

INTRODUCTION

The Floridan aquifer system is one of the most productive in the world and is the most extensive and widely used aquifer in Florida. In 1985, almost 2,500 Mgal/d were withdrawn from the aquifer, including about 680 Mgal/d for public-supply use, about 1,180 Mgal/d for agricultural use, and about 520 Mgal/d for industrial use (R.L. Maslett, St. Johns River Water Management District, written commun., 1987). Withdrawals from the Floridan represent about 40 percent of the total freshwater use for all purposes in Florida. Water use has increased greatly during the past two decades and is expected to continue to increase as the population of Florida continues to grow.

The increased demand for water and reliance upon the Floridan aquifer system for much of the water requires that future development of this valuable resource be adequately managed. Information on the hydrologic characteristics of the Floridan is necessary for proper planning and management.

The objective of this report is to describe the areal distribution of recharge and discharge of the Floridan aquifer system in Florida. Recharge from rainfall is the principal source of water for the Floridan aquifer system. Natural discharge through springs and seepage to streams accounts for the largest quantity of water discharged from the Floridan. Information on the occurrence and distribution of recharge and discharge is important in managing the water resources of Florida, both in terms of providing adequate supplies in the future and protecting critical recharge areas for water supplies in the present. This report was prepared in cooperation with the Bureau of Ground-Water Protection, Florida Department of Environmental Regulation.

Recharge is defined as "the process of addition of water to the zone of saturation" (U.S. Geological Survey, 1986, p. 462). Discharge in this report includes ground-water discharge to the land surface, surface-water bodies, or overlying aquifers by diffuse upward leakage or by spring flow.

PREVIOUS INVESTIGATIONS

Many local hydrogeologic studies have described the recharge and discharge characteristics of parts of the Floridan aquifer system (Tibbals, 1975; Grubb, 1977; Phelps, 1985; Stewart, 1986) presented a map that qualitatively showed variations in recharge and discharge throughout the State under natural conditions. He relied principally on characteristics of the confining unit overlying the Floridan aquifer and differences in head between the surficial aquifer and the upper Floridan aquifer to determine rates of recharge. Roseau and others (1977) described the springs of Florida. More recent studies based on ground-water flow models of the Floridan (Buell, 1986; Bush and Johnson, in press; Krause and Randolph, in press; Maslett and Hayne, in press; and Tibbals, in press), developed for the Regional Aquifer System Analysis (RASA) effort, have provided more quantitative descriptions of recharge and discharge.

GENERAL HYDROGEOLOGY OF THE FLORIDAN AQUIFER SYSTEM

The Floridan aquifer system is composed chiefly of limestone and dolomite of the following geologic formations of Tertiary age, from oldest to youngest: Ocala Formation, Tampa Limestone, and the lower part of the Hawthorn Formation. It contains permeable limestone beds that are hydraulically connected to the older limestones. The Floridan ranges in thickness from about 100 feet near the Florida-Alabama border to about 3,500 feet in west-central Florida. The thickness of the part of the Floridan aquifer system that contains potable water is a maximum of about 2,000 feet (Lichter, 1972; Healy, 1975; Cooney and Lowe, 1978; and Miller, 1986). The upper permeable zone of the aquifer system, which is known as the Upper Floridan aquifer, yields large quantities of water generally of good chemical quality and, as a result, few wells penetrate beyond it. Where the Floridan is not at land surface, it is covered by a variable thickness of sand, silt, and limestone that ranges in thickness from a few feet in parts of west-central Florida to hundreds of feet in south-central Florida and in the extreme western Panhandle of Florida. Deposits of sand overlie the Floridan aquifer system in much of Florida. The sand forms a surficial aquifer that captures that part of the rainfall that is not lost to evapotranspiration or overland runoff. Where thick deposits of clay and marl lie between the surficial aquifer and the Floridan, the clay and marl impede movement of water between the aquifers and cause water in the Floridan to be confined. The thickness of overlying confining materials and areas where the Floridan occurs at land surface are shown in figure 1. Water in the Floridan is under some degree of overpressure with the Floridan at notable elevations in northern and non-central Florida. The Floridan is unconfined in southern Florida.

GENERAL FLOW-SYSTEM CHARACTERISTICS

The principal source of water to the hydrologic system in Florida is rainfall. Average annual rainfall is about 55 inches statewide and ranges from 40 inches in the Florida Keys to as much as 64 inches in northwest Florida (Hughes and others, 1977).

The largest loss from the hydrologic system is in evapotranspiration, which generally ranges from 27 to 50 inches annually across the State, or from about 50 to almost 100 percent of the rainfall (Buell, 1986; Roseau and others, 1977). Springs are clustered in Florida in areas where the Floridan is near the surface, in low-lying areas, such as the Suwannee River Valley and in Wakulla County, and in the west-central Gulf coast area (Chas, Hernando, and Pasco Counties). Springs are concentrated points of discharge from the Floridan to surface-water bodies. The depiction of springs as discharge areas on the large map where surrounded by recharge areas is not possible because of map scale.

Discharge also occurs as diffuse upward leakage through overlying confining units where the head gradient between the surficial aquifer and the Floridan is upward. Principal areas where this occurs are in many river valleys, in low-lying coastal areas, in much of south Florida, and in off-shore areas. The areas of highest discharge are the north and central Florida Panhandle and the Suwannee, Wakulla, Santa Fe, St. Johns, and Apalachicola River valleys. The area of lowest discharge is in the central Florida Panhandle. The areas of highest discharge are in the central Florida Panhandle and the Suwannee, Wakulla, Santa Fe, St. Johns, and Apalachicola River valleys. The area of lowest discharge is in the central Florida Panhandle. The areas of highest discharge are in the central Florida Panhandle and the Suwannee, Wakulla, Santa Fe, St. Johns, and Apalachicola River valleys. The area of lowest discharge is in the central Florida Panhandle.

FACTORS AFFECTING RECHARGE AND DISCHARGE

The thickness and hydraulic conductivity of materials overlying the Floridan aquifer system greatly affect recharge and discharge to and from the Floridan. In areas where overlying confining materials are thick and relatively impermeable, the downward (recharge) or upward (discharge) movement of water through them is significantly inhibited. In areas where the overlying material is thin or non-existent or is highly permeable, the movement of large quantities of water is possible. Local branches in the overlying material have been formed in some areas in response to structural weaknesses in the aquifer framework and local hydrologic factors such as water-level declines (Sindlar and Stewart, 1986). Sinkholes, which commonly provide a better hydraulic connection between the surface and the Floridan than in non-sinkhole areas, can allow large quantities of water to move into the Floridan. Springs are points of direct hydraulic connection between the surface and the Floridan where water discharges from the system. Areas where springs and sinkholes occur are typically areas where large quantities of water enter and leave the ground-water flow system.

The upward component of the head gradient is the driving force to move water vertically through overlying materials. Water moves in the direction of and at a rate proportional to the gradient. Hydraulic head, which is a measure of energy, is a function of various factors including the location and altitude of an area in the flow system, the water available for input into the system, and the distribution of hydraulic conductivity within the flow system.

The amount of precipitation available to recharge the ground-water system is the fraction left after evapotranspiration losses and overland runoff are subtracted. In Florida, evapotranspiration accounts for the greatest losses of precipitation. A map of precipitation minus potential evaporation is shown in figure 3. This figure shows that more water is available for recharge to the ground-water system in southeastern Florida and in the Florida Panhandle relative to other areas of the State. Potential evaporation is approximately equal to evapotranspiration where ground-water levels are at or near land surface. In areas where the water table is relatively deep, such as in the Florida Panhandle, potential evaporation is significantly greater than evapotranspiration. As a result, areas such as the panhandle would have an even greater amount of water available for recharge than indicated in figure 3. Consequently, the information shown in figure 3 generally represents a conservative estimate of water available for recharge to the ground-water system.

Another factor that can affect recharge is the ability of the aquifer to accept recharge to transmit water away from the area. If aquifer transmissivity is low, water may back up, and cause water levels to rise; this results in rejected recharge and increased evapotranspiration. In areas where this occurs, recharge rates will be less than would be the case if aquifer transmissivity were greater or if water levels were lower.

AREAL VARIATION IN RECHARGE AND DISCHARGE FOR PREDEVELOPMENT CONDITIONS

The areal variation in recharge to and discharge from the top of the Floridan aquifer system prior to development is depicted in the large map. The approach used in developing this map report was to combine the qualitative approach used by Stewart (1980), including more recent regional information on confining unit thickness (Miller, 1986, plate 25), with the Florida RASA quantitative modeling work (Ryder, 1986; Bush and Johnson, in press; Krause and Randolph, in press; Maslett and Hayne, in press; and Tibbals, in press) to produce a map that best describes current knowledge of recharge and discharge for the Floridan aquifer system statewide.

The largest area of highest recharge is where the Floridan aquifer system is at or near land surface, extending from Leon County in the northwest to Pasco County in the south. Little or no confining material overlies the Floridan in this area, and the vertical head gradient is

downward, hence, water is able to percolate rapidly into the aquifer. Other areas of relatively high recharge include the part of Polk County in the central part of the State where numerous sinkhole lakes are present to provide effective conduits for recharge; parts of Jackson and Washington Counties; and the Deland Ridge in west-central Volusia County where the Floridan is overlain by permeable deposits of sand. Recharge is high in parts of Jackson and Washington Counties that comprise the southernmost extension of the Dougherty Plain because the land surface is exposed at land surface, providing direct access for water into the highly permeable aquifer.

Recharge areas that have thick confining units of low permeability material overlying the Floridan, such as those that occur in northeast and extreme northeast Florida, are areas of low recharge. Other areas of low recharge include some topographically high areas to the east and west of the Suwannee River basin that have thicker confining materials overlying the Floridan than do areas to the north. The Jackson County area, which has relatively thick deposits of clayey material overlying the Floridan, is also an area of low recharge.

Swamps in Florida are generally found in low topographic areas and typically represent the end of ground-water flow paths at the land surface. An exception to this is the Green Swamp, which is an upland swamp located in southern Lake County and northern Polk County. The high in the potentiometric surface that dominates the Floridan flow system in central Florida is centered in the Green Swamp (fig. 2). This indicates that the Green Swamp is at the beginning of a flow path.

A popular misconception is that the Green Swamp is the principal recharge area in the State of Florida. Overall, the Green Swamp is an area of only moderate recharge (Grubb, 1977) when compared to other nearby areas such as parts of Citrus, Hernando, and Polk Counties. Two factors restrict recharge in this area. The first and most important factor is that the transmissivity of the Floridan in the Green Swamp area is relatively low. This reduces the ability of the aquifer to transmit water away from the area. In essence, more water is available for recharge than the aquifer can accept and transmit, causing the water table to be at or near land surface much of the year and resulting in rejection of water available for recharge to the Floridan aquifer.

Swamps are underlain by surficial materials of low permeability that further reduce the ability of the aquifer to accept recharge (Grubb, 1977). The Floridan aquifer system is the source of water for some of the largest springs and most concentrated areas of spring flow in the world. Springs discharge from the Floridan in Florida. Buell (1986, p. 17) estimated that 90 percent of the discharge from the Floridan prior to development was through springs and seepage to surface-water bodies. Five magnitude springs (discharge greater than 100 ft³/s), second magnitude springs (discharge between 10 and 100 ft³/s), and significant submarine springs are noted in the large map (Roseau and others, 1977). Average discharge for first magnitude springs are less, a discharge estimate of 2,000 ft³/s for Spring Creek springs in Wakulla County was reported by Roseau and others (1977). Springs are clustered in north-central Florida where the Floridan is near the surface, in low-lying areas, such as the Suwannee River Valley and in Wakulla County, and in the west-central Gulf coast area (Chas, Hernando, and Pasco Counties). Springs are concentrated points of discharge from the Floridan to surface-water bodies. The depiction of springs as discharge areas on the large map where surrounded by recharge areas is not possible because of map scale.

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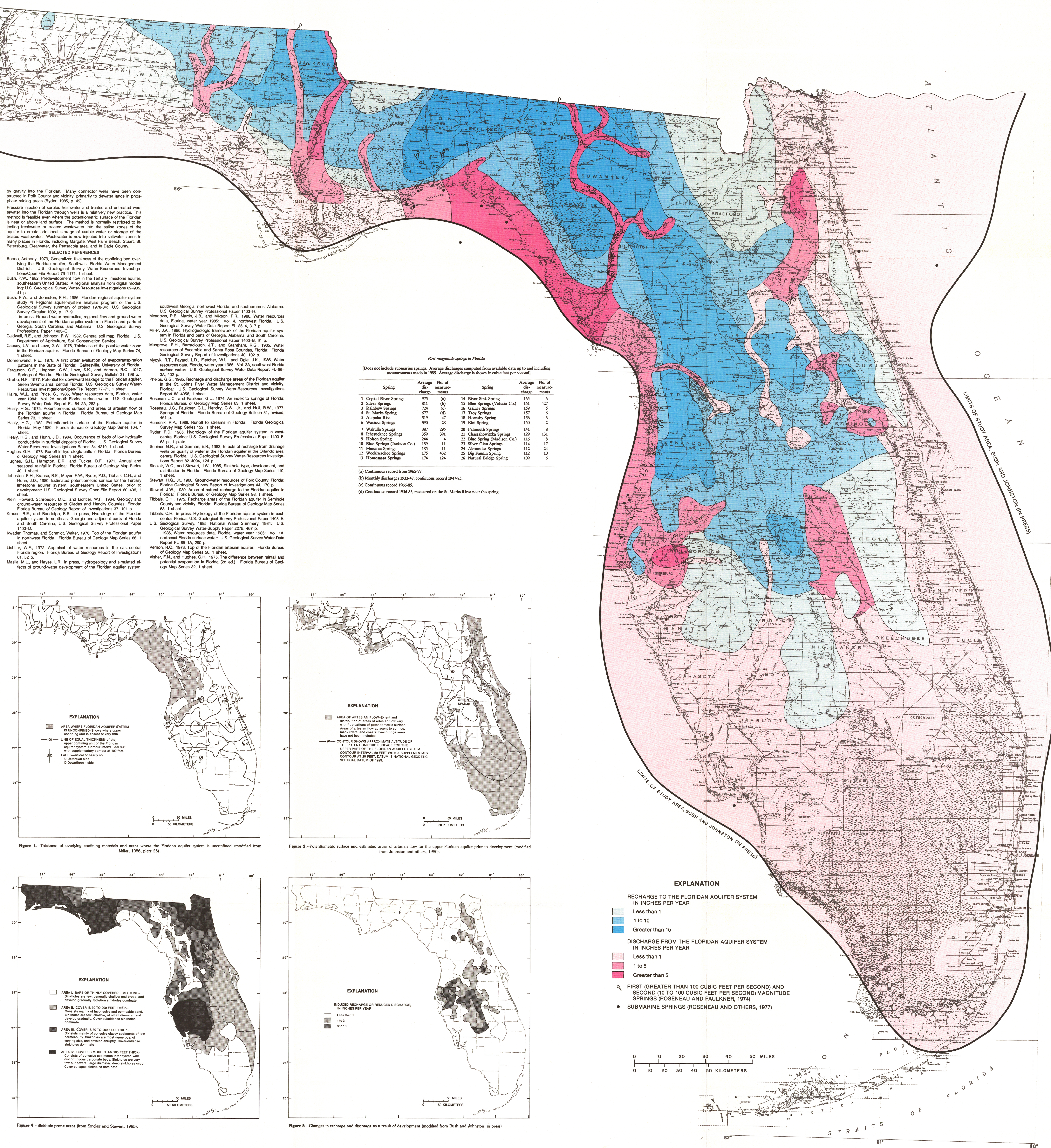


Figure 1.—Thickness of overlying confining materials and areas where the Floridan aquifer system is unconfined (modified from Miller, 1986, plate 25).

Figure 2.—Potentiometric surface and estimated areas of areal flow for the upper Floridan aquifer prior to development (modified from Johnson and others, 1980).

Figure 3.—Precipitation minus potential evaporation (Vaher and Hughes, 1975).

Figure 4.—Sinkhole-prone areas (Sindlar and Stewart, 1986).

Figure 5.—Changes in recharge and discharge as a result of development (modified from Bush and Johnson, in press).