STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES

BUREAU OF GEOLOGY
Robert O. Vernon, Chief

REPORT OF INVESTIGATION NO. 54

WATER RESOURCES OF NORTHEAST FLORIDA

(St. Johns River Basin and Adjacent Coastal Areas)

By
L. J. Snell and Warren Anderson
U. S. Geological Survey

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

Tallahassee, Florida
1970

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Bureau of Geology
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February 25, 1970

Governor Claude R. Kirk, Chairman
Florida Department of Natural Resources
Tallahassee, Florida

Dear Governor Kirk:

The Bureau of Geology of the Division of Interior Resources, Florida Department of Natural Resources, is publishing as its Report of Investigations No. 54 a study, Water Resources of Northeast Florida (St. Johns River Basin and Adjacent Coastal Areas). This report was prepared as a part of the cooperative program between the Bureau of Geology and the U.S. Geological Survey and is written by L. J. Snell and Warren Anderson of the U.S.G.S.

The study is published at a time when the St. Johns Watershed and coastal areas are being rapidly developed and urbanized, and it will provide data on the amounts of ground and surface water that will be available in the area and will be the basis for planning so far as the quality and quantity of these waters are concerned. A summary of these data indicates that there are adequate amounts of potable water in the area to meet the needs for the immediate future. Certain problems, such as the reduction of ground water recharge, the reduction of the amount of water flowing from wells and contamination of water in some local areas, will probably accelerate the declines in quality and quantity of water but adequate management will reduce the severity of these problems.

Respectfully yours,

R. O. Vernon, Chief

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WATER RESOURCES OF NORTHEAST FLORIDA
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U. S. Geological Survey

ABSTRACT

The St. Johns River basin and adjacent coastal basins, an elongated area of approximately 11,200 square miles in northeast Florida, comprise one-fifth the land area of Florida and contain one-fourth its population.

Rapid industrial expansion and population growth in both the present centers of population and the less densely populated rural areas places increasing demands on water resources in the area. Total water use is expected to quadruple by the year 2020.

Ground water from the Floridan aquifer, a limestone aquifer which underlies the entire area, is the principal source of water for all uses except cooling water used in the generation of electric power and in some industrial processes. Some small municipalities and rural domestic users obtain ground water from sand or sand and shell aquifers that occur above the Floridan aquifer. Surface water is used for irrigation in some areas and a few municipalities obtain water from lakes.

Large supplies of good quality water may be obtained from much of the Floridan aquifer, which ranges from about 500 feet to more than 1,000 feet in thickness. The top of the limestone, which is at or near land surface near the western divide, is more than 400 feet below land surface and sea level in the northern and southern parts of the area. Wells drilled into the aquifer may yield more than 5,000 gallons per minute. The quality of the deep aquifer water varies from good in or near the recharge areas in the western part of the area to poor along the St. Johns River and near the coast where high concentrations of chloride and other constituents render the artesian waters unsuitable for most uses. An exception is the Jacksonville area where good quality water has been located in formations at a depth of about 2,100 feet.

Moderate amounts of good quality water can be obtained from the shallow sand and shell aquifers and from sand and shell-beds in the Hawthorn Formation in the areas along the coast where the water in the Floridan aquifer is of poor quality.

The St. Johns River and its principal tributary, the Oklawaha River, receive much of their flow from large perennial springs, which are among Florida's many tourist attractions. Silver Springs, near Ocala, discharges an average of 530 mgd (million gallons per day) of good quality water; other smaller springs discharge waters which vary in quality from good to highly saline.

The low relief of the area is typical of Florida; the fall in more than 300 miles from the marshes at the source of the St. Johns River to its mouth is only 25 feet. The river is affected by tides for 161 miles upstream from its mouth. Numerous shallow lakes occur in the Oklawaha River subbasin and others occur as widened parts of the St. Johns River main stem. Waters in swampy areas are highly colored from decayed vegetation but otherwise are of good chemical quality. Springs contribute high carbonate waters to streams throughout the basin and some saline water is added to the main stem of the St. Johns River.

Ample quantities of good quality water are available to meet the foreseeable water needs in the report area. Exclusive of saline waters used for cooling in electric power generation, the water withdrawn from surface and ground water sources is less than 10 per cent, and that consumed is less than 5 per cent of the estimated available supply. The problems of water supply, therefore, are essentially problems of distribution rather than availability because most sources of readily available good quality water are in the western parts of the report area and the centers of greatest demand are presently along the Atlantic coast. Urbanization and drainage of lands tend to reduce ground-water recharge; free flowing wells and heavy industrial pumping without return of used water to the aquifers reduce the ground water levels; excessive pumping invites saline-water intrusion in some areas. Contamination of both surface and ground waters is a problem which must be controlled to insure the quality of waters in the area.

INTRODUCTION

PURPOSE AND SCOPE

The rapidly expanding population and economic growth in northeast Florida places increasing demands on its water resources. Although water is abundant in most parts of the area covered by this report and more than meets the demands at the present time, the demand for water is expected to double by 1980 and to more than quadruple by the year 2020, indicating a need for thorough and continued evaluations, understanding, and proper management of the water resources. Further, though water is generally abundant in the area as a whole, the quality of the surface water in the lower St. Johns River and of the artesian water in Brevard County and some other areas, for example, is unacceptable for most uses. Also, though the quality of water in the streams and aquifers in much of the area is acceptable now, increased development with

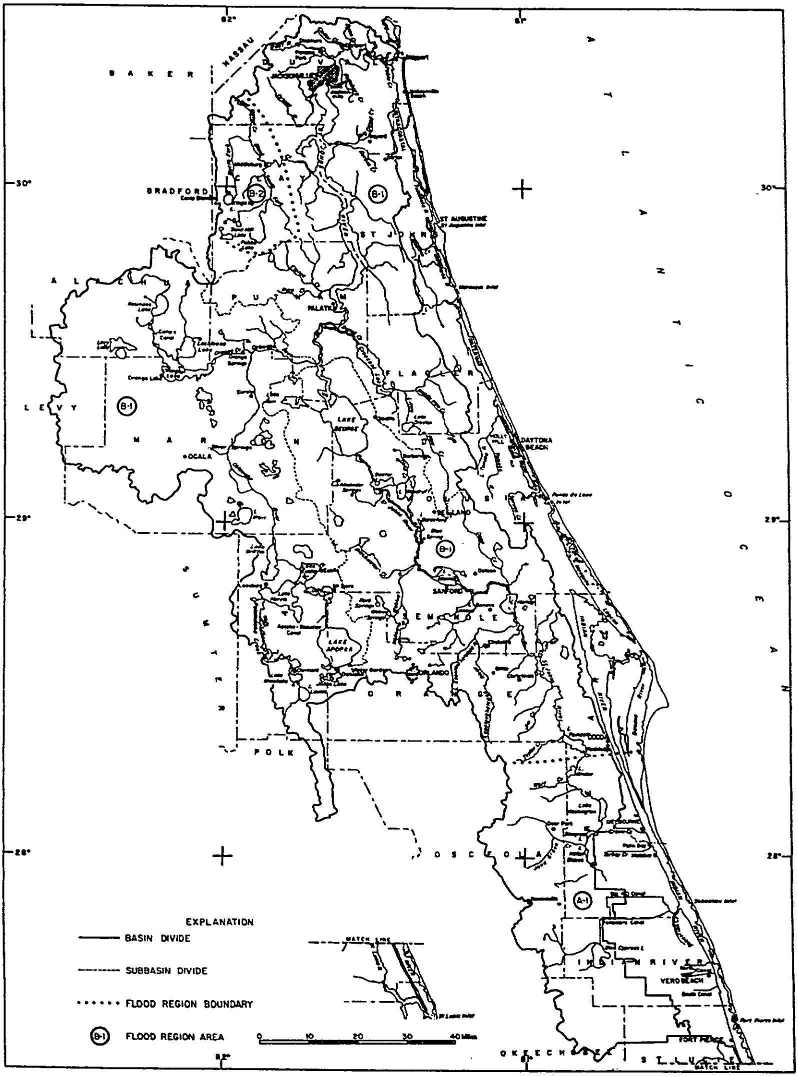

Figure 1 Map of northeast Florida showing drainage system and flood regions

attendant disposal of waste and modification of the hydrologic cycle portend increased problems relating to quality.

This report summarizes and appraises the water resources of the St. Johns River basin and the adjacent narrow coastal strip of northeast Florida (as shown in Figure 1). The area includes all or major parts of Duval, Clay, St. Johns, Alachua, Putnam, Flagler, Marion, Volusia, Lake, Seminole, Orange, Brevard, Osceola, and Indian River counties, and small parts of Levy, Sumter, Polk, Okeechobee and St. Lucie counties. The area contains 11,200 square miles, approximately, and has about one quarter (more than 1,500,000) of Florida's population. The report provides information on the occurrence, availability, chemical quality, and use of surface and underground waters as a guide for public and private agencies for planning the most beneficial development of the water resources of the area, to recognize areas of excess and deficient water, areas of good and poor quality waters, and areas where further detailed investigations are desirable. The population and economic expansion creates the need for additional water supplies either from present sources or from new sources. Sources should be investagated in order to maintain acceptable water quality, to assure flood protection, and to otherwise determine water availability to enhance the economic and recreational aspects of the area.

The report was prepared under the general supervision of Clyde S. Conover, District Chief, Water Resources Division, U. S. Geological Survey, at the request of the Florida Board of Conservation, Water Resources Division, as part of the statewide cooperation with the Division of Geology to evaluate the water resources of Florida. Reports and publications, including those from which the report material has been extracted, are given in the list of references. The efforts of the original investigators and the review provided by colleagues are appreciated and gratefully acknowledged.

EXPLANATION OF TERMS

Knowledge of the water resources of the area has expanded considerably since 1930. The period 1950-65 was used as the base for comparative purposes in portions of this report. Rainfall, which is the source of all fresh-water resources in the area, was close to the long-term average during the 15-year period. However, The record of long-term yearly rainfall indicates that wet and dry cycles in this period were more severe than in earlier years.

Definitions are given herewith for a number of terms used in this report.

Surface water is water on the surface of the earth.

Ground water is water beneath the surface of the earth in zones of saturation. It does not include "soil moisture" which normally is not directly available for use by man.

Drainage basin is an area occupied by a drainage system into which all surface waters within the area flow. The boundary between two drainage basins is called a "drainage divide." The basin may contain "noncontributing areas," which are areas in which water is diverted for use, returned to the atmosphere by evapotranspiration, or enters the ground at a rate sufficient to prevent or reduce surface runoff.

Runoff is considered that part of precipitation that appears in surface streams. However, runoff herein is considered essentially synonomous with streamflow which is derived both from "overland flow" and "base flow." In Florida "base flow", which is a major part of the total flow in most streams, is essentially "ground-water runoff" and is supplied from ground water emerging as springs or as seepage, sometimes without regard to topographic divides.

Surface-water discharge is the rate of flow of a stream. It is expressed as cubic feet per second (cfs) in this report.

Aquifer is a formation, group of formations, or part of a formation that is water-bearing. It is often called a "ground-water reservoir."

Recharge is water added to an aquifer by infiltration of precipitation into the soil or rock, by seepage through the soil or sinkholes, by seepage from streams, lakes and other surface water bodies, by flow from one aquifer to another, and by introduction through or into recharge wells and sinkholes. Recharge is generally expressed as a rate of inches per year over an area.

Water table is the upper surface of a ground-water body under atmospheric pressure, as indicated by the level of water in a well or open hole that penetrates the top of the zone of saturation. The water table is usually synonymous with the "shallow" or "nonartesian" water level.

Artesian water is water under hydrostatic pressure confined in an aquifer by relatively impervious materials, which rises in a well above the top of the aquifer. Flowing wells occur where hydrostatic pressure in the aquifer is great enough to raise the water above the land surface.

Piezometric level is the level to which water rises under hydrostatic pressure in a tightly cased well that penetrates an artesian aquifer. An artesian pressure surface is defined by the piezometric levels in a number of wells that penetrate the same confined aquifer.

Ground-water discharge is water that leaves an aquifer by any means, including pumping, natural flow as springs or seepage to streams, lakes, or canals, or by evapotranspiration.

HYDROLOGIC AND GEOLOGIC SETTING

The area covered in this report includes 11,200 square miles, approximately, of which about 9,430 are in the St. Johns River basin and the balance are in coastal basins between the St. Johns River and the Atlantic Ocean. The area has a humid subtropical climate which supports heavy growths of native pine and scrub oak in the generally sandy and well-drained soils, and cypress in wet bottom lands. The principal source of fresh water is rain on the area although some ground water flows into the area through aquifers from the central highlands of Florida.

The St. Johns River basin and the adjacent coastal area receive an average of about 28 bgd (billion gallons per day) of precipitation, all of which occurs as rain. About 20 bgd reenters the atmosphere through the processes of evapotranspiration, about 3 bgd percolates into the aquifers, and 6.5 bgd runs off through streams to the ocean. Of the 3 bgd which percolates into the aquifers, more than half emerges as springs to augment the surface flow, some is withdrawn through wells, and the remainder emerges as off-shore submarine springs, or underground flow to the Suwannee and Withlacoochee River basins.

The St. Johns River is the largest river wholly in Florida and is one of the few large northerly-flowing rivers in the United States. It is affected by tides to Lake Monroe, 161 miles above its mouth. The altitude of most of the area is less than 50 feet above mean sea level, although altitudes along the western drainage divides generally range from 75 to 200 feet and exceed 300 feet in the upper Oklawaha River basin. Along headwater reaches of the St. Johns River in Indian River County, more than 300 river miles from its mouth, the flood plain is only 25 feet above sea level. The average slope of the St. Johns River main stem is less than 0.1 ft. per mile in the 300 mile length and less than 0.05 ft. per mile for the lower half of the river. Relief is greater in the Oklawaha River subbasin. Low terraces which parallel the coast, formed when the ocean stood at higher levels during Pleistocene time, are the Silver Bluff, Pamlico, Talbot and Penholoway terraces at altitudes approximately 8, 25, 42, and 70 feet above present sea level. Other, less readily recognizable terraces are at higher altitudes.

The area is underlain by several water-bearing formations which vary as to water availability and quality. In descending order they are the marine deposits of Pleistocene and Holocene (Recent) age; undifferentiated deposits and the Hawthorn Formation of Miocene age;

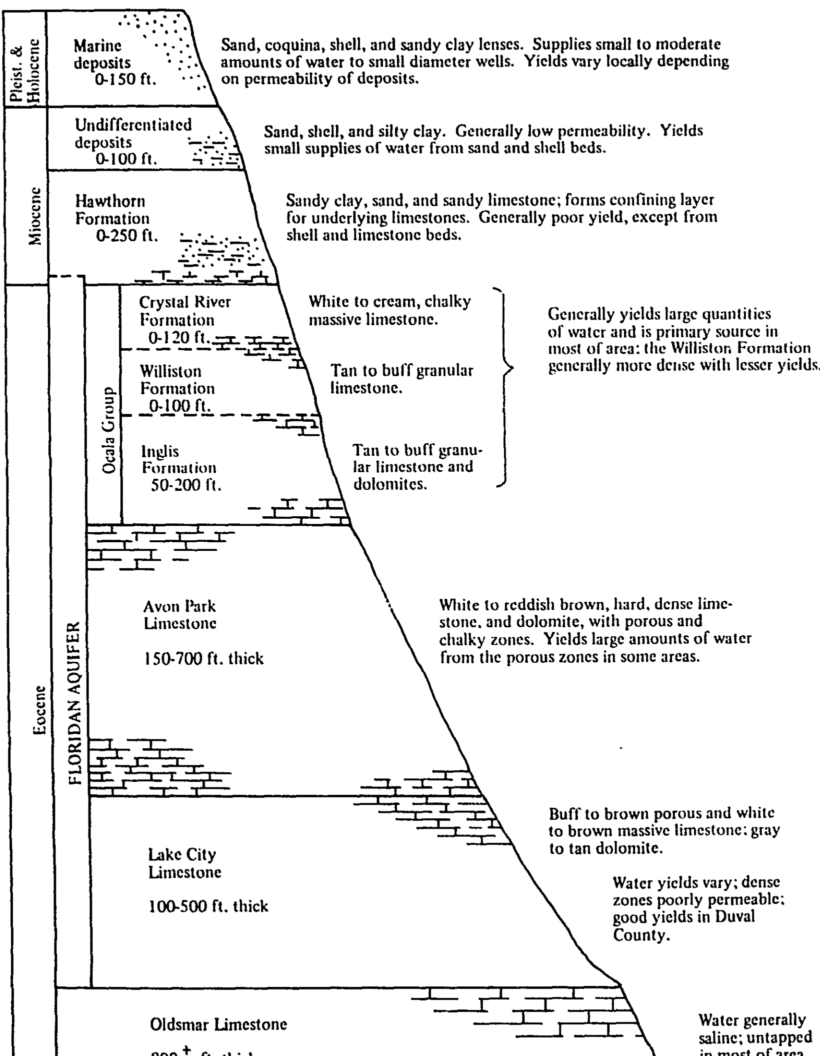

Figure 2. Geologic Formations penetrated by water wells in northeast Florida.

Figure 2 Geologic formations penetrated by water wells in northeast Florida

the Ocala Group[1], consisting of the Crystal River, Williston and Inglis Formations, the Avon Park Limestone and the Lake City Limestone, all of Eocene age, which, with the hydraulically connected linestone in the lower part of the Hawthorn Formation, compose the Floridan aquifer; and the Oldsmar Limestone, also of Eocene age. Figure 2 shows the geologic formations penetrated by water wells in northeast Florida, with their general characteristics and approximate thicknesses, which vary from one locality to another. The Floridan aquifer which underlies all of the area, is the principal source of water. The Oldsmar Limestone is generally untapped in the area.

The top of the Floridan aquifer is at or near the land surface in central Marion County, Alachua County, and some other areas, and is at a depth of more than 400 feet at the extreme ends of the basin, in Duval and Indian River counties. The Floridan aquifer ranges in thickness from about 500 to more than 1,000 feet. It is overlain by sand, sandy clay, and shell deposits of Miocene, Pliocene, Pleistocene and Holocene ages. These deposits have generally low to moderate permeability and limited thickness and thus yield small to moderate quantities of water to wells. Porous limestones of the Floridan aquifer near the land surface in the highlands area, and permeable surficial sands in Marion, Alachua, Lake, Orange, and other counties, absorb much of the rainfall. On such areas recharge to the Floridan aquifer may be, locally, in excess of 16 inches per year. Some of the water later emerges as springs, seeps along streams, or from free-flowing or pumped wells, perhaps many years and miles from the time and place of its occurrence as rain. Most ground water in the area flows through the Floridan aquifer in a generally easterly direction toward the Atlantic Ocean although, in Alachua and western Marion counties, some ground water moves westward out of the St. Johns River basin into the Withlacoochee and Suwannee River basins. Many of Florida's large springs, including Silver Springs, Alexander Springs, Blue Springs, Wekiva Springs, and others are in the report area, some of which obtain their waters from relatively local recharge. Some ground water is discharged from submarine springs in the Atlantic Ocean.

In contrast to the areas of rapid ground-water recharge characterized by the absence of surface streams, are parts of Clay, Putnam, Flagler and other counties that are underlain by deposits that have low permeability and are characterized by numerous surface streams and swampland. Rainfall does not readily recharge the ground water

[1] The geologic nomenclature used in this report conforms to that of the Florida Geological Survey, and is not necessarily conformable to that of the U. S. Geological Survey.

aquifers in such areas because both the deep and the shallow aquifers are usually full so that water runs off in surface streams or is lost by evapotranspiration. Surface runoff averages about 12 inches per year in the entire area but ranges from zero in large parts of Alachua, Marion, Lake and Orange counties to more than 20 inches in others. Average evapotranspiration is estimated to be about 37 inches.

The report area contains a large supply of available water of good quality and, also, large amounts of less desirable water. Under good management the water needs of the area should be fulfilled to the year 2020 and beyond. Distribution of water to the localities of concentrated demand, control practices to reduce or eliminate salt water and other contamination in ground water and surface water, and the competition or conflict of interest between domestic, recreational, industrial, and agricultural needs, are water management problems that will require resolution in the future.

DRAINAGE

The St. Johns River, the most prominent drainage feature of the area (figure 1), has its source at an altitude of less than 25 feet in a broad swampy area just west of Fort Pierce, in St. Lucie County, about 300 river miles from its mouth at Mayport. From the headwaters a marsh extends northward approximately 40 miles before a natural channel becomes recognizable, upstream from Lake Hellen Blazes. This area has been modified extensively by canals and dikes and considerable interchange of water with the Lake Okeechobee basin to the south and the coastal basins to the east occurs. From the head of the channel the river flows generally northward for 250 miles to Jacksonville where it turns eastward and flows an additional 23 miles to the Atlantic Ocean. The river passes through eight shallow lakes, such as Lake Harney and Lake George; six other lakes are in the flood plain. Downstream from Palatka the river averages more than a mile in width. The total surface area of the main stem of the river at low water exceeds 300 square miles, from which the average loss by evaporation is approximately 530,000,000 gallons per day. The St. Johns River is perennially tidal as far upstream as Lake George (106 miles) and, under combined conditions of drought and high tide, the tidal effects occur as far upstream as Lake Monroe (161 miles). Approximately two-thirds of the drainage area in the St. Johns River basin, including the Oklawaha River basin, lies west of the main stem.

Drainage in the coastal strip between the St. Johns River basin and the Atlantic Ocean is into lagoons, formed by barrier islands, and to the ocean.

WATER QUALITY

The chemical quality of waters varies according to the materials available for solution or suspension according to varying hydrologic conditions and to actions of man. Rain is not chemically pure but contains low concentrations of carbon dioxide, oxygen and nitrogen. Water acts as a solvent and dissolves chemical constituents during passage over the ground or through an aquifer; industrial and other wastes, pesticides and fertilizers add contaminants to water. Suspended sediment, which is a serious problem in some parts of the United States, is not a serious problem in peninsular Florida. Dissolved minerals, water temperature, color, and salt water intrusion are the natural and man-influenced water-quality phenomena that are significant to use of water in the report area. Unless controlled, water quality will deteriorate as the result of man's effects on water from use of fertilizers and pesticides and the movement of the effluents from industrial, municipal and domestic sources into water courses and ground water aquifers.

The significance and effects of certain common dissolved or suspended chemical constituents and properties of water are given in Table 1. Some dissolved minerals are detrimental in extremely small concentrations. Tolerance limits for drinking water have been suggested by the U. S. Public Health Service, and limits for industrial uses have been suggested by the American Water Works Association. At the present time, quality of water standards are under detailed study by the State of Florida and by the Federal Water Pollution Control Administration. Table 2 lists suggested tolerances, or maximum allowable limits, for certain water uses.

The chemical character of the water in streams in the area differs from stream to stream and varies seasonally and even daily in individual streams due to natural causes and to development. The water is generally low in mineral content if it is direct runoff or seepage from nonartesian aquifers and generally high in dissolved minerals if it was derived from the artesian aquifer. The chloride content is sometimes high in the upper as well as lower reaches of the St. Johns River, because of upward leaking saline water from the artesian aquifer; also, salinity in the lower reaches is from the influx of seawater as a result of tides. Near the mouth of the river the salinity varies from brackish to that of seawater.

Wells that tap the Floridan aquifer in the upper reaches of the St. Johns River basin discharge water which is high in chlorides but nevertheless is used to irrigate citrus groves. The salty drainage water from citrus groves is diluted during periods of high runoff. Figure 3

TABLE 1. WATER QUALITY CHARACTERISTICS AND THEIR SIGNIFICANCE

Constituent or properties	Significance
Dissolved solids	A measure of the total amount of dissolved matter, usually determined by evaporation. Excessive solids interfere in most industrial processes and cause foaming in boilers.
Silica	Causes scale in boilers and deposits on turbine blades.
Sulfate	Excessive amounts are cathartic and unpleasant to taste. May cause boiler scale.
Nitrate	High concentrations indicate pollution. Causes methemoglobinemia in infants. Helps to prevent intercrystalline cracking of boiler steel.
Fluoride	Over 1.5 mg/l cause mottled tooth enamel, small amounts (about 1.0 mg/l) prevent tooth decay.
pH	Values below 7.0 indicate an acid water and a tendency for the water to be corrosive.
Iron and Manganese	On precipitation cause stains; unpleasant taste in drinking water; scale deposits in water lines and boilers; interferes in many processes such as dyeing and paper manufacture.
Chloride	Unpleasant taste in high concentrations. Increases corrosive nature of water.
Sodium	Large amounts injurious to humans with certain illnesses and to soils and crops.
Hardness	Due to calcium and magnesium salts causes excessive soap consumption, scale in heat exchangers, boilers, radiators, pipes, and interfered in manufacturing processes. Less than 60 mg/l soft; 60-120 is moderately hard; 120-200 is hard.
Alkalinity	Causes foaming in boilers and carryover of solids with steam, embrittlement of boiler steel.
Color	Stains products in process use. May cause foaming in boilers. Not desirable in drinking water.
Suspended solids	Unsightly appearance in water. Causes deposits in water lines, process equipment, and boilers.

TABLE 2 – SUGGESTED WATER-QUALITY TOLERANCES FOR SELECTED USES (maximum allowable limits in milligrams per liter)

Use	Turbidity	Color	Hardness as Calcium Carbonate	Iron (Fe)	Dissolved Solids	Alkalinity as $CaCo_3$	Odor Taste	Hydrogen Sulfide (H_2S)	Silica (SiO_2)
Air Conditioning	-	-	-	0.5	-	-	low	1	-
Baking	10	10	-	.2	-	-	low	.2	-
Boiler feed water									
0-150 PSI	20	80	80	-	3000-500	-	-	5	40
150-250PSI	10	40	40	-	2500-500	-	-	3	20
250-400 PSI	5	5	10	-	1500-100	-	-	0	5
Over 400 PSI	1	2	2	-	50	-	-	0	1
Brewing									
Light beer	10	10	-	.1	500-1500	75-80	low	.2	50
Dark beer	10	10	-	.1	500-1500	80-150	low	.2	50
Carbonated Beverages	2	10	200-250	0.1-.2	850	50-128	low	0-0.2	-
Confectionary	-	-	-	.2	50-100	-	low	.2	-
Dairy industry	-	0	180	0.1-.3	500	-	none	-	-
Food Canning and Freezing	10	-	3/50-85	.2	850	30-250	none	1.0	-
Food Equipment washing	1	20	10	.2	850	-	none	-	-
Food Processing, general	10	10	10-250	.2	850	30-250	low	-	-
Ice	5	5	-	.2	300	30-50	-	-	10
Laundering	-	-	50	.2	-	-	-	-	-
Plastics, clear, uncolored	2	2	-	.02	200	-	-	-	-
Paper and Pulp:									
Kraft pulp	25	15	100	.2	300	-	-	-	-
Soda and sulfate	15	10	100	.1	200	-	-	-	-
High grade light papers	5	5	50	.1	200	-	-	-	-

1/American Water Works Association 1950 and Water Quality Criteria, McKee and Wolf 1963.

2/P indicates that potable water, conforming to USPHS standards, is necessary.

3/Peas 200-400, fruits and vegetables 100-200, legumes 25-75.

Bicarbonate (HCO_3)	Carbonate (CO_3)	pH Minimum	Nitrate (NO_3)	Chloride (Cl)	Calcium (Ca)	Magnesium (Mg)	Sulfate (SO_4)	Fluoride (F)	Other requirements
-	-	-	-	-	-	-	-	-	No corrosiveness, slime formation
-	-	-	-	-	-	-	-	-	P
50	200	8.0	-	-	-	-	-	-	
30	100	8.4	-	-	-	-	-	-	
5	40	9.0	-	-	-	-	-	-	
0	20	9.6	-	-	-	-	-	-	
-	50-68	6.5-7.0	10	60-100	100-200	30	-	-	P NaCl less than 275 mg/l
-	50-68	6.5-7.0	10	60-100	200-500	30	-	-	P NaCl less than 275 mg/l
-	-	-	-	250	-	-	250	0.2-1.0	P
-	-	7.0	-	-	-	-	-	-	P No corrosiveness, slime formation
-	-	-	17	30	-	-	60	-	P
-	-	7.5	8.6	400-600	-	-	-	1.0	P
-	-	-	-	250	-	-	-	1.0	P
-	-	-	-	-	-	-	-	1.0	P
-	-	-	-	-	-	-	-	-	P
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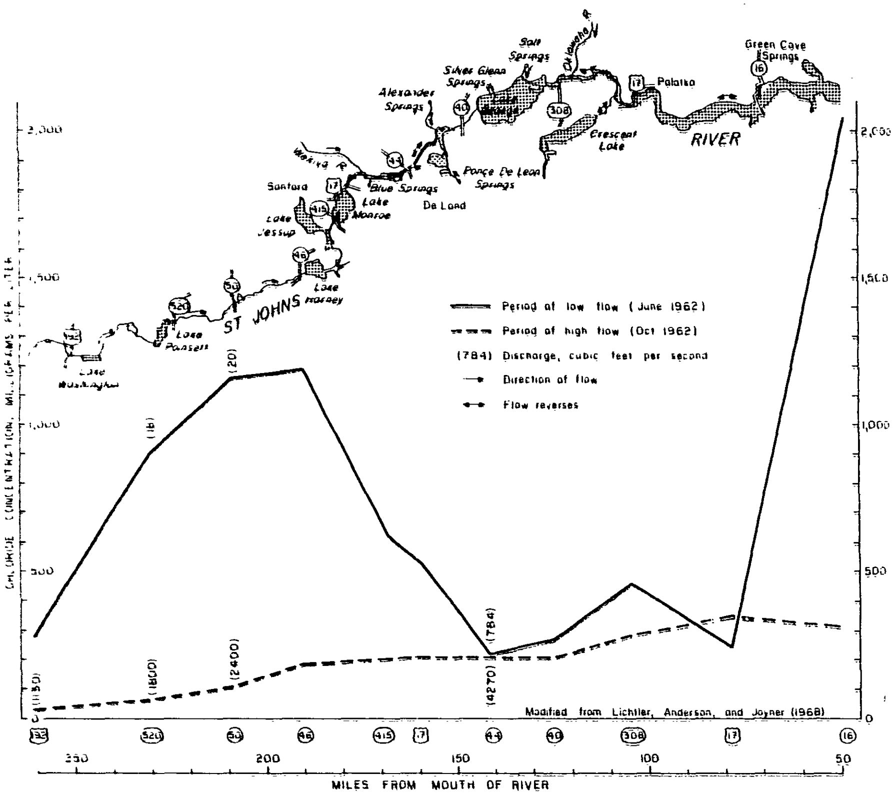


Figure 3 Diagram showing chloride concentration in St. Johns River during periods of high and low flow

shows the relation of the chloride concentration to water discharge along a stretch of the St. Johns River during a period of high flow and of low flow. The main stem data show the effects of saline inflows, the dilution by fresh-water tributaries, and the effect of tidal action in the lower reach.

Streams in the coastal area are generally more saline than tributaries of the St. Johns River and water in the coastal lagoons is too saline to be used for purposes other than cooling and recreation.

Color of surface waters is extremely variable throughout the study area and normally ranges from zero to about 200 Hazen units. After heavy rains when highly colored water is flushed into small streams from swampy areas, the color reaches as high as 600 units.

Additional information on quality of surface water is given in the sections of the report which follow. The quality of ground waters s variable with depth and with location and is discussed in the section on ground water. Table 3 lists the observed extremes in quality of surface water for some of the more important streams and lakes in the report area.

FLOODS

Data on floods in the area were analyzed by Barnes and Golden (1966) to determine the relation between flood magnitude, drainage area, and the average frequency of occurrence. The flood-frequency analysis shows that because of physiographic differences the area must be delineated into two flood regions; "A," south of Lake Poinsett, and "B," north of Lake Poinsett, and that region "B" must be further divided into two hydrologic areas, area B-1 and area B-2. These subdivisions are shown on figure 1.

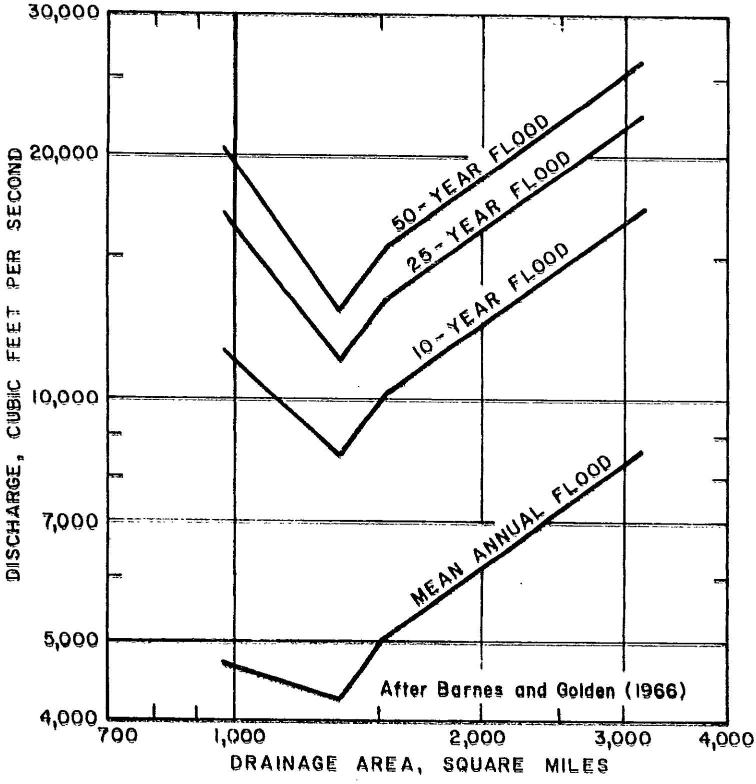


Figure 4 Flood-frequency curves for the main stem of the St. Johns River

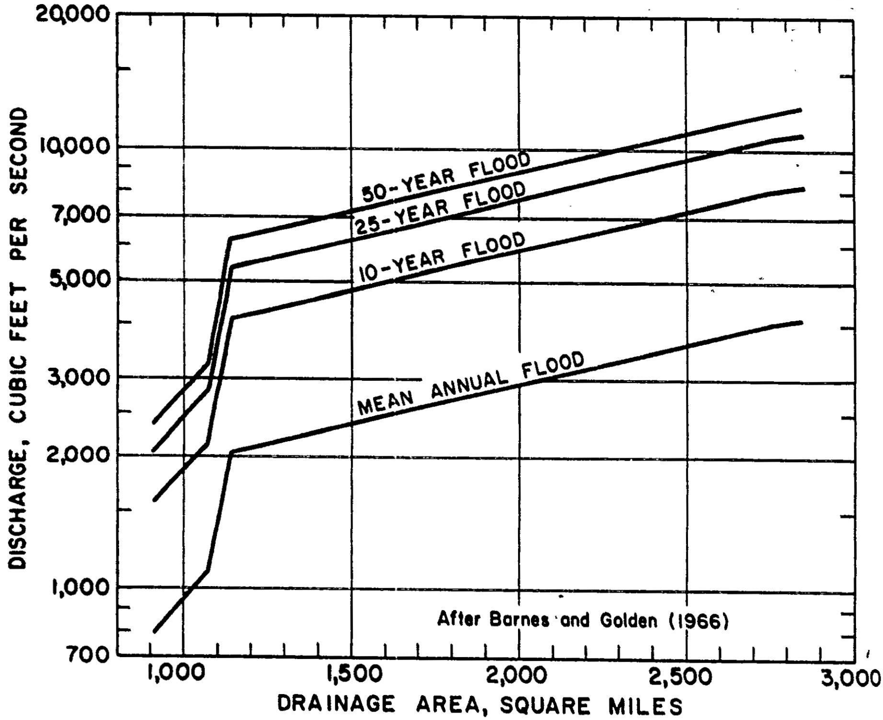


Figure 5 Flood-frequency curves for the main steam of the Oklawaha River

Special analyses were required for the main stem of the St. Johns and Oklawaha Rivers because their hydrologic characteristics differ from those of the smaller streams in the area. Figures 4 and 5 are the flood frequency curves developed for the main stems of the St. Johns and Oklawaha Rivers. Flood-frequency curves for region A, area 1 (south of Lake Poinsett) are given in Figure 6; for region B, area 1, north of Lake Poinsett in Figure 7; and for region B, area 2 (Black Creek basin) in Figure 8.

Drainage basins that contain lakes and swamps have lower flood peaks than otherwise equivalent basins because of the temporary storage of flood runoff. Discharge records from streams draining lakes and swamps in central Florida have been analyzed to determine the effect of storage on the attenuation of flood peaks. This effect

TABLE 3. OBSERVED EXTREMES IN QUALITY OF SURFACE WATER IN ST. JOHNS RIVER BASIN AND COASTAL AREAS, PERIOD 1952-65.
(chemical constituents in milligrams per liter. Analyses by USGS)

Source	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids		Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
													Calculated	Residue	Calcium, magnesium	Non-carbonate				
Alexander Springs near Astor	10 -12	0.00	40 - 49	15 - 18	100 - 121	3.0- 3.3	92 - 97	52 - 61	169 - 232	0.1-0.2	0.0- 3.0		436- 525	352- 502	164- 192	88- 502	813- 988	7.3-7.8	0- 5	72-73
Blue Springs near Orange City	8.5- 8.6	.00-.01	57 - 60	20 - 26	215 - 240	7.7- 9.0	128 -160	37 - 80	245 - 560	.1- .2	.8- 1.3	*0.80	563- 920	553- 835	212- 280	106- 166	480- 2,490	7.5-7.6	2- 5	73-74
Clear Lake near Cocoa	1.9-13	.08-.22	8.0- 19	3.8- 11	29 - 85		12 - 24	9.0- 32	54 - 165		.1- 1.3		152- 320		36- 93	24- 73	229- 646	6.2-6.8	80-180	
Crane Creek at Melbourne	.5-20	.00-.55	25 -168	5.3- 31	**‡17	-119	62 -279	15 - 77	38 - 300	.1- .4	.0- 1.8		131- 808		84- 462	33- 248	261- 1,410	7.0-8.1	30-280	
Deep Creek near Osteen	.4- 6.6	.08-.97	4.4- 21	.0- 4.4	4.1- 12	.2- 1.4	9 - 34	3.6- 21	6.5- 44	.1- .4	.0- 1.7		28- 86		14- 66	6- 29	42- 225	6.2-7.3	80-260	50-88
Econlockhatchee River near Bithlo	.0- 8.9	.02-.50	2.6- 26	.2- 2.7	1.8- 15	.2- 1.6	8 - 83	0 - 6.4	3.0- 23	.0- .8	.0- 1.3		16- 108	32- 163	8- 74	0- 19	24- 197	5.7-7.8	35-400	
Econlockhatchee River near Chuluota	1.7-12	.00-.60	3.6- 51	1.0- 14	**‡	.7-112	10 -112	1.0- 58	8.0- 179	.2- .6	.0-14		31- 468		13- 162	5- 74	55- 873	6.2-7.6	40-600	
Ellis Canal near Indian River City	7.4-14	.00-.71	120 -209	27 - 49	**‡270	-409	126 -274	199 - 278	315 -1,150	.4	.4- 3.6		1,380- 1,640		410- 690	308- 500	1,840- 4,410	7.1-7.9	35-160	
Fellsmere Canal near Fellsmere	5.0-19	.00-.50	36 -101	5.4- 16	**‡19	- 83	96 -214	23 - 57	46 - 270	.2- .6	.0- 2.0		193- 524		112- 284	34- 108	331- 1,180	7.3-7.9	50-300	
Jane Green Creek near Deer Park	.4-19	.01-.50	3.8- 19	.2- 4.1	.7- 12	.1- 1.2	4 - 34	0 - 18	6.5- 36	.1- .2	.0- 2.8		29- 96		18- 54	3- 28	57- 261	5.5-7.2	25-360	50-87
Johns Lake at Oakland	.0- 1.6	.01-.18	7.2- 8.0	2.9- 6.1	10 - 20	6.0- 8.0	7 - 13	26 - 42	18 - 24	.1- .3	.0- 1.4		77- 111	114- 146	30- 44	20- 38	150- 202	5.8-6.5	25- 80	
Kingsley Lake near Camp Blanding	.3- 1.9	.01-.03	2.2- 3.4	.7- 1.0	4.7- 6.2	.2- .6	4 - 8	2.9- 5.6	8.0- 10	.0- .1	.0- .1		20- 32	22- 37	10- 12	3- 5	36- 57	5.9-6.6	5- 8	56-82
Lake Apopka at Winter Garden	5.1-15	.01-.27	28 - 38	8.8- 13	8.4- 23	3.3- 13	104 -186	15 - 20	16 - 25	.4- .6	.9- 3.7		149- 229	206- 285	106- 150	0- 25	333- 385	7.0-7.9	20- 45	
Lake Geneva near Keystone Heights	.0- 2.5	.00-.02	.8- 2.0	.7- 1.3	5.6- 6.4	.0- 1.0	1 - 4	3.0- 6.8	8.5- 10	.0- .1	.0- .2		26- 28	26- 34	8- 8	4- 7	52- 56	5.1-5.6	0- 10	60-88
Lake Lochloosa near Lochloosa	.0- 5.7	.06-.56	8.0- 15	1.7- 3.3	5.8- 7.8	.1- 1.0	29 - 50	3.2- 12	10 - 16	.2- .3	.0- 1.0	.00-1.1	44- 84	49- 91	29- 51	5- 12	83- 142	6.6-6.8	15- 75	59-85
Lake Maitland at Winter Park	.0- .9	.00-.04	18 - 24	4.9- 6.8	9.3- 14	3.7- 5.2	52 - 72	24 - 31	15 - 20	.1- .5	.0- 2.8		104- 131	128- 154	65- 88	22- 32	195- 230	6.6-7.6	5- 10	
Little Econlockhatchee River near Union Park	.3-11	.01-.77	5.4- 16	.6- 4.8	5.2- 16	.2- 2.4	9 - 51	1.2- 6.8	9.5- 20	.0- .4	.0- .8	*1.0	35- 75	69- 146	16- 48	4- 20	58- 146	5.6-8.0	20-400	
Moultrie Creek near St. Augustine	7.0-23	.00-.60	1.4- 96	1.5- 28	8.7- 128	.3- 3.8	11 -234	.2- 132	14 - 242	.0- .6	.0- 1.8			68- 820	15- 354	0- 194	64- 1,390	5.7-8.1	5-560	42-78
Newnans Lake near Gainesville	.1- 3.0	.14-.65	3.2- 5.6	.9- 1.7	3.8- 9.0	.0- 1.0	4 - 21	1.2- 3.2	2.5- 14	.2- .3	.0- 4.4	.00- .10	21- 45	53- 76	12- 21	4- 9	49- 86	5.3-6.6	50-110	55-88
North Fork Black Creek near Highland	.8-33	.02-.25	2.4- 59	.0- 6.1	4.2- 72	.0- 1.8	0 - 36	4.0- 199	3.8- 12	.0- .4	.0- 3.6	.00- .50	26- 316	54- 336	8- 157	0- 146	35- 581	4.1-7.1	5-280	40-80
North Fork Black Creek near Middleburg	1.1-11	.00-.28	.8- 28	.0- 3.9	3.2- 20	.0- 1.9	1 - 25	.8- 96	3.5- 12	.1- .4	.1- 1.7	.00- .50	20- 170	59- 184	8- 86	6- 68	38- 279	4.7-6.8	5-340	48-75
Oklawaha River near Orange Springs	5.5-12	.00-.75	38 - 69	2.9- 18	16 - 53	.0- 2.0	70 -158	22 - 102	28 - 96	.1- .8	.0- 1.2			223- 441	38- 222	30- 130	301- 663	6.8-8.3	5-400	
Orange Lake near Boardman	2.3- 4.3	.16-.23	6.0- 6.8	1.2- 1.9	4.6- 4.7	.1- .8	18 - 21	.8- 3.0	7.0- 10	.1- .3	.2- 1.3		33- 42	49- 66	20- 25	4- 8	61- 83	6.3-6.5	50- 80	59-83
Ponce De Leon Springs near De Land	5.6- 7.4	.00-.01	25 - 50	6.8- 18	33 - 135	2.0- 5.6	122 -138	15 - 36	66 - 240	.1- .2	.1- 5.0	.14- .25	221- 558	242- 532	128- 195	24- 221	329- 1,000	7.7-7.9	0- 5	63-74
Salt Springs near Lake Kerr	10 -12	.00-.05	452 -200	44 -110	878 -1,620	18 - 58	67 - 90	368 - 626	1,550 -2,900	.0- .2	.3- 5.7		3,110- 3,710	3,110- 4,030	777- 876	780- 811	5,380- 9,500	7.3-7.7	2- 5	72-75
Silver Springs near Ocala	10 -11	.00-.02	67 - 73	8.0- 9.8	5.4- 5.7	.5	200 -202	38 - 52	7.0- 9.0	.2- .3	1.2- 2.0		233- 259	252- 254	200- 220	34- 56	352- 430	7.7-8.0	0- 5	73-74
South Fork Black Creek near Penney Farms	1.4-18	.02-.58	1.0- 34	.1- 3.2	1.8- 7.2	.0- .7	4 - 90	0 - 22	3.0- 13	.0- .4	.0- 3.4	.30- .50	12- 118	3- 156	3- 98	0- 30	18- 228	5.3-7.5	10-360	50-80
St. Johns River at Christmas	.2-11	.00-.43	7.5-162	2.2- 77	11 - 606	.6- 15	21 -138	2 - 364	20 -1,150	.0- .5	.0- 6.4		57- 2,350	188- 2,830	28- 720	11- 672	110- 4,800	6.3-7.5	45-220	
St. Johns River near Cocoa	.0-16	.00-.83	8.4-136	1.5- 56	12 - 454	.0- 14	5.2-136	2.5- 156	21 - 900	.0- .7	.0- 5.6		67 1,760	103- 2,320	16- 570	9- 494	40- 3,500	6.4-7.9	30-280	46-95
St. Johns River near De Land	1.0-11	.00-.20	16 - 84	7.0- 41	43 - 312	.6- 12	31 -152	14 - 166	88 - 570	.0- .4	.0- 2.2		213- 1,090	628- 1,440	69- 378	40- 312	350- 2,220	6.6-7.6	12-240	51-86
St. Johns River near Geneva	.8-30	.00-.28	7.5-146	3.0-105	††‡17	-644	20 - 116	6.8- 402	30 -1,210	.1- .7	.0- 5.6		760- 1,570	1,080- 2,730	31- 796	14- 752	152- 4,230	6.5-7.4	35-300	
St. Johns River at Jacksonville	.7- 4.7	.00-.13	27 -225	10 -633	71 -5,520	2.6-200	60 -112	28 -1,320	128 -9,720	.3- .7	.1-11	.00- .32	394-17,700	360-18,700	109-3,170	45-3,080	618-30,000	6.8-7.3	10-120	
St. Johns River near Melbourne	.3-20	.00-.26	7.1- 62	1.1- 11	4.8- 62	.8- 2.5	17 -128	0 - 30	14 - 140	.0-1.2	.0- 1.2		50- 258	188- 546	23- 200	5- 94	91- 696	6.2-7.4	45-280	
Tomoka River near Holly Hill	2.5- 7.3	.16-.32	15 - 42	1.6- 4.0	10 - 18	.0- .8	39 -134	4.0- 13	18 - 30	.1- .4	.0- .3		77- 181		47- 122	9- 18	122- 292	6.9-7.4	180-240	

* Result from one sampling only during period.

‡ Combined sodium and potassium.

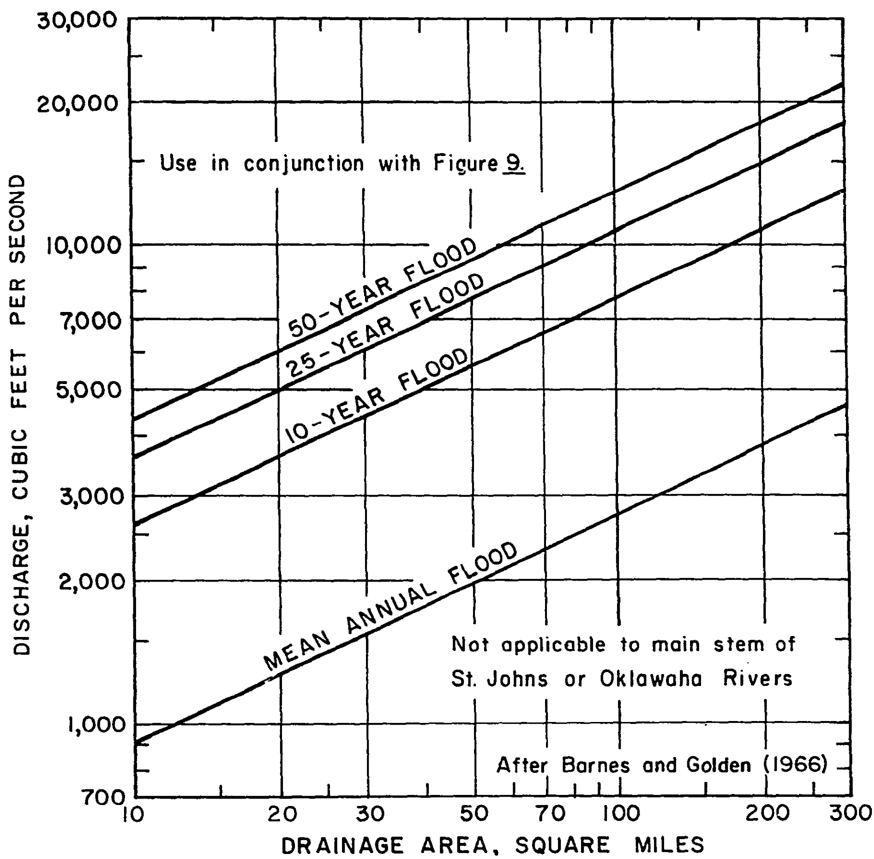


Figure 6 Flood-frequency curves for Region A, area 1 in northeast Florida

was found to be significant only if the lakes and swamps covered as much as three per cent of the total drainage basin. Figure 9 supplies the values for reduction in the mean annual flood discharge for drainage areas containing a significant percentage area of lakes and swamps. The adjustment factor for attenuation is applicable to streams of each of the three area in figures 6, 7, and 8, with the exception of mainstem streams. Large parts of the area, including sink-hole areas from which there is no flow, and areas where canals and dikes are constructed, are not subject to regional flood analysis. Caution should be used in applying these flood-frequency analyses to parts of the area because the installation of control structures on

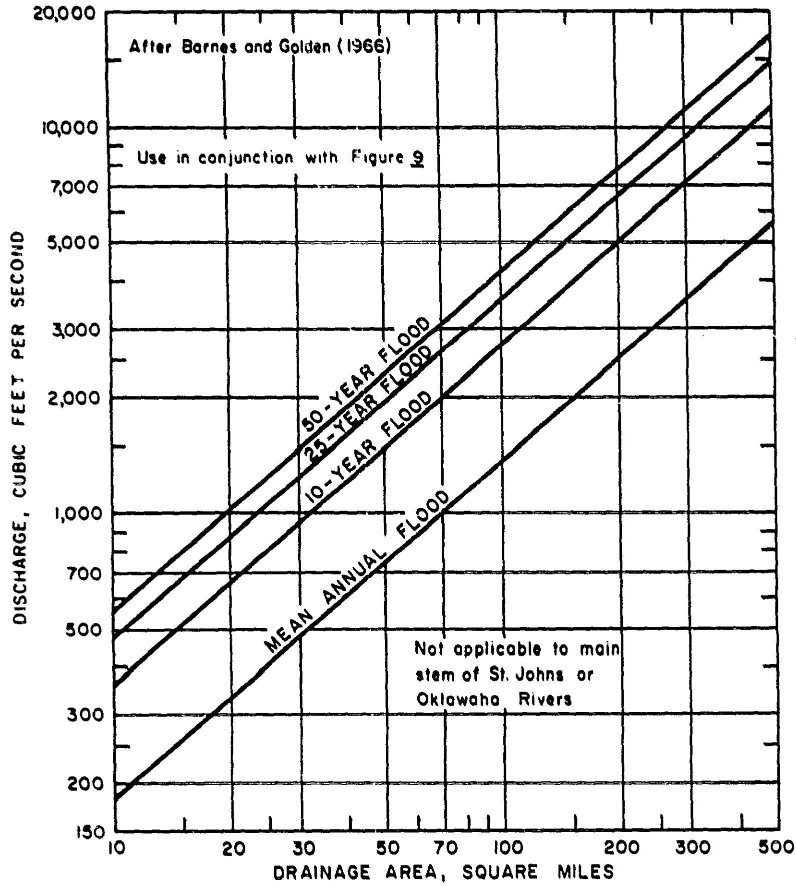


Figure 7 Flood-frequency curves for Region B, area 1 in northeast Florida

natural drainage-ways and canals, and urbanization, modify the relation.

Peak flood stages are more significant than peak flood discharges. Much of the flood plain is under cultivation and extensive crop and other damage is caused by extended periods of inundation rather than by high discharge. A stage-frequency analysis for the St. Johns River in the 158 mile reach between State Highway 60, in Indian River County, and DeLand is presented in figure 10. The profiles of three significant floods that occurred since 1950 are shown in Figure 11. Comparison of the profiles in figure 11 with the stage-frequency analysis in figure 10 shows, for example, that the recurrence interval of the flood of October 1953 on Lake Poinsett is about 30 years whereas that for October 1956 is about 8 years.

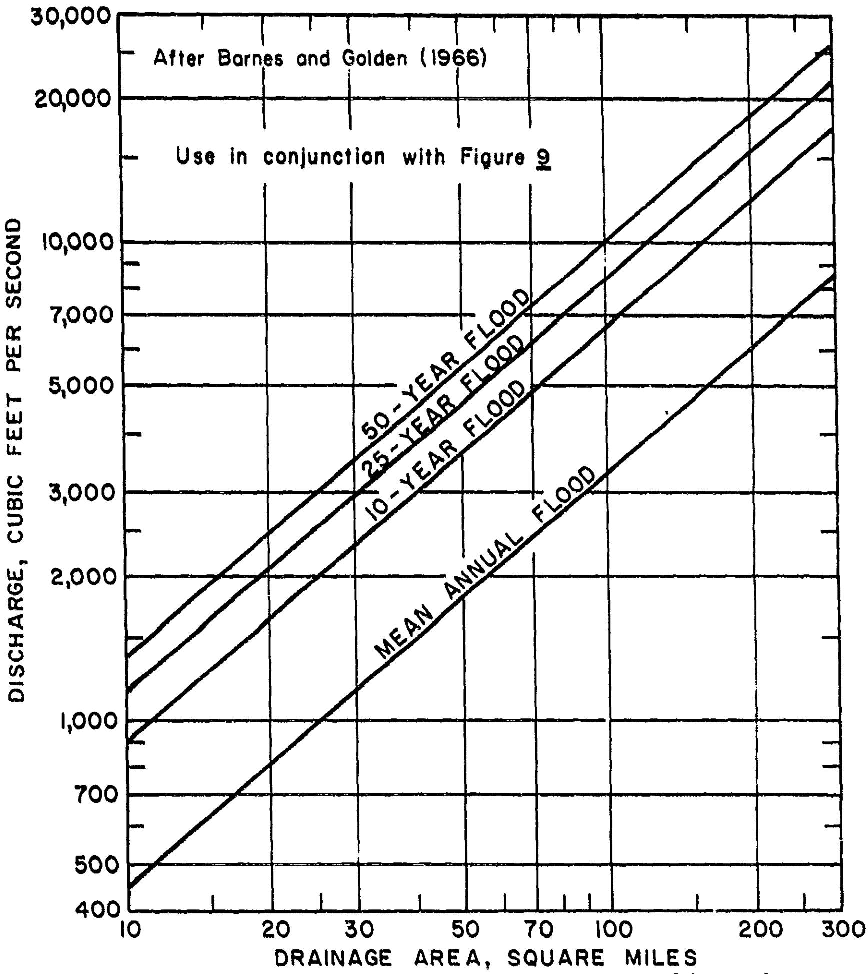


Figure 8 Flood-frequency curves for Region B, area 2 in northeast Florida

LOW FLOW

Low-flow characteristics of a stream determine whether it can be used for a specific purpose without artificial storage. Figures 12 and 13 provide low-flow frequency curves for the St. Johns River near Christmas and Econlockhatchee River near Chuluota.

Although the storage capacity of the main stem of the St. Johns River is great, water in storage may be depleted by outflow and by evaporation during droughts as is illustrated by comparing the minimum flow at the Christmas station with that of its tributary, the

Econlockhatchee River. Although the drainage area of the St. Johns River near Christmas is more than six times that of the Econlockhatchee River near Chuluota, during the spring of 1939 the St. Johns River stopped flowing on three separate occasions while the flow of the Econlockhatchee River did not fall below 9 cfs. Figures 12 and 13 indicate that a condition wherein the minimum 7-day flow of the St. Johns River will be less than that of the Econlockhatchee River will average not more than once in almost 30 years.

Flow of the St. Johns River in the reach downstream from Lake George reverses with each tidal change except under conditions of high freshwater inflow or strong winds which offset the tidal influence. About 75 per cent of the time the net flow is toward the ocean but at other times the net flow is upstream for several consecutive days. The maximum number of days during which the net flow is likely to be equal to, or less than, a specific amount at Palatka and at

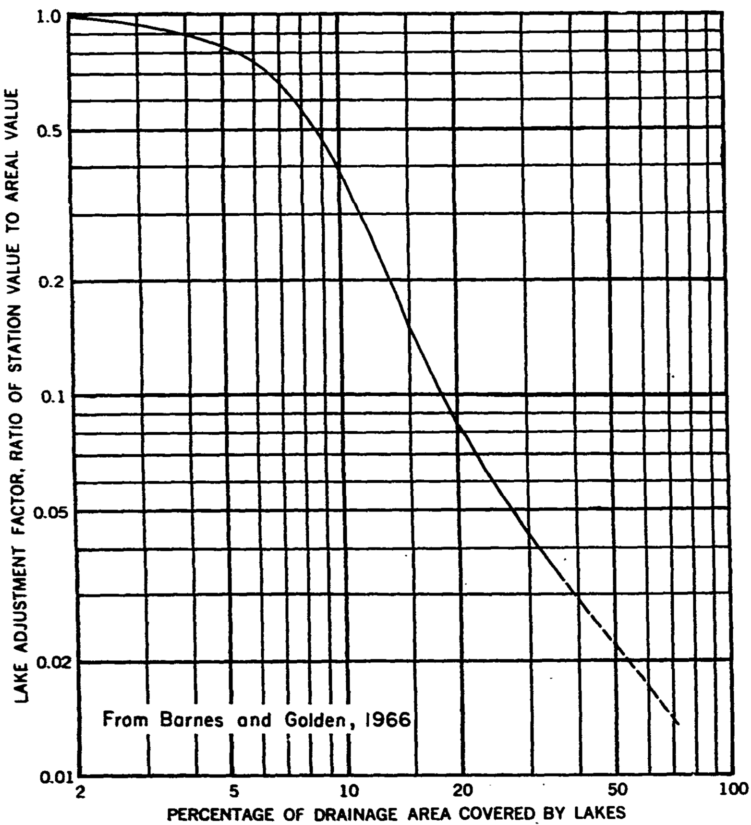


Figure 9 Graph showing attenuation adjustment to mean annual flood due to lake and swamp storage

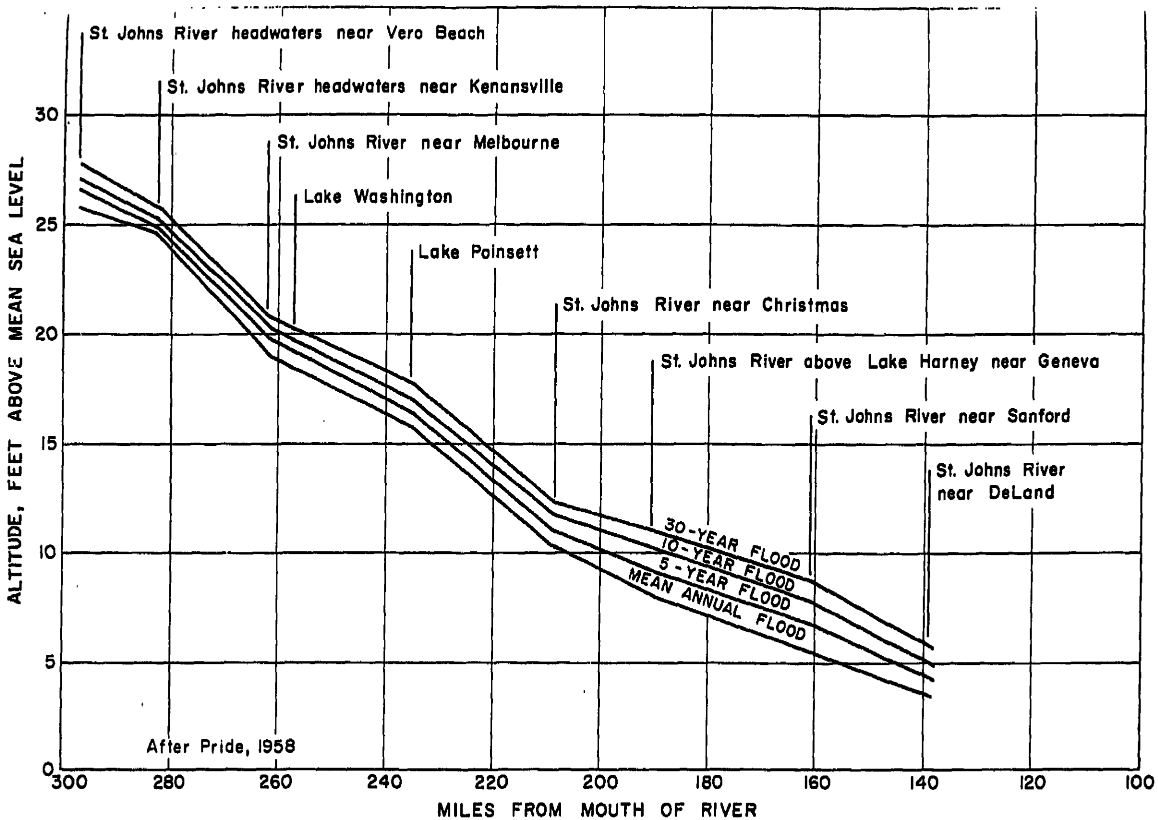


Figure 10 Graphs showing variation of mean annual, 5-, 10-, and 30- year flood stages with channel distance for main steam of St. Johns River

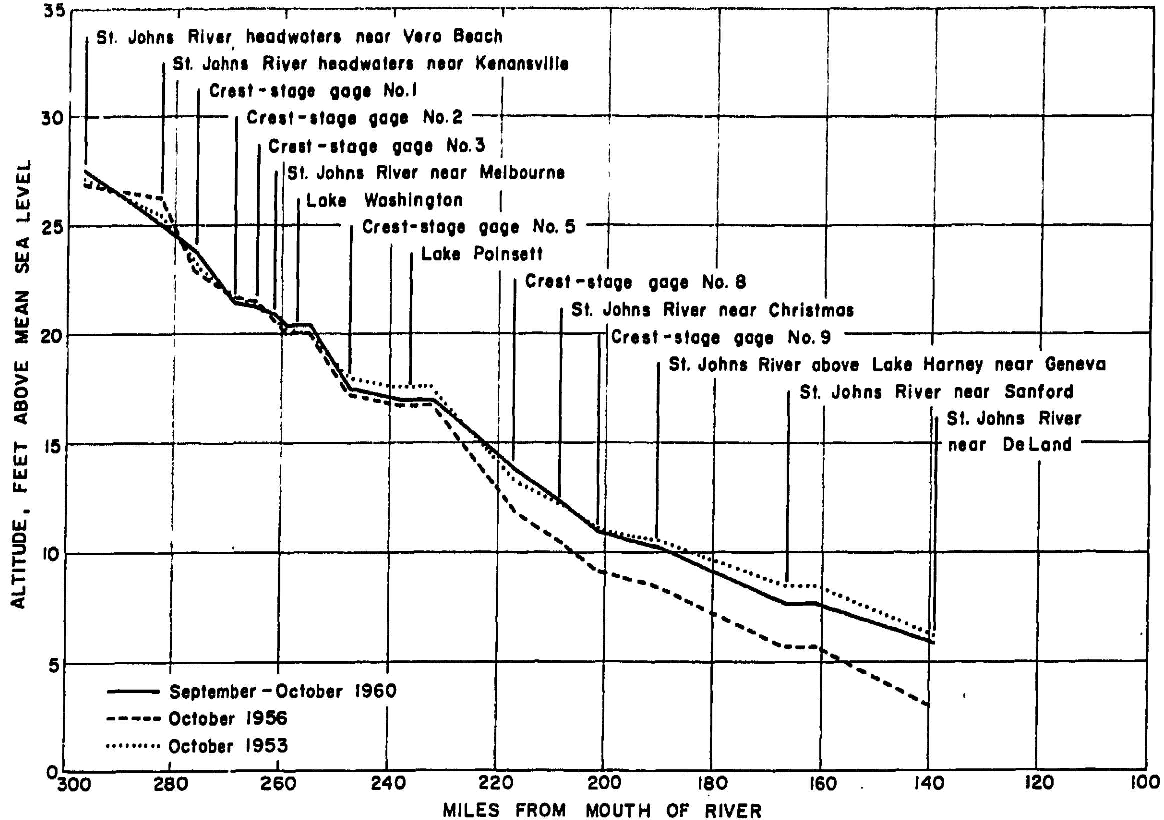


Figure 11 Graphs showing profiles of maximum stages on St. Johns River for selected floods

Jacksonville are shown in Figure 14. The periods of upstream, or negative, net flow usually occur during periods of low fresh-water inflow, high evaporation rates, and increasing tidal range.

FLOW DURATION

The per cent of time that specific discharges are likely to be equaled or exceeded is shown in Figures 15 and 16 for locations on the St. Johns River near Melbourne, Christmas, and DeLand and for some tributaries. The flat slopes of these curves at high discharge rates reflect the effects of storage of water in lakes and on the flood plain. During extreme droughts, however, the flood plain becomes dry and the drainage of water stored in lakes is greatly reduced. Under these drought conditions, river flow decreases rapidly as indicated by the steeper slopes of the lower parts of the curves for the stations at Christmas and Melbourne. At DeLand, the rapid recession of the flow-duration curve is the result of backwater from tides and wind effect during periods of reduced fresh-water flow.

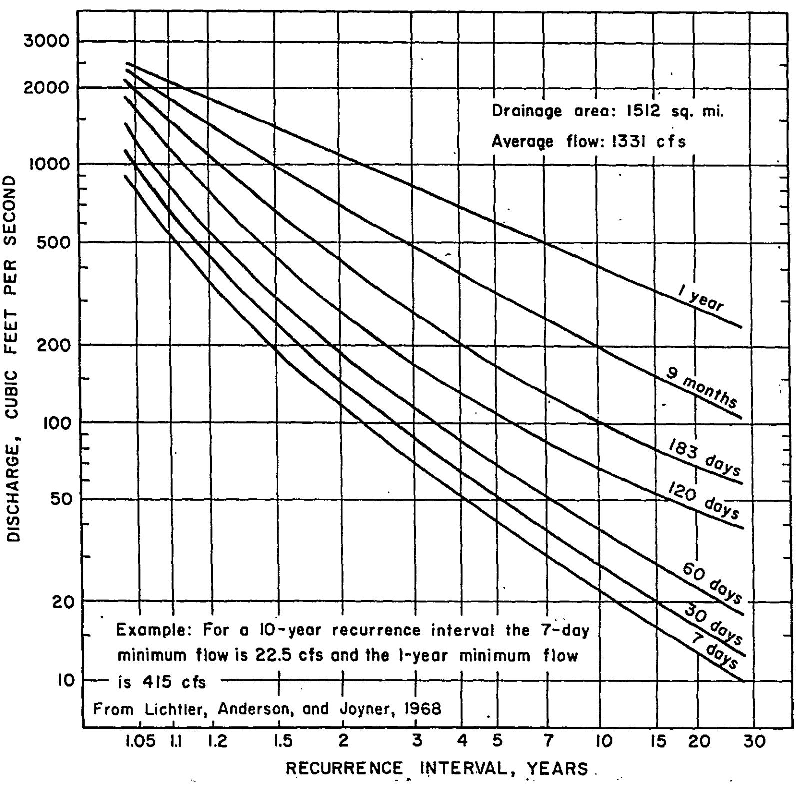


Figure 12 Low-flow frequency curves for St. Johns River near Christmas

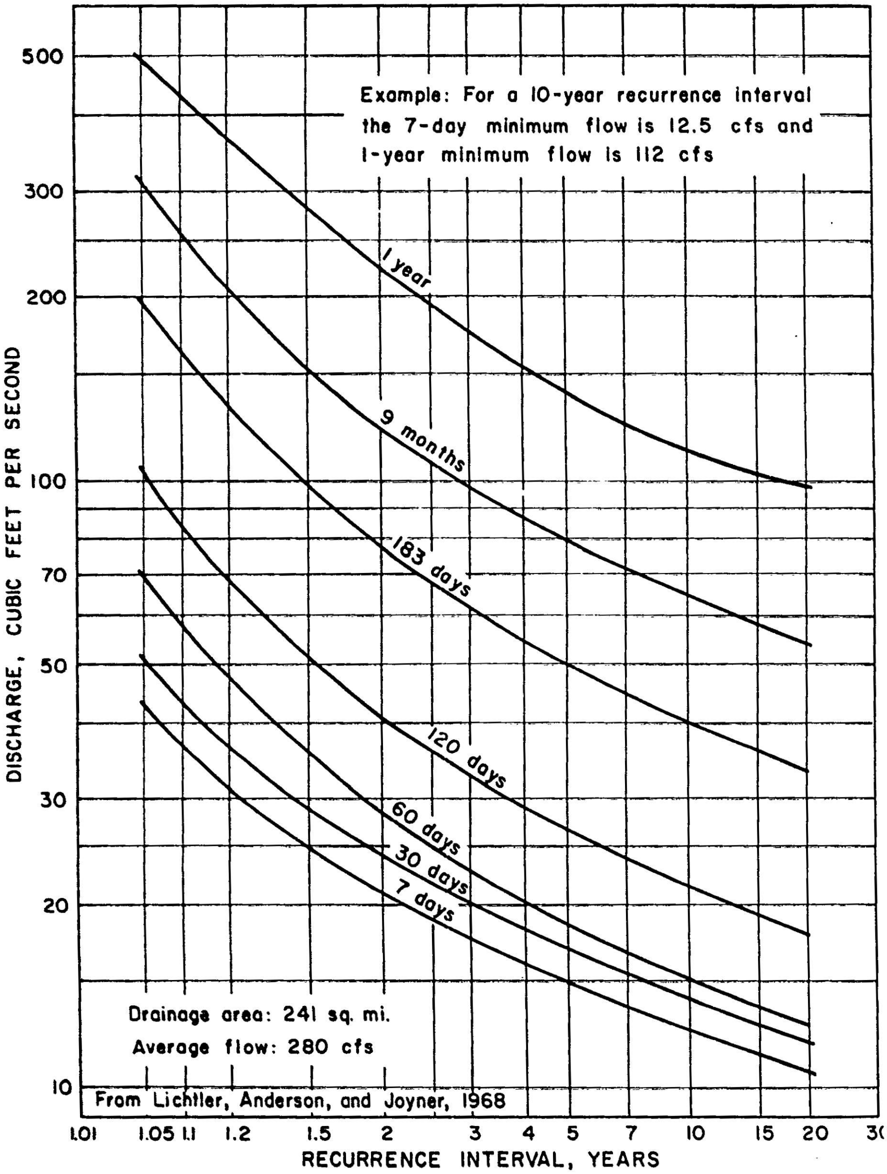


Figure 13 Low-flow frequency curves for Econlockhatchee River near Chuluota

WATER USE

A survey of water use was made by the U. S. Geological Survey in 1965 and these data are used in this report. Water withdrawal and water use are listed by counties, source, and purpose. The sources considered are ground water, fresh surface water, and saline surface water. The classifications in which all water uses are included are public supply, which includes some publicly supplied industrial water; rural domestic and stock-water; irrigation; self-supplied industrial; and fuel-electric power.

Water use may be classed as withdrawal use and nonwithdrawal use. Withdrawal use requires that water be pumped or otherwise diverted from the ground water or surface water sources whether for consumptive or non-consumptive use. Nonwithdrawal use includes water used for waste disposal or dilution, navigation, fish and wildlife propagation and recreation and is not removed from the flow system; however, it may be made unfit for other uses. As nonwithdrawal use does not deplete the supply, data on that use is not included herein.

Water consumed is water evaporated or incorporated into the product through vegetative growth or through processing; non-consumptive use is water used in industrial processing and cooling that is returned to the water source, although usually altered in quality or temperature. In the context of this report, water extracted from the artesian aquifer is not classified as consumptive use in the broad term of the water budget in the basin. However, in a real sense, water extracted from the artesian aquifer is consumed as far as the aquifer system is concerned because the water is not returned to the aquifer in most parts of the area.

PUBLIC SUPPLIES

Water for public supply includes that furnished by both public and private utilities for all uses including domestic, fire fighting, street flushing, irrigation of lawns and parks, commerce and industry served by the utility, and leakage in the system. The population served from public supplies in the report area in 1965 is estimated as 1,220,000. A total of 178 mgd was withdrawn for public supply (an average use of 140 gpd per person), of which 53.5 mgd, or 30 per cent, was consumed. Most of the water withdrawn was from wells and only 5.4 mgd, or 3.0 per cent, was from streams or lakes. Table 4 lists water-use data for public supply, by counties, and the population served.

RURAL

Self-supplied water for domestic and small scale livestock and gardening uses not included under irrigation are included in this category. An estimated 23.6 mgd was withdrawn of which 18.8 mgd

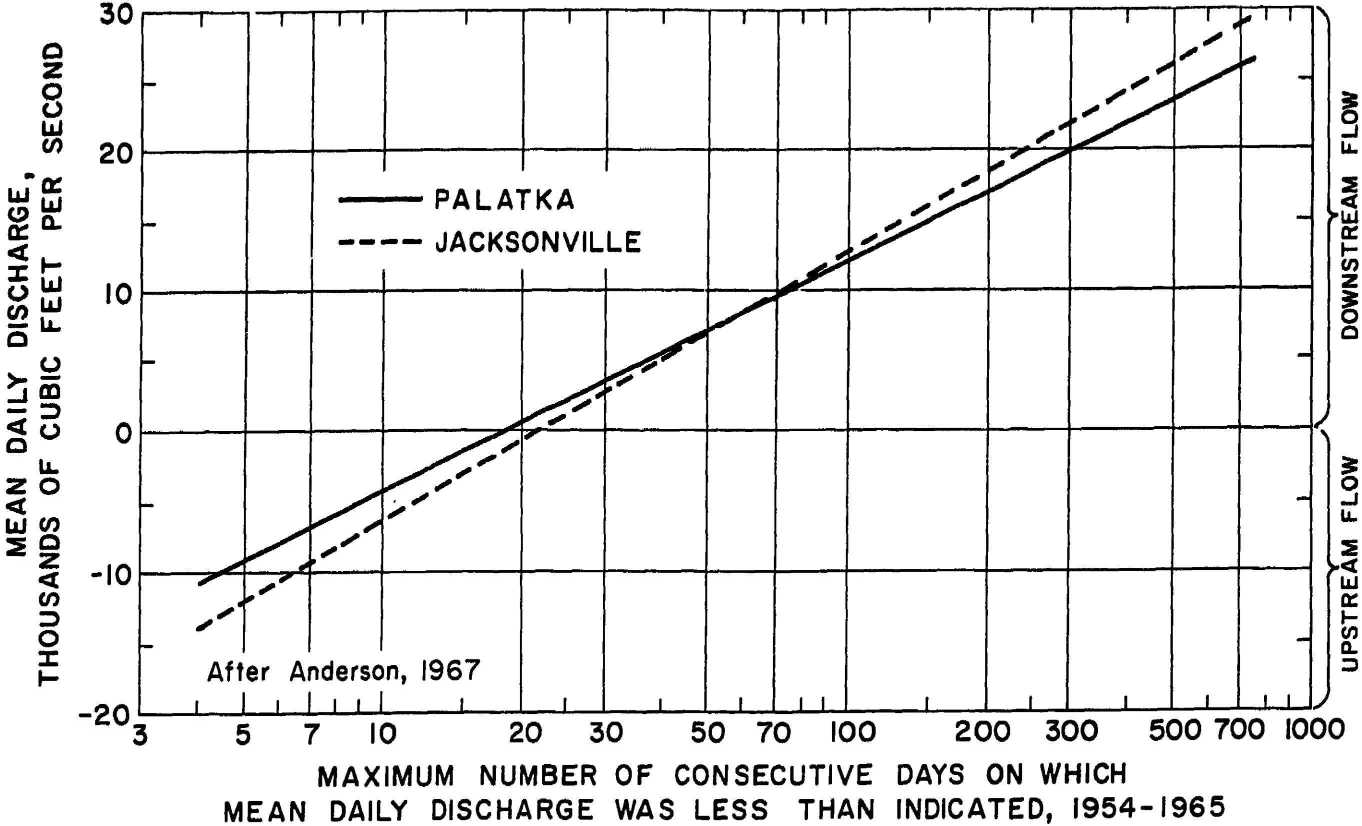


Figure 14 Curves showing the maximum periods during which discharge was less than given amounts, St. Johns River at Palatka and Jacksonville

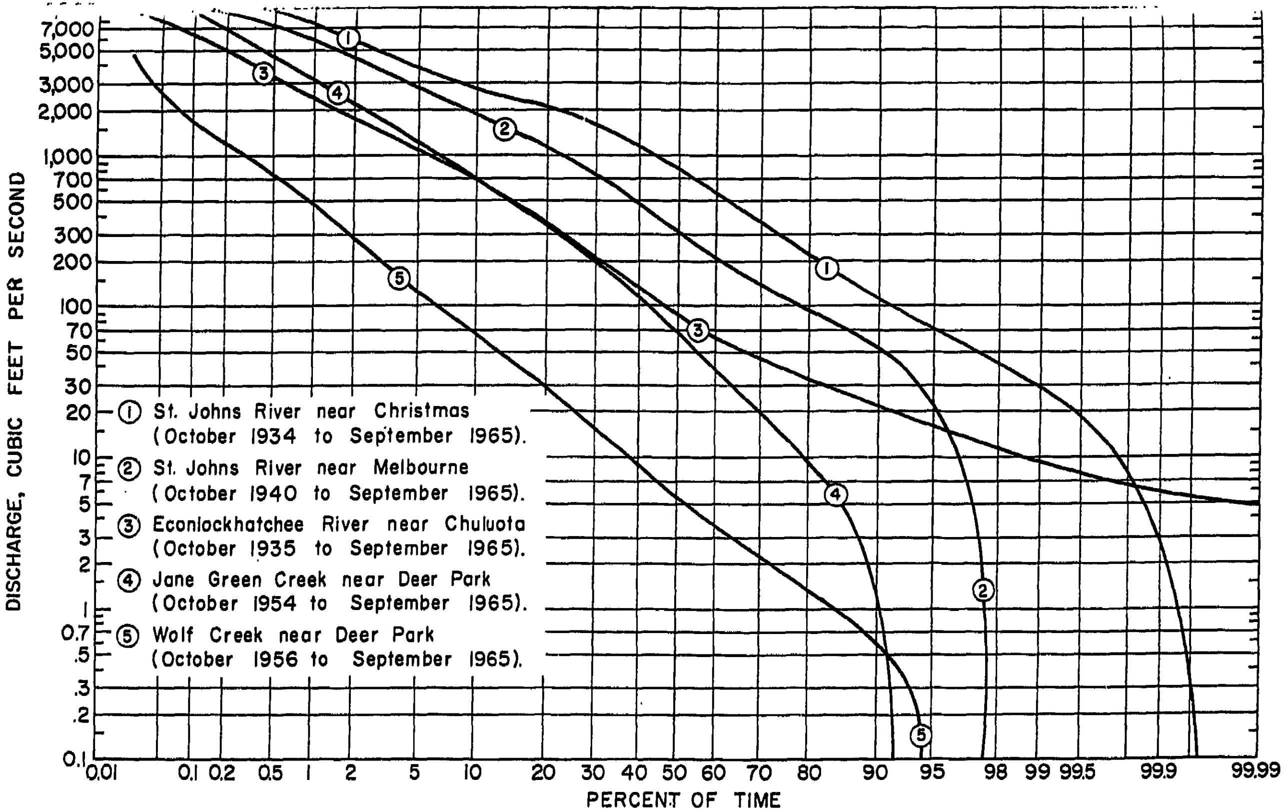


Figure 15 Flow-duration curves for streams in St. Johns River basin above Lake Monroe

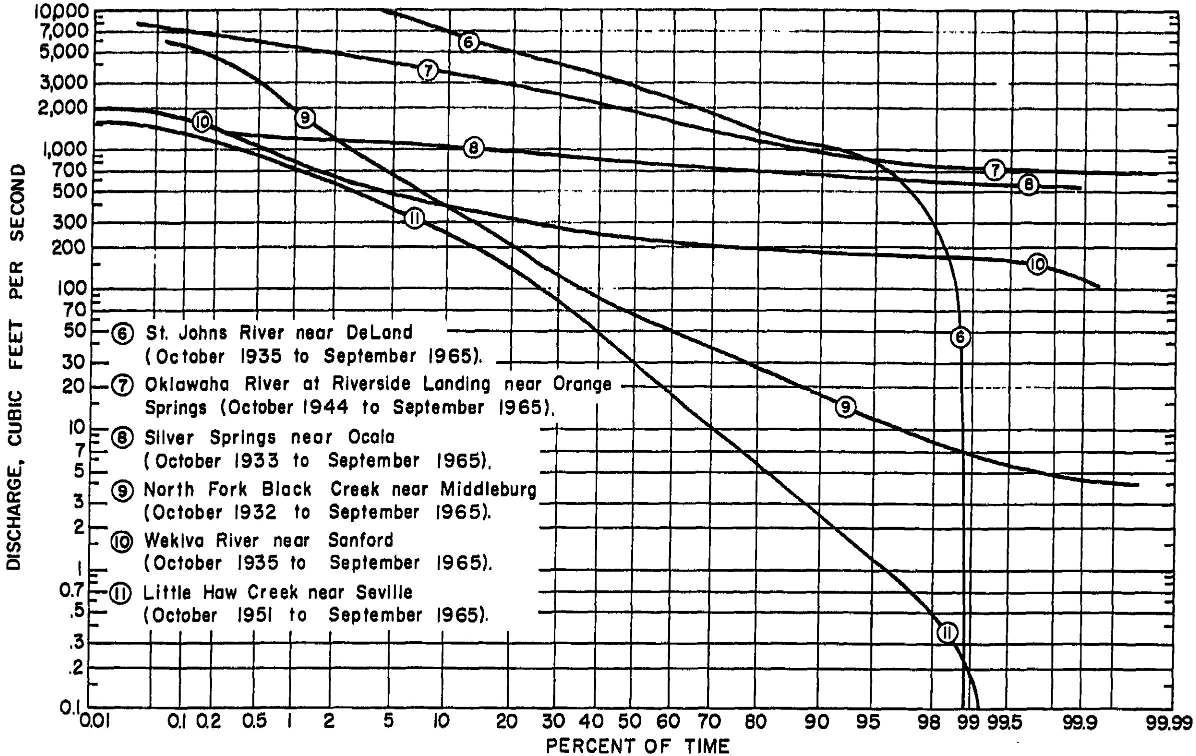


Figure 16 Flow-duration curves for streams in St. Johns River basin below Lake Monroe

TABLE 4 – WATER USED FOR PUBLIC SUPPLIES BY COUNTIES, IN ST. JOHNS RIVER BASIN, AND ADJACENT COASTAL AREAS, 1965.

COUNTY	POPULATION SERVED			WATER WITHDRAWN				INDUSTRIAL AND COMMERCIAL (from public supplies)			WATER CONSUMED (mgd)
	Ground water (thousands)	Surface water (thousands)	All water (thousands)	Ground water (mgd)	Surface water (mgd)	All uses (mgd)	Per capita (gpd)	Air cond. (mgd)	Other (mgd)	All Uses (mgd)	
* Alachua	68.4	0	68.4	8.1	0	8.1	118	0.05	0.95	1.0	3.5
Brevard	107.7	40.0	147.7	20.9	3.6	24.5	166	4.0	3.7	7.7	12.0
Clay	11.2	0	11.2	1.0	0	1.0	89	0	.1	.1	.4
* Duval	498.7	0	498.7	60.0	0	60.0	120	2.5	2.6	5.1	12
Flagler	2.8	0	2.8	.2	0	.2	70	0	.02	.02	.1
Indian River	12.5	0	12.5	1.5	0	1.5	120	0	.3	.3	.3
* Lake	44.2	0	44.2	8.0	0	8.0	181	.1	1.9	2.0	5.0
* Levy	1.6	0	1.6	.2	0	.2	125	0	.04	.04	.06
* Marion	20.4	0	20.4	3.6	0	3.6	176	.1	.6	.7	1.0
* Okeechobee					Negligible						
* Orange	250.0	0	250.0	47.0	0	47.0	188	.1	4.7	4.8	9.6
* Osceola					Negligible						
* Polk					Negligible						
Putnam	14.0	0	14.0	2.0	0	2.0	143	0	.2	.2	1.0
St. Johns	9.0	13.0	22.0	1.2	1.8	3.0	136	.2	.1	.3	.15
* St. Lucie	20.0	0	20.0	2.2	0	2.2	110	.03	.07	.1	.4
Seminole	33.1	0	33.1	4.2	0	4.2	127	.03	.57	.6	2.0
Volusia	126.2	0	126.2	13.0	0	13.0	103	.4	1.6	2.0	6.0
Entire area	1,219.8	53.0	1,272.8	173.1	5.4	178.5	140	7.51	17.45	24.96	

* Indicates that figures listed are for portion of the county within the St. Johns basin, not for the total county.

TABLE 5 – WATER FOR RURAL USE, BY COUNTIES, IN ST. JOHNS RIVER BASIN AND ADJACENT COASTAL AREAS, 1965.

	DOMESTIC USE (MGD)			LIVESTOCK USE (MGD)			DOMESTIC AND LIVESTOCK (MGD)			
	WATER WITHDRAWN			WATER WITHDRAWN			WATER WITHDRAWN			
	Ground water	Surface water	WATER CONSUMED	Ground water	Surface water	WATER CONSUMED	Ground Water	Surface water	ALL WATER	WATER CONSUMED
* Alachua	0.4	0	0.4	0.6	0.1	0.6	1.0	0.1	1.1	1.0
Brevard	4.0	0	2.8	.3	.1	.4	4.3	.1	4.4	3.2
Clay	.6	0	.5	.3	0	.3	.9	0	.9	.8
* Duval	.1	0	.1	.2	0	.2	.3	0	.3	.3
Flagler	.1	0	.1	.2	0	.2	.3	0	.3	.3
Indian River	1.0	0	.8	.2	.1	.3	1.2	.1	1.3	1.1
* Lake	1.4	0	1.2	.1	.2	.2	1.5	.2	1.7	1.4
* Levy	.1	0	.1	e	e	e	.1	e	.1	.1
* Marion	1.8	0	1.6	.8	.1	.9	2.6	.1	2.7	2.5
* Okeechobee	.1	0	e	.1	.1	.2	.2	.1	.3	.2
* Orange	2.4	0	1.7	.3	.1	.4	2.7	.1	2.8	2.1
* Osceola	.2	0	.1	.3	.2	.4	.5	.2	.7	.5
* Polk	.1	0	.1	.2	.1	.2	.3	.1	.4	.3
Putnam	.9	0	.6	.2	e	.2	1.1	e	1.1	.8
St. Johns	.6	0	.3	.1	e	e	.7	e	.7	.3
* St. Lucie	.6	0	.3	e	.1	.1	.6	.1	.7	.4
Seminole	1.8	e	1.6	.1	.1	.2	1.9	.1	2.0	1.8
Volusia	1.7	0	1.4	.2	.2	.3	1.9	.2	2.1	1.7
Entire area	17.9	e	13.7	4.2	1.5	5.1	22.1	1.5	23.6	18.8

* Indicates that figures listed are for portion of the county within the St. Johns basin, not for the total county.

e Less than 0.05 mgd.

was consumed in serving the rural population. A total of 22.1 mgd was from ground water and 1.5 mgd from surface water. Water for rural use, by counties, is tabulated in Table 5.

IRRIGATION

Water withdrawn for irrigation was determined to be 351 mgd, or 394,000 acre-feet, in 1965, applied on 232,000 acres. Of that total, 200 mgd was withdrawn from ground water and 150 mgd from surface water sources. Of the water withdrawn for irrigation, an estimated 172 mgd, or 49 per cent, was consumed. Water used for sprinkler irrigation is mostly lost through evapotranspiration in this climatic region although in conventional irrigation systems the return flow and losses to streams or to ground water are considerable. The large consumptive use in irrigation indicates a relatively inefficient use of water as compared to industrial use. Water used for irrigation is tabulated in Table 6.

SELF-SUPPLIED INDUSTRIAL

Industry in the area is increasing rapidly. Some industrial uses have high withdrawal requirements but consume little water since most is used for cooling and processing without being evaporated or incorporated into a product. The withdrawal was 172 mgd in 1965 of which 7.7 mgd, or 4.5 per cent was consumed. By source of water, 117 mgd was from wells and 55.0 mgd from surface sources, of which 1.0 mgd was saline surface water. Fuel-electric power generation is not included in the above industrial use. A total of 1,997 mgd was withdrawn for fuel-electric power cooling water, of which only 9.4 mgd, or less than half of one per cent, was consumed. Most of the fuel-electric cooling water is saline surface water. Table 7 lists the self-supplied industrial water use, and Table 8, the water used for fuel-electric power production in 1965, by counties.

Figure 17 shows the water-use distribution by source and purpose and a comparison of water withdrawn and water consumed. The pie-charts show the portions obtained from ground water, surface water, and saline waters and the consumptive use of water for public supply, rural, irrigation, industrial, and fuel-electric power uses. The bar chart in the figure shows the consumptive use as compared to total use, or withdrawal, and the water source.

Although industrial and fuel-electric power withdrawals are great, the consumptive use is relatively small. Re-use, or recirculation of water could be a means of lowering withdrawal demands. About

TABLE 6 – WATER USED FOR IRRIGATION, BY COUNTIES, IN ST. JOHNS RIVER BASIN AND ADJACENT COASTAL AREAS.

COUNTIES	ACRES IRRIGATED	WATER WITHDRAWN			CONSUMED	WATER WITHDRAWN			CONSUMED
		Surface Water Ac/ft	Ground Water Ac/ft	Total Ac/ft	Ac/ft	Surface Water mgd	Ground Water mgd	Total mgd	mgd
* Alachua	2,270	400	1,300	1,700	1,100	0.4	1.2	1.6	1.0
Brevard	24,000	5,100	56,500	61,600	39,400	4.5	50.4	54.9	35.2
Clay	3,000	0	5,600	5,600	4,500	0	5.0	5.0	4.0
* Duval	0	0	0	0	0	0	0	0	0
Flagler	6,500	0	3,900	3,900	1,600	0	3.5	3.5	1.4
Indian River	50,600	44,000	29,300	70,300	29,000	36.6	26.2	62.8	25.9
* Lake	20,000	13,500	15,700	29,200	10,600	12.1	14.0	26.1	9.5
* Levy	100	0	200	200	200	0	.2	.2	.2
* Marion	14,400	3,400	16,100	19,500	5,400	3.0	14.4	17.4	4.8
* Okeechobee	4,000	7,200	1,100	8,300	3,600	6.4	1.0	7.4	3.2
* Orange	18,900	15,900	13,600	29,500	13,200	11.9	12.1	24.0	11.8
* Osceola	† 1,200	1,100	1,100	2,200	1,100	1.0	1.0	2.0	1.0
* Polk	† 9,200	† 1,000	† 14,900	† 15,900	8,000	.9	13.6	14.5	7.1
Putnam	13,000	1,700	13,000	14,700	7,500	1.5	11.6	13.1	6.7
St. Johns	22,000	0	15,600	15,600	7,000	0	13.9	13.9	6.2
* St. Lucie	† 29,220	73,000	24,000	97,000	49,000	65.0	21.4	86.4	43.7
Seminole	10,000	6,600	5,400	12,000	5,400	5.9	4.8	10.7	4.8
Volusia	3,700	1,300	6,900	8,200	6,000	1.2	6.2	7.4	5.4
Totals	232,090	171,200	223,200	394,400	192,600	150.4	200.5	350.9	171.5

* Indicates that figures listed are for portion of the county within the St. Johns basin, not for the total county.

† From SCS report.

TABLE 7 – SELF-SUPPLIED INDUSTRIAL WATER, BY COUNTIES, IN ST. JOHNS RIVER BASIN AND ADJACENT COASTAL AREAS, 1965.

COUNTIES	WATER WITHDRAWN, MILLION GALLONS PER DAY						USED FOR AIR COND. (mgd)	CONSUMED Fresh (mgd)
	Ground Water		Surface Water		All Water			
	Fresh	Saline	Fresh	Saline	Fresh	Saline		
* Alachua	11.7	0	0	0	11.7	0	9.4	2.7
Brevard	1.0	0	0	0	1.0	0	0	.1
Clay	1.5	0	0	0	1.5	0	0	.2
* Duval	47.0	0	0	1.0	47.0	1.0	2.5	2.0
Flagler	0	0	0	0	0	0	0	0
Indian River	0	0	0	0	0	0	0	0
* Lake	15.4	0	0	0	15.4	0	0	.8
* Levy	0	0	0	0	0	0	0	0
* Marion	4.5	0	0	0	4.5	0	0	.2
* Okeechobee	0	0	0	0	0	0	0	0
* Orange	4.8	0	0	0	4.8	0	.2	.2
* Osceola	0	0	0	0	0	0	0	0
* Polk	27.0	0	0	0	27.0	0	0	.7
Putnam	3.0	0	54.0	0	57.0	0	0	.5
St. Johns	0	0	0	0	0	0	0	0
* St. Lucie	.3	0	0	0	.3	0	.1	.1
Seminole	0	0	0	0	0	0	0	0
Volusia	.4	.2	0	0	.4	.2	0	.2
Totals	116.6	.2	54.0	1.0	170.6	1.2	12.2	7.7

* Indicates that figures listed are for portion of the county within the St. Johns basin, not for the total county.

TABLE 8 – WATER USED FOR FUEL-ELECTRIC POWER, BY COUNTIES, IN ST. JOHNS RIVER BASIN AND ADJACENT COASTAL AREAS, 1965.

COUNTIES	COOLING WATER					OTHER WATER					ALL WATER SUPPLIED	CONSUMED
	SELF SUPPLIES (mgd)				PUBLIC SUPPLY (mgd)	SELF SUPPLIES (mgd)				PUBLIC SUPPLY (mgd)		
	Surface Water		Ground Water			Surface Water		Ground Water				
	Fresh	Saline	Fresh	Saline		Fresh	Saline	Fresh	Saline			
Alachua	0	0	0	0	1.0	0	0	0	0	0	1.0	0.4
Brevard	0	785	0	0	0	0	0	.2	0	.1	785.3	4.8
Duval	0	553	0	0	.7	0	0	.1	0	0	553.8	0
Indian River	0	75	0	0	0	0	0	e	0	0	75.0	.2
Levy	0	0	0	0	0	0	0	e	0	0	e	.1
Orange	95	0	0	0	0	0	0	0	0	e	95.0	.1
Osceola	0	0	.2	0	0	0	0	0	0	0	.2	0
Putnam	130	0	0	0	0	0	0	.1	0	0	130.0	.7
St. Lucie	0	6	0	0	0	0	0	0	0	e	6.0	.2
Volusia	350	0	0	0	0	0	0	.2	0	0	350.2	2.9
Totals	575	1,419	.2	0	1.7	0	0	.6	0	.1	1,996.6	9.4

e Less than 0.05 mgd.

half of the water withdrawn for irrigation is consumed and more than two-thirds of the water for public use is returned to the surface or ground water sources. Quantities for parts of counties within the St. Johns River basin and adjacent coastal area are either from actual data obtained from the users or estimated on the basis of land area and land use.

SURFACE WATER

For convenience in the discussion of the surface water features, the area is divided into four sub-areas: the upper St. Johns River basin upstream from the mouth of the Oklawaha River; the Oklawaha River basin; the lower St. Johns River basin, below the mouth of the Oklawaha River; and the narrow coastal strip between the St. Johns River basin and the Atlantic Ocean.

UPPER ST. JOHNS RIVER BASIN

The relation of the average discharge to drainage area along the main stem of the St. Johns River is shown in Figure 18. As indicated by the solid part of the plot, the unit runoff in the upstream reaches is very uniform. The downward extension of the plot suggests that the computed drainage area upstream of Melbourne is too small or that considerable water is diverted from the basin in this area. The likelihood of some diversion is substantiated by the higher unit runoff in the coastal basins immediately to the east of this area south of Melbourne (see section on coastal areas). Diking and canalization in the area upstream of Melbourne complicates delineation of the drainage divide for the St. Johns River.

The relation between average discharge and drainage area downstream from DeLand is based on estimates of the average flow at Palatka and at Jacksonville. The accuracy of net flow determinations at Jacksonville is questionable as records are adequate only to evaluate the upstream and downstream volumes of tidal flow. The average discharge of the St. Johns River above the mouth of the Oklawaha River is estimated as 4,000 cfs on the basis of 3,270 cfs discharge at the gaging station near DeLand, which has 86 per cent of the drainage area. The increase in average flow of the main stem as it is successively joined by its tributaries is indicated by the flow chart (as shown in Figure 19).

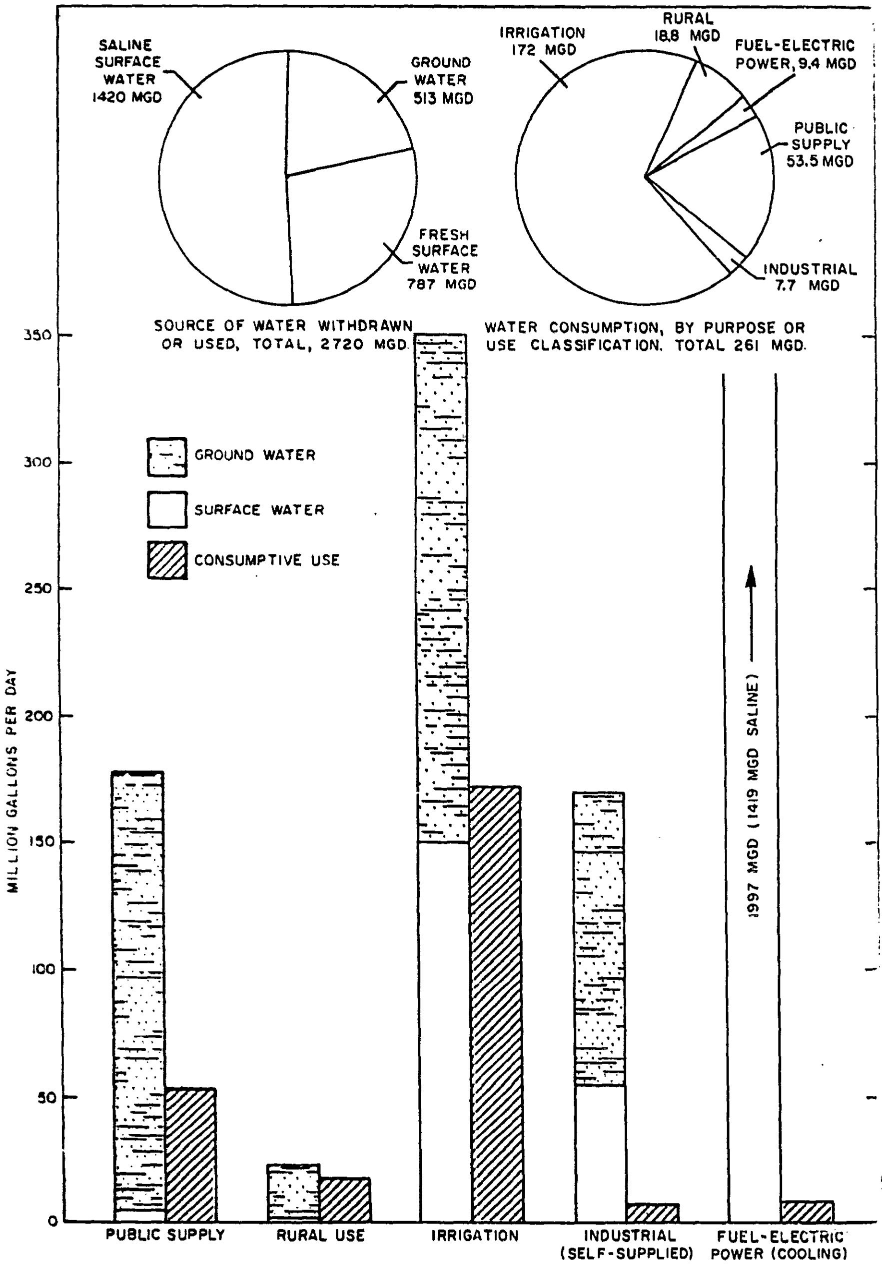


Figure 17 Graphs showing water source, purpose, and relation of consumptive use to water withdrawal in northeast Florida

Average discharge increases quite uniformly with drainage area in the reach downstream from Jane Green Creek. The average discharge in the St. Johns River near Cocoa, with 1,331 square miles drainage area, is 1,210 cfs or 0.91 cfs per square mile; however, minimum flows approach zero.

Figure 20 shows the maximum, minimum and median concentration of dissolved solids, and the concentration equaled or exceeded 5 and 25 per cent of the time, for the St. Johns River near Cocoa. Also shown are the calcium, sodium, sulfate, and chloride proportions of the total dissolved solids, and the corresponding hardness as calcium carbonate. The water temperature varies daily and seasonally (as shown in Figure 21). Information on the water temperature is valuable in planning the use of the water for industrial cooling and for evaluating the suitability of the water for fish and

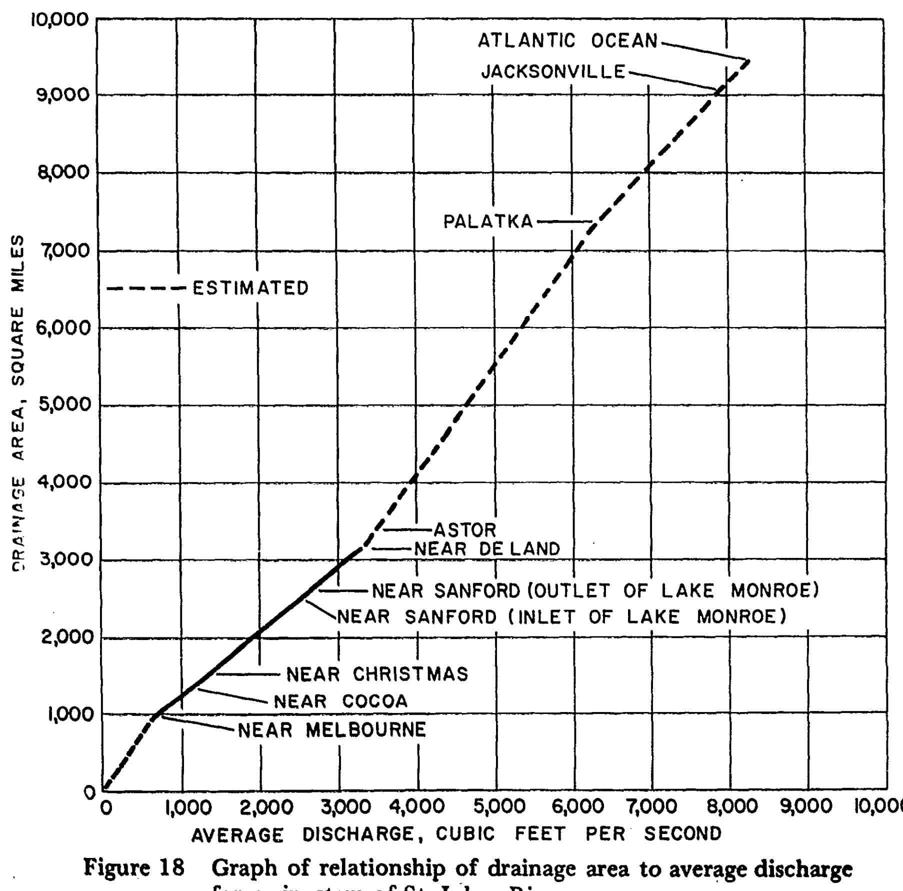


Figure 18 Graph of relationship of drainage area to average discharge for main stem of St. Johns River

other aquatic life. It is interesting to note that the maximum daily temperature, which occures in August, is nearly 35°C (95°F).

JANE GREEN AND WOLF CREEKS

Jane Green Creek drains 260 square miles in the upper St. Johns River basin. The average flow of 1.38 cfs per square mile of drainage

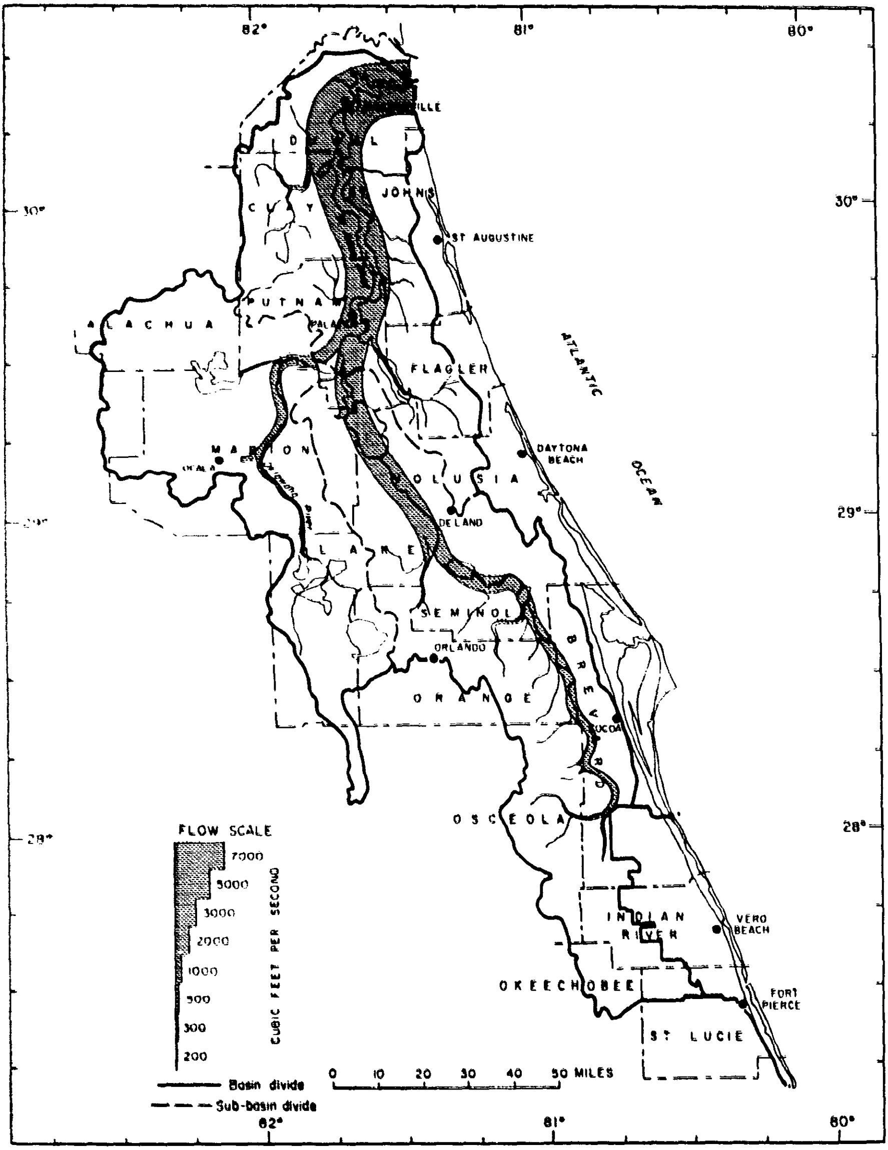


Figure 19 Flow chart showing average flow of streams in northeast Florida

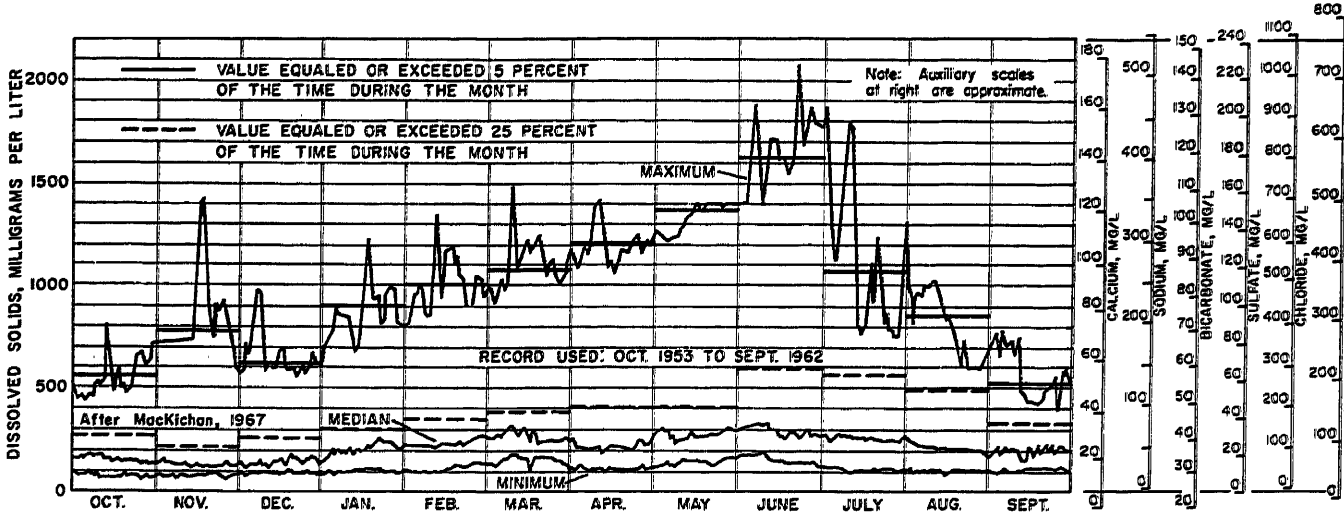


Figure 20 Graph showing maximum, minimum, and median daily dissolved solids equaled or exceeded 5 and 25 per cent of the time, for St. Johns River near Cocoa

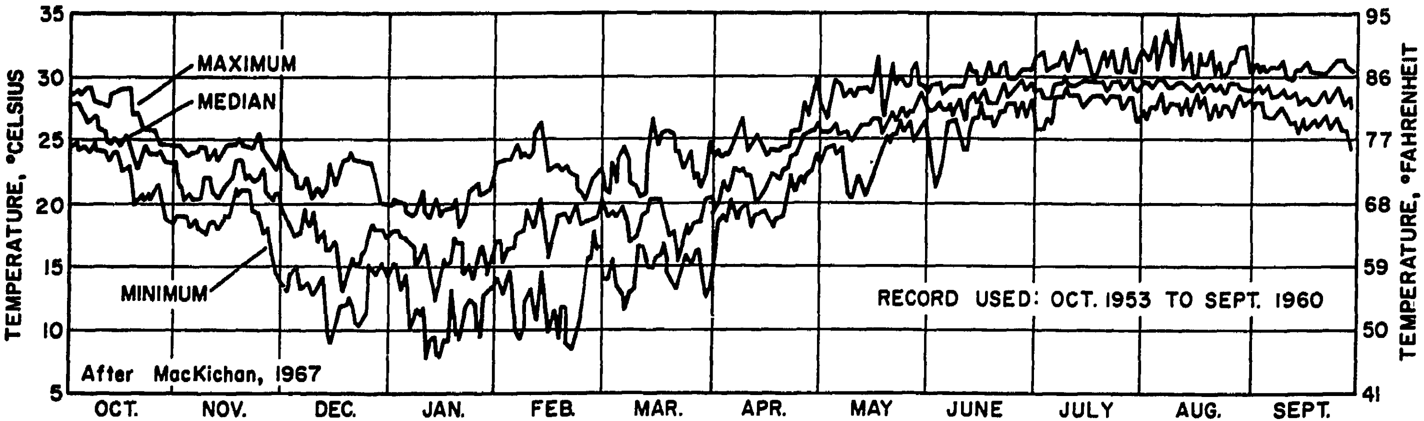


Figure 21 Graph showing maximum, minimum, and median daily temperature for St. Johns River near Cocoa

area is the second highest of the gaged tributaries and probably is a result of the relative steepness of the basin slope coupled with low soil permeabilities that impede infiltration. The maximum observed discharge of 18,400 cfs is equal to 73 cfs per square mile. The creek has been dry for long periods, such as 116 days in 1956. The recurrence interval of a discharge of 18,400 cfs is 48 years (Barnes and Golden). The flow duration curve for Jane Green Creek (fig. 15) shows it to be dry about 8 per cent of the time.

The unit runoff for Jane Green Creek is exceeded by that for Wolf Creek which averages 1.49 cfs per square mile. The maximum runoff from the 31 square mile area of Wolf Creek near Deer Park is 293 cfs per square mile. Water quality in both streams is generally good except for high color values at times. Specific conductivity varies inversely with discharge from about 50 to 400 micromhos. Hardness and chloride are low.

ECONLOCKHATCHEE RIVER

The Econlockhatchee River drains 260 square miles of the western slope of the St. Johns River basin between Orlando and Bithlo. The headwaters are an elongated swamp from which drainage is slow and evaporation and transpiration losses are high. Some of the topographically delineated drainage basin of its largest tributary, the Little Econlockhatchee River, are karst areas that contribute no runoff. The unit runoff is 1.16 cfs per square mile. The maximum recorded discharge at Chuluota is 11,000 cfs which is equivalent to 46 cfs per square mile. The recurrence interval of a flood of this magnitude exceeds 50 years. The channel of the Econlockhatchee River is well developed in its lower reach. In this reach the channel is incised into the water-table aquifer so that the river derives some base flow from the shallow aquifer during even the most severe droughts. Further, some low flow augmentation (11 cfs in 1963) is derived from effluent from the Orlando sewage plant. Figure 13 shows the frequency at which the minimum average flows for selected durations are likely to recur.

Chemical quality of the water is generally within acceptable limits with moderate hardness but with fairly high color during high flows.

DEEP CREEK

Deep Creek drains about 160 square miles in Volusia County. Discharge varies from no flow at times to maximum flows that exceed 2,600 cfs. Water quality is good except for fairly high color at all times.

WEKIVA RIVER

The Wekiva River drains about 200 square miles from State Highway 46, much of which is karst terrain from which no surface flow occurs. Much of the rainfall infiltrates downward to recharge the Floridan aquifer and emerges in the basin from Rock and Wekiva springs. The remainder of the basin includes many swamps and lakes, most of which drain to the Wekiva River by way of its tributary, the Little Wekiva River.

The combined surface runoff and spring inflow provide an average yield of 1.39 cfs per square mile, or 278 cfs, at State Highway 46. The effect of infiltration of rainfall to ground-water storage and subsequent return to the stream through large springs is so pronounced that the average discharge is less than three times the minimum discharge. Low-flow frequency curves are shown in Figure 22. The flow-duration curve (figure 16) shows that at least 100 cfs (65 mgd) is available at State Highway 46 near Sanford at all times.

The water has an average hardness of about 110 mg/l (milligrams per liter). Specific conductance varies only about 15 per cent from an average of about 260 micromhos.

OKLAWAHA RIVER BASIN

The Oklawaha River, the largest tributary of the St. Johns River, has a drainage area of 2,870 square miles. It comprises about one-third of the drainage basin and contributes about one-quarter of the surface water outflow from the St. Johns River basin. The average discharge of about 2,050 cfs is equivalent to 0.72 cfs per square mile. The relatively low unit runoff is the result of a large noncontributing area, the flow of ground water out of the basin, high evaporation losses from the large lakes in the upper reaches and evapotranspiration losses from the swamps in the lower reaches.

Variation in the flow of the Oklawaha River near its mouth is small because of the attenuating effects of temporary storage of water in the ground and in lakes that is subsequently released at relatively uniform rates, as, for example, from Silver Springs. The maximum observed discharge is only 4.3 times the average flow and the average flow is only 2.9 times the minimum discharge. The dependable flow of this river is at least 450 mgd, or 697 cfs.

Average yield from the basin above Silver Springs is 420 cfs, only 0.39 cfs per square mile. Yield from the Orange Creek basin is 188 cfs or only 0.17 cfs per square mile. That subbasin, however, includes Paynes Prairie, a non-contributing area of 675 square miles in parts of Alachua, Levy, and Marion counties. The remainder of the

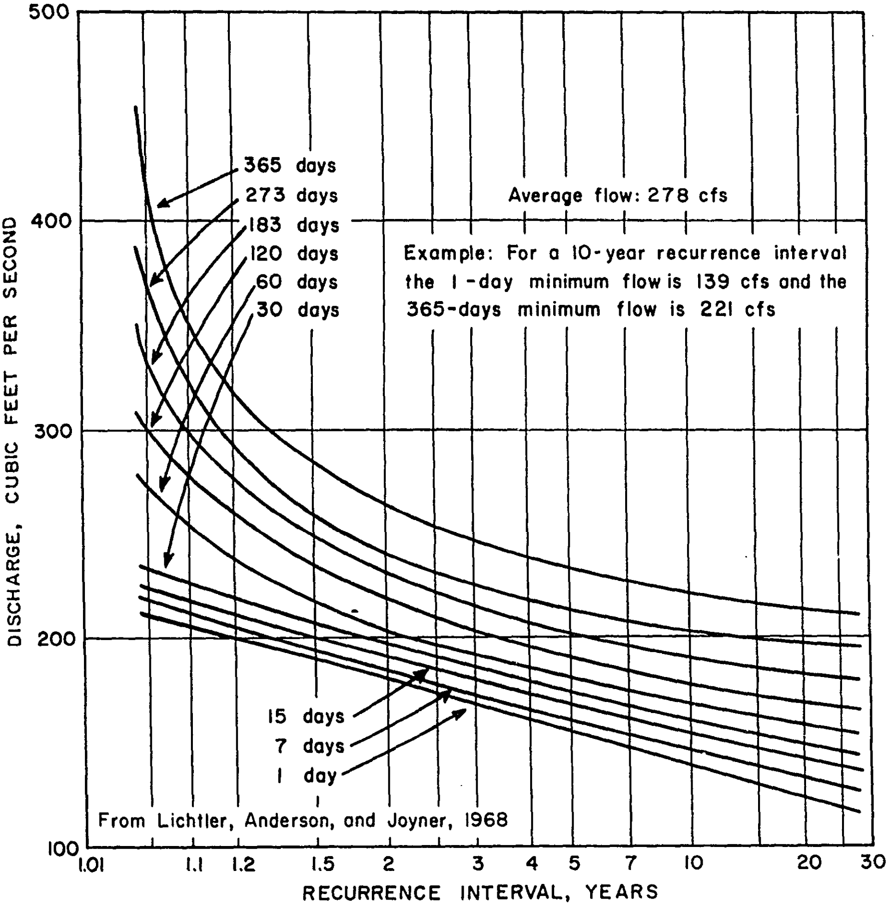


Figure 22 Low-flow frequency curves for Wekiva River near Sanford

Oklawaha River basin has an average yield of 1,450 cfs or 2.2 cfs per square mile. This high yield results from the emergence of previously infiltrated water as springs in this part of the basin, including Silver Springs with an average flow of 530 million gallons per day of good quality water.

Water in the Oklawaha River basin is generally of good quality except near the mouth where springs and seepage from the Floridan aquifer and discharge from deep artesian wells contribute more highly mineralized water to the stream. Numerous lakes in the Lake

Louisa and Lake Minnehaha vicinity contain water of excellent quality, with total dissolved solids averaging only 25 to 40 mg/l. Palatlakaha Creek contains water of similar quality. Lake Apopka and Lake Dora have total dissolved solids above 200 mg/l, with calcium carbonate hardness of 100-160 mg/l, which is probably due partly to large inflows from the artesian aquifer through springs. Lakes Eustis, Harris, and Griffin have about half the dissolved solid concentration as that of Lakes Apopka and Dora. Silver Springs contributes a large flow of high carbonate water which again raises the total dissolved solids to more than 200 mg/l. Other constituents in water from Silver Springs are low. Chloride and other chemical constituents are low throughout the basin. Spring discharges are clear and all lakes and streams are low in color except in the extreme headwaters, where color reaches more than 200 units in small creeks and lakes. Contamination from fertilizers and pesticides, especially from the intensively farmed citrus groves and muck farms, has contributed to the dissolved chemical constituents in the basin waters. Water in the Orange Creek basin contains an average of about 70 mg/l of dissolved solids; it is generally good for all purposes but color and iron are sometimes objectionable in Newnans Lake and Camps Canal.

LOWER ST. JOHNS RIVER BASIN

The average discharge of the St. Johns River at its mouth is estimated at 8,300 cfs. Reversal of flow by tidal action causes upstream and downstream flow at Jacksonville to reach 130,000 cfs.

The capacity of the main stem of the St. Johns River to store water is tremendous owing to: (1) the great width of channel in the reach between Palatka and Jacksonville, (2) its low gradients, (3) several large lakes upstream from Palatka, and (4) the low flood plain which in places is more than ten miles wide. Storm water is held in storage for long periods before being discharged to the sea.

The recorded range in stage along the main stem varies from 5.9 feet at State Highway 60, in Indian River County, to 11.0 feet at State Highway 46, near Lake Harney. The range in stage of 7.1 feet at Jacksonville is partly the effect of wind and tide. The greatest ranges occur in the reach between Lake Washington and Lake Harney.

Water quality in the main stem is generally poor during low water and fair during high water, as indicated by the graph in figure 3 which shows the chloride concentration below Lake Harney to exceed 200 mg/l most of the time. The water is also very hard and color exceeds 200 units at times. Serious pollution from industrial wastes and urban centers is presently under investigation by several agencies.

The principal tributaries to the lower St. Johns River are Dunns Creek, Rice Creek, and Black Creek. Their flow characteristics and general chemical quality are discussed below.

DUNNS CREEK

Dunns Creek is the second largest of the St. Johns River tributaries. Its drainage basin includes about 400 square miles of low swamps, a hundred square miles of karst terrain with no surface runoff and about 30 square miles of lakes on the east side of the St. Johns River. Little Haw Creek and Middle Haw Creek, 2 tributaries of Dunns Creek, have average flows of 90 cfs and 60 cfs, equal to 0.75 and 1.50 cfs per square mile. The prorated yield from the total gaged area is 0.94 cfs per square mile, or an average runoff of about 500 cfs for this basin. The yield from Little Haw Creek basin is low because about half of its drainage area has no surface runoff. The maximum recorded discharge of 27 cfs per square mile from the part of Little Haw Creek basin drained by streams is indicative of the flat slopes and the storage capacity of the swamps in this basin. Middle Haw Creek has a maximum recorded flow of 60 cfs per square mile, and in most years the flow declines to insignificant amounts or ceases. Flow in Dunns Creek is subject to twice daily reversal at Crescent Lake because of tide induced backwater from the St. Johns River.

Except for high color, water quality in Dunns Creek basin varies from excellent in the upper reaches of Haw Creek to poor in and downstream from Crescent Lake. Specific conductance in Crescent Lake exceeds 1000 micromhos and chloride concentration exceeds 200 mg/1 much of the time. In the upper reaches, Lake Disston and Little Haw Creek have specific conductances of only 70 micromhos and chloride concentration less than 20 mg/1; color, however, reaches 165 units. Middle Haw Creek is high in color with up to 700 units at times although its chemical quality is excellent.

RICE CREEK

Rice Creek drains 354 square miles north and west of Palatka. The average flow for six years of record is 404 cfs, or 1.14 cfs per square mile. The estimated yield from 174 square miles of the upper basin is 0.30 cfs per square mile, which indicates runoff of 1.95 cfs per square mile from the swampy area in the lower basin. Water from wells penetrating the Floridan aquifer in the Etonia Creek basin contributes to the base flow. The maximum observed discharge of about 7,000 cfs, or 20 cfs per square mile, is low and probably results from the storage of storm runoff in swamps and lakes. The lower reaches of Rice Creek are affected by tidal backwater from the St. Johns River. As much as 100 million cubic feet of water per day may enter the creek from the St. Johns River as a result of rising tide.

The water quality in the upper reaches of Rice Creek and of Etonia Creek is good, with low to moderate concentrations of all chemical constituents. Total dissolved solids and chloride content increase in the lower reaches of Rice Creek but are within acceptable tolerances. Serious industrial pollution occurs in lower Rice Creek, which affects St. Johns River upstream as well as downstream because of tidal action.

BLACK CREEK

Black Creek drains 474 square miles of the eastern slope of Trail Ridge west of the St. Johns River. The creek bed slopes an average of 10 feet per mile which results in high flow per unit area despite some attenuation by lakes and swamps. The maximum observed discharge of 13,900 cfs for the South Fork is 104 cfs per square mile and for the North Fork is 12,600 cfs, 72 cfs per square mile.

The South Fork contributes 44 per cent and the North Fork contributes 39 per cent of the 515 cfs total average flow from Black Creek and small tributaries below the confluence of the North and South Forks contribute the remainder. Average runoff ranges from 0.37 cfs per square mile from the upper Yellow Water Creek basin to 1.48 cfs per square mile from part of the upper North Fork. Average runoff from the entire basin is 1.08 inches.

The concentration of dissolved solids in the upper reaches of North Fork Black Creek averages about 30 mg/l and increases downstream to about 130 mg/l, but has reached more than 300 mg/l. The average concentration of dissolved solids in the South Fork Black Creek is about the same as in North Fork, but with a greater upper range and with considerable organic matter. Except for some objectionable color and iron at times, water from South Fork Black Creek is suitable for all uses.

COASTAL BASINS

The streams draining the coastal area have relatively small drainage basins. The largest, Tomoka River, drains only 152 square miles. The coastal lagoons (Tolòmato, or North River, Matazas River, Halifax River and Indian River) are connected with artifical channels where required to establish continuity of the Intracoastal waterway, and Pablo Creek is connected to Tolomato River to form a section of the waterway east of Jacksonville, thus changing the drainage pattern in that area. Water draining from the coastal area into the lagoons reaches the ocean through five inlets that connect the coastal lagoons to the ocean.

Information on the more important coastal streams and canals is given below. Flow and quality of water are variable as drainage is both natural and by drains from intensely farmed agricultural areas which at times utilize highly mineralized artesian water for irrigation.

MOULTRIE CREEK

Moultrie Creek drains 23 square miles of ridges and swamps on the eastern slope of the coastal ridge. The channel cuts through several of the sand ridges which permits drainage to a coastal lagoon, known as Matanzas River.

The average discharge of Moultrie Creek is 24 cfs or about 1 cfs per square mile. The maximum observed discharge of 1,450 cfs, or 62 cfs per square mile, is fairly low and reflects the attenuating effects of storage in the swamps feeding the creek and percolation into the surficial sandy material. The minimum discharge is 0.1 cfs.

The water quality varies inversely with discharge and although low in most chemical constituents is moderately hard to very hard; color is high during periods of high discharge when decayed vegetation is flushed from swampy areas.

TOMOKA RIVER

Tomoka River drains a swampy area south and west of Daytona Beach similar to the area drained by Moultrie Creek. The average discharge from the basin is estimated to be 155 cfs, or 1 cfs per square mile. The maximum observed discharge is 2,170 cfs, or 28 cfs per square mile, at the gaging station and indicates that the peak flow is attenuated by swamp storage and probably some percolation into the surficial sediments. The minimum recorded flow is 0.6 cfs.

Quality of water is generally good except for color values that at times exceeds 400 units in Little Tomoka River, and about 200 units in Tomoka River near Holly Hill. The water is generally soft but during low flows is moderately hard.

TURKEY CREEK

Turkey Creek drains 95.5 square miles above the gaging station southwest of Melbourne. The entire drainage basin is gridded by an extensive system of canals. Some interconnection by gravity flow exists and considerable, but unevaluated, amounts of water are diverted by pumping into the Turkey Creek basin from the St. Johns River basin.

The average flow at the gaging station is 135 cfs, or 1.42 cfs per square mile; considerably greater than that from the undeveloped basins to the north. This higher yield is caused partly by increased drainage of the water-table aquifer by the canals and partly by pumpage from the St. Johns basin. The maximum discharge of 2,798 cfs, or 29 cfs per square mile, is low despite the improved channels of flow. The high minimum flow of 15 cfs is the result of inflow from the water-table aquifer.

Water in Turkey Creek is considered hard and specific conductivity varies from about 50 micromhos during high flows to more than 1,500 during low flows. Chloride concentration exceeds 250 mg/l much of the time.

FELLSMERE CANAL

This canal drains 78.4 square miles above the gaging station into Sebastian Creek between Melbourne and Vero Beach. A complete system of irrigation and drainage canals with dikes and pumps has been constructed in the area drained. Considerable interconnection exists with the St. Johns River and with the parallel Big 40 Canal to the north.

The average flow in the canal is 131 cfs, or 1.67 cfs per square mile. This relatively high yield results from causes similar to those mentioned for Turkey Creek; and, in addition, the basin contains numerous flowing wells. As with Turkey Creek the high base flow of 18 cfs is the result of drainage from the water table aquifer and flow from artesian wells. The maximum flow of record is 1,880 cfs, or 24 cfs per square mile.

Water in the canal is hard and average chloride concentration exceeds 100 mg/l in the eastern end. The water is suitable for most uses although color at times is objectionable.

CANALS NEAR VERO BEACH

Three canals, North Canal, Main Canal, and South Canal, drain an area of topographically undetermined size west of Vero Beach. The canals are the primary outlets of the drainage and irrigation system in the area derived in part from return flow from artesian wells. The flows are completely controlled by dams and pumps and empty into Indian River between Sebastian and Fort Pierce Inlets.

The average flows from the canals are as follows: North Canal, 27.6 cfs; Main Canal, 75.8 cfs; and South Canal, 38.2 cfs. The respective maximum flows resulting from the storm of September 23, 1960 are 1,790, 1,900 and 1,930 cfs. The minimums are 2.6 cfs, 1.2, and 2.0 cfs.

Quality of the water is comparable to that in Fellsmere Canal, and is affected by return irrigation drainage waters and flow from artesian wells which add dissolved minerals to the water in the canals.

Indian River, Banana River, and other lagoons along the coast contain water that is brackish or approaches seawater in quality. The chloride concentration, which at times has exceeded that of seawater, becomes as low as 5,000 mg/l during periods of high runoff.

OTHER SMALL STREAMS

Some data have been collected on many other streams as shown in table 9.

TABLE 9. DRAINAGE AREAS AND OBSERVED EXTREMES OF DISCHARGE FOR OTHER SMALL STREAMS IN THE ST. JOHNS RIVER BASIN AND COASTAL AREA.

Name of Stream	Drainage area, square miles	Discharge, CFS Maximum	Minimum
Taylor Creek near Cocoa	55.2	3,000	0
Jim Creek near Christmas	22.7	3,750	0
Deep Creek near Osteen	120	*2,630	0.09
Deep Creek near Barberville	23	492	0.06
Big Davis Creek at Bayard	13.6	780	0.59
Durbin Creek near Durbin	36.7	4,140	0
Ortega River near Jacksonville	27.8	1,670	0.2
Pottsburg Creek near South Jacksonville	9.89	1,490	0.16
Trout River at Dinsmore	19.9	646	—
Cedar Creek near Panama Park	12	—	0
Dunn Creek near Eastport	4.86	720	0
Spruce Creek near Samsula	32	1,610	0
Crane Creek at Melbourne	12.6	665	1.8

*Maximum daily

LAKES

A large part of the "lake country" of Florida is within the area of this report. The chain of interconnected lakes in the Oklawaha River basin, including Apopka, Harris, Eustis, Griffin, and others, are important recreational assets and, through their temperature moderating effect during short periods of extreme cold, are a great benefit to the citrus industry. The large, shallow lakes along the main stem of the St. Johns River, such as Lakes George, Harney, Monroe, and others, are a distinct feature of the basin although they may be considered only wide reaches of the channel.

The interconnection of lakes by improved or artificial channels is a continuous development that modifies drainage divides and flow patterns to some degree. Controlled storage of water in some lakes for recreation and the drainage of swamps and some shallow lakes to develop land for urban and agricultural purposes change the basin runoff characteristics.

Water-stage data have been collected for 56 lakes in the area. Data range from a few spot observations to as much as 45 years of record.

Lake altitudes range from half a foot below sea level along the St. Johns River during droughts to almost 178 feet above sea level for Kingsley Lake during flood periods. Fluctuations in stage range from less than 2 feet for Sand Hill Lake to more than 32 feet for Pebble Lake.

Lakes in the area range in size from less than one acre for some sinkhole lakes to about 70 square miles for Lake George. Lake Apopka, with 47.9 square miles, is the largest lake that is not a part of the main stem of the St. Johns River. Seven other lakes exceed 10 square miles in area.

Figure 23 shows hydrographs of Lake Apopka, Lake Poinsett, and Orange Lake, each lake being in a different hydrologic setting. Lake Apopka is located where the piezometric surface is higher than the lake surface on the south side but lower on the north side; however, the formations below the lake bottom restrict the upward or downward movement of water so that the lake level is largely independent of changes in artesian pressure. Regulation of outflow by the control structure in Apopka-Beauclair Canal tends to limit the fluctuations of the lake level. Lake Poinsett is a widening of the main stem of the St. Johns River and fluctuates with river stages. The river is capable of transporting large volumes of water in a short time, which results in abrupt changes and a considerable range in stage. Lakes Washington, Monroe, Harney, George, and other main stem

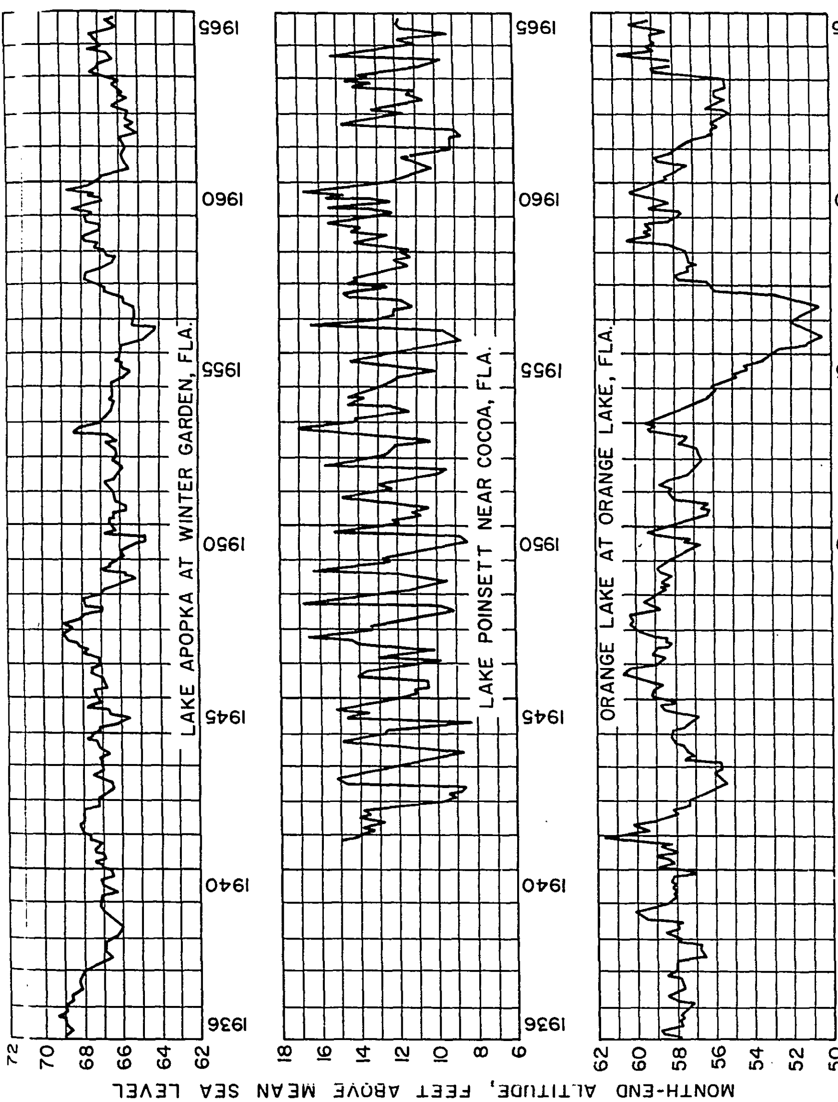


Figure 23 Hydrographs of month-end elevations of Lake Apopka, Lake Poinsett, and Orange Lake

lakes react similarly. The connection between Orange Lake and the Floridan aquifer is fairly good so that the lake tends to fluctuate, except as affected by surface flow, with the same range and patterns as the piezometric surface.

Figures 24, 25, 26, and 27 are stage-duration curves for selected lakes in the area and show the percent of time that specific

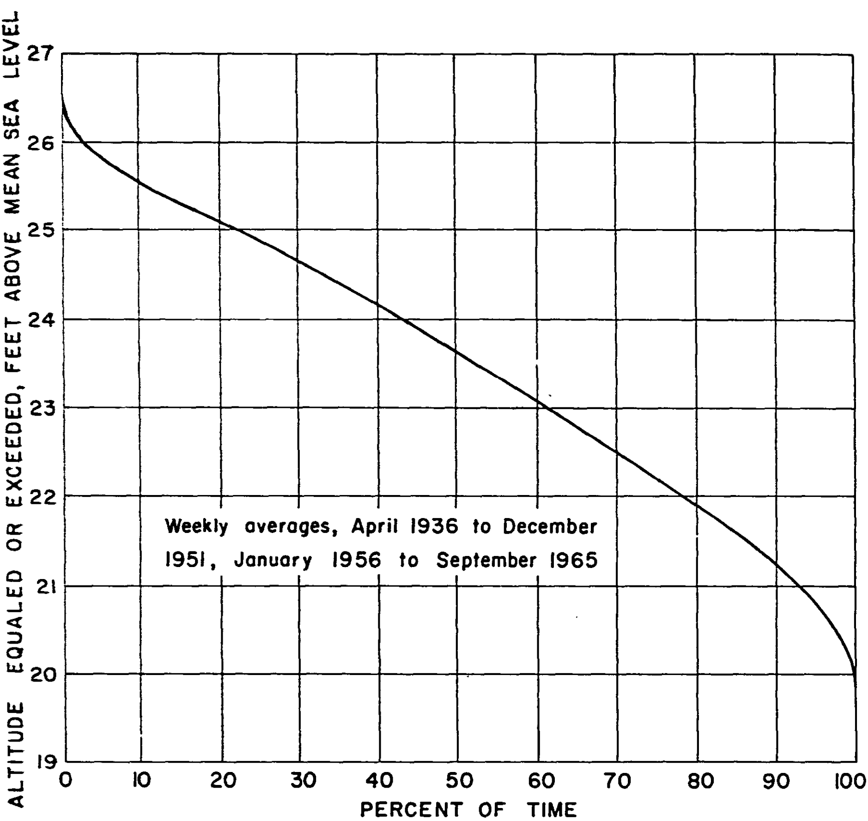


Figure 24 Stage-duration durve for Lake Kerr near Eureka

elevations were equaled or exceeded. Stage-duration curves do not, however, indicate the chronological sequence of events or the length of time that the lake may have remained at or above specific levels.

The quality of water in lakes, such as those along the St. Johns and Oklawaha Rivers, tends to be similar to that in the stream system of which they are a part. Lakes without surface outlets, and sinkhole type lakes, have good quality water because the water movement is generally downward from surface runoff containing little mineralization. However, man's use of fertilizers and pesticides, some of which are subsequently carried by surface and subsurface waters draining into lakes, are adding chemical constituents which are deleterious to the water quality.

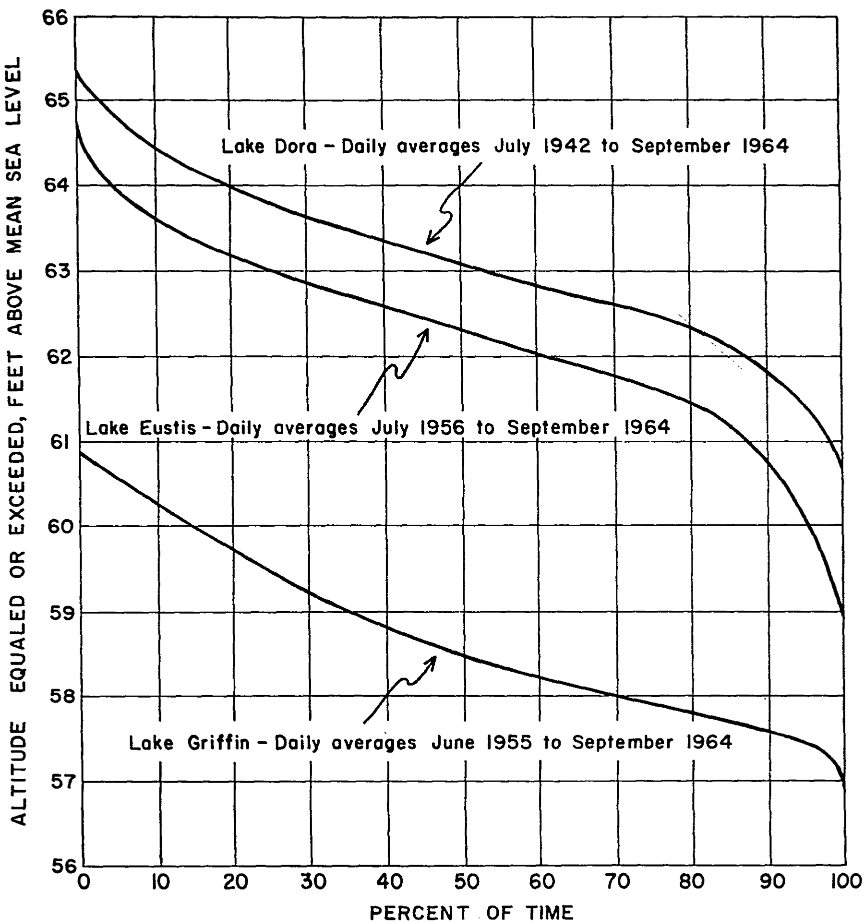


Figure 25 Stage-duration curve for Lakes Dora, Eustis and Griffin, in northeast Florida

Although lake water is used for the irrigation of residential areas and adjacent citrus groves, the primary use of lakes is for recreation and for home sites both for the tourist industry and for permanent residents. A few lakes are used as a source of municipal supply, such as Lake Washington for the city of Melbourne, however, ground water is the more dependable supply in the report area. The accelerating development of lake property for residential use and the esthetic and recreational values of lakes at optimum levels make control of levels within a limited range desirable.

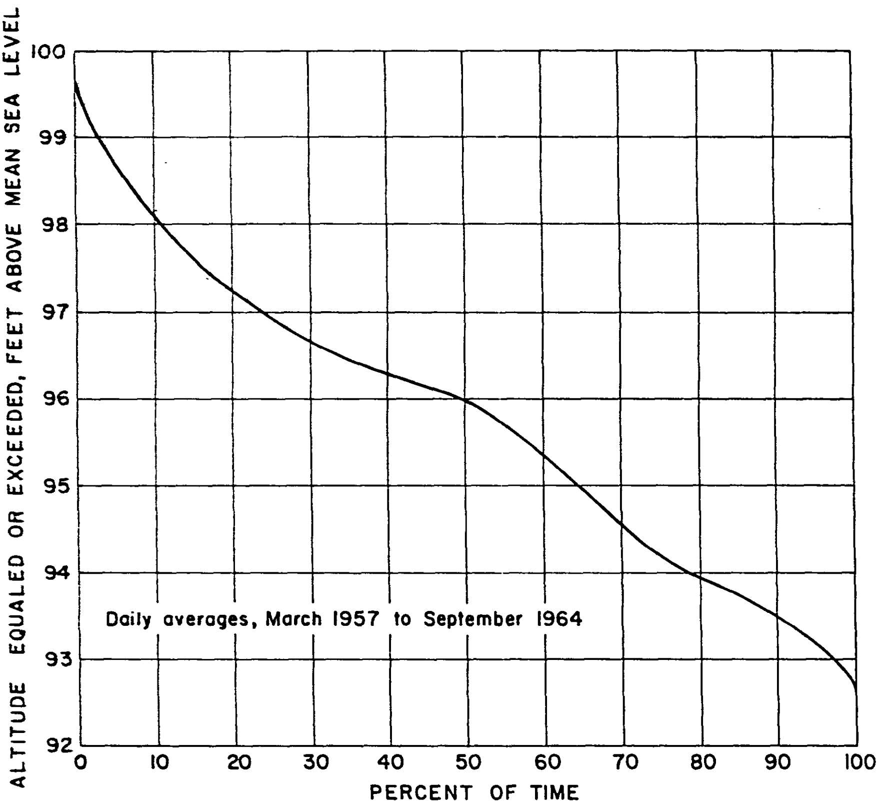


Figure 26 Stage-duration curve for Lake Louisa near Clermont

GROUND WATER

The largest and most important source of potable water in the St. Johns River basin is ground water in artesian and overlying shallow aquifers.

SHALLOW AQUIFERS

Ground water in shallow aquifers includes water in the zone of saturation under water-table conditions as well as water in shallow artesian aquifers below the water-table aquifer and above the Floridan aquifer. The water-table aquifer consists mainly of sand and clayey sand of Miocene, Pliocene, Pleistocene and Holocene ages and the shallow artesian aquifers occur in limestone layers and shell beds

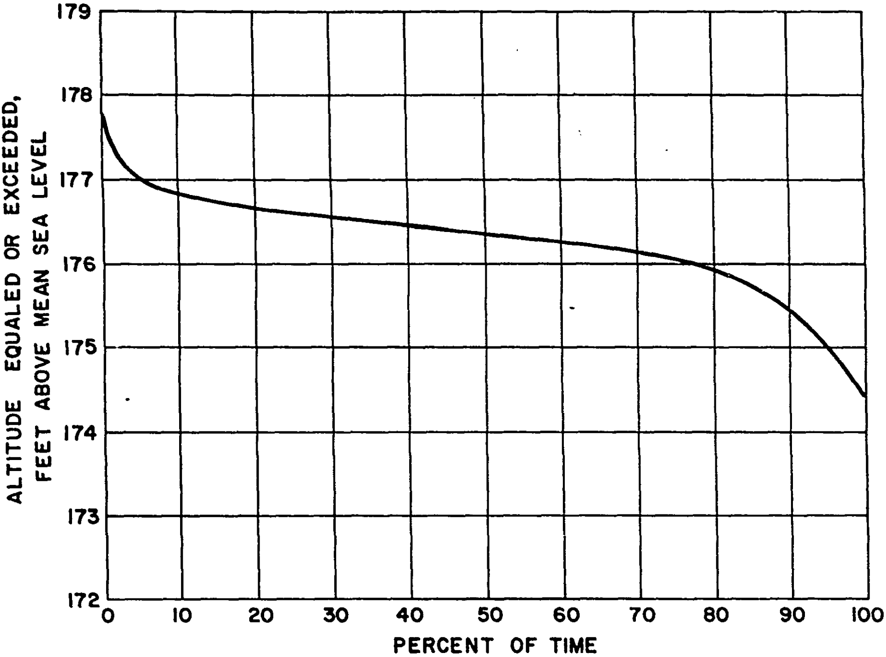


Figure 27 Stage-duration curve for Kingsley Lake near Camp Blanding

in the Hawthorn Formation and occasionally in sand beds within the more recent formations where clayey lenses create local artesian conditions.

The thickness of the water-table aquifer, or materials overlying the Floridan aquifer, ranges from less than a foot in parts of Marion and Alachua counties to more than 400 feet in Indian River and St. Lucie counties. Permeability varies from relatively high to very low, with the thicker more permeable zone in the eastern part of the report area. The two geologic sections in Figure 28 show the relative thickness of the shallow deposits.

Considerable water for both domestic and municipal uses has been obtained from the sandy shallow aquifer in Indian River and Brevard counties. The cities of Titusville, Eau Gallie, and Melbourne pumped several million gallons per day from the shallow aquifers prior to their use of supplies more recently developed from artesian or surface sources. Moderate supplies may be obtained under controlled pumping in the coastal ridge area in Brevard County and other counties and lesser supplies are available on the barrier islands, while shallow ground-water reservoirs supply low capacity domestic wells. In eastern St. Johns and Flagler counties, in Seminole County, western Clay County, and southeastern Alachua County moderate supplies are obtained for domestic use from wells that draw water

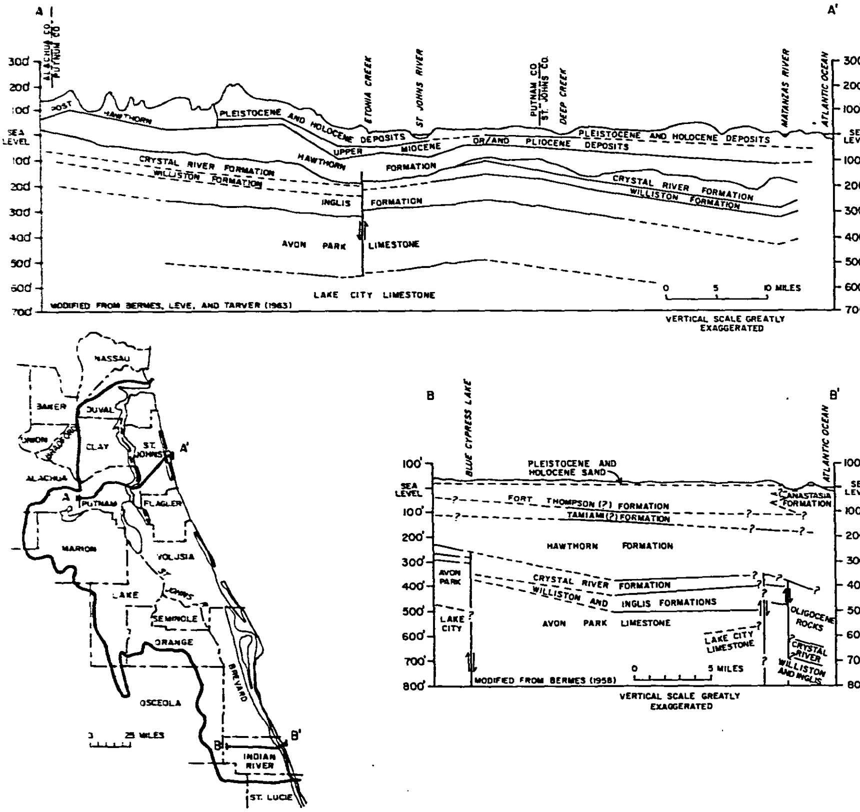


Figure 28 Two geologic sections through northeastern Florida.

from sand or coquina aquifers and from permeable Miocene age limestone beds. In Duval County, wells 40 to 150 feet deep supply water to many users. Wells range from 1¼-inch sand points to wells 24 inches in diameter which yield in excess of 100 gpm (gallons per minute). Supplies from wells in the shallow aquifers are often limited by the seasonal fluctuations of the water-table or by insufficient depth of the well; however, shallow wells are a valuable source of water in areas where the depth to artesian water, or the quality of the artesian water, does not justify its use.

The chemical quality of shallow waters is generally good, although higher in iron and color it is lower in other constituents than water from the underlying artesian aquifers. This is especially true in areas of Orange and Seminole counties underlain by quartz sands where total hardness under 10 mg/l is common. Chloride is low except in some areas where the water-table aquifers have become contaminated by intrusion of salt water from Indian River or the Atlantic Ocean, or where the piezometric surface of the artesian aquifer is higher than the water table so that relatively saline ground water can move upward into the water-table aquifer. Such conditions occur naturally in years of low rainfall, as in 1956, or are artifically induced by heavy pumping, both of which lower the head of the shallow water table permitting upward and landward migration of salt water. Temperatures of shallow ground water range from about 19° to 27° C., with seasonal variation, in contrast to the nearly constant temperature of water from the upper part of the Floridan aquifer, which is most commonly 22°–24°C (72°–75°F) in the report area.

The shallow aquifers are recharged directly by local rainfall and by percolation from surface-water bodies. The water moves by gravity from a higher to a lower level at a rate dependent on the permeability of deposits and the slope of the water table. The water table in shallow aquifers generally follows the topography but with less relief, and is generally from 10 to 40 feet below land surface on high ground and at or near land surface at lakes and swamps. Annual water-level fluctuation ranges from about five to twenty feet on high ground to practically none in low or swamp areas, but extremes over longer periods between years of excess rainfall and drought may be considerable greater. Figure 29 shows the fluctuation in water level in a water-table well near Bithlo, Orange County, and its relation to rainfall and to fluctuations of water level in a nearby well in a secondary artesian aquifer and in a Floridan aquifer well; and shows the more rapid response of the shallow water table to rainfall.

Discharge from the shallow aquifers in the report area is by (1) natural seepage into streams, lakes and the ocean, (2) downward movement into the Floridan aquifer, (3) loss by evapotranspiration, and (4) pumpage for irrigation, domestic, and industrial uses. In much of the Oklawaha River basin, mostly in Lake, Marion, Alachua,

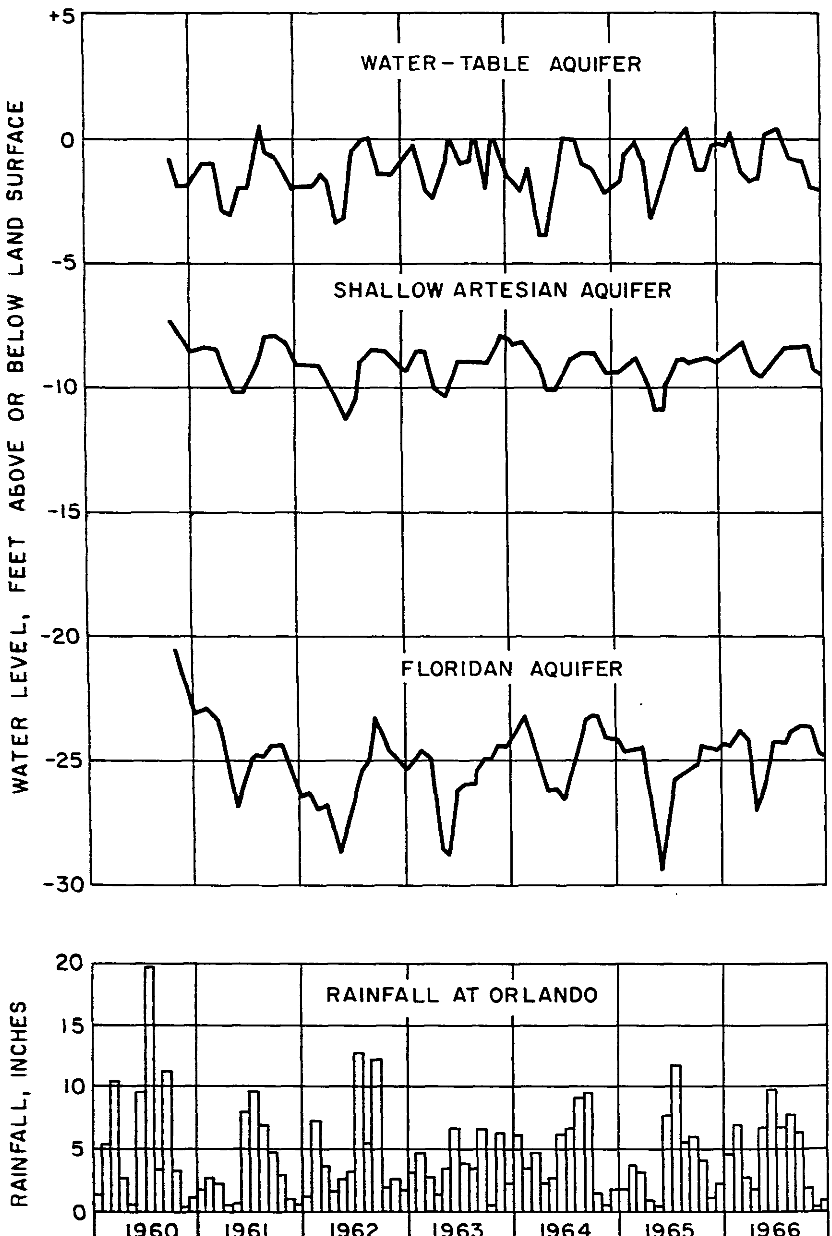


Figure 29 Hydrographs of wells in water-table, shallow artesian, and Floridan aquifers one mile east of Bithlo, Orange County, Florida

and Putnam counties, the discharge from the shallow aquifer is primarily as downward movement into the Floridan aquifer except for water lost through evapotranspiration. In most of this area little water is pumped from the shallow aquifer and surface runoff is negligible. The water table usually fluctuates closely with rainfall as indicated by the hydrograph in figure 29 of the shallow well near Bithlo. Where the water-table aquifer is directly or partially connected to the artesian aquifer, water levels fluctuate similarly to the piezometric surface of the artesian water. Water moves downward into the artesian aquifer through materials of low to moderate permeability in areas where the head in the shallow water aquifer is higher. Where artesian pressure is higher the movement may be upward into the shallow aquifer.

Much shallow ground water is pumped from small capacity wells for domestic and livestock uses in the report area. Where artesian water is of poor quality, especially in Brevard and Indian River counties, shallow water may economically meet increased needs. Since permeability and physical conditions are extremely variable, the shallow aquifer should be thoroughly investigated to determine local aquifer characteristics prior to the development of well fields to supply large quantities of water.

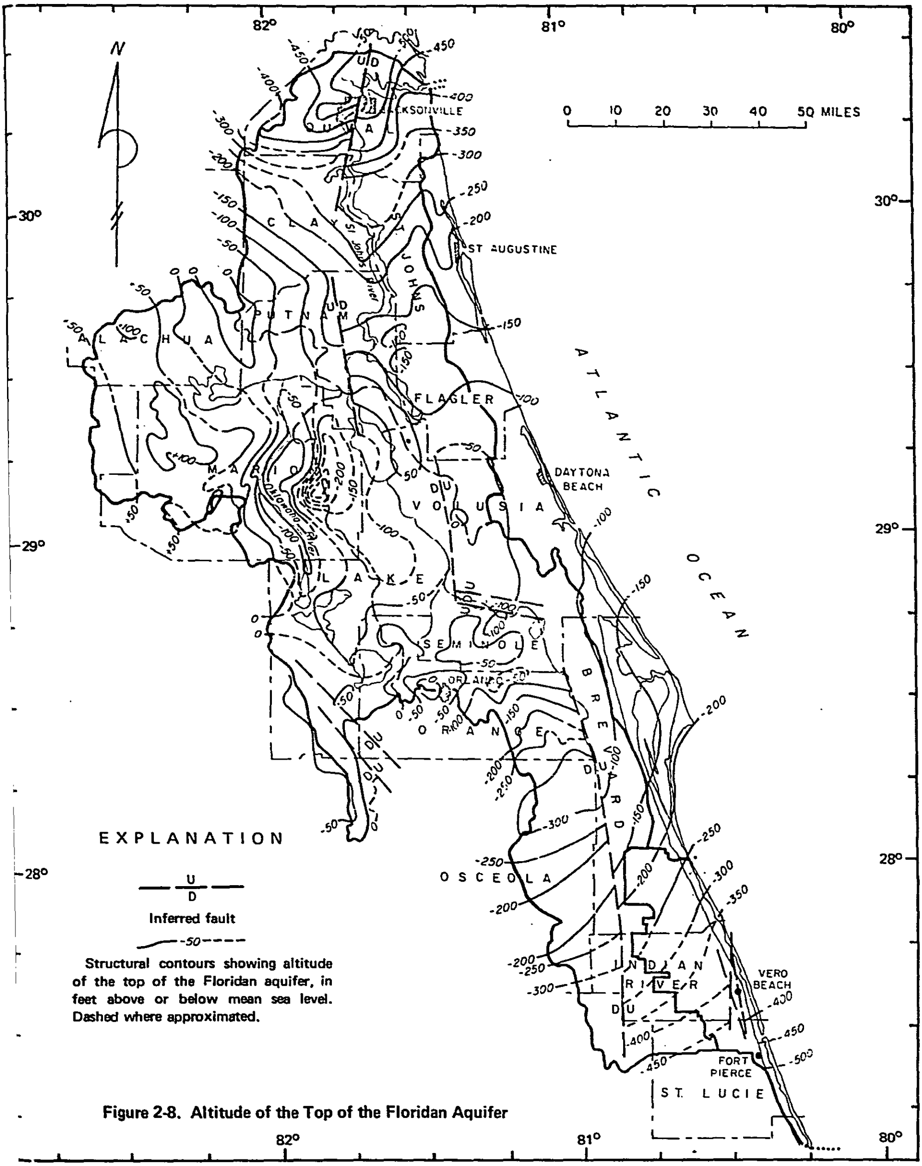
ARTESIAN AQUIFERS

The entire report area is underlain by the Floridan aquifer, one of the most prolific and most studied sources of ground water. The Floridan aquifer includes the hydraulically connected permeable limestone and shell beds of the Hawthorn Formation of Miocene age, the Ocala Group consisting of the Crystal River, Williston, and Inglis Formations, and the underlying Avon Park and Lake City Limestones, all of Eocene age. The Ocala Group, which is generally the most productive unit, is not uniform throughout the area and is thin, or entirely absent, in parts of Seminole, Orange, Volusia, Marion, Lake and Osceola counties, where the Hawthorn Formation, or undifferentiated deposits of Miocene and younger age, lie unconformably on limestones older than the Ocala Group. In most areas, however, the Ocala Group is from 50 to 200 feet thick and has relatively good permeability because of many cavities and solution channels. Some cavities are now filled with sand and clay so that the permeability has been reduced. The Oldsmar Limestone which underlies the Lake City Limestone, generally yields saline water and is not generally considered as part of the Floridan aquifer.

The uplifted backbone of peninsular Florida is in general both a surface water and a ground water divide although locally the divides may not coincide by several miles. Two geologic sections across parts of the St. Johns River basin, shown on figure 28, portray somewhat similar geologic patterns. In general, good quality ground water is more easily obtained where the water-producing formations are higher in altitude and in or near recharge areas. These are mostly west of the St. Johns River except in central Volusia County. In the northern and southern parts of the area, the prolific water-bearing formations are generally lower in altitude, greater in depth, more costly to exploit, and more liable to saline contamination.

Wells drilled into the Floridan aquifer are cased into the upper limestone bed below which an open hole is drilled to a sufficient depth so that the well will produce water in adequate quantity. Figure 30 shows the configuration of the top of the Floridan aquifer as compiled from recent published and unpublished reports. The approximate depth to limestone and the length of casing required may be roughly estimated from figure 30 if the land surface altitude at the desired location is known. Locally small filled depressions in fault and sinkhole areas are not uncommon and the top of the aquifer may differ considerably from that shown.

The height at which water stands in a tightly cased well penetrating an artesian aquifer is called the piezometric level. Figure 31 shows the piezometric suface of the principal artesian aquifer in the St. Johns River basin and adjacent coastal area and the areas of artesian flow as of July 1961. The piezometric surface fluctuates in response to recharge to and discharge from the aquifer. In locations where heavy withdrawal exceeds recharge to the aquifer, the water levels will progressively decline so that upward movement of saline water may result; therefore, new well fields and wider spacing of wells become necessary. The hydrographs of water levels in five wells in the Floridan aquifer are shown inFigure 32. The long-term, as well as seasonal, changes in the piezometric level at different locations in the report area are shown. A graph of annual precipitation at Gainesville in Alachua County which is near a principal recharge area, is included for comparison of annual variations. The well in Marion County near Silver Springs, and the one in Volusia County near Barberville show that the piezometric surface in areas unaffected by large man-made withdrawals respond to below average and above



From Bermes, Leve, Lichtler, Faulkner, Vernon, Wyrick.

Figure 30 Map of northeast Florida showing altitude of top of Floridan aquifer

average rainfall, but maintain their levels over a long period of years. The water level in the well in Duval County has a net decline as a result of large increases in pumping at Jacksonville. The water level in the well in Putnam County is affected by pumping in the Palatka area which increased in the mid 1950's. Decline of water level first became appreciable in the late 1950's but then stabilized, perhaps due to salvage of natural discharge or because of increased natural recharge. The slow decline of water level in the well in southwestern Brevard County is probably caused by increasing reclamation and development of lands for agriculture and increasing pumpage for irrigation.

Recharge to the artesian aquifer is almost entirely from rainfall within the St. Johns River basin and occurs where rainwater percolates through relatively thin surficial deposits in the highlands area in Alachua, Marion, Lake, Polk and other counties. Recharge also takes place through sinkholes and lakes connected to the aquifer, and through the relatively thick and less permeable surficial deposits where the water table stands at a level higher than the piezometric level, as in parts of Seminole, Volusia and Orange counties. Some recharge also occurs in the coastal ridge area. There is no recharge to the artesian aquifer in Indian River County, in most of Brevard County, or in large areas of Duval, St. Johns, and Flagler counties. Movement of water into the basin is shown by the slope of the piezometric surface in Polk, Lake, and Highlands counties. Flow is in the direction of lower water levels, generally at right angle to the piezometric contours. Movement of water out of the basin to the west occurs in western Alachua and Marion counties.

Artesian heads may not be uniform throughout the entire thickness of the aquifer because the more permeable zones are separated by less permeable zones. Leakage or movement in one zone may occur without appreciably affecting the head in another higher or lower zone in the aquifer. In parts of Volusia County, eastern Orange, Brevard, and Seminole counties, and other areas, upward movement and discharge from the upper part of the aquifer has reduced the pressure head in that part of the aquifer. Saline water and fresh water move upward or downward through fractures or uncased holes from one zone to another in response to differences in head. Upward movement also occurs along faults or fractures as along Haw Creek and the St. Johns River. In areas where Floridan aquifer water moves upward to the water table and to land surface much water is lost to unproductive evapotranspiration and no recharge takes place. Under these conditions pumping water for beneficial use from the ground-water aquifer tends to lower the water table and to reduce that loss. Lowering of the water-table would increase recharge in areas where the gound-water reservoir is filled and potential recharge is rejected.

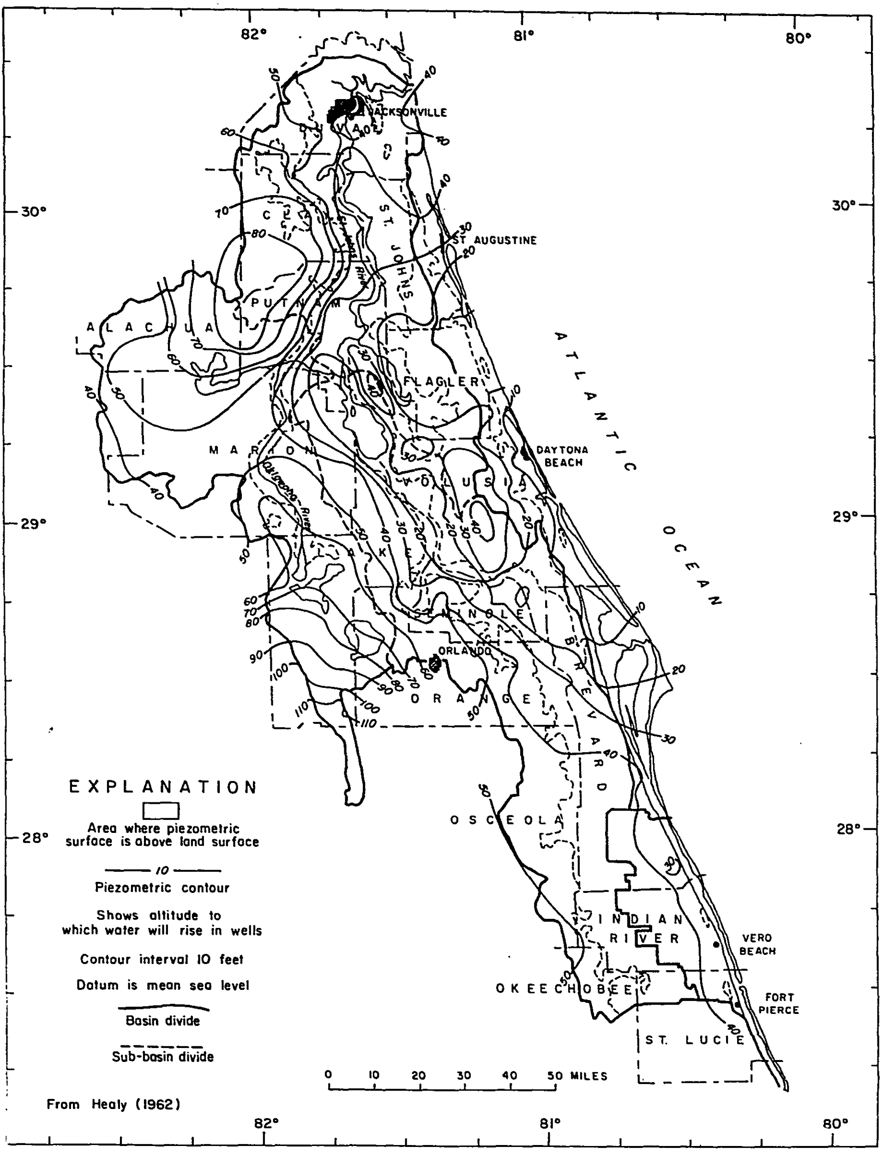


Figure 31 Map of northeast Florida showing piezometric surface of Floridan aquifer as of July 1961

The chemical quality of water in the Floridan aquifer varies laterally and with depth throughout the report area. Water in the upper 200 feet of the aquifer is generally of better quality than water in lower zones. It contains less than 10 mg/1 of chloride and 200

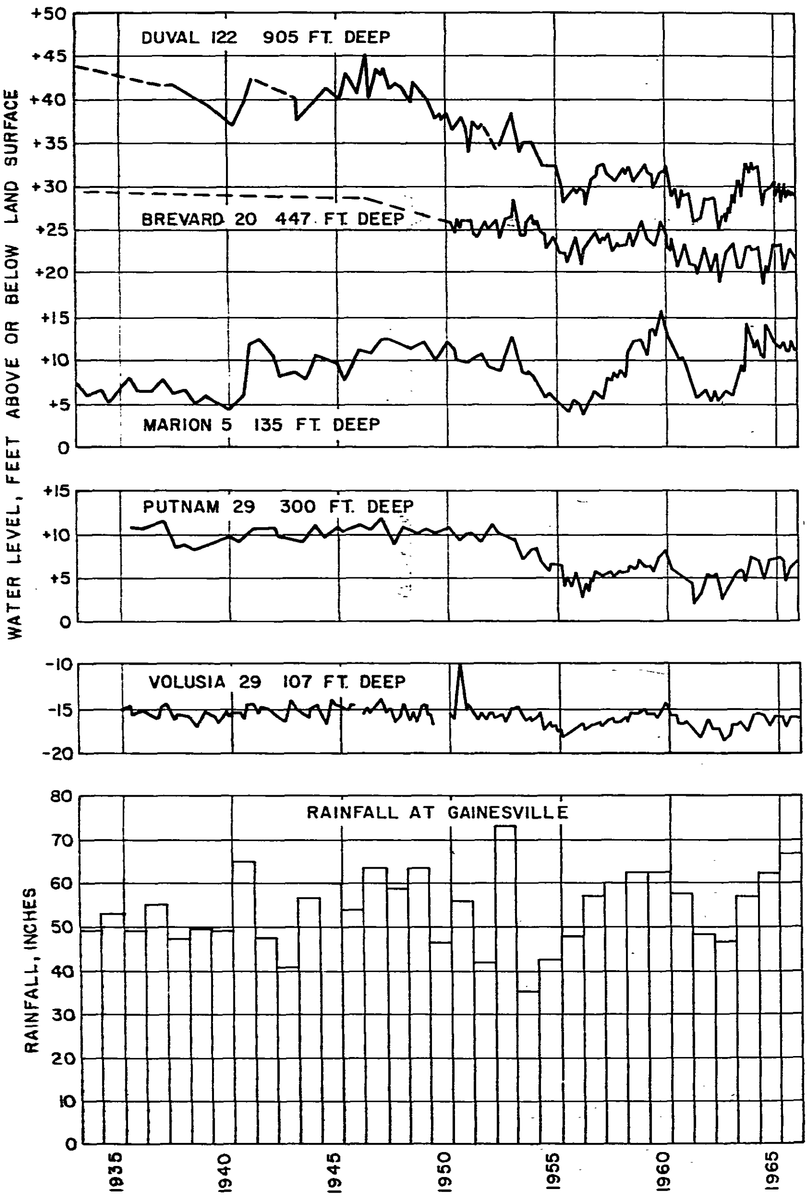


Figure 32 Graphs showing water level fluctuations in five wells that penetrate the Floridan aquifer, and rainfall at Gainesville

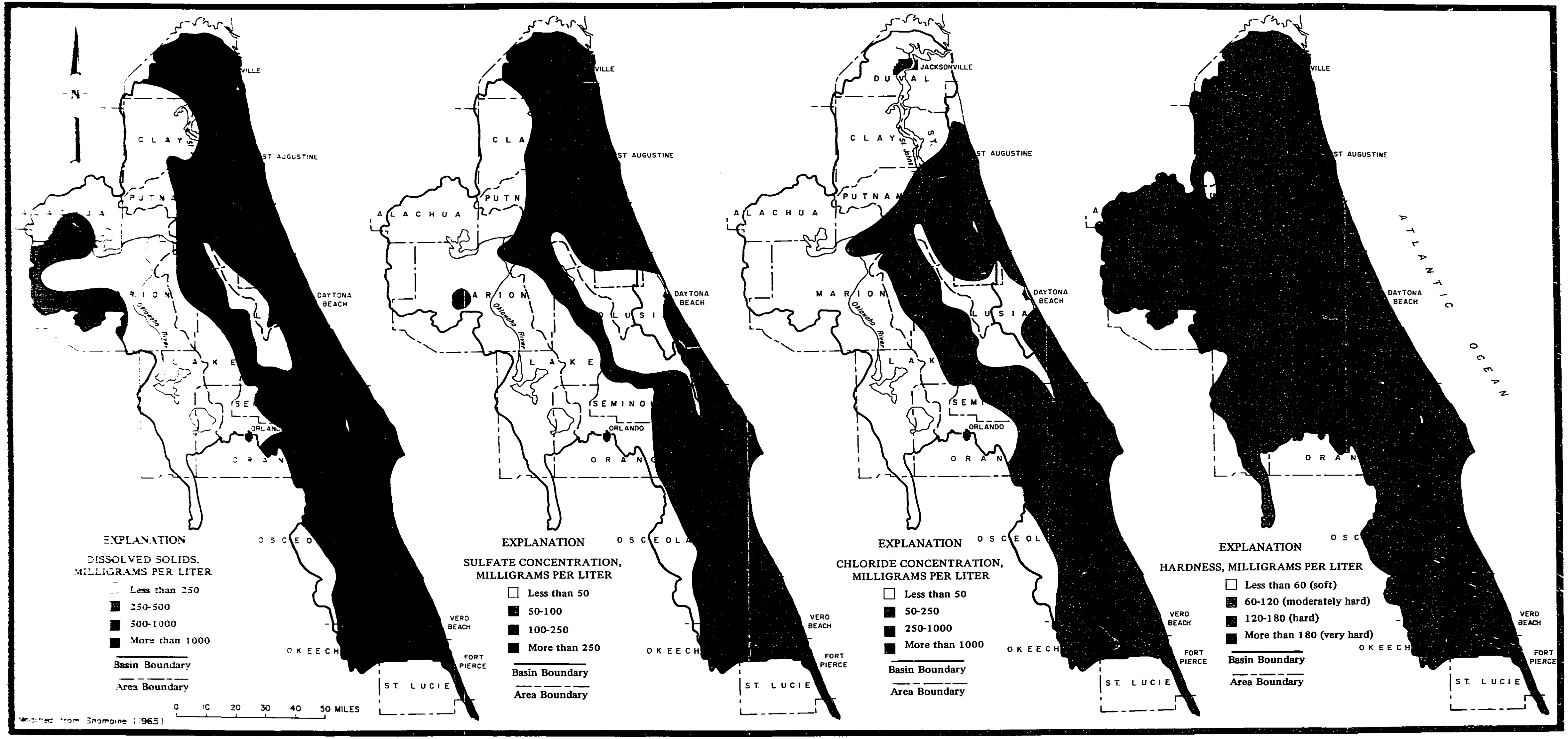


Figure 33. Maps of Northeast Florida showing chloride concentration, hardness, total dissolved solids, and sulfate concentration in water in upper part of Floridan aquifer.

mg/l dissolved solids in and near recharge areas. Water from the deeper zones is generally more saline because saline water in the deeper zones, perhaps remaining since ancient times, has not yet been completely flushed away. Artesian water in Indian River County, the eastern part of Brevard County except under the coastal ridge, and much of Flagler and St. Johns counties contains certain dissolved minerals in concentrations that exceed U. S. Public Health Service standards for water for domestic use. However, the water is used for irrigation of citrus groves and for stock water. Wells in the City of Cocoa well field, in southeastern Orange County, yield water containing between 40 and 300 mg/l of chloride from zones about 250 to 800 feet deep. The water utility operators are able to control the salinity of the composite water by controlled pumping and mixing of water from various wells within the well field. A multi-zoned salinity monitoring well in the Cocoa well field, from which samples are obtained from five levels, yields water containing more than 600 mg/l chloride from a depth of more than 1,350 feet and 40 to 90 mg/l chloride from depths of less than 1,200 feet below land surface.

The chemical quality of artesian water differs from place to place depending largely on distance from the recharge area as well as depth in the aquifer. Figure 33 shows the generalized concentration of chloride, hardness, dissolved solids, and sulfate in the upper part of the Floridan aquifer in the report area. Figure 34 shows variations in chloride content of waters from the Floridan aquifer with depth above an east-west line between Groveland and Daytona Beach. Detailed information on the chemical quality of water is available in several reports listed in the references based on analyses of water from hundreds of wells in many locations and to different depths in the area. A general rule is that chemical quality of water in the Floridan aquifer deteriorates as water moves away from recharge areas and to greater depths.

SUMMARY OF CONDITIONS

Ground water in the St. Johns River basin and coastal areas is abundant but the depth to, and the quality of, the water differ from place to place. Summaries by county are given in order to more closely identify the water availability and problems within the individual counties.

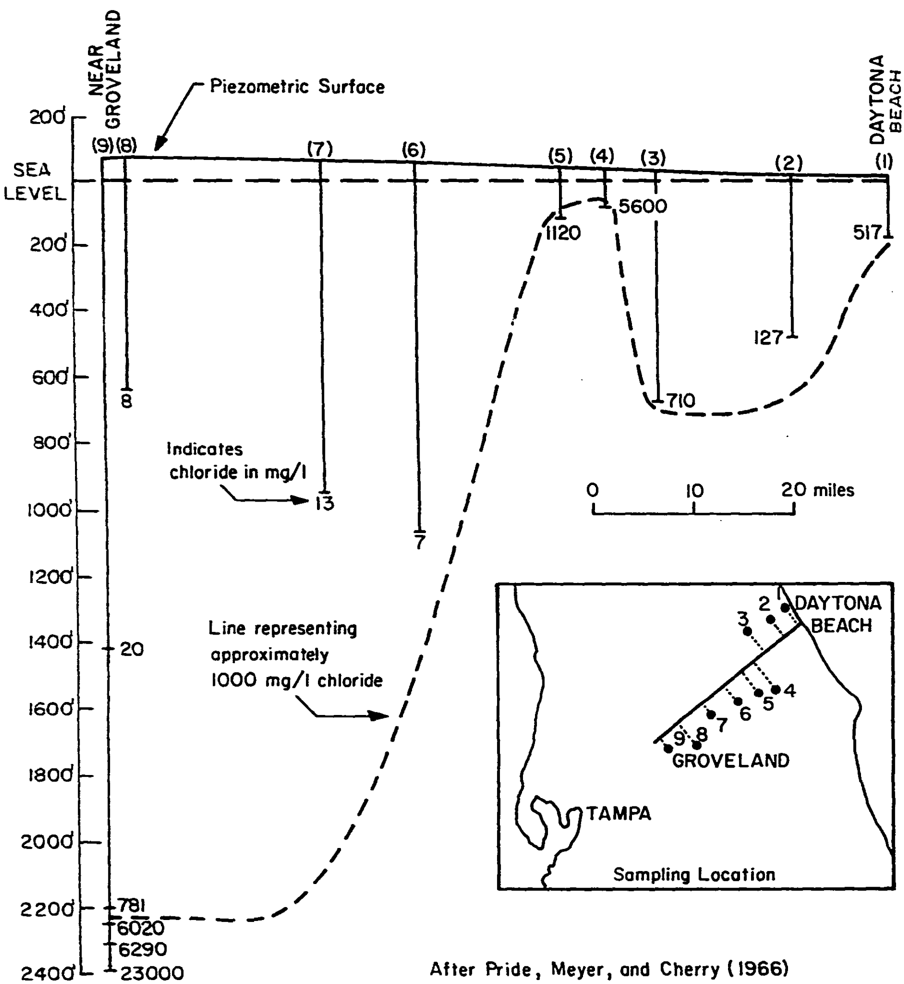


Figure 34 Section showing variation in chloride content of waters from the Floridan aquifer with depth along a line between Groveland and Daytona Beach

DUVAL COUNTY

The Floridan aquifer is about 1,000 feet thick and is the principal source of water in Duval County; the altitude of the top of the aquifer from south to north varies from 300 to 550 feet below msl (mean sea level). It is overlain by the relatively impermeable clay, sand and sandy clay of the Hawthorn Formation and the silty clay, shell, and sand of more recent deposits. Recharge is from counties to the west and south; deeper zones produce a greater supply, artesian flow occurs in most of the county. The natural artesian flow of small wells is as much as 500 gpm and of large wells is as much as 2,000 gpm; the capacity of large pumped wells can exceed 5,000 gpm. Large withdrawals by more than a hundred municipal and other supply wells in the Jacksonville area have depressed the piezometric surface more than 30 feet in the past three decades. Water in the county is generally suitable for domestic use; chloride content varies from less than 10 mg/l in the southwest to 40 mg/l in the northeast. Most rural wells are constructed by jetting or driving a 2- to 4- inch casing to the top of limestone and then drilling a few feet into the limestone. Lowering of the piezometric level in the county by increased pumping will increase salt water intrusion problems in some areas, as has been experienced in the Hastings area. A good water-bearing zone between 1,900 and 2,050 feet below land surface, with a chloride concentration of 14 mg/l, has recently been located by a test well near Jacksonville.

CLAY COUNTY

The top of the Floridan aquifer varies in altitude from approximately mean sea level in the southwest to 300 feet below msl in the northeast. The piezometric level is about 90 feet above msl in the southwest corner of the county and decreases to about 30 feet above msl along the St. Johns River. Artesian flow occurs near the St. Johns River and in the Black Creek basin. The piezometric levels declined from the mid-1940's to mid-1950's, but appear to have stabilized since. Specific capacities of wells range from 2 to 60 gpm per ft. (gallons per minute per foot of drawdown) in the eastern and northern part to 22 to 300 gpm per ft. in the western part. The Floridan aquifer is the most productive aquifer but many small wells obtain water from secondary artesian aquifers in the Hawthorn Formation for domestic and stock water. Chemical quality of water is generally good except for hardness which is in excess of 200 mg/l from both the Floridan and secondary aquifers in the southeastern part of the county.

ST. JOHNS COUNTY

The major source of water is the Floridan aquifer. Although some recharge occurs in the central part of the county most of the water in the aquifer is derived from underflow from neighboring counties to the west. The piezometric level decreases from about 45 feet above msl in the north to 20 feet above msl in the south;

artesian flow occurs in the western and eastern parts of the county. The top of the aquifer ranges from about 100 feet below msl in the south to 300 feet below msl in the north. The upper 50 to 200 feet of the aquifer is the most productive. Quality of water in the upper 200 feet is generally good, with less than 250 mg/l of chloride in the northern part of the county; however, chloride content is several thousand milligrams per liter in some wells along the coast south of St. Augustine. The shallow aquifers contain water of better quality and supply domestic needs in coastal areas from wells 20 to 150 feet deep.

ALACHUA COUNTY

The Floridan aquifer is the main water source in Alachua County although shallow wells and wells tapping shallow artesian aquifers are also used extensively. Recharge to the Floridan aquifer occurs in most of the county. The aquifer is more than 700 feet thick and the limestones are at or near land surface in the southern part of the county. Specific capacity of wells range from 2 to 700 gpm per ft of drawdown and pumping rates ranged up to 5,000 gpm; most of the lower capacity wells are in the eastern part of the county. Large capacity wells are generally 200 to 800 feet deep. There is some artesian flow in low areas in the southeastern part of the county. Hundreds of millions of gallons per day of additional water can be withdrawn by pumping without depleting the county's water resources. Water quality is generally good except for hardness in excess of 200 mg/l in the southern part of the county.

PUTNAM COUNTY

The Ocala Group in the Floridan aquifer is the principal source of water in Putnam County. The altitude of the top of the Ocala Group ranges generally from about 25 feet below msl in the western part to 170 feet below msl in the eastern part. The overlying Hawthorn Formation is relatively impervious but discontinuous. Artesian flow occurs in lowlands along the St. Johns River and nearby tributary streams, but pressures have declined recently. The best producing zone is the upper 50 to 200 feet, and some wells in the county yield in excess of 5,000 gpm. Water quality is generally good in the upper 200 feet of the aquifer except in small areas along the St. Johns River and northwest of Lake George, where total hardness may exceed 250 mg/l and chloride content is over 500 mg/l.

FLAGLER COUNTY

The Floridan aquifer is the major source of water for irrigation, industry and public supply. Its top ranges from 50 to 150 feet below msl and slopes from south to north. The piezometric level is only 15 to 20 feet above msl, but there is artesian flow in the vicinity of Crescent Lake and the Atlantic coast. Some wells 150 to 450 feet deep yield more than 200 gpm, principally from the Ocala Group and the Avon Park Limestone. Artesian water is highly mineralized in the central and northeastern parts of the county except in or near small local recharge areas. Chloride and hardness exceed 1,000 mg/l in artesian waters in the Haw Creek basin and in the northeast, so that domestic supplies in these areas are from the shallow aquifers generally less than 70 feet deep. However, many shallow wells in the Haw Creek basin yield brackish water which in part is derived from upward leaking saline water from the underlying Floridan aquifer.

MARION COUNTY

The Floridan aquifer is near land surface in the central part of the county but the depth to its upper surface varies considerably. Localized depressions in the buried surface of the aquifer extend to 300 feet below msl in the eastern part of the county, probably the result of sinkholes and collapsed caverns. The county is an area of major recharge to the artesian aquifer; recharge is estimated at about 12 to 18 inches per year. Silver Springs is a major fresh water discharge point (530 mgd average) whereas Salt Springs is a large highly saline spring (52 mgd). Wells in lowlands along the St. Johns and Oklawaha Rivers have artesian flow. In general, the upper part of the Floridan aquifer yields supplies of water adequate for existing and foreseeable future needs and hundreds of millions of gallons per day are available for development and use. Water quality is good throughout the county except near Lake George. No serious water supply problems are anticipated in the near future. Because of adequate recharge the piezometric level has not yet been seriously affected by pumping.

VOLUSIA COUNTY

The top of the Floridan aquifer ranges from sea level to 50 feet below msl in the west-central part and slopes to 150 feet below msl in the southeastern part of the county. It is overlain by sand, shell, and clay. The water table is higher than the piezometric level in much of the county so that the Floridan aquifer is recharged by water percolating through the overlying beds. The aquifer is more than 500 feet thick and furnishes most of the water used in the county. Wells are generally 125 to 180 feet deep. The chemical quality of the water is the best of any of the counties along the coast east of the St. Johns River. Chloride concentrations are generally under 50 mg/l; however, hardness is in the 200-400 mg/l range. As in all coastal areas an increase in salinity is probable if increased pumping lowers the water levels excessively.

LAKE COUNTY

The altitude of the top of the Floridan aquifer ranges from near sea level in the central part to about 100 feet below msl in the northeastern part. Water of good quality is available in large quantities in most of the county. Good recharge occurs through the relatively thin and porous deposits overlying the limestone, and piezometric levels are relatively high. Artesian flow occurs in the St. Johns River lowlands and near Lake Griffin. In places, old sinkholes and depressions in the limestone are filled with Miocene or more recent sand and sandy clay deposits to considerable depth. Although water quality is generally good it is poor near the St. Johns River.

SEMINOLE COUNTY

The altitude of the top of the Floridan aquifer is at sea level in the western part and 50 to 100 feet below msl elsewhere in the county. Most wells tap the Ocala Group or the Avon Park Limestone at depths of 90 to 250 feet and yield up to 500 gpm. The underlying Lake City Limestone is an even more productive unit. The piezometric level ranges from 15 to 50 feet above msl and artesian flow occurs in lowlands along the St. Johns, Wekiva and Econlockhatchee rivers. The piezometric level has declined 4 to 10 feet in the past 50 years. Recharge takes place in upland areas of the county and in Orange County. The chemical quality of the Floridan aquifer water is generally good in the western part and in the hilly upland areas. Both chloride and total dissolved solids increase to more than 1,000 mg/l toward the St. Johns River lowland areas. Throughout most of the county the chloride content of water from the Floridan aquifer generally increases slightly with depth and shows seasonal variations as well as an average small increase over long periods of time. Water from surficial sand aquifers is of good quality except for excessive iron.

ORANGE COUNTY

Most water used in the county is obtained from the very productive Floridan aquifer which is more than 1,300 feet thick. The top of the aquifer ranges in altitude from 50 feet above msl in the western part to 300 feet below msl in the southeastern corner. Recharge is mostly from rainfall in the county but some water migrates into Orange County from Lake and Polk counties. Artesian flow occurs in lowlands along the St. Johns and Wekiva River and in other low areas. In most of the county, yields in excess of 4,000 gpm are obtained from large wells at depths generally less than 600 feet, although some wells are more than a thousand feet deep. Chemical quality is generally good with less than 150 mg/1 dissolved solids; however, all dissolved constituents increase toward the St. Johns River.

BREVARD COUNTY

The piezometric level of the Floridan aquifer is above land surface in most of the county. The altitude of the top of the Floridan aquifer ranges from about 75 feet below msl in the northwest to more than 300 feet below msl in the southeast. The aquifer is about 1,000 feet thick. The principal source of replenishment is recharge in Orange County. Ground water moves generally toward the northeast and leaks upward into the shallow aquifers and discharges to submarine springs off the coast. Except in small areas west of Titusville the artesian water is highly mineralized but none the less is used for stock water and citrus irrigation. Well yields are generally high; wells 8 inches in diameter and from 120 to 600 feet deep yield more than 1,000 gpm. Because the Floridan aquifer water is highly mineralized, water from shallow aquifers is pumped for domestic and commercial uses. Existing small diameter domestic wells drilled into the shallow aquifers yield as much as 30 gpm of good quality water from the sands of the coastal ridge and from limestone or shell lenses in the Hawthorn Formation. The potential of these shallow aquifers to meet or supplement future water demands is not known. After an evaluation is available the results may indicate that increased importation of water from neighboring counties may be necessary to meet demands for potable water.

INDIAN RIVER COUNTY

The principal source of water is the upper part of the Floridan aquifer, the top of which ranges from about 200 feet below msl in the northwest to 400 feet below msl in the southeast part of the county. Recharge from Polk and Osceola counties is the principal source of replenishment. The piezometric level ranges from a high of about 50 feet above msl in the west to 25 feet above msl along the coast, except for some slight variation in the southeast. Flowing wells occur throughout the county even through the piezometric surface has declined a few feet in recent years, probably as a result of extensive pumping for irrigation. Artesian water from the Floridan aquifer is highly mineralized and generally contains more than 500 mg/l of chloride. Water from the coastal ridge sands or from some shallow secondary artesian aquifers is used for domestic and municipal supplies but upward leakage of poor quality water from the underlying Floridan aquifer is a problem.

OTHER COUNTIES

The above summaries by county do not include discussions of parts of other counties which are within the area of this report. Information for parts of Levy, Osceola, Polk, St. Lucie, and other counties may be obtained from the figures showing the altitude of the top of the Floridan aquifer, the piezometric level, the chemical constituents and other generalized data, as well as the information given for adjacent counties and from published reports.

ESTIMATED QUANTITY OF WATER AVAILABLE

Water use varies with water availability and in many respects follows the law of supply and demand. In general, population concentrations, agricultural development and industrial expansion occur where water of good quality is available at reasonable cost.

The St. Johns River basin and the adjacent coastal area is blessed with a large supply of fresh water in most of the area, and a practically unlimited supply of brackish or salty water in lagoons and in the Atlantic Ocean. Although fresh water is plentiful at this time, future large-scale water needs in heavily populated coastal areas may of necessity be met by importation of water from the west and by desalinization of brackish water.

Good quality water is available in large quantity in the report area from the Floridan aquifer and from shallow aquifers. Surface sources are also plentiful but, owing to high mineralization or contamination in some areas are utilized mainly for agricultural and industrial use. The City of Melbourne, in Brevard County, and St. Augustine, in St. Johns County, use some surface waters for public supply. Although much of the water discharged to the sea by streams is at present largely unfit for public supplies, it contains far lower concentrations of dissolved minerals than does sea water.

Under present-day (1968) conditions the estimated total discharge through streams and from springs in the report area to the ocean exceeds 10,000 cfs, or 6,500 mgd. This volume of water is sufficient to supply 43 million people at the rate of 150 gpd (gallons per day) per person, or for about 4 million people if agricultural and industrial use is included, at present day rates of use if total consumption of the water is assumed. However, because only a small percentage of water used is actually consumed or rendered unfit for subsequent uses due to some kind of pollution, much larger populations can be supplied simply by reusing the available water many times. Even more people could be accommodated if more efficient use is made of the water supply and some reduction of evapotranspiration is accomplished, thus making more water available for man's use.

Ground water is the most readily available and is the traditional source of most water for public, rural, industrial, and irrigation supply in the area. The amount of ground water available perennially is large and can be only approximated on the basis that water naturally discharged or withdrawn from the aquifers should not exceed potential recharge. Withdrawals over a period of years in excess of potential recharge will lower the water levels and result in increased cost of withdrawal and at places will permit salt water intrusion. However, additional withdrawals will tend to reduce evapotranspiration, runoff, and submarine spring discharge, thus tending to increase recharge and thereby increase the usable supply. An estimate of the recharge in the approximately 4,000 square miles of the area in which recharge is known, or presumed, to occur is 3,000 mgd, a quantity that would supply a population of about 18 million persons at the rate of 150 gpd (gallons per day). In Marion County alone, more than a billion gallons per day of ground and surface water are perennially available for withdrawal under present-day conditions of recharge. However, increased urban and industrial development, with accompanying impermeable buildings, streets, parking areas, and highways will reduce the area of natural recharge so that artificial recharge might be necessary to maintain water levels in some areas.

Springs are an excellent source of good water which are still unused except for maintenance of stream flow and for recreational purposes. Silver Springs in Marion County has an average flow of 530,000,000 gallons per day, which is greater than the total quantity of water used in the St. Johns River basin and coastal areas for public, rural, and industrial use in 1965. Other smaller springs which discharge good quality water are excellent sources for increased development and use. Large-scale development of ground water upgradient from springs, may, however, affect their flow.

Direct withdrawal of water from streams for use as cooling water for thermal-electric power, and for industry and irrigation, is increasing. Some streams, however, including the lower reaches of the St. Johns River, are sometimes highly mineralized from the upstream movement of sea water by tidal action; upper reaches are affected by highly mineralized springs and flowing wells.

SUMMARY OF WATER AVAILABILITY, USE AND PROBLEMS

Water in the St. Johns River basin and adjacent coastal area is available in large quantity. The supplies of best quality are from the Floridan aquifer and are largely in the western part of the basin in contrast to much of the concentration of population which is along the coast in the eastern part of the area. Industrial and population growth is increasing in inland areas as indicated by the growth in the vicinity of Orlando. Future industrial growth will undoubtedly occur near the inland water-rich areas. The total water withdrawal, exclusive of water for fuel-electric cooling water, was 725 mgd in 1965 and less than 10 per cent of the estimated 8,000 mgd difference between rainfall and evapotranspiration over the area; water consumed was 261 mgd, only 3.3 per cent of that total but 36 per cent of that withdrawn. The area is in a very favorable position in so far as water supplies are concerned.

The problems in the field of water supply are the continuing ones of having water of good quality at the right place at the right time. The location of industries and their accompanying urban populations in the inland counties would tend to resolve part of that problem. The establishment of forest, water and wildlife conservation preserves, and zoning, may assure that some inland ground-water recharge areas are maintained to counter the loss that may result from the urbanization. Artificial recharge of ground water can also increase available water supplies through the salvaging of water otherwise removed from an area by unbeneficial evapotranspiration or surface runoff to the sea. Any management plan must be based on data that can predict the effects on the system, as withdrawals at any point in the system will be compensated for by reduced runoff, evapotranspiration, or spring flow.

The conveyance of good quality water from the "have" to "have not" areas requires management and cooperation between counties or other political units. The hydrologic problems will require evaluation but the engineering is uncomplicated and costs are appreciable. Although conflicts of interest would arise in the event that it became necessary, it is of interest that the Oklawaha River below Silver Springs can supply all the fresh-water requirements for the entire report area at the use rate determined in 1965. Conveyance of water from interior ground-water or surface-water sources to the coastal cities would assure good quality water without the constant threat of saline contamination in well fields near the coast. Controlled pumping for public supply or other beneficial use from wells in selected areas where artesian and shallow aquifers are filled can reduce nonbeneficial evapotranspiration and increase recharge to the aquifers.

Development of water in conformance to the environment and the control and management of the water in the areas are the long-range needs, with conservation of water for the most beneficial uses as the aim of long-range planning. The expansion of industries and agriculture and the increasing population near industrial centers and along the coast are accompanied by ever-increasing demands for supplies of good quality water. Recreational, conservation, waste disposal, and pollution dilution needs must also be met. Economic factors will ordinarily relieve possible agricultural and industrial use conflicts; social and health requirements can be adjusted through political means. Long-range planning based on complete knowledge of the availability of good quality water is the present need.

The areas of abundant water of good quality are mostly west of the St. Johns River and north of Osceola County, as in parts of Marion, Lake, Alachua, Seminole, Orange, Putnam, and Clay counties. In some of the coastal area, however, as in much of Brevard, Indian River, and parts of St. Johns, Flagler and other counties the chemical quality of otherwise ample ground water precludes its use for public supplies without expensive treatment; and, surface waters are deficient or too saline for economical use. Duval County has been able to develop suitable ground water and is continuing intensive investigations to further the knowledge of its water resources. Volusia and Orange counties likewise have intensive investigations under way. Investigations are needed in several other areas to better understand water movement, quality, and availability to meet the expanding needs of the future.

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