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Florida's Water Resources[1]

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Introduction

Water is important to Floridians for household uses, to industry for cooling and processing, to agriculture for irrigation, and to recreationists for boating and swimming. Water sustains wildlife and is an integral part of Florida's environment. Rates of water use, especially freshwater for public supplies and for irrigation, have increased steadily over the years (Marella 2004). Such increases in the use of Florida's freshwater have caused many Floridians to pay closer attention to plans for further development of water supplies. A better understanding of Florida's water resources is a first step toward assuring adequate freshwater supplies.

The Hydrologic Cycle

Where does water come from? How much water is available? These questions pertain to the fundamental nature of water as it "cycles" through the environment. The continual circulation/distribution of water on the surface of the land, in the ground, and in the atmosphere is referred to as the "hydrologic cycle" or "water cycle." There are five basic processes in the hydrologic cycle: 1) condensation, 2) precipitation, 3) infiltration, 4) runoff, and 5) evapotranspiration (Figure 1). These processes can occur at the same time and, except for precipitation, continuously.

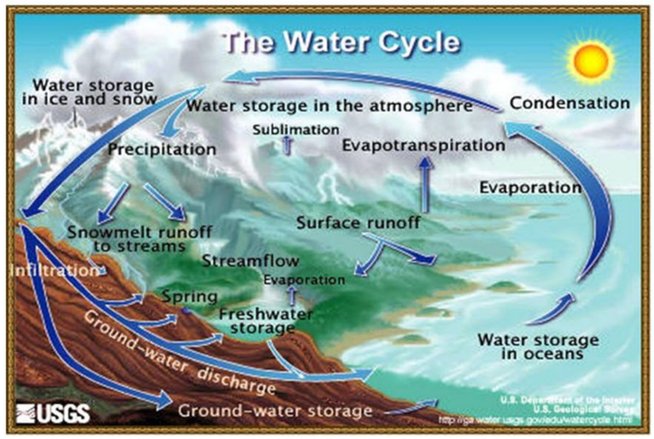

Figure 1. Water cycle (Source: USGS 2008).

Condensation occurs as moist air cools. The cooling water vapor at first forms tiny droplets that cling to dust particles in the air and then forms clouds or fog. As the droplets increase in size, they gain weight, causing them to fall as rain (or as snow, hail, or sleet, depending upon conditions). When raindrops or snowflakes fall, the second stage of the hydrologic cycle, precipitation, has started. Rainfall varies in

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amounts and in intensity from one season to another and from one region to another. Differences in rainfall patterns result from general differences in climate across time and space. When rainfall reaches the Earth's surface, it can do one of three things: 1) enter the ground (infiltration), 2) collect into surface streams and lakes (runoff), or 3) return to the atmosphere as water vapor (evapotranspiration). The phases of runoff and infiltration are highly interrelated and are influenced by the form of precipitation, the type and amount of vegetation upon which the precipitation falls, topography, and permeability of the soil.

When water infiltrates the soil, it first enters the surface zone where it can be absorbed by plant roots. Some soil types (e.g., sandy soils) do not retain water readily. When this is the case, the water quickly percolates (seeps) downward until it encounters a stratum (zone) where the pores in the soil or rocks are saturated. Water in this zone of saturation is called groundwater. Underground layers of porous material that are saturated with water are called aquifers. The water level can rise and fall in shallow or surface aquifers, depending upon local rainfall conditions. When a shallow groundwater aquifer is underlain by a stratum of low permeability called an aquiclude, water is forced to move laterally through the aquifer and emerge into a surface stream or lake. On the other hand, when groundwater levels are low, water may flow in the opposite direction – from surface streams and lakes into the shallow aquifer.

Sometimes freshwater exists deep underground in "confined aquifers," so-called because the water-bearing aquifer is confined below a stratum of low permeability. A confined aquifer can sometimes hold water under sufficient pressure such that water will rise above the confining layer when a tightly cased well penetrates the aquiclude. These are known as "artesian aquifers." When tapped, they sometimes produce free-flowing artesian wells. Naturally occurring springs also result from this same phenomenon.

Water enters the aquifer through recharge areas which are zones where the water-bearing stratum emerges at the surface or where the confining layer is broken up by faults or natural sinkholes that allow downward infiltration of water. Recharge areas may be some distance away from the spring or well that is fed by the aquifer.

Water that does not enter the ground collects in rivers and streams, comprising the runoff phase of the hydrologic cycle. This water evaporates, percolates into the ground, or flows out to sea. Some of the surface water is tapped as a water supply for agricultural, residential, or industrial use.

An additional stage of the hydrologic cycle is evapotranspiration. "Evaporation" is the process by which water is changed into its gaseous form (water vapor). "Transpiration" is the process whereby moisture in plants is returned to the atmosphere through plant leaves. To prevent wilting, plants must absorb water through their roots to replenish water lost through evapotranspiration.

Florida's Hydrologic Cycle

This overview of Florida's water resources is organized with reference to the hydrologic cycle. Describing the resource in this fashion provides a sense of where the water is at any point in time and a perception of how much water is accessible in each phase of the hydrologic cycle.

Rainfall in Florida

Florida receives an average of 54 inches of rainfall each year, which is second only to Louisiana. In other comparisons, rainfall averages 30 inches per year for the nation as a whole, and 9 inches per year in Nevada, which is the driest state in the nation.

Total rainfall for Florida can vary considerably from one part of the state to another, from one season of the year to another, and from one year to the next. Florida's highest mean annual rainfall occurs in the Panhandle (in northwestern Florida) and in Palm Beach and Broward Counties (in southeastern Florida), with averages exceeding 60 inches per year (Figure 2). The Florida Keys are the region of lowest mean annual rainfall, averaging 40 inches per year, followed by Tampa (in southwestern Florida) with an average of 44 inches per year.

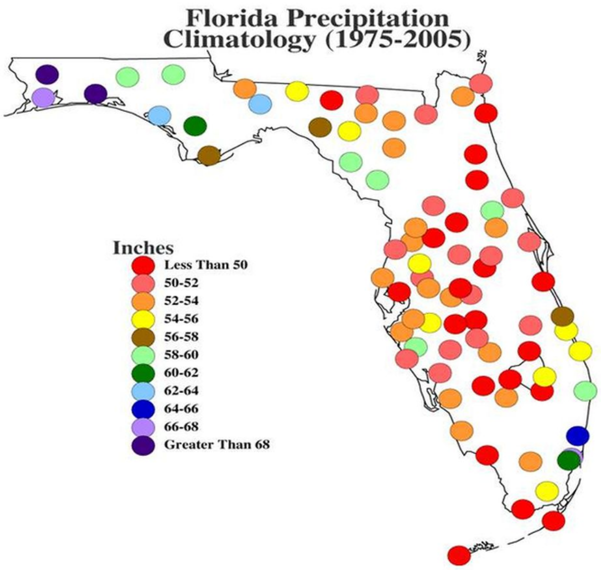

Figure 2. Mean annual rainfall in Florida (Source: Melissa Griffin, Assistant State Climatologist for Florida, Florida State University).

Seasonal variations in rainfall are evident. Traditionally, summer is the wettest season in Florida, with 55% of the annual rainfall occurring during the June to September "wet season." However, this pattern of seasonal precipitation varies. And while precipitation during the wet season is always greater than that during the dry season (December to March), the difference is only 40% in the Panhandle, but about 400% in South Florida.

Annual variations in rainfall can be extreme. For example, in 1953, rainfall in Pensacola measured about 90 inches while, in 1954, it measured less than 29 inches. Key West registered a maximum annual rainfall of 63 inches in 1969 and a minimum of 20 inches in 1974. Similar extremes in annual rainfall have been recorded for other parts of the state, and are responsible for the drought conditions of some years and the periods of frequent flooding in other years.

Tropical storms are normal in Florida, with some delivering over 10 inches of rainfall during a 24-hour period, which usually causes flooding. The highest state record of almost 39 inches in 24 hours was registered in Yankeetown (in west-central Florida) during Hurricane Easy in 1950.

Flow characteristics of streams, groundwater recharge, and levels of lakes and reservoirs are all functions of the amount and intensity of rainfall. Plans for water supply development and flood control must take into account short- and long-term variations in rainfall volume.

Outflow: Rainfall Minus Evapotranspiration

The difference between rainfall on an area and evaporation from that area is called "outflow." Outflow is the total amount of water that is available as surface or ground flow from an area. The potential for evaporation depends upon atmospheric conditions such as temperature and wind speed. Evaporation is also affected by factors such as soil permeability, the type and amount of vegetative ground cover, and slope of the land. For example, outflow is relatively high in parts of northwestern Florida. This area is well-drained and, compared with other parts of Florida, has steep slopes. Much of the area is covered by permeable soils that readily pass rainfall into a shallow aquifer. An aquiclude (impermeable ground layer) underlying the shallow aquifer in this area ensures that most of the outflow appears in streams. On the other hand, for portions of extreme southern Florida, where topography is flat and drainage is poor, water is readily available for evaporation, and outflow is relatively low.

A water deficiency exists when potential evapotranspiration (i.e., moisture demand by plants) exceeds actual evapotranspiration (i.e., soil moisture that is available for plants to use). Monthly climatic water budgets indicate that, in Key West, water deficiency persists throughout the year while, in the Panhandle, a deficit rarely happens. In the rest of the state, deficiencies are common in winter and spring.

Runoff

Runoff is that part of water outflow that appears in surface streams. It includes water that flows directly into gullies, creeks, and rivers, as well as water that emerges into surface streams from underground aquifers (such as through springs).

Runoff averages only 0 to 10 inches per year in much of the extreme southern part of Florida, from

20 to 40 inches in parts of the Panhandle, and 10 to 20 inches per year across much of the rest of the state. Estimated median runoff in the state as a whole is about 14 inches per year.

Runoff is readily observed by Florida citizens as several major streams and rivers (Figure 3). Of Florida's five largest streams, four are in the drainage basins of northern Florida. They are the Apalachicola, Suwannee, Choctawhatchee, and Escambia Rivers. The fifth largest stream is the St. Johns River that flows north from headwaters near Vero Beach to the Atlantic Ocean at Jacksonville in northern Florida.

Georgia-Florida line. The Apalachicola River drains 17,200 square miles in Alabama and Georgia, and 2,400 square miles in Florida. From 1977 to 1992, mean daily discharge of the river at Sumatra (a midpoint of river length in Florida) was about 20,000 cubic feet per second (12,926 million gallons per day), with a variation between approximately 6 and 180,000 cubic feet per second (from 4 to 116,337 million gallons per day).

The Suwannee River (Florida's second-largest river) drains about 11,000 square miles from its headwaters in southern Georgia to its mouth at the Gulf of Mexico. At the measuring station in Wilcox

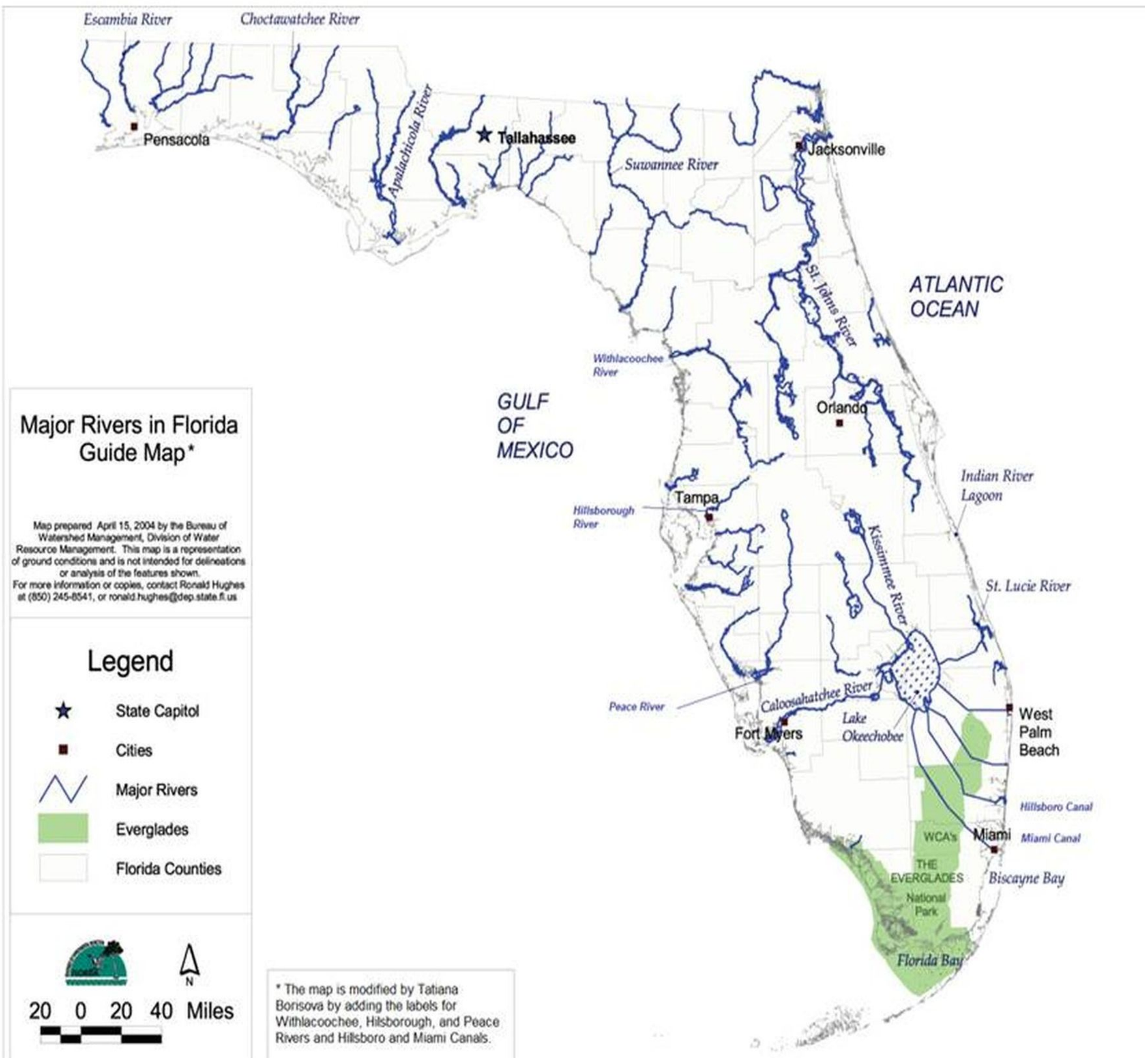

Figure 3. Major streams in Florida (Developed by Ronald Hughes, altered by Tatiana Borisova).

The largest of Florida's streams is the Apalachicola River, formed by the confluence of the Flint and Chattahoochee Rivers at the

(33 miles above the mouth), the river discharges about 10,600 cubic feet per second (6,851 million gallons per day). The Santa Fe River flows into the

Suwannee River, as do a number of springs, such as Troy, Ichetucknee, Fanning, and Manatee.

The Choctawhatchee River (Florida's third-largest river) drains 3,100 square miles in southeastern Alabama and 1,500 square miles in Florida. Choctawhatchee Bay opens to the Gulf of Mexico in the vicinity of Fort Walton Beach. At the measurement station near Bruce, 21 miles above the river's mouth, average discharge is about 7,200 cubic feet per second (4,653 million gallons per day).

The Escambia River and its tributaries drain 3,760 square miles in Alabama and 425 square miles in Florida before flowing into Pensacola Bay at a rate of more than 6,189 cubic feet per second (4,000 million gallons per day). Near Century, 52 miles above the river's mouth, average annual discharge is 6,300 cubic feet per second (4072 million gallons per day)

The St. Johns River drains about 9,400 square miles from marshes west of Vero Beach to its mouth at the Atlantic Ocean in Jacksonville. It is one of the few rivers in the United States that flows north. At about mid-point, near Deland, 142 miles above the mouth, flow is about 3,150 cubic feet per second (2,036 million gallons per day). The St. Johns River connects seven major lakes, from Lake Washington to Lake George. Its tributary, the Oklawaha River, connects nine lakes, from Lake Apopka to Lake Lochloosa.

The Kissimmee River, with headwaters near Orlando, flows south down the center of the Florida Peninsula, emptying into Lake Okeechobee at a rate of about 2,166 cubic feet per second (1,400 million gallons per day). The Kissimmee River drains about 3,000 square miles, and connects nine major lakes, from East Lake Tohopekaliga to Lake Placid. Lake Okeechobee, which is roughly 30 miles wide, is a managed source of water supply for much of southeastern Florida.

The Peace, Withlacoochee, and Hillsborough Rivers drain portions of the central Florida Peninsula into the Gulf of Mexico. The Peace River flows into Charlotte Harbor. At a measurement station near Arcadia (36 miles above the river's mouth), the average annual discharge is about 1,200 cubic feet per second (776 million gallons per day). A long-term decline in the river's flow has been observed since 1960, which is attributed to reduction in average rainfall and groundwater withdrawals for public supply, agriculture, and industries.

The Withlacoochee River flows to the northwest from an area called the Green Swamp in Polk, Sumter, and Lake Counties, emptying into the Gulf of Mexico near Yankeetown. Near Holder, 38 miles above the river's mouth, average annual discharge is about 1,100 cubic feet per second (711 million gallons per day). The Hillsborough River also originates in the Green Swamp and discharges into Tampa Bay. Southern Florida streams, for the most part, are poorly developed. Most of the drainage occurs through a system of canals that have been constructed to relieve high water conditions and deliver water supplies to growing population centers.

The St. Lucie Canal connects Lake Okeechobee to the Atlantic Ocean near Stuart, and the Caloosahatchee Canal and River connect Lake Okeechobee with the Gulf of Mexico near Fort Myers. Together they form a navigable cross-state waterway. Other canals from Lake Okeechobee to the Atlantic Ocean are the Hillsboro, North New River, Miami, and West Palm Beach Canals.

The streams, rivers, springs, and lakes produced by the runoff phase of Florida's hydrologic cycle are familiar to Floridians as water supply sources, recreational attractions, transportation routes, and havens for the state's abundant fish and wildlife populations. Closely related to Florida's surface water systems, but much more important as a source of water supply, are Florida's major groundwater systems.

Principal Aquifers in Florida

Florida has several prolific aquifers that yield large quantities of water to wells, streams, lakes, and some of the world's largest springs (Figure 4). The principal source of groundwater for most of the state is the Floridan aquifer—the source of the municipal water supply for the cities of Tallahassee, Jacksonville, Gainesville, Orlando, Daytona Beach, Tampa, and St. Petersburg. It also yields water to thousands of domestic, industrial, and irrigation wells throughout the state.

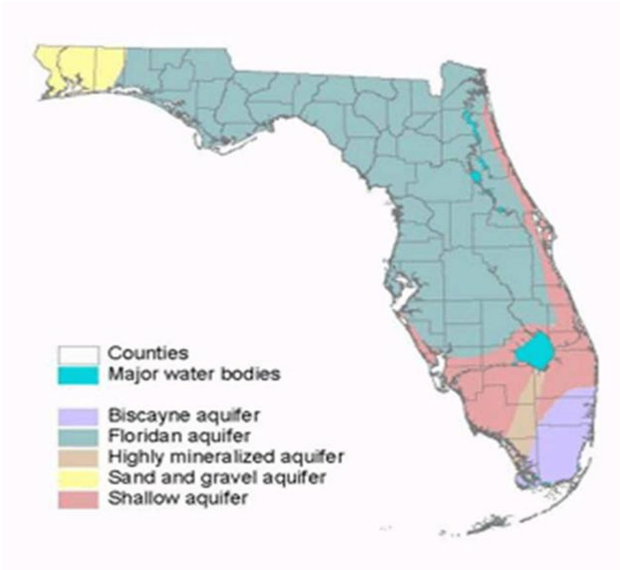

Figure 4. Florida's aquifers vary in depth, composition, and location (Sources: Cervone 2003, citing USGS).

Thick layers of porous limestone of the Floridan aquifer underlie all of the state, although in South Florida the water it contains is too highly mineralized (salty) to be usable. Except in those areas where its limestone formations break the surface of the ground, the Floridan aquifer underlies several hundred feet of sediment, including thick beds of relatively impermeable material that restrict upward movement of the water. This restriction causes the aquifer to have artesian pressure. Water in the Floridan aquifer is replenished by rainfall in central and northern Florida, where the aquifer emerges at the surface or is covered by permeable materials, or where the confining material is broken up by sinkholes.

The non-artesian Biscayne aquifer underlies an area of about 3,000 square miles in Dade, Broward, and Palm Beach Counties on Florida's lower east coast. Water in the Biscayne aquifer is derived chiefly from local rainfall and, during dry periods, from canals ultimately linked to Lake Okeechobee. The Biscayne aquifer is an important water supply for lower east coast Florida cities.

A non-artesian, sand-and-gravel aquifer is the major source of groundwater in the extreme western part of the Florida Panhandle. Water in the sand-and-gravel aquifer is derived chiefly from local rainfall and is of good chemical quality. Wells tapping this aquifer furnish most of the groundwater used in Escambia and Santa Rosa Counties, and part of Okaloosa County.

A shallow, non-artesian aquifer is present across much of the state, but in most areas it is not an important source of groundwater because a better supply is available from deeper aquifers. However, in rural areas where residential water requirements are relatively smaller by comparison to other areas, this aquifer is tapped by small-diameter wells. The water in this shallow aquifer is derived primarily from local rainfall.

Salt Water Intrusion

Florida's geography as a peninsula between two bodies of salt water creates the potential for salt water intrusion into the fresh groundwater supply. Salt water is denser than freshwater and exerts a constant pressure to permeate the porous aquifers. As long as freshwater levels in the aquifers are above sea level, the freshwater pressure keeps salt water from moving inland and upward into the aquifers. For example, the level of water flowing through south Florida's coastal canals is generally several feet above sea level, which is enough to prevent ocean water from moving inland and upward into the aquifer. However, if during dry periods the freshwater levels in canals without locks and dams fall to or below sea level, this would allow salt water to move upward in the canals.

In some places, excessively pumping a well can increase salt water intrusion. If water is pumped at a rate faster than the aquifer is replenished, the pressure of freshwater over salt water in the land mass is decreased. This decrease may cause the level of the saltwater-freshwater interface to rise in the aquifer, degrading water quality. This problem must be controlled by careful attention to well location and pumping rates. The problem of saltwater intrusion is aggravated by drought periods when there is not enough rainfall to replenish the freshwater aquifers.

Florida's Springs

There are over 700 springs in Florida, including more than 30 first-magnitude springs with an average flow of over 100 cubic feet per second (64.6 million gallons per day, Figure 5). There are also about 200 second-magnitude springs, with average flow between 10 and 100 cubic feet per second (6.46 to 64.6 million gallons per day). Spring water emerges from cavities in the porous limestone of the Floridan aquifer and mixes with the water in streams and lakes. The Floridan aquifer is replenished by rainfall across northern and central Florida, southern Alabama, and southern Georgia.

Glossary of Terms

- Artesian aquifers – confined aquifers that hold water under sufficient pressure such that water will rise above the confining layer when a tightly cased well penetrates the aquiclude. When tapped, they sometimes produce free-flowing artesian wells. Naturally occurring springs also result from this same phenomenon.
- Confined aquifers – the water-bearing aquifers confined below a stratum of low permeability.

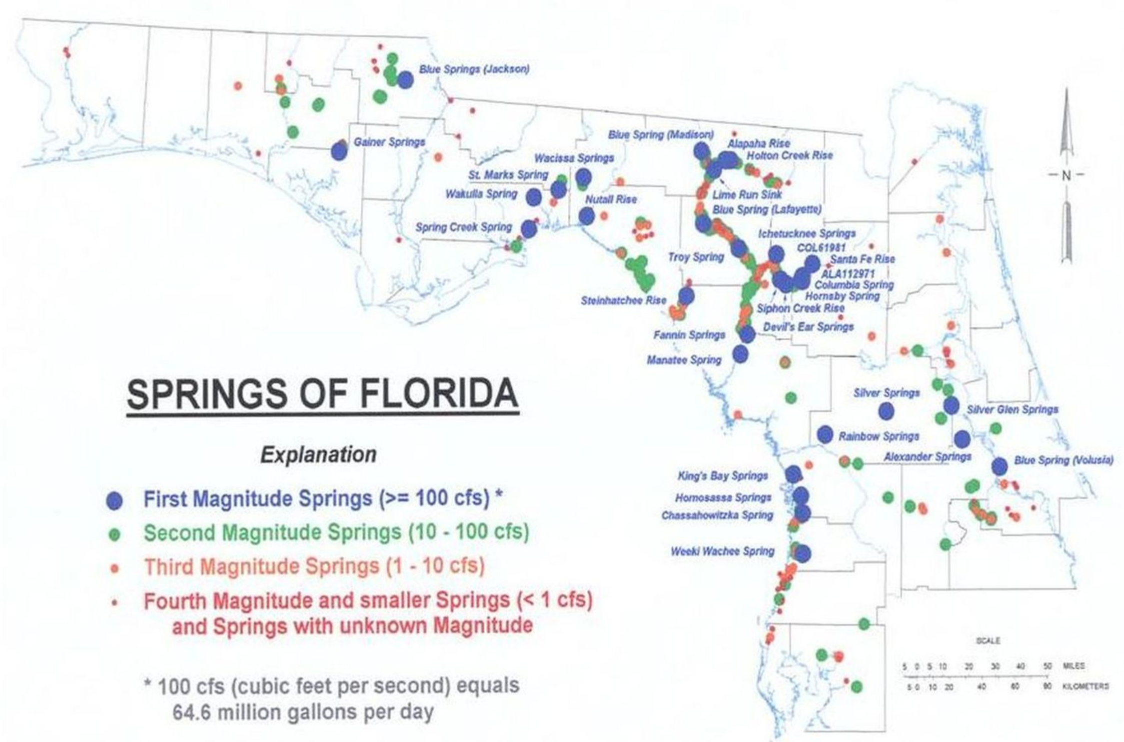

Figure 5. Springs of Florida (Source: The Florida Springs Task Force 2000).

Summary

A description of Florida's water resources is usefully organized in terms of the hydrologic cycle. Since the cost and feasibility of making water supplies available for municipal, agricultural, and industrial uses is determined to a great extent by the patterns of rainfall, runoff, and infiltration over time and space, it is important that Florida citizens become familiar with the water cycle.

- Evaporation – the process by which water is changed into its gaseous form (water vapor).
- Hydrologic cycle (used interchangeable with “water cycle”) – the continual circulation/distribution of water on the surface of the land, in the ground, and in the atmosphere.
- Outflow – the difference between rainfall on an area and evaporation from that area.

- Runoff – the part of water outflow that appears in surface streams. It includes water that flows directly into gullies, creeks, and rivers, as well as water that emerges into surface streams from underground aquifers (such as through springs).

- Transpiration – the process whereby moisture in plants is returned to the atmosphere through plant leaves.

- Water cycle (used interchangeable with "hydrologic cycle") – the continual circulation/distribution of water on the surface of the land, in the ground, and in the atmosphere.

- Wet season in Florida – usually defined as the months of June to September, when the state receives on average about 55% of the annual rainfall. However, this pattern of seasonal precipitation varies from year to year and from location to location.

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