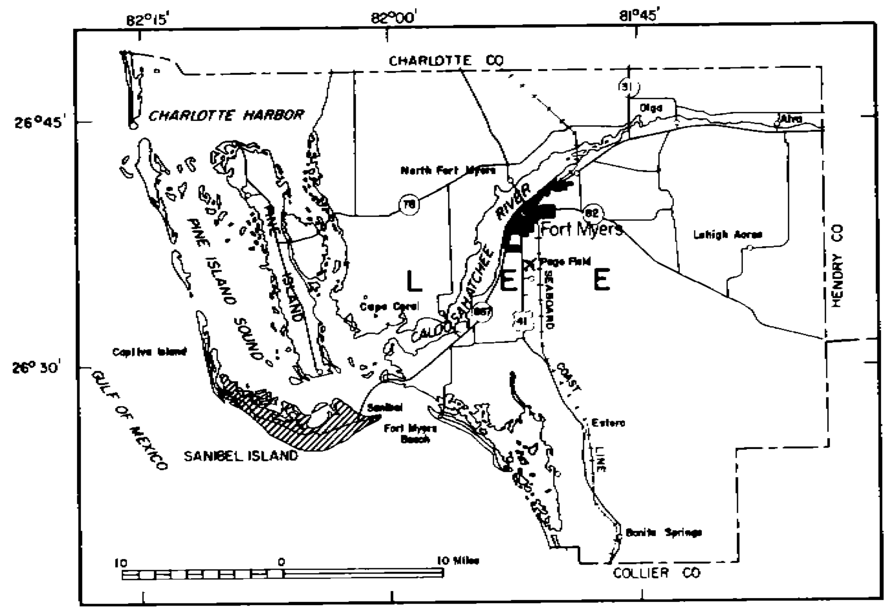
CLIMATE

The climate of Sanibel Island is subtropical; temperature extremes are modified by the tempering influence of the Gulf. The estimate average annual temperature is 74°F -- similar to that at Fort Myers. Average monthly temperatures range from 64°F in January to 83°F in August.

The prevailing wind direction is east and usually of relatively low velocity except during the passage of thunderstorms, tropical storms, or hurricanes.

RAINFALL

Monthly rainfall totals at two locations on Sanibel Island and at Page Field near Fort Myers are summarized in table 1. Station 1 on the island is near Beach Road and station 2 is 2.5 miles west, at the post office (fig. 2). Both stations are equipped with standard 8-inch metal gages, one of which is of the automatic recording type.



Base map from U.S.G.S. Topographic map

Figure 1. Map of Lee County showing location of Sanibel Island.

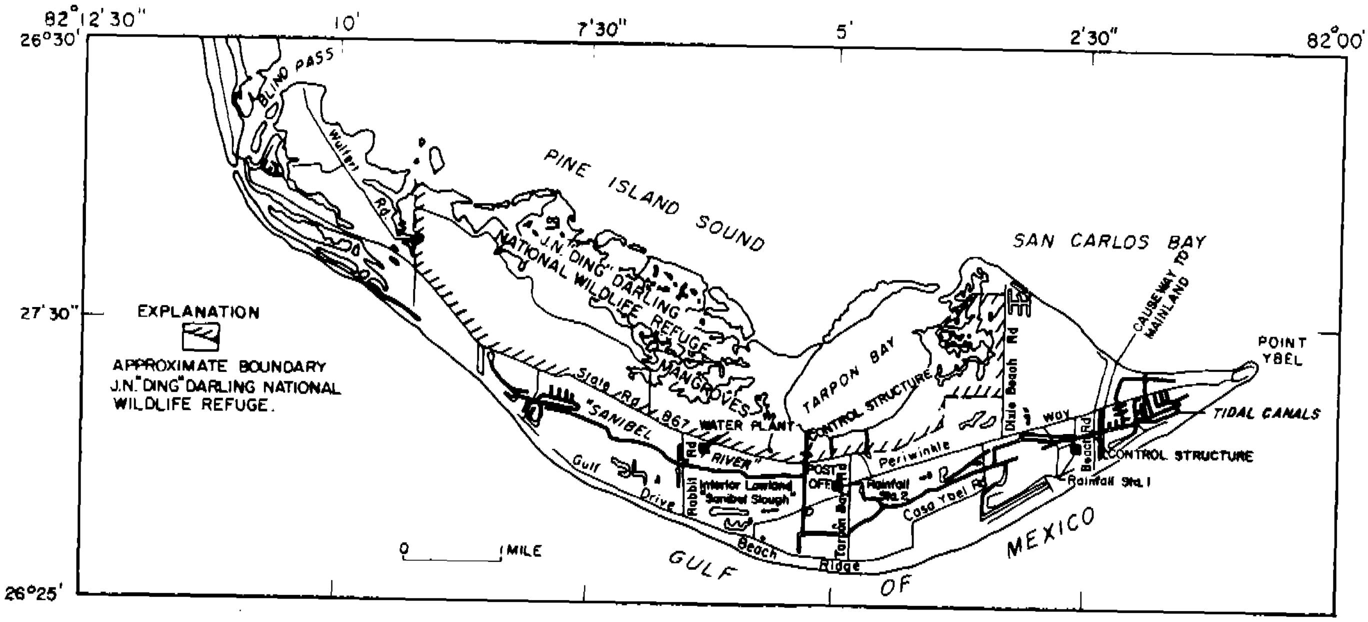


Figure 2. Map of Sanibel Island showing road network, interior drainage system, and other features or names used in the report.

TABLE 1. MONTHLY RAINFALL TOTALS IN INCHES FOR STATIONS 1 AND 2 ON SANIBEL ISLAND AND PAGE FIELD NEAR FORT MYERS, 1971 - 72.
(Records for Page Field from Environmental Data Service, U. S. Department of Commerce.)

1971

Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Sanibel Island Station 1	2.45	1.90	0.14	0.90	1.33	2.67	3.59	9.50	15.25	5.16	0.33	1.14	44.36
Sanibel Island Station 2	–	–	–	–	–	–	–	6.36	17.88	5.40	0.42	1.06	–
Page Field near Ft. Myers	0.85	1.55	0.55	0.70	3.97	6.18	9.50	8.06	9.21	6.49	0.16	0.30	47.32

1972

Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Sanibel Island Station 1	1.32	2.07	5.35	0	0.52	7.82	3.84	8.49	4.17	1.03	5.41	1.32	42.34
Sanibel Island Station 2	1.19	1.77	4.75	0	0.57	7.34	3.57	3.57	3.61	0.94	5.26	1.30	37.75
Page Field near Ft. Myers	0.77	2.14	4.72	0.27	5.20	7.86	9.72	16.22	2.33	2.20	3.85	1.43	56.71

The seasonal distribution of rainfall typical of south Florida where wet and dry seasons alternate is evident. For example, the cumulative rainfall for station 1 is about 36 inches for June to November 1971 and about 11 inches, or about one-fourth of the annual total, from November 1971 to June 1972. The seasonal pattern at Page Field is similar.

Monthly rainfall totals for stations 1 and 2 are somewhat different particularly during the wet season. In August 1971, this difference was about 3.5 inches. Most of this difference resulted from afternoon thunderstorms on August 5-7 and 11 when 4.8 inches was recorded at station 1 and 1.7 inches at station 2. These differences are largely related to the erratic path of thunderstorms which cause heavy rainfall in some areas and little or none elsewhere.

Comparison of records from Sanibel Island with those from Fort Myers provides an even greater contrast. Table 1 shows wide difference in monthly totals for June, July, and September 1971 and May, July, and August 1972. These differences may nearly balance over longer periods as indicated by the annual totals for 1971, or may result in a difference in annual totals of more than 15 inches such as in 1972.

Continuous records from station 2 show that the rainfall intensity was maximum on March 31, 1972 when 3.5 inches was recorded between noon and 1:00 p.m. By 2:00 p.m. the total had reached 4.5 inches. In September 1971, the intensity ranged from about 1.3 to 2.1 inches per hour.

WELL CONSTRUCTION, INVENTORY, AND NUMBERING SYSTEM

During the investigation, 54 observation wells were drilled or driven on the island (fig. 3). Most of these were constructed in pairs about 2 feet apart. One well of each pair was used to obtain core samples to depths ranging from about 25 to 36 feet, to collect water samples, and to measure water level. The other well, equipped with a screen, was driven to depths ranging from about 8 to 13 feet and was used to measure water levels and collect water samples. At two of these sites, a third well was driven to a depth of about 17 feet. Four wells were drilled to depths of 10-12 feet along a north alignment across the island. All of the shallower wells were used for the collection of water samples and measurement of ground-water levels.

In addition to the observation well network, existing wells or those under construction supplies geologic and hydrologic information. Selected information from wells or test holes inventoried during the investigation is summarized in table 2. (See appendix.)

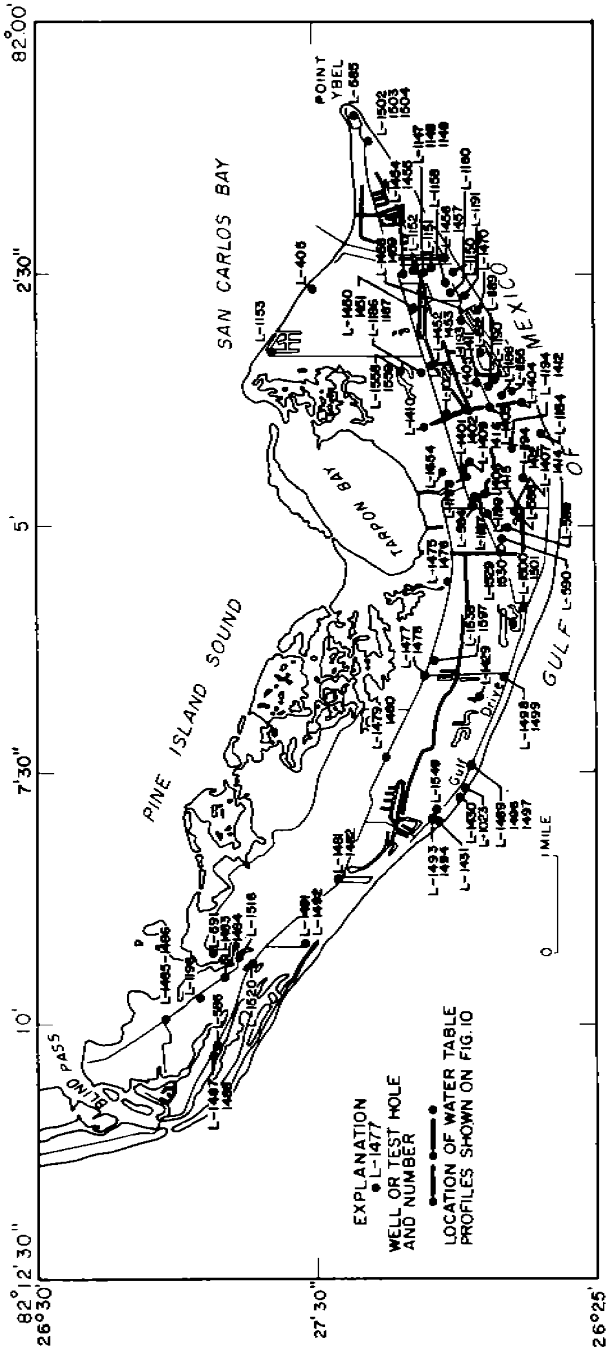


Figure 3. Map showing location of wells and test holes on Sanibel Island.

The well numbers used in this report are part of a county-wide system where numbers are assigned in sequence as each well is inventoried. The letter prefix L refers to Lee County. Thus, well L-405 indicated that information had been obtained on 404 wells in the county at the time this well was added to the inventory. In table 2, a second series of numbers is given which more precisely identifies the well location to the nearest second of latitude and longitude.

WATER–BEARING FORMATIONS

DEEP ARTESIAN AQUIFERS

Relatively little information is available on the lithology of the deeper sediments underlying Sanibel Island. The deepest test hole (L-1533) on which detailed information was obtained during the investigation was drilled to a depth of 895 feet at the Island Water Association water plant. Based on drill cuttings and geophysical logs obtained on this test hole, the geologic formations and aquifer underlying the island have tentatively been identified on the log shown on figure 4. Information from other deep wells on the island, however, indicate that the log for test hole L-1533 may not by typical. The sediments comprising the Tamiami Formation are thicker than elsewhere on the island and sediments that occur at shallower depths are of different composition.

Although making a complete inventory of deep artesian wells was not within the scope of this investigation, some information on 18 deep wells or test holes is included in this report. Many of these wells were drilled to the Hawthorn Formation or the underlying Tampa Limestone. The water-bearing zone which includes the lower part of the Hawthorn Formation or the underlying Tampa Limestone. The water-bearing zone which includes the lower part of the Hawthorn Formation and the upper part of the Tampa Limestone is termed the lower Hawthorn aquifer by Sproul and others, (1972, p. 9). Wells more than 700 feet deep may also tap the Suwannee aquifer which includes the upper part of the Suwannee Limestone and the lower part of the Tampa Limestone (Sproul op. cit.). Both the lower Hawthorn and Suwannee aquifers are generally present beneath the island. Based on well depths and available geologic information, most of the deep artesian wells on Sanibel Island tap the lower Hawthorn aquifer.

The highest head measured during the investigation was for well L-585 near the eastern tip of the island. In November 1970, the head was 27.4 feet above the land surface, or about 32.4 feet above mean sea level. A recorder installed on this well showed a direct response to tidal loading, with a change in head of about 1 foot during a tide cycle. Levels in other wells drilled to the lower Hawthorn aquifer have artesian heads ranging from about 16 to 32 feet

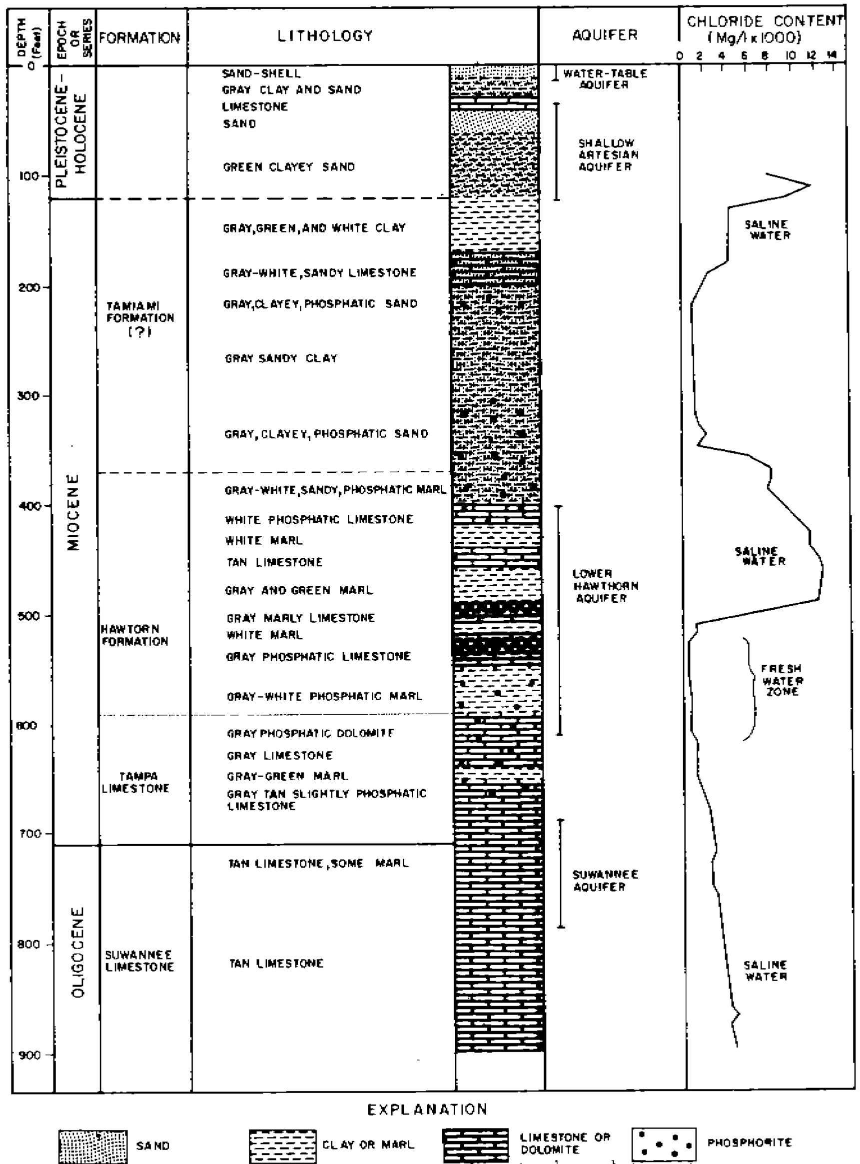


Figure 4. Log showing the geologic formations, lithology, aquifers, and chloride concentrations in water from test hole L-1533.

above mean sea level. The lower artesian head in wells in some areas may be related to previous discharge from the well or continued discharge from other wells in the same general area. The lower head may also indicate that if the metal well casing has deteriorated, water could be leaking from the well into other aquifers.

Saline water as defined by the U.S. Geological Survey is water which contains more than 1,000 mg/l (milligrams per liter) of dissolved solids. Highly saline water refers to concentrations of dissolved solids exceeding 10,000 mg/l. The chloride concentration which is one of the chemical constituents comprising the dissolved solids, is used in the report as an indicator of salinity.

Highly saline water was encountered at two depth intervals in test hole L-1533 (fig. 4). The peak chloride concentration occurred at a depth of about 100 feet within the shallow artesian aquifer. The high chloride concentrations in the depth interval 350-500 feet occurs near the contact between the Tamiami and Hawthorn Formations, or entirely within the latter. Well drillers commonly report this zone of highly saline water in other parts of the island. A water sample from well L-1512 near the east end of the island has a chloride content of 13,100 mg/l at a depth of 372 feet.

The water from the lower Hawthorn aquifer is less highly mineralized near the west or northwest end of the island than near the center or on the east end. These differences in water quality may be related to vertical displacement of the formations resulting from minor faults, one of which is indicated by correlation of gamma ray logs of wells on the east end of the island. Because few wells tap the Suwannee aquifer, little is known about the water quality. As indicated by the data shown on figure 4, the chloride concentrations can be expected to increase with depth in the Suwannee aquifer.

Because of these saline-water zones, 350 to 500 feet of casing are required in constructing wells on Sanibel Island where as on the mainland, wells drilled to comparable depths seldom contain more than about 150 feet of casing. These fully cased wells provide a more accurate indication of artesian pressure in the deeper aquifers than most wells on the mainland.

SHALLOW ARTESIAN AQUIFER

Core samples were obtained from a series of wells drilled throughout the island. Most of these wells penetrated a limestone stratum at depths ranging from about 29 to 34 feet below land surface. The core samples were used in the preparation of figure 5, which shows the approximate altitude of the top of the limestone beneath the island. None of these wells penetrated the full thickness

of the limestone. However, drill cuttings from wells L-1472 and L-1512 (not shown on fig. 5) near the east end of the island, show that the limestone stratum extends to a depth of about 130 feet in that area. Near the center of the island, drill cuttings from test hole L-1533 and well L-1597 indicate that the limestone extends to a depth of only 41 feet, where it is underlain by about 100 feet of green and tan sand. Although the limestone is of variable thickness, it apparently underlies all of Sanibel Island.

The water-bearing parts of this limestone, together with the permeable shell bed immediately above and the hydraulically connected sandy sediments below, are referred to herein as the shallow artesian aquifer. The aquifer is overlain by clay or marl deposits which act as a confining bed and which separate the aquifer from the overlying water-table aquifer.

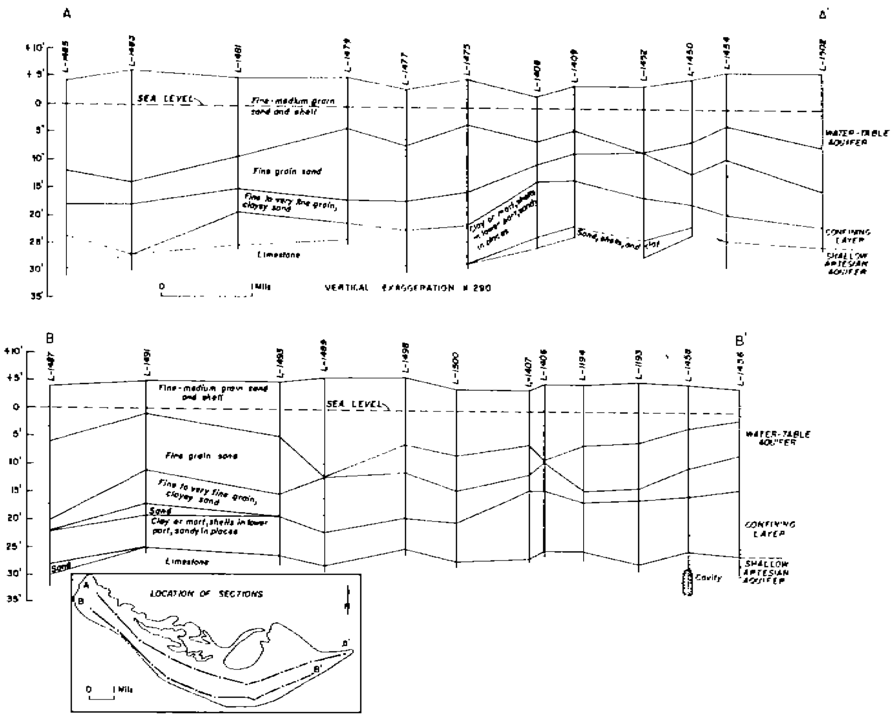


Figure 5. Lithologic sections showing thickness of surficial sediments.

WATER-LEVEL FLUCTUATIONS

Typically, fluctuations of water level in the shallow artesian aquifer reflect only very small changes in ground-water storage. Water levels in the shallow artesian aquifer fluctuate primarily in response to the tides in the Gulf as shown on figure 6. On the incoming tide, the additional weight of water compresses the aquifer causing an increase in artesian pressure and a rise in water levels in wells penetrating the aquifer. This mechanism reverses during the out going tide. Thus, the fluctuation in water levels is largely related to tidal loading rather than to an exchange of water between the aquifer and water in the Gulf. This is virtually the same mechanism responsible for the tidal variations in artesian pressure within the lower hawthorn aquifer as previously described.

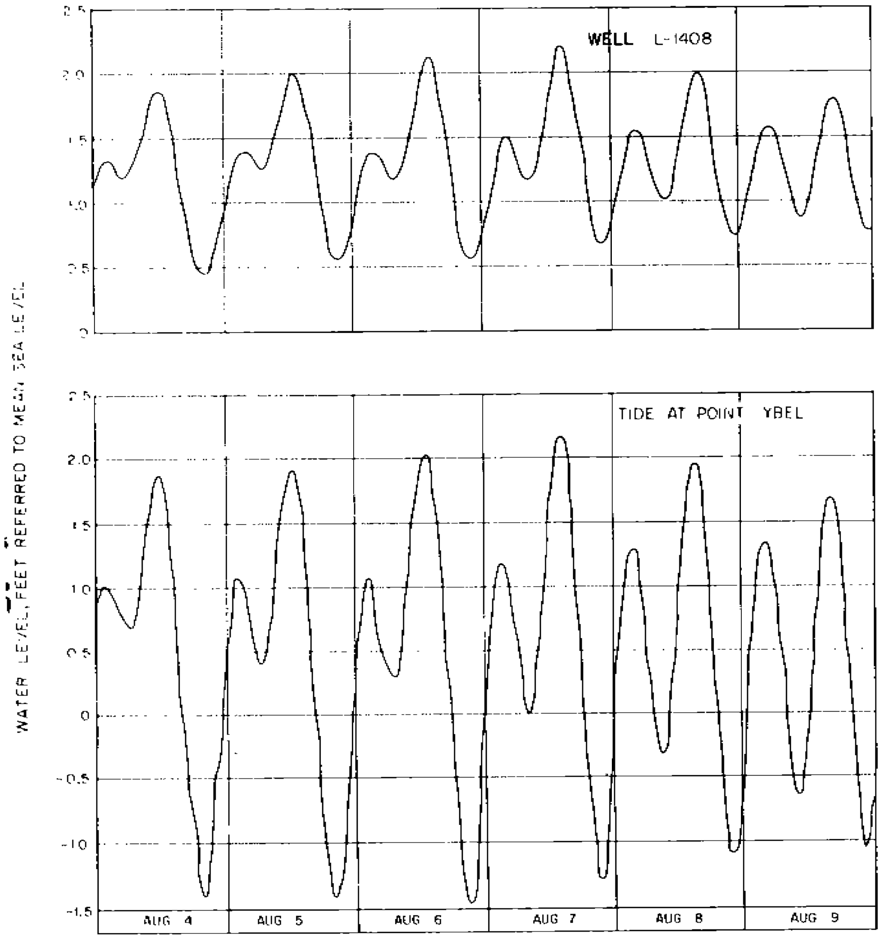


Figure 6. **Tracing of records from the tide gage at Point Ybel and well L-1408, Aguust 4 - 9, 1971.**

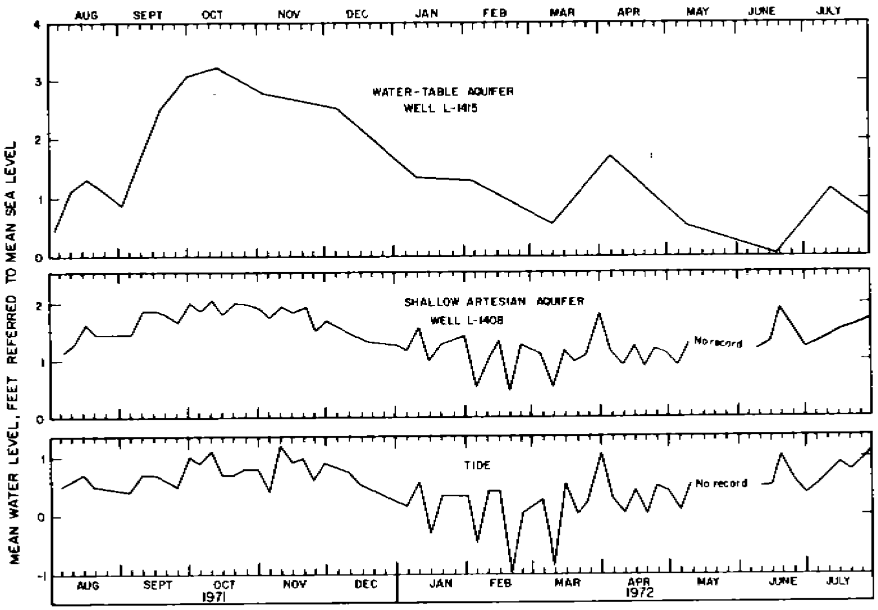


Figure 7. **Graph showing water-level fluctuations in wells L-1408 and L-1415 and tide at Point Ybel, August 1971 - July 1972.**

The water level in well L-1408 fluctuates about 43 percent of the range in tide levels (fig. 7). This is referred to herein as the tidal efficiency of the well, although it is recognized that minor effects resulting from changes in barometric pressure are also included. The tidal efficiency of other wells drilled to the shallow artesian aquifer was from about 10 percent in well L-1479 to 77 percent in well L-1456 and averaged 43 percent.

Inasmuch as water levels in a confined aquifer are related to the tide, it follows that the water levels are highest at highest tide stages and lowest during low tide stages. The highest water level recorded over the period of record was 3.45 feet above mean sea level in well L-1456 on June 19, 1972 with a tide level 3.60 feet above mean sea level. The lowest level recorded was 1.80 feet below mean sea level in the same well on January 16, 1972 with a low tide level 3.03 feet below mean sea level. This indicates a range in fluctuation of water level in the shallow artesian aquifer of 5.25 feet at the location. However, based on the tidal efficiency of each well versus the maximum range in tide levels, it was estimated that water levels in the aquifer fluctuate annually over a range of only about 3 feet. Although water levels in the aquifer fluctuate in response to changes in tide levels, they do not occur at the same time. Generally the change in water level within the aquifer lags the change in tide level from 10 minutes to about 3 hours.

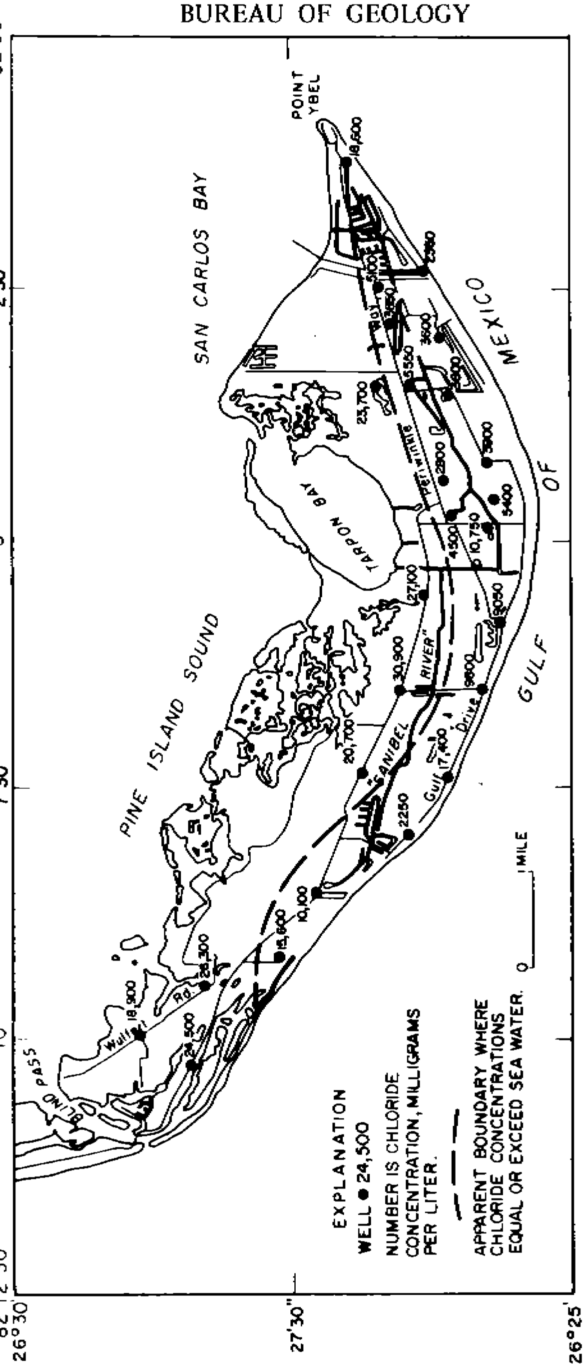


Figure 8. Map of Sanibel Island showing chloride concentrations in water form the upper part of the shallow artesian aquifer.

Over a year, as shown on figure 7, the fluctuations in water levels within the shallow artesian aquifer are responsive to changes in the tide level rather than to changes in water levels in the overlying water-table aquifer. The tide level is lower during the winter months; water levels in the shallow artesian aquifer are lower during this period than at any other time.

CHLORIDE CONCENTRATIONS

The chloride concentrations in water from the shallow artesian aquifer ranged from 2,250 mg/l (milligrams per litter) in well L-1493 to 30,900 mg/l in well L-1477. The distribution of chloride in the upper part of the aquifer is shown on figure 8. The water samples were collected while the wells were being constructed, December 1970 to November 1971. The chloride concentrations in the aquifer along the north half of the island equals or exceeds that of sea water (see fig. 8). This suggests the presence of evaporite beds in the upper part of the aquifer resulting from the concentration of sea water while the sediments were being deposited. The chloride concentration of 24,600 mg/l in water from well L-1447 at a depth of 62 feet suggests that similar beds also occur at greater depth.

Apparently some flushing of the upper part of the aquifer has occurred within recent geologic time as indicated by the lower chloride concentrations in some areas. Perhaps this occurred during lower stand of the sea when difference in head between the water table and shallow artesian aquifers was greater. However, it is unlikely that the effects of flushing have significantly altered the predominantly saline character of water in the lower part of the aquifer.

WATER–TABLE AQUIFER

The shallow subsurface sediments underlying Sanibel Island are predominately sandy. On the basis of lithology and apparent hydrologic characteristics, these sediments may generally be divided into an upper, middle, and lower zone. The upper zone, consisting of fine to medium grained sand and shell, is of relatively high permeability. The middle zone, of fine sand, is of relatively low permeability. The lower zone, with the fine sand, containing varying percentages of silt and clay sized particles, is of relatively low permeability. Collectively, the saturated part of these sediments comprises the water-table aquifer. The water table is the upper surface of the zone of saturation.

The strata underlying the water-table aquifer consist predominantly of silt and clay size sediments, apparently of low permeability. These clay strata function primarily as a barrier to the movement of water either downward from the water-table aquifer, or upward from the underlying shallow artesian aquifer.

WATER–LEVEL FLUCTUATIONS

Changes in the position of the water table indicate changes in the volume of water in storage. The water table fluctuates primarily in response to recharge from rainfall and discharge as base flow to streams, ponds, canals, and other surface water bodies and to natural processes of evaporation and transpiration. Fluctuations of the water table in well L-1403 are related to rainfall at station 2 as shown on figure 9. Note that the water table rises during periods of heavy rainfall and declines during periods of little rainfall. Thus, during the annual cycle the water table is highest near the end of the wet season in September or October and lowest near the end of the dry season in May or June. Superimposed on this annual recharge cycle are the effects of evaporation and transpiration which probably reach a maximum during the summer and a minimum in January.

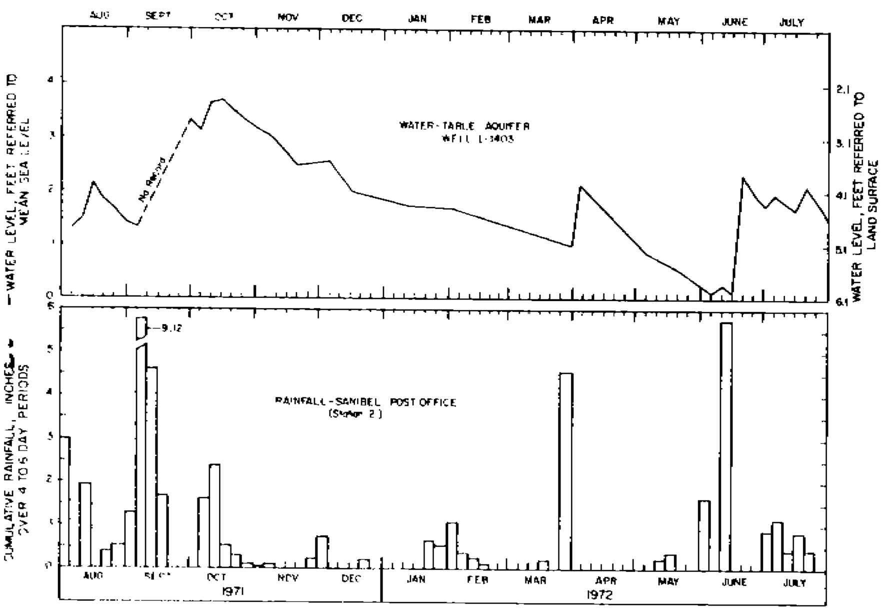


Figure 9. Graph showing fluctuation of the water table in well L-1403 and rainfall at station 2 (Sanibel Post Office).

The water table, generally following the topography of the land surface, is higher beneath the upland beach ridge areas and lower in the interior lowlands or along the coastal margins. Profiles of the water table across the island at different times are shown on figure 10. Water-level data from the four wells shown, indicate the general changes that occur at different water stages.

The water level in well L-1403, on the upland area along Casa Ybel Road, was consistently higher than in other wells. The water table was near or below mean sea level for about 10 weeks in April, May, and June 1971 (fig. 10). Levels in observation wells L-1411 through L-1416 in adjacent areas also were low.

During these low-water stages, saline water from tidal water bodies surrounding the island may move inland into the water-table aquifer. The extent of this inland movement is controlled in part by the hydraulic gradient and the length of time over which these conditions prevail.

The annual range in fluctuation of the water table is variable depending on recharge and discharge factors. As shown by the hydrographs for wells L-1412, L-1414, and L-1416 on figure 11, the water table reached both lower and higher altitudes in 1971 than in 1972. The range in fluctuation of the water table of 3.6 to 4.8 feet as indicated in these wells in 1971, probably represents near extreme conditions of high and low water levels in this part of the island.

An observation well network in the water-table aquifer was completed in November 1971. The highest and lowest observed water-levels in 1972 are shown on figure 12. Levels were generally lowest during June 1972, except for wells L-1455, L-1457, and L-1503 at the east end of the island, and wells L-1484, L-1486, and L-1488 at the northwest end of the island whose levels were lowest in March 1972. The highest and lowest levels shown on figure 12 represent extremes over a very short period of record and levels both higher and lower should be expected as shown on figure 11.

Not all the high water levels shown on figure 12 occurred at the same time because of the erratic distribution of rainfall. However, most occurred during or immediately following the wet season.

Short-term records from most of the observation wells indicate an annual fluctuation of the water table from about 1 to 3 feet.

CHLORIDE CONCENTRATIONS

Water from the water-table aquifer ranged in chloride from 12 mg/l in well L-1401 to 23,200 mg/l in well L-1516 (table 2). This extreme range is related to

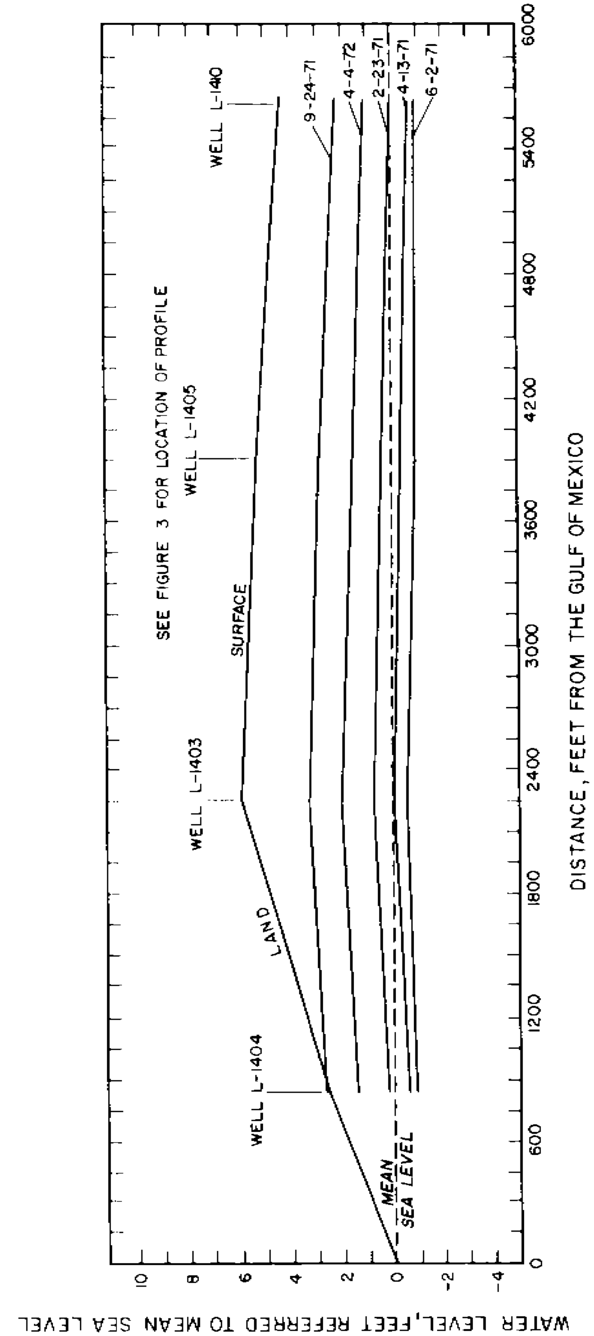


Figure 10. Profile across Sanibel Island between wells L-1404 and L-1410 showing seasonal water levels in the water-table aquifer.

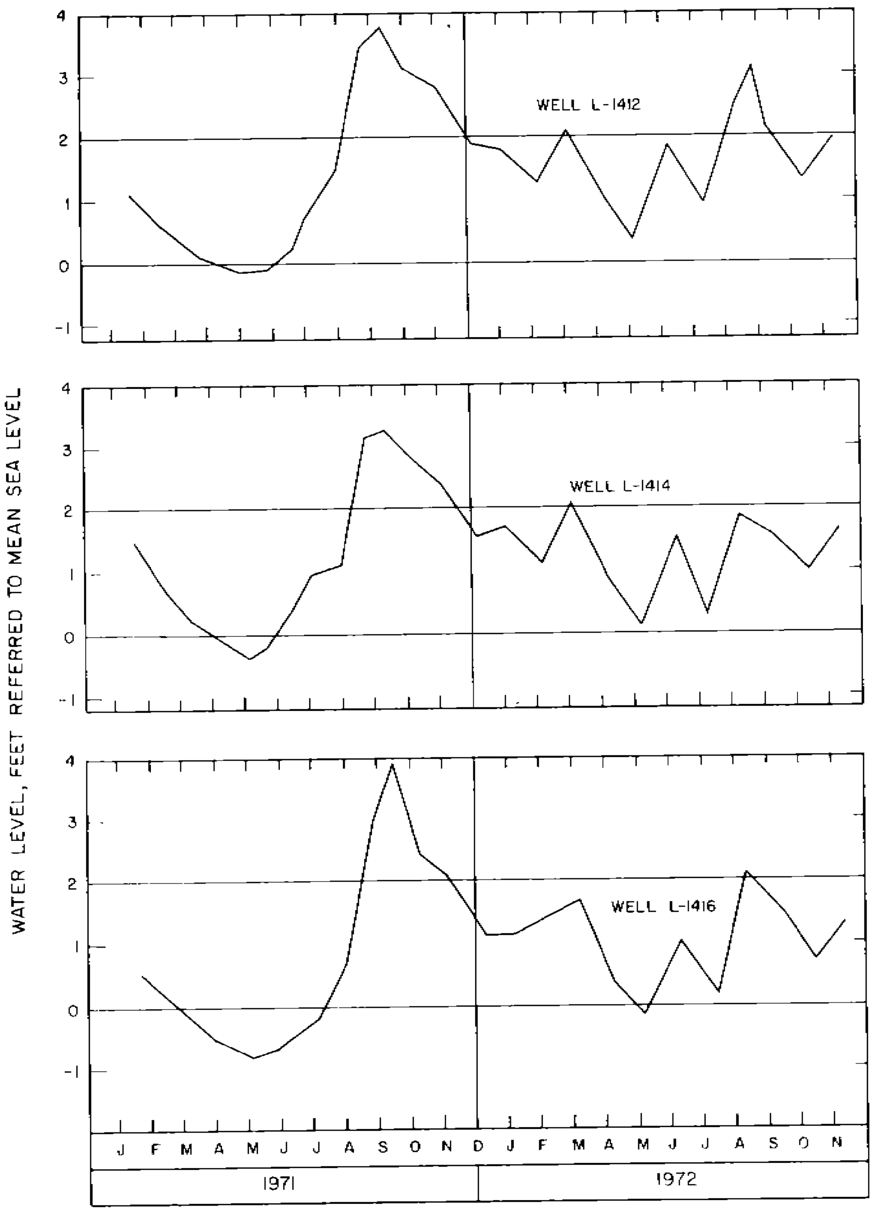


Figure 11. Hydrographs showing fluctuations of the water table in wells L-1412, L-1414, and L-1416, in 1971 - 72.

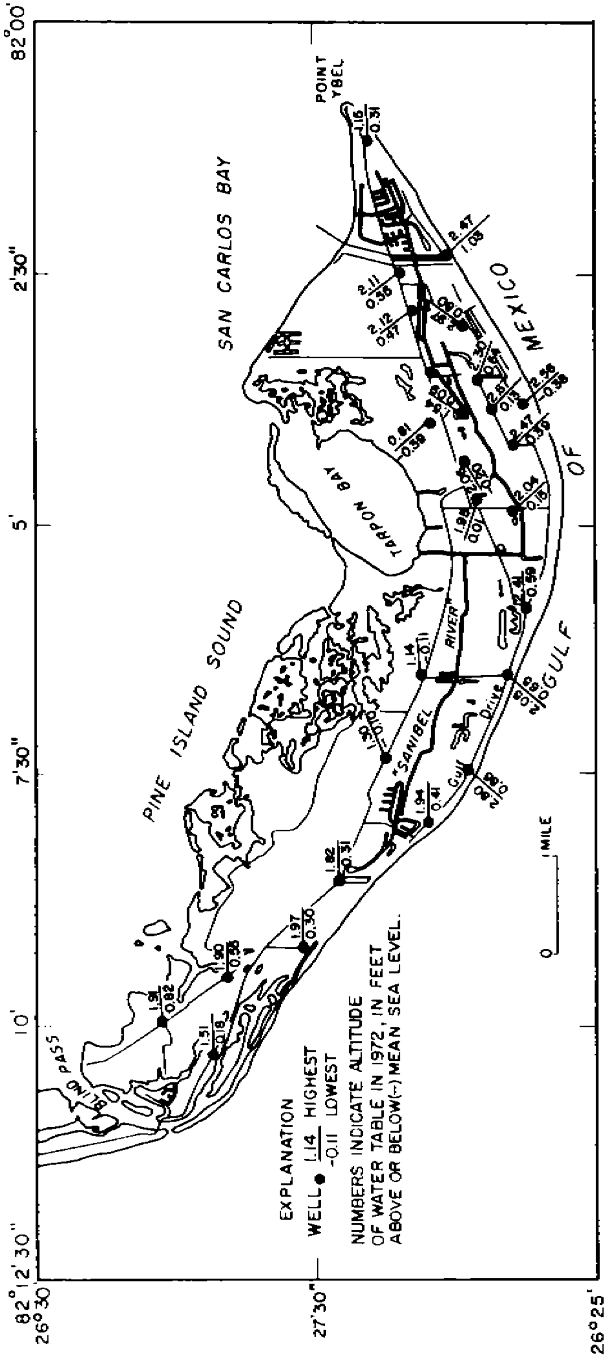


Figure 12. Map of Sanibel Island showing highest and lowest altitude of the water table in 1972.

several different factors. Concentrations are generally higher in the low lying areas along the north half of the island. Concentrations generally are lower beneath the interior upland areas.

In most parts of the island, the chloride concentrations increase with depth in the water-table aquifer as indicated on figure 13. For example, water

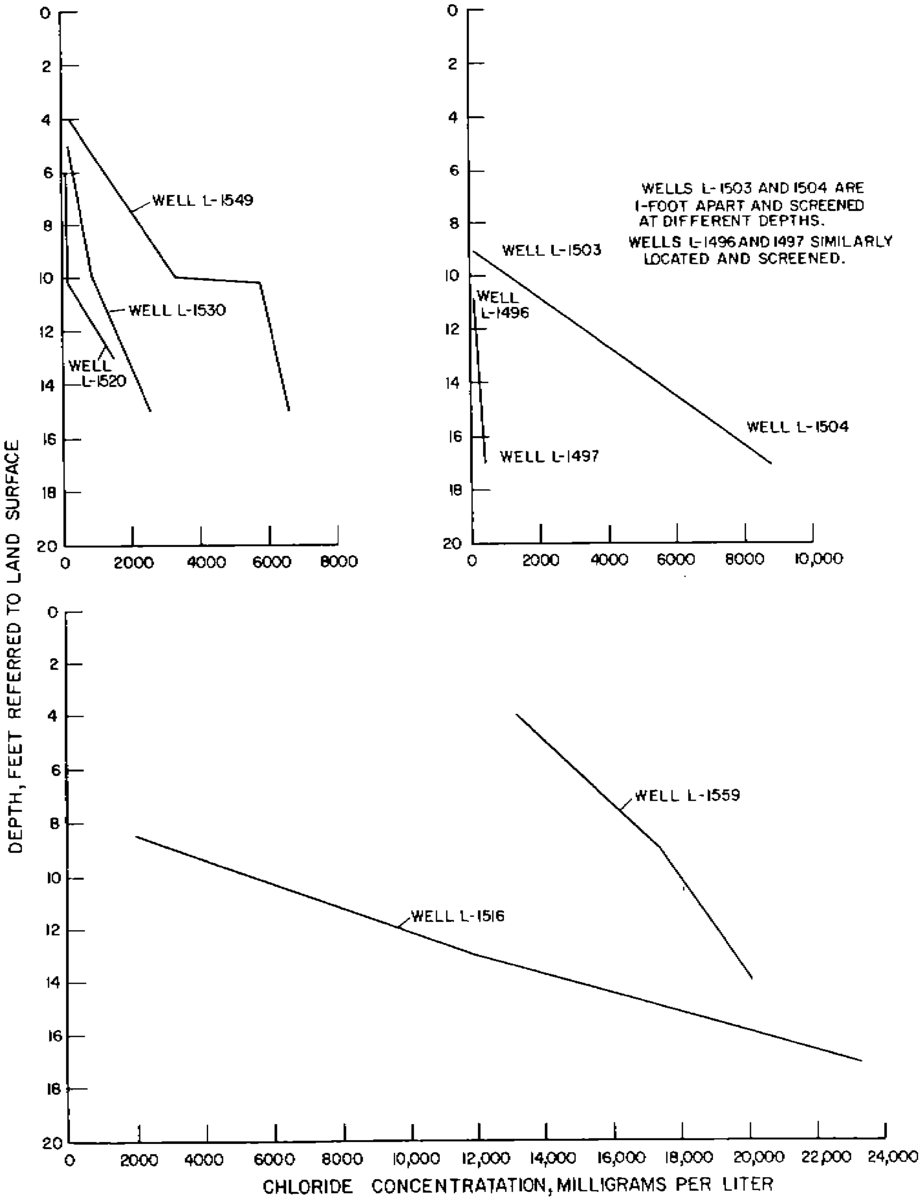


Figure 13. Graphs showing increase in chloride content of water with depth in the water-table aquifer.

from well L-1559, near the mangrove swamp on the north side of the island, increased progressively in chloride from 13,250 mg/l at a depth of 4 feet to 20,050 mg/l at 14 feet. Water from well L-1516 in a similar environment near the northwest end of the island, increased in chloride from 2,250 mg/l at a depth of 8 feet to 23,200 mg/l at 17 feet. Chloride concentrations greater than the 19,000 mg/l determined for water in the Gulf of Mexico, as stated earlier, indicates the presence of evaporite beds where sea water has been concentrated by evaporation. In the interior of the island, particularly beneath the beach ridges, chloride concentrations increased less with depth. For example, the chloride content in water from well L-1496 was 130 mg/l at a depth of about 11 feet, whereas in well L-1497 the chloride was 375 mg/l at a depth of about 17 feet. The two wells are 1 foot apart. In contrast wells L-1503 and L-1504, both near the shore and of similar construction, showed a chloride content of 190 mg/l at a depth of about 9 feet and 8,950 mg/l at about 17 feet. Other test wells that tap the water-table aquifer on the island show similar increases in chloride concentrations with depth but the rate of increase is highly variable.

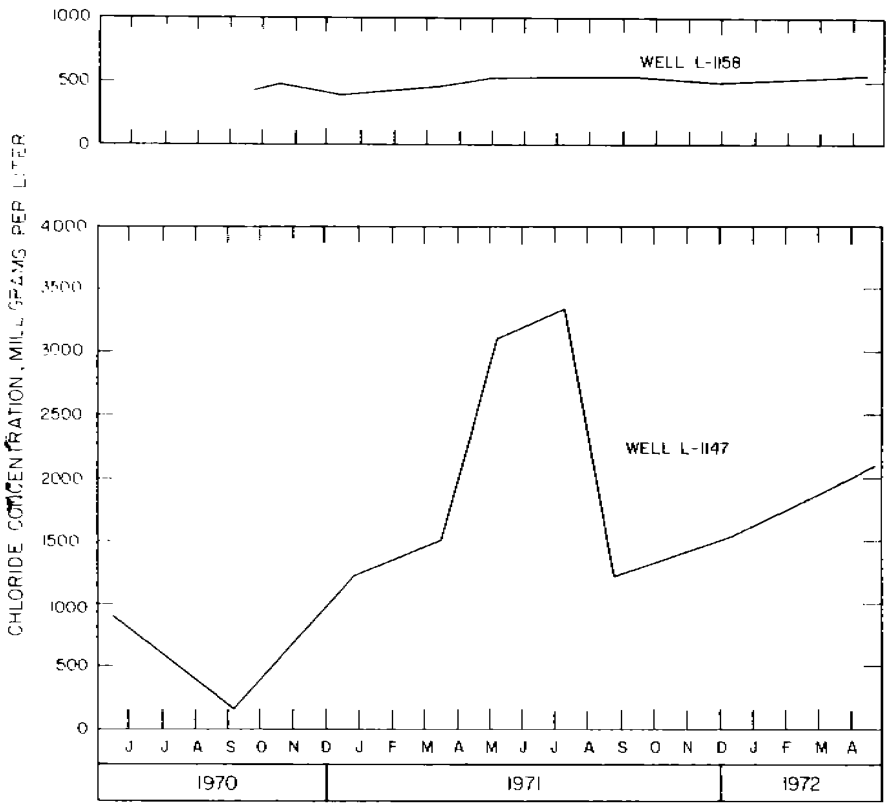


Figure 14. **Graph showing variation in chloride content in wells L-1147 and L-1158, June 1970 - May 1972.**

Chloride concentration of water at a given depth interval also varies with time. The wide variation in chloride content shown in figure 14 for well L-1147 probably is not typical of the aquifer generally because of the proximity of this well to the Sanibel River which contained highly saline water during part of the period of record. In contrast, the relatively small variations in chloride in well L-1158 may be typical of water only in the aquifer beneath the beach ridge bordering the gulf. Nevertheless, periodic measurements in other water-table wells indicated variations in chloride concentrations within the same depth interval ranging from 25 to 1,550 mg/l.

SURFACE WATER

Surface water on the island includes the central interior drainageway of the Sanibel River and connected secondary drainage ditches and other small natural channels, canals, ponds, lakes, and other water-storage areas. Tide water canals, channels, and ditches also form a part of the surface-water network because they provide avenues for the inland movement of saline water, or drainage routes for discharge of water from the interior of the island.

During the investigation, surface-water samples for chloride determination were obtained at numerous sites throughout the inland (fig. 15). Generally the chloride concentrations were determined from specific conductance-chloride curves developed from water samples from the island. Because of the density stratification in water which commonly occurs where saline and fresh water are present, samples were obtained from near the surface and at the bottom at each sampling site where the water depth exceeded 3 feet. Unless otherwise specified chloride concentrations shown are those of bottom samples. In addition, during low-water periods the culverts beneath road crossings along the Sanibel River did not permit an exchange of water, so that it was necessary to collect both upstream and downstream samples at some sites. By definition upstream refers to the west, downstream to the east.

SANIBEL RIVER

The main channel of the Sanibel River is connected throughout most of its length beginning at a pond at site S-23 toward the west end of the island to the tidewater canal system at Beach Road (S-1) near the east end (fig. 15). The length of the channel is about 8 miles, and the width varies from less than 10 feet to more than 50 feet depending on the extent of modification by dredging. The altitude of the stream bed also is highly variable although nearly always at or below mean sea level.

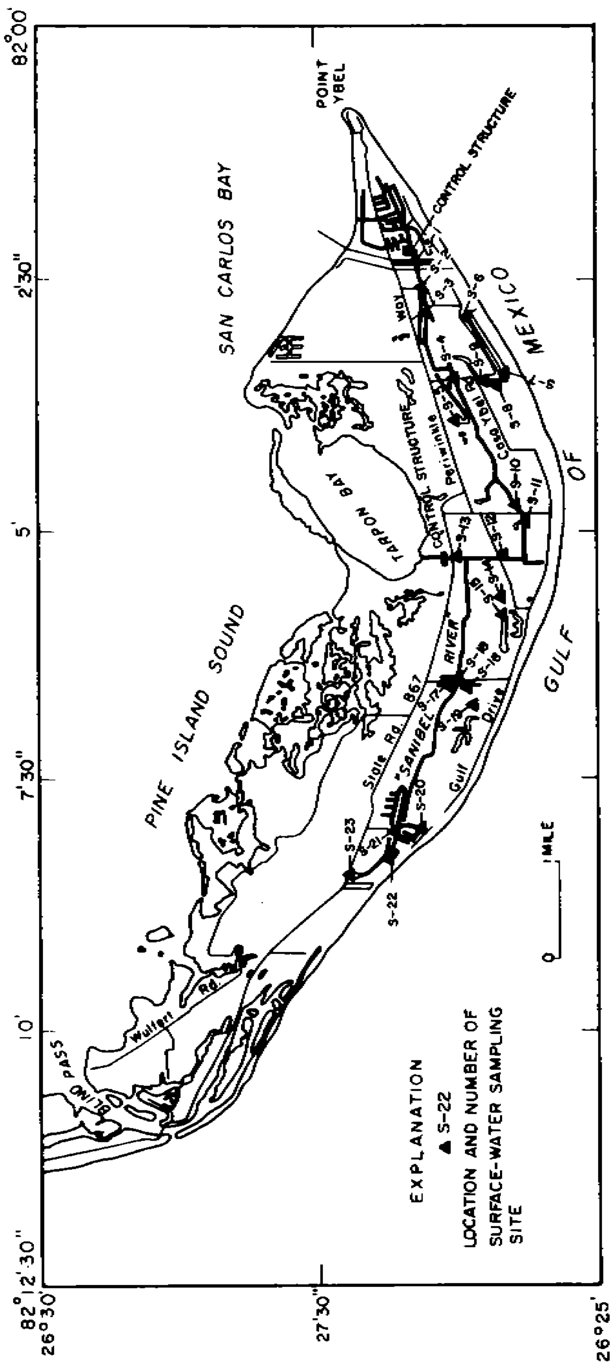


Figure 15. Map of Sanibel Island showing location of selected surface-water sampling sites.

The stream is connected at all road crossings by culverts. The bottoms of some culverts are several feet above the stream bed. These culverts, plus other irregularities in the stream bed result in segmentation of the stream during low water. During high water stages, water flows through the culverts to points of discharge through control structures at Tarpon Bay or at Beach Road. Because of relatively low gradients throughout the length of the stream, water may flow toward either the Tarpon Bay or Beach Road control structures. However, during most of the period of this investigation, the area west of site S-4 on the Casa Ybel Road drained toward the Tarpon Bay control structure because the channel east of site S-4 was blocked by an earthen dam.

The river discharges to the bays only after heavy rainfall, and then usually for only a short time. It is estimated that about 500 million gallons of water was discharged through the control structure into Tarpon Bay after the heavy rainfall in September 1971. About 100 million gallons was discharged into the tidal canal at Beach Road over the same period.

Sanibel River was sampled at nine sites, S-1, S-2, S-3, S-4, S-10, S-11, S-13, S-18, and S-21. Site S-1 is about 20 feet upstream from the control structure at Beach Road. The chloride content at site S-2 (downstream) was virtually the same as site S-1. The chloride concentrations at site S-1 were highest during the low river stages in May, June, and July 1971 (fig. 16). The progressive increase in chloride content from November 1970 until May 1971 was the result of upstream leakage of saline water through the Beach Road control structure. The intruding saline water moved upstream to the downstream side of site S-2 where a roadway prevented further movement. The culverts beneath the road were above the stream level over most of this period. The heavy rainfall in September 1971 flushed most of the saline water in the reach between sites S-1 and S-2 downstream. Modification of the control structure in September 1971, combined with generally higher water stages,reducing the upstream leakage of saline water, has lowered chloride concentrations in water in the reach between sites S-1 and S-2.

The sharp increase in chloride content of water on the upstream side of site S-2 in October 1971 was the result of continuous discharge of water into the river from artesian well L-1472 which contained 5,850 mg/l of chloride. This well was capped in October 1971 and the effects were largely dissipated by November 1971 as indicated by the chloride samples at site S-2 (upstream).

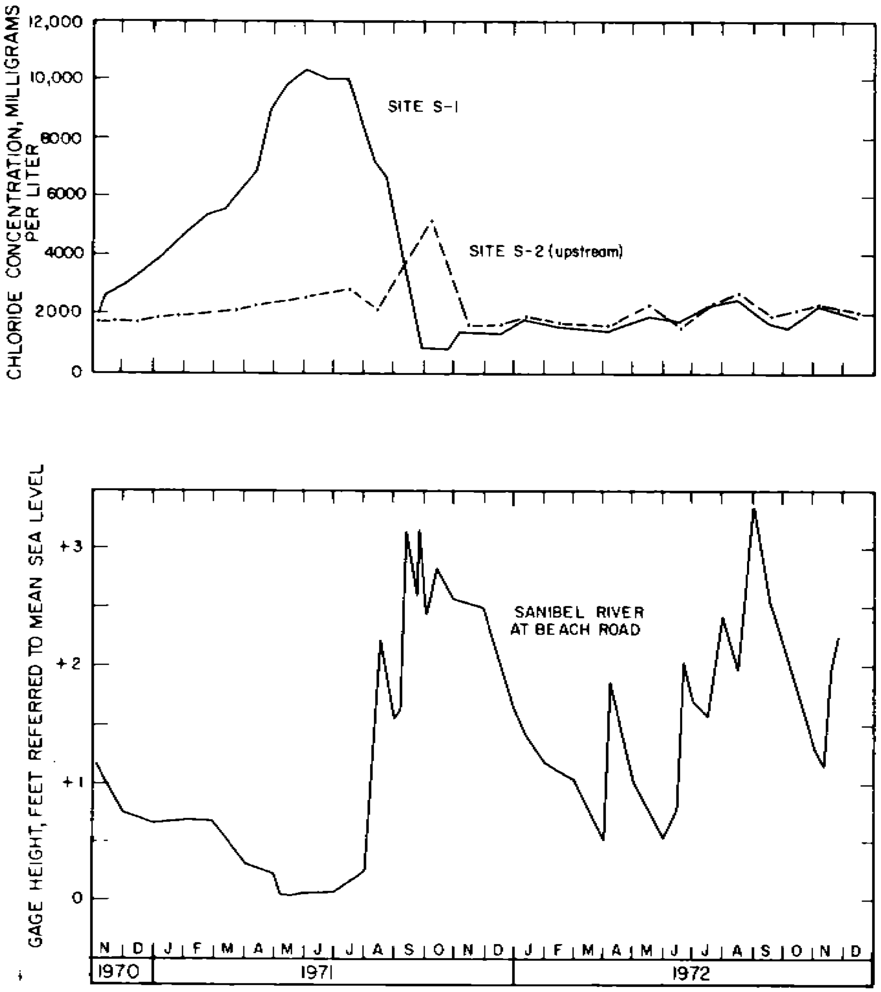


Figure 16. Graph showing variation in river stage at Beach Road and chloride concentrations in water at sites S-1 and S-2 (Upstream) November 1970 - December 1972.

The bottom chloride concentrations in water at sampling sites S-3 and S-4 downstream are shown on figure 17. Over most of the period of record, an earthen dike near site S-4 prevented an interchange of water between these sites. In addition, parts of the former river channel had been filled and an alternate by-pass canal had been excavated. The initial high chloride of 11,000 mg/l in water at site S-3 on June 20, 1970, probably was caused by previous dewatering operations during the excavation of the canal near site S-6. Water pumped from

this excavation drained into the Sanibel River through a series of connecting ditches. By October 1970, the saline water at site S-3 had been dissipated as a result of discharge at Beach Road. Since then, the records from site S-3 indicate a seasonal increase in chloride concentrations during the day season which is reduced during the wet season as a result of discharge from the river and dilution by rainfall.

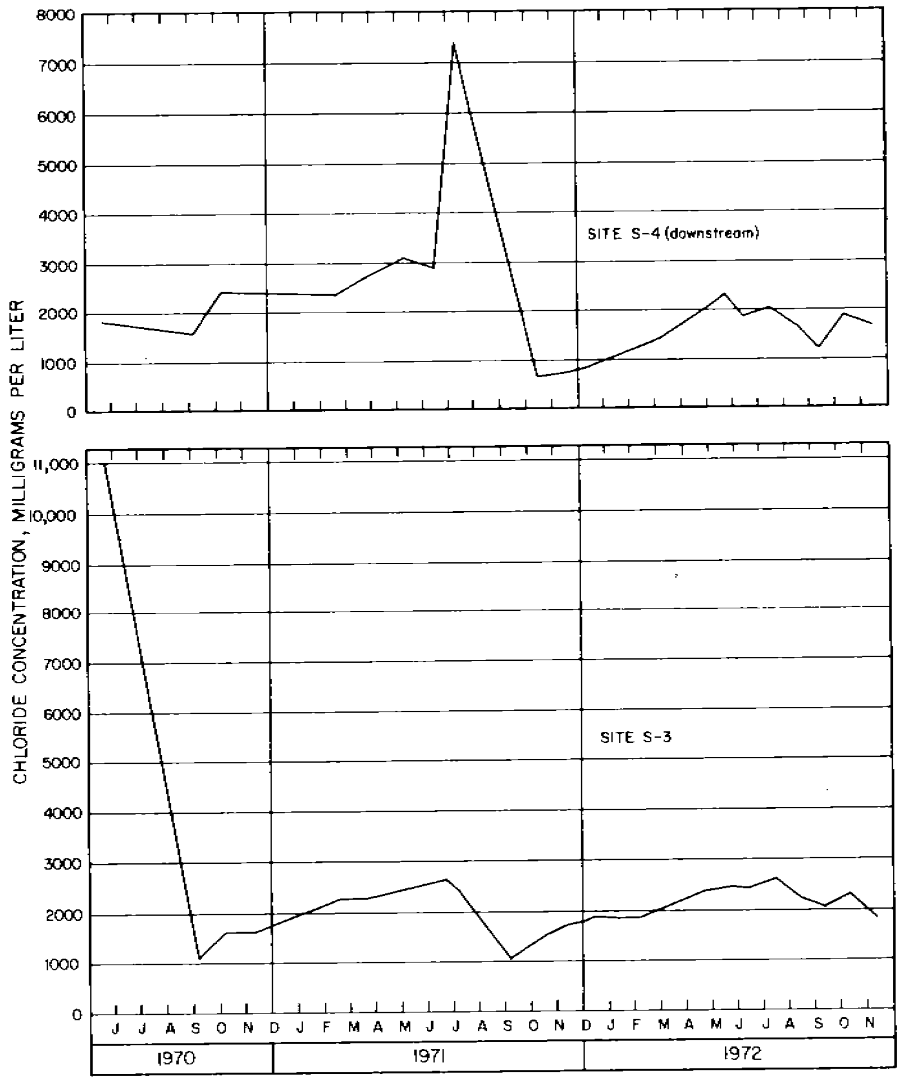


Figure 17. Graph showing chloride concentrations at sites S-3 and S-4 (downstream) June 1970 - December 1972.

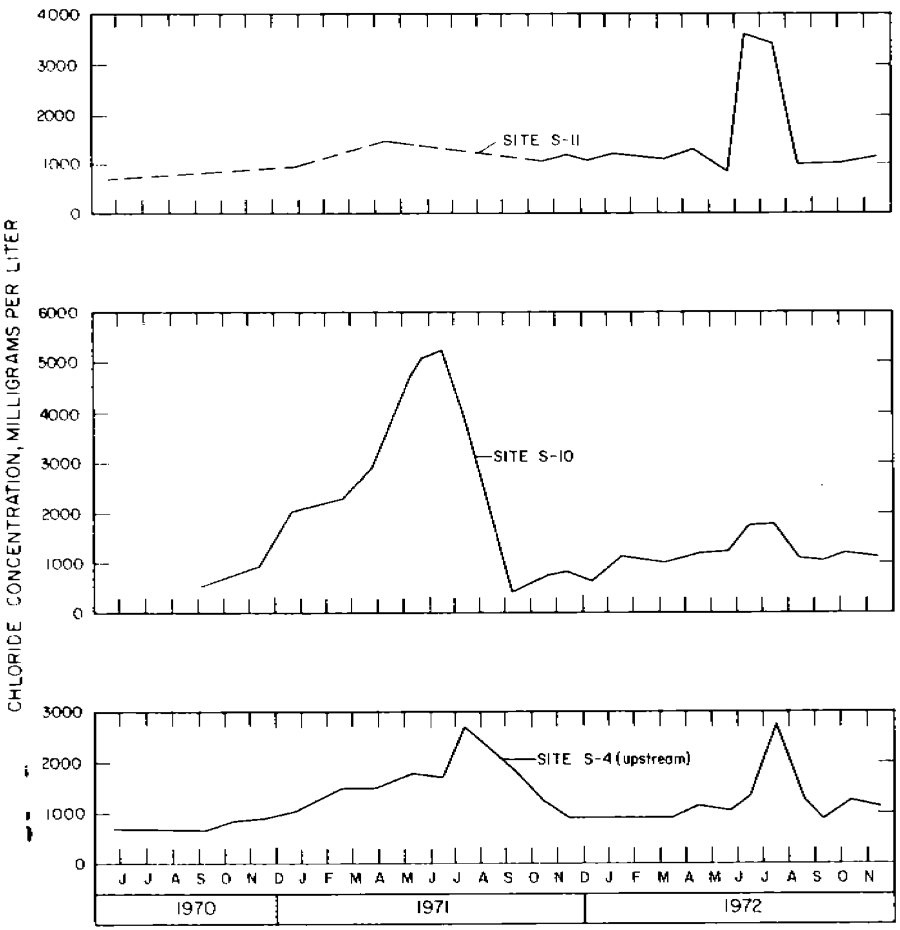


Figure 18. Graph showing chloride concentrations at sites S-4 (upstream), S-10 and S-11, June 1970 - December 1972.

The high chloride concentration in water on the downstream side of site S-4 in August 1971 resulted from the temporary failure of an earthen dike which allowed saline water to move upstream from an area under excavation. The break was quickly repaired and the heavy rainfall in the following month reduced the chloride concentration to the lowest point of record.

The peak concentration on the upstream side of site S-4 in August 1971 (fig. 18) also stemmed from the temporary dike failure. Although the stream is not normally connected across this roadway during low water stages because of the altitude of the culverts, the failure of the earthen dike probably caused the stream level to rise temporarily so that some of the saline water crossed the road. However, the effects of this intrusion was much less on the upstream side as indicated by comparing the graphs for site S-4 on figures 17 and 18.

The large progressive increase in chloride concentrations at site S-10 between October 1970 and July 1971 cannot be explained by any of the saline water sources previously identified. As indicated by the records from sites S-4 (upstream) and S-11, the source of the saline water was between these sites. The increase in chloride content of water at site S-10 coincided with a period of declining water levels suggesting a possible upward migration of saline water from the underlying aquifers. This, coupled with the normal increase in chloride concentrations resulting from the reduction in water volume by evaporation and transpiration during low water stages, may account for increase in chloride content at site S-10. However, the evidence is inconclusive. Most of this saline water was flushed from the area by October 1971.

The peak chloride concentration at sites S-4, S-10, and S-11 which occurred in July and August 1971 (fig. 18) apparently all stemmed from a major intrusion of saline water over the Tarpon Bay control structure on June 18, 19, 1972. On these dates maximum tide levels were 3.45 and 3.60 feet above mean sea level at Point Ybel. At that time the top of the board spillway at the control structure was about 2.25 feet above mean sea level. Thus, when the tide level exceeded the height of the spillway, saline water from Tarpon Bay flowed inland. Similar inflow did not occur at the Beach Road control structure although the height of the spillway was set at 2.70 feet above mean sea level. An alert local resident placed a temporary barrier in the spillway which increased its height above the maximum tide levels.

The effects of intrusion of saline water from Tarpon Bay are also indicated on the graphs for sites S-13, S-18, and S-21 on figure 19. The chloride concentrations in water at site S-13 were more variable than at any other sampling site. The progressive increase in chloride concentrations at site S-13 between December 1971 and June 1972 is largely attributed to leakage of saline

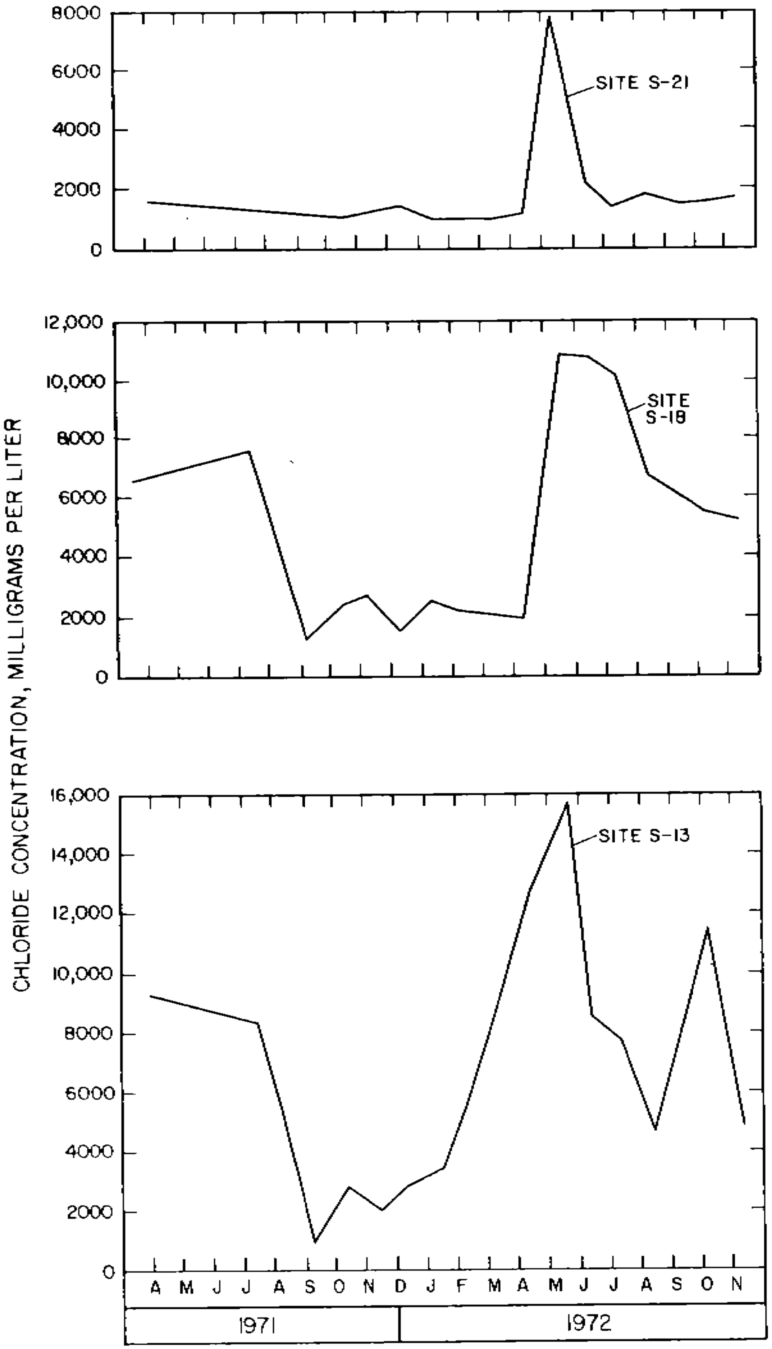


Figure 19. **Graph showing chloride concentrations at sites S-13, S-18 and S-21, April 1970 - December 1972.**

water through the loose fitting boards of the Tarpon Bay control structure. The peak in June -- 15,700 mg/l -- was determined several days after the tidal inflow over the spillway. During the period of maximum tidal inflow, the chloride concentration probably was similar to the composition of sea water, about 19,000 mg/l.

The intruding saline water of higher density flowed inland eventually reaching the canal at sites S-11, and S-10 and S-4 (upstream) as shown on figure 18. The saline water also moved westward to sites S-18 and possibly to site S-21 as indicated by the peaks in June 1972. However, the increase in chloride content at site S-21 may have resulted from some local inflow of saline water from the Gulf when the high tide overtopped the beach ridge near site S-22.

The high chloride concentrations at sites S-13 and S-18 in April through August 1971 (fig. 19), apparently were from two different sources. While the pond at site S-17 was being excavated, water was pumped into the Sanibel River. The chloride content of this water ranged from about 6,500 to 7,300 mg/l, or about the same as that determined at site S-18. During this same period leakage through the Tarpon Bay control structure had increased the chloride concentrations in water at site S-13 to between 8,000 and 9,000 mg/l. Thus the chloride concentrations in the reach between these sites represented a mixture of saline water from both sources.

PONDS, LAKES, AND CANALS

Numerous ponds, lakes, and canals have been excavated on Sanibel Island and many more are currently (1973) under consideration. The primary purpose of most of these excavations is to obtain fill material for increasing the altitude of adjacent land areas, usually residential housing development. The shapes, sizes, and depths of the excavations are largely dependent on the quantity of fill material needed, the area available for development, the location, and other related factors.

Water samples for chloride determination were collected periodically from ponds, lakes, and canals. Selected locations are shown on figure 15. Although both surface and bottom samples were obtained at most sites, only the analyses of bottom samples are shown.

The analyses of water samples from sites S-7, S-8, and S-9 in the canal system are shown on figure 20. A more detailed investigation of this canal system is currently underway (1973). The sustained high chloride concentrations in the canal at site S-7 indicates a continued source of saline water although the chloride content was generally lower in 1972 than in the previous year. This canal was dewatered during excavation and the water was discharged into the Sanibel River before June 1970. This caused a large increase in chloride concentrations in the river between sites S-1 and S-3. This means of disposal had been discontinued several weeks before the first set of water samples was collected on June 20, 1970. The water discharged to the river must have been very saline. For example, samples collected at site S-6 indicated a density stratification of the water with chloride concentrations of 5,300 mg/l at the surface and 16,100 mg/l at the bottom.

The canal at site S-8 is separated from the main canal at site S-7 by an earthen dike which prevents a direct interchange of water between these sites. During the early stages of excavation at site S-8, ground water entering the

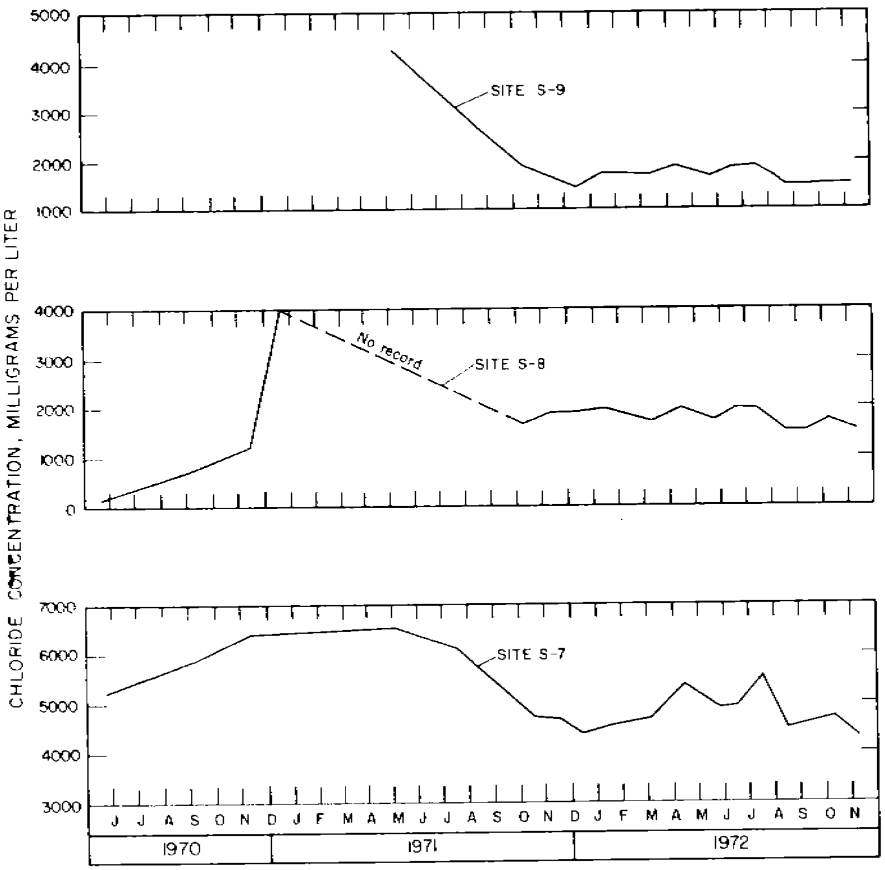


Figure 20. Graph showing chloride concentrations at sites S-7, S-8, and S-9, June 1970 - December 1972.

bottom of the excavation had a chloride content of less than 200 mg/l. The canal was dewatered by stages during excavation resulting in a progressive increase in chloride concentration. A similar increase was noted within the same canal during the excavation near site S-9. After the initial chloride concentrations during the period of excavation, the chloride content has generally stabilized.

The chloride concentrations in water in ponds or lakes at sites S-5, S-12, and S-14 are illustrated on figure 21. The chloride content of water in the lake at site S-5 is inversely related to ground-water levels: the chloride increases when the water level declines. A water sample obtained from observation well L-1405 near the lake at a depth of 11 feet showed a chloride content of 5,100 mg/l. This suggests that the lake is underlain by saline ground water. After a heavy rainfall such as that of September 1971, a density stratification of the water in the lake is apparent. For example, on October 6, 1971 a water sample from the surface contained 670 mg/l of chloride, whereas a sample from the bottom contained more than 2,000 mg/l.

The pond at site S-14 illustrates the effects of saline-water intrusion from other surface-water sources. As previously described, water from Tarpon Bay over topped the control structure during the high tides of June 18-19, 1972. This highly saline water moved inland through the main stream channel, from which it spread into connecting secondary drainageways. One of these secondary drainageways was connected to the pond at site S-14 which permitted saline water to enter the pond. This resulted in a rapid increase in chloride concentrations in the bottom of the pond from less than 2,000 to more than 12,000 mg/l, while near the surface the chloride content increases from 1,600 to about 8,000 mg/l. Following this intrusion of saline water, the chloride content at the bottom generally decreases although it was still above 7,000 mg/l in November 1972.

Water in the pond at site S-12 has varied only slightly in chloride content over the period of record. The source of the saline water which has caused the progressive increase in chloride during most of 1972 is probably the adjacent Sanibel River which contained saline water over most of that period.

The chloride concentrations in water in two elongate ponds paralelled to Rabbit Road are shown on figure 22. Both ponds have about the same shape. Neither is directly connected to the adjacent Sanibel River. The chloride content of water in the pond at site S-17 generally exceeded 5,000 mg/l; the chloride content in the adjacent pond at site S-16 was less than 2,000 mg/l. As described in the previous section on the Sanibel River, the pond at site S-17 was dewatered during excavation. The water pumped from the excavation ranged in chloride content from about 6,400 to 7,300 mg/l. After the pond was excavated some freshening occurred as a result of heavy rainfall in September 1971, although the chloride concentrations have increased since then.

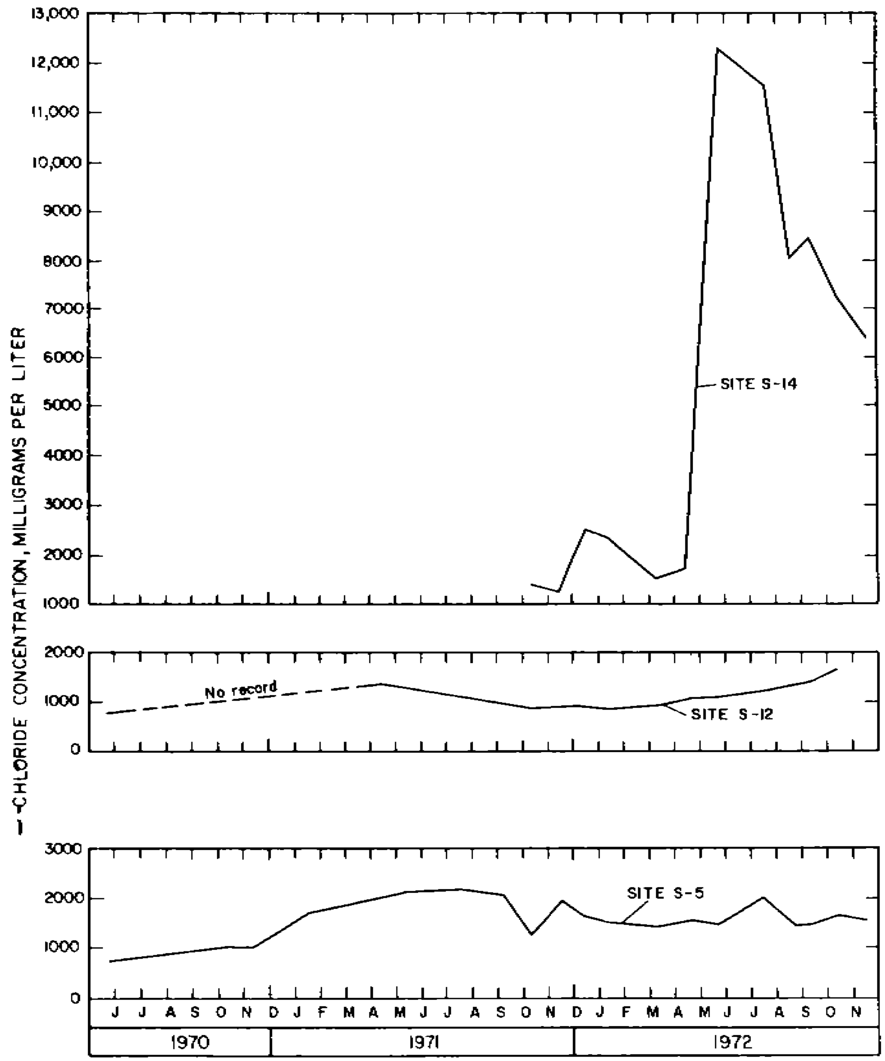


Figure 21. **Graph showing chloride concentrations at sites S-5, S-12, and S-14, June 1970 - December 1972.**

Water samples from well L-1478 near sites S-17 indicated that the chloride content of water in the water-table aquifer ranged between 1,350 and 1,500 mg/l at a depth of about 10 feet. Thus it appears unlikely that the saline water (chloride 6,400 to 7,300 mg/l) pumped from the excavation at site S-17 was from the water-table aquifer. However, samples from well L-1477 which was drilled to the shallow artesian aquifer, contained 30,900 mg/l of chloride at a depth of 32 feet. Thus, upconing of saline water from the artesian aquifer would result in a mixture of water from the two aquifers which should readily account for the saline water pumped from the excavation at site S-17. That similar saline-water conditions did not exist during the excavation of the pond at site S-16, is evident from the graph of figure 22.

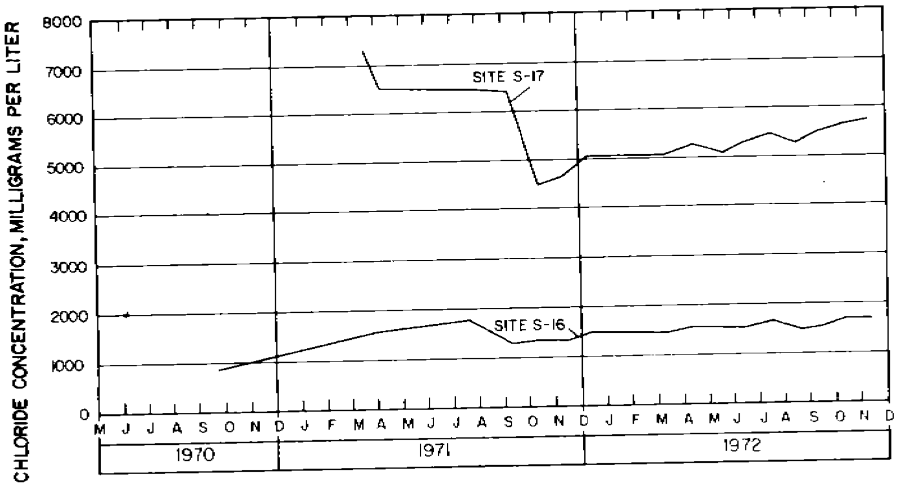


Figure 22. **Graph showing chloride concentrations at sites S-16 and S-17, October 1970 - December 1972.**

The chloride analyses for samples collected periodically from other lakes and ponds are shown on figure 23. The lake at site S-15 has shown the least variation and generally lower chloride concentrations than any other sampling site on the island. Similarly, the ponds or lakes at sites S-20 and S-23 have varied only slightly in chloride concentrations over the period of record. The rapid increase in chloride content of water in the lake at site S-22 in July 1972, and the progressive increase at site S-19 beginning at the same time, apparently were related to the inflow of sea water during the high tides in June 1972. At site S-19 the saline water entered from a secondary drainage channel connected to Sanibel River. At site S-22, the saline water probably came directly from the Gulf when one of the high tides overtopped the beach ridge. By October 1972 the effects of this intrusion at site S-22 were largely dissipated. In November 1972, however, the effects of intrusion at site S-19 were still evident.

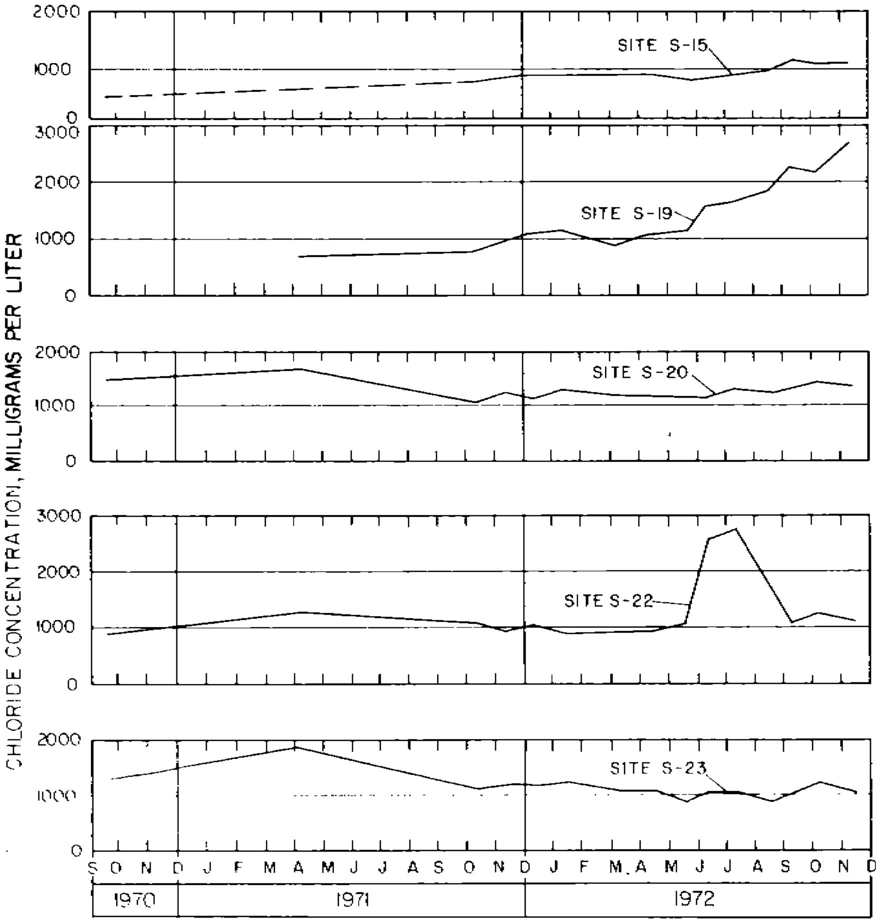


Figure 23. Graph showing chloride concentrations at sites S-15, S-19, S-20, S-22, and S-23, October 1970 - December 1972.

EXCAVATIONS

The large number of excavations on the island both existing and proposed warrants more detailed study and consideration. Based on the available information, the sequence of events and the probable changes which occur in water quality if ponds or lakes are dewatered during excavation are briefly outlined as follows: after removal of the surface vegetation and soil cover, pumps are installed when the water table is reached and the dewatering process begins; as the depth of the excavation increases, the pumps are placed at progressively lower levels and dewatering continues; near the final stages of excavation, the pumps remove water from a sump several feet below the planned depth of excavation; and finally upon reaching the planned depth, the pumps are removed and the excavation allowed to refill with water. The dewatering process may extend over a period of weeks or months depending on the size and depth of the excavation.

The changes which may occur in water quality if the dewatering procedure is used are related to the existing geo-hydrologic conditions beneath and adjacent to the excavation site. Dewatering the excavation is comparable to pumping a well of very large dimensions. A cone of depression develops around the pumping site so that the affected area usually is much larger than the area of excavation. As the depth of excavation increases and water levels are lowered, the cone of depression tends to expand outward from the pumping site. Under these conditions, saline water may enter the excavation from several different sources. Saline surface water within the cone of depression then moves toward the pumping site. Beneath the excavation or in adjacent areas, more highly saline water in the lower part of the water-table aquifer will move toward the excavation. As the water table is lowered by pumping, the difference in head between the water-table and shallow artesian aquifers increases, thereby creating a much larger upward gradient than would occur under natural conditions, and result in increased movement of saline water from the shallow artesian aquifer. Thus, it is concluded that dewatering during excavation should be avoided in areas where the water-table aquifer contains fresh water.

Any excavation which breaches the clay barrier or otherwise improves the hydraulic connection between the water-table and shallow artesian aquifers, may become a permanent source of saline-water contamination of the shallow fresh-water system. This may require a depth limitation on excavations to avoid this problem. Because of the variations in thickness, depth, and character of the surficial sediments and the difference in water quality between the water-table and shallow artesian aquifers, any fixed depth limitation for excavations on the island would be arbitrary. However, considering that these excavations will function as saline-water traps after invasions by sea water, as has occurred in the past, suggests that they be constructed to minimum practical depths depending on location.

SOURCES OF SALINE WATER

Some of the sources of saline water which affect the interior fresh-water system of Sanibel Island have been identified. The tidal water bodies completely surrounding the island represent a major source of saline water which may enter the interior in several different ways. Extremely high tides generated by wind action during the passage of hurricanes or other major storms, have in the past resulted in widespread flooding of the interior with sea water. The effects of these massive invasions of saline water of the interior fresh-water system are relatively unknown. However, based largely on theoretical factors, future flooding of the interior with saline water will have a much greater impact on the fresh-water system than past flooding.

During past invasions of the sea, few ponds were in existence, and these were relatively shallow. Today, numerous ponds, lakes, and canals have been excavated to greater depths and many more are under consideration. If an invasion of the sea were to occur, the fresh water in these excavations would largely be displaced by saline water. Because this water will not be removed by gravity drainage, each excavation will function as a saline-water trap. This entrapped sea water can, in turn, contaminate the underlying water-table aquifer. Although this contamination would not be permanent the saline water would be dissipated only over an extended period of time.

Leakage through or over the control structures at Tarpon Bay and Beach Road represents another means by which sea water from the surrounding tidal water bodies gains entry into the interior fresh-water system. The effects of this intrusion within the shallow drainageway of the Sanibel River are more readily apparent because of damage to the vegetation than they are in the deeper excavations. However, the long-range effects on the fresh-water system from the intrusion of saline water into the deeper excavations probably is of greater significance.

Another major source of saline water is the shallow artesian aquifer. As indicated by wells which tap the upper part of the aquifer, the salinity of the water equals or exceeds sea water salinity at many places. In places where the salinity in the upper part of the aquifer is relatively low (fig. 8), the water at somewhat greater depths probably is more highly saline. A more detailed investigation would be required to evaluate fully the effect of this saline-water aquifer on the fresh-water system of the island. However, the available evidence indicates that upward leakage of water from this aquifer is responsible in part for the higher salinity of water in the lower part of the water-table aquifer. Upward leakage from the shallow artesian aquifer also provides a reasonable explanation for the highly saline water encountered in some areas during the excavation of ponds and canals where dewatering procedures are used.

Other sources of saline water are the deep artesian aquifers. The highly saline water zone in the upper part of the Hawthorn Formation, apparently occurs beneath a large part of the island. The principal path by which water moves upward from this deeper aquifer is through artesian wells or test holes. Because most of the artresian wells are cased through the formations containing highly saline water to tap formations containing water of relatively low salinity, they have little effect on water quality in the shallow fresh-water system. However, deterioration of the metal well casing with time can allow saline water to enter and the well may become a source of contamination. Saline water may also move to the surface through the uncased well bore of test holes or those containing casing which have not been plugged after serving their intended purpose.

Other known sources of saline water, or mechanisms through which this water enters the fresh-water system of the island are beyond the scope of this investigation. Among these, the direct inland movement of saline water from the surrounding tidal water bodies during low-water stages warrants more detailed investigation. During high stages of the water table, the hydraulic gradient is toward the tidal water bodies and fresh water moves toward the sea. Conversely, as the water table declines to near sea level or below, the hydraulic gradient is reversed and sea water moves inland. The extent of this inland movement would largely be dependent on the hydraulic gradient, the permeability of the sediments, the density of the water, and the length of time over which these conditions persisted. Some inland movement of sea water into the water-table aquifer probably occurs along the shoreline as indicated by the water-level data collected during this investigation.

SUMMARY AND CONCLUSIONS

The water-table aquifer contains the only fresh water underlying Sanibel Island and seldom is more than 25 feet thick. The aquifer thickness is largely controlled by the clay deposits at the base and seasonal water level changes. thus a 1-foot rise in the water table above mean sea level will result in 1-foot increase in the thickness of the fresh-water zone.

Within the water-table aquifer, the dissolved solids content of the water increases with depth; relatively fresh water occurs only in the upper part. The lithologic and apparent hydrologic characteristics of the sediments, generally grading downward from more permeable to less permeable materials, are not conducive to adequate flushing by rainfall, particularly in the lower part of the aquifer. Thus it is surmised that the brackish or saline water in the lower part of the aquifer may be unflushed remnants of a former high stand of the sea. However, an alternate and probably more tenable hypotheses concerns the relationship between the water-table aquifer and the underlying shallow artesian aquifer.

The clay and marl strata which separate the water-table and shallow artesian aquifers are thin or absent in some areas and contain permeable sandy sediments in other areas. Most likely these strata, where present, function as a "barrier" to the upward leakage or downward infiltration of water dependent upon the head difference. During seasonal high stages of the water table, the tide generated fluctuations of water level within the shallow arestian aquifer may be continuously below those in the water-table aquifer. Under these conditions a gradient would exsist such that some water would infiltrate downward. During low stages of the water table a gradient would exist such that upward leakage from the shallow artesian aquifer would occur. This hypothesis is consistent with many of the observed conditions on Sanibel Island, including (1) the brackish or saline water in the lower part of the water-table aquifer, (2) the source of recharge to the shallow artesian aquifer, (3) the flushing of saline water from this aquifer in some areas and the complete lack of flushing in other areas, and (4) the observed effects of dewatering during the excavation of lakes, ponds, and canals.

Although the head as indicated by water levels in the shallow artesian aquifer follows the daily and seasonal variations in tide levels, it nevertheless fluctuates at an altitude above mean sea level beneath most of the island. This suggest that the altitude of the potentiometric surface in the shallow artesian aquifer over an extended period may be similar to the long-term mean altitude of the water table. It further infers that recharge to the shallow artesian aquifer is from the overlying water-table aquifer during rainy periods when the water table is generally higher.

The Sanibel River and smaller interconnected drainageways form an integral part of the shallow fresh-water system on the island. The major problems of saline-water contamination noted during the investigation can largely be eliminated. The inland intrusion of sea water at Tarpon Bay and Beach Road could be prevented by reevaluating the design and operation of the control structures at those locations. The discharge of saline water into the interior drainage system as a result of dewatering excavations has largely been curtailed, although this remains as a possile future source of contamination.

The central drainageway of the stream is of shallow depth although deeper pockets occur in some areas and deeper canals form part of the channel in other areas. Saline water entering the central drainageway tends to collect and remain more highly concentrated in the deeper parts of the channel. At times the position or size of the culverts beneath road crossings prevents the spread of saline water to other parts of the channel, whereas at other times they hamper flushing of saline water from the stream, or restrict flow rates which cause periodic flooding in some areas. Ideally, the central drainageway should be of uniform shallow depth and connected throughout its length. Making the culverts of adequate size would permit the rapid movement of water to points of discharge. This would create a flow system which would minimize the effects of

flooding and provide an effective means of flushing saline water from the interior of the island.

Generally it is concluded that the volume of water in storage in the fresh-water system of the island is highly variable, reaching a maximum near the end of the wet season in September or October and a minimum near the end of the dry season in May or June. Little opportunity exists for increasing storage of fresh water in either the water-table aquifer or the interior surface water bodies. Thus, it is concluded that maintenance of the fresh-water system on the island is largely dependent on the elimination or reduction in factors which adversely affect water quality.

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APPENDIX

TABLE 2. RECORDS OF WELLS ON SANIBEL ISLAND

Abbreviations used in tables:

Aquifer - WT (water table), SA (shallow water), LH (lower Hawthorn), Su (Suwannee).

Well number	Latitude-Longitude number	Depth (feet)	Casing (feet)	Diameter (inches)	Altitude of land surface (feet)	Water level above (+) or below (-) land surface	Date of measurement	Yield, gpm Flow-F	Temperature °C	Chloride (milligrams per liter)	Date	Aquifer	Remarks
L- 405	262727NO820234.1	500		6	5	+26.6	12-29-7	F		950	12-70	LH	Chloride 1035 mg/1 (1-46)
584	262605NO820448.1	421	393	4	5							LH	Water salty. Well destraged
585	262711NO820053.1	475	335	6	5	+27.4	11-18-70	F	27	1500	11-70	LH	Chloride 1530 mg/1 (1-64)
586	262823NO821008.1	735	415	8	4	+23.3	1-14-64	F 100	27			LH	Well plugged back to 235 ft.
588	262538NO820457.1	557	403	4	3	+13.1	1-15-64	F 40	27	1000	6-70	LH	
589	262545NO820458.1	609		6	3	+14.4	1-15-64	F 100	27			LH	
590	262547NO820512.1	620		4	3			F 60	27	1150	1-64	LH	
591	262822NO820912.1	654	405	6	5	+25.6	1-16-64	F 60	27	950	12-70	LH	Head +21.0 (12-8-70)
1022	262621N0820353.1	631	440	4	5	+20.5	11-18-70						
1023	262611N0820735.1	490	461	6	7							LH	
1147	262633N0820228.1	8.6		1¼	4	−3.74	6-19-70			900	6-70	WT	
1148	262632N0820229.1	7.4		1¼	4	−2.62	10-2-70					WT	
1149	262632N0820228.1			1¼	4					400	10-70	WT	
1150	262617N0820228.1	8		1¼	5					380	10-70	WT	Three drive points
1151	262631N0820225.1	7		1¼	5				26	110	10-70	WT	
1152	262639N0820226.1	7.4		1¼	4	−2.80	10-8-70					WT	
1153	262755N0820318.1	231	147	4	5	+1.91	10-8-70			420	10-70		
1154	262528N0820401.1	400	389	2½	5			F 2		340	10-70	LH	
1155	262547N0820341.1	8		1¼	4					180	10-70	WT	
1158	262619N0820234.1	7		1¼	7					420	10-70	WT	Three drive points
1160	262617N0820237.1	7		1¼	7	−2.25	10-23-70					WT	
1185	262621N0820244.1	8		1¼	6					80	10-70	WT	

TABLE 2. RECORDS OF WELLS ON SANIBEL ISLAND (Cont'd)

Abbreviations used in table:

Aquifers - WT (water table) SA (shallow water), LH (lower Hawthorn), Su (Suwannee).

Well number	Latitude-Longitude number	Depth (feet)	Casing (feet)	Diameter (inches)	Altitude of land surface (feet)	Water level above (+) or below (-) land surface	Date of measurement	Yield, gpm Flow-F	Temperature °C	Chloride (milligrams per liter)	Date	Aquifer	Remarks
L-1186	262633N0820327.1	700	500	6	4	+17.2	11-16-70			1020	11-70	LH	
1187	262633N0820328.1	9		1¼	4					405	11-70	WT	
1188	262552N0820342.1	7		1¼	4					240	11-70	WT	
1189	262558N0820338.1	8		1¼	5					60	6-70	WT	
1190	262553N0820337.1	8		1¼	4					330	6-70	WT	
1191	262608N0820245.1	600		6	4	+24.5	11-16-70			1500	11-70	LH	
1193	262602N0820334.1	28.5	20	2	5.6	−4.38	12-23-70	100		3600	12-70	SA	
1194	262544N0820414.1	29.9	23	2	5.0	−3.63	12-29-70	35	24	3900	12-70	SA	
1196	262833N0820940.1	600		6	5	+19.1	12-1-70		27	980	12-70	LH	
1197	262605N0820447.1	500	480	4	4			F 5		600	1-71	LH	Strong salt water flow 400 ft.
1198	262613N0820425.1	8	1¼	5						75	1-71	WT	
1199	262601N0820451.1	7	1¼	4						1000	1-71	WT	
1401	262613N0820424.1	7-17		1¼	5					12	1-71	WT	Two drive points
1402	262613N0820424.2	7.3		1¼	5	−4.39	1-27-71					WT	
1403	262549N0820353.1	11.9	12	4	6.1	−5.07	2-10-71	3		230	2-71	WT	Slotted pipe
1404	262540N0820351.1	9.8	10	4	2.6	−2.29	2-12-71	10		920	2-71	WT	Slotted pipe
1405	262608N0820354.1	11.6	12	4	5.4	−4.80	2-12-71	20		5100	2.71	WT	Slotted pipe
1406	262535N0820443.1	29.2	20	2	4.7	−3.62	2-15-71	5		5400	2-71	SA	
1407	262540N0820451.1	29.9	20	2	4.1	−3.48	2-17-71	1		10750	2-71	SA	
1408	262603N0820447.1	25.4	19	2	2.2	−1.93	2-17-71	4		4500	2-71	SA	

TABLE 2. - RECORDS OF WELLS ON SANIBEL ISLAND (Cont'd)

Abbreviations used in table:

Aquifers - WT (water table) SA (shallow water), LH (lower Hawthorn), Su (Suwannee).

Well number	Latitude-Longitude number	Depth (feet)	Casing (feet)	Diameter (inches)	Altitude of land surface (feet)	Water level above (+) or below (-) land surface	Date of measurement	yield, gpm Flow-F	Temperature °C	Chloride (milligrams per liter)	Date	Aquifer	Remarks
L-1409	262612N0820420.1	26.4	19	2	3.6	−2.49	2-18-71	2		2800	2-71	SA	
1410	262630N0820354.1	11.3	12	4	4.5	−4.25	2-19-71		23	2600	2-71	WT	Slotted pipe
1411	262602N0820334.2	9.7		1¼	5.6	−5.51	2-23-71	3		80	2-71	WT	Chloride 1500 mg/1 (6-72)
1412	262544N0820414.2	10		1¼	5.0	−3.87	2-23-71	3		535	2-71	WT	Chloride 750 mg/1 (6-72)
1413	262535N0820443.2	8.5		1¼	4.7	−3.60	2-23-71	3	23	580	2-71	WT	Chloride 640 mg/1 (11-72)
1414	262540N0820451.2	7.5		1¼	4.1	−2.62	2-23-71	3		1200	2-71	WT	Chloride 1450 mg/1 (11-72)
1415	262603N0820447.2	7.5		1¼	2.1	−1.19	2-23-71	3	21	1150	2-71	WT	Chloride 900 mg/1 (6-72)
1416	262612N0820420.2	8.0		1¼	3.5	−3.06	2-23-71	3		2325	2-71	WT	Chloride 1900 mg/1 (6-72)
1429	262605N0820644.1	9		1¼	5					1675	4-71	WT	
1430	262614N0820738.1	10.5		1¼	5					785	4-71	WT	
1431	262627N0820758.1	10.5		1¼	5			15		220	4-71	WT	
1447	262632N0820247.1	62		6	4					24600	6-71	SA	Testhold
1450	262638N0820253.1	26.8	26	2	4.9	−4.37	7-26-71	2		3850	7-71	SA	
1451	262638N0820253.2	12.6		1¼	4.9	−4.65	7-26-71	3		1700	7-71	WT	Chloride 450 mg/1 (11-71)
1452	262629N0820327.1	29.9	26	2	3.8	−3.14	7-26-71	60	25	5550	7-71	SA	
1453	262629N0820327.2	12.6		1¼	3.8	−3.67	7-26-71	3		350	7-71	WT	Chloride 450 mg/1 (6-72)
1454	262646N0820226.1	34.6	34	2	5.7	−4.96	7-27-71	30	25	5100	7-71	SA	
1455	262646N0820226.2	11.9		1¼	5.7	−5.41	7-27-71		26	1350	7-71	WT	Chloride 1528 mg/1 (6-72)
1456	262622N0820220.1	33.2	33	2	5.3	−3.81	7-27-71	50	25	2350	7-71	SA	
1457	262622N0820220.2	10.8		1¼	5.3	−4.22	7-27-71	3	26	205	7-71	WT	Chloride 275 mg/1 (11-71)

TABLE 2. RECORDS OF WELLS ON SANIBEL ISLAND (Cont'd)

Abbreviations used in table:

Aquifers - WT (water table) SA (shallow water), LH (lower Hawthorn), Su (Suwannee).

Well number	Latitude-Longitude number	Depth (feet)	Casing (feet)	Diameter (inches)	Altitude of land surface (feet)	Water level above (+) or below (-) land surface	Date of measurement	Yield, gpm Flow-F	Temperature °C	Chloride (milligrams per liter)	Date	Aquifer	Remarks
L-1458	262611N0820258.1	36.4	32	2	5.8	−5.47	7-27-71	40	25	2950	7-71	SA	
1459	262611N0820258.2	10.1		1¼	5.8	−5.44	7-27-71	3	26	45	7-71	WT	Chloride 120 mg/1 (6-72)
1470	262603N0820253.1	542	420	4	6	+16.7	8-3-71			1050	8071	LH	
1472	262632N0820247.2	786	660	4	4			F 125		5850	10-71	LH-Su	
1475	262618N0820538.1	32.4	32	2	5.2	−4.64	11-3-71	40	25	27100	11-71	SA	
1476	262618N0820538.2	11.3		1¼	5.2	−3.15	11-3-71	5	26	4000	11-71	WT	
1477	262633N0820630.1	31.8	31	2	2.9	−2.24	11-3-71	15	25	30900	11-71	SA	
1478	262633N0820630.2	9.9		1¼	2.9	−1.44	11-3-71	3	27	1350	11-71	WT	Chloride 1500 mg/1 (6-72)
1479	262651N0820712.1	29.4	29	2	5.1	−3.67	11-8-71	3	27	20700	11-71	SA	
1480	262651N0820712.2	7.9		1¼	5.1	−3.29	11-8-71	5	27	1700	11-71	WT	Chloride 1400 mg/1 (6-72)
1481	262718N0820832.1	30.1	30	2	5.0	−3.35	11-8-71	4	27	10100	11-71	SA	
1482	262718N0820832.2	9.5		1¼	5.0	−2.74	11-8-71	3	27	1350	11-71	WT	Chloride 1000 mg/1 (6-72)
1483	262815N0820924.1	33.9	33	2	6.2	−5.21	11-9-71	12	25	26300	11-71	SA	
1484	262815N0820924.2	10.0		1¼	6.2	−5.67	11-9-71	3	26	1250	11-71	WT	
1485	262854N0820954.1	33.2	33	2	4.6	−3.04	11-9-71	12	24	18900	11-71	SA	
1486	262854N0820954.2	11.2		1¼	4.6	−2.78	11-9-71	3	24	7100	11-71	WT	Chloride 7600 mg/1 (6-72)
1487	262824N0821009.1	35.9	35	2	3.5	−2.78	11-10-71	4	26	24500	11-71	SA	
1488	262824N0821009.2	10.8		1¼	3.5	−2.54	11-10-71	3	26	4150	11-71	WT	Chloride 4750 mg/1 (6-72)
1489	262610N0820728.1	36.2	35	2	7.1	−1.50	11-17-71	50	25	17400	11-71	SA	
1491	262738N0820910.1	29.9	29	2	3.4	−2.19	11-10-71	50	24	15600	11-71	SA	
1492	262738N0820910.2	8.7		1¼	3.4	−1.83	11-10-71	3	25	500	11-71	WT	Chloride 600 mg/1 (6-72)

TABLE 2. RECORDS OF WELLS ON SANIBEL ISLAND (Cont'd)
Abbreviations used in table:
Aquifers - WT (water table) SA (shallow water). LH (lower Hawthorn), Su (Suwannee).

Well number	Latitude-Longitude number	Depth (feet)	Casing (feet)	Diameter (inches)	Altitude of land surface (feet)	Water level above (+) or below (-) land surface	Date of measurement	Yield, gpm Flow-F	Temperature °C	Chloride (milligrams per liter)	Date er	Aquifer	Remarks
L-1493	262631N0820758.1	30.6	30	2	5.5	−3.33	11-11-71	3	26	2250	11-71	SA	
1494	262631N0820758.2	10.7		1¼	5.5	−3.36	11-11-71	3	27	175	11-71	WT	Chloride 100 mg/1 (6-72)
1496	262610N0820728.2	10.8		1¼	7.1	−5.62	11-17-71	5	26	130	11-71	WT	Chloride 180 mg/1 (6-72)
1497	262610N0820728.3	16.6		1¼	7.1	−5.59	11-17-71		26	375	11-71	WT	Chloride 350 mg/1 (6-72)
1498	262548N0820630.1	33.2	31	2	6.0	−4.48	11-15-71	22	26	9800	11-71	SA	
1499	262548N0820630.2	10.6		1¼	6.0	−4.01	11-17-71	3	29	670	11-71	WT	Chloride 600 mg/1 (6-72)
1500	262536N0820548.1	31.8	31	2	4.6	−2.88	11-17-71	18	25	9050	11-71	SA	
1501	262536N0820548.2	9.7		1¼	4.6	−2.40	11-17-71	3	27	1950	11-71	WT	Chloride 1600 mg/1 (6-72)
1502	262602N0820127.1	30.2	29	2	4.8	−2.55	11-17-71	50	26	18600	11-71	SA	
1503	262602N0820127.2	9.3		1¼	4.8	−2.60	11-17-71	3	27	190	11-71	WT	Chloride 275 mg/1 (6-72)
1504	262602N0820127.3	17.1		1¼	4.8	−2.60	11-17-71		26	8950	11-71	WT	Chloride 8800 mg/1 (6-72)
1512	262552N0820327.1	565	465	4	5			F 25	26	1340	1-72	LH	Chloride 12000 mg/1 at 220 ft.
1516	262813N0820916.1	16.2		1¼	2.6	−2.36	1-5-72			23200	1-72	WT	
1520	262808N0820924.1	13.2		1¼	3.9	−2.82	1-10-72			1500	1-72	WT	
1529	262541N0820558.1	29		2	4.5					5200	1-71	SA	Casing removed. Well cemented
1530	262541N0820558.2	14.6		1¼	4.5					2500	1-71	WT	
1533	262628N0820618.1	895	496	4	5			240	28			LH-Su	Plugged with cement.
1549	262632N0820752.1	15		1¼	2.3	−1.20	2-4-72			6600	2-72	WT	
1558	262644N0820330.1	34		2	2.3					23700	3-72	SA	Casing removed. Well cemented
1559	262644N0820330.2	13.7		1¼	2.3	−2.73	3-8-72			20050	3-72	WT	
1597	262627N0820618.1	575	503	10	4							LH	
1654	262625N0820418.1	6.8		1¼	2.2	−2.50	8-11-72			2u700	8-72	WT	