Water Resources of Duval County, Florida

By G.G. Phelps

U.S. Geological Survey

Water-Resources Investigations Report 93-4130

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
Area		
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
Volume		
acre-foot (acre-ft)	1,233	cubic meter
Flow		
cubic feet per second (ft^3/s)	0.02832	cubic meters per second
foot per day (ft/d)	0.3048	meter per day
gallons per minute (gal/min)	0.549	cubic meters per day
million gallons per day (Mgal/d)	0.04381	cubic meters per second
Mass		
pound (lb)	0.4536	kilogram
Transmissivity		
foot squared per day (ft^2/d)	0.0929	meter squared per day
Hydraulic conductivity		
foot per day (ft/d)	0.3048	meter per day
inch per year (in/yr)	2.54	centimeter per year

Temperature in degrees Fahrenheit (˚F) may be converted to degrees Celsius (˚C) as follows:

$$^\circ C = 5/9 \times (^\circ F - 32).$$

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Transmissivity: In this report, transmissivity is shown in feet squared per day (ft^2/d) rather than in standard unit cubic foot per day per square foot times foot of aquifer thickness.

Abbreviated Water-Quality Units

μg/g	=	micrograms per gram
μg/L	=	micrograms per liter
μS/cm at 25 ˚C	=	microsiemens per centimeter at 25 ˚C
mg/L	=	milligrams per liter
NOAA	=	National Oceanic and Atmospheric Administration
SMCL	=	Secondary Maximum Contaminant Level
USGS	=	U.S. Geological Survey

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INTRODUCTION

Duval County, as well as most of Florida, is experiencing extensive population growth. Abundant and well-managed water resources are fundamental to nurture and maintain a dynamic population. Over the years, water scientists and administrators have studied and managed the water resources of Duval County and have gained much knowledge about hydrologic conditions. Most of this information, however, is highly technical and not always readily available to the public. The City of Jacksonville, recognizing the need for a better understanding of water resources by the general public, entered into a cooperative program with the U.S. Geological Survey to prepare a report that would describe the hydrology of Duval County in a nontechnical style.

Purpose and Scope

This report presents a comprehensive, nontechnical description of the water resources in Duval County. The report begins with a background of the study area, population, general water consumption, climate, and an explanation of the hydrologic cycle. Next, the geology of Duval County, the surficial aquifer system, and the deeper Floridan aquifer system are analyzed. Then follows a summary of the available sources of surface water, including a description of drainage basins, streamflow characteristics, and an illustration delineating the flood-prone areas in Duval County. Additionally, information is provided on the quality of the public water supply in Duval County by emphasizing several factors that contribute to water degradation. Each section in this report is formatted in an easy-to-read layout that contains a glossary and text, tables, and illustrations on facing pages. Most of the information presented here is from published water-resources investigation reports prepared by the U.S. Geological Survey (USGS) in cooperation with local, State, and other Federal agencies. Many of these investigations have continued for more than 50 years.

STUDY AREA AND POPULATION

Duval County, in northeastern Florida, is bordered on the north by Nassau County, on the east by the Atlantic Ocean, on the south by St. Johns and Clay Counties, and on the west by Baker County (fig. 1). The county covers about 850 mi^2, with approximately 775 mi^2 of land area and 75 mi^2 of surface water. The incorporated area of Jacksonville includes most of the county, except for the incorporated areas of Jacksonville Beach, Atlantic Beach, Neptune Beach, and Baldwin.

The population of Duval County has increased 32 percent, from an estimated 509,500 in 1965 (University of Florida, 1967, p. 20) to 672,971 in 1990 (University of Florida, 1991, p. 13). Duval is the fourth most densely populated county in Florida, having about 855 persons per square mile (Purdum and Anderson, 1988). The population of the county could exceed 800,000 by the year 2000 (University of Florida, 1990, p. 45).

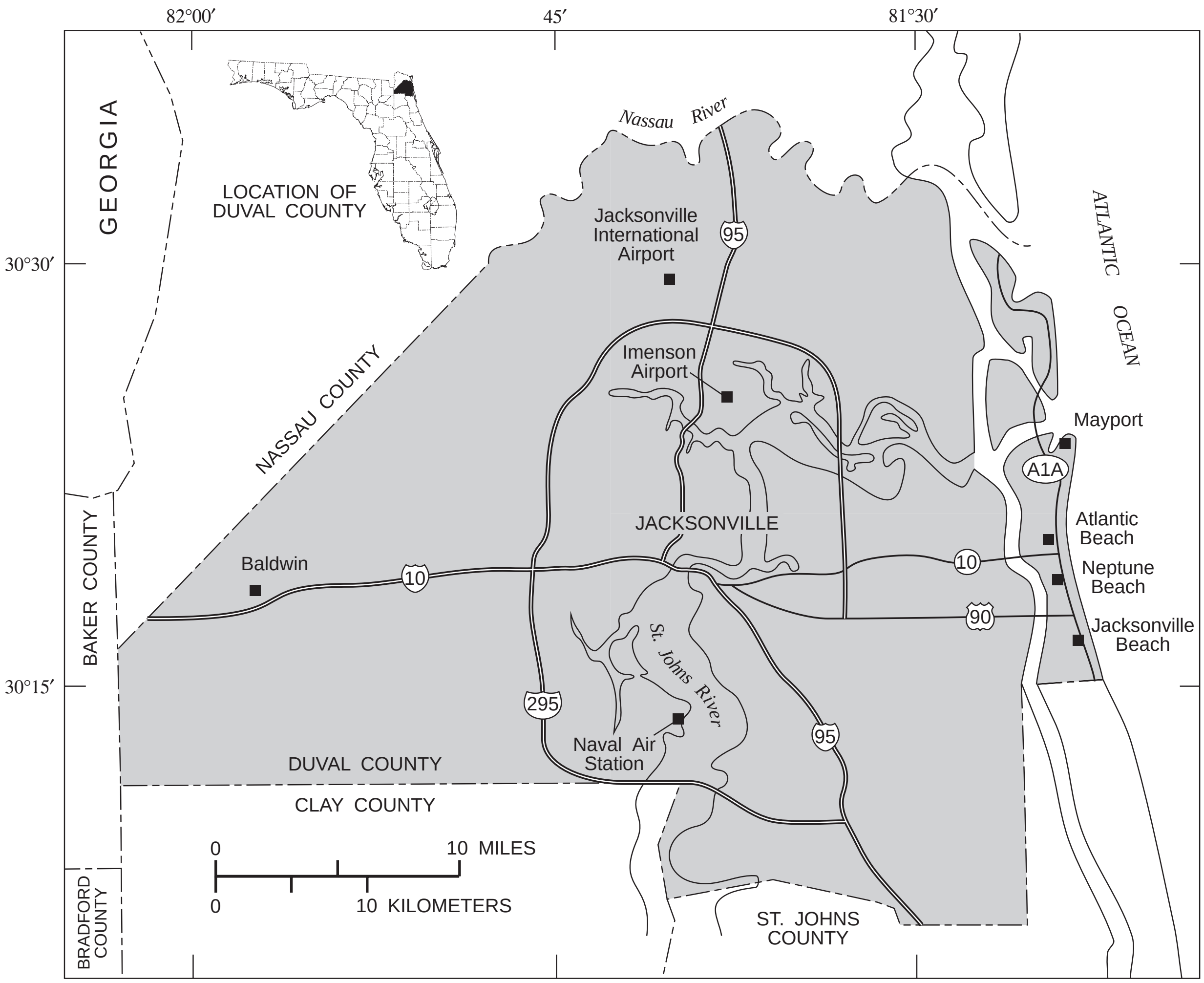


Figure 1. Location of Duval County, Florida.

WATER USE IN DUVAL COUNTY

Rapid population growth in Duval County has been accompanied by an increase in the demand for total freshwater. Total freshwater use has increased from about 128 Mgal/d in 1965 to about 154 Mgal/d in 1990. Of the total water used in Duval County during 1990, 99 percent was withdrawn from ground-water sources (table 1). The Floridan aquifer system supplied nearly 94 percent of the withdrawals during 1990 (Marella, 1992). Public-supply water use in Duval County increased from 60 Mgal/d in 1965 to 96 Mgal/d in 1990 (table 1, fig. 2). The amount of water withdrawn by commercial and industrial users from their own wells has decreased from about 61 Mgal/d in 1970 to about 34 Mgal/d in 1990. This decrease is attributed to changes in the types of industry, increased water conservation by industrial users, or a shift to public supply by some self-supplied industrial and commercial users. All fresh surface-water withdrawals were for agricultural irrigation (Marella, 1992).

Domestic self-supplied water use (water withdrawn from individual household wells) decreased from more than 36 Mgal/d in 1970 to about 8 Mgal/d in 1990. The decrease is probably due to self-supplied water users switching to public-supply water. The increase in the combined public-supply and domestic self-supplied water use from 1965 to 1990 (35 percent) is approximately equal to the increase in population (32 percent). Average per capita use (public supply and domestic self-supplied) in Duval County is 156 gal/d (Marella, 1992). This freshwater demand would be equivalent to about 4 in. of water spread over the county. If the population of Duval County increased by another 100,000 people from 1990 to 2000 and the quantities of water used for all other purposes remained constant, the total demand for freshwater could increase to nearly 170 Mgal/d by 2000.

Table 1. Freshwater use in Duval County by category, 1965-90

[Withdrawals are given in million gallons per day; GW, ground-water; SW, surface-water]

Year[1]	Public supply		Domestic self-supplied		Commercial industrial		Agricultural irrigation		Thermoelectric power generation		Totals		
	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	Total
1965	60.00	0.00	17.40	$\boxed{0.00}$	47.00	1.00	0.04	0.09	2.80	0.00	127.24	1.09	128.33
1970	67.80	.00	36.20	.00	60.90	.00	3.70	.00	.30	.00	168.90	.00	168.90
1975	73.50	.00	32.90	.00	48.63	.14	2.33	.22	2.10	.00	159.46	.36	159.82
1980	73.25	.00	20.26	.00	49.46	.00	4.79	1.39	2.70	.00	150.46	1.39	151.85
1985	84.86	.00	15.50	.00	38.08	.00	18.80	1.37	2.06	.00	159.30	1.37	160.67
1990	96.32	.00	8.37	.00	33.93	.00	9.53	1.40	4.83	.00	152.98	1.40	154.38

[1]Source:

1965 - Unpublished data, U.S. Geological Survey, Tallahassee, Fla.

1970 - Pride, 1973

1975 - Leach, 1978; Marella, 1987

1980 - Leach, 1983; Marella, 1987

1985 - Marella, 1988

1990 - Marella, 1992

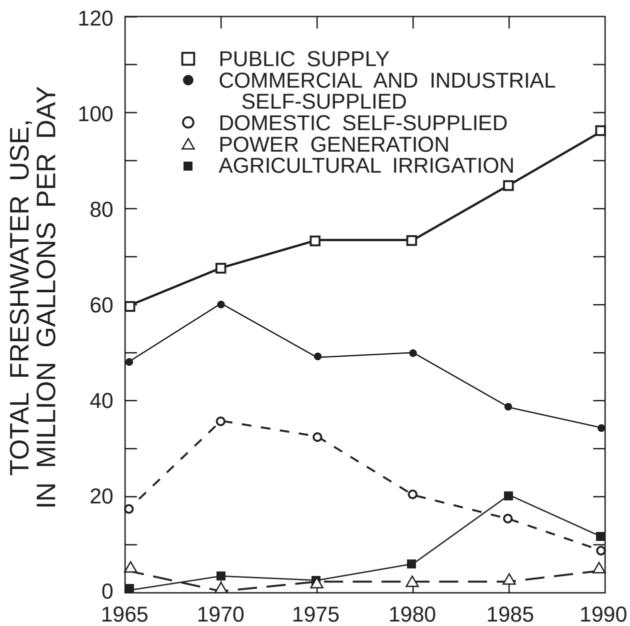


Figure 2. Total freshwater use in Duval County, 1965-90.

THE HYDROLOGIC CYCLE

Water is a recyclable resource. Nearly all water on Earth is moving through the hydrologic cycle, a continuous process through which water in the liquid, gaseous, and solid states circulates among the oceans, atmosphere, and land. Water is kept in motion by gravity and by heat energy from the sun. As part of the hydrologic cycle, water evaporates from the land surface and from surface-water bodies such as the ocean, lakes, and rivers, or transpires from plants. This process is called evapotranspiration. The water vapor that enters the atmosphere eventually condenses and becomes precipitation. Precipitation that reaches the land surface either returns to the atmosphere by evapotranspiration, runs overland into the rivers, lakes, and ocean (surface runoff), or soaks into the ground (ground-water recharge). The water in the subsurface moves from areas of recharge to areas of discharge (inland and submarine springs, seepage areas into wetlands, lakes, rivers, or ocean). The hydrologic cycle in Duval County is illustrated in figure 3.

Human activities, such as the pumping of large amounts of water and draining of wetlands, can interrupt the natural flow of water in parts of the hydrologic system and divert it to other parts of the system so as to affect the quantity and quality of existing water supplies. Information on the recycling of water and the amounts of water involved in surface runoff, recharge and discharge, and ground-water movement are necessary for effective and efficient management of water needs for Duval County. Climate is a particularly important aspect of the hydrologic cycle, because it determines the amount of freshwater available to the county.

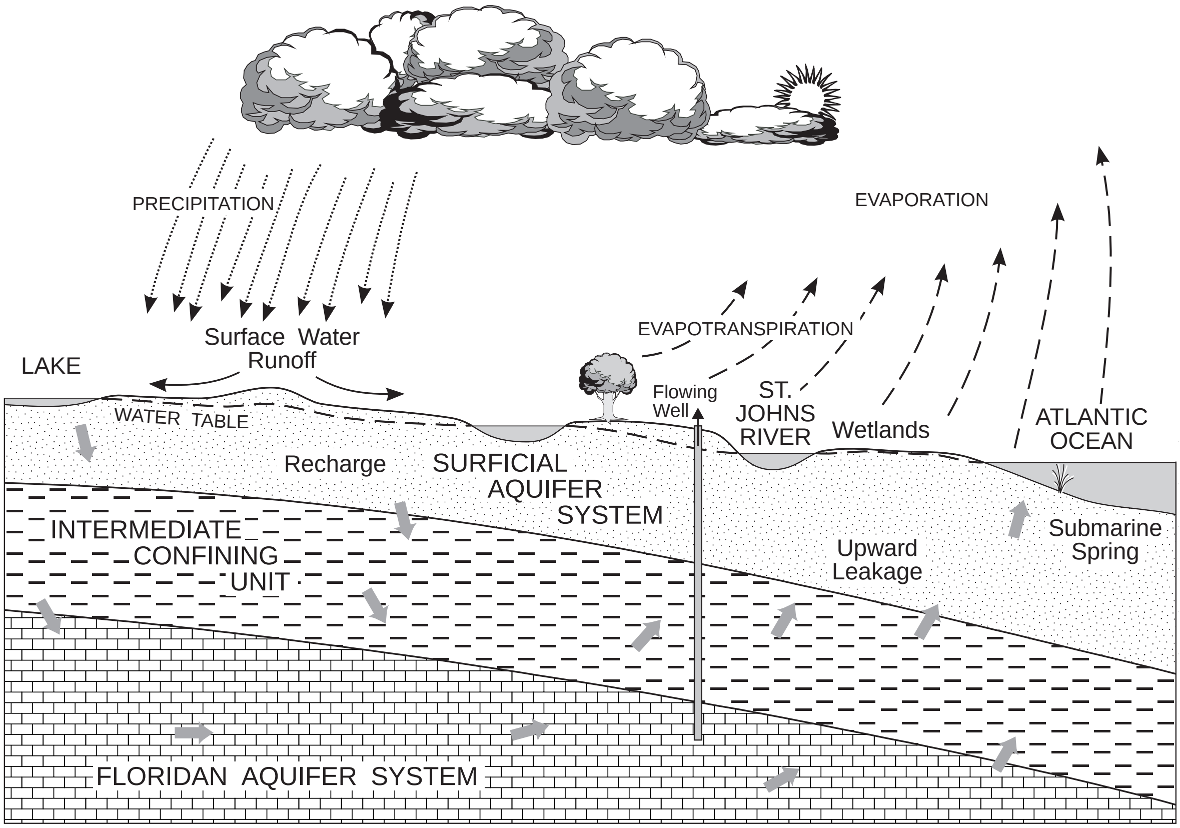


Figure 3. The hydrologic cycle in Duval County.

CLIMATE

Temperature and Evaporation

Duval County has a humid (ranging from 50-95 percent relative humidity), subtropical climate. Winters are mild, with occasional invasions of northern cold air from weather fronts. Freezing temperatures might occur each winter, but are rare because the county borders the Atlantic Ocean and is close to the Gulf Stream that produces moderate winter temperatures.

Average minimum, average maximum, and average monthly temperature at Jacksonville from 1951 to 1980 is shown in figure 4. Average monthly temperatures during this period ranged from a minimum of 42 °F for January to a maximum of 91 °F for July. On the basis of monthly average temperatures, the average annual temperature is 68 °F. The hottest months are July and August, with monthly average temperatures about 80 °F. The coldest months are December through February, with monthly average temperatures of about 55 °F (National Oceanic and Atmospheric Administration, 1988-90). The lowest recorded temperature for the area was 10 °F in February 1899; the highest was 105 °F in July 1942.

Most of the rain in Duval County evaporates after it reaches the land surface. Many factors, such as temperature, wind, and solar radiation, affect evaporation rates. Evaporation rates in Duval County are measured using monthly pan-evaporation estimates. Pan evaporation is measured using a special open tank and the rates are always greater than the evaporation from a natural water body such as a lake or reservoir. Data are collected at the Gainesville and Lake City weather stations, each about 60 mi from Jacksonville. In Duval County, the annual lake evaporation is about 76 percent of annual pan evaporation (Kohler and others, 1959, pl. 3).

Monthly pan evaporation at Gainesville in 1988 is shown in figure 5. In 1988, maximum of 7.7 in. (May) and a minimum of 2.3 in. (December) of pan evaporation were measured. The total pan evaporation during 1988 for Gainesville was 61.4 in., thus averaging 5.1 in. per month. In 1990, total pan evaporation was 67.9 in. at Gainesville and 69.0 in. at Lake City. The maximum monthly evaporation occurs in May at both locations (National Oceanic and Atmospheric Administration, 1988).

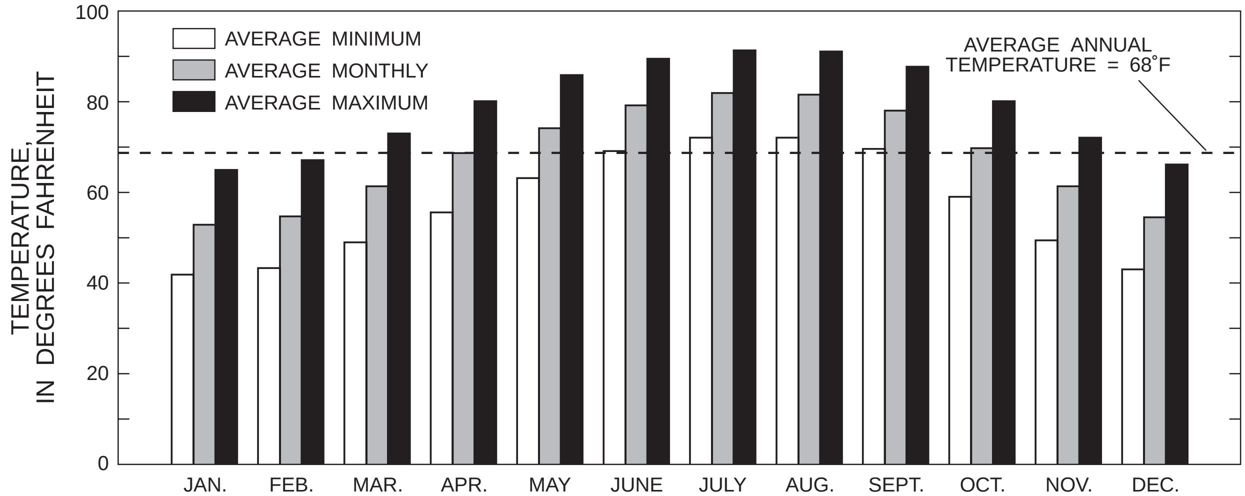
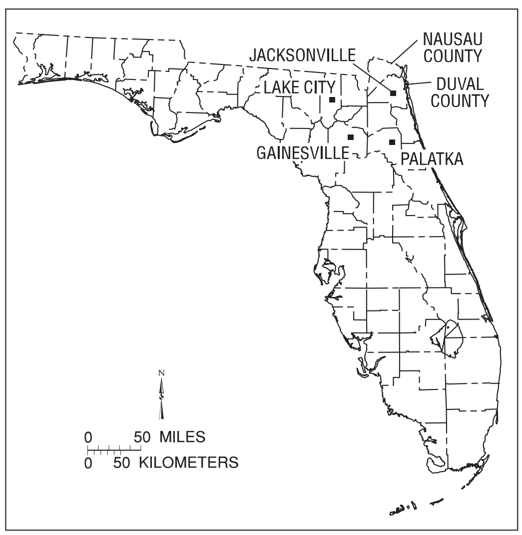


Figure 4. Average minimum, average maximum, and average monthly temperatures in Jacksonville, 1951-80.



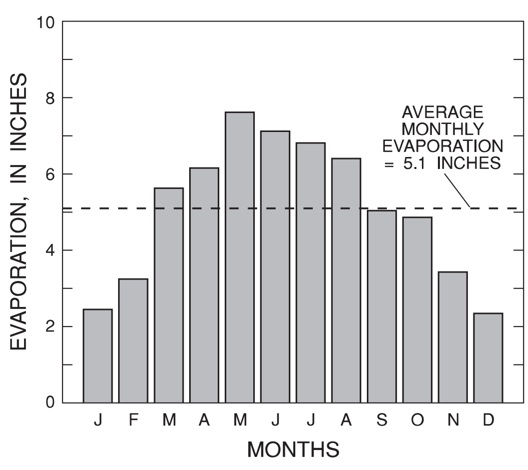


Figure 5. Monthly pan evaporation in Gainesville, 1988. (From U.S. National Oceanic Atmospheric Administration, 1988.)

CLIMATE--Continued

Rainfall

Since 1866, rainfall data have been continuously recorded at a weather station in Jacksonville, the oldest continuously operating weather station in the State. The original weather station, established in 1851, was located in downtown Jacksonville and operated until 1930 with an interruption in data collection from 1861 to 1866. In October 1930, the station was moved to the Imeson Airport (fig. 1); in July 1967, the station was again relocated to its current site at the Jacksonville International Airport. The average rainfall recorded at Jacksonville is representative of the average rainfall for all of Duval and Nassau Counties (Anderson, 1972).

Typical weather patterns for Duval County include frontal activity during winter months, causing widespread rainfall and short periods of cooler temperature, and scattered thunderstorm activity during summer months. Florida has more thunderstorm activity than any other State in the Nation. The Tampa area has the most days of thunderstorms (85 days per year). The least days of thunderstorms in Florida is 65 days per year in the Florida Keys and in Jacksonville (Winsberg, 1990).

Minimum, average, and maximum monthly rainfall at Jacksonville from 1951 to 1980 is shown in figure 6. During the rainy season, from June through September, Duval County receives about 63 percent of its total annual rainfall. November is the driest month because temperature are usually too cool for thunderstorms, but too warm to allow northern cold fronts to move far enough south to bring rain to northeastern Florida. Rainfall amounts normally vary widely within the county, especially during the summer. The hurricane season from June through November can bring widespread rainfall and occasional hurricane-force winds (National Oceanic and Atmospheric Administration, 1978).

The long-term average yearly rainfall during the period 1852-1989 was 51.73 in. (fig. 7). The maximum annual rainfall was 82.27 in. in 1947, and the minimum was 30.44 in. in 1927. The cumulative departure from the average rainfall from 1867 to 1981 (Tibbals, 1990, fig. 6) shows that wet conditions prevailed from 1867 through 1888, and the total rainfall above average during the 22-year period was about 105 in., or about 4.8 in/yr (fig. 8). Conditions were relatively dry from 1888 through 1931 and the cumulative rainfall deficiency was 192 in. (4 in/yr). Rainfall was about average (the cumulative deficit did not change) from 1931 to 1945. Wetter conditions prevailed again from 1945 to about 1975, but became dryer from 1975 to 1981. Many years of data are needed to separate short-term fluctuations from significant trends.

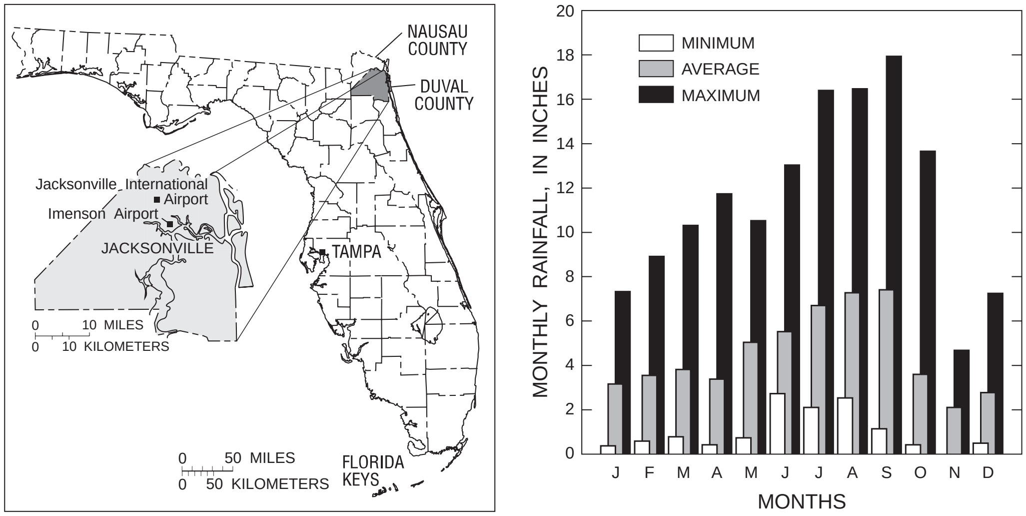


Figure 6. Minimum, average, and maximum monthly rainfall in Jacksonville, 1951-80.

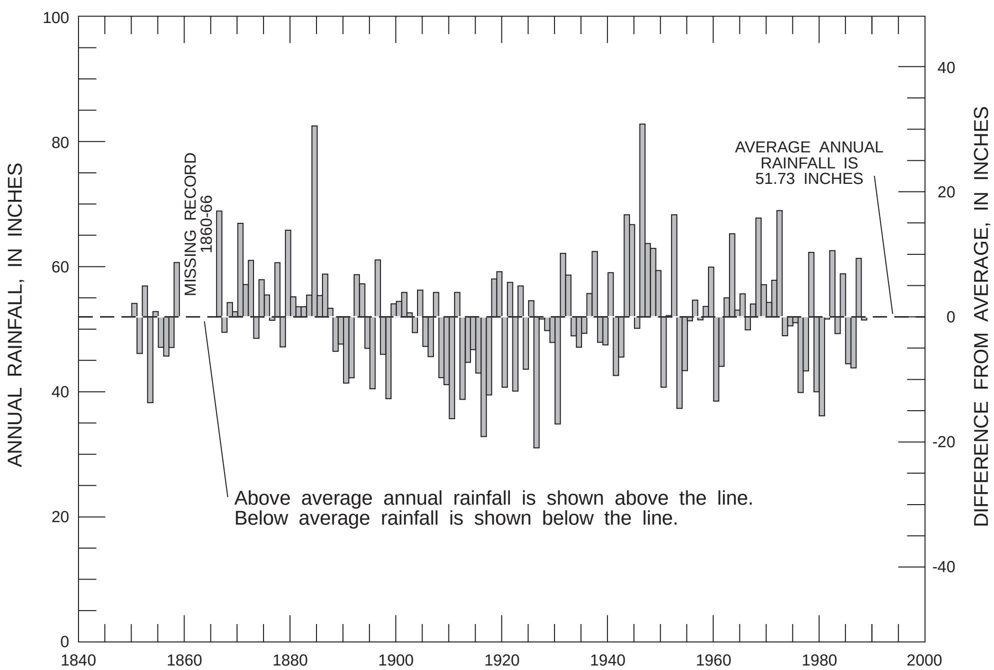


Figure 7. Rainfall above and below the average annual rainfall in Jacksonville, 1852-1989.

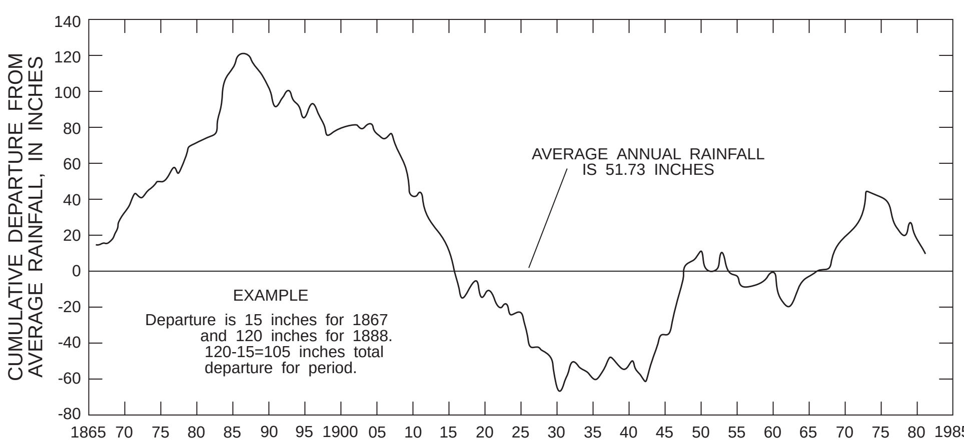


Figure 8. Cumulative departure from average rainfall in Jacksonville, 1867-81.
(From Tibbals, 1990, fig. 6.)

GEOLOGY

Geologic History

The surface- and ground-water resources of Duval County are related to the geologic history of northeastern Florida. For millions of years the area was covered by water and was far from any source of sediment. Thick layers of limestone and dolomite were formed in the clear, warm marine environment. Today, those carbonate rocks are major sources of water (aquifers).

Later in geologic time, sediments derived from the Appalachian Mountains were transported southward and began to influence the geology of Florida (fig. 9). Sand and clay deposited over the limestone attained significant thickness. Sand is very permeable and when it occurs at land surface, as it does over much of Duval County, rainfall is able to soak rapidly into the ground. The layers of relatively impermeable clay deposited during this time period retard the movement of water that percolates through the soil from overlying sediments.

Later still, alternating advances and retreats of continental glaciers in other parts of the world caused fluctuations of sea level during the Pleistocene geologic epoch (10,000-2,000,000 years ago). The result in northeastern Florida was that for thousands of years sea level was at times either much lower than at present or as much as 200 ft higher than at present. During times of lower sea level, the large area of carbonate rocks underlying Duval County and much of Florida existed as dry land. Gradually, the sea level rose again, superimposing a pattern of beach and near-shore features on top of the eroded land features.

Since the last glacial episode, Duval County has been above sea level, and erosion has continued to alter the land surface. The relatively flat land surface of Duval County and the present course of the St. Johns River have been influenced by the more recent geologic history of the area (White, 1970).

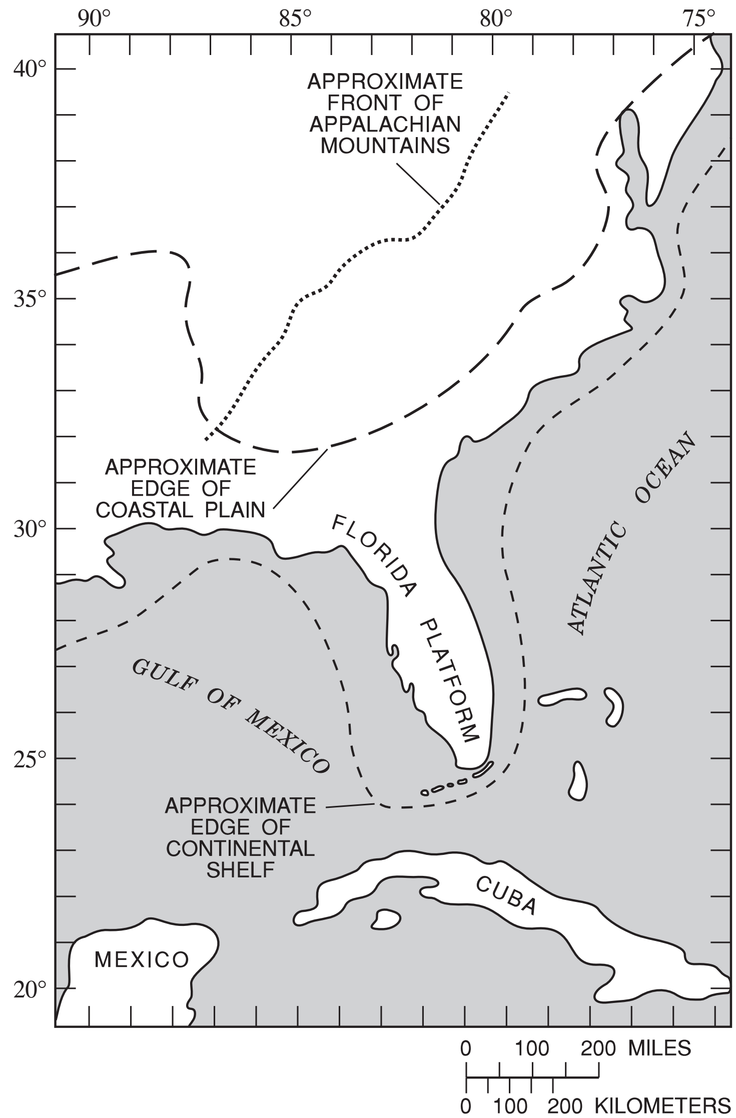
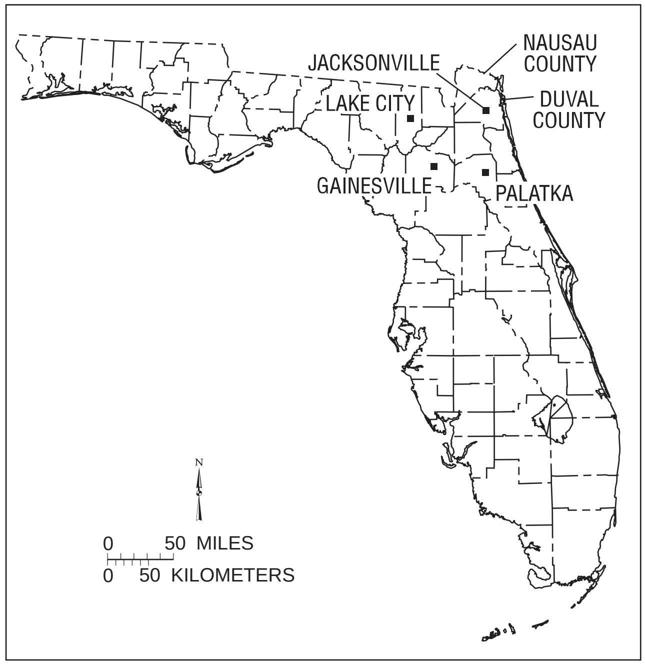


Figure 9. The Florida Platform and its relation to the Appalachian Mountains. (Modified from Clark and Stearn, 1968, fig. 14-8.)

Physiography

A physiographic subdivision is an area of similar geologic structure and history, similar climate, and having features or landforms (topography) that differ from adjacent areas. Duval County contains four major physiographic subdivisions: the Duval Upland in the west; the St. Marys Meander Plain in the north; the Eastern Valley in the south-central part of the county; and the Center Park Ridge in the southeast (fig. 10). These subdivisions, delineated by White (1970, pl. 1-B) are regional features, extending into adjacent parts of northeastern Florida.

The Eastern Valley could have been an ancient lagoon or beach ridge plain. North of Palatka, located about 60 miles (mi) south of Duval County, the St. Johns River flows through the Eastern Valley. White (1970, p. 111) believes that the influence through time of large amounts of riverborne sediments from the north onto the St. Marys Meander Plain is responsible for the abrupt eastward turn of the St. Johns River toward the Atlantic Ocean. The Duval Upland is predominantly flatwoods with elevations ranging 70 to 100 ft above sea level; the Center Park Ridge is typically flatwoods and river swamps with elevations ranging from 20 to 30 ft above sea level (Brooks, 1981).



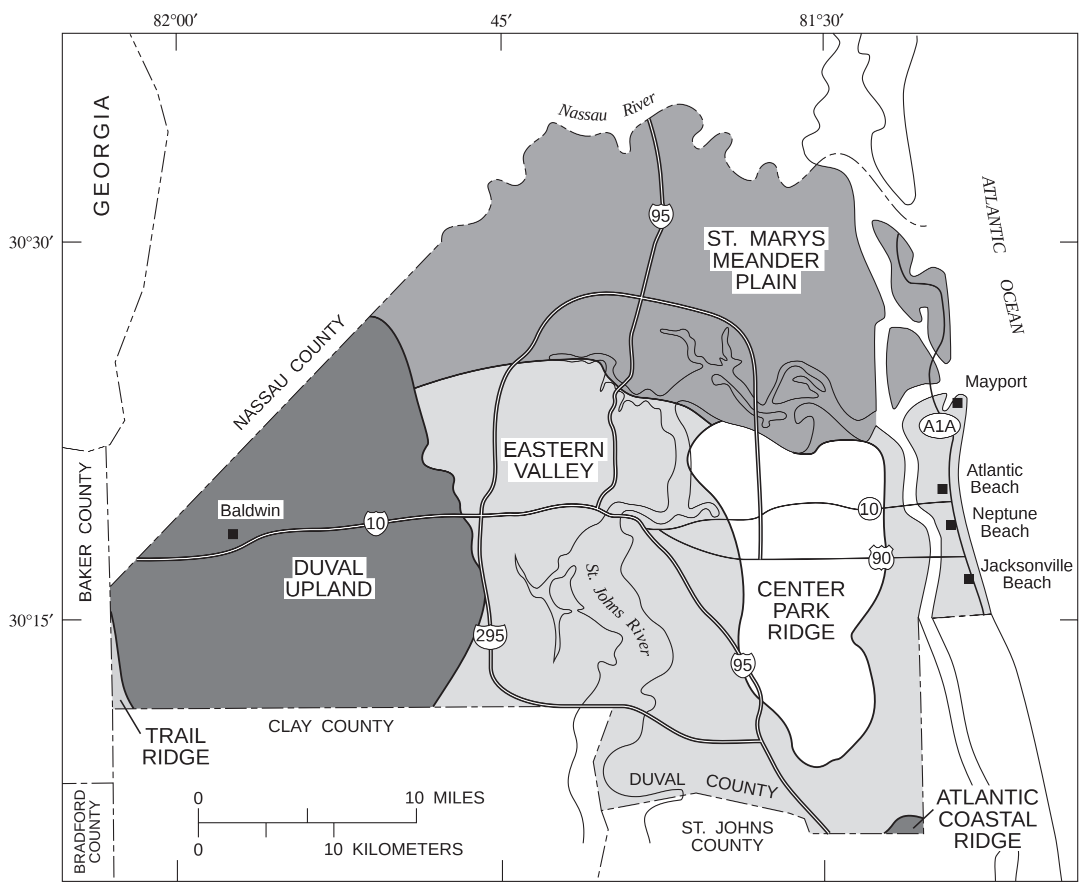


Figure 10. Physiographic subdivisions of Duval County. (From White, 1970, pl.1-B.)

Terraces

Ancient marine terraces form much of the present-day land surface of Duval County. The terraces were formed during the Pleistocene epoch when the sea level rose and fell repeatedly in response to the retreats and advances of the glaciers. As the sea level dropped and a lower level was maintained, the seafloor emerged as a level plain, or terrace, and the landward edge of the terrace became an abandoned shoreline that is generally marked by a low scarp. Each successive lower terrace was similarly formed.

The highest and oldest terraces, the Coharie, Sunderland, and Wicomico, are in western Duval County (fig. 11). They form an upland that ranges in altitude from 70 to more than 200 ft. The highest and most prominent surface feature of the upland is locally known as “Trail Ridge,” probably a remnant of the Coharie Terrace, that ranges in altitude from 170 to more than 200 ft.

The Sunderland Terrace in extreme southwestern Duval County is highly eroded. Remnants of this terrace consist of rolling hills that range in altitude from 100 to 170 ft. A remnant of the Wicomico Terrace is the most extensive feature of the uplands area, consisting of an irregular flat plain ranging in altitude from 70 to 100 ft.

The Penholoway and Talbot Terraces have been severely eroded by the numerous streams that drain the higher and older terraces. In southeastern Duval County east of the St. Johns River, these erosional remnants form a particularly well-defined coastal ridge at altitudes of about 25 to 70 ft. Ancient dunes on the coastal ridge form a series of narrow, sandy ridges and low, intervening swampy areas parallel to the coastline.

The Pamlico and Silver Bluff Terraces form a low coastal plain throughout most of the central and eastern part of northeastern Florida. The altitude of the plain generally ranges from slightly above sea level to 25 ft above sea level, although some dunes along the present coastline are more than 50 ft above sea level. In northern Duval County, the plain slopes irregularly eastward toward the Atlantic Ocean. In central and southern Duval County, the plain formed by the Pamlico and Silver Bluff Terraces slopes toward the St. Johns River west of the remnants of the Penholoway Terrace and toward the Atlantic Ocean east of the Penholoway.

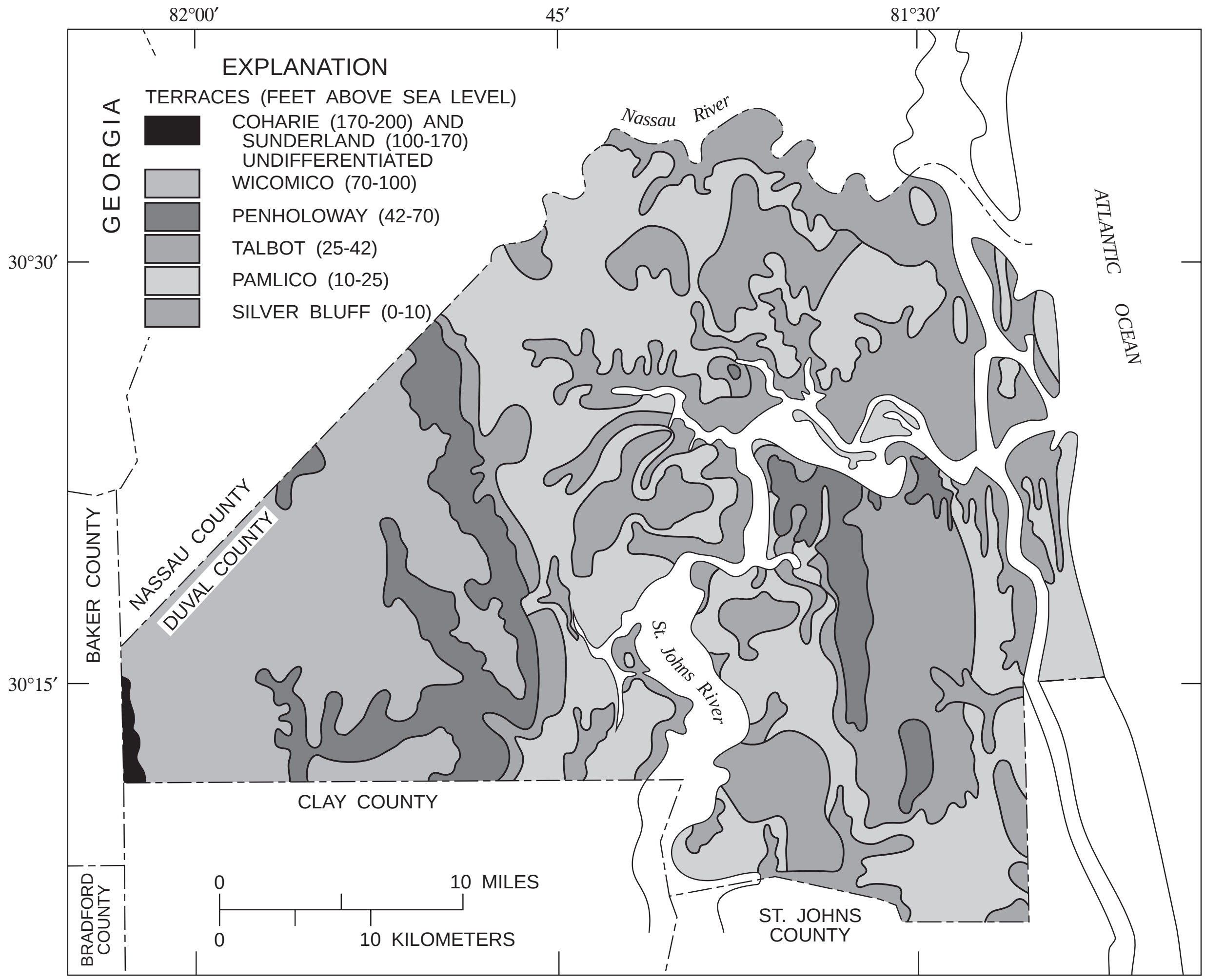


Figure 11. Terraces of Duval County. (From Leve, 1966, fig. 3.)

GROUND-WATER RESOURCES

General Concepts

Hydrogeologic Setting

The availability and quality of ground water in Duval County are closely related to the geologic units that underlie the county. The geologic formations significant to the hydrology of the county total about 2,100 ft in combined thickness (fig. 12). Some formations transmit or yield water easily (aquifers); others retard or prevent the movement of water (confining units).

The uppermost sediments consist mostly of unconsolidated sand with some clay, shell, and limestone. Thickness of the upper unconsolidated deposits, which compose the surficial aquifer system, ranges from 10 to 100 ft. The surficial aquifer system, commonly referred to as the surficial aquifer, has two water-bearing units, the water-table unit composed predominately of sand (Holocene and Pleistocene deposits) and the underlying limestone unit (Pliocene or upper Miocene deposits).

Underlying the surficial aquifer system are about 400 ft of mostly fine, clayey sediments that also include some sand, shell, and limestone. These clayey sediments are known as the Hawthorn Formation. The Hawthorn Formation is most important as the intermediate confining unit that covers and confines the water in the Floridan aquifer system.

Underlying the Hawthorn Formation is a thick sequence of consolidated carbonate rocks. In descending order, the consolidated formations include the Ocala Limestone, the Avon Park Formation, and the Oldsmar Formation. Together, these three units are more than 1,600 ft thick and comprise the Floridan aquifer system. Because of variations in the permeability of the carbonate rocks, the system is subdivided into the Upper Floridan aquifer and the Lower Floridan aquifer that are separated by a semiconfining unit of denser, dolomitic limestone about 800 ft below sea level.

Beneath the Floridan aquifer system is a confining unit called the sub-Floridan confining unit. The sub-Floridan confining unit generally corresponds to the Cedar Keys Formation. The geologic units beneath the Cedar Keys Formation are unimportant from a water-supply standpoint because they do not contain freshwater.

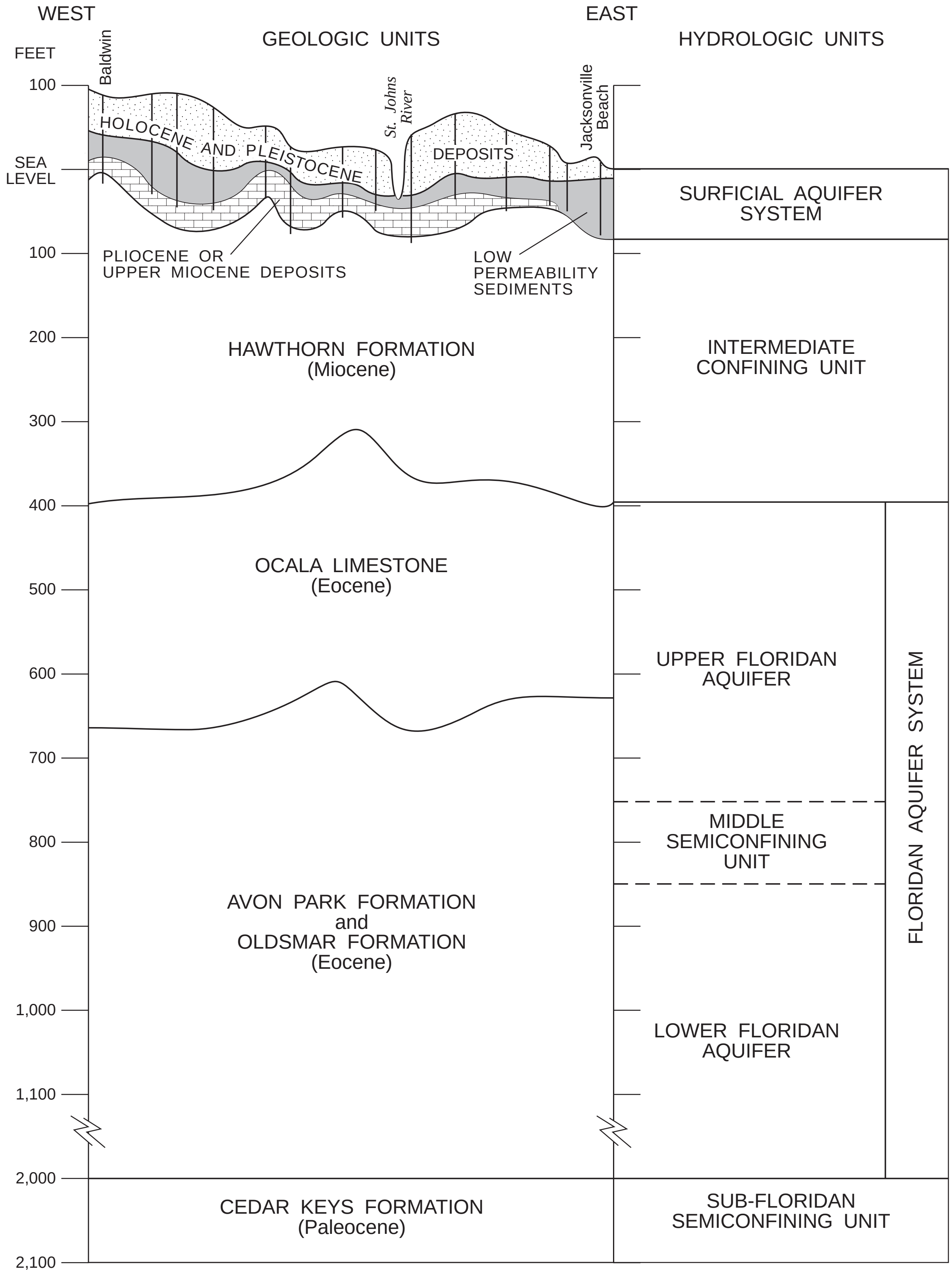


Figure 12. Relation of geologic and hydrologic units in Duval County.

General Concepts--Continued

Ground-Water Occurrence

An aquifer is a porous rock unit that yields usable quantities of water to wells or springs. Most rocks have a primary porosity that is related to the openings (voids) left between individual particles of the rock when it was formed. Some rocks develop a secondary porosity when they are later fractured or are partially dissolved by ground water. Formation of openings in limestone is a common occurrence in Florida.

Aquifers are described as being unconfined or confined. In an unconfined aquifer, water is in direct contact with the atmosphere through open spaces in permeable material (Davis and DeWiest, 1966, p. 43). The top of the saturated zone in an unconfined aquifer, below which all interconnected spaces are filled with water, is called the water table. Ground water in the upper part of the surficial aquifer system in Duval County is generally unconfined.

In a confined aquifer, the pressure of overlying sediments causes the water levels in wells to rise above the top of the aquifer. Another name for a confined aquifer is an artesian aquifer. The imaginary surface representing the level to which water will rise in a tightly cased well is called the potentiometric surface. If the overlying pressure is great enough, water levels in wells will rise above land surface (the potentiometric surface is above land surface) and the wells will flow. The aquifer shown in figure 13 is under water-table conditions where it is exposed to the atmosphere (not covered by a confining unit) and is artesian in the area where it is covered by the confining unit. Wells A and B are artesian wells. Well B is a flowing artesian well. In Duval County, ground water is confined in the Floridan aquifer system and, in places, in limestone of the surficial aquifer system.

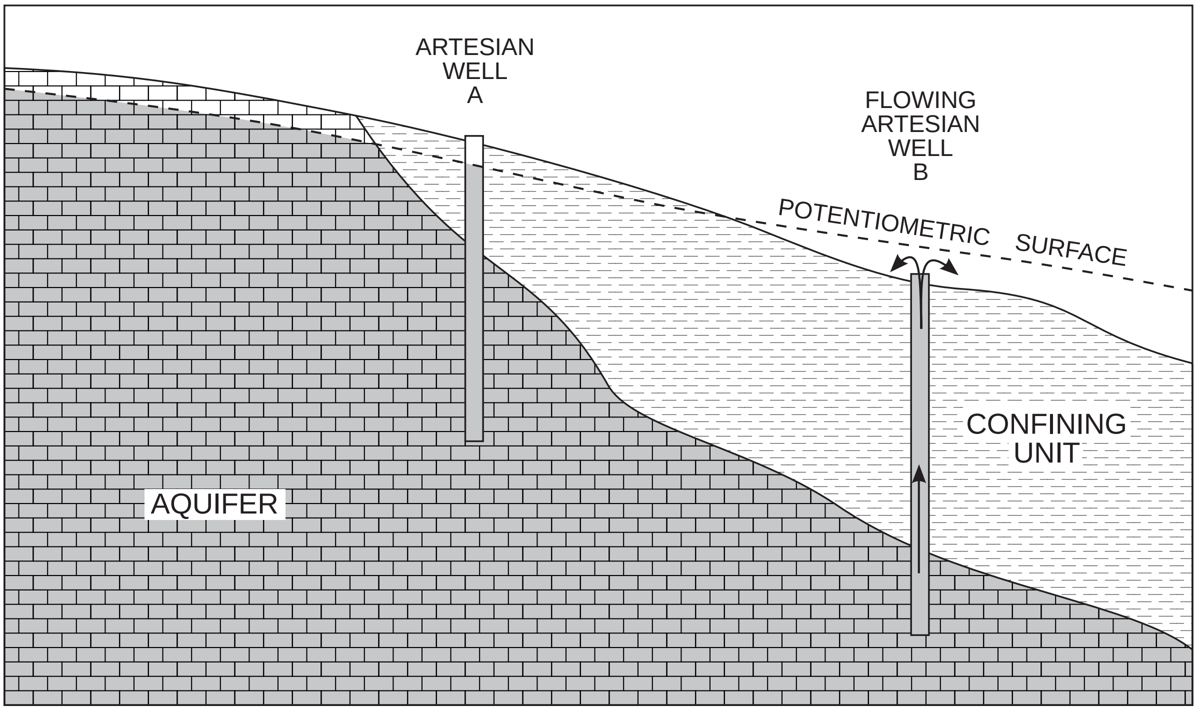


Figure 13. Generalized section of an aquifer.

The Surficial Aquifer System and Intermediate Confining Unit

Lithology and Thickness

In most of Duval County, the surficial aquifer system is divided into two water-bearing units, the upper water-table unit and the lower limestone unit. These two units are separated by sediments of low permeability so that water cannot easily move from one unit to the other. The surficial aquifer system ranges in thickness from less than 10 ft in the St. Johns River Valley to about 100 ft in western Duval County (Fairchild, 1972) and is separated from the underlying Floridan aquifer system by the intermediate confining unit.

The water-table unit is the upper part of the surficial aquifer system and consists of sediments ranging from 25 to 50 feet that were deposited during the formation of the marine terraces and beach ridges associated with glaciation. The surficial sediments consist mostly of fine to medium-grained quartz sand, but could contain thin beds of sandy clay. In places, especially near the coast, shell beds are present in the surficial sediments. In some areas the sand or shell is stained reddish brown or orange by iron oxide (a compound of iron and oxygen). Discontinuous (unevenly distributed) layers of sand cemented by iron oxide, known as hardpan, underlie parts of the county and range in thickness from about 0.5 to 20 ft.

The limestone unit is the lower part of the surficial aquifer system and contains deposits ranging in thickness from less than 10 ft in the southwestern part of Duval County to as much as 130 ft in the west-central part of the county (Fairchild, 1972). The varying thickness is due to irregularities in the surface of the underlying Hawthorn Formation. The limestone-unit deposits consist of interbedded lenses of fine-to-medium sand, shell, green calcareous silty clay, and limestone. The limestone is a soft, cavernous, sandy limestone that is dolomitic in places. Along the coast and in the southern part of the county, the limestone becomes discontinuous and grades into medium-to-coarse sand and shell deposits.

The intermediate confining unit (the Hawthorn Formation) lies between the surficial aquifer system and the Floridan aquifer system. The unit ranges in thickness from about 300 to 600 ft and consists mostly of clay and sandy, phosphatic limestone. The combined thickness of the surficial aquifer system and the intermediate confining unit varies considerably throughout Duval County (fig. 14).

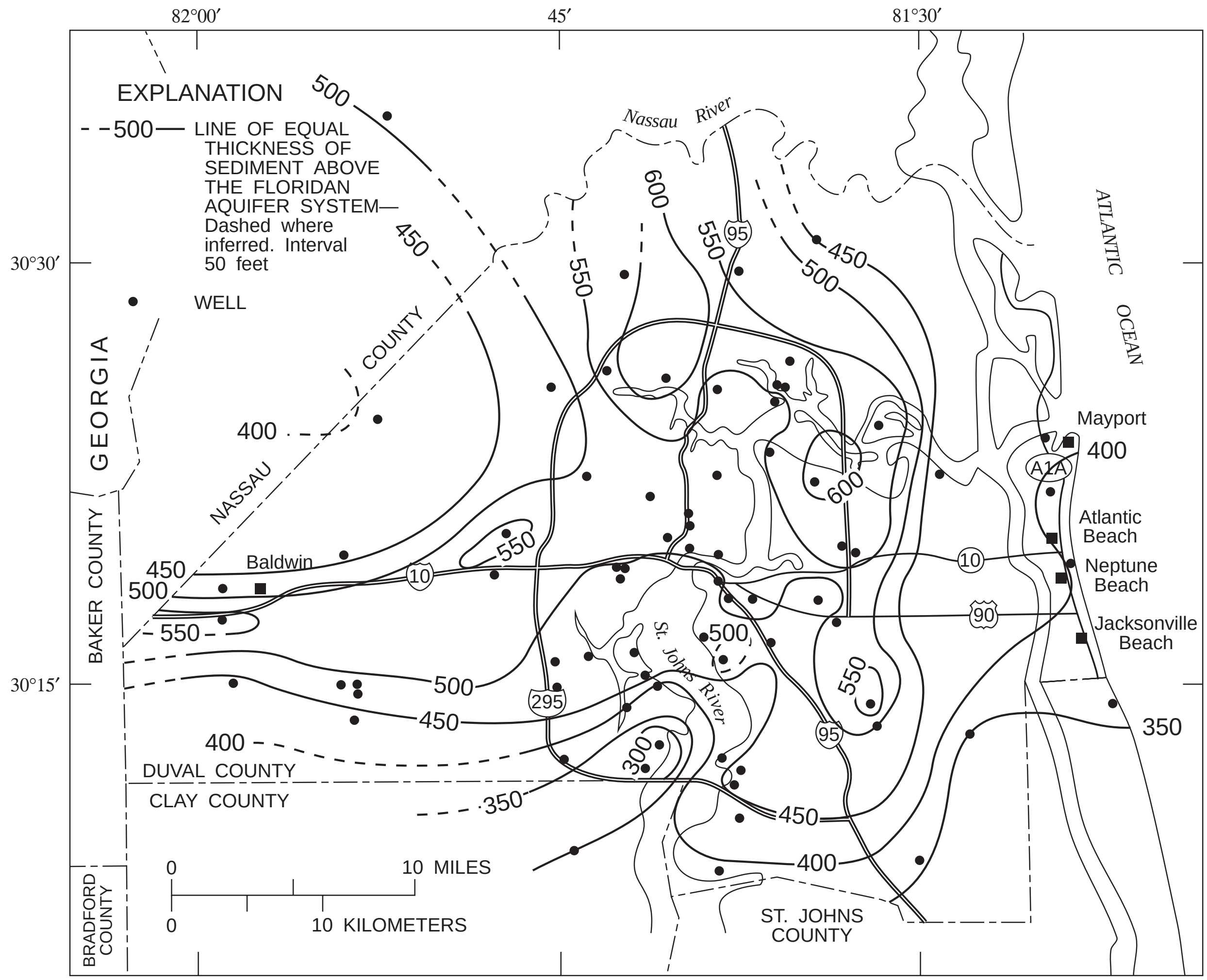


Figure 14. Thickness of sediments overlying the Floridan aquifer system in Duval County. (From Causey and Phelps, 1978, fig. 2.)

The Surficial Aquifer System and Intermediate Confining Unit--Continued

Water-Table Unit and Wetlands

The upper 25 to 50 ft of surficial sediments compose the water-table unit of the surficial aquifer system. This unit, although the source of only small supplies of water from shallow wells, is an important hydrologic unit because it contains the water table that influences water movement in the hydrologic system.

Throughout most of Duval County, the water table is within 5 ft of land surface (Causey, 1975). Locally, usually on ridges, the depth to the water table is 10-12 ft. In urban areas, the natural water table sometimes can be modified by construction.

Areas where the water table is nearly always at or very near land surface are called wetlands. Wetlands serve as important habitats for many plant and animal species. As of 1984, about 84,000 acres (15.5 percent) of Duval County were classified as wetlands (Hampson, 1984, table 2) (fig. 15). Wetlands are an integral part of the hydrologic cycle. Evapotranspiration from wetlands is approximately equal to evaporation from open-water bodies (Visher and Hughes, 1975). Thus, changes in the size of wetland areas or the amount of time the water table is at land surface can change the amount of water evaporating to the atmosphere.

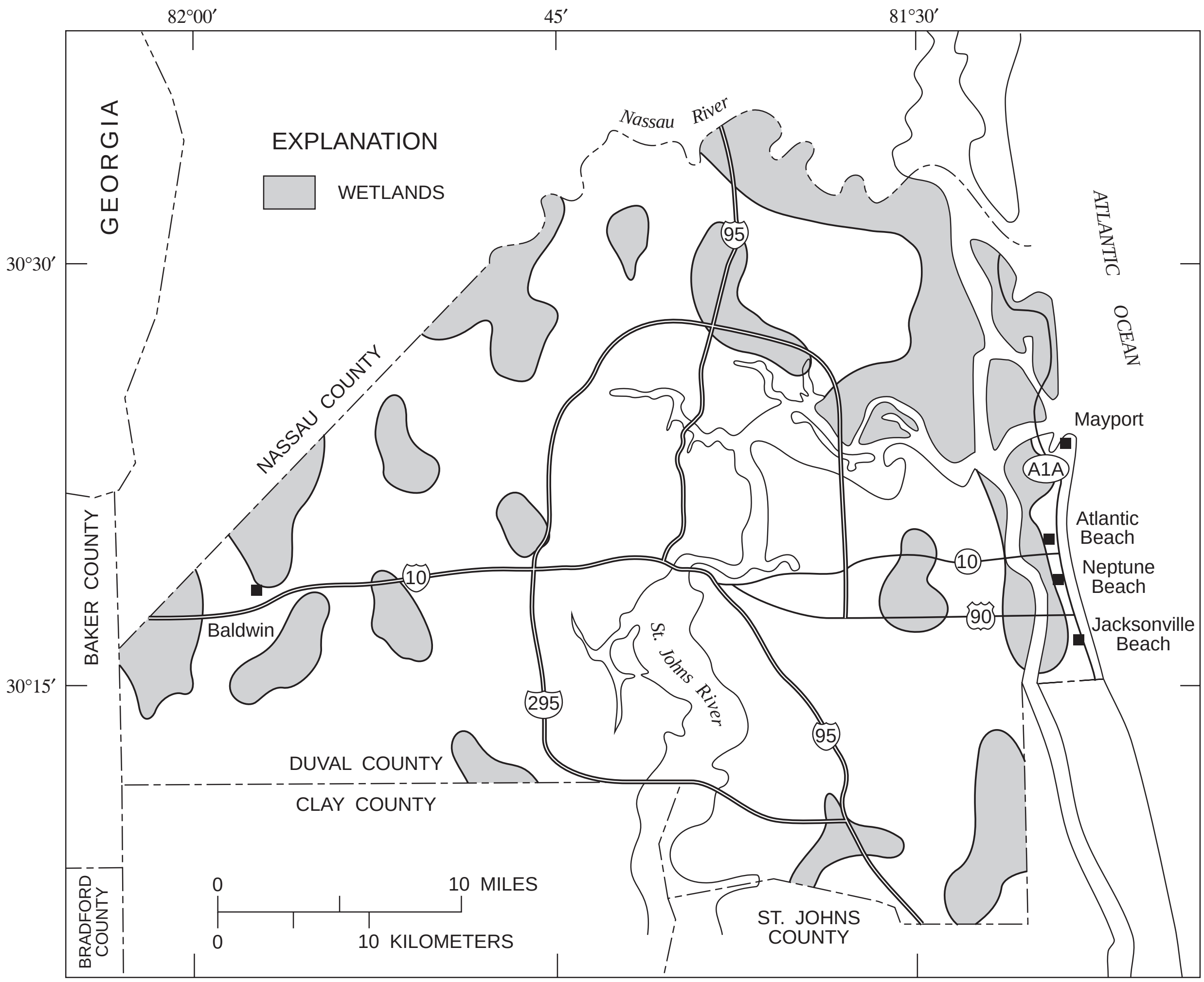


Figure 15. Wetlands of Duval County. (From Hampson, 1984.)

The Surficial Aquifer System and Intermediate Confining Unit--Continued

The Limestone Unit

The limestone unit, lowermost and generally the most productive water-bearing zone of the surficial aquifer system, ranges from about 5 to 40 ft in thickness. The top of the unit ranges from about 0 to 60 ft below sea level or about 40 to 100 ft below land surface (fig. 16). Water levels in the limestone unit range from about 35 ft below land surface to about 20 ft above land surface.

The limestone unit is not present everywhere in Duval County. Along the coast, the unit is usually absent, as at Mayport where the surficial aquifer system consists of a single water-table unit of sand 70 ft thick (Franks, 1980). In some areas of the county, the limestone unit is an artesian aquifer. Dredging in the river channel of the St. Johns River has removed overlying sediments so that the limestone unit is in direct contact with the river.

The water-table unit provides most of the recharge to the limestone unit, although some recharge can occur from the underlying Upper Floridan aquifer. Wherever the potentiometric surface of the limestone unit is lower than that of the Upper Floridan aquifer, water will move upward from the Upper Floridan aquifer into the limestone unit. Where the potentiometric surface of the limestone unit is higher than that of the Upper Floridan aquifer, water in the limestone unit moves downward to recharge the Upper Floridan. Because of the presence of the intermediate confining unit, however, the amount of water flowing between the two aquifers is relatively small.

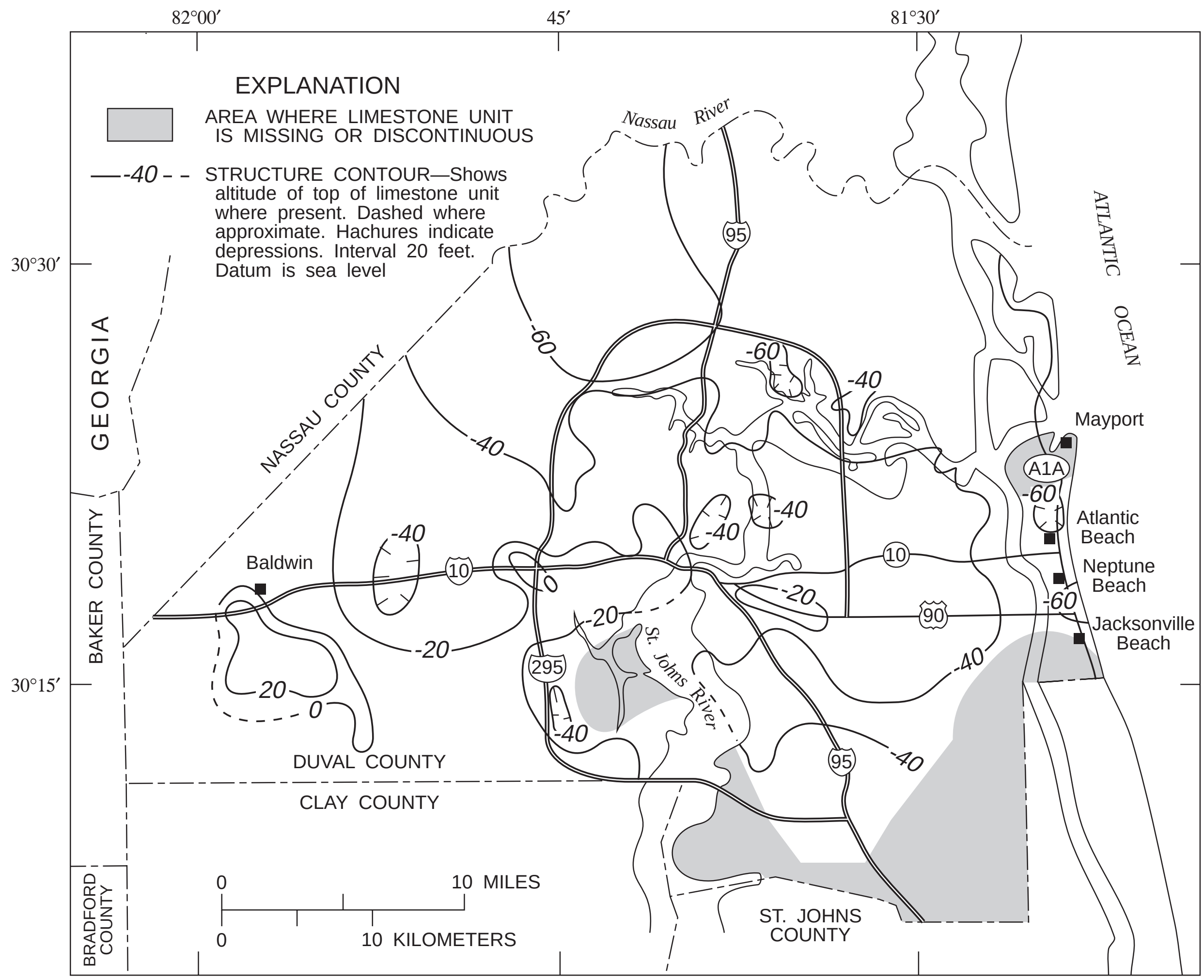


Figure 16. Altitude of the top of the limestone unit of the surficial aquifer system. (From Spechler, 1982.)

GROUND-WATER RESOURCES--Continued

The Surficial Aquifer System and Intermediate Confining Unit--Continued

Water Levels and Well Yields

Water levels in wells that tap the water table and limestone units of the surficial aquifer system fluctuate seasonally in response to rainfall. The water-table unit receives most of its recharge directly from rainfall. The rainy season usually lasts from June through September, when more than half of the annual rainfall occurs. The water table can fluctuate as much as 5 ft between the wet and dry seasons.

Most of the wells completed in the water-table unit are 1-2 in. in diameter, 30-50 ft deep, and have a screen or a length of slotted pipe at the bottom to keep sand from being pumped into the well. The yield of water-table wells is usually about 10-15 gal/min, but the yield can vary greatly depending upon the permeability of the tapped sediments. For example, wells that tap shell beds yield as much as 40 gal/min. Water from the water-table unit is used mostly for lawn and garden irrigation and for residential heat pumps.

Water levels in wells completed in the limestone unit, like those in the water-table zone, fluctuate seasonally. Generally, the seasonal water-level fluctuation in the limestone unit is about 1-5 ft (fig. 17).

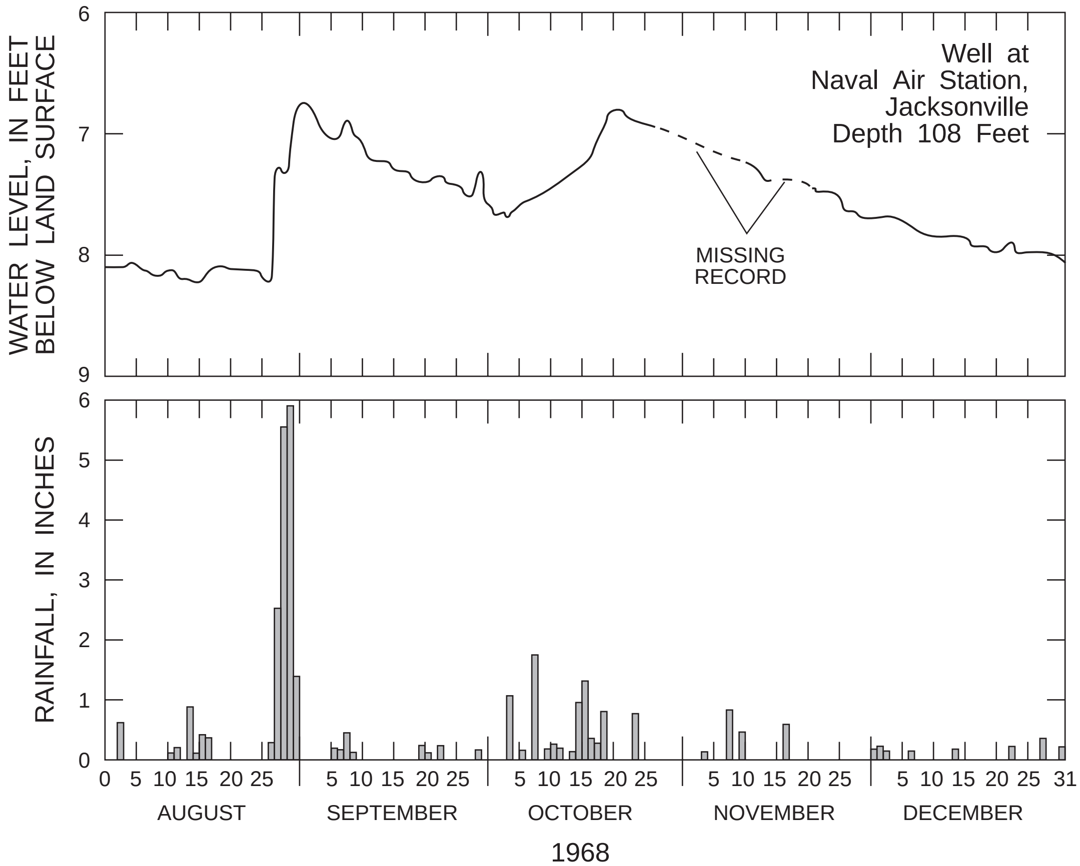


Figure 17. Water level in a well completed in the limestone unit, and daily rainfall at the Naval Air Station, Jacksonville, 1968. (From Fairchild, 1972, fig. 10.)

The Surficial Aquifer System and Intermediate Confining Unit--Continued

Water Levels and Well Yields—Continued

Wells are commonly completed in the limestone unit by inserting a casing through the overlying sediments, then drilling into the consolidated limestone; the hole in the limestone generally remains open. Sometimes a well screen is needed in the open hole to block the intrusion of sand that sometimes is associated with limestone. Most of the limestone unit wells are 2 in. in diameter. Minimum well yields are 5 to 20 gal/min, but most wells yield about 30-100 gal/min. The maximum reported yield from a 2 in. well in the limestone unit is 200 gal/min (Causey and Phelps, 1978, p. 23). Tests were performed to determine specific capacities of wells drilled into the limestone-unit aquifer at 13 different locations (fig. 18, table 2).

Table 2. Specific capacites of wells tapping the surficial aquifer system in Duval County

[ft, feet; gal/min, gallons per minute; gal/min/ft, gallons per minute per foot. In areas where the limestone unit is absent, the aquifer tested was a shellbed. Data from Causey and Phelps, 1978, tables 3 and 5]

Site No.[1]	Approximate depth below land surface to top of water bearing zone (ft)	Approximate aquifer thickness (ft)	Static water level[2]	Pumping rate[3] (gal/min)	Duration of test (hours)	Specific capacity (gal/min/ft)
1	53	11	- 3.6	18	8.7	0.8
2	45	18	- 4.7	4	1.7	.2
3	73	11	- 9.1	30	5.0	1.9
4	86	22	-15.3	10	2.7	1.0
5	41	8	- 1.9	18	4.2	.8
6	83	43	-11.3	10	7.7	.7
7	80	5	+ 2.6	51	12.7	2.3
8	63	17	- 4.8	15	13.5	.7
9	83	20	- 6.0	48	10.8	2.5
10	210	10	- 5.4	20	9.5	1.0
11	45	22	- 6.2	6	5.0	.3
12	67	21	- 7.6	45	5.4	2.6
13	88	18	- 8.7	37	4.7	2.3

[1]Site numbers refer to figure 18.
[2]Above (+) or below (-) land surface.
[3]Pumping rate was maximum obtained with a shallow-well pump (about 25 feet of lift).

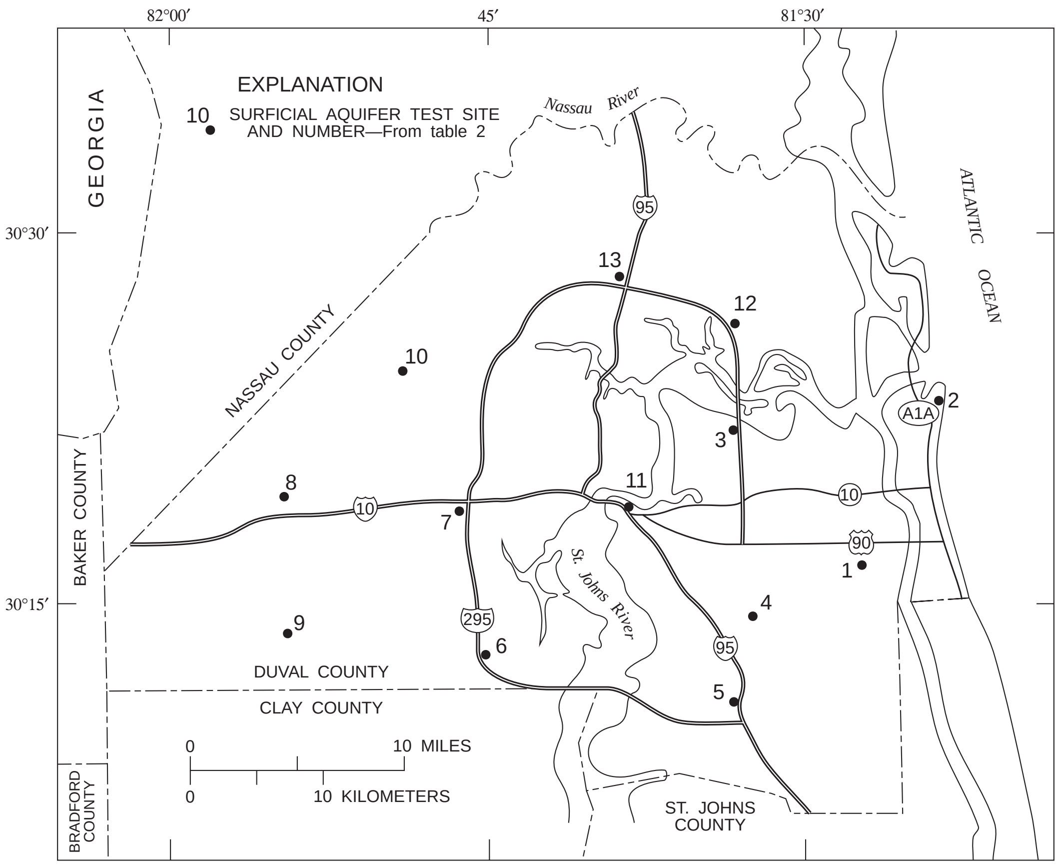


Figure 18. Aquifer test sites of the surficial aquifer system in Duval County. (From Causey and Phelps, 1978, fig. 1.)

GROUND-WATER RESOURCES--Continued

The Surficial Aquifer System and Intermediate Confining Unit--Continued

Quality of Water

The chemical quality of water from the surficial aquifer system is largely controlled by the mineral composition of the sediments that compose the aquifer. Because the composition of the shallow sediments is variable, the quality of the water from the surficial aquifer can vary considerably. For example, if the tapped part of the aquifer system is predominately iron-stained sand, the water it yields commonly has a high iron concentration. Water from shell beds or limestone generally is hard, and water from hardpan or organic-rich sediments can be acidic. Also, in some areas, particularly along the lower St. Johns and the Nassau Rivers and the coast, infiltration of brackish water or seawater into the surficial aquifer system can cause the chloride concentration of aquifer water to exceed 250 mg/L (Spechler and Stone, 1983, p. 24-28). A generalized map of chloride concentration in water from the surficial aquifer system is shown in figure 19.

The quality of water from the surficial aquifer system in most areas of Duval County is generally suitable for domestic, commercial, and industrial uses. Some chemical characteristics of water from the surficial aquifer system are summarized in table 3. The summary is based on the analysis of water samples collected by the U.S. Geological Survey from wells less than 125 ft deep. Wells affected by water with high chloride concentrations from the St. Johns River or estuarine areas were not included in table 3.

Overall, water from the surficial aquifer system ranges from soft (total hardness less than 60 mg/L) to hard (total hardness greater than 120 mg/L). Wells completed in relatively clean sands typically yield soft, slightly acidic water (pH less than 7.0). Wells that tap the shellbeds of limestone generally yield hard, slightly alkaline water (pH greater than 7.0).

Some chemical constituents in water, such as iron, can be esthetically unsatisfactory if present in high concentrations. For example, iron concentrations greater than about 300 mg/L can stain laundry and plumbing fixtures. The U.S. Environmental Protection Agency (1988) has prepared a list of such constituents and recommended limits, designated SMCL’s (Secondary Maximum Contaminant Levels). SMCL’s are not enforceable limits but are intended as guidelines. Applicable SMCL’s are shown in table 3.

Table 3. Summary of chemical quality of water from the surficial aquifer system in Duval County, 1970-89

[All concentrations are dissolved and expressed in milligrams per liter, except where noted. SMCL, Secondary Maximum Contaminant Level (from Florida Department of Environmental Regulation, 1989). µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter]

Constituent	Mean	SMCL	Range of values
Specific conductance, µS/cm	218	none	31 - 960
pH, standard units	5.8	6.5-8.5	3.8 - 8.1
Calcium	120	none	51 - 180
Magnesium	4.2	none	1.6 - 13
Sodium	9.5	none	6.4 - 14
Potassium	.8	none	.4 - 1
Sulfate	12.	none	.2 - 87
Chloride	16	250	3 - 100
Total hardness, as calcium carbonate	80	none	10 - 470
Iron, µg/L	1,510	300	10 - 12,000

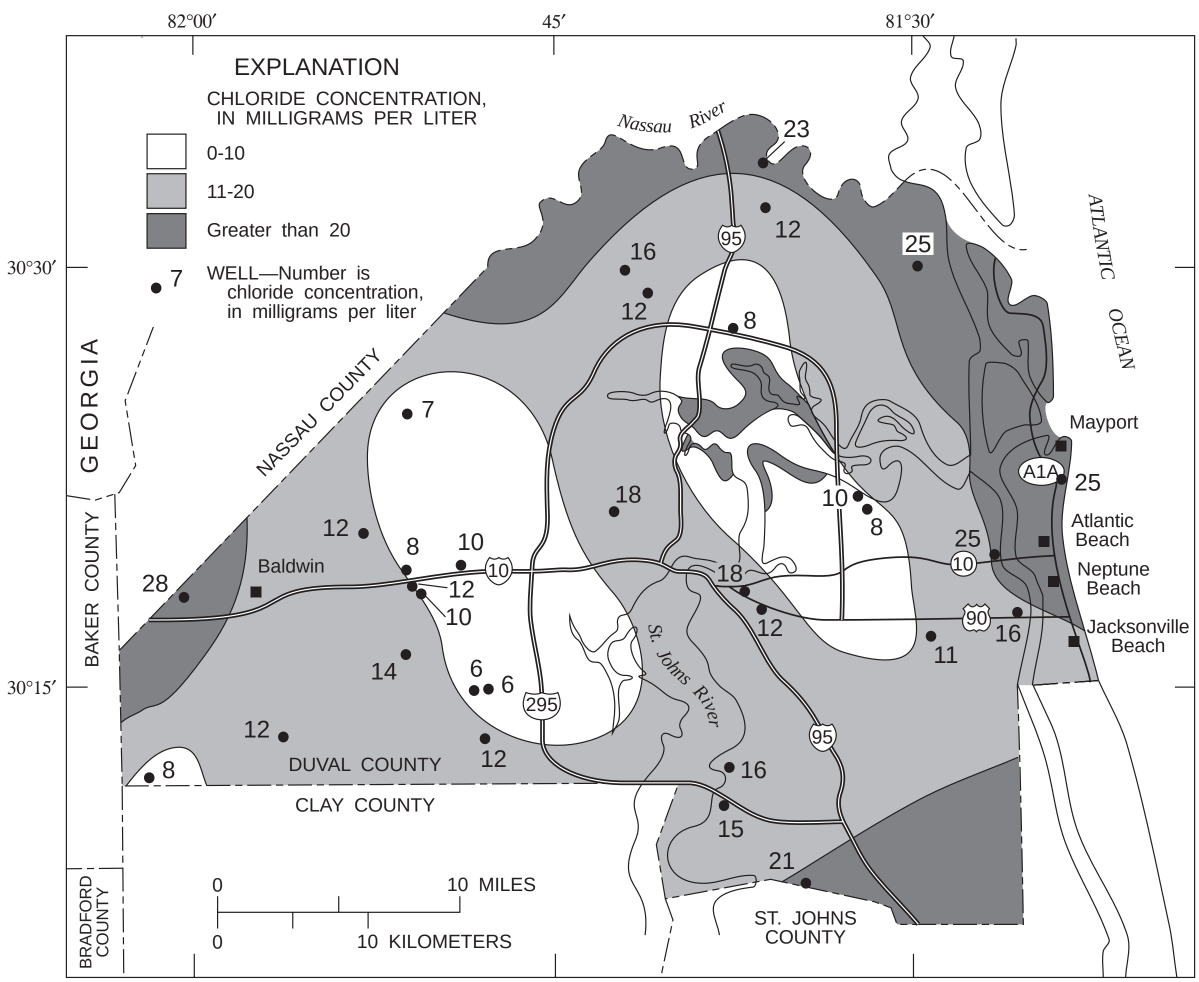


Figure 19. Generalized distribution of chloride concentration in water from the surficial aquifer system. (Modified from Fairchild, 1972, fig. 14; and Spechler and Stone, 1983, fig. 13.)

The Floridan Aquifer System

Lithology and Thickness

The Floridan aquifer system, composed of a thick sequence of limestone and dolomite, is the principal source of freshwater in Duval County. The system includes (from youngest to oldest) rocks of the Ocala Limestone, the Avon Park Formation and the Oldsmar Formation. The combined thickness of the rocks that compose the Floridan aquifer system ranges from about 1,600 ft in southwestern Duval County to more than 2,200 ft in northeastern Duval (Miller, 1986).

The top of the Floridan aquifer system is generally the top of the Ocala limestone. The altitude of the surface of the Floridan ranges from 300 ft below sea level in the southeastern part of the county to more than 600 ft below sea level in the central part (fig. 20). The surface of the aquifer system is an erosional remnant of an ancient land surface and shows the effects of sinkhole-collapse features. Discontinuities in the altitude of the top of the aquifer could be the result of faulting or ancient collapse features (mostly sinkholes). Fractures (broken rock) related to the possible faults or to collapse features could form conduits that contribute to increased permeability of the aquifer.

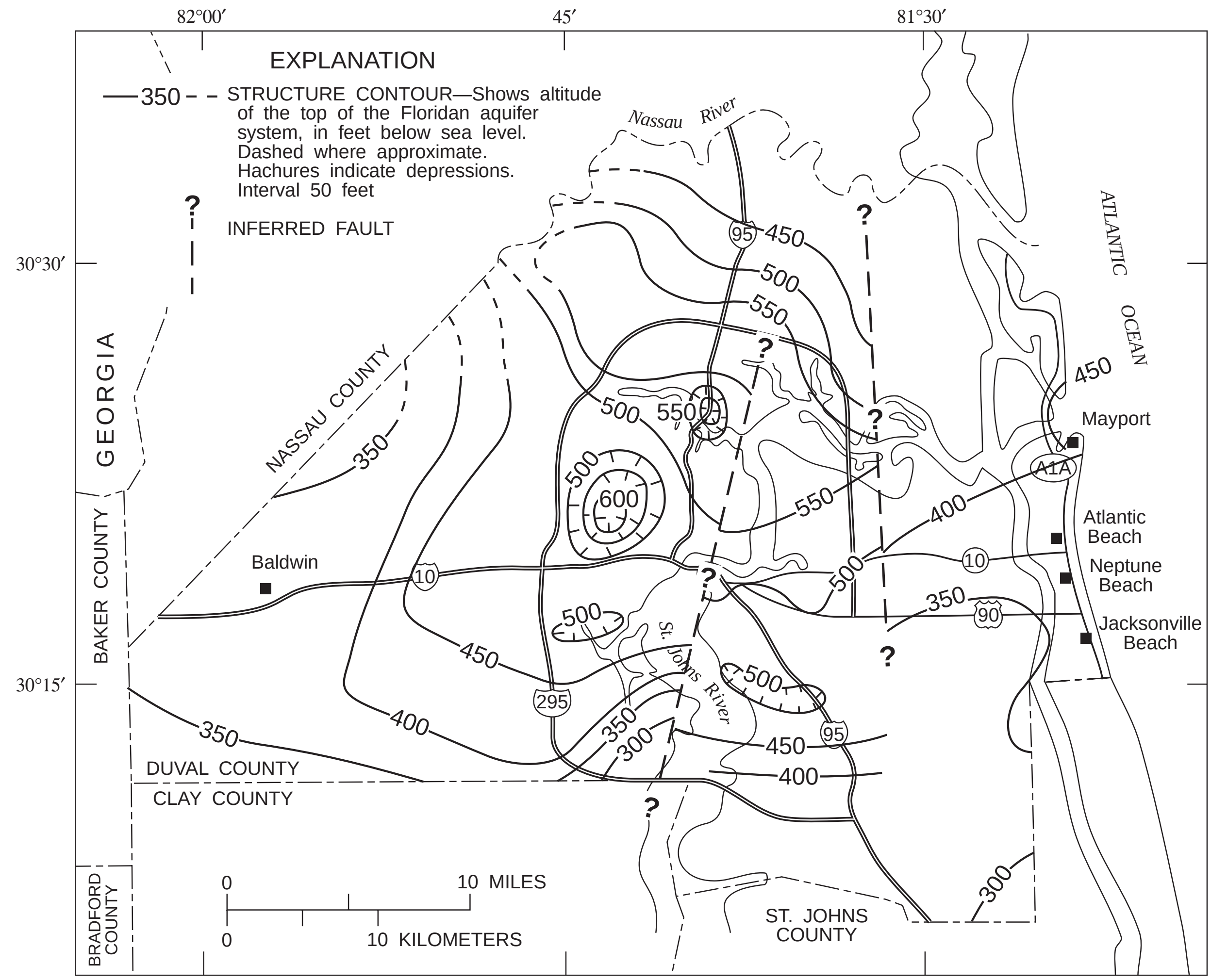


Figure 20. Altitude of the top of the Floridan aquifer system. (Modified from Leve, 1978.)

The Floridan Aquifer System--Continued

Recharge and Discharge

Recharge to the Floridan aquifer system occurs where the altitude of the water table is higher than the potentiometric surface of the Floridan aquifer system and movement of water is downward. In the recharge areas of western Duval County (fig. 21), the sediments overlying the Floridan aquifer system are thick and clayey, and the rate of recharge is low to moderate. Recharge in Duval County is not sufficient to replace the amount of water withdrawn (pumped) from the Floridan aquifer system. As water is withdrawn from a heavily stressed aquifer, the water is replaced by water moving laterally from an unstressed part of the aquifer. Ground water in Duval County is replaced by water underlying areas to the west and southwest of the county.

The rate of recharge can be estimated from the calculation of a water budget, which is a summation of all the inflow and outflow that take place in a hydrologic system. In western Duval County, input to the ground-water reservoir comes from rainfall that averages about 54 in/yr. Outflow to surface streams in the area is about 20 in/yr (Fairchild, 1972, p. 30). A major output component of the water budget is evapotranspiration. In northeastern Florida, the minimum evapotranspiration rate is about 30 in/yr (Visher and Hughes, 1975).

Assuming there is no net change in the amount of water stored in the surficial aquifer system, rainfall (54 in.) minus stream outflow (20 in.) and evapotranspiration (30 in.) leaves about 4 in. of water available to enter the surficial aquifer system and recharge the ground-water reservoir. Results of a computer-model simulation of ground-water flow in northeastern Florida (Krause, 1982) indicates that the rate of recharge to the Floridan aquifer system in western Duval County ranges from about 0.1 to almost 10 in/yr.

Most of eastern Duval County is a natural ground-water discharge area (fig. 21); the potentiometric surface of the Floridan aquifer system is higher than the water table, and movement of ground water is upward. Computer simulations of prepumping conditions in the aquifer (Krause, 1982, pl. 4) indicate that the rate of natural discharge through the intermediate confining bed was less than 0.1 in/yr in eastern Duval County, because the confining beds are so thick that very little movement of water occurs through them. Computer simulations indicate the possibility of higher rates of natural discharge (in the range of 1-10 in/yr) in the St. Johns River Valley in southern Duval and northern Clay Counties.

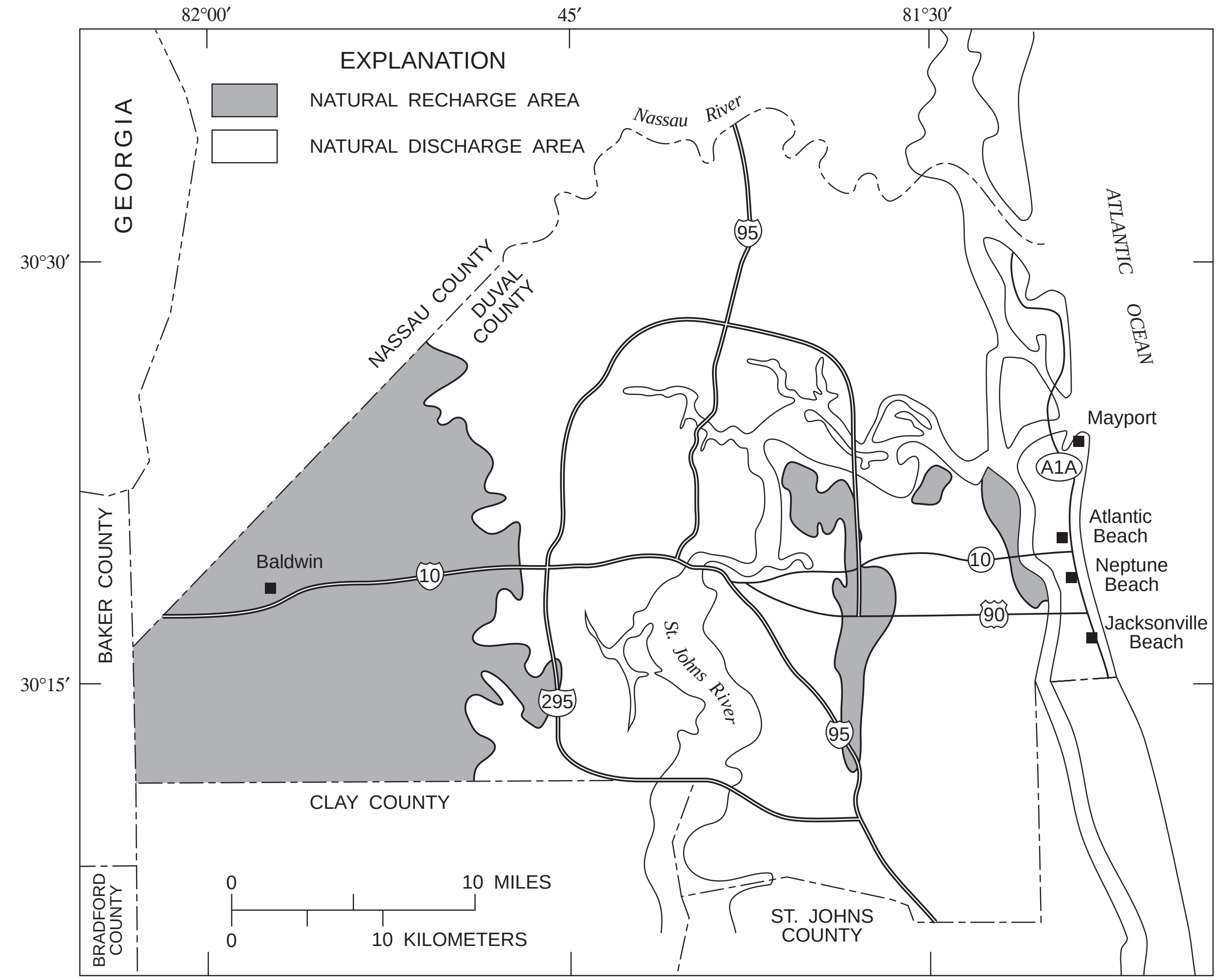


Figure 21. Approximate extent of natural recharge and discharge areas of the Floridan aquifer system in Duval County. (From Causey, 1975; and Phelps, 1984, fig. 2.)

The Floridan Aquifer System--Continued

Transmissivity and Well Yields

The rate at which water moves through an aquifer (hydraulic conductivity) multiplied by the thickness of an aquifer results in a value called transmissivity. The location of aquifer test sites (wells) for which transmissivity in the Floridan aquifer system in Duval County was calculated are shown in figure 22. In Duval County, transmissivity varies greatly (table 4). For example, at test sites 1 and 3, the same thickness of aquifer material was tested, but the hydraulic conductivity is greater at site 3 than at site 1; therefore, a well at site 3 is able to provide a greater yield of water than a well at site 1.

The higher the transmissivity of an aquifer, the easier it supports a large number of wells, depending on the diameters of the well and length of open hole or well screen. In Duval County, domestic wells, which usually range 2-4 in. in diameter, tap 100 ft or less of the Floridan aquifer system and yield 50-350 gal/min. Wells drilled for public, commercial, and industrial supplies are generally larger in diameter, are drilled deeper into the Floridan aquifer system, and yield as much as 1,500 gal/min.

Table 4. Transmissivity of the Floridan aquifer system in Duval County

[Site numbers refer to fig. 22. ft, feet; ft/d, feet per day; ft^2/d, feet squared per day. Modified from Krause, 1982, pl. 1]

Aquifer test site No.	Hydraulic conductivity (ft/d)	Aquifer thickness tested (ft)	Transmissivity (ft^2/d, rounded)
1	50	565	28,000
2	170	756	130,000
3	230	565	130,000
4	40	540	22,000
5	50	542	27,000
6	290	697	202,000

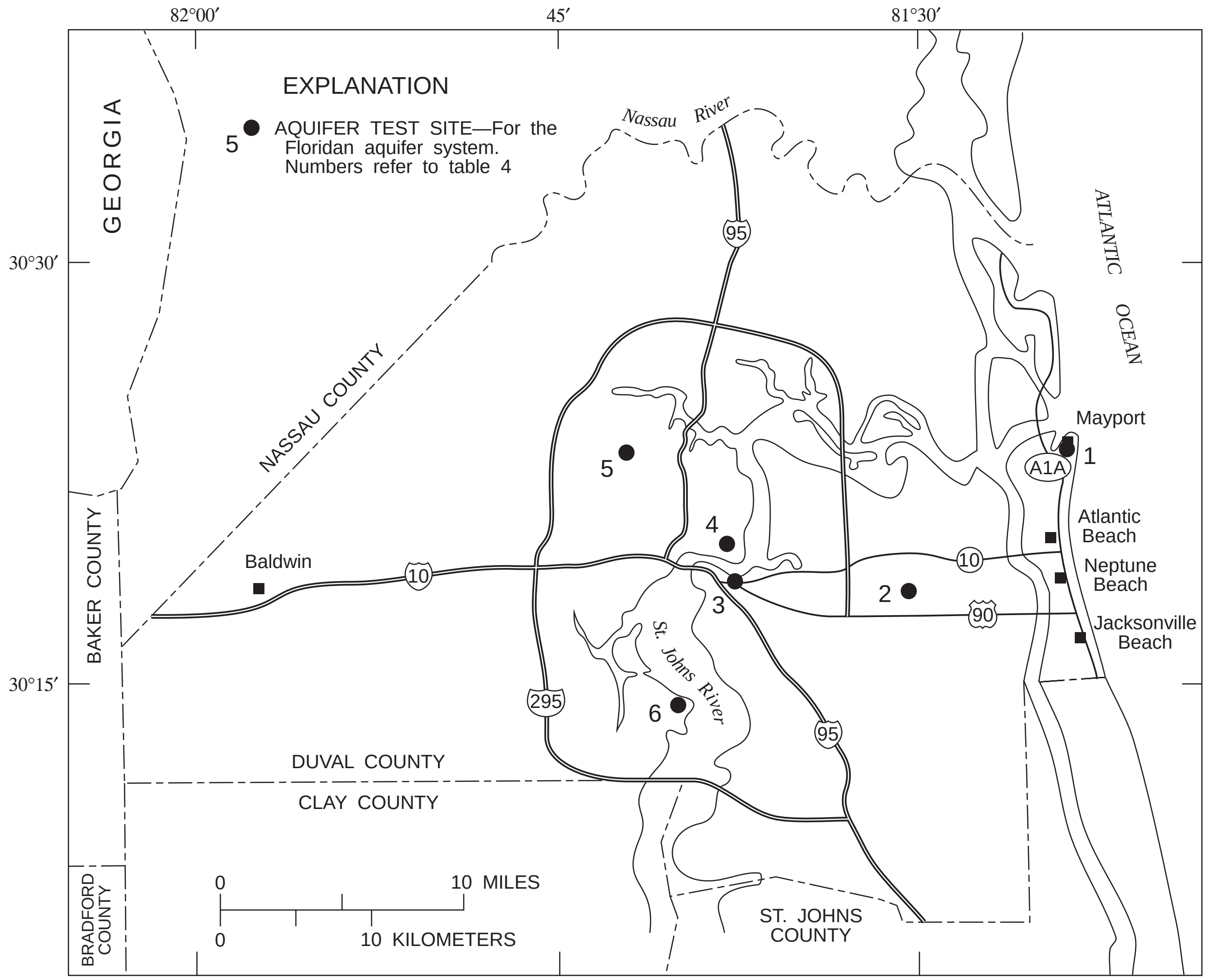


Figure 22. Aquifer test sites in the Floridan aquifer system in Duval County.

The Floridan Aquifer System--Continued

Potentiometric Surface

A potentiometric-surface map, also called a water-level map, can help in understanding the flow system in an aquifer. The potentiometric surface is the height to which water will rise in a tightly cased well that is open to a given aquifer. By plotting water levels of many wells on a map and contouring equal water levels by a line, an imaginary surface can be depicted that is called the potentiometric surface. Because water flows from areas of high potential (high water-level altitude) to areas of low potential (low water-level altitude), potentiometric contours can readily illustrate the direction of flow in an aquifer, as well as the gradient of the flow.

The estimated potentiometric surface of the Upper Floridan aquifer of the Floridan aquifer system in northeastern Florida prior to development is shown in figure 23. The surface shown is representative of natural conditions before there was significant pumpage from the aquifer.

The map, based on computer simulations, shows a high potentiometric surface (the closed 90 ft contour) in the Keystone Heights area of southern Bradford and Clay Counties. Flow lines projected north from this high potential enter Duval County, indicating that the Keystone Heights area contributes part of the ground-water inflow to Duval County. The predominant flow direction in Duval County is from the western border toward the coast. The closed 30 ft and 40 ft depression contours near Green Cove Springs are the result of natural discharge from the aquifer through springs.

Prior to a substantial increase in well pumpage, natural recharge to and discharge from the Floridan aquifer system in northeastern Florida were in balance. The potentiometric surface fluctuated only in response to seasonal and long-term variations in rainfall, but its overall configuration remained unchanged.

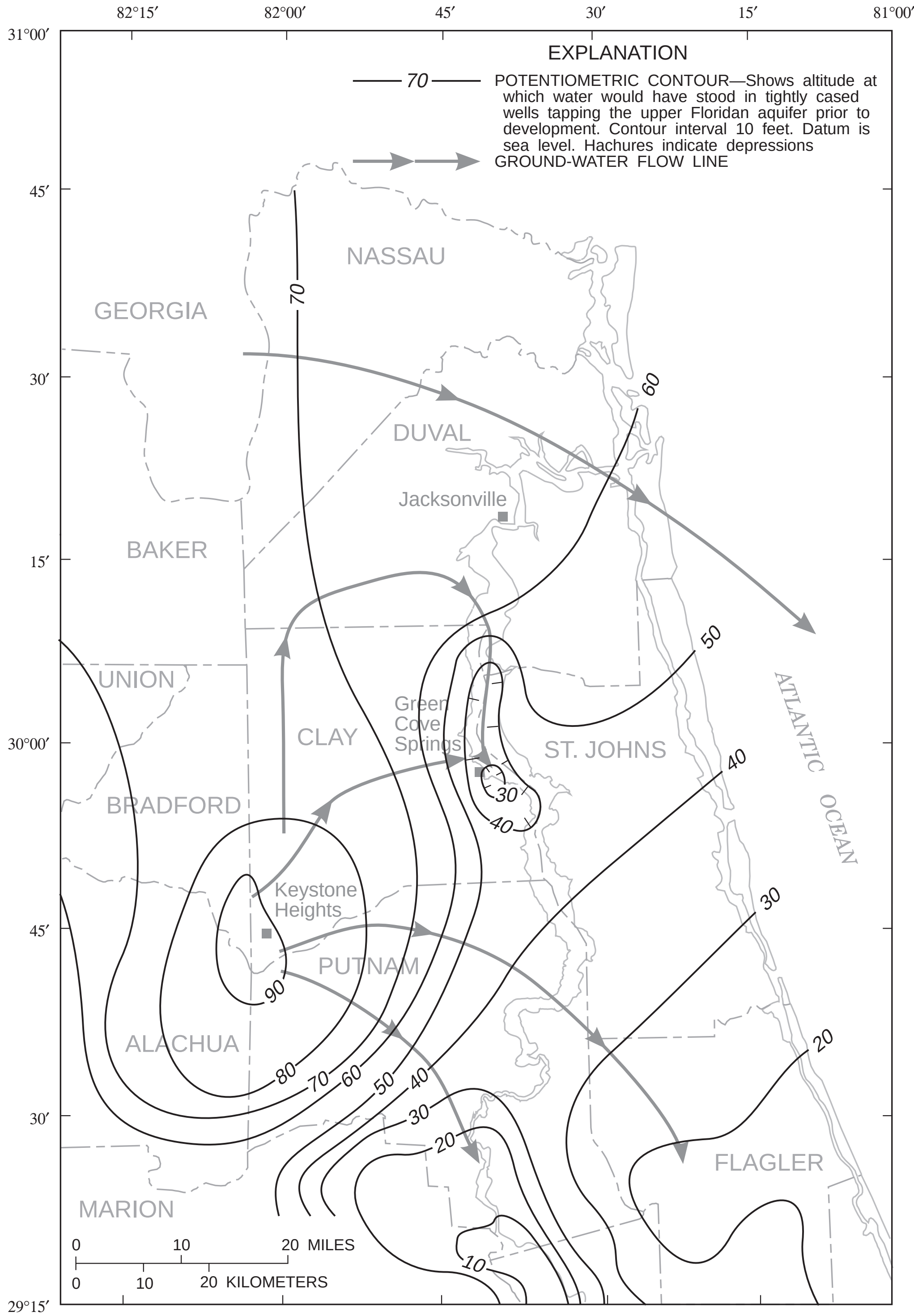


Figure 23. Potentiometric surface and direction of ground-water flow in the Upper Floridan aquifer prior to development. (Modified from Krause, 1982, p. 2.)

GROUND-WATER RESOURCES--Continued

The Floridan Aquifer System--Continued

Potentiometric Surface--Continued

A comparison between the predevelopment potentiometric-surface map of the Upper Floridan aquifer in Duval County and a potentiometric-surface map for September 1989 (fig. 24), shows that the 1989 surface is as much as 30 ft lower than the predevelopment surface. The lowered potentiometric surface is the result of pumping from the aquifer. The depression in the potentiometric surface centered on the St. Johns River in Duval County is related to the natural discharge of water from the Upper Floridan aquifer into the river, and to aquifer transmissivity variations. This depression may have been present prior to development according to ground-water simulation studies.

One of the consequences of the lowering of the potentiometric surface of the Upper Floridan aquifer is the increase in head differences between the Upper and Lower Floridan aquifers. The lowering of the potentiometric surface in the Upper Floridan aquifer also has the potential to increase recharge from the overlying surficial aquifer.

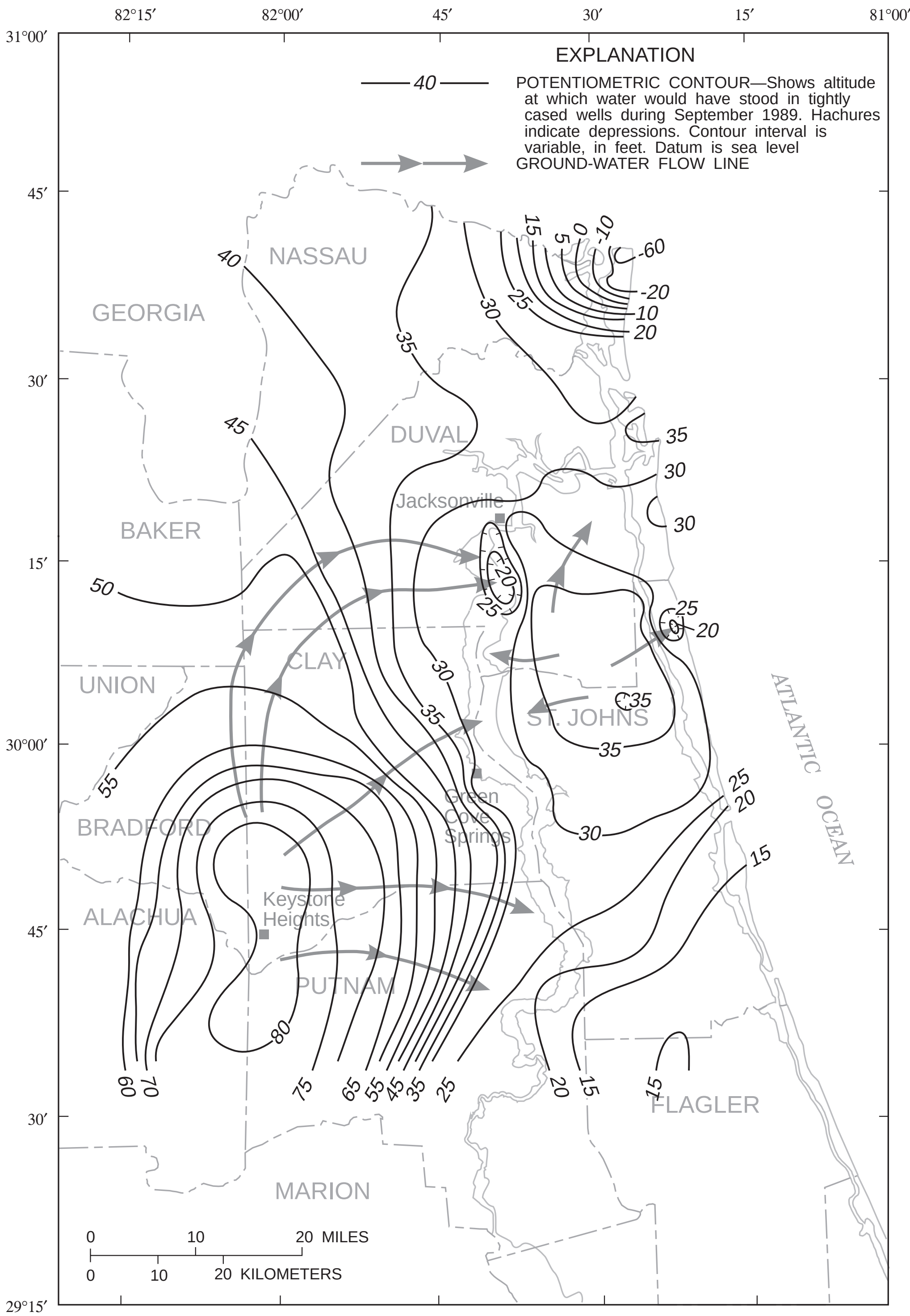


Figure 24. Potentiometric surface and direction of ground-water flow in the Upper Floridan aquifer, September 1989. (Modified from Burtell, 1990.)

The Floridan Aquifer System--Continued

Quality of Water

The Floridan aquifer system yields water of acceptable quality for most uses. Through time, some of the minerals that compose the rocks of the aquifer are dissolved by the ground water, increasing the mineralization of the water. For example, limestone is made of calcium carbonate, which is moderately soluble and is dissolved by the water. Dolomite, which is less soluble, however, contributes calcium, magnesium, and carbonate; gypsum, which is highly soluble, contributes calcium and sulfate.

When limestone and dolomite dissolve, the minerals contribute hardness to water in the aquifer. The total hardness of water from the Upper Floridan aquifer is shown in figure 25. Hard water is considered undesirable because, among other things, it causes the buildup of scale in water pipes and industrial machinery, and requires the use of increased amounts of soap. Generally, water in the Upper Floridan aquifer in western Duval County is softer than in other parts of the county, probably because that area is closer to the system's major recharge area and less dissolution of limestone occurs because of the shorter contact time between the water and rock. Water from the Upper Floridan aquifer usually is less mineralized than water from the Lower Floridan aquifer. Therefore, most water-supply wells tap about the upper 600 ft of the aquifer system.

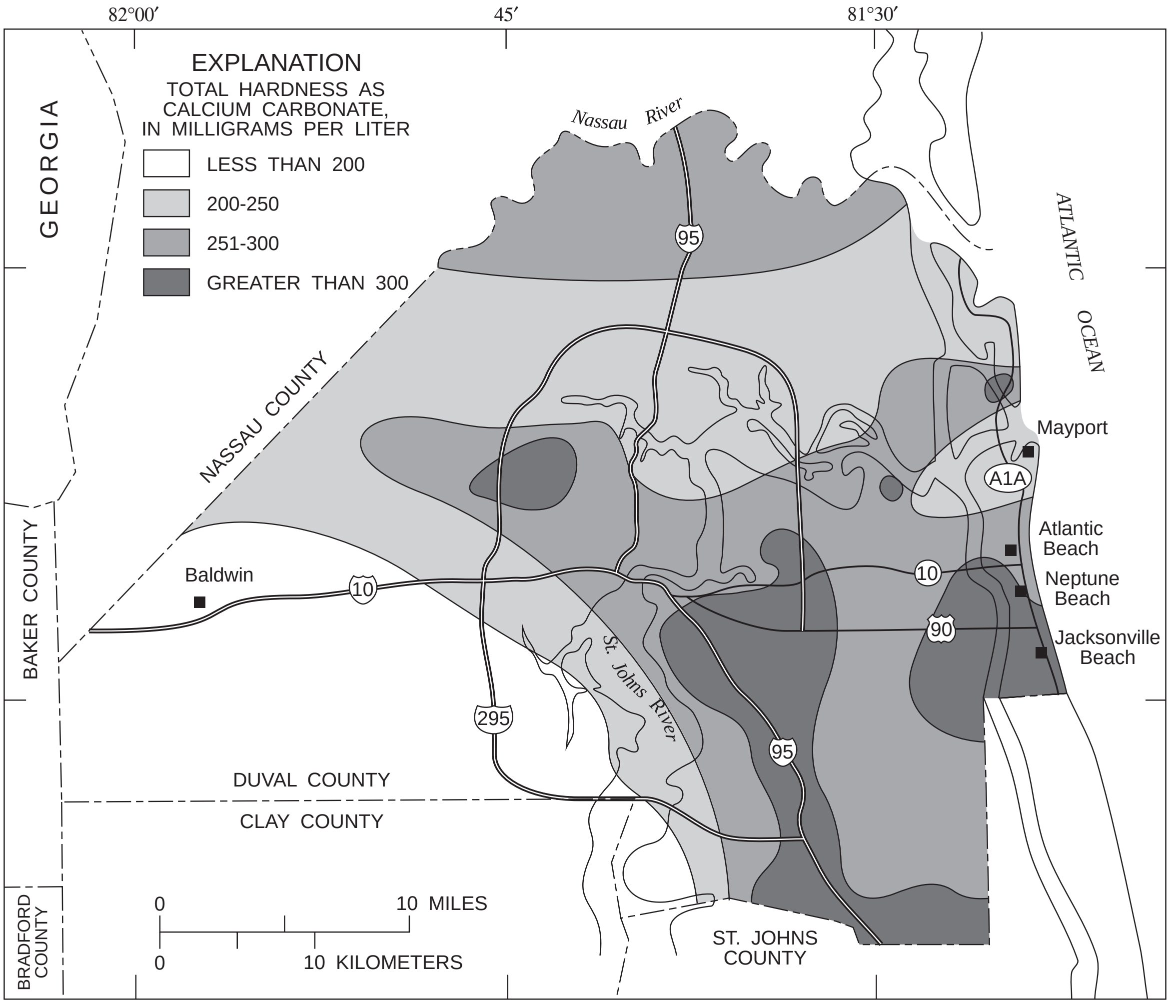


Figure 25. Total hardness of water from the Upper Floridan aquifer in Duval County. (Modified from Thompson, 1982, fig. 3.)

The Floridan Aquifer System--Continued

Quality of Water--Continued

The threshold at which most people can detect a salty taste in water is 250 mg/L chloride concentration and is the secondary drinking water standard established by the U.S. Environmental Protection Agency (1988) and the Florida Department of Environmental Regulation, 1991. Water from the Upper Floridan aquifer in almost all of Duval County has chloride concentrations less than 30 mg/L (fig. 26). Chloride concentrations are generally less than 15 mg/L in southwestern Duval County. The chloride concentration in water from the deeper part of the Lower Floridan aquifer, however, can exceed 16,800 mg/L.

In local areas of eastern Duval County, high chloride concentrations (greater than 30 mg/L) have been measured in water from some wells that tap the Upper Floridan aquifer. For example, in the area of Fort George Island, chloride concentrations exceed 250 mg/L throughout an area of several square miles. Chloride concentrations ranging from about 34 to 250 mg/L have also been measured in water from wells at scattered locations in the eastern part of the county (fig. 26). The higher chloride values probably result from the upward movement of saline water from the Lower to the Upper Floridan aquifer. Pumping in the Fort George area and locally around isolated wells has lowered the head in the upper part of the aquifer, creating the potential for saline water to move upward, either in wells open to all parts of the aquifer or along fractures.

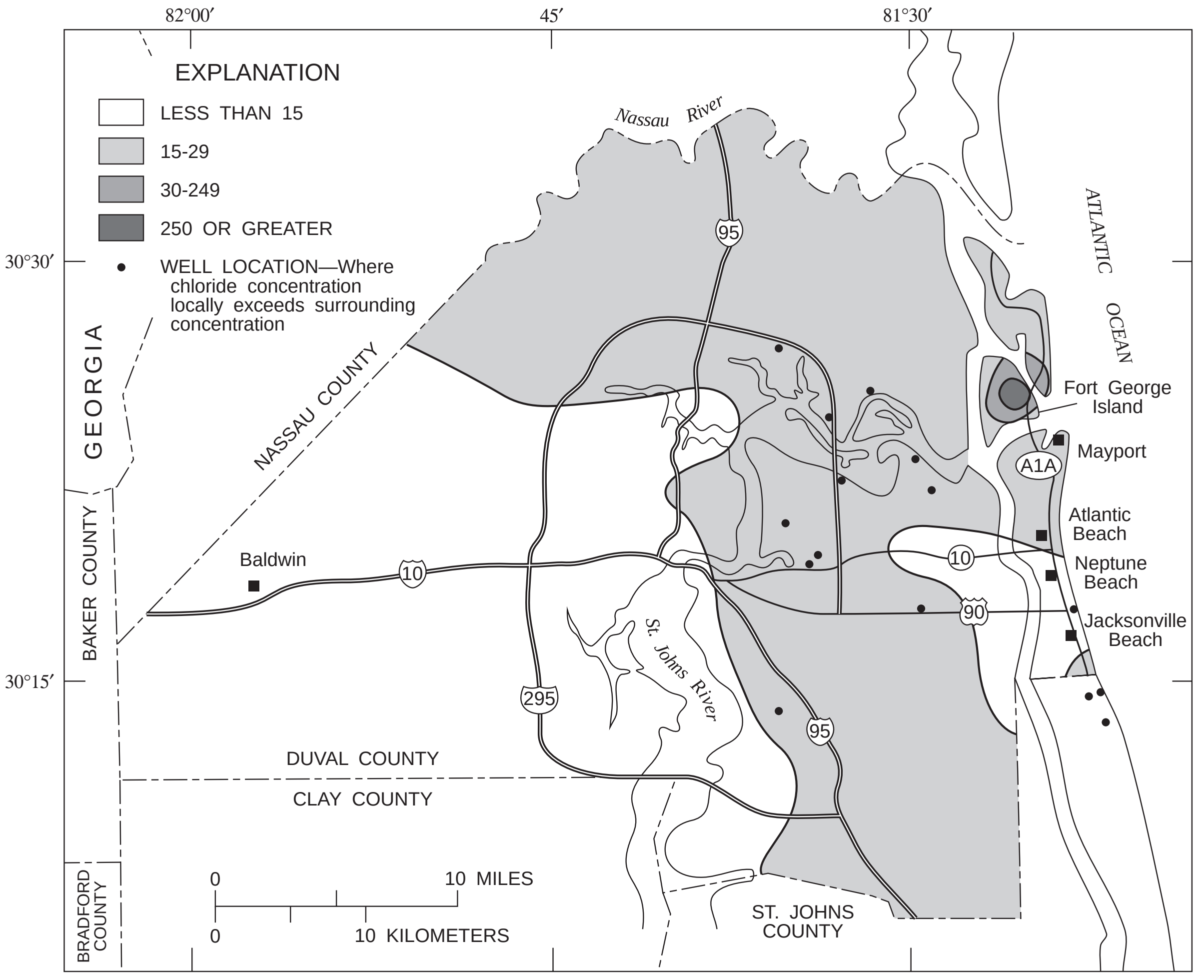


Figure 26. Generalized distribution of chloride concentration in water from the Upper Floridan aquifer. (Modified from R.M. Spechler, U.S. Geological Survey, written commun., 1992.)

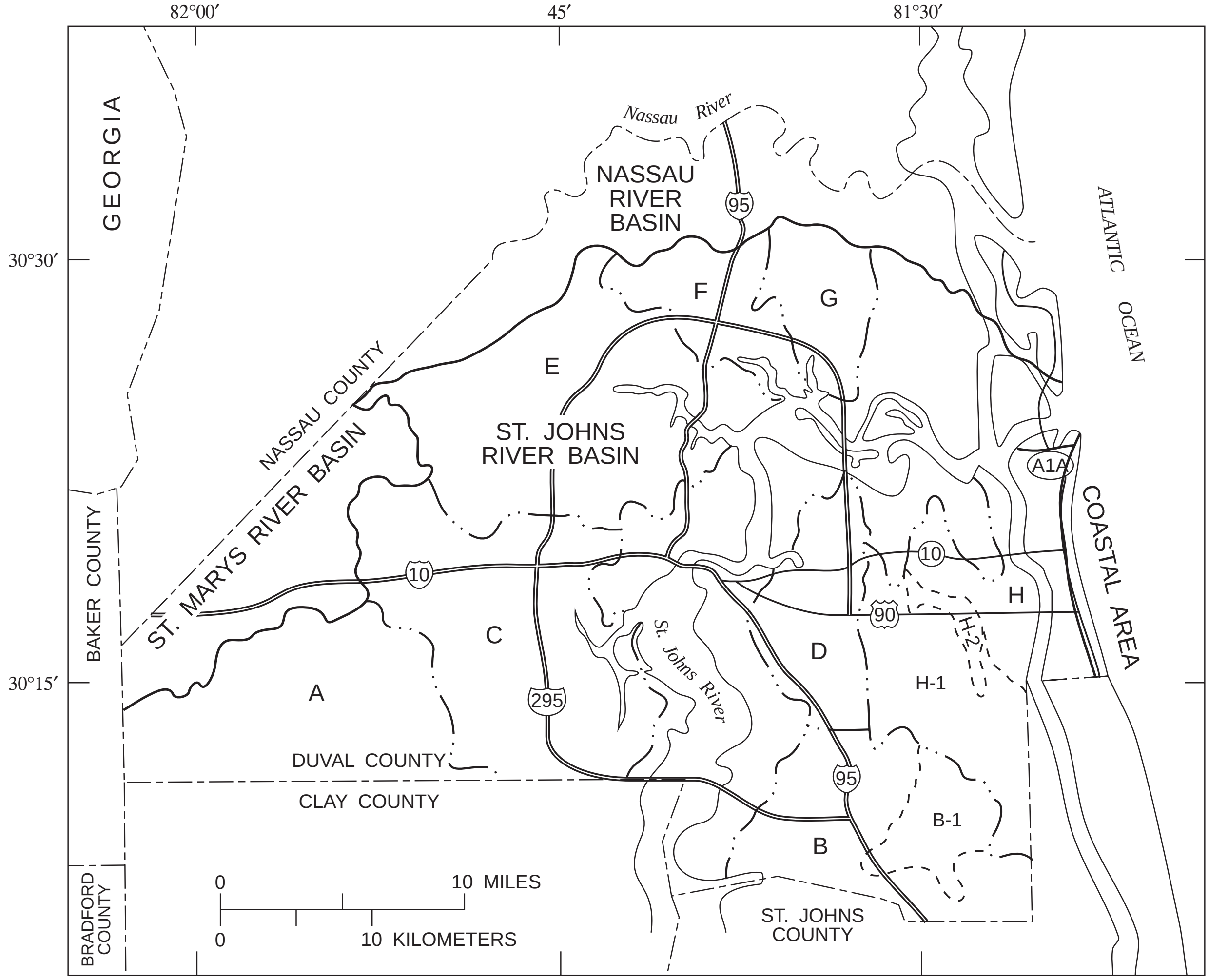
SURFACE-WATER RESOURCES

Drainage Basins

About 75 mi^2 of surface water cover parts of Duval County. The interior of the county is drained by three major rivers: the St. Johns River, the Nassau River, and the St. Marys River. Coastal areas are drained by numerous small streams that discharge into the Intracoastal Waterway or the Atlantic Ocean.

A major drainage basin consists of a main surface stream, its tributaries, and the surrounding land that they drain. The drainage basin is bounded by drainage divides that are ridges or high land areas that separate adjacent stream-drainage systems. A major river basin can be divided into progressively smaller basins or subbasins.

The major river basins and subbasins of Duval County are shown in figure 27. Because parts of the county are relatively flat, some of the drainage divides in low areas are indistinct. During floods, water can overflow low divides and discharge into another drainage basin.



EXPLANATION

MAJOR RIVER BASIN BOUNDARY

RIVER BASIN DIVIDE

A	Black Creek	E	Trout River
B	Julington Creek	F	Broward River
C	Ortega River	G	Dunn Creek
D	Arlington River	H	Intracoastal Waterway

SELECTED SUBBASIN DIVIDE

B-1 Big Davis Creek
H-1 Pablo Creek
H-2 Cedar Swamp Creek

Figure 27. Drainage basins in Duval County. (Modified from Stone and Largen, 1983.)

Gaging-Station Network

To understand the hydrology of an area, systematic collection of streamflow data is necessary. For basins where streamflow data have been collected over a period of many years, statistics of streamflow characteristics, such as peak discharge, flow duration, low-flow frequencies, and mean average flow rates, are determined. This information is especially important in the analysis of the effects of droughts and floods on streamflow. Data collected at gaging-station network sites are used to estimate streamflow characteristics for sites where data are not collected.

Streamflow data are collected at three kinds of gaging-station sites in Duval County. At some streams, a continuous record of the height of the water surface (stage) is collected along with periodic measurements of streamflow (discharge). By using data collected for a period of years, a mathematical relation between stage and discharge can be determined and a continuous record of flow can be calculated for the stream. Such sites are called daily discharge sites. At other sites, periodic measurements of stage and discharge are made. Such sites are called miscellaneous measurement sites. A third type of site has a peak-stage indicator, a device that shows the maximum stream stage at a site since the previous time the site was visited. Streamflow measurements are made at a network of 45 sites in Duval County--20 continuous, 18 miscellaneous, and 7 peak-stage sites (fig. 28 and table 5).

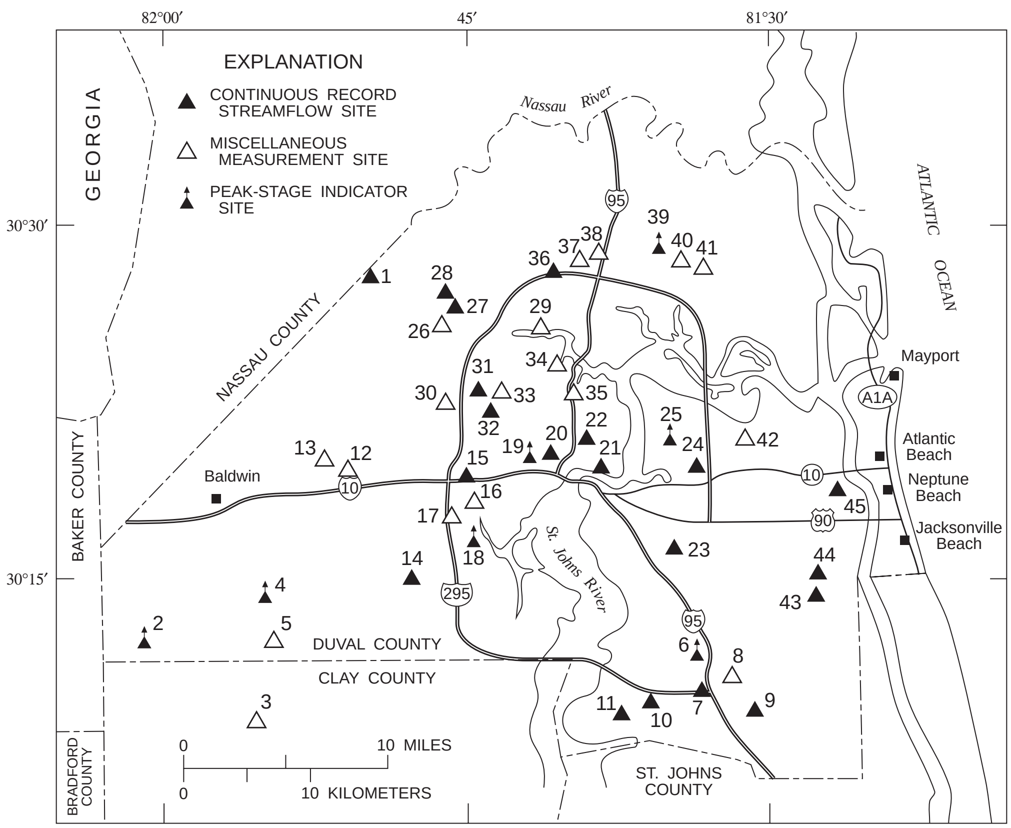


Figure 28. Streamflow measuring sites in Duval County.

Table 5. Streamflow data-collection sites in Duval County

[Site number refers to figure 28. Site identification number is a unique identifier. Site type: CON, continuous daily (stage); CSI, peak-stage indicator; MIS, miscellaneous]

Site No.	Site identification No.	Site name	Latitude	Longitude	Site type
1	02231280	Thomas Creek near Crawford	302739	0814957	CON
2	02245850	Long Branch at Maxville	301203	0820106	CSI
3	02245860	North Fork Black Creek near Maxville	300833	0815548	MIS
4	02245900	Yellow Water Creek near Maxville	301344	0815517	CSI
5	02245920	Sal Taylor Creek at Fiftone	301200	0815441	MIS
6	02246100	Julington Creek near Greenland	301119	0813345	CSI
7	02246108	Julington Creek near Mandarin	301001	0813341	CON
8	02246110	Sweetwater Creek near Greenland	301003	0813229	MIS
9	02246150	Big Davis Creek at Bayard	300905	0813135	CON
10	02246201	Oldfield Creek near Mandarin	300933	0813622	CON
11	02246202	Cormorant Branch near Mandarin	300856	0813743	CON
12	02246277	Whitehouse Branch at Whitehouse	301919	0815056	MIS
13	02246280	McGirts Creek at Whitehouse	301948	0815142	MIS
14	02246300	Ortega River at Jacksonville	301450	0814749	CON
15	02246359	Cedar River at Marietta	301850	0814513	CON
16	02246360	Cedar River near Marietta	301755	0814520	MIS
17	02246455	South Fork Wills Branch near Marietta	301705	0814605	MIS
18	02246460	Williamson Creek at Cedar Hills	301619	0814505	CSI
19	02246497	McCoy Creek at Jacksonville	301935	0814156	CSI
20	02246498	McCoy Creek near Brooklyn	301939	0814128	CON
21	02246500	St. Johns River at Jacksonville	301916	0813954	CON
22	02246502	Hogan Creek near Springfield	302027	0813942	CON
23	02246515	Pottsburg Creek near South Jacksonville	301550	0813525	CON
24	02246520	Strawberry Creek near Arlington	301926	0813400	CON
25	02246522	Red Bay Branch Tributary at Jacksonville	302040	0813522	CSI
26	02246598	Trout River at Illinois Street at Dinsmore	302535	0814616	MIS
27	02246600	Trout River at Dinsmore	302551	0814607	CON
28	02246602	Little Trout River at Dinsmore	302623	0814621	CON
29	02246621	Trout River near Jacksonville	302502	0814148	MIS
30	02246645	Sixmile Creek at Pickettville	302146	0814624	MIS
31	02246650	Sixmile Creek near Marietta	302214	0814447	CON
32	02246700	Little Sixmile Creek near Marietta	302151	0814416	CON
33	02246709	Ribault River near Jacksonville	302229	0814337	MIS
34	02246721	Ribault River near Jacksonville	302343	0814058	MIS
35	02246732	Moncrief Creek near Jacksonville	302215	0814017	MIS
36	02246750	Cedar Creek near Panama Park	302730	0814049	CON
37	02246754	Pickett Branch near Eastport	302759	0814005	MIS
38	02246760	Little Cedar Creek near Eastport	302805	0813923	MIS
39	02246800	Dunn Creek near Eastport	302815	0813607	CSI
40	02246807	Caney Branch near Eastport	302743	0813453	MIS
41	02246810	Rushing Branch near Eastport	302745	0813403	MIS
42	02246820	Jones Creek near Arlington	302032	0813209	MIS
43	02246828	Pablo Creek at Jacksonville	301407	0812842	CON
44	02246832	Cedar Swamp Creek near Jacksonville	301438	0812826	CON
45	02246835	Sandalwood Canal near Jacksonville Beach	301822	0812732	CON

Streamflow

The amount of natural streamflow that passes any point in a stream is a combination of amounts contributed by stormwater runoff (surface runoff) and base flow (ground-water discharge). Stormwater runoff and base flow vary from one basin to another depending on stream characteristics, near-surface geology, amount of rainfall on the basin, and degree of urbanization in the basin. Stormwater runoff is the overland runoff that occurs after rainfall that causes the rapid rise in streams, especially during the wet season when the soil is saturated or nearly saturated. Base flow is the “fair-weather” part of streamflow and depends on the continual discharge of ground water from storage before, during, and after periods of surface runoff. The stormwater runoff and base flow components of a stream hydrograph are shown in figure 29.

Streamflow is usually measured as a volume over time, in terms of cubic feet per second (1 ft^3/s is about 450 gal/min or 0.65 Mgal/d). Total streamflow for a year can also be expressed as the depth of water spread over the area of the basin where it originated. This depth can then be compared directly with the rainfall that fell onto the basin.

The monthly rainfall at the Jacksonville airport and monthly streamflow in the Ortega River at Jacksonville during l989 are shown in figure 30. Rainfall was highest in July, August, and September, ranging from 9 to 15 in. Streamflow was greatest in September, about 9 in., due to the large rainfall amounts in July, August, and September. Despite heavy rain, the amount of streamflow increased only slightly through July and August, probably because most of the rain soaked into the ground or returned to the atmosphere by evapotranspiration. In September, when the ground-water reservoir was full and evapotranspiration reduced, streamflow increased significantly because more of the rain ran off as stormwater runoff. In October, streamflow was greater than rainfall because of the release of base flow from ground-water storage. Streamflow in most other months was less than 1 in.

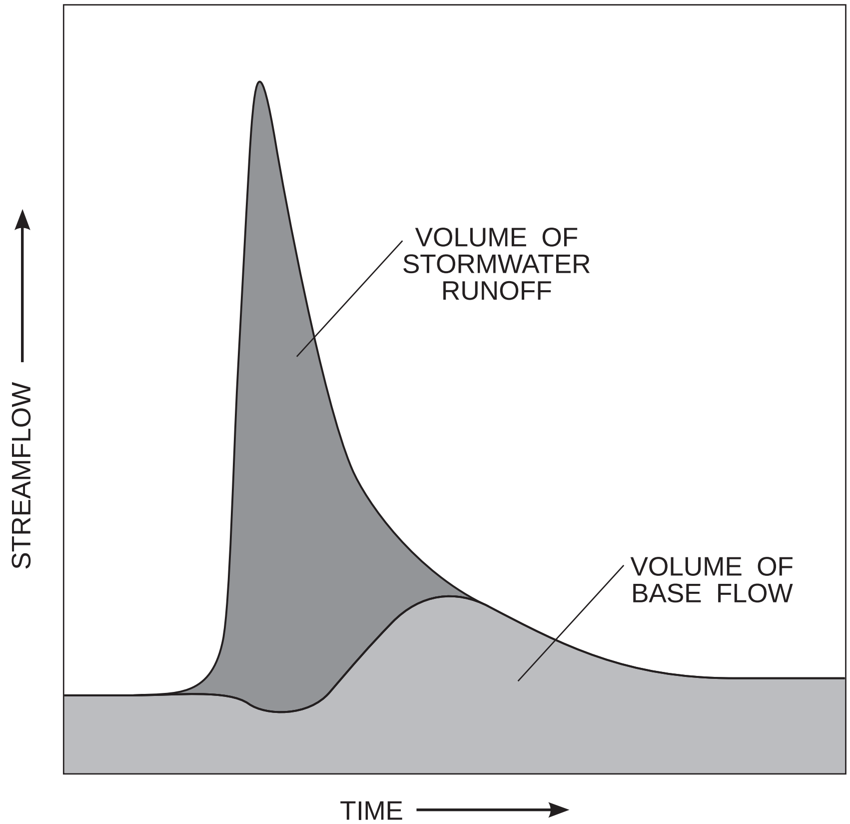


Figure 29. Components of base flow and stormwater runoff in a streamflow hydrograph.

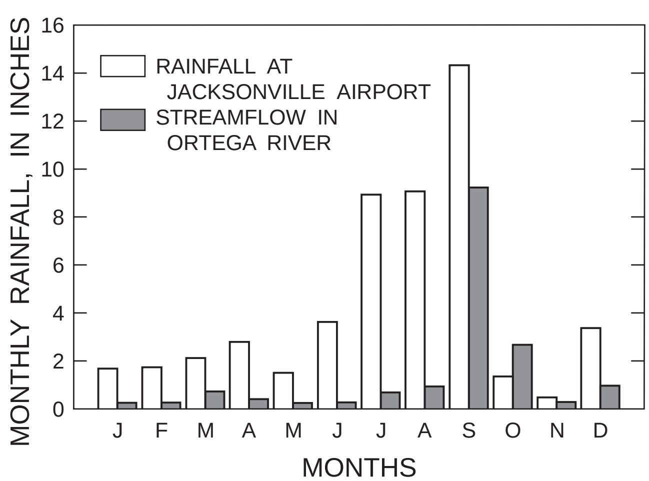


Figure 30. Monthly rainfall at the Jacksonville airport and streamflow in the Ortega River, 1989.

SURFACE-WATER RESOURCES--Continued

Streamflow--Continued

Duration of Flow

A flow-duration curve shows the percentage of time specific flow rates at a given site on a stream were equaled or exceeded. The reliability of duration curves for predicting future flow rates depends on the length and accuracy of the streamflow record and on how well the record represents the long-term climatic conditions in the basin. Duration curves for coastal stream systems are difficult to compile because the cyclic ebb and flow of tides affects streamflow.

The shape of the flow-duration curve is determined by the hydrologic and geologic characteristics of the drainage basin. A steep curve suggests “flashy” streamflow (very rapid increase and decrease of stormwater runoff) that is a characteristic of basins with mostly direct stormwater runoff and little or no base flow. Such conditions are typical of small urban basins. A more gently sloping curve is characteristic of larger rural basins with greater amounts of surface- or ground-water storage.

Flow-duration curves for several streams in Duval County (fig. 31) are based on the mean daily flows for the period of record at the discharge measurement site. The greatest daily streamflows (composed mostly of stormwater runoff) occur least frequently and are directly related to basin size. The Ortega River (site 14, table 5) has the largest drainage basin and the greatest maximum flow; the smallest basin, Cedar Swamp Creek (site 44, table 5), has the smallest maximum flow. Five percent of the time, the flow of the Ortega River exceeds 150 ft^3/s. By comparison, five percent of the time, the flow of Cedar Swamp Creek exceeds 22 ft^3/s. Cedar Swamp and Pablo Creeks are in ground-water discharge areas and a greater amount of their total streamflow is base flow. Thus, their low-flows are proportionally higher, based on their basin size, than the low flows of the Ortega River and Cedar Swamp Creek.

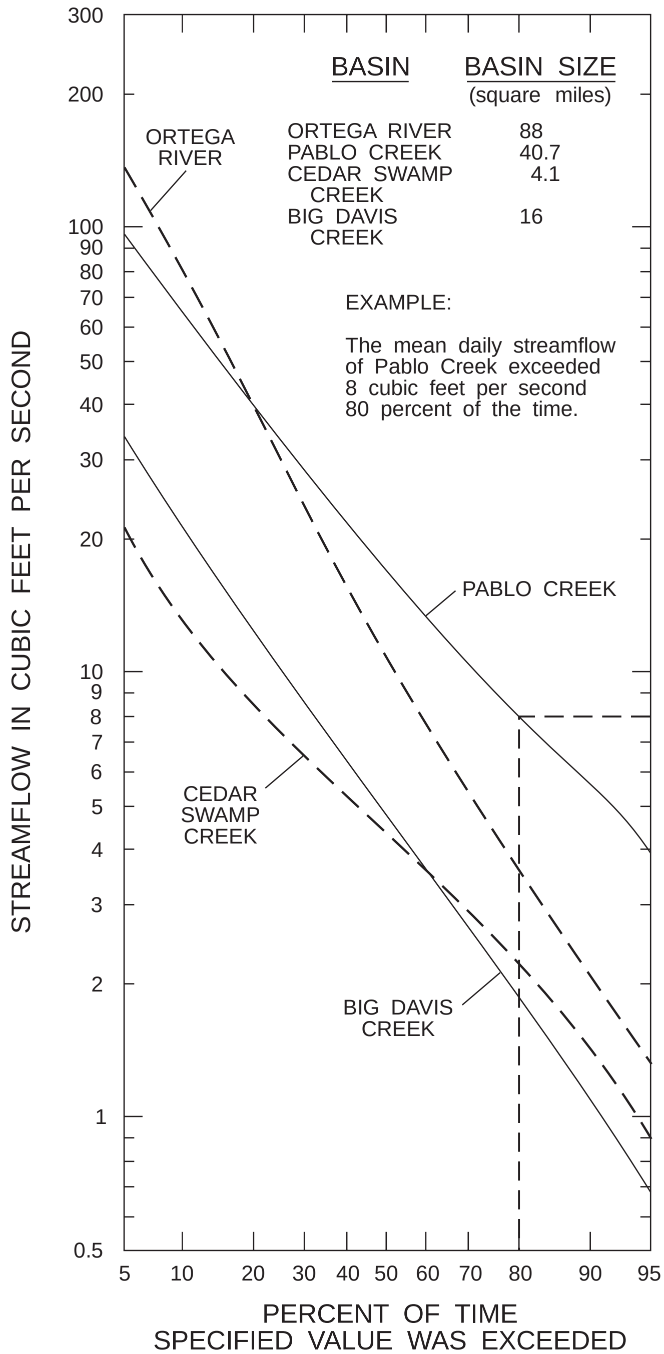


Figure 31. Flow-duration curves for mean daily flow of the Ortega River, Pablo Creek, Cedar Swamp Creek, and Big Davis Creek.

Streamflow--Continued

Flood Frequency

Accurate information about the magnitude and frequency of floods is necessary for the planning, design, and regulation of development along rivers and streams to prevent flood damage to homes and businesses as well as to roads and bridges. The most reliable way to estimate the probabilities of future floods is by frequency analyses of maximum (peak) discharges observed in existing streamflow records. The longer the period of streamflow record available for any site, the more accurate the estimate of future flooding will be.

A flood-frequency curve is a plot of the magnitude and frequency of floods at a particular site. Individual peak discharges for large storms are ranked according to the frequency with which they occur in the record. A curve is mathmetically fitted to the ranked peaks and is extended beyond the observed range of streamflow peaks to estimate the frequency of occurrence of larger streamflows. From this curve, peak streamflow for any recurrence interval can be estimated.

Flood-frequency curves for four streams in Duval County are shown in figure 32 (M. Franklin, U.S. Geological Survey, written commun., 1992). Recurrence intervals from 2 to 100 years are shown. The recurrence interval gives the frequency where a particular discharge can usually be expected. On average, storms with a specified peak streamflow occur once in the interval, as indicated by the curves in figure 32. If the geometry and hydraulic characteristics of the channel and flood plain are known, estimated peak streamflows can be used to predict the extent of flooding.

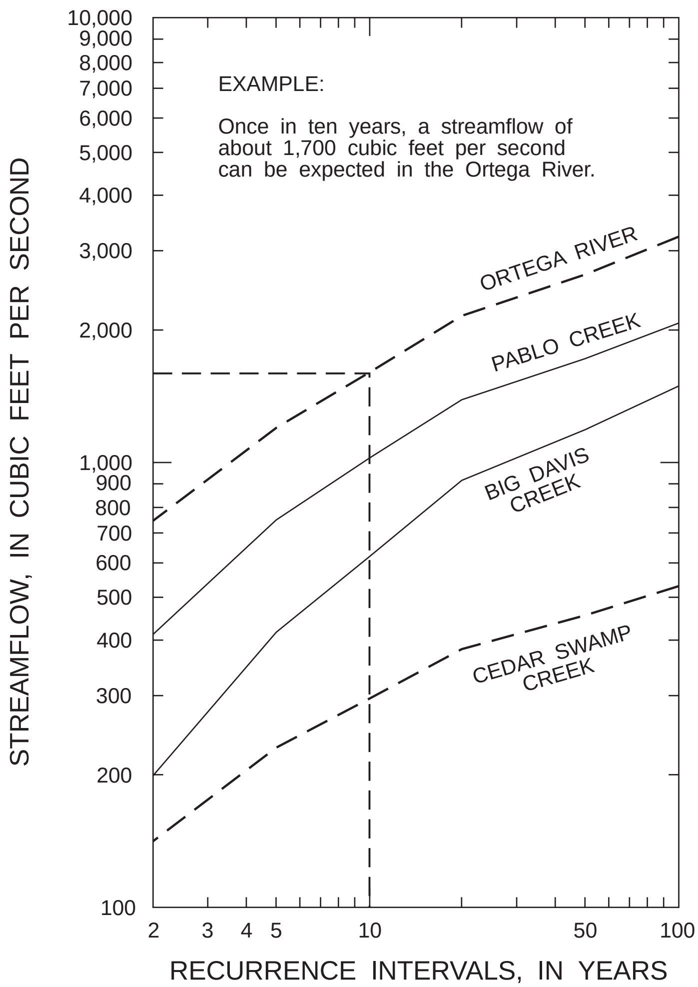


Figure 32. Flood-frequency curves for the Ortega River, Pablo Creek, Cedar Swamp Creek, and Big Davis Creek.

Flood-Prone Areas

In Duval County, flooding is generally restricted to the flood plains of major streams and tributaries, but occasionally after severe storms, poorly drained low-lying areas in smaller basins are flooded. The most severe flooding is usually caused by hurricanes that have generated as much as 9 in. of rainfall on Duval County within a 24-hour period. Flooding can be intensified when heavy rainfall coincides with high, storm-driven tides and saturated soil conditions.

Streamflow records from established gaging stations and other hydrologic data were used to delineate the approximate areal extent of floodwaters that are expected to occur about once in 100 years, called a 100-year flood (fig. 33). Along individual streams, flooding of this extent could occur more or less frequently within any 100-year period.

The most extensive flooding documented in Duval County occurred in September 1964 during Hurricane Dora. Major flooding also occurred during hurricanes in October 1944, October 1950, March 1962, and during the “northeaster” in September 1947.

The extensive flooding during Hurricane Dora resulted from a combination of exceptionally high tides created by the storm and runoff from heavy rainfall. Record flood stages were observed on most streams in the area. Prior to Hurricane Dora, little flood damage had occurred along the lower St. Johns River and its tidal estuaries. Also, before urbanization of the area, few residents were affected by flooding. After Hurricane Dora, the need for more flood data became apparent, and flood profiles were developed by identifying high-water marks and expanding the stream-gaging network.

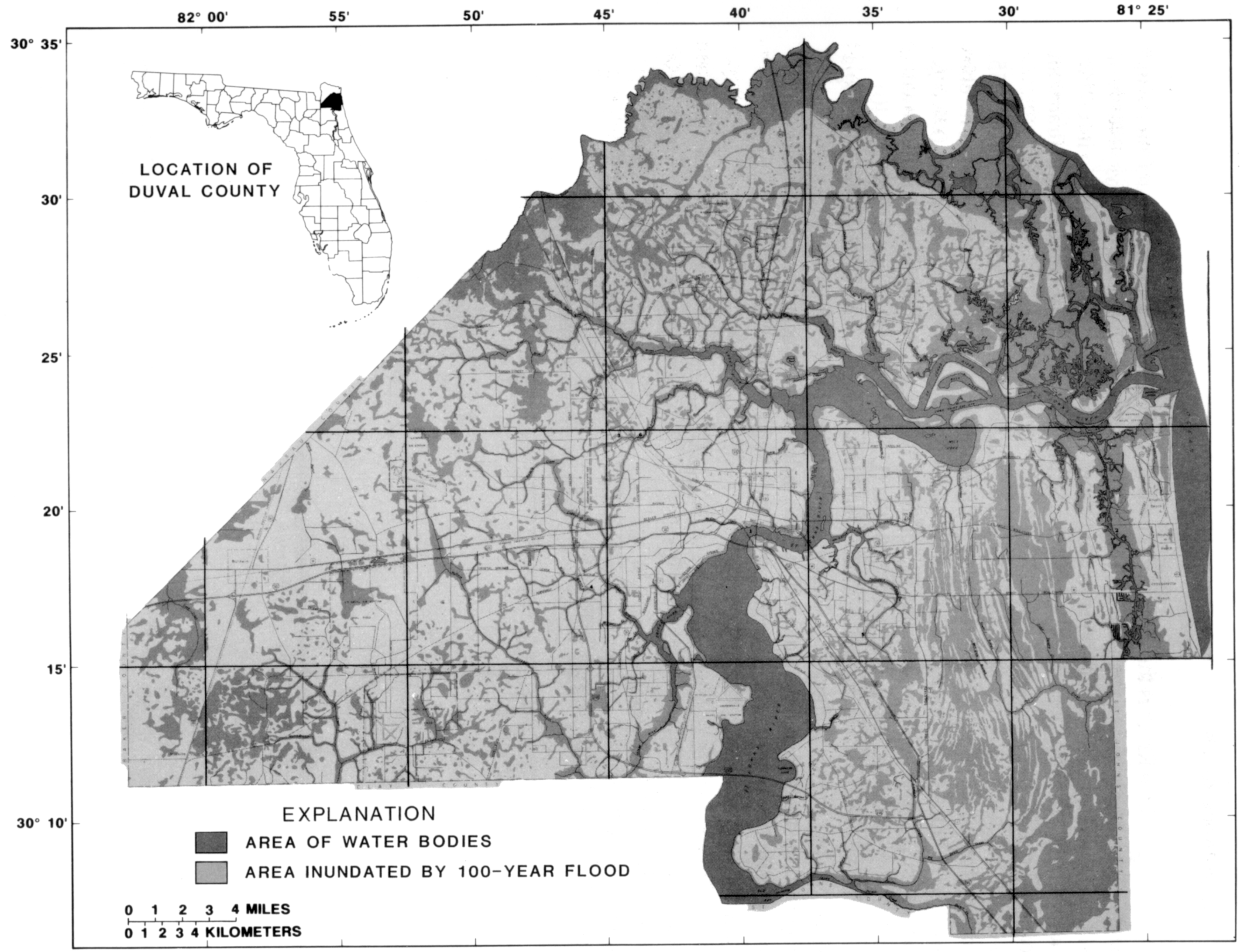


Figure 33. Flood-prone areas of Duval County. (From Stone, Causey, and Tucker, 1975.)

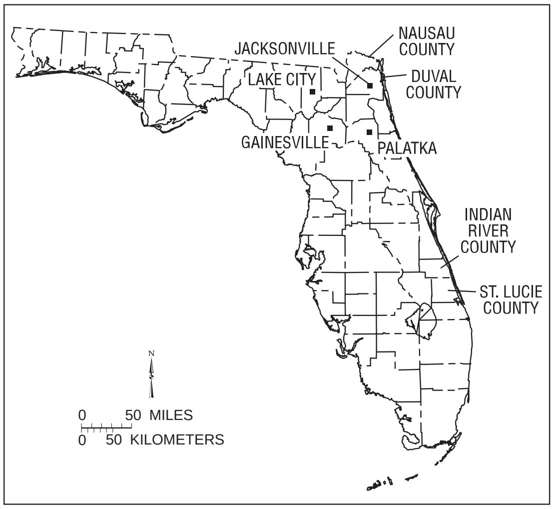
SURFACE-WATER RESOURCES--Continued

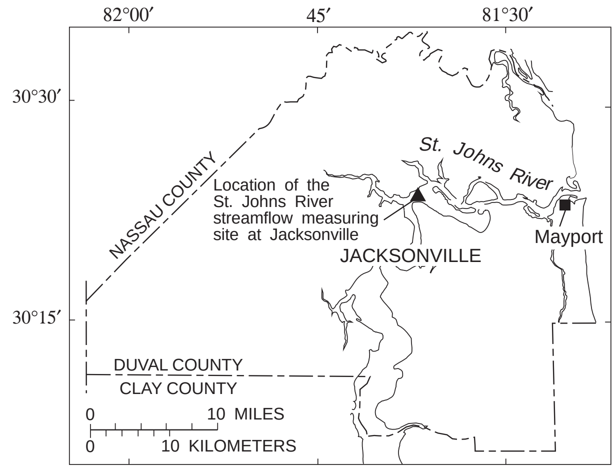
St. Johns River

The St. Johns River is the most prominent surface-water feature of Duval County and is one of the largest rivers in Florida. From its headwaters in the St. Johns River Marsh of St. Lucie and Indian River Counties located about 185 miles of Duval County to its confluence with the Atlantic Ocean at Mayport, the St. Johns is about 400 mi long and drains an area of about 8,750 mi^2.

Although streamflow measurements of the St. Johns River have been made since 1955, the total freshwater discharge of the river is difficult to measure because of the cyclic ebb and flow of tides in the river. The daily downstream flow of the river is about 63,000 ft^3/s and the daily upstream flow is about 57,200 ft^3/s. Therefore, the average net daily downstream flow of the St. Johns is about 5,800 ft^3/s (U.S. Geological Survey, 1991, p. 140)

The variations of velocity, streamflow, and total flow for the St. Johns River during a tidal cycle are shown in figure 34. The net downstream flow is the difference between the measured upstream and downstream flows. In order to make accurate calculations of net flow, a complete record of flow over many tidal cycles is needed.





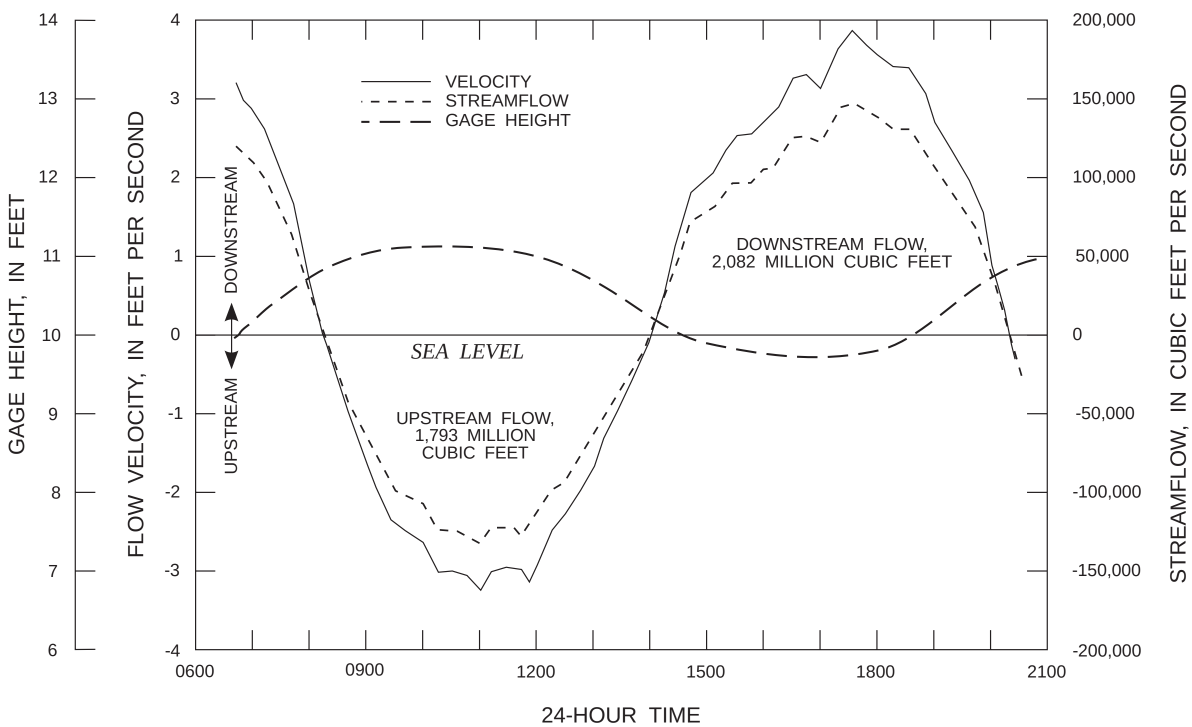


Figure 34. Tidal cycle in the St. Johns River, Jacksonville, showing variations of velocity, streamflow, and total flow. (Modified from Anderson and Goolsby, 1973, fig. 6.)

SURFACE-WATER RESOURCES--Continued

Quality of Surface Water

The chemical quality of surface water in Duval County is generally highly variable and changes in response to stream discharge and tides. In most coastal streams, high tides coupled with low discharge allow seawater to travel upstream. However, during periods of high discharge, or during low tide, freshwater from the upper part of the basins pushes the seawater downstream, resulting in a large decrease in concentrations of many constituents. The quality of water in the St. Johns River is affected significantly by tides. For example, figure 35 shows that the chloride concentration in the St. Johns River at Jacksonville during a tidal cycle ranged from about 5,000 mg/L at low slack tide to about 9,000 mg/L at high slack tide.

In streams unaffected by tidal inflows, the chemical characteristics of surface water can vary considerably in response to varying rates and sources of streamflow. Stormwater runoff, although likely to contain contaminants, is generally less mineralized than the base flow (ground-water discharge) that maintains streamflow in most streams during periods of little or no rainfall. Because stormwater runoff is less mineralized, water in streams is diluted and, consequently, the concentrations of some constituents decline as streamflow increases.

The chemical character of streamwater in any drainage basin is affected by the type of development in that basin. For example, water quality in a rural farming area will differ from that in an urban area. Some constituents, trace elements, for example, might be more concentrated in stormwater runoff from an urban basin than from a rural basin. Thus, water quality in most streams is dynamic, and changes in response to several factors.

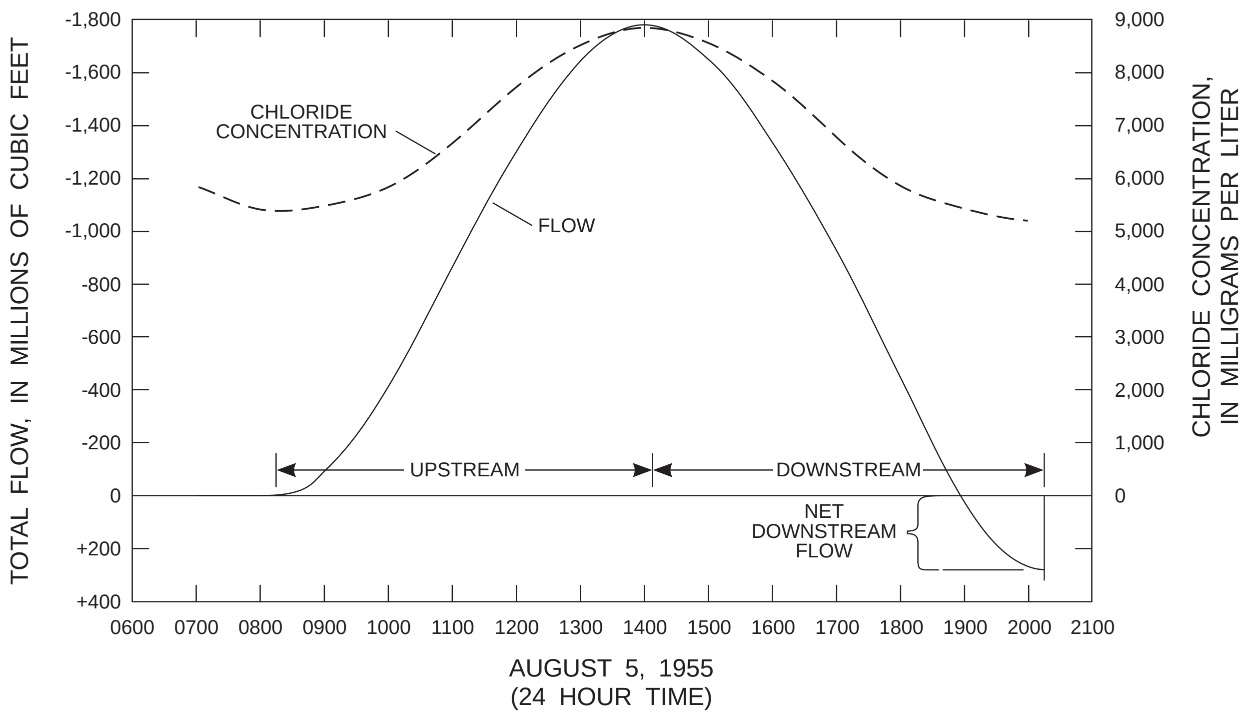


Figure 35. A tidal cycle in the St. Johns River, Jacksonville, showing variations of total flow and chloride concentration with time. (Modified from Anderson and Goolsby, 1973, fig. 6.)

Quality of Surface Water—Continued

Surface-water quality data have been collected by the U.S. Geological Survey at 51 sites in Duval County (fig. 36 and table 6). The period of record and number of samples range widely among the 51 locations, from a single analysis at many locations to 133 analyses for the St. Johns River over a period of 15 years (site 17). Some samples are a composite of the water and stream-bottom material. The earliest data are for April 1956 at sites 3 and 10. The most recent available data were collected from December 1982 until July 1988 at site 47 (Nassau River). As of 1990, no U.S. Geological Survey surface-water quality sampling sites are active in Duval County.

The most commonly analyzed constituents in streamwater are the major ions that include calcium, chloride, magnesium, potassium, sodium, and sulfate. Less frequently, samples are analyzed for nutrients (nitrogen and phosphorous) and trace elements, such as arsenic, cadmium, chromium, copper, iron, lead, mercury, and zinc. At some locations, samples of bottom sediments were analyzed for nutrients, trace elements, and organic compounds.

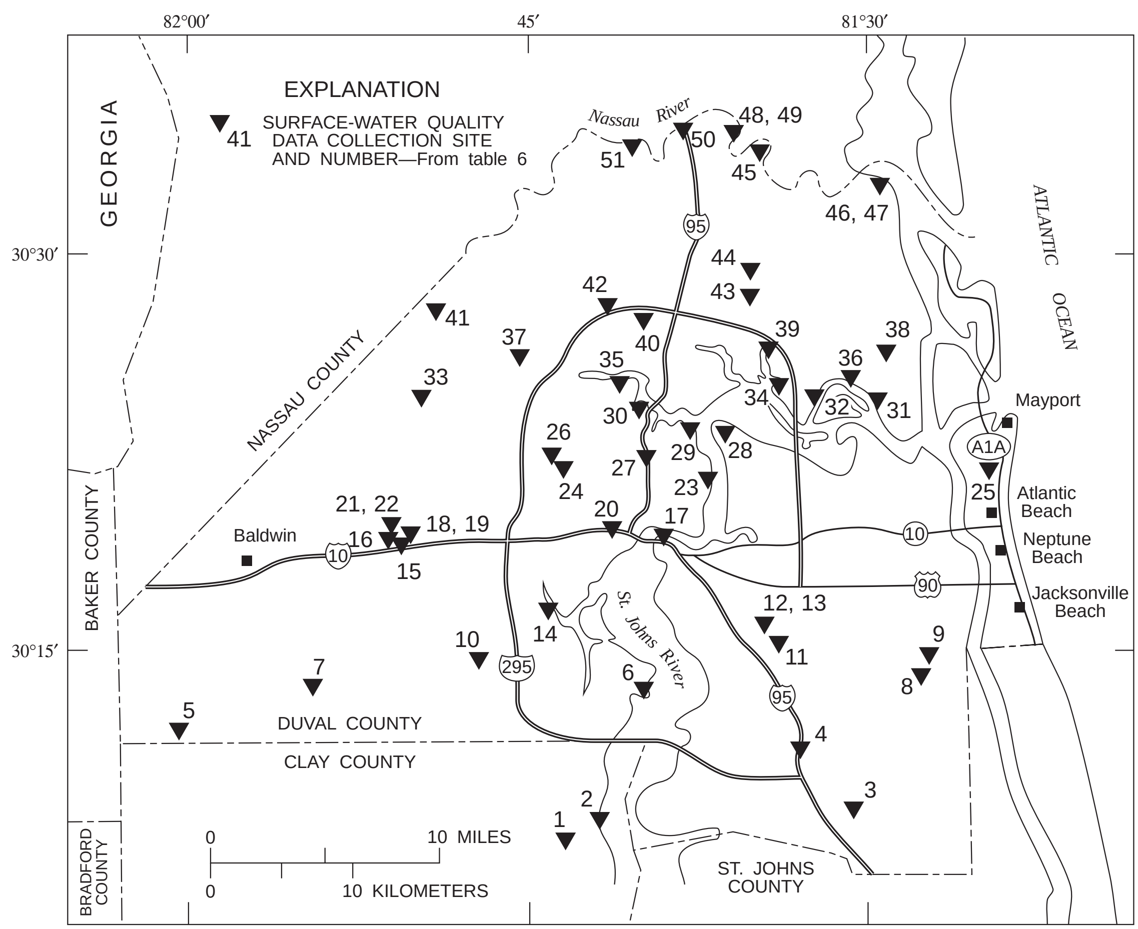


Figure 36. Surface-water quality data-collection sites in Duval County and vicinity.

Table 6. Surface-water quality data-collection sites in Duval County and vicinity

[Site numbers refer to figure 36; site identification number is a unique site identifier]

Site No.	Site identification No.	Site name	Number of analyses
1	02246210	Doctors Lake	2
2	02246211	Doctors Inlet	1
3	02246150	Big Davis Creek	105
4	02246100	Julington Creek	22
5	02245850	Long Branch	13
6	02246250	St. Johns River	27
7	02245900	Yellow Water Creek	13
8	02246828	Pablo Creek	12
9	02246832	Cedar Swamp Creek	11
10	02246300	Ortega River	124
11	3015270813455301	Pottsburg Creek	9
12	02246515	Pottsburg Creek	1
13	02246550	Pottsburg Creek	14
14	02246460	Williamson Creek	1
15	301901081512300	McGirts Creek	1
16	301910081511400	Whitehouse Branch	31
17	02246500	St. Johns River	133
18	02246277	Whitehouse Branch	1
19	301923081512900	McGirts Creek	1
20	02246497	McCoy Creek	1
21	301948081514701	McGirts Creek	9
22	02246280	McGirts Creek	1
23	02246530	St. Johns River	17
24	02246700	Little Sixmile Creek	15
25	302200081242600	Borrow Pit Lake	1
25	302200081243000	Borrow Pit Lake	1
25	302201081242400	Borrow Pit Lake	1
25	302204081242400	Borrow Pit Lake	1
25	302210081243000	Borrow Pit Lake	1
25	302211081242200	Borrow Pit Lake	1
26	02246650	Sixmile Creek	15
27	02246732	Moncrief Creek	1
28	02246737	St. Johns River	1
29	302335081375001	Trout River	18
30	02246721	Ribault River	1
31	302420081303001	Clapboard Creek	5
32	302423081331001	Nichols Creek	6
33	302425081503301	Trout River	10
34	302500081345001	Dunns Creek	1
35	02246621	Trout River	1
36	302513081315101	Browns Creek	6
37	02246600	Trout River	6
38	302607081301701	Clapboard Creek	6
39	302610081350501	Dunns Creek	6
40	02246750	Cedar Creek	10
41	02231280	Thomas Creek	111
42	302754081422601	Cedar Creek	4
43	02246800	Dunns Creek	13
44	302901081360901	Dunns Creek	9
45	303334081354700	Nassau River	38
46	303347081300400	Nassau River	45
47	303357081301500	Nassau River	1
48	02231289	Nassau River	1
49	303429081363200	Nassau River	98
50	303432081384600	Nassau River	18
51	303453081410900	Nassau River	21

Quality of Surface Water--Continued

Specific Conductance

Specific conductance is the most frequently determined property of surface water in Duval County. Conductance, the ability of water to carry an electrical current, depends on the dissolved-solids concentration of the water. The dissolved-solids content affects the suitability of water for many uses, including drinking. In areas affected by tides, chloride is usually the dissolved constituent present in the highest concentration. Specific conductance, which is a fast and inexpensive measurement, is an indicator of the concentrations of dissolved solids.

The greatest values and variations in specific conductance of surface water occur at sites affected by seawater inflow, such as the St. Johns and Nassau Rivers. In both rivers, specific conductance can vary by nearly a factor of 100. The variation of specific conductance at inland sites not affected by seawater, such as Yellow Water and Big Davis Creeks, is small in comparison.

The fluctuation of specific conductance in the St. Johns River at Jacksonville during several months in 1966-67 ranged from about 500 to more than 31,000 μS/cm at 25 °C (fig. 36). This range is indicative of the volume and upstream extent of tidal flow and the amount of freshwater discharge of the river. Smaller variations due to daily tidal cycles are not apparent in figure 37 that shows only the maximum specific conductance recorded each day.

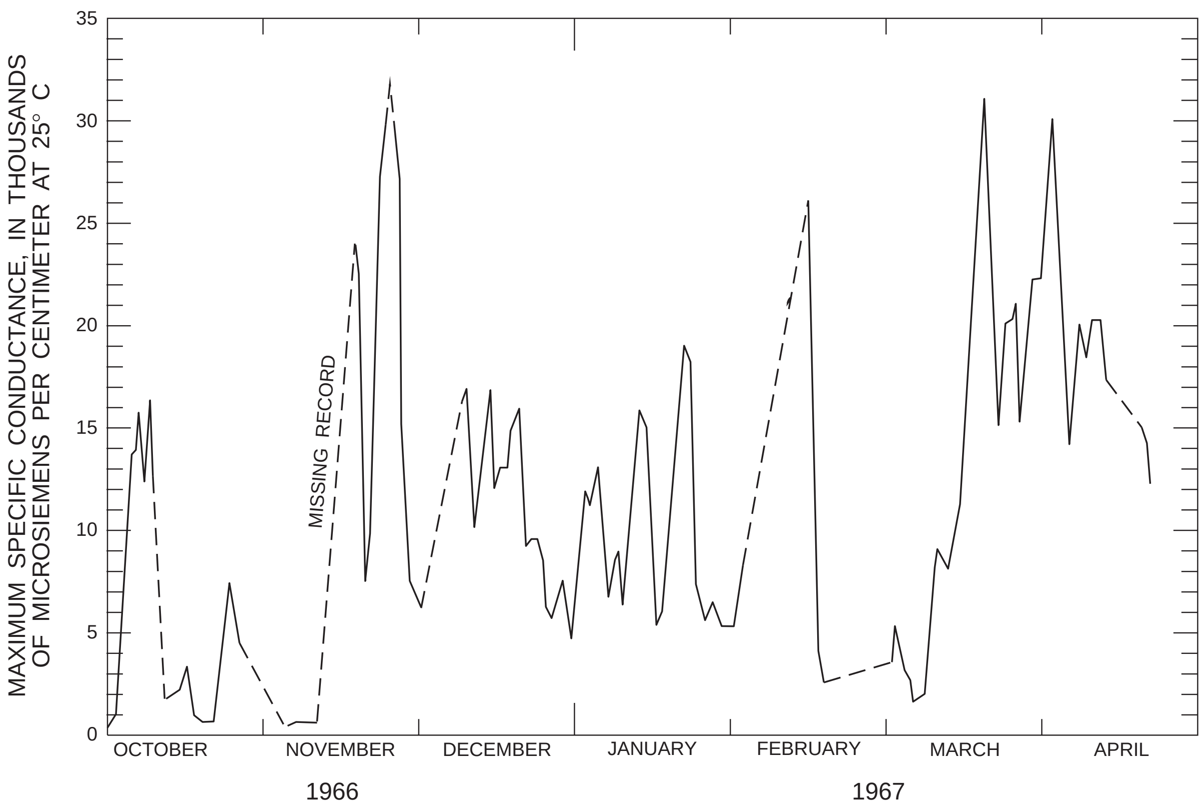


Figure 37. Daily maximum specific conductance of the St. Johns River, Jacksonville, October 1966 to April 1967. (From Anderson and Goolsby, 1973, fig. 24.)

Quality of Surface Water--Continued

Chloride

The chloride concentration of tidally affected streams in Duval County has been frequently determined. Although surface water is not used for drinking water in Duval County, high concentrations of chloride could make the water unusable for cooling purposes or industrial processing. The locations of surface-water data collection sites in Duval County with more than five chloride analyses are shown in figure 38 and the data are summarized in table 7.

Chloride concentrations of all inland streams in Duval County not affected by tidal fluctuations are less than the recommended 250-mg/L limit for drinking water set by the U.S. Environmental Protection Agency (1988) and the Florida Department of Environmental Regulation (1991). Trout River (site 33), having a median chloride concentration of 9 mg/L, is typical of inland streams that are not affected by tides or by the inflow of highly mineralized ground water or industrial and domestic wastewater. At sites such as Julington Creek (site 4), the low median chloride concentration of 17 mg/L indicates a place beyond the reach of most tidal fluctuation, but the maximum chloride concentration of 210 mg/L indicates that the site could be affected by seawater during extreme low stream discharge and high-tide conditions.

Table 7. Chloride concentrations at selected surface-water sampling sites in Duval County

[Site numbers refer to figure 38 and are listed from highest to lowest chloride concentration. Site identification number is a unique site identifier. Data are for sites with more than five analyses. Concentrations are in milligrams per liter]

Site No.	Site identification No.	Site name	Number of analyses	Chloride concentrations		
				Minimum	Median	Maximum
38	302607081301701	Clapboard Creek	6	5,200	9,100	12,000
36	302513081315101	Browns Creek	6	5,700	8,950	10,000
32	302423081331001	Nichols Creek	6	5,300	8,550	10,000
23	02246530	St. Johns River	11	258	3,700	9,500
17	02246500	St. Johns River	109	69	2,800	11,000
39	302610081350501	Dunns Creek	6	760	2,200	7,800
6	02246250	St. Johns River	18	76	500	6,900
24	02246700	Little Sixmile Creek	14	12	34	80
11	301527081345301	Pottsburg Creek	8	17	28	46
9	02246832	Cedar Swamp Creek	9	17	23	38
13	02246550	Pottsburg Creek	13	9	22	30
43	02246800	Dunn Creek	13	11	20	252
44	302901081360901	Dunns Creek	9	18	20	21
40	02246750	Cedar Creek	8	9	20	23
8	02246828	Pablo Creek	11	11	17	22
4	02246100	Julington Creek	20	2	17	210
5	02245850	Long Branch	11	4	13	20
26	02246650	Sixmile Creek	14	6	13	35
7	02245900	Yellow Water Creek	11	5	12	18
3	02246150	Big Davis Creek	16	8	12	18
21	301948081514701	McGirts Creek	8	8	12	14
33	302425081503301	Trout River	8	8	9	12
10	02246300	Ortega Creek	26	5	9	14
41	02231280	Thomas Creek	20	5	6	9

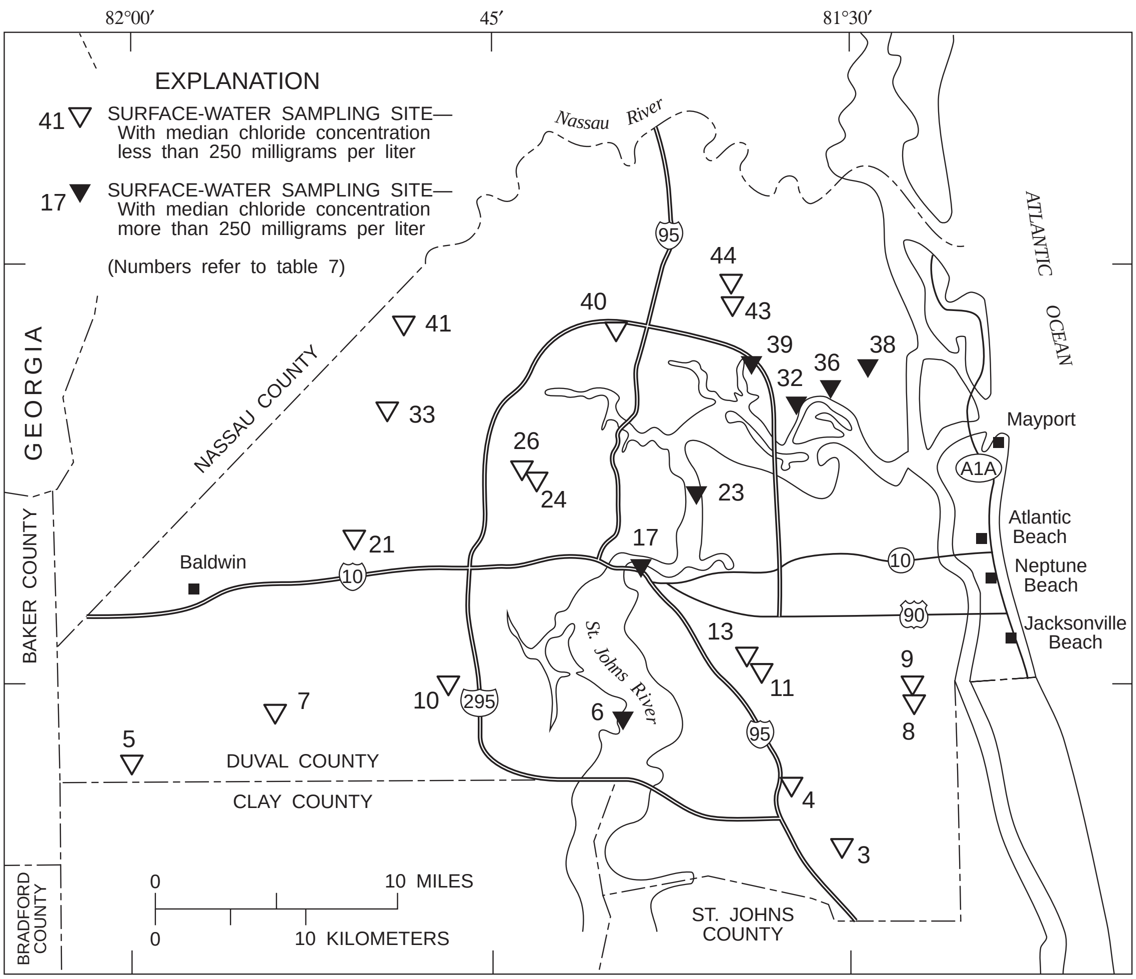


Figure 38. Surface-water sites sampled for chloride concentration.

SURFACE-WATER RESOURCES--Continued

Quality of Surface Water--Continued

Nutrients

Nitrogen and phosphorous are nutrients that can promote undesirable growth of algae and rooted aquatic plants. The most common sources of nitrogen and phosphorus are industrial and domestic wastewater and fertilizers. The location of surface-water sites with more than five nutrient analyses are shown in figure 39. A summary of the data is given in table 8.

The low maximum nitrate concentrations observed (0.43 mg/L or less) at Cedar Creek (site 40), Trout River (site 37), Thomas Creek (site 41), Yellow Water Creek (site 7), Big Davis Creek (site 3), and Dunns Creek (site 43) probably represent natural conditions where there is little or no wastewater discharge or runoff from fertilized lands. Higher concentrations could be related to inflow or seepage of wastewater or fertilizer runoff, especially at the sites where nitrate concentrations exceed 2 mg/L. The highest observed orthophosphate concentration, 2.6 mg/L at Julington Creek (site 4), could be due to wastewater discharge and fertilizer-rich runoff.

Unlike chloride, the concentration of dissolved nutrients in streams does not increase because of tidal seawater inflow. On the contrary, seawater dilutes streamwaters that have high nutrient concentrations. The highest concentrations and the greatest variation of dissolved nitrate occur in the St. Johns River (site 17) and Pottsburg Creek (site 13). In Pottsburg Creek, the nitrate variations are probably caused by changes in the rates of inflow of treated wastewater and runoff that carries dissolved nutrients from fertilizers. However, a combination of changes in the rates of wastewater inflow and effects of tides probably caused the variations in the St. Johns River.

Table 8. Dissolved nutrient concentrations at selected surface-water sampling sites in Duval County

[Site numbers refer to fig. 39. Site identification number is a unique site identifier. Data are for sites with more than five analyses. Concentrations are in milligrams per liter. --, no data]

Site No.	Site identification No.	Site name	No. of analyses	Nitrate nitrogen			No. of analyses	Orthophosphate phosphorus		
				Minimum	Medium	Maximum		Minimum	Medium	Maximum
3	02246150	Big Davis Creek	16	0.00	0.03	0.27	--	--	--	--
4	02246100	Julington Creek	15	.00	.07	1.50	9	0.13	0.68	2.60
5	02245850	Long Branch	11	.00	.07	.90	--	--	--	--
6	02246250	St. Johns River	18	.00	.08	.63	18	.02	.06	.14
7	02245900	Yellow Water Creek	12	.00	.03	38	--	--	--	--
8	02246828	Pablo Creek	--	--	--	--	10	.08	.13	.28
9	02246832	Cedar Swamp Creek	--	--	--	--	8	.16	.54	.88
10	02246300	Ortega Creek	27	.00	.09	1.17	--	--	--	--
11	301527081345301	Pottsburg Creek	--	--	--	--	9	.02	.10	.56
13	02246550	Pottsburg Creek	13	.00	.72	2.71	--	--	--	--
17	02246500	St. Johns River	61	.00	.25	2.48	71	.02	.11	.23
21	301948081514701	McGirts Creek	--	--	--	--	9	.03	.04	.10
23	02246530	St. Johns River	11	.00	.14	1.17	9	.04	.13	.21
24	02246700	Little Sixmile Creek	13	.00	.18	.99	--	--	--	--

Table 8. Dissolved nutrient concentrations at selected surface-water sampling sites in Duval County--Continued

[Site numbers refer to fig. 39. Site identification number is a unique site identifier. Data are for sites with more than five analyses. Concentrations are in milligrams per liter. --, no data]

Site No.	Site identification No.	Site name	No. of analyses	Nitrate nitrogen			No. of analyses	Orthosphosphate phosphorus		
				Minimum	Medium	Maximum		Minimum	Medium	Maximum
26	02246650	Sixmile Creek	13	.00	.05	.88	--	--	--	--
33	302425081503301	Trout River	--	--	--	--	9	.04	.16	.32
37	02246600	Trout River	6	.00	.08	.43	--	--	--	--
40	02246750	Cedar Creek	7	.00	.09	.29	--	--	--	--
41	02231280	Thomas Creek	21	.00	.05	.41	--	--	--	--
43	02246800	Dunns Creek	13	.00	.02	.32	--	--	--	--
44	302901081360901	Dunns Creek	--	--	--	--	9	.16	.47	.55
45	303334081354700	Nassau River	--	--	--	--	6	.05	.10	.30
46	303347081300400	Nassau River	--	--	--	--	14	.07	.10	.28
49	303429081363200	Nassau River	--	--	--	--	32	.05	.10	.98
50	303432081384600	Nassau River	--	--	--	--	12	.02	.05	.14
51	303453081410900	Nassau River	--	--	--	--	13	.10	.14	.33

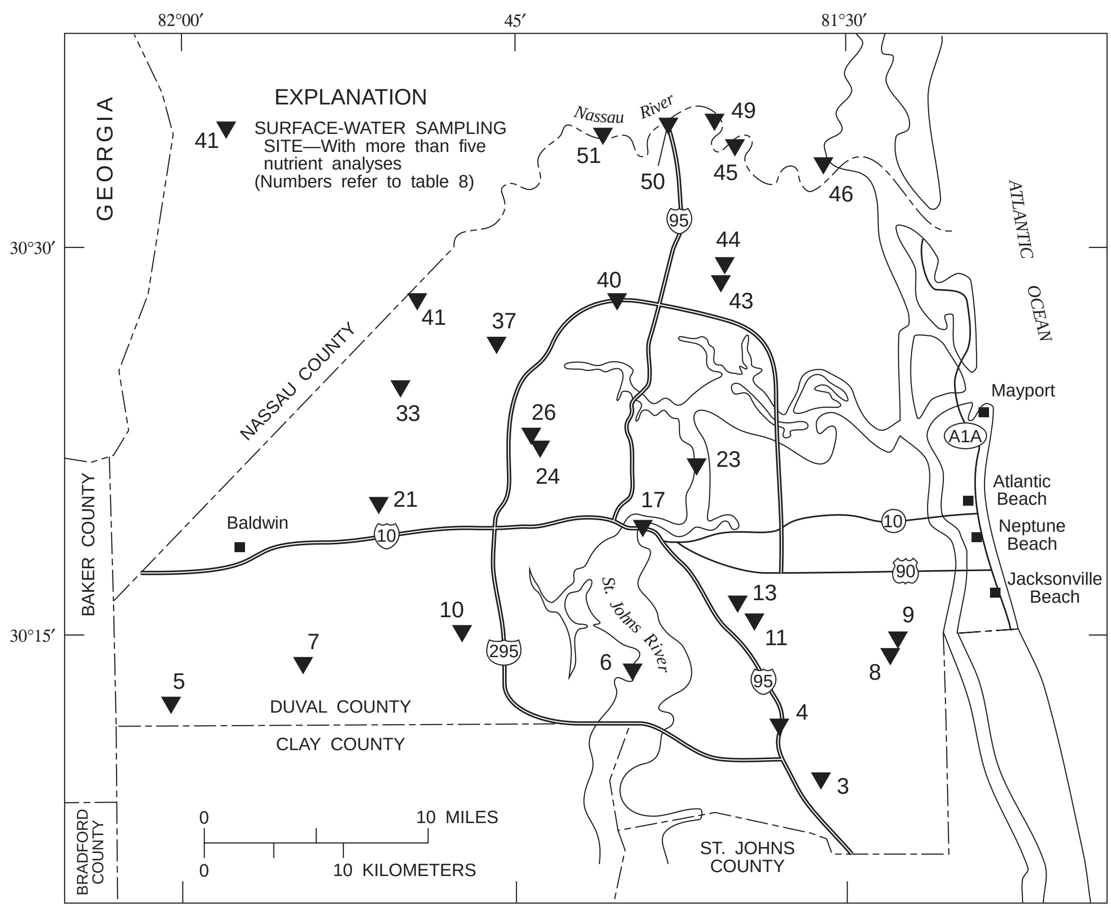


Figure 39. Surface-water sampling sites with more than five nutrient analyses.

AVAILABILITY OF ADDITIONAL INFORMATION

The U.S. Geological Survey (USGS) cooperates with the city of Jacksonville and other local, State, and Federal agencies to provide water-resources data that can be used for management and planning (table 9). Program development and planning in the USGS is strongly influenced by changes in data needs and water-related problems. The USGS programs in Duval County are of three major types: (a) hydrologic data collection and dissemination, (b) problem-oriented water-resources appraisals, and (c) hydrologic research. The programs are strongly interrelated. For example, theories that come from research are the foundation of data collection and problem-oriented water-resources appraisals, and data collection is a major component of all water-resources appraisals and most of the research studies.

Long-term programs include the Federal-State cooperative programs; coordination of water-data acquisition; assistance to other agencies; the research program; the water-use information program; and the hydrologic data-collection program, including the National Stream Quality Accounting Network and the National Benchmark Program. These programs provide the data and research needed for topical programs.

Topical programs are designed to provide critically needed information on issues of major and immediate concern. These programs include hazardous-waste hydrology; regional aquifer systems analysis; acid rain; land subsidence and flood hazards; and a nationwide water-quality assessment.

Technical-assistance programs include the instrumentation program, a central water-quality laboratory, and the National Training Center. These programs are internal to the USGS but contribute significantly to the continuing development of hydrologic capabilities and thus to the success of the mission of the USGS.

The results of virtually all of the water-resources activities of the U.S. Geological Survey are released in reports and are available to water agencies and the public. Most Survey reports on the water resources of Florida are available for reference at USGS offices, the offices of Florida’s five water management districts, and at libraries of the State University system.

Table 9. Federal, State, and local agencies involved in the investigation of water resources in Duval County

U.S. Geological Survey 3728 Phillips Highway, Suite 222 Jacksonville, Florida 32207 (904) 398-2121	Florida Department of Environmental Protection 7825 Baymeadows Way, Suite 200 Jacksonville, Florida 32256-7577
City of Jacksonville Bio-Environmental Services Division 421 W. Church Street, Suite 412 Jacksonville, Florida 32202 (904) 630-3666	Florida Department of Natural Resources Marine Patrol 2510 2nd Avenue, North Jacksonville Beach, Florida 32250 (904) 359-6580
U.S. Army Corps of Engineers 400 W. Bay Street Jacksonville, Florida 32250 (904) 791-2234	St. Johns River Water Management District P.O. Box 1429 Palatka, Florida 32077 (904)329-4500
Jacksonville Electric Authority Environmental Affairs 21 W. Church Street, 8th Floor Jacksonville, Florida	City of Jacksonville Beach P.O. Box 51389, 11 N., 3rd Street Jacksonville Beach, Florida 32250 (904) 249-2381
Florida Geological Survey 903 W. Tennessee Street Tallahassee, Florida 32304 (904) 488-9380	Federal Emergency Management Agency 1371 Peachtree St., NE, Suite 735 Atlanta, Georgia 30309 (904) 853-4406
Florida Game and Fresh Water Fish Commission 4005 South Main Street Gainesville, Florida 32601	

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