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REPORT OF INVESTIGATIONS

NO. 2

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GROUND WATER IN THE LAKE OKEECHOBEE AREA

FLORIDA

By

V. T. Stringfield

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Prepared in cooperation between the Florida
Survey and the United States Geological
Survey

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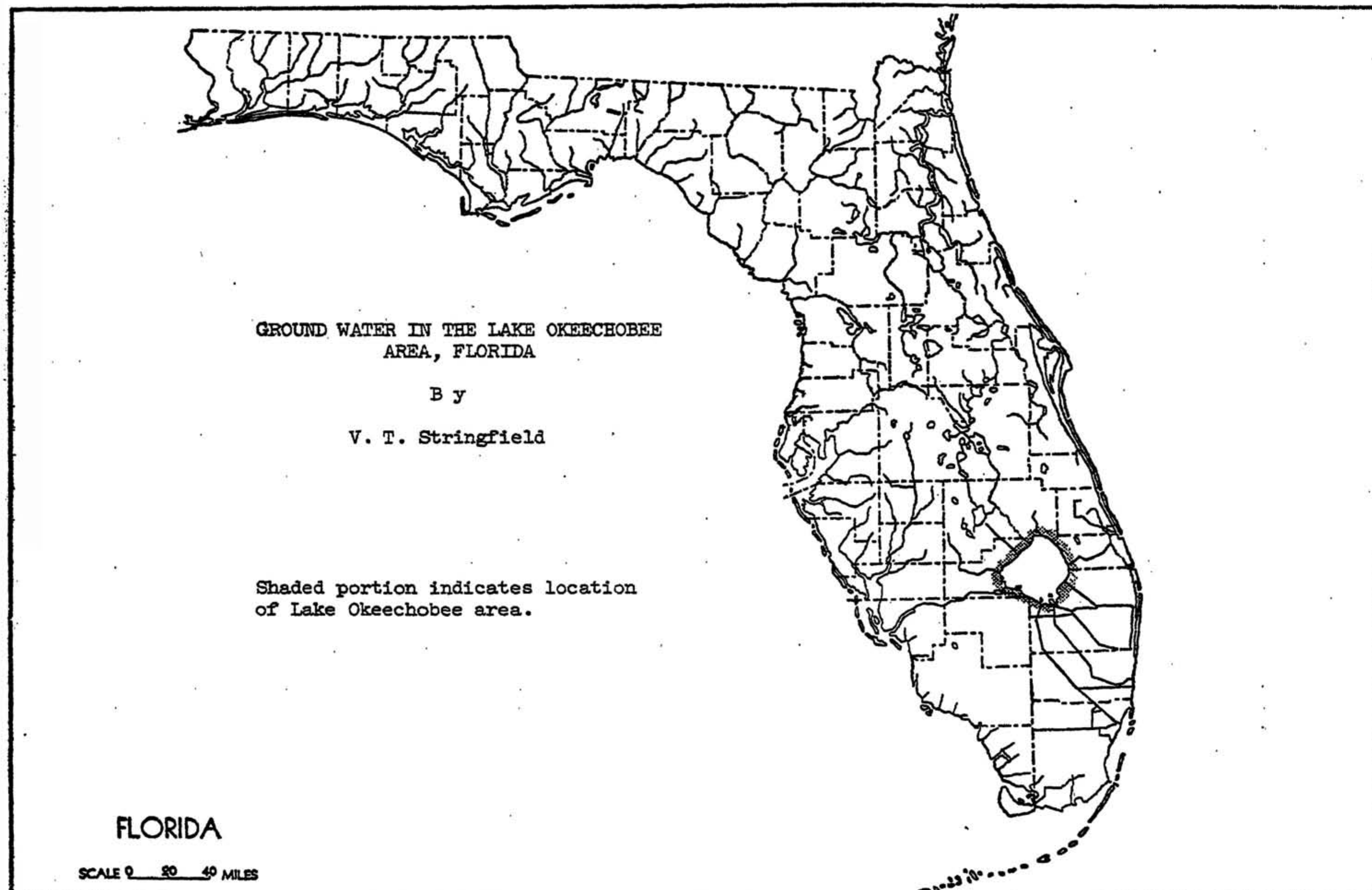
GROUND WATER IN THE LAKE OKEECHOBEE
AREA, FLORIDA
By
V. T. Stringfield
Shaded portion indicates location
of Lake Okeechobee area.
FLORIDA
SCALE 0 20 40 MILES

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Ground water in the Lake Okeechobee area, Florida

Introduction

Location.- The area covered by this report is in the southern part of the Florida peninsula and consists of parts of Okeechobee, Martin Palm Beach, Hendry, and Glades Counties that border Lake Okeechobee. It lies in the northern part of the Florida Everglades.

Purpose and scope of investigation.- The investigation that forms the basis of this report was made during the latter part of April 1933, in order to obtain information regarding the available ground water suitable for domestic and public supplies. This work was undertaken as a part of a comprehensive investigation of the gound-water resources of Florida provided by a cooperative agreement between the Florida State Geological Survey and the United States Geological Survey. The work is under the direction of Herman Gunter, State geologist, and O. E. Meinzer, geologist in charge of the division of ground water of the Federal Survey. Several reports[1] on the work done in other parts of the State have been prepared.

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[1] Thompson, D. G., and Stringfield, V. T., Ground-water resources of Florida: Florida Geol. Survey Press Bull. 13, April 4, 1931.

Thompson, D. G., Problems of ground-water supply in Florida: American Water Works Assoc. Jour., vol. 23, no. 12, pp. 2085-2100, December 1931.

Stringfield, V. T., Ground-water resources of Sarasota County, Florida, and Exploration of artesian wells in Sarasota County, Florida: Florida Geol. Survey Twenty-third and Twenty-fourth Ann. Repts., 1933.

Stringfield, V. T., Ground-water investigations in Florida: Florida Geol. Survey Bull. 11, 1933.

Within the Lake Okeechobee area there are several towns -- Okeechobee (north side of Lake Okeechobee, in Okeechobee County), Pahokee and Belle Glade (southeast side of Lake Okeechobee, in Palm Beach County), Clewiston (south side of Lake Okeechobee, in Hendry County), and Moore Haven (southwest side of Lake Okeechobee, in Glades County). According to the Federal census of 1930 the population of Okeechobee was 1,795 and the population of Pahokee was 2, 256. The other towns had a population of less than 1,000 each.

There are comparatively few wells in this area, and most of these yield highly mineralized water. The ground-water supplies available from wells at the State farm near Belle Glade and several other localities are not entirely satisfactory, and there is a demand for the development of most desirable ground-water supplies or systems whereby water may be obtained from Lake Okeechobee.

In the course of the field work well data and information in regard to the formations penetrated by wells were obtained. The electric resistance of the water was measured at different depths in several wells to determine differences in the amount of mineral matter dissolved in the water and thus to ascertain the depth at which highly mineralized water enters the wells. Field tests were made of the chloride content of samples of water from all the wells visited. Samples of water were obtained from representative wells and analyzed in the water-resources laboratory of the United States Geological Survey by S. K. Love.

The writer is indebted to the citizens who have contributed information to this investigation. Thanks are due especially to Messrs. A. R. Richardson and R. V. Allison and other state officials at Belle Glade. Mr. J. Clarence Simpson, of the State Geological Survey, gave effective assistance in the field work.

Topography

The area slopes gently southward from an altitude of about 35 feet above sea level at Okeechobee and merges into the Everglades. As stated by Cooke and Mossom[1/], "The Everglades form a level grassy plain that slopes gently southward from an altitude of about 18 feet above sea level near Lake Okeechobee and merges into the mangrove-covered keys in Florida Bay. This plain is floored with Pliocene shell marl and limestone (Caloosahatchee marl), which is generally covered by 6 or 8 feet of peaty muck or by a thin layer of Pleistocene limestone. Before their artificial drainage was undertaken the Everglades were usually flooded, but now so much of their water is carried off by canals that their higher parts stand above normal water level."

Lake Okeechobee is a fresh-water body about 35 miles across and not more than about 15 feet deep. It lies in an original depression in the floor of the sea that once covered that part of the peninsula. The Kissimmee River and Taylor Creek flow into the lake on the north side, and

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1/ Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., p. 143, 1929.

Fisheating Creek empties into the lake on the west side. St. Lucie, West Palm Beach, Hillsborough, North New River, and Miami Canals extend from Lake Okeechobee to the Atlantic Ocean. On the west the Caloosahatchee Canal connects the lake with the headwaters of the Caloosahatchee River, which drains westward into the Gulf of Mexico. On the northwest side of the lake the Indian Prairie Canal drains into it. The St. Lucie and Caloosahatchee Canals are normally the chief spillways for the lake. A sand ridge or natural levee a few feet above the general land surface forms a rim around the lake except in several places at the southern edge, which are natural spillways during flood stages.

Outline of geology

General features

The geologic formations of the Florida peninsula consist of several thousand feet of sedimentary rocks that overlie a basement of metamorphic rocks.

The formations exposed at the surface in different parts of the peninsula include the Ocala limestone, of Eocene age, and younger formations of Miocene, Pliocene, Pleistocene, and Recent age. The most recent complete description of the geology of the State is given in a report by Cooke and Mossom[1/] which includes a geologic map showing the distribution of the geologic formations at or near the surface.

1/ Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., pp. 29-228, 1929

Florida forms the emerged part of a peninsula of the continent of North America, known as the Floridian Plateau, which includes not only the State of Florida but also part of the adjacent floor that is less than 300 feet below sea level. In the Gulf of Mexico the edge of the plateau lies from somewhat less than 75 miles to more than 100 miles west of the present coast of the peninsula of Florida. Along the south and east coast of the peninsula, from Key West to Palm Beach, the edge of the plateau is less than 20 miles off the coast.

The sedimentary rocks that overlie the basement rocks of the plateau are arched into a broad anticline or elongated dome. As described by Mossom[1/], the arch trends northwest and plunges toward the southeast in the southern part of the Florida peninsula. In the northwestern part of the peninsula the crest of the arch is eroded and the Ocala limestone lies at or near the surface. On some parts of the crest the Ocala limestone is more than 120 feet above sea level, and dips under the younger formations, which are exposed on the flanks of the fold. This large fold forms a structural feature that is favorable for the occurrence of water under artesian pressure in the Ocala and Tampa limestone and the Hawthorn formation.

In the Lake Okeechobee area the Ocala limestone dips in a general southerly direction, and the formations that overlie it become thicker toward the south.

1/ Mossom, Stuart, A review of the structure and stratigraphy of Florida: Florida Geol. Survey Seventeenth Ann. Rept., pp. 171-268, 1926.

Geologic formations in the Lake Okeechobee area

The geologic formations that are believed to underlie the Lake Okeechobee area are represented in the following table:

Age	Formation	Thickness (feet)	Character
Recent and Pleistocene		0-20	Undifferentiated sand, soil and muck
Pleistocene	Fort Thompson formation	10+-	Marl, limestone, and sand. Yields water to shallow wells
Pliocene	Caloosahatchee marl	50-100	Marl, shells and sand. Yields water to wells.
	Hawthorn formation (of Alum Bluff group)	400-500	Interbedded clay, marl, sand, and limestone. Contains water.
	Tampa limestone	150-250	Limestone. Yields water to wells
Eocene	Ocala limestone (of Jackson age)	500+-	Limestone. Yields water to wells.
Eocene and Cretaceous			Undifferentiated sediments.
Paleozoic or older			Mica, schist, etc., metamorphic basement.

Log of well 5 at Everglades Experiment Station of the University of Florida near Belle Glade, Florida

(FSGS. No. W-20)

	Thickness (feet)	Depth (feet)
Muck	8	8
Fort Thompson formation and Caloosahatchee marl:		
Limestone, white, hard and soft, with broken shell material	24	32
Caloosahatchee marl:		
Limestone, gray-white, broken shell material; some gray-green marl	20	52
Limestone, gray-white, with blue hard limestone, *Chione cancellata*, *Phacoides multilineatus*, *Corbula barrettiana*, *Ostrea* sp., *Arca* sp., *Turritella* sp., and other fossil fragments	13	65
Dark-gray jagged semicrystalline material, much broken shell matter cemented with crystalline calcium carbonate. Same material as above and masses of broken shell. *Plicatula marginata*, *Chione cancellata*, *Phacoides waccamawensis*, *Dosinia* sp., *Olivella mutica*, *Turritella* sp., *Ostrea* sp., *Arca* sp., and other forms as fragments.	18	105
Marl, light-colored, gray-green and broken shell (top sample) Limestone, white, soft, with broken shell (middle sample).	70	175
Hawthorn formation:		
Sand, mostly drab, micaceous; small amount of shell (bottom sample) Sand, dark-green, micaceous.	200	375
Marl, gray with greenish cast, earthy, very calcareous; some shell	165	540
Marl, same as above with *Ostrea* sp	10	550
Marl, same as marl at 540 feet	20	570
Clay or shale, dull green, slightly calcareous . .	5	575

	Thickness (feet)	Depth (feet)
Limestone, white, fairly hard; some gray-green marl (2 samples)	20	595
Limestone, same as above, with considerable gray-green marl and some shell	10	605
Limestone, white, soft, pure; some shell material	10	615
Limestone, light-colored, and gray-green clay	10	625
Limestone and clay, same as above, with black pebble	15	640
Limestone, same as limestone at 625 feet (3 samples)	32	672
Tampa limestone:		
Limestone, similar to that above but lighter-colored and more calcareous (9 samples)	88	760
Limestone, light-colored, with green calcareous clay (3 samples)	30	790
Gray-white, very calcareous material	10	800
Light-yellow calcareous material	10	810
Gray-white, very calcareous material	10	820
Light gray-green, very calcareous material (3 samples)	30	850
Limestone, light gray-white; some clay	10	860
Gray-green, very calcareous material (4 samples)	40	900
Ocala limestone:		
Limestone, white soft	25	925
Limestone, white, soft and hard; Lepidocyclina sp., Operculina sp., and mollusk fragments	45	970
Limestone, similar to above but slightly browner; finely powdered by drill	30	1,000

	Thickness (feet)	Depth (feet)
Limestone, white, hard; many small Laganum sp. cf. L. dalli, Dictyoconus sp. and orbitoids . . .	190	1,190
Limestone, white powdered fine.	15	1,205
Limestone, white, hard and soft, contains some blue limestone and smaller Foraminifera	127	1,332

The log of this well 5 to a depth of 900 feet is published in a report by Mossom. With reference to the probable stratigraphy he states:[1/]

"The first diagnostic material is the Caloosahatchee marl (Pliocene) at 52 feet. Above this the Pleistocene limestone and marl had probably been passed through. The Caloosahatchee is present at 105 feet, and the shell in the first two samples of 105 to 375 seems to represent this formation also. The micaceous green sand or marl is probably of Miocene age, and the limestone toward the bottom from 585 feet down seems also to be of this age, possibly the equivalent of the Tampa limestone, though no fossil evidence is present. The material from 625 to 900 is much the same. As the samples are powdered fine by the drill it is difficult to determine the true nature of the rock. At 625 feet the material is very calcareous -- possibly an impure limestone or very calcareous marl. At 640 there are some semicrystalline pieces of

1/ Mossom, Stuart, A review of the structure and stratigraphy of Florida: Florida Geol. Survey Seventeenth Ann. Rept., p. 251, 1926.

limestone, and these are found intermittently in the succeeding samples. Some samples contain more impurities than others, but the whole should probably be regarded as an impure limestone.

The material from 925 to 950 feet is certainly the Ocala limestone. The sample just above may belong to this formation and probably does. The material from 1,000 to 1,190 also is Ocala; the echinoid Laganum sp. cf. L. dalli is characteristic of the Ocala limestone. Apparently all the material to 1,332 feet should be placed in the Ocala. Thus at this location we have a thickness of over 400 feet for the Ocala with none of the brown limestone usually encountered."[1/]

Log of well 1 at Okeechobee, Fla., on lot 5, block 134, at site of old water plant of Okeechobee.[2/]

	Thickness (feet)	Depth (feet)
Caloosahatchee marl and younger material:	2	2
Sand and soil, fine gray sand, chocolate-colored, fine, some of it indurated organic matter, ordinary hardpan	10	12
Sand, gray or slightly brownish, indurated	3	15
Sands, gray.	23	38

1/ Idem, p. 252, and unpublished notes.

2/ Mossom, Stuart, op. cit. p. 236.

	Thickness (feet)	Depth (feet)
The sample preserved consists chiefly of black clay containing considerable sand, one fragment of shell, but aside from this no indications of marl	3	41
Marl, shell, sandy; shells much broken	15	56
Shell marl, pecten, barnacles, etc., marine shallow-water marl	6	62
Marl, gray, sandy, similar to material at 41-56 feet	3	65
Coarse, clear grain sand and broken shell <u>Ostrea</u> sp., <u>Turritella</u> sp., Bryozoa.	16	81
Hawthorn formation:		
Sand, light gray, incoherent	58	139
Marl, light-colored, sandy, with shell fragments, pecten sp., occasional phosphate pebbles, black and shiny.	19	158
Sand, olive-green, or very sandy marl.	17	175
Clay, olive-green, with black, smooth shiny pebbles, phosphatic.	37	212
Marl, dark-colored, very sandy, or calcareous sands; some broken shells.	28	240
Clays, olive-green, very sandy and calcareous, or clayey sands.	5	245
Marl, dark-colored, very sandy, with shell fragments.	31	276
Clay, calcareous and very sandy, or clayey sand. .	24	300
Sand, dark-colored, broken rock and shell fragments.	80	380

	Thickness (feet)	Depth (feet)
Marl, dark-colored, very sandy; small sand grains	23	403
Sand, light-colored, broken rock and shell fragments.	55	458
Clay, dark, and broken shells.	10	468
Tampa limestone:		
Clay, drab	32	500
Limestone, white, with fragments of echinoderm spines.	10	510
Limestone, white, with fragments of echinoderm spines; also pieces of dark-colored rocks with small phosphate pebble. The dark rock is probably from above the light rock		510
Chiefly white sand		608
Ocala limestone:		
Limestone, white, with <u>Operculina</u> sp., <u>Gypsina</u> sp., <u>Lepidocyclina</u> sp.	7	615
Limestone powdered fine by the drill	160	775

In a discussion of the probable stratigraphy of the material penetrated by well 1 at Okeechobee, Mossom[1/] states:

[1/] Mossom, Stuart, op. cit., p. 237.

"The material from the surface down to the samples marked 94-139 represents the Pleistocene and Pliocene; the contact of the Pliocene and Miocene seems to be in the interval from 94 to 139, for the material from 139 to 500 feet represents the Miocene. From 500 to 608 feet the rock is probably of Oligocene age or basal Miocene, and from 608 to 775 feet is the Ocala limestone, of Eocene age."

Eocene and Miocene Rocks

Ocala limestone

The Ocala limestone, of Eocene age, is the oldest and most deeply buried of the formations that are penetrated by wells drilled for water in this area. The logs of only two wells (see pp. 7-12) penetrating this formation are available. The Ocala is present at a depth of about 600 feet below the surface at the town of Okeechobee, in the northern part of the area, and at about 900 feet below the surface 40 miles to the south, at Belle Glade. It is exposed about 150 miles north of this area in Citrus, Sumter and Marion counties.

The formation consists essentially of limestone but in places contains beds of chert. The material penetrated by well 1 (see p. 10) and well 5 (see p. 7) is chiefly hard and soft white limestone, part of which is fossiliferous.

The maximum thickness of the Ocala limestone in the Florida peninsula has not been definitely determined. The contact with the older Eocene rocks in Florida is not exposed, and no complete section of the formation has been described. It is estimated to have a thickness of about 500 feet in the northern part of the peninsula and possibly is somewhat thicker in the Okeechobee area.

The limestone is one of the chief water-bearing formations of the peninsula. In the southern part of Florida, however, the formation is deeply buried and yields mineralized water. The chemical composition of the water from the two wells penetrating the Ocala is shown on page 31. The fresh water of the Ocala limestone enters the formation in the area where it is at or near the surface, in the central part of the State, or in areas where it is overlain by permeable material that permits free downward percolation. The water in the Ocala limestone is under artesian pressure, and wells penetrating the formation normally overflow at the surface.

Tampa limestone

In the southern part of the State the Tampa limestone, of Miocene age, overlies the Ocala and is overlain by the Hawthorn formation. It is penetrated by many wells drilled for water northwest of the Lake Okeechobee area in a large area that includes Sarasota, Manatee, Hillsborough, and Pinellas counties. It lies at or near the surface in an area that includes all parts of Hillsborough, Pinellas, Pasco, Sumter, and Citrus counties. Well records indicate that in the eastern and northeastern part of the peninsula the Tampa limestone is absent, although no diagnostic fossils of the Tampa limestone have been found in cuttings from wells in the Lake Okeechobee area, the material overlying the Ocala probably represents the Tampa limestone. Normally the Tampa limestone ranges in color from white to brown. The texture and hardness of the formation are variable; some parts may consist of loose masses of fossils, and other parts may be dense, compact, and silicified. The material referable to the Tampa limestone penetrated by wells 1 and 5 is essentially limestone with calcareous clay or marl. The formation has an estimated thickness of 150 to 250 feet in this area. Apparently the greatest thickness is in the southern part of the area.

The Tampa limestone is an important water-bearing formation in the west-central part of the peninsula and yields large quantities of water to wells in Hillsborough and Pinellas counties. In the Lake Okeechobee area, however, although water under artesian head may be found in the formation, it is likely to be highly mineralized, especially in the southern part of the area. The water from well 9, at Moore Haven (see analyses on p. 31), is probably in part from the Tampa limestone.

Hawthorn formation

The Hawthorn formation, of Miocene age, is one of the most extensive formations of Florida and is present throughout the peninsula except in areas where it has been removed by erosion and older formations are exposed. It occurs at or near the surface in an extensive area which includes all or parts of Hardee, Manatee, Polk, and Hillsborough counties, northwest of the Lake Okeechobee area. The formation overlies the Tampa limestone in the southern part of the peninsula and is overlain by the

Caloosahatchee marl or younger material.

It is estimated to have a thickness of 400 to 550 feet and consists of interbedded clay, sand, sandy phosphatic limestone, and marl. As indicated by cuttings from well 1, much of the material penetrated in the northern part of the area is green-gray marl or sandy marl. Cuttings from well 5 indicate that in the southern part of the area the upper part of the formation is chiefly gray-green marl and sandy marl and the lower part is chiefly limestone.

The formation contains water under sufficient artesian head to produce flowing wells. Some of the water, however, is highly mineralized.

Pliocene, Pleistocene and Recent rocks

Surficial materials representing the Pliocene, Pleistocene and Recent series overlie the Hawthorn formation and are present at or near the surface.

Caloosahatchee marl

The Caloosahatchee marl[1/] probably includes all the known marine Pliocene deposits in Florida. According to Cooke the marl probably rests unconformably on the Hawthorn formation and is overlain by Pleistocene material.

The formation underlies the entire Lake Okeechobee area and is

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[1/] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., p. 152, 1929.

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exposed at or near the surface in the northern half of the area. It consists chiefly of sand, shells, limestone, and marl and ranges in color from white to gray, blue, or yellow. The thickness of the formation is estimated at 50 to 100 feet. According to Mossom[1] the contact with the Miocene rocks at Okeechobee (see log of well 1, p. 10) seems to be in the interval between 94 to 139 feet below the surface. At Belle Glade (see log of well 5, p. 7) the contact of the Caloosahatchee with the Miocene rocks is probably between 105 and 150 feet below the surface.

The Caloosahatchee yields moderate amounts of water to shallow wells but some of the water is highly mineralized.

Fort Thompson formation

The Fort Thompson formation, of Pleistocene age, consists of alternating deposits laid down in fresh- and brackish-water and marine shell, and is present in the southern part of the Lake Okeechobee area. It overlies the Caloosahatchee marl and is overlain by 8 to 10 feet of peaty muck in most of the area.

According to Cooke and Mossom:[2]

> "The marine beds in the Fort Thompson consist chiefly of great quantities of *Chione cancellata* in sand. The beds deposited in brackish-water are similar but contain also *Rangia cuneata* (Gray) and other shells whose favorite

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1/ Mossom, Stuart, op. cit. p. 236.
2/ Cooke, C. W., and Mossom, Stuart, op. cit., pp. 211-212.

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habitat is in bays or estuaries. The fresh water origin of certain gray limestone is shown by the abundance in them of shells of Planorbis.

"The Fort Thompson formation is generally less than 10 feet thick but may be somewhat thicker in parts of the Everglades. The individual beds range in thickness from a few inches to about 3 feet.

"The formation covers an area occupied by Lake Okeechobee at a time when it was much larger than it is now. The northern boundary of the lake was probably not far from its present shore line, but the lake extended westward as far as LaBelle and southeastward probably to the eastern border of the Everglades. The lake was separated from the Atlantic Ocean by barriers that at times were swept away or overflowed so completely that salt water penetrated inland to the farthest part of the lake. The alternation of marine and brackish-water deposits with beds deposited in fresh water records several invasions of the sea.

"The surface of the Fort Thompson is a plain that ranges in height from a foot or two below mean sea level at the deepest places in Lake Okeechobee to a maximum of little more than 10 feet above sea level in the Everglades."

This formation supplies water to shallow driven wells. Some of the most suitable water obtained from wells for domestic use at Pahokee apparently comes from this formation. Recharge of the formation is in part local, and in some localities the formation yields water with a swamp coloring. Water from well 11 (see analysis, p. 31) is probably derived from the Fort Thompson formation.

The surficial sands of Recent age supply shallow wells. The water, however, is subject to pollution from contaminated surface water.

Water Supplies

Surface Water

Water supplies in the area are obtained from both surface and ground water sources. The surface water is drawn from Lake Okeechobee or from canals connected to it. Water from the lake is suitable for public and domestic use after is has been decolorized, filtered, and chlorinated. However, owing to the shallowness of the lake the intake pipe line must be laid and maintained to a distance of several hundred yards into the lake. The public water supply of Okeechobee is obtained from the lake. The public water supplies of Clewiston and Moore Haven are obtained from canals connected with the lake.

Ground Water

Wells

The record of 12 representative wells are shown in the table on page 29. Except at Okeechobee there are only three deep flowing wells (Nos. 2, 5, and 9) in the area. There are 6 or more deep flowing wells in Okeechobee, the record of one of which is shown on pages 10 to 13. Probably all those wells penetrate the Ocala or Tampa limestone.

The public water supply of Belle Glade is furnished by a 3-inch well, 26 feet deep (well 6, p. 29). A 6-inch well 810 feet deep (well 1, p. 10) formerly furnished water for the public supply of Okeechobee. A 6-inch well 804 feet deep (well 9, p. 30) is used for emergency purposes for the Moore Haven public supply.

There are numerous driven wells 10 to 15 feet deep that draw water from the ridge or natural levee of the lake. Some of these wells, as well 11, p. 30 are in the muck areas and penetrate the Fort Thompson formation.

Another group of wells that probably yields most of the ground water in the area are 25 to about 150 feet deep and about 2 to 6 inches in diameter and draw water from the Caloosahatchee marl or the upper part of the Hawthorn formation. Wells 3, 4, 6, 7, and 8 belong to this group. The static water level in these wells is from a few inches to a few feet below the surface. Wells of this type are found along the natural levee bordering the lake, at the field camps of the United States Sugar Corporation, and in most of the towns of the area.

Artesian conditions

Water in the Ocala and Tampa limestones and in the Hawthorn formation is under artesian pressure, and wells penetrating these formations overflow. Well 1, at Okeechobee, has sufficient artesian head to raise the water 12 feet above the surface, or about 50 feet above sea level. Measurements of the artesian pressure on wells 2 and 5 indicate that the artesian head in the southern part of the area is probably slightly less than that in the northern part of the area. This suggests that there may be a circulation of artesian water toward the south.

Water in wells terminating in the Caloosahatchee marl or in the upper part of the Hawthorn formation rises to levels ranging from a few inches to a few feet below the surface.

Relative resistivity of the water at different depths

The resistance of the water at different depths was measured in representative wells (Nos. 1, 2, 3, 5, 8, and 10) to indicate differences in the concentration of dissolved mineral matter in order to determine the depth at which the most highly mineralized water enters the wells. The resistance of the water was measured between a pair of electrodes with a slide wire bridge using a 1,000-cycle alternating current obtained from an audio-oscillator operated by four $1\frac{1}{2}$ -volt dry-cell batteries. A reel operated by hand and a wire cable with an insulated wire core were used for lowering the electrodes into the well. The insulated wire and the outer steel strands served for the leads from the bridge to the electrodes[1/]. The electrodes were lowered a few feet at a time into the well, and a measurement of the resistance was made. An odometer consisting of a trip counter and a grooved brass wheel with a circumference of 1 foot, over which the cable passed, was used for recording the distance the electrodes were lowered into the well. The electrodes were not calibrated to furnish a basis for calculation of the actual resistivity.

1/ Stringfield, V. T., Exploration of artesian wells in Sarasota County: Florida Geol. Survey Twenty-third and Twenty-fourth Ann. Rept., pp. 215-216, 1933.

The resistivity of the water in the wells that were examined in this area decreased with increasing depth, but the decrease was probably no more than can be attributed to the increase in the temperature, indicating that there was no appreciable difference in the concentration of the water at different depths. In wells 1, 2, 3, and 5, which yield highly mineralized water, the records of the measured resistance indicate that the mineralized water comes from strata penetrated in the lower parts of the wells. If fresh or less concentrated water were entering the lower part of the wells, there would have been an appreciable increase in the resistivity of the water in that part of the well.

A record of the resistance of the water as measured with the electrodes used in well 5 is shown in the following table. This well was drilled 10 inches in diameter to a depth of 300 feet, and 10-inch casing was inserted to that depth, below which it was drilled 8 inches in diameter, and 8-inch casing, extending from the surface, was seated at a depth of 900 feet. The total depth of the well is 1,332 feet. At the present time the well yields water from both the 10-inch and the 8-inch casing. The water from the 10-inch casing is more highly mineralized (see analyses, p. 31) than that from the 8-inch casing, and prior to the examination of the well it appeared that water from the 10-inch casing might be leaking into the 8-inch casing and thereby causing the high mineralization of the water from that source. The resistance record, however, indicated that there is no appreciable difference in the concentration of the water at different depths in the 8-inch hole and therefore that there is no transfer of highly mineralized water from the 10-inch hole to the 8-inch hole. The records also indicate that no water of low mineralization enters the lower part of the well. The construction of the well prevents exploration to determine the source of the water in the 10-inch casing. However, the head of water in the 10-inch casing was about 2 feet less than that in the 8-inch casing, indicating that the water comes from some source above 900 feet. The 8-inch casing doubtless was tightly seated, and there was no subsurface leakage of water, because lowering the head as much as 30 feet in that casing had no effect on the head in the 10-inch casing. The water from the 8-inch casing is from the Ocala limestone and that from the 10-inch casing probably from the Hawthorn formation.

Apparent resistance of water at different depths in

Well 5, near Belle Glade.

Depth (feet)	Resistance (ohms)	Depth (feet)	Resistance (ohms)	Depth (feet)	Resistance (ohms)	Depth (feet)	Resistance (ohms)
10	81	350	77	725	72	1,100	67
28	81	375	77	750	71	1,125	67
51	81	400	76	775	71	1,150	67
75	81	425	76	800	71	1,175	67
100	80	450	75	825	71	1,200	66
125	80	475	75	850	71	1,225	66
150	80	500	74	875	70	1,250	66
175	79	525	74	900	70	1,275	65
200	79	550	73	925	69	1,300	65
225	79	575	73	950	69	1,325	65
250	79	600	73	975	69	1,320	65
275	78	625	72	1,000	68		
300	78	650	72	1,025	68		
325	77	675	72	1,050	68		
		700	72	1,075	68		

Chemical composition of the water

Analyses of water from 10 representative wells and Lake Okeechobee are shown on page 31. All the ground water analyzed except that from wells 7 and 12 is excessively hard or otherwise highly mineralized and is unsatisfactory for domestic or public supplies. With proper treatment, however, such water as that from well 6 may be made suitable for domestic use.

The chloride content of the water may be referred to as an indication of the relative saltiness of the water. It has little effect on the suitability of the water for domestic purposes unless there is enough to cause a disagreeable taste. Water containing as much as 1,000 parts per million of chloride is undesirable for drinking, and to be acceptable to most people it should not contain more than about 250 parts per million. All the samples of water collected from wells penetrating the Ocala and Tampa limestones and the Hawthorn formation contained more than 400 parts per million of chloride. Some of the samples from the Caloosahatchee formation were high and some were comparatively low in chloride. There are variations in the quality of the water with reference both to horizontal distribution and to depth. For example, well 7, near Clewiston, yields water with a chloride content of 135 parts per million from the Caloosahatchee formation, and a few miles north of that area salt water is encountered at about the same depth. Variations in the quality of water with depth is shown by a comparison of analyses of water from wells 3, 4, and 6. Although the water from wells 3 and 4 is relatively soft, it is high in sodium and bicarbonate and therefore undesirable for domestic use. All the samples of water collected from the Fort Thompson formation and the younger overlying material were low in chloride. Samples of water from the Fort Thompson and upper part of the Caloosahatchee formation had a swamp color.

Water from Lake Okeechobee is moderately soft and is satisfactory for domestic or public supplies after decolorization, filtration, and chlorination. Analyses of the lake water are shown on page 31 and published in a report by Collins and Howard[1/]. The report also includes analyses of water from the lake 3 miles north of Ritta Island and from the mouth of the Kissimmee River, which flows into the lake.

Summary and conclusion

Flowing wells that yield large quantities of water from the Ocala and Tampa limestones may be obtained in this area, but all the water from these formations is hard and is likely to be high in chloride. According to the available information it appears unlikely that water supplies satisfactory for domestic or public use can be obtained from these formations in the southern part of the area. In the northern part of the area wells that are not drilled too deep may obtain water similar to that from well 1, (see analysis, page 31) which is usable although of poor quality, whereas water from deeper sources is likely to be still more highly mineralized.

The Hawthorn formation also yields water to wells, but although the composition of the water may not be the same throughout the formation, the water is likely to be too highly mineralized for domestic or public

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[1/] Collins, W. D., and Howard, C. S., Chemical character of waters of Florida: U. S. Geol. Survey Water-Supply Paper 596, pp. 222-224, 1928.

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use, except possibly in the northern part of the area.

In some localities the Caloosahatchee formation yields water relatively low in mineralization that is fairly satisfactory for domestic use (see analysis 7), but in other places the water is excessively hard or otherwise highly mineralized (see analyses 3, 4, and 6). With proper treatment the hard water from well 6, derived from the upper part of the Caloosahatchee at Belle Glade, could be improved. There is a possibility, however, that with heavy draft from the well the water would become more concentrated in dissolved material.

Wells 3 and 4, at the Florida State farm No. 2, near Belle Glade, yield water from the Caloosahatchee formation that is unsatisfactory for domestic use. Probably hard water similar to that from well 6 (26 feet deep) at Belle Glade may be obtained from wells of similar depth at the State farm, but with heavy draft water similar in quality to that from wells 3 and 4 may be drawn in from below. There are no wells yielding water from the lower part of the Caloosahatchee formation in this area, and the quality of the water is undetermined. However, the presence of mineralized water at a depth of only 40 feet below the surface suggests that the prospects are poor for obtaining water of low mineralization in the lower part of the formation in this locality.

It appears that although large quantities of ground water are available, the poor quality of the water offers little encouragement for the development of water supplies from either deep or shallow wells, although in some localities in the northern part of the area it may be possible to obtain small supplies of usable water from shallow wells. In view of the fact that satisfactory water can be obtained from Lake Okeechobee, it appears advisable to develop water supplies so far as practicable from the lake or from the canals connected with it.

Records of wells in Lake Okeechobee area
(For analyses see following table)

No.	Location	Owner or name	Depth of well (feet)	Diameter of well (inches)	Depth to which well is cased (feet)	Pressure head or altitude of water level above or below surface (feet	Remarks
1	Lot 5, block 134 Okeechobee (Okeechobee Co.)	City of Okeechobee	718	8-6	484	+12	Original depth was 810 feet. See log p. 15.
2	SW 1/4 Sec. 12 T. 42 S. R. 18 E. south of Conners Highway, 3 miles SE of Canal Point (Palm Beach Co.)	United States Sugar Corp.	958	6	800±	+32	Yield from Tampa & Ocala limestones.
3	Florida State Farm No. 2, near Belle Glade (Palm Beach Co.)	Florida State Farm	42	4	20±	-1.5	Yield from Caloosahatchee marl.
4	do	do	37	3	20±	-.9	do
5	University of Fla. Everglades Experiment Station, near Belle Glade (Palm Beach Co.)	Everglades Experiment Station Univ. of Fla.	1,332	10-8	957	+35	See resistance record on p. 27 & log on p. 10 10-inch casing to depth of 300 feet. Yield from Ocala limestone.
6	Belle Glade (Palm Beach Co.)	Town of Belle Glade	26	3	26	-	Yield from Caloosahatchee marl.

No.	Location	Owner or name	Depth of well (feet)	Diameter of well (inches)	Depth to which well is cased (feet)	Pressure head or altitude of water level above or below surface (feet)	Remarks
7	Dairy about 1 mile west of Clewiston (Hendry Co.)	Clewiston Dairy Company	107	3	100±	-3	do
8	Essambee Farms Sec. 30, T. 42 S. R. 34 E, east side of Moore Haven Rd. (Glades Co.)	T. P. McBride	142	6	-	-3	do
9	Moore Haven (Glades Co.)	Town of Moore Haven	804	6	700		Yield from Tampa or Hawthorn.
10	West of Brighton south side of St. Rd. No. 8 (Highlands Co.)	Brighton	219	12	-	-3	Test well for oil. Plugged at 219 feet.
11	Torry Island (Palm Beach Co.)	H. A. Braddock	15	6	-	-3	Yield from Fort Thompson formation.
12	La Belle Everett Hotel	Everett Hotel	650	6	-	+30 ±	Yield from Hawthorn and Tampa formations.

Analyses of water from the Lake Okeechobee area.
(Parts per million. Numbers in first column refer to corresponding numbers in preceding table. S. K. Love, analyst).

No.	Location or source	Depth (feet)	Date of collection	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as ($CaCO_3$) (calculated
1	Okeechobee City Fla. Near Canal	718	Apr. 24,1933	1,344	111	60	294	124	248	570	(a)	524
2	Point State Farm	958	Apr. 11,1933	1,941	108	86	495	157	233	942	(a)	623
3	near Belle Glade	42	Apr. 17,1933	2,740	29	42	1,011	1,323	170	838	(a)	245
3 b/	do	do	do	2,757	30	43	1,013	1,313	179	845	(a)	251
4	do	37	May 8, 1933	2,311	57	72	758	1,186	192	648	(a)	438
5	Experiment Station near Belle Glade	1,332	May 17, 1933	3,470	144	138	948	151	516	1,650	(a)	926
5 c/	do	do	do	4,530	104	150	1,375	37	630	2,255	(a)	875
6	Belle Glade	26	May 5, 1933	1,162	230	80	64	615	398	87	(a)	903
7	Clewiston	107	Apr. 20,1933	678	146	12	105	518	25	135	(a)	414
9	Moore Haven	800	May 1, 1933	2,660	136	105	694	22	426	1,290	(a)	770
11	Torry Island	15	Apr. 18,1933	1,058	217	66	26	427	244	45	250	813
12	La Belle	650	Apr. 24,1933	1,282	57	47	342	120	312	465	(a)	335
13 d/	Lake Okeechobee at Pahokee		Aug. 17,1923	272 e/	37	11	34 e/	128	19	58	(trace)	138

a/ Less than 0.5 parts per million.
b/ Sample collected after pumping for 1.5 hours.
c/ Sample collected from flow from 10-inch casing.
d/ Analysis from U. S. Geol. Surv. Water-Supply Paper 596, p. 224, 1928.
e/ Determined.