Prepared in cooperation with the
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

INTRODUCTION

The Floridan aquifer is the source of most freshwater used in the St. Johns River Water Management District. The aquifer is composed chiefly of limestone and dolomite and underlies the entire Management District. It also is found in southern Georgia and parts of Alabama and South Carolina. Although the aquifer is one of the largest and most productive in the United States, its capability to supply water is not unlimited. Water continuously enters the aquifer (recharge) but also continuously leaves the aquifer (discharge) at varying rates, both naturally and by pumping. These variations in rates of recharge and discharge cause seasonal and long-term fluctuations in water levels. Seasonal fluctuations are usually cyclic, but if discharge exceeds recharge over a period of years, water levels decline, and water-quality problems, such as saline water intrusion, may occur. Delineation of recharge and discharge areas is necessary to effectively manage the water resources of the Floridan aquifer.

Purpose and Scope

This report is part of the St. Johns River Water Management District Water Atlas series, which summarizes significant regional hydrologic conditions. The purpose of this report is to provide a general description of the Floridan aquifer in the District and vicinity and to delineate the recharge and discharge areas of the aquifer there. The data in this report were compiled from numerous studies of the water resources of Florida listed in the Selected References at the end of this report, as well as from current studies in progress.

HYDROLOGY OF THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

Hydrologic Cycle

The exchange of water between the Earth and the atmosphere is called the hydrologic cycle (Leopold, 1974, p. 4). This exchange takes place continuously, powered by heat energy from the Sun and by gravity. Rain falls on the surface of the Earth, evaporates, runs into rivers or lakes, or infiltrates into the ground. Some water evaporates from the surface of the rivers, lakes, and oceans, is carried back into the atmosphere as water vapor, and is again available to fall as precipitation. Some of the water that infiltrates into the ground evaporates or is transpired by plants. These processes are often collectively referred to as evapotranspiration. Water that percolates into the ground may be stored for long periods of time in underground reservoirs of permeable rock or sediments called aquifers. Water in an aquifer moves slowly from points of recharge to points of discharge and eventually is discharged by springs, seeps into lakes or rivers, or is withdrawn by wells. Most of the water withdrawn by wells is eventually returned to rivers or to the ground, although its quality may be adversely affected by use. Thus, water is continuously circulated from the surface of the Earth to the atmosphere and back again.

Geohydrology

A generalized section of the important hydrogeologic features in the District is shown in figure 1. The principal aquifer is the Floridan, which is composed of porous limestone and dolomite as much as 2,000 feet thick deposited primarily during the Oligocene and Eocene Epochs (about 24 to 55 million years ago). The aquifer is at land surface in Marion and Lake Counties in the west-central part of the District but dips below land surface and thickens eastward.

Except in the outcrop area in Marion and Lake Counties, the Floridan aquifer is overlain by a mixture of clay, sand, shell, and limestone. These deposits are much less permeable than the Floridan aquifer so that water in the Floridan is confined below them. The Floridan aquifer is said to be a confined or artesian aquifer wherever the water level in a well cased into the Floridan stands above the top of the aquifer. The surface defined by the levels to which water will rise in tightly cased wells drilled in an artesian aquifer is called the potentiometric surface (fig. 1, well A). In areas where the potentiometric surface is above land surface, water will flow from the wells (fig. 1, well C).

Relatively small beds of limestone or shell within the confining layer that overlies the Floridan aquifer form local artesian aquifers (fig. 1, well B). The yield of wells in these shallow or local artesian aquifers is much less than yields from wells in the Floridan aquifer, but is usually sufficient for domestic supply.

The surficial deposits overlying the confining beds are predominantly sand. Wells drilled into the surficial sand (water-table wells) usually intersect the water table (the top of the zone of saturation) within 10 to 20 feet below land surface (fig. 1, well D). Although water-table wells yield less than the Floridan aquifer or shallower artesian wells, they are widely used for lawn and garden irrigation.

Delineating Recharge and Discharge Areas

Some factors to be considered when delineating recharge and discharge areas are:

1. Altitude and configuration of the potentiometric surface of the Floridan aquifer: Water moves from areas of high potentiometric surface toward areas of low potentiometric surface. The potentiometric contours in figure 2 indicate that water generally enters the aquifer in the west and central parts of the District and moves eastward; however, there is some westward flow from local recharge areas in Putnam, Volusia, and Seminole Counties. Closed contours showing a high potentiometric surface, such as near Polk City (Polk County) and in the Keystone Heights area of Clay, Putnam, and Alachua Counties, are usually indicative of recharge areas. Closed contours showing a low potentiometric surface, near Lake George in Volusia County for example, usually indicate natural discharge areas. Closely spaced contours with an extremely low potentiometric surface (Fernandina Beach, Nassau County) usually indicate discharge caused by pumping.
2. Direction and magnitude of the hydraulic gradient between the water table in the surficial aquifer and the potentiometric surface of the Floridan aquifer: For recharge to occur, the Floridan aquifer must either be unconfined or the water table must be higher than the potentiometric surface. (Where the Floridan is unconfined, the water table and the potentiometric surface of the Floridan are coincident.) If the water table is higher than the potentiometric surface, a downward hydraulic gradient exists. Conversely, an upward gradient exist when the potentiometric surface is higher than the water table. An upward gradient exists in the areas of artesian flow shown in figure 2. Extreme local relief may result in rapid changes in the direction of gradient over short distances. This explains why springs, such as Rainbow Springs in Marion County, occur in the recharge areas shown in figure 2.
3. Thickness and permeability of confining beds overlying the Floridan aquifer: In addition to a downward gradient, the overlying confining beds must also be relatively thin or very permeable for much recharge to occur. Conversely, though an upward gradient may exist, if the overlying confining beds are thick or relatively impermeable, little upward leakage will take place. This situation exists in some areas of artesian flow shown in figure 2, such as in Indian River County and parts of Duval County.

RECHARGE AND DISCHARGE

The major areas of recharge to and discharge from the Floridan aquifer are shown in figure 2. Some recharge and discharge that occur outside the District affect ground-water conditions in the District. (Water Management District boundaries are drawn on the basis of surface-water basins, which generally do not coincide with ground-water basins.) For this reason, adjacent areas are also shown in figure 2.

The most effective recharge areas are shaded dark blue in figure 2. Considerable recharge occurs where the Floridan aquifer is close to land surface, the overlying confining beds are relatively thin or permeable, and a downward hydraulic gradient exists. Significant recharge may also occur where lakes and sinkholes are hydraulically connected to the Floridan aquifer.

The unshaded areas in figure 2 are areas of downward gradient, but the permeability and thickness of the confining bed and the magnitude of the downward gradient are less favorable for recharge than in the most effective recharge areas.

Areas of generally no recharge are shaded in light blue. In these areas, the altitude of the potentiometric surface is usually above the water table, and in some areas, above the land surface. Discharge occurs through numerous springs, flowing wells, and by upward leakage through the confining beds.

Recharge Areas

Recharge to the Floridan aquifer comes almost entirely from rainfall within the District (Snell and Anderson, 1970, p. 62) and adjacent areas. Contrary to some popular beliefs, water from Georgia or other areas to the north does not have a significant effect on recharge in Florida. As can be seen from the direction of the flow lines in figure 3, most of the recharge that occurs in Georgia discharges from the aquifer before reaching the Florida peninsula.

Significant recharge to the Floridan aquifer occurs where the aquifer is at or very near land surface, such as in Marion County. Stringfield (1966, p. 128) briefly described ground-water conditions in Marion County, and Tibbals (1981, fig. 8) estimated recharge rates in Marion County to be 10 to 14 inches per year (in./yr).

In other recharge areas, such as in Polk, Lake, Seminole, and Orange Counties, overlying confining beds are thick but are composed primarily of very permeable sand, so recharge occurs by downward leakage. Lichtler and others (1968, p. 112-116) estimated that in 1961 total recharge in Orange and Seminole Counties was about 210 million gallons per day (Mgal/d)—about 7 in./yr. Tibbals (1981) estimated rates of 2 to 10 in./yr for Orange and Seminole Counties.

Stewart (1966, p. 126) reported that widespread areal recharge occurs in Polk County, partly by leakage through overlying deposits and partly through sinkholes or sinkhole lake basins, but did not estimate the recharge rate. Tibbals (1981) estimated recharge rates of 4 to 6 in./yr for Polk County.

Wells (called connector wells) have been constructed in nearby areas specifically for the purpose of recharging the Floridan aquifer. These wells connect the Floridan aquifer with overlying aquifers in areas of downward gradient, and bypass the natural movement of water through the intervening confining beds. An experiment described by Bush (1979) indicated that connector wells could be a significant source of recharge, but no estimate of the net gain of water to the Floridan aquifer was made. No known connector wells existed in the District in 1981, although such wells are widely used in the phosphate mining areas of Polk and Hillsborough Counties in the Southwest Florida Water Management District.

Discharge Areas

According to Tibbals (1981, p. 58) under predevelopment conditions (before wells were drilled and pumping began), about 28 percent of the total natural discharge from the Floridan aquifer in central Florida was by upward leakage to overlying deposits, and about 69 percent of the discharge was to springs. The remaining 3 percent of the discharge flowed laterally out of the study area to adjacent areas. Rosenau and others (1977) described 54 springs in the District. Their locations are shown in figure 2 and their discharge rates are given in table 1. Total spring discharge, at present (1982) is about 1,600 Mgal/d, mostly from the Florida aquifer. Numerous water-table springs or seeps are also found in the District, such as Gold Head Branch Springs in Clay County, Elder and Heath Springs in Seminole County, and possibly Whitewater Springs in Putnam County. However, total discharge from water-table springs is very small compared to Floridan aquifer springs.

In addition to the springs listed in table 1, at least two springs discharge from the Floridan aquifer into the Atlantic Ocean: Crescent Beach Springs, east of Crescent Beach, and Red Snapper Sink, east of Marineland (St. Johns County). No discharge estimates have been made for Red Snapper Sink. Estimates of discharge from Crescent Beach Springs range from 40 ft³/s (Stringfield, 1966, p. 183) to 1,500 ft³/s (Kohout, 1966, p. 396). A depression in the potentiometric surface that occurs along the coast from St. Johns County to Brevard County (fig. 2) indicates substantial discharge into the ocean directly by springflow or by upward leakage through thin confining sediments (Stringfield and Cooper, 1951, p. 66). Discharge by upward leakage through thin confining beds is probably the cause of the cone of depression in Flagler County.

There is a potential for loss from the Floridan aquifer by evapotranspiration where the aquifer and the potentiometric surface are both near land surface (such as in some areas of western Marion County). However, such areas are very localized; thus, direct loss from the aquifer by evapotranspiration is probably small compared to other sources of discharge.

Uncontrolled flowing wells and improperly constructed wells in areas of artesian flow can cause significant discharge from the aquifer. The District and several county and local governmental agencies are attempting to locate and plug uncontrolled flowing wells.

Discharge by pumping occurs throughout the District in both recharge and discharge areas. Water-use data are published yearly by the U.S. Geological Survey and by the St. Johns River Water Management District. Table 2 shows the withdrawal rates of fresh ground water in 1980 (S.D. Leach, written commun., 1981). In 1980, the highest ground-water withdrawal rate in the District was in Orange County (67 Mgal/d); Duval County, with almost 60 Mgal/d ranked second. In both counties most of the water pumped from the Floridan aquifer was for public supply.

The sum of spring discharges (table 1) is about 1,600 Mgal/d and total pumpage (table 2) is about 1,000 Mgal/d. Thus, the total discharge from point sources in the aquifer is estimated to be 2,600 Mgal/d.

Balance of Recharge and Discharge

Under predevelopment steady-state conditions (before wells were drilled into the aquifer) discharge by springs, upward leakage, and lateral outflow approximately balanced recharge to the aquifer in central Florida (Tibbals, 1981, p. 8). Additional discharge by pumping may or may not be balanced by decreased spring discharge or increased downward leakage. Examination of long-term trends in the potentiometric surface can indicate whether or not recharge and discharge balance. If water levels generally decline with time, it is probable that discharge exceeds recharge.

For example, long-term water-level data in Duval County show a decline of about 8 feet in four key wells between 1960 and 1977 (Leve, 1980). The smallest decline (about 5 feet) was in the western part of the county, far from areas of heavy pumping. The center of the existing cone of depression caused by pumpage declined about 15 feet. Under natural conditions, Jacksonville is a discharge area. Long-term water-level declines indicate that a new equilibrium between recharge and discharge has not been reached.

Bermes and others (1963, p. 64), however, noted that water levels had not changed appreciably in 60 years in western Putnam County, indicating that recharge and discharge are in balance. A comparison of the potentiometric surface map drawn by Bermes and others (1963, figs. 22, 23, 24) with a recent potentiometric surface map (Schiner and Hayes, 1981), indicates little change since the late 1950's.

Similarly, in the Orlando area a cone of depression has not developed because of pumping (Kimrey, 1978, p. 15). The potentiometric surface in the Orlando area in September 1980 (Schiner and Hayes, 1981) was about 5 to 8 feet lower than the potentiometric surface for normal water-level conditions in July 1961 (Lichtler and others, 1968, fig. 47), but is nearly the same as the potentiometric surface for extreme low water-level conditions in May 1962 (Lichtler and others, 1968, fig. 49). Rainfall at Orlando for September 1979 through August 1980 (42.43 inches) was 8.78 inches below average. Thus, in the Orlando area, recharge balances discharge when rainfall is sufficient.

Figure 4 shows fluctuations of rainfall, water levels, and pumpage at Jacksonville, Daytona Beach, and Orlando. In Jacksonville (where there is little recharge) water levels decline during periods of below average rainfall, mostly in response to increased pumping because residents compensate for lack of rainfall by increased water use. In the Orlando area the decline in water levels during dry periods reflects both decreased local recharge and increased pumping. In Daytona Beach (an area of low to moderate recharge), an additional factor to be considered is the influx of about 52,000 tourists during spring and early summer. For this reason, municipal pumpage may increase causing water levels to decline even during the rainy season (June through September).

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ABBREVIATIONS AND CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in the report are listed below:

Multiply	*By*	*To obtain*
mile (mi)	1.609	kilometer (km)
square mile (mi²)	2.590	square kilometer (km²)
foot (ft)	0.3048	meter (m)
inch (in.)	25.4	millimeter (mm)
cubic foot per second (ft³/s)	0.02832	cubic meter per second (m³/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m³/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929).—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. In this report sea level is referred to as NGVD of 1929 and this datum is understood when the term altitude is used.

Table 2.—*Fresh ground water withdrawn in the St. Johns River Water Management District, Florida, 1980*

[Data provided by S.D. Leach, written commun., 1981. Values are in million gallons per day; to obtain equivalent acre-feet per year, multiply by 1,120]

County	Public supply	Rural (self-supplied)	Irrigation	Industrial (self-supplied)	Thermo-electric power generation
Alachua[1]	16.56	6.87	10.22	0.68	0.51
Baker[1]	.60	1.87	.69	.30	.0
Bradford[1]	.0	.04	.0	.0	.0
Brevard	[2]19.31	4.45	158.64	.24	.25
Clay	1.83	8.69	1.04	3.20	.0
Duval	59.56	20.11	.12	45.29	4.93
Flagler	.77	.51	4.07	.0	.0
Indian River	6.21	4.13	64.06	1.07	4.30
Lake[1]	11.39	5.96	64.79	11.18	.0
Marion[1]	6.54	7.97	14.36	1.57	.0
Nassau	2.77	5.69	.39	59.18	39.0
Okeechobee[1]	.0	.67	7.08	.0	.0
Orange[1]	[3]67.18	14.23	59.84	5.66	.0
Osceola[1]	.0	.27	3.20	.0	.0
Polk[1]	.97	.82	.0	.01	.0
Putnam[1]	2.86	5.03	32.67	19.23	.0
St. Johns	2.98	4.81	29.55	.01	.0
Seminole	13.98	13.01	23.63	3.80	.0
Volusia	26.57	5.57	17.30	.33	.55
Total	240.08	110.70	[4]491.64	151.75	49.54
Total of all sources 1,043					

[1]Ground water withdrawn reflects only the area of the county that is in the St. Johns River Water Management District.
[2]Includes 16.0 Mgal/d imported from Orange County.
[3]Does not include 16.0 Mgal/d exported to Brevard County.
[4]Irrigation water use is based on optimum application rates for various crops, not actual use. Actual use for 1980 probably is between 300 and 492 Mgal/d.

Table 1.—*Springs and spring discharges, by county*

[Compiled from Rosenau and others, 1977]

County	Spring name	Estimated mean discharge, in cubic feet per second
Alachua	Boulware	—
	Ford	—
	Glen	0.35
	Iron	—
	Magnolia	.79
	Sulfur	—
Clay	Gold Head Branch	"Appreciable" (Rosenau and others, 1977, p. 97)
	Green Cove	3.52
	Magnolia	—
	Pecks	—
	Wadesboro	—
Lake	Alexander	120
	Apopka	29
	Blue	3.04
	Bugg	14.5
	Camp La No Che	.58
	Holiday	3.90
	Messant	20.5
	Seminole	25
Marion	Blue	10.6
	Fern Hammock	15.9
	Juniper	12.8
	Orange	7.8
	Rainbow	763
	Salt	82
	Silver Glen	112
	Silver	820
	Sweetwater	—
Nassau	Su-No-Wa	—
Orange	Barrel	—
	Camp	—
	Mill Creek	—
	Rock	64.6
	Wekiwa	74.2
	Witherington	6.6
Putnam	Beecher	10.7
	Forest	.30
	Mud	2.26
	Nashua	.37
	Satsuma	1.80
	Welaka	—
	Whitewater	1.41
Seminole	Clifton	1.7
	Elder	.02 (estimated)
	Heath	.02 (estimated)
	Lake Jessup	1.04
	Miami	5.85
	Palm	9.75
	Sanlando	19.0
	Starbuck	16.6
Sumter	Fenny[1]	27.4
	Panasoffkee River group[1]	43.7
Volusia	Blue	162
	Gemini	7.67
	Green	.79
	Ponce de Leon	30.8
	Seminole	.05

[1]These springs are outside the St. Johns River Water Management District, but some of their discharge is derived from ground water flowing out of the District.

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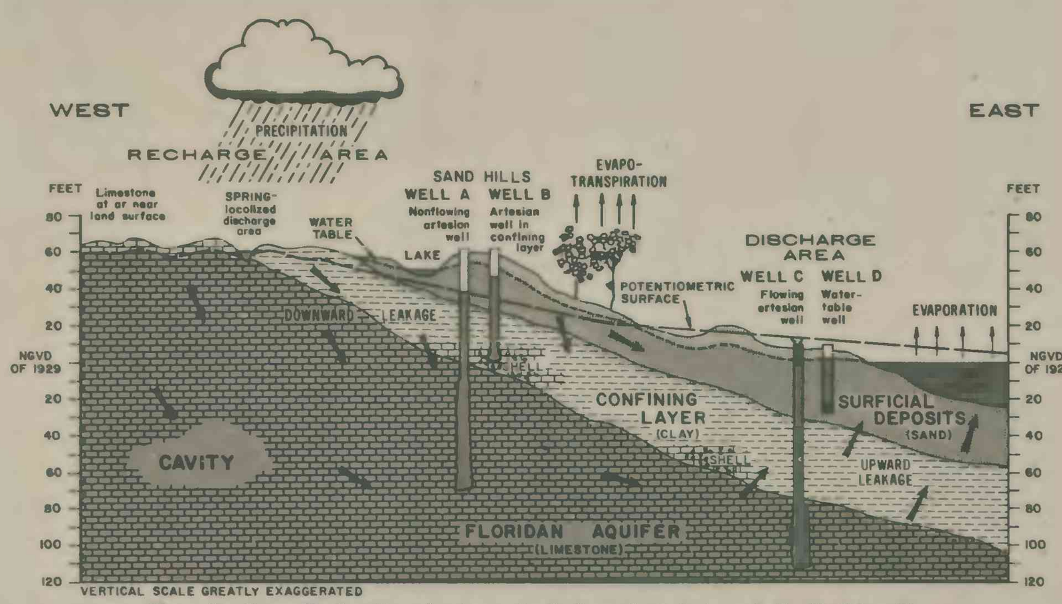

Figure 1.—Generalized section showing major hydrogeologic features in the St. Johns River Water Management District.

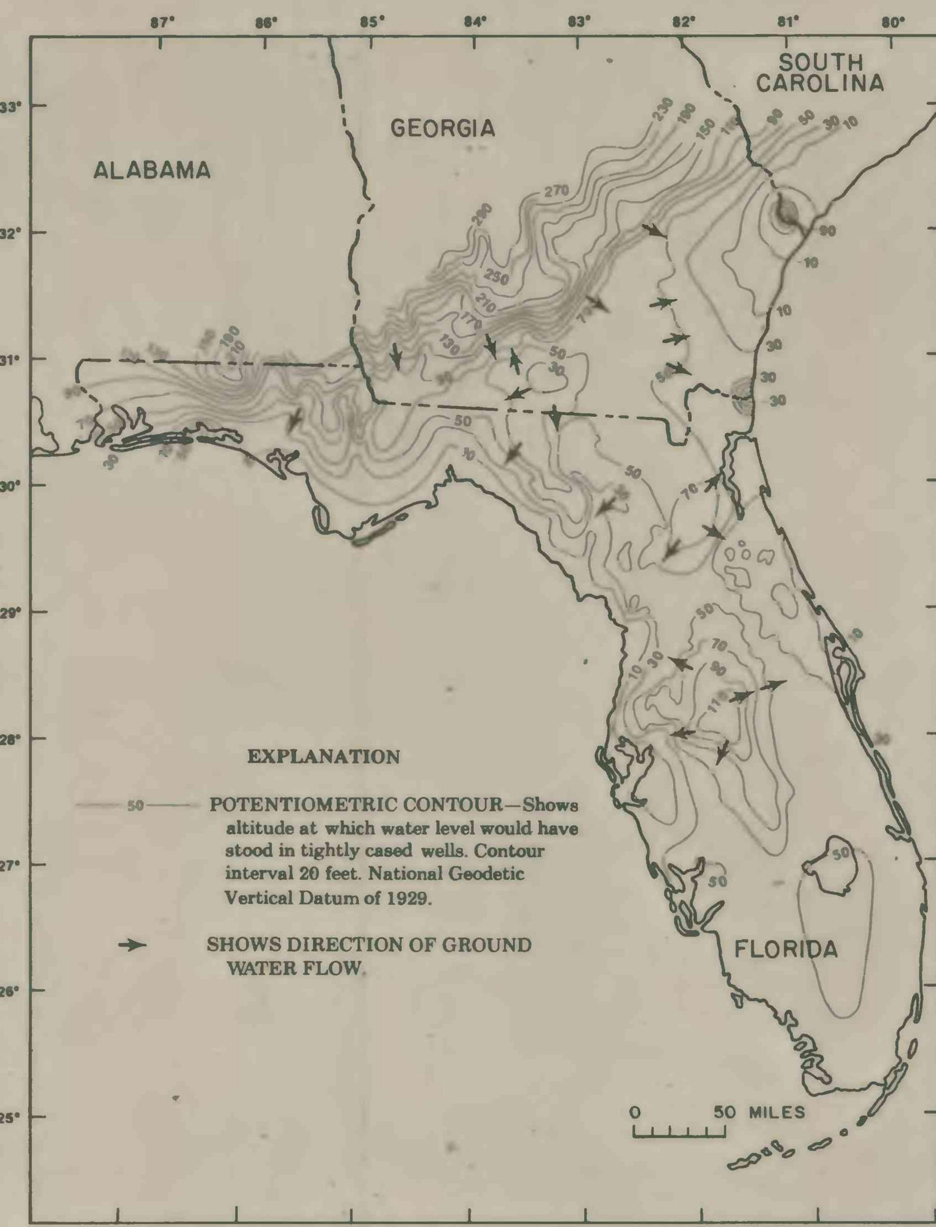

Figure 3.—Potentiometric surface of the Tertiary limestone (Floridan in Florida) aquifer system, and general direction of ground-water flow, southeastern United States, May 1980 (modified from Johnston and others, 1981).

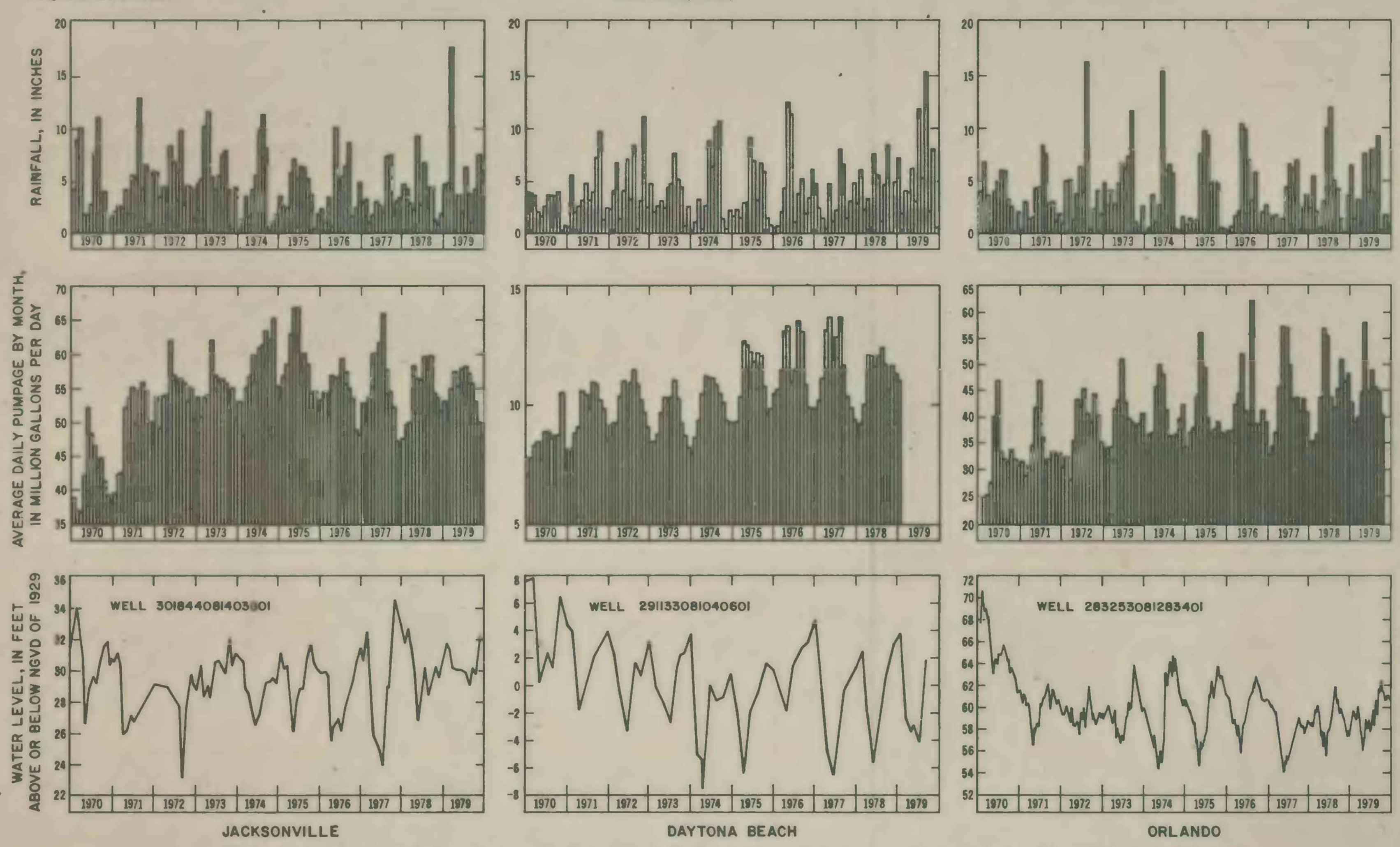

Figure 4.—Rainfall, municipal pumpage, and hydrographs of Floridan aquifer wells in Jacksonville, Daytona Beach, and Orlando, 1970 to 1979.

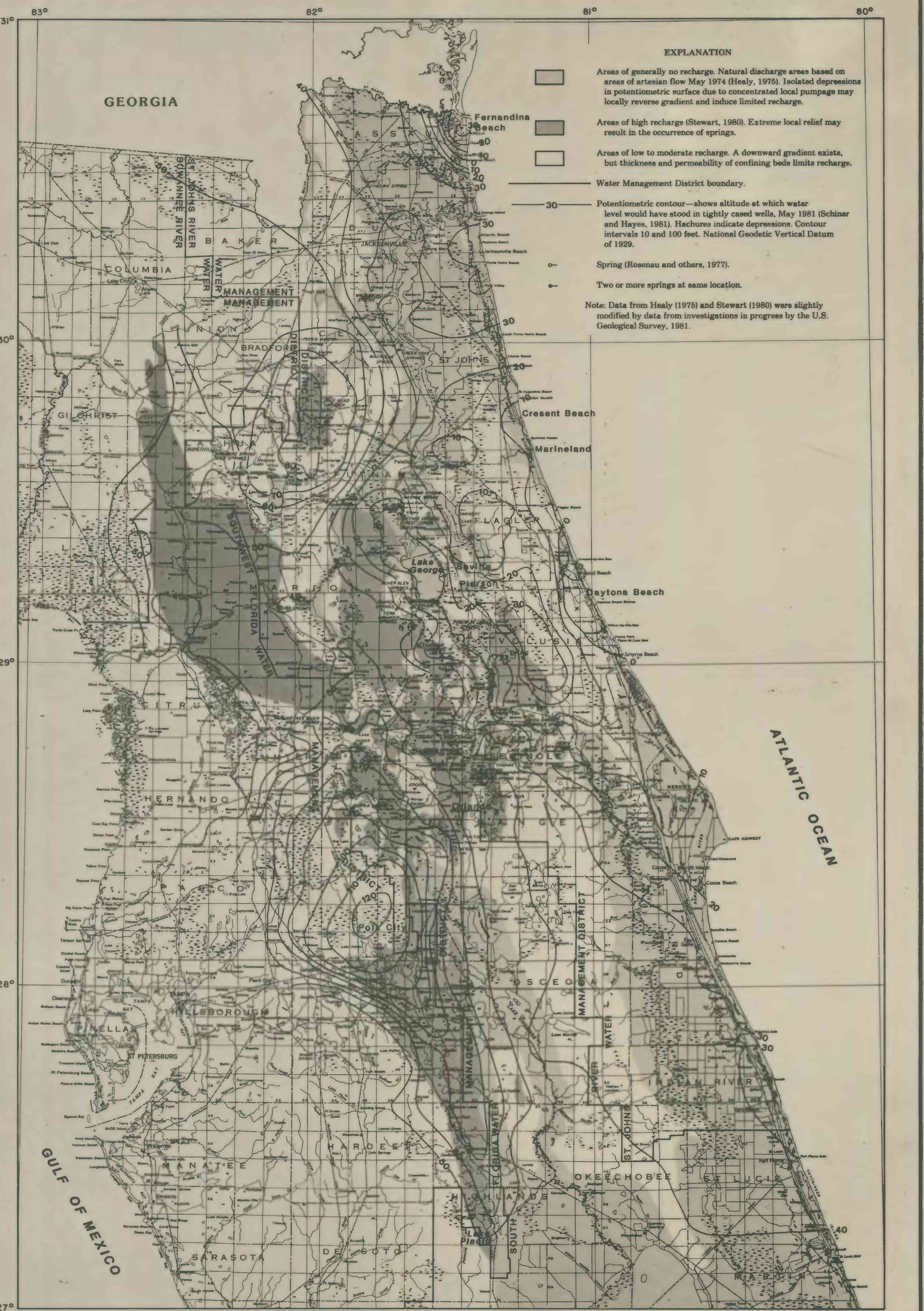

Figure 2.—Approximate extent of major natural recharge and discharge areas in the St. Johns River Water Management District and potentiometric surface of the Floridan aquifer, May 1981.

RECHARGE AND DISCHARGE AREAS OF THE FLORIDAN AQUIFER IN THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT AND VICINITY, FLORIDA

By
G.G. Phelps

1984