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INTERIM REPORT ON THE GROUND-WATER RESOURCES OF ST. JOHNS COUNTY, FLORIDA

By
George R. Tarver

Prepared by
U. S. Geological Survey
in cooperation with the
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ABSTRACT

St. Johns County is on the eastern seaboard in the northern part of the Florida Peninsula. Beds of sand, clay, marl, shell, and sandy limestone, of Pliocene, Pleistocene and Recent age, are exposed at the surface over all the county. They range from 25 to 140 feet in total thickness, and are underlain by relatively impervious beds of clay, sand, and limestone of Miocene or Pliocene age that range in thickness from 50 to 220 feet. A series of limestone beds several thousand feet thick underlies the Miocene or Pliocene clay. The uppermost unit of this limestone series is the Ocala group[1] of the late Eocene age.

Measurements of artesian pressure head show that the piezometric surface fluctuates through a range of about five feet each year in most of the county, being high in the winter and low in the summer. Withdrawal of large quantities of water for irrigation in southwestern St. Johns County, during the potato-growing season of 1956, depressed the piezometric surface about 20 feet below the winter high. A study of old water-level records indicates that there has been a decline of about five feet in the piezometric surface in most of the county in the past 16 years and a much greater decline in the farming area.

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[1]The stratigraphic nomenclature used in this report conforms to the usage of the Florida Geological Survey. It conforms also to the usage of the U. S. Geological Survey with the exception of the Ocala group and its subdivisions. The Florida Geological Survey has adopted the Ocala group as described by Puri (1953). The U. S. Geological Survey regards the Ocala as a formation, the Ocala limestone.

The chloride content of water from the principal artesian aquifer in St. Johns County ranges from less than 10 parts per million (ppm) in the northern section, where the piezometric surface is relatively high, to more than 7,000 ppm near Crescent Beach, where the piezometric surface is relatively low. Deep wells in the farming area produce water having a chloride content as high as 2,500 ppm, whereas shallow wells in the same area produce less saline water, indicating that the chloride content of the water increases with depth.

INTRODUCTION

In St. Johns County, wells supply nearly all the water for irrigation, municipal, and domestic uses. There has been a gradual increase in population throughout the county and a rapid increase in the tilled acreage in the western part of the county. The use of artesian water to prevent drought and frost damage has increased, and the ground water levels have shown a progressive decline during the last three or four years. The decline in water levels could result in the contamination of the fresh-water supply by an intrusion of saline water from the deep zones of the principal artesian aquifer.

In recognition of this and other water-supply problems, the State Legislature appropriated funds for an investigation of the water resources of the county. The ground-water phase of the investigation was begun in November 1955 by the U. S. Geological Survey as a part of the statewide investigation in cooperation with the Florida Geological Survey.

The purpose of this investigation is to make a study of the geology and ground-water resources of St. Johns County, with emphasis upon salt-water contamination and declining water levels in the artesian aquifer. This report reviews the progress made in the county during the first year of the investigation.

Listed below are some of the most important data that were collected.

1. Information concerning the depth, distribution, use, and construction of wells.

2. Measurements of water levels throughout the county to determine seasonal fluctuations, long-term trends, and declines due to pumping.

3. Chemical analyses of ground-water to determine areal and vertical distribution of saline water and possible changes in water quality with time and pumping.

3. Drillers' logs and samples of formation penetrated by water wells, to determine the character of sediments and their relationship to the water supply.

The investigation was made under the general supervision of A. N. Sayre, Chief, Ground Water Branch, U. S. Geological Survey, and under the immediate supervision of M. I. Rorabaugh, District Engineer for Florida.

Previous Investigation

The geology and ground-water resources of St. Johns County are mentioned in several reports published by the U. S. Geological Survey and the Florida Geological Survey.

A study of the geology and ground water of St. Augustine well-field area was made by A. G. Unklesbay (1945). The report included a geologic cross section of the well field and a table of chemical analyses of water from all the city wells. A structure and isopachous map of the Miocene sediments in North Florida, and other geological information pertaining to St. Johns County, were presented in a report by Vernon (1951, fig. 11, 13, 33; pl. 2).

A report on the geology of Florida by Cooke (1945,

p. 42, 48, 272. 296, 310; pl. 1), contains descriptions of the surface and subsurface formations of the county and a geologic map of the State.

St. Johns County was studied briefly by Stringfield (1936) as part of an investigation of the ground-water resources of the peninsula of Florida. Stringfield's report included a general map of the areas of artesian flow, a map of areas in which artesian water is highly mineralized, a map of the piezometric surface of the principal artesian aquifer in the peninsula, and a broad discussion of all aspects of the artesian system.

A collection of 67 complete chemical analyses of water from wells throughout the county was presented by Black and Brown (1951, p. 97, 98).

GEOGRAPHY

St. Johns County is on the eastern seaboard of the northern part of the Florida Peninsula and has an area of 608 square miles, or 389,260 acres (fig. 1). In 1955 the U. S. Bureau of the Census estimated the population to be 29,378. Most of the population is concentrated within the corporate limits of St. Augustine, the county seat and largest city.

The mean temperature of the county is 70°F, and the average annual rainfall is about 50 inches. According to the records of the St. Augustine and Racy Point stations of the U. S. Weather Bureau, two-thirds of the rain falls during the period June-October.

St. Johns County led the State in the production of Irish potatoes in 1954, producing 3,037,887 bushels, according to the 1954 Florida Agriculture Census (U.S. Dept. Commerce, Census Bureau, 1955).

Most of the county is covered by forests and pasture land, but an estimated 17,500 acres or 4½ percent of the total acreage is tilled.

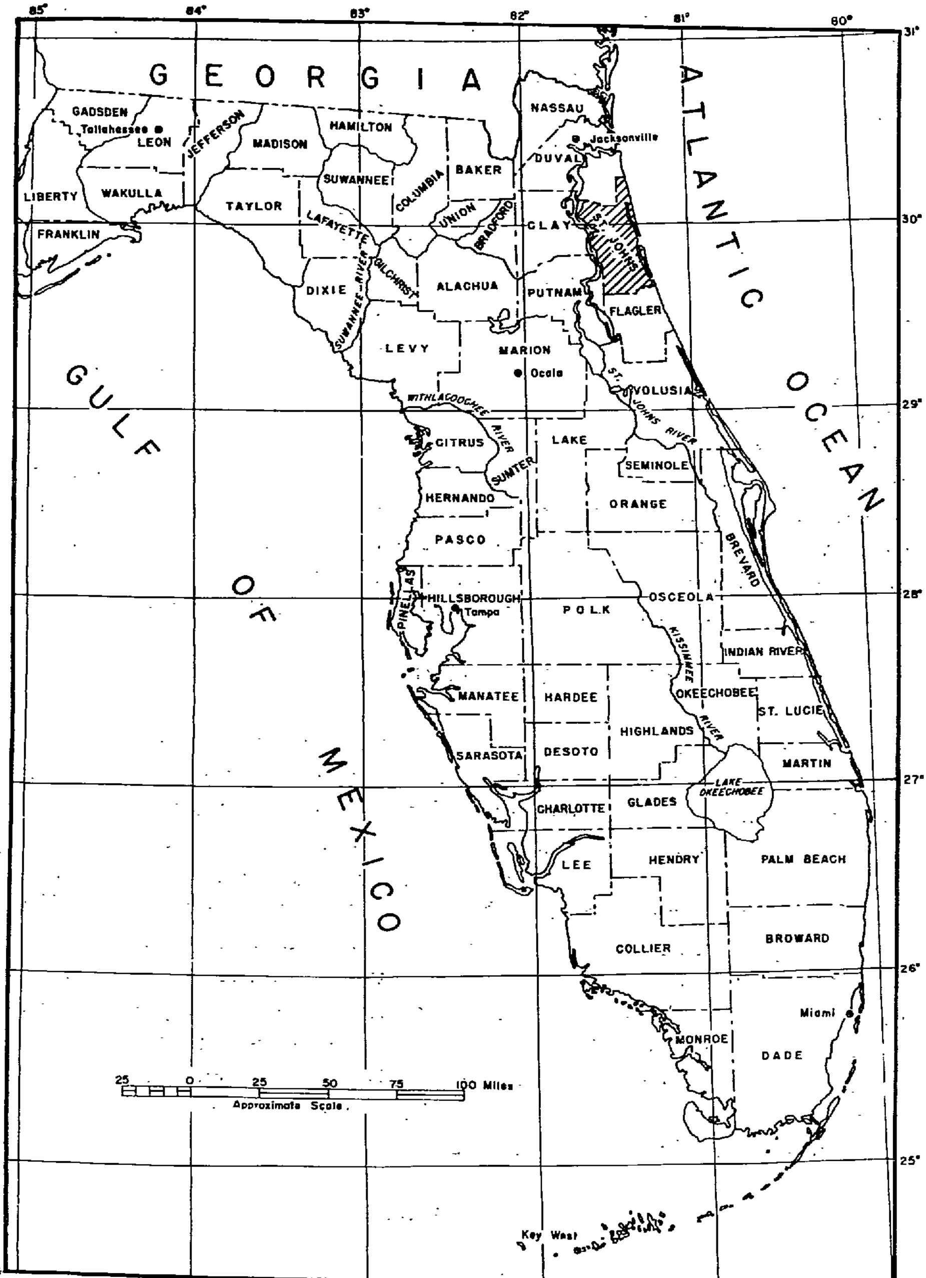

Figure 1. Map of the peninsula of Florida showing the location of St. Johns County.

The Tolomato or North River, the Matanzas River, and their tributaries drain the eastern third of the county. The St. Johns River and its tributaries drain the western two-thirds. The drainage divide is nearly a straight line that traverses the county in a north-northwest-south-southeast direction.

The area may be divided into four general topographic divisions, as follows: (1) An offshore bar that ranges in width from a few yards to a mile, along the eastern coast, (2) a lagoonal area about a mile wide immediately west of and parallel to the bar, (3) a ridge and swamp belt about five miles wide which parallels the coastline, and (4) a gently sloping plain along the St. Johns River. The ridges and swamps are relatively straight and narrow and form a distinct trellis drainage pattern. The plain that slopes gently to the St. Johns River is the largest division. It occupies nearly two-thirds of the county and has a dendritic drainage pattern. The altitude of the land ranges from about 65 feet in the ridge and swamp belt to sea level at the coast.

WELL-NUMBERING SYSTEM

Each well inventoried during this investigation was assigned an identifying well number. Therefore, wells referred to by number in the text may be located on figure 2. The well number was assigned by first locating each well on a map which was divided into 1-minute quadrangles of latitude and longitude, then numbering, consecutively, the wells in each quadrangle. The well number is composed of the last three digits of the line of latitude south of the well, followed by the last three digits of the line of longitude east of the well, followed by the number of the well in the quadrangle. For example, well 943-129-3 is the well numbered 3 in the quadrangle bounded by latitude $29^{\circ}43'$ on the south and longitude $81^{\circ}29'$ on the east.

GEOLOGY

Rock cuttings from wells show that St. Johns County is underlain by beds of linestone, clay, sand, and shells. The lowermost rock penetrated by water wells is a series of

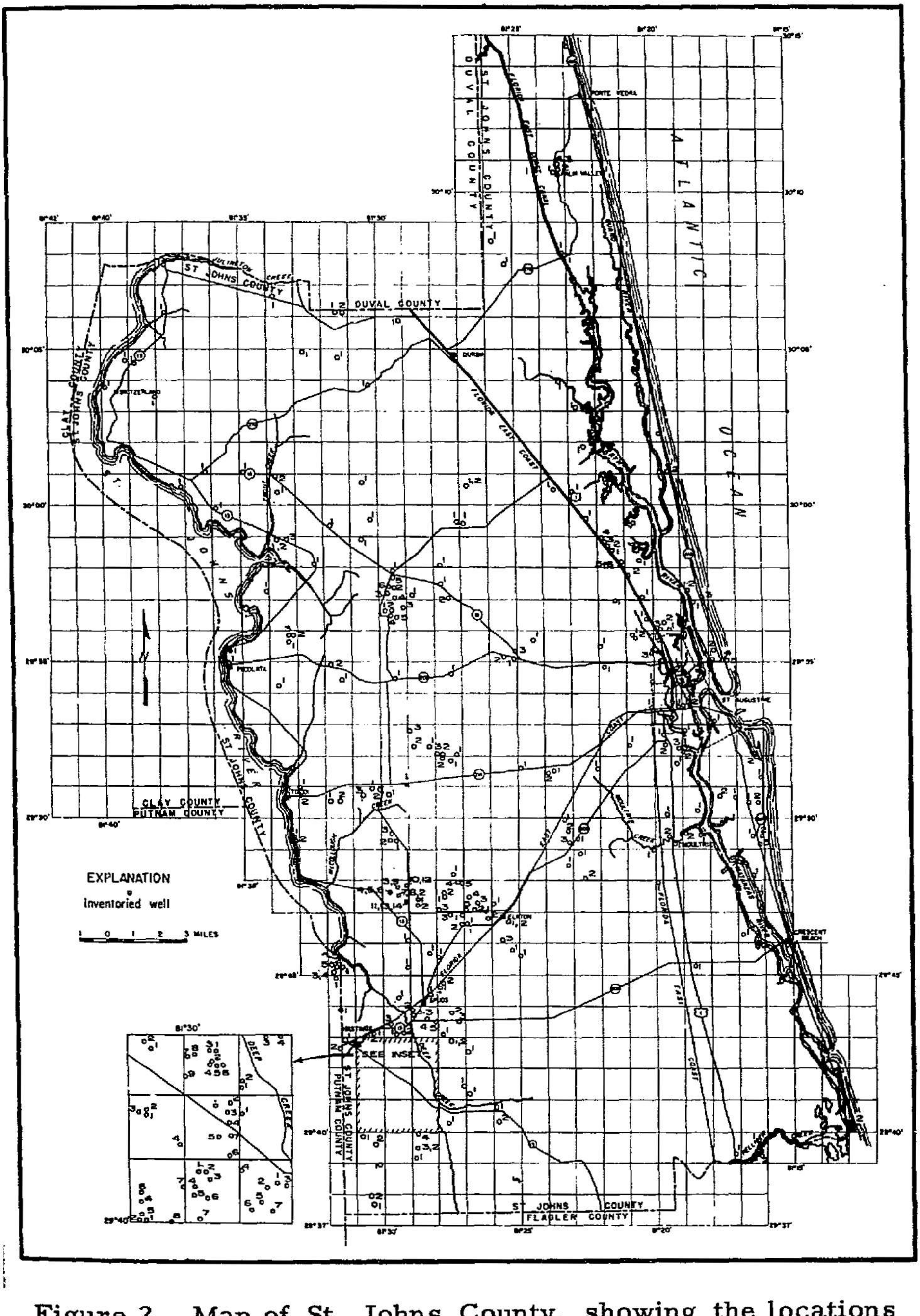

Figure 2. Map of St. Johns County, showing the locations of wells that obtain water from the principal artesian aquifer.

massive limestone beds whose upper surface ranges in depth from 90 feet below sea level in the southwestern section of the county to more than 290 feet below sea level in the northern section of the county. The limestones extend to a depth of several thousand feet.

The upper part of this limestone section consists of the Oldsmar, Lake City, and Avon Park limestones and the Ocala group of Puri (1953), all of Eocene age. These limestones are of marine origin and consist of alternating hard and soft zones. The Ocala limestone described by Cooke (1945, p. 53-73) was established by Puri (1953, p. 130) as a group composed of three similar formations. The first two were named by Vernon (1951), who, however, did not retain the name Ocala. The three formations, in ascending order, are the Inglis and Williston formations of Vernon (1951) and the Crystal River formation of Puri (1953). All three are fragmental marine limestones which are differentiated on the basis of fossil content and lithology.

The Crystal River formation of Puri is a white to cream pure friable coquina composed of tests of large Foraminifera, zoaria of Bryozoa, and other small marine fossils. The upper two to 20 feet of this formation is composed of a hard, dense, gray limestone containing many thin chert streaks. This zone is commonly referred to as the bedrock.

Beds of clay of Miocene or Pliocene age overlie the limestone and confine the water in it throughout the county. These beds range in thickness from less than 50 feet at Hastings and Marineland to more than 220 feet at Palm Valley. The upper part is composed of gray to blue clay, sandy clay, thin lenses of fine white quartz sand, and lenses of large, well-preserved marine shells. The lower part is composed of green and brown clay, thin lenses of black phosphatic pebbles and cobbles, and thin lenses of coarse, white quartz sand. A limestone bed one foot to five feet thick occurs about 40 feet above the base of the clay sequence.

Beds of sand, marl, shell, and sandy limestone of Pliocene, Pleistocene, and Recent age overlie the beds of clay. They occur in no particular sequence except that sand is exposed at the surface over the entire county. These beds of Pliocene, Pleistocene, and Recent age have an aggregate thickness of 140 feet in the ridge and swamp belt and a thickness of less than 40 feet near the Atlantic Coast. Part of this sequence has been named the Anastasia formation, a formation occupying a belt about five miles wide that parallels the Atlantic Coast from St. Augustine south to southern Palm Beach County. The Anastasia formation is composed of whole and broken mollusk shells and some quartz sand. It occurs both as a loose aggregate and as well-indurated coquina cemented with calcium carbonate. Beds of shells in other sections of the county are composed principally of mollusk shells and appear to be more widespread than the Anastasia formation. The surficial sand in the county is composed of fine to medium quartz grains that range in color from white to black or buff, according to the amount of iron and organic matter present. Underlying the land surface at a depth of one foot to 10 feet is a thin hardpan composed of buff to chocolate brown sand partially cemented with organic material and iron oxide. The lower surface of the hardpan coincides approximately with the water table.

The geologic cross sections (fig. 3) show the approximate depth to the principal artesian aquifer in St. Johns County, and figure 4 shows the configuration of the top of the aquifer. The aquifer dips slightly to the north and its upper surface is irregular. The irregularity was caused by stream erosion, when the limestone was exposed at the surface, and by the solution and removal of the limestone by circulating ground water after the limestone was covered by younger sediments (Stringfield, 1936, p. 124, 125).

GROUND WATER

Ground water is the subsurface water in that part of the zone of saturation in which all pore spaces are filled with water under pressure greater than atmospheric. Water in this zone moves more or less laterally under the influence of gravity to places of discharge, such as rivers, springs, wells, or the ocean.

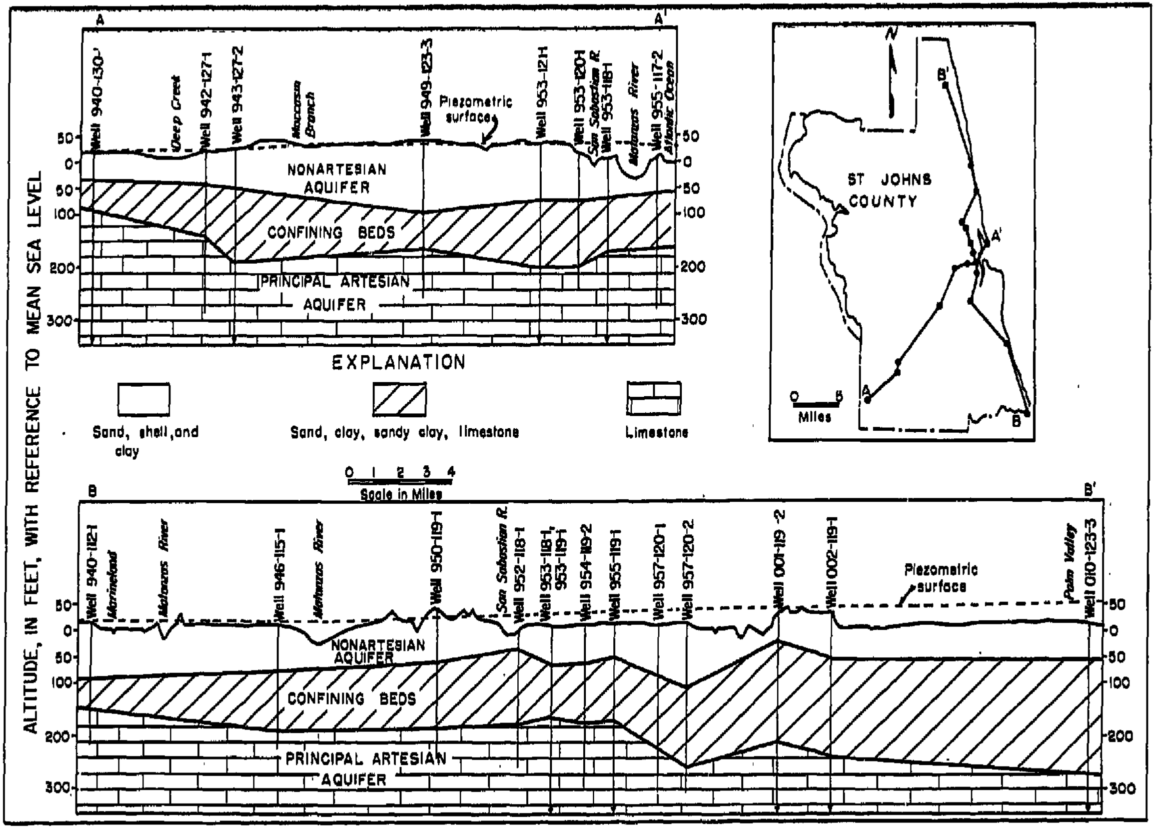

Figure 3. Generalized geologic sections, showing the rocks penetrated by wells in St. Johns County.

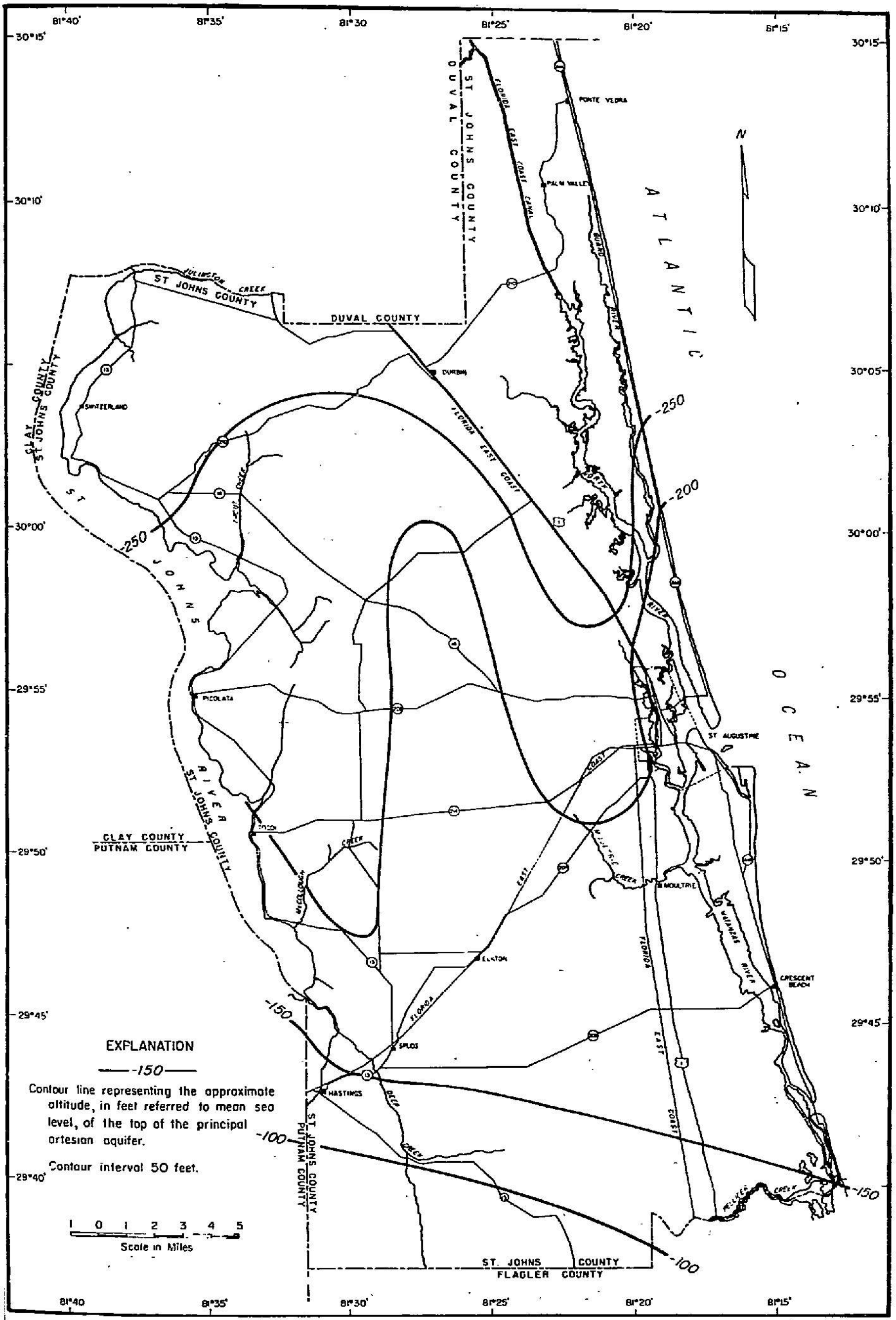

Figure 4. Map of St. Johns County, showing contours on the top of the principal artesian aquifer.

Ground water may occur under either nonartesian (water-table) or artesian conditions. Where it is unconfined, its surface is free to rise and fall and it is said to be under nonartesian conditions. The upper surface of nonartesian water is known as the water table. Where the water is confined in a permeable bed that is overlain by a relatively impermeable bed, it is said to be under artesian conditions. The term "artesian" is applied to water, which is under sufficient pressure to rise above the top of the permeable bed that contains it, although not necessarily above the land surface.

An aquifer is a formation, group of formations, or part of a formation, below the water table, that will yield water in usable quantities to springs and wells. Areas of recharge are those areas in which an aquifer receives water, and areas of discharge are those in which an aquifer loses water.

The Nonartesian Aquifer

The surficial sands of Pleistocene and Recent age in the county contain water under nonartesian conditions (fig. 3), though locally, artesian conditions may exist where the sand contains interbedded clay.

Water from the nonartesian aquifer is used extensively in the rural areas for domestic purposes and in the towns for lawn irrigation. The city of St. Augustine obtains part of its municipal supply from a shallow sand bed in this aquifer. In most areas the water is very soft but contains objectionable quantities of iron, which stains utensils and clothing. Several wells along waterways and near the ocean yield brackish water, but fresh water can generally be obtained very close to bodies of salt water. Most of the wells are less than 50 feet deep and are equipped with a sand-point screen and a hand or electric suction pump.

The nonartesian aquifer receives most of its recharge from rainfall in the immediate area, but in the farming area it receives a considerable amount of recharge from irrigation water flowing over the land. Many nonartesian wells in this area yield water very similar to the artesian water in taste and chloride content.

The Thin Artesian Aquifers

Within the confining beds that overlie the principal artesian aquifer (fig. 3) are many beds of shell, limestone, and sand that contain water under artesian conditions. Water from these beds is used in the rural areas for domestic purposes and small irrigation systems. The city of St. Augustine obtains part of its supply from these beds. In 1956 the city pumped approximately 1.2 million gallons per day (gpd), using an average of 12 wells, some screened in an artesian sand and the others in the nonartesian sands.

Water from the thin artesian aquifers is relatively hard and contains excessive amounts of iron. A rubble bed at the base of the confining bed contains water very similar to that obtained from the limestone immediately below the bedrock surface. The wells are usually driven or drilled 20 to 280 feet deep and are cased to the bottom.

The Principal Artesian Aquifer

Limestone of Eocene age in the upper part of the principal artesian aquifer of the Florida Peninsula and adjacent areas (fig. 3), is the main source of water for irrigation in the county. It is composed mostly of soft limestone containing streaks of hard limestone. Differences in artesian pressure within the aquifer indicate that the hard streaks are relatively impervious. Water from the aquifer is highly mineralized, and in some areas of heavy pumping or natural flow the mineralization of the water is extremely high, rendering the water useless for irrigation and human consumption. Most of the wells in this aquifer are less than 350 feet deep and are cased either to the bedrock or to near the bottom of the confining bed, the remainder of the well being an open hole in the limestone. Centrifugal pumps equipped with electric motors are the type most widely used in the areas where the natural flow of wells is insufficient for irrigation use.

The water that is obtained from artesian wells in St. Johns County comes from rainfall which infiltrates through sinkholes in areas to the north and west. Recharge may take place also by a downward percolation of ground water through the confining beds in areas where the water table is higher than the piezometric surface. From these areas of intake the water moves laterally through the limestone to areas where discharge takes place through wells and springs and by upward leakage through the confining beds in areas where the piezometric surface is higher than the water table.

Piezometric Surface

The piezometric surface is the imaginary surface that everywhere coincides with the static water level in the aquifer. It is the surface to which the water from a given aquifer will rise under its full head.

The piezometric surface for the principal artesian aquifer in Florida is shown by the contour lines in figure 5. The contour lines on this map indicate that water enters the aquifer in the north-central part of Florida and moves southward and eastward through the county to areas of discharge in St. Johns County and south and east of the county. Water levels in several wells in St. Johns County have been measured periodically since 1940 by the U. S. Geological Survey. The measurements show that there has been a loss of five to 10 feet in artesian pressure head over the area in the past 16 years, the greatest loss having occurred in the southwestern section where irrigation has increased rapidly. In figure 6, the water level in well 953-118-1 shows a decline of about eight feet between 1946 and 1956. Figure 7 is a map showing the piezometric surface in Flagler, Putnam, and St. Johns counties. It gives a broader picture of the movement of water in the principal artesian aquifer than is given in figures 8 and 9, which show the piezometric surface in St. Johns County. During the potato-growing season, when withdrawal is heavy and the piezometric surface is relatively low, the artesian water in the southern part of the county reverses its direction of flow, which is normally southeastward, and moves northwestward from Flagler County into the Hastings area (fig. 8, 9). Figure 7 shows that some

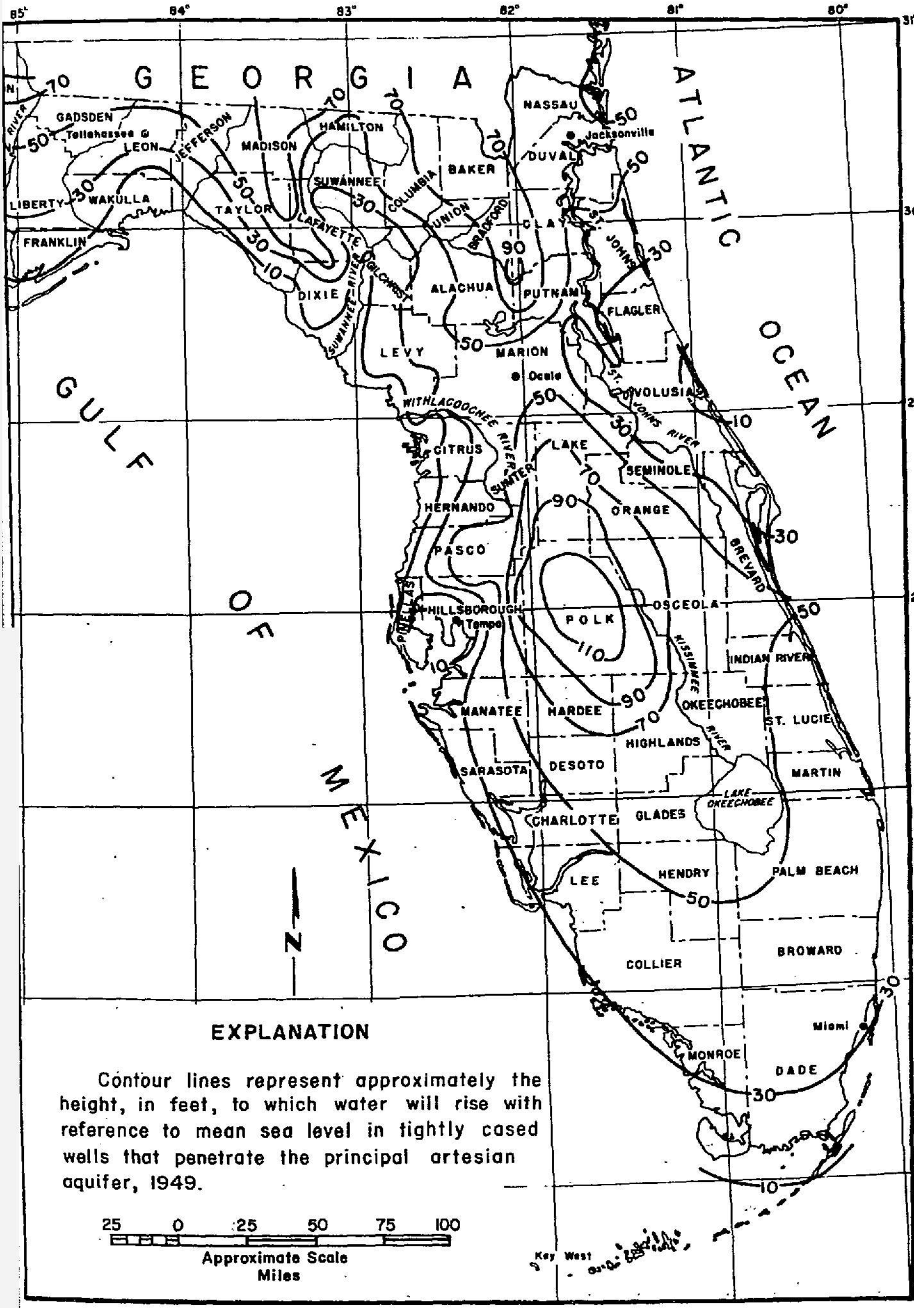

Figure 5. Map of the peninsula of Florida, showing the piezometric surface of the principal artesian aquifer.

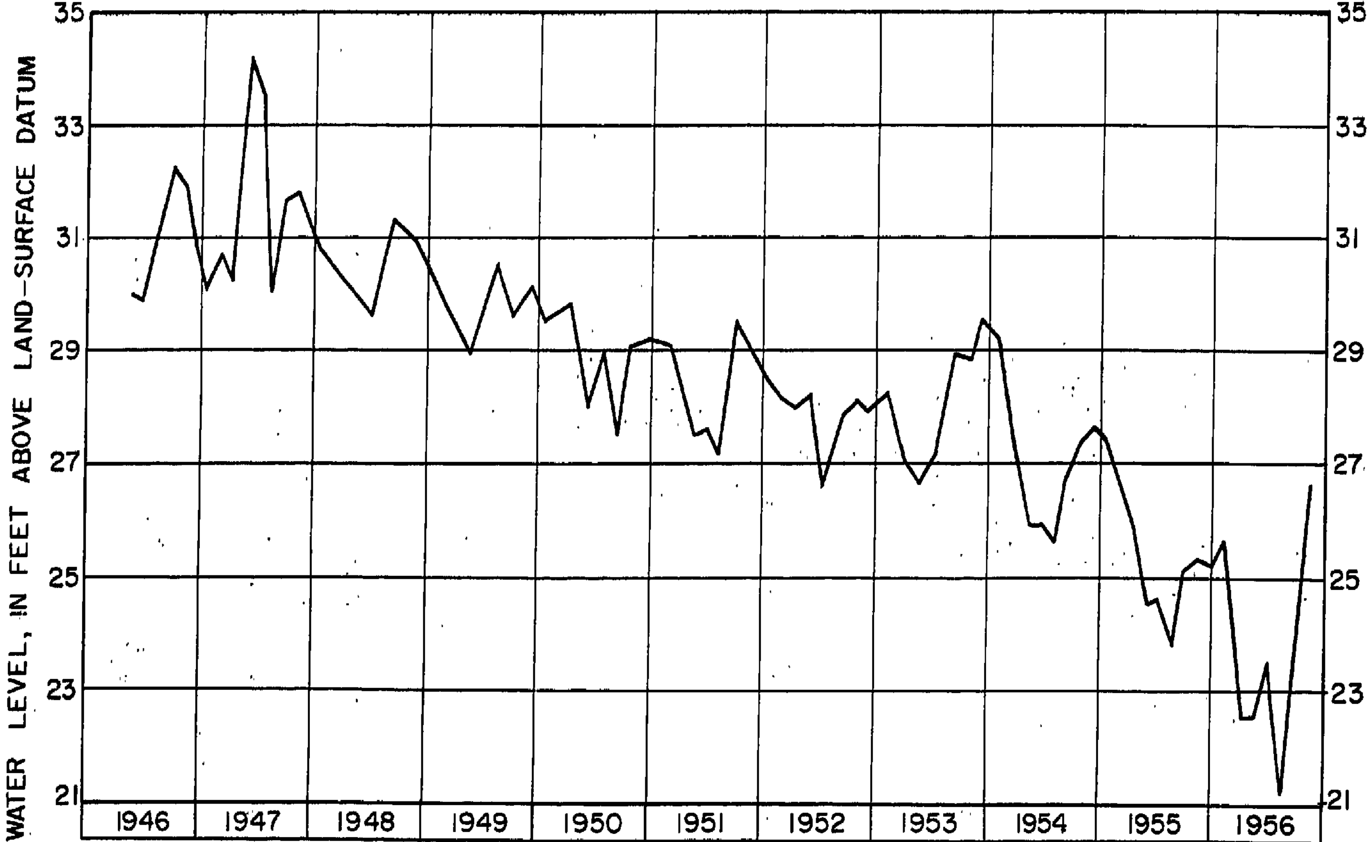

Figure 6. Hydrograph of well 953-118-1, in east-central

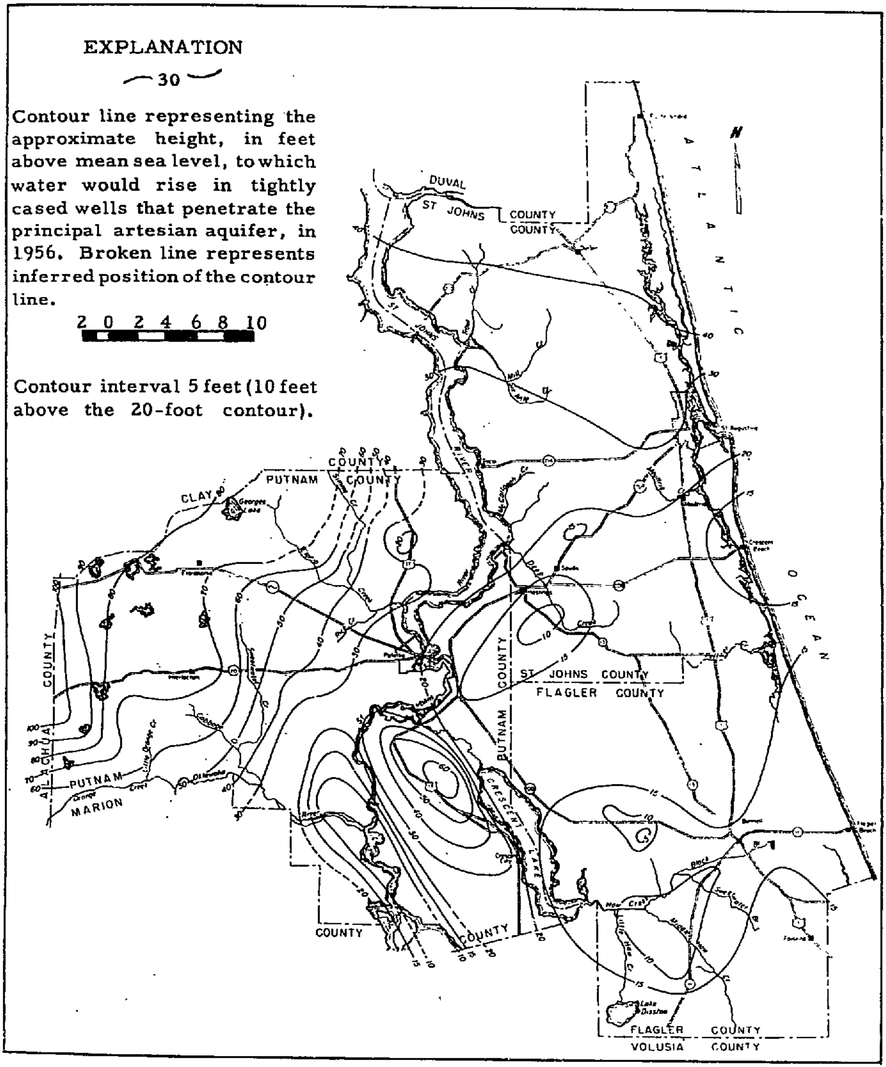

Figure 7. Map of Flagler, Putnam, and St. Johns counties, showing the piezometric surface in 1956.

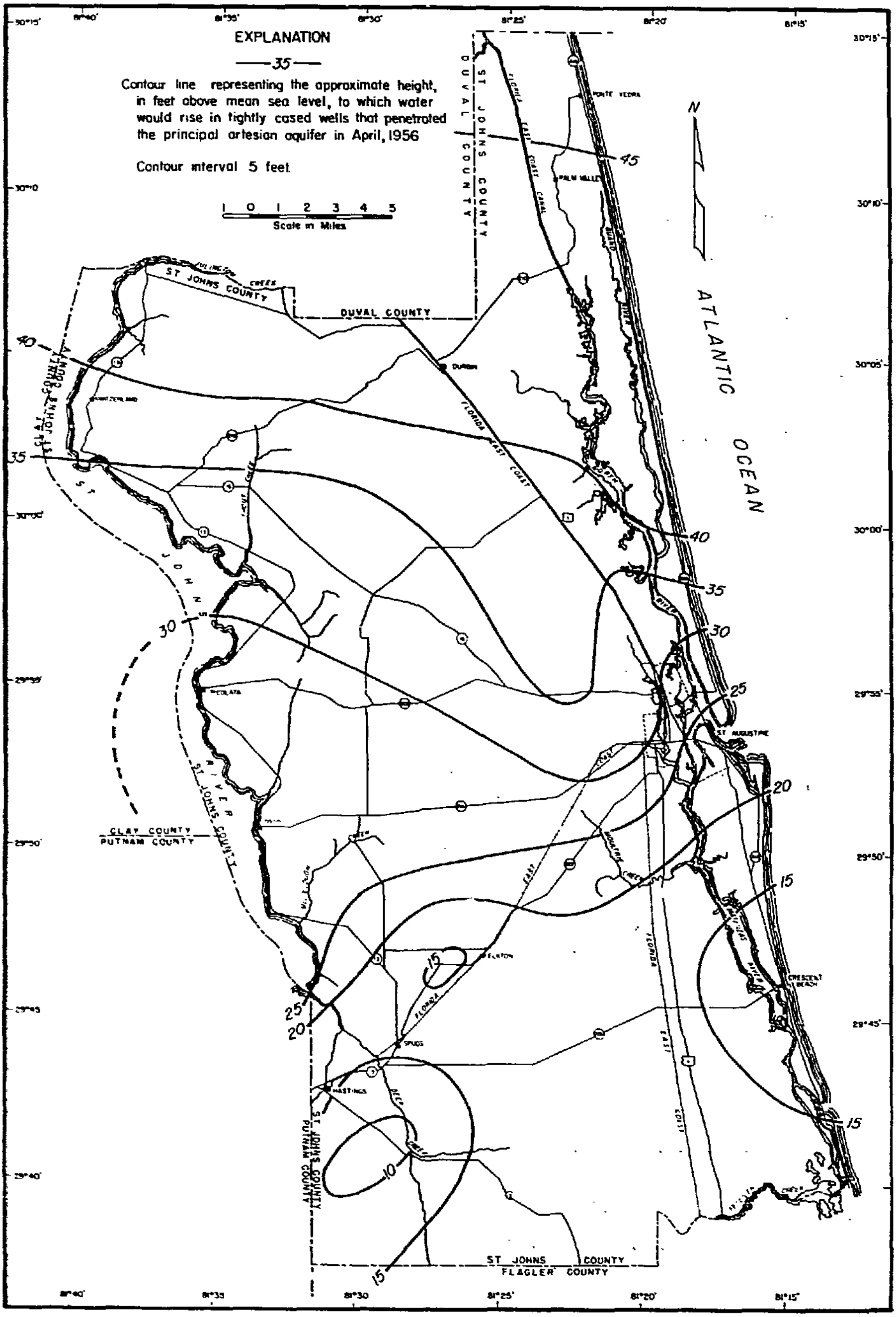

Figure 8. Map of St. Johns County, showing the piezometric surface in April 1956.

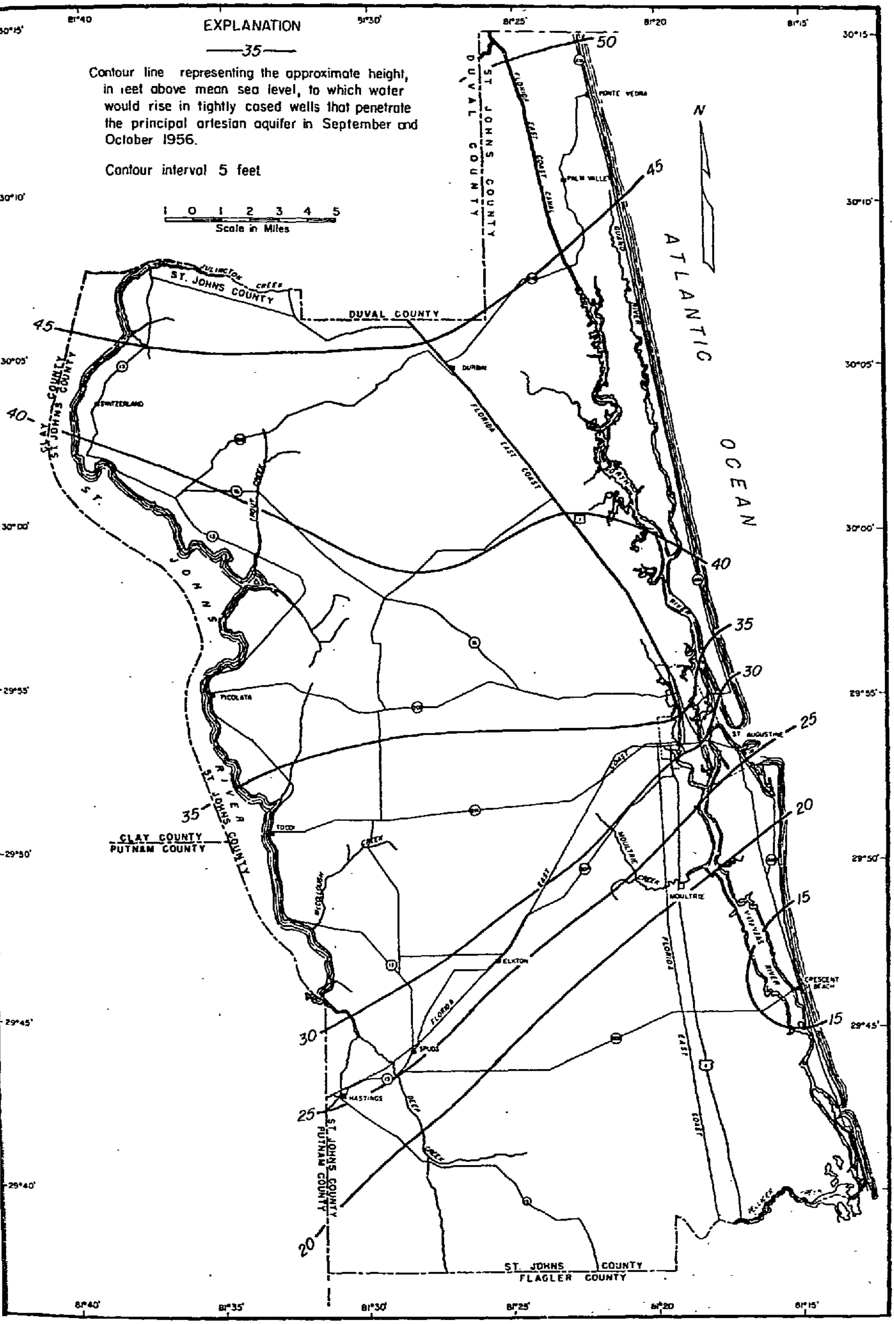

Figure 9. Map of St. Johns County, showing the piezometric surface in September and October 1956.

of the water pumped in the Hastings area has entered the aquifer a few miles to the west in the hilly recharge area of northwestern Putnam County.

Measurements were made in 90 wells in 1956 to determine the seasonal fluctuations of water level and the effect of pumping on the water level. From these measurements, the two maps of the piezometric surface in St. Johns County were made. Elevations of the measuring points were estimated from topographic maps. Figure 8, which is based on measurements made during the last week of the potato-growing season, shows four discharge areas. Figure 9 is based on measurements made in September and October, when very little water was being used for irrigation, and the piezometric surface was rising.

The two depressions in the Hastings and Elkton areas (fig. 8) are caused by the withdrawal of large quantities of water for irrigation during the potato-growing season. Water levels in some wells in the Elkton area dropped 20 feet below observed highs during times of maximum withdrawal. A third depression, centered in the Crescent Beach area, is caused - at least in part - by the continuous discharge of a large submarine spring about two miles east of Crescent Beach. The curving of the contour lines to the north in the St. Augustine area indicates another area of artesian discharge. Hundreds of wells in the St. Augustine area are used for lawn irrigation, swimming pools, and domestic purposes, and a few overflowing wells discharge water freely to waste. Their combined discharge is probably large enough to cause a sizable depression in the piezometric surface.

Some recharge probably occurs over much of the area of no artesian flow in St. Johns County, but the thick, relatively impermeable confining beds probably prevent any large volume of water from reaching the aquifer (fig. 10). Recharge may be indicated by the southward bulge in the contour lines northwest of St. Augustine. A slight decrease in the salinity of the water immediately west of Moultrie (fig. 11) may be due to recharge in the high ridge and swamp belt in that area. A comparison of figures 8 and 9 shows

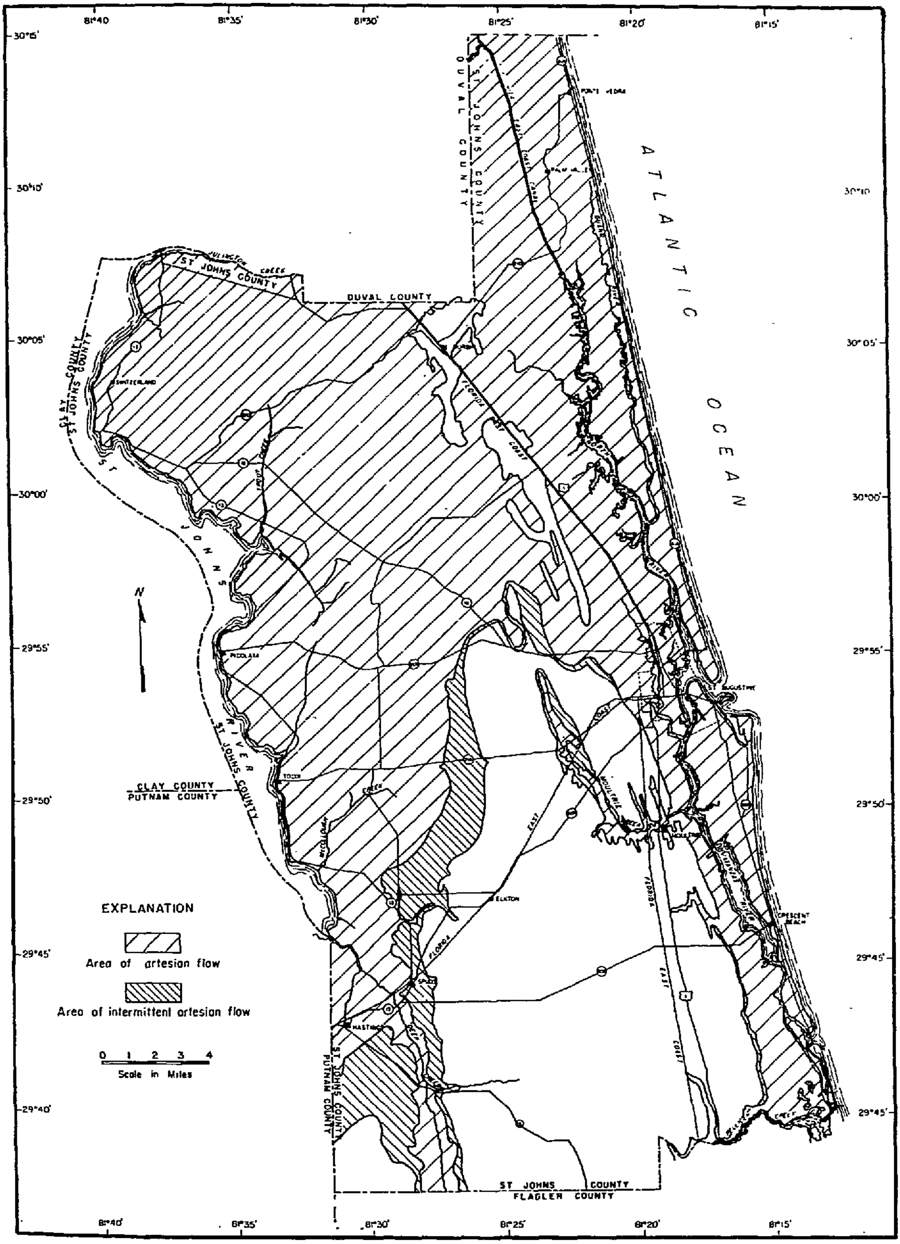

Figure 10. Map of St. Johns County, showing the areas of artesian flow in 1956.

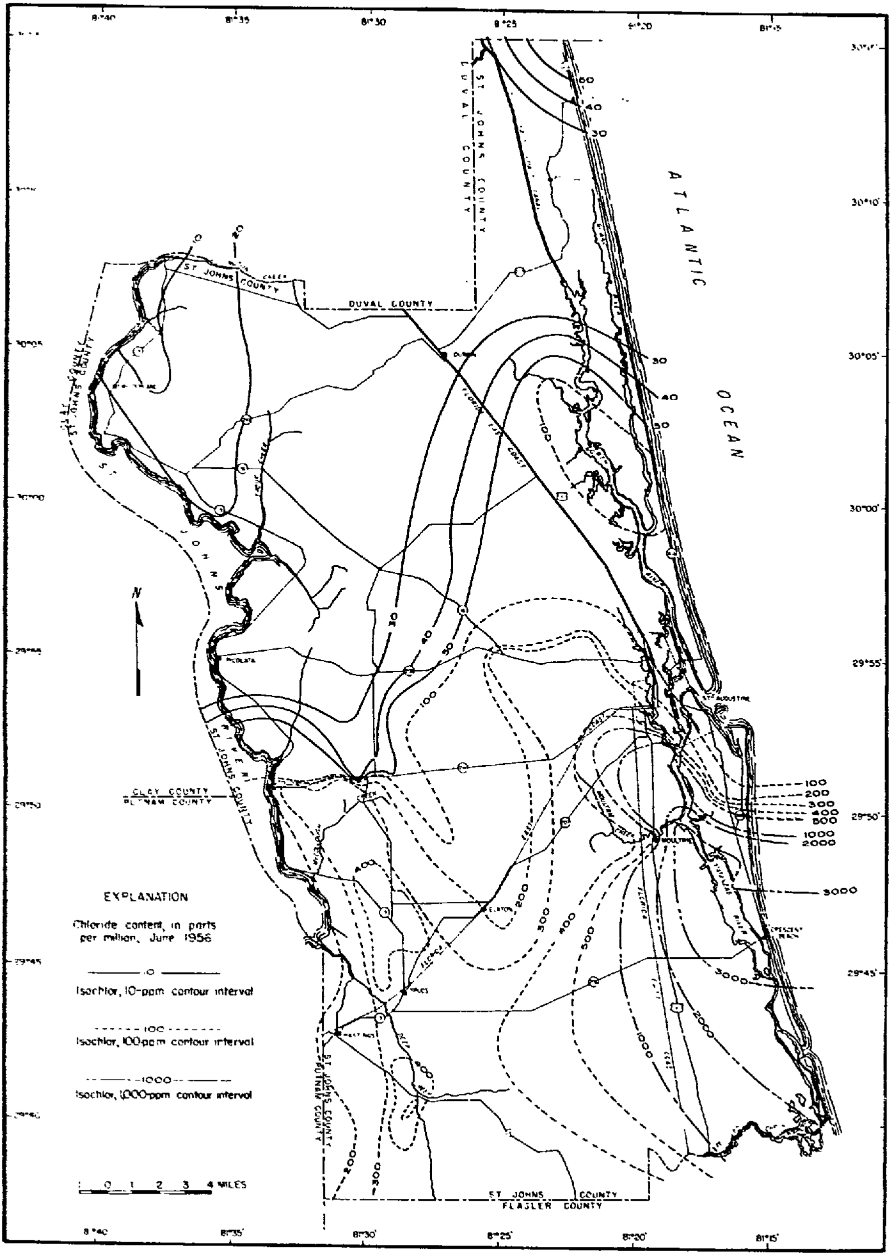

Figure 11. Map of St. Johns County, showing the chloride content of water from the principal artesian aquifer.

that between April and September or October the water level rose about five feet throughout the county and that the depressions created by pumping in the Hastings and Elkton areas disappeared completely. The water levels and artesian pressures in approximately 20 wells in the county were measured periodically to determine the seasonal fluctuations.

Area of Artesian Flow

Water will flow from artesian wells when the piezometric surface stands higher than the land surface. Figure 10 shows approximately the areas where water flowed perennially or intermittently from wells in St. Johns County during 1956. The measurements of artesian pressure head from which figure 10 was constructed were made in April and September, the times of maximum and minimum use of artesian water.

The area of perennial artesian flow extends in a wide belt up the St. Johns River valley, across the northern part of the county, down the east coast, and inland in narrow belts along the valleys of Pellicer Creek, Moultrie Creek, Deep Creek, and others. It becomes considerably narrower to the south because the artesian pressure head is less.

In the Hastings-Elkton area there is a broad area of intermittent artesian flow where the piezometric surface is lowered below the land surface as the result of heavy pumping during the potato-growing season. Immediately after the season, the area of artesian flow begins to expand rapidly to the east until it occupies the area of intermittent flow shown in figure 10. The area of artesian flow does not change perceptibly in the northern part of the county, where water is withdrawn at a relatively constant rate throughout the year.

The area of no artesian flow is principally in the south-central part of the county, where the land surface is relatively high and the artesian pressure head is low. In a few isolated areas in the northern part of the county wells do not flow (fig. 10), and there is no flow from artesian wells at the top of many sand dunes along the Atlantic Coast. Many wells in the area of no artesian flow once overflowed throughout the year and supplied water to second-story bathrooms and elevated, spray-tank refill lines. A map similar to figure 10 was made by Stringfield (1936). It indicated that the area of artesian flow encompassed all the county except for a small wedge-shaped area that extended southward from a point in the center of the county, about 15 miles north of the Flagler-St. Johns county line, to the county line where the wedge was about eight miles wide. All available evidence indicates that 40 years ago the area of flow probably would have covered the entire county with the exception of a small area at Durbin, a very small area at the southwestern corner of the county and a narrow strip about two miles wide that extended northward about 12 miles from the Flagler-St. Johns county line, in the ridge and swamp belt. The area of artesian flow will continue to diminish if the withdrawal of artesian water continues to increase.

Artesian Pressure Heads and Their Fluctuations

Artesian pressure heads in several wells in St. Johns County are reported to increase with depth. A driller's log for well 953-118-1, at the Ponce de Leon Hotel, indicated an increase in artesian pressure head of 10 feet between depths of 170 feet and 520 feet. Also, the artesian pressures in well 950-119-1, at Moultrie, and well 957-120-2, north of St. Augustine, were reported to have increased with depth. Wells 943-128-3 and 943-128-1, at Spuds, were completed at 180 feet with 180 feet of casing and at 350 feet with 300 feet of casing, respectively. They are less than 10 feet apart and have a difference in artesian pressure of 0.35 foot, which indicates that water will leak from the lower zones to the upper zones in the uncased parts of wells. A slow leakage from lower zones to higher zones, through beds of low permeability, probably occurs over the entire area.

Fluctuations in atmospheric pressure affect water levels in all artesian wells. A drop of an inch of mercury on a barometer will be accompanied by a rise of as much as 0.7 foot in water level. This explains why some wells commence to flow just before storms, which are characterized by low atmospheric pressure. Water levels in wells near the ocean are affected by the tides. The water level in well 945-115-1, a few yards from the ocean at Crescent Beach, was observed to fluctuate about two feet with each tidal cycle.

Wells

It is estimated that 450 irrigation wells penetrate the principal artesian aquifer in the county. Information obtained for 170 of these wells shows that they range in depth from 150 to 900 feet but that most are less than 350 feet deep. Almost all are four or six inches in diameter. It is estimated that an additional 1,000 artesian wells completed in this aquifer are used for other purposes. These range in depth from 156 to 1,440 feet. Information obtained for 192 of these wells shows that they range in diameter from two to 12 inches, most being four inches in diameter and less than 300 feet deep.

About 40 known artesian wells have uncontrolled discharges totaling about 3,000,000 gallons per day.

QUALITY OF WATER

The water that falls as rain is almost devoid of mineral matter other than carbon dioxide and other gases dissolved from the air, but upon entering the ground it immediately begins to acquire organic acids, more carbon dioxide, and other substances which help it to dissolve rocks and minerals through which it moves. There are three possible sources of chloride contamination of the water in the principal artesian aquifer: (1) Connate sea water, which is water that was in the materials when they were deposited, (2) sea water that entered the formation during Pleistocene time when the sea covered the present land surface, and (3) present-day intrusion of water from the ocean. The first two sources are probably the cause of most of the salinity of the water in the principal artesian aquifer in St. Johns County.

The concentration of chloride in ground water is of great concern to water users in the county. Chloride salts constitute about 90 percent of the dissolved solids in sea water; thus, the chloride content of ground water is generally a reliable index of the amount of contamination from the sea.

Analyses were made of 500 water samples collected from wells of different depths throughout the county. Many wells were sampled several times to observe variations of chloride concentration. The chloride content ranged from a low of three ppm in well 004-137-1 at Switzerland, in the northwestern part of the county where the piezometric surface is relatively high, to 7,200 ppm in well 946-116-1, two miles west of Crescent Beach, where the piezometric surface is relatively low.

Saline water has been partially flushed from the aquifer by fresh water that entered the aquifer from rainfall, and generally the flushing has been more complete in the upper part of the aquifer. An isochloride map (fig. 11) representing the approximate chloride content of the water was made from analyses of samples collected in June 1956. A comparison of this map with a piezometric map of the same area indicates a general correlation between low artesian pressure heads and high chloride content. The correlation suggests either that the aquifer has been flushed less in low-pressure areas or that higher artesian pressures in deep zones of the principal artesian aquifer are causing saline waters to percolate upward into the zones that supply water to wells. Another possibility is that the Pleistocene seas encroached farther into the aquifer in areas where the piezometric surface was low. Figures 12 and 13 indicate that water from wells deeper than 350 feet has a much higher chloride content than that from wells of shallower depth. Analyses of water collected at 50-foot intervals in well 940-128-6, which draws water from the aquifer to a depth of 457 feet in the Hastings area, showed that the salinity increased from 1,470 ppm at 300 feet to 1,735 ppm at 350 feet. The samples were collected from the open hole after the well was drilled.

Well 942-130-1, in the town of Hastings, where little water is used, is 700 feet deep and yields water having a chloride content of 200 ppm. Wells 500 to 600 feet deep, half a mile to the southwest, in the irrigated area, yield

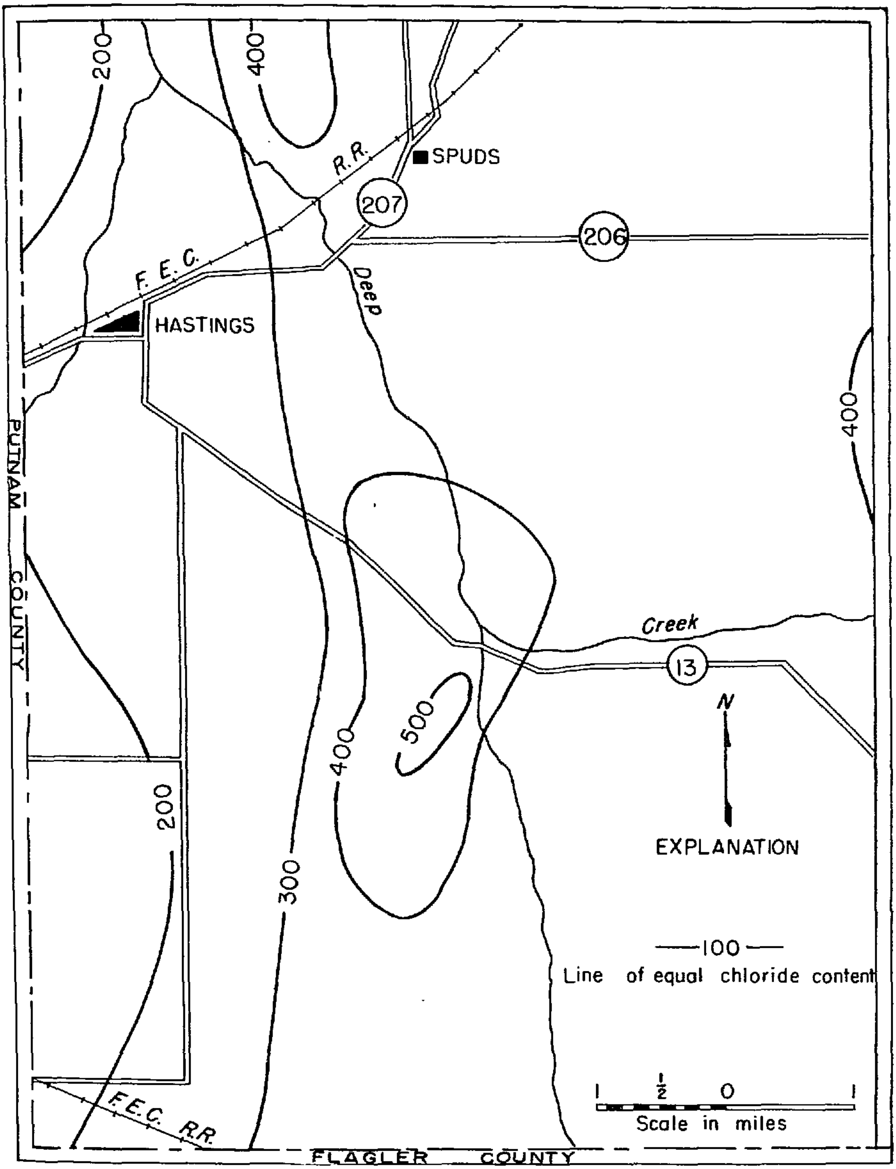

Figure 12. Map of the Hastings area, showing the chloride content of artesian water, in parts per million, in June 1956, from wells less than 350 feet deep.

water having chloride contents as high as 2,500 ppm. Such high chloride concentrations indicate that saline waters are being drawn up from deeper zones in the areas of greatest water use.

Chemical analyses of water samples collected periodically from wells in the Hastings area showed a general increase in salinity during the pumping seasons, when the piezometric surface was lowest, and a general decline in salinity when heavy pumping terminated.

Water from the principal artesian aquifer is relatively hard, which is to be expected of water obtained from beds of limestone and dolomite. Excessive hardness causes difficulty in the use of soap. Iron, which is present in objectionable quantities in the water of the shallow aquifers, is absent or occurs in minute quanitites in water from the principal artesian aquifer. The most objectionable constituent in the artesian water, with reference to domestic use, is hydrogen sulfide, which gives the water a distinct odor of rotten eggs and turns silverware and metal plumbing fixtures black. Chloride and sulfate ions are present in the artesian water throughout the county, but occur in different proportions in the north and south sections. The general ratio in sea water off Florida is seven parts of chloride to one part of sulfate. This ratio is completely reversed in northern St. Johns County, indicating the absence of sea water and suggesting deposits of anhydrite or gypsum. The seven to one ratio is present in southern St. Johns County, suggesting the presence of sea water. The analyses for selected wells are given in table 1.

SUMMARY AND CONCLUSIONS

The following things have been accomplished to date in this investigation:

1. Information was collected on 362 artesian wells that obtain water from the principal artesian aquifer.

Table 1. Chemical Analyses of Water from Wells in St. Johns County
(Analyses in parts per million by Geological Survey)

Well number	941-129-3	954-135-1	946-116-1	007-137-1	957-120-1	011-121-1
Date of collection 1956	Aug. 9	Aug. 8	Aug. 9	Aug. 8	Aug. 8	Aug. 8
Silica (SiO_2)	16	16	22	18	25	26
Iron (Fe), dissolved [1]	.00	.00	.00	.00	.00	.00
Iron (Fe), total	.36	.61	.28	.81	.26	.40
Manganese (Mn), dissolved [1]	---	---	---	---	---	---
Manganese (Mn), total	---	---	---	---	---	---
Calcium (Ca)	354	228	389	38	94	64
Magnesium (Mg)	250	107	459	23	60	39
Sodium (Na)	1,070	11	3,890	8.9	51	19
Potassium (K)	20	2.6	119	2.0	3.9	2.4
Bicarbonate (HCO_3)	120	98	159	132	164	166
Carbonate (CO_3)	0	0	0	0	0	0
Sulfate (SO_4)	850	830	1,080	79	288	175
Chloride (Cl)	2,250	16	7,090	10	82	23
Fluoride (F)	.6	.5	.6	.6	1.0	.9
Nitrate (NO_3)	1.0	.1	.0	.1	.2	.1
Dissolved solids						
Sum	4,870	1,260	13,100	---		
Residue on evaporation at 180°C	---	---	---	247	790	452
Hardness as $CaCO_3$	1,910	1,010	2,860	189	481	320
Noncarbonate	1,810	928	2,730	81	346	184
Specific conductance (micromhos at 25°C)	8,070	1,550	21,200	451	1,010	641
pH	7.7	7.7	7.6	7.8	7.8	7.8
Color	4	2	3	2	2	4
Density at gms/ml at 20°C			1.008			

[1] In solution at time of analysis

2. Continuous water-level recording gages were installed on two wells, to determine rapid fluctuations of the piezometric surface which are not detected by periodic measurements.

3. Water-level measurements were made every six weeks on 30 wells in the county, to determine progressive trends of the water levels.

4. Water-level measurements were made twice a year on 90 wells, for use in making piezometric maps.

5. Analyses of chloride content were made of 500 water samples from 300 wells. Periodic analyses of the chloride content of water samples from 15 wells were made to determine changes in salinity in relation to fluctuations in the piezometric surface.

6. Comprehensive chemical analyses of six water samples were made, to determine the chemical quality of artesian water in different parts of the county.

7. Logs of 40 wells were made by the author or collected from drillers, and borehole cuttings were collected from six wells, for use in making geologic structure maps and geologic cross sections.

The principal conclusions, which follow, cannot be considered final, owing to lack of data in many areas. Many more data will have to be collected before firm conclusions can be reached.

Large quantities of ground water are available in all parts of the county from the principal artesian aquifer, a limestone aquifer whose upper surface ranges from less than 125 feet below the land surface in the southern section of the county to more than 290 feet in the northern section.

The aquifer is overlain by a relatively impervious clay sequence, 50 to 220 feet thick, that confines the water in the limestone under pressure. Many thin lenses of sand, shell, and limestone within the confining clay sequence supply water to small domestic wells.

Relatively large quantities of ground water may be obtained from beds of sand, clay, marl, shell, and sandy lime that overlie the confining clay and range in thickness from 25 to 140 feet. The city of St. Augustine and most farm homes obtain part or all of their water supplies from these beds.

Analyses of water samples from artesian wells in southern St. Johns County indicate that salt water is present in the deep zones of the aquifer. Analyses of water from wells completed at depths greater than 350 feet, in the Hastings area, show a maximum chloride content of 2,500 ppm. The chloride content at the bottoms of the wells is probably much higher because most samples were collected at the well head and were mixtures of highly saline water from the lower zone and less saline water from the upper zone. Water from wells completed at depths less than 350 feet have a maximum chloride content of approximately 500 ppm. Water in the upper part of the artesian aquifer is contaminated by saline water that is drawn upward from deeper zones when the wells are pumped.

The chloride content of water from artesian wells in northern St. Johns County ranges from less than three ppm near Switzerland to slightly more than 100 ppm north of St. Augustine. There is no noticeable increase in salinity with increased depth in these wells.

The principal artesian aquifer in St. Johns County is replenished almost entirely by rainfall that enters the aquifer in the recharge area to the north and west. Local recharge occurs to a minor degree in part of the ridge and swamp belt of the county. Natural discharge occurs by flow from small springs in the northwest section and probably by leakage through the confining beds in the area of artesian flow. A large depression has been formed in the piezometric surface near Crescent Beach owing to the discharge of a submarine spring two miles to the east.

A combination of drawdown from pumping and a seasonal decline lowered the piezometric surface more than 20 feet in some wells in the farming section at the height of the potato-growing season in 1956. There has been a net decline of about five feet in the piezometric surface over the entire county since 1940, and an even greater decline in the farming section. Most of this decline has occurred between 1950 and 1956, a period of subnormal rainfall.

Future work will consist of the following:

1. An inventory of all wells that obtain water from the principal artesian aquifer in the farming area.

2. An inventory of many wells that obtain water from the nonartesian and thin artesian aquifers.

3. A study of nonartesian conditions and the mapping of the water table.

4. Determinations of more accurate elevations of the measuring points on wells used to map the piezometric surface and the water table.

5. Additional pumping tests to determine the water-transmitting and water-storing capacities of the aquifers.

6. Exploration of selected wells with a deep-well current meter and a water-sampling device, to determine the quantity and quality of water from each producing zone.

7. A study of drillers' logs, electric logs, and borehole cuttings, to determine the thickness and extent of geologic formations.

8. A collection of data on ground-water use, to permit an estimate of the total annual withdrawal.

9. An interpretation of information collected on withdrawals, water levels, and water-transmitting and storing capacities of the producing zones, to predict changes in water levels that would result from increased pumping.

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