GROUND-WATER WITHDRAWALS IN THE UPPER PEACE AND UPPER ALAFIA RIVER BASINS, FLORIDA

by A.F. Robertson and L.R. Mills

Prepared by
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INTRODUCTION

An investigation of ground-water withdrawals in the upper Peace River and upper Alafia River basins was begun in July 1970 as part of a cooperative agreement with the Southwest Florida Water Management District. The investigation was prompted by the need to quantitatively evaluate the cause of the large declines in artesian water levels in the area which have occurred in recent years. Information gathered as part of the investigation an presented herewith provide a base for decisions as to the means to alleviate the situation.

Many direct measurements of pumpage were made during the course of this investigation. Extrapolations that were necessary were based on data obtained by direct measurements made during 1970 and 1971.

Numerical values in the text of this report are given in English units. Water-quality data are reported in metric units only, and other tabular data and contour values on maps are in English units only. The following table will aid the reader in converting English units to metric units.

Multiply English units	By	To get metric units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons (gal)	3.785×10^{-3}	cubic meters (m^3)
acre-feet (acre-ft)	1233	cubic meters (m^3)
	1.233×10^{-3}	cubic hectometers (hm^3)
million gallons per day (mgd)	43.81	cubic decimeters per second (dm^3/s)
	.04381	cubic meters per second (m^3/s)
gallons per minute (gpm)	.06309	liters per second (ls)
tons	.9072	Tonne (t)

ACKNOWLEDGMENTS

The cooperation of the many grove owners, industrial plant managers, and municipal water superintendents, who permitted discharge measurments of their wells and provided information that made this study possible, is gratefully acknowledged.

The assistance of personnel from many governmental agencies and other organizations was also useful to this study and a special thanks is given. These include: County Extension Service, Polk County; Florida Citrus Experiment Station; Florida Crop and Livestock Reporting Service; Florida Department of Agriculture, Division of Fruit and Vegetable Inspection; Florida Phosphate Council and the Southwest Florida Water Management District. The investigation was made by the U.S. Geological Survey under the general supervision of C.S. Conover, district chief for Florida, and under the immediate supervision of J.S. Rosenshein, chief of the Tampa subdistrict.

DESCRIPTION OF THE AREA

The upper Peace and upper Alafia River basins, as referred to in this report, are the drainage areas upstream from the U.S. Geological Survey gaging station on the Peace River at Zolfo Springs, and the station on the Alafia River at Lithia (fig. 1). The two basins encompass about 1,160 square miles. Flatlands, generally less than 150 feet above mean sea level, lie between three ridges. The ridges, which trend northwest reach a maximum elevation of 350 feet. The sandy soils in the area, especially along the ridges, are well drained and extensively cultivated for citrus.

One of the most productive phosphate-ore deposits in the world is in the area of investigation. This ore has been mined extensively (fig. 1) and is the basis for many industries.

Fourteen cities and towns lie in or adjacent to the basins. The largest city is Lakeland, which had a population of about 41,500 in 1970. Three others--Bartow, Plant City and Winter Haven--each had populations greater than 10,000.

Hundreds of wells in the area are used for a variety of water needs. However, most of the water is pumped for municipal, irrigation, and industrial use. The principal source of water is the Floridan aquifer. This aquifer, which underlies the entire area is highly productive. Individual wells produce as much as 8,000 gpm (gallons per minute). The aquifer consists of several thousand feet of limestone and dolomite overlain by 50 to 100 feet of sand and clay beds. Few wells are deeper than 1,500 feet and most are about 800 feet deep.

METHODS USED TO DETERMINE GROUND-WATER WITHDRAWAL

Ground-water withdrawal was determined as follows: (1) reading meters at most municipal wells; (2) measuring discharge of many industrial and irrigation wells; (3) determining the relation between electrical-power consumption and pumpage from pilot wells for extrapolation of pumpage to wells where only power consumption was known; and (4) determining the relation between pumpage and tons of phosphate production, boxes of citrus production, and acres of citrus irrigated at pilot areas for extrapolation of pumpage to the total area of investigation.

Eight of the 14 cities and towns, representing 90 percent of the water withdrawn for municipal use, had some method of metering their total water use. The figures given for municipal water-use are considered to be the most accurate of the three water-use categories shown.

Pump discharges for many industrial and irrigation wells measured by direct methods were used as a basis for estimating discharges of other wells by indirect methods. One indirect method involved determining the relation between discharge rate and power consumption. Records of power consumption were used to determine the amount of water withdrawn by pumps driven by electric motors. Owners or plant managers provided estimates of the total operating time (during 1970-71) of pumps that were not equipped with electric meters.

Another indirect method involved the determination of the quantity of water used per ton of phosphate mined, per box of citrus processed and per acre of citrus grove irrigated. These figures, determined at pilot areas, were used with phosphate and citrus production data and with citrus acreage data to estimate total industrial water use and total irrigation water use during 1970-71. This indirect method also was used to determine annual water use from 1935 to 1970. The figures that were used were: (1) 2,800 gallons per ton of phosphate mined; (2) 120 gallons per box of citrus processed for concentrate; and (3) 432,000 gallons per year per acre of citrus irrigated. Past investigations also provided some data (Stewart, 1966; Kaufman, 1967; Pride, 1970; and Robertson, 1972).

GROUND-WATER WITHDRAWALS

Annual ground-water withdrawal from the Floridan Aquifer in the upper Peace and upper Alafia River basins was slightly more than 120 billion gallons in 1970 and 1971. In 1971, 11.6 billion gallons were used by municipalities, 76 billion gallons by industries, and 33 billion gallons by citrus irrigators. The general locations of centers of pumpage in 1971 are shown on figure 2.

The highest annual water use was 143 billion gallons and occurred in 1968. The decrease in water use between 1968 and 1971 is mainly the result of decreased withdrawals by industry.

MUNICIPAL WITHDRAWALS

Fourteen municipalities in, or immediately adjacent to, the area used 11.6 billion gallons of water, or about 10 percent of the total pumpage in the area during 1971. Lakeland, the largest city in the area, used the most, almost half of the municipal demand. Municipal water use has increased steadily since 1935 (fig. 3). The increase has been dramatic for some cities. For instance Lakeland's water use has more than tripled since 1951 (table 1). Although some municipalities supply water to industries in the cities, most of the increase in municipal pumpage is due to increase in population. The population in the area of investigation was not determined directly, but was determined indirectly by assuming that the population of Polk County since 1935 (fig. 4) is representative of the growth of the area.

Water use by cities is influenced by rainfall. On the average the greatest use is during the drier months of April, May, and June when almost one-third of the annual withdrawals occur (fig. 5) and rainfall is low (fig. 6).

INDUSTRIAL WITHDRAWALS

In 1971, the 76 billion gallons of ground water used by industry represented 63 percent of the total water used that year in the area of investigation. Industries include phosphate mining and processing, citrus processing and packing, ice manufacturing, concrete batch plants, and laundries. The phosphate and citrus industries are by far the largest industrial water users.

The increased ground-water withdrawals by industry since 1935 (fig. 3) reflects the increase of industrial output. For example, the production of both phosphate and citrus (fig. 4) has grown markedly. However, this growth has not been steady. Water-use for citrus processing dropped considerably for several years after 1962 when a severe freeze destroyed many trees and cut production. Water withdrawals by the phosphate industry have decreased since 1968 because of increased use of recirculated water in mining operations.

Industrial withdrawals vary during the year (fig. 5). Withdrawals for citrus processing were determined monthly and vary considerably due to the seasonal nature of the citrus crop. Withdrawals for phosphate mining and processing also vary considerably because of the use of recirculated water from holding ponds that is replenished by rainfall during part of the year. These variations are apparent because the area of greatest water-level recovery in 1971 occurred in the area of phosphate mining, (fig. 2). However, the data available for withdrawals by the phosphate industry was only sufficient to determine total annual withdrawals. Therefore, for the purpose of showing the relative magnitudes of all water-use categories, pumpage by the phosphate industry was assumed to be constant.

IRRIGATION WITHDRAWALS

Water use for irrigation of citrus is the second largest water requirement in the area on an annual basis. During 1971, irrigation pumpage was 33 billion gallons, about 27 percent of the total quantity of groundwater withdrawn that year. Estimates of the amount of water used for irrigation from 1935 to 1971 (fig. 3) were based on the total citrus acreage during those years and adjusted on the basis of annual precipitation (fig. 7). The percentage of citrus acreage irrigated was assumed to have increased linearly from 10 percent in 1935 to 75 percent in 1971.

Because irrigation is supplemental to rainfall, withdrawals are high during dry periods and low or zero during wet periods. Monthly irrigation during 1970-71 (fig. 5) varied inversely with monthly precipitation (fig. 6).

The water used to irrigate 14 citrus groves that represent about 20 percent of the total irrigated acreage was monitored in 1970 and 1971. The water use per acre was determined, and that value was used to estimate total irrigation pumpage.

EFFECTS OF GROUND-WATER WITHDRAWALS ON POTENTIOMETRIC LEVELS

Levels of the potentiometric surface of the Floridan Aquifer fluctuate mainly in response to withdrawals from the aquifer. Levels have declined since about 1948 as ground-water withdrawals increased (figs. 3 and 8). Levels declined more than 40 feet between 1949 and 1969 in the central part of the area (Stewart and others, 1971). Between June 1969 and May 1971 water levels declined by as much as 20 feet in part of the area (Robertson, 1973, p. 22).

Seasonal water-level fluctuations are caused by seasonal pumpage variations (figs. 5 and 9). Levels are generally lowest during the spring when pumpage is greatest and rainfall is least and highest during the fall. These seasonal water-level fluctuations are greatest, slightly more than 20 feet, near the central and southern parts of the area of investigation (fig. 2).

SUMMARY

In 1971, 120 billion gallons of groundwater was withdrawn from the Floridan Aquifer in the upper Peace and upper Alafia River basins. Withdrawals increased from 22 billion gallons in 1935 to 143 billion gallons in 1968. Industries associated with phosphate mining and production and with citrus processing used about 76 billion gallons in 1971. Withdrawals for irrigation were 33 billion gallons and for municipal supplies were 11.6 billion gallons in 1971.

The decrease in total water withdrawals since 1968 is caused mainly by the decrease in industrial withdrawals. Phosphate mining operations, using more recirculated water from holding ponds, have reduced their withdrawals from the aquifer for make-up water.

Increased annual withdrawals have resulted in declines of water levels in the Floridan Aquifer of more than 40 feet since 1949. Seasonal variations in ground-water withdrawals are reflected in seasonal water-level fluctuations of as much as 20 feet over the central and southern parts of the area of investigation.

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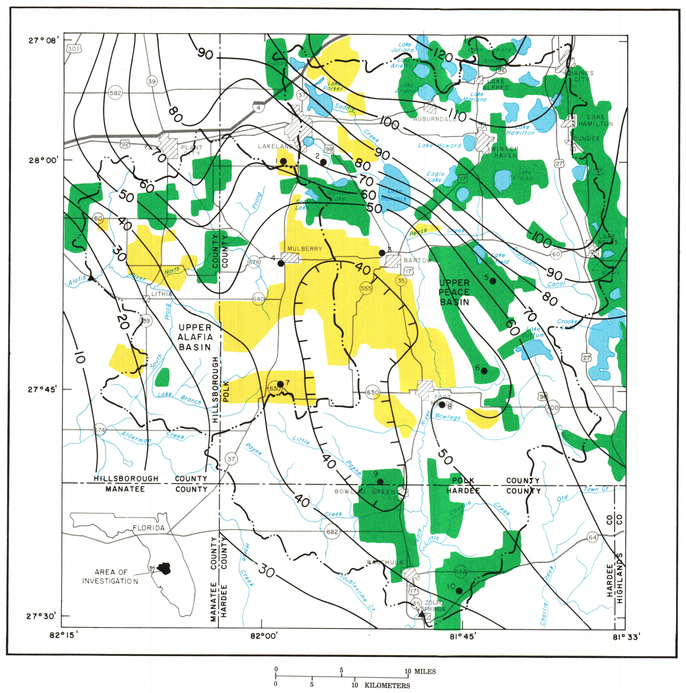
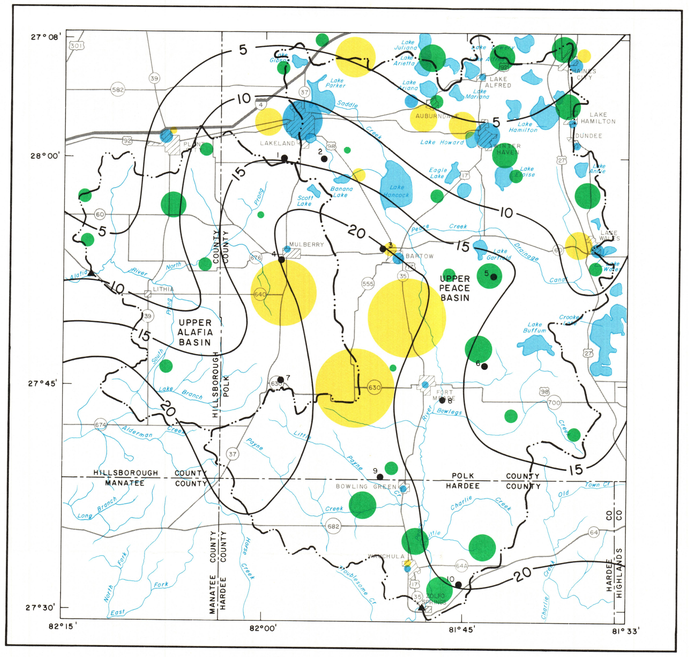


EXPLANATION

- Generalized Area of Phosphate Mining
- Generalized Area of Citrus Cultivation
- 9● Observation Well and Number
- ▲ Stream Gaging Station
- Drainage Basin Boundary
- —20— Potentiometric Contour—Shows Elevation of the Potentiometric Surface of the Floridan Aquifer in May, 1971. Contour Interval 10 Feet. Datum is Mean Sea Level.

Figure 1. Potentiometric surface of the Floridan Aquifer in May 1971 and areas of phosphate mining and citrus cultivation.



EXPLANATION

- Center of Industrial Pumpage
- Center of Irrigation Pumpage
- Center of Municipal Pumpage
- 9● Observation Well and Number

Area of Circle Indicates Annual Ground-Water Withdrawals, in Billion Gallons

0.3 0.3-1 1-3 3-6 6-10 10-15 15-25

- ▲ Stream Gaging Station
- Drainage Basin Boundary
- —20— Line of Equal Water-Level Rise in the Floridan Aquifer from May to Sept, 1971. Interval 5 feet.

Figure 2. Centers of pumpage and rise in level of the potentiometric surface of the Floridan Aquifer from May to September, 1971.

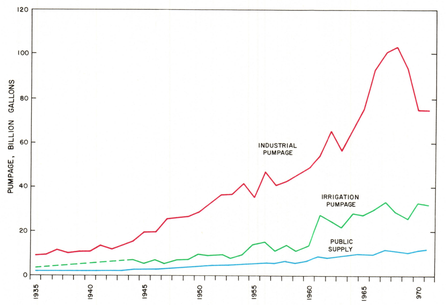


Figure 3. Estimated annual ground-water pumpage for public supply, industry and irrigation, 1935-71.

Table 1. Pumpage in the Upper Peace and Upper Alafia River Basins, 1951, 1961, 1971.

	Pumpage, billion gallons		
Municipality	1951	1961	1971
Lakeland	1.715	3.904	5.442
Winter Haven	.700	1.231	1.773
Bartow	.290	.600	.926
Plant City	.295	.702	.899
Lake Wales	.310	.599	.709
Haines City	.225	.451	.438
Wauchula	—	.258	.266
All others	.295	.840	1.195
Total	3.830	8.585	11.648
Industrial	32.5	54.1	76.0
Irrigation	9.2	28.9	32.7
Total	45.5	91.6	120.3

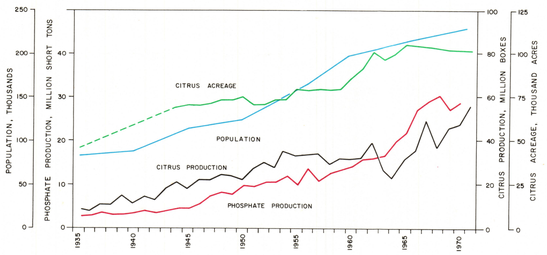


Figure 4. Citrus acreage, phosphate production, citrus production, and Polk County population, 1935-71.

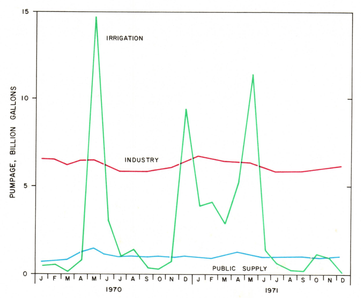


Figure 5. Monthly ground-water pumpage for public supply, industry, and irrigation, 1970-71.

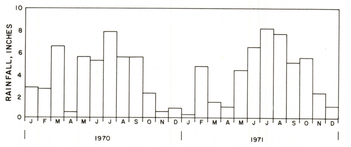


Figure 6. Rainfall in the upper Peace and upper Alafia River basins, 1970-71. Data from the National Oceanic and Atmospheric Administration Environmental Data Service.

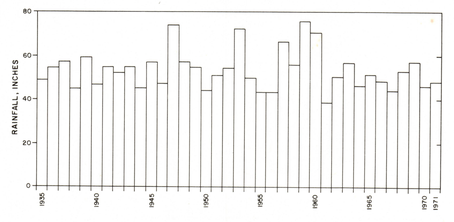


Figure 7. Rainfall in the upper Peace and upper alafia River basins, 1935-71. Data from the National Oceanic and Atmospheric Administration Environmental Data Service.

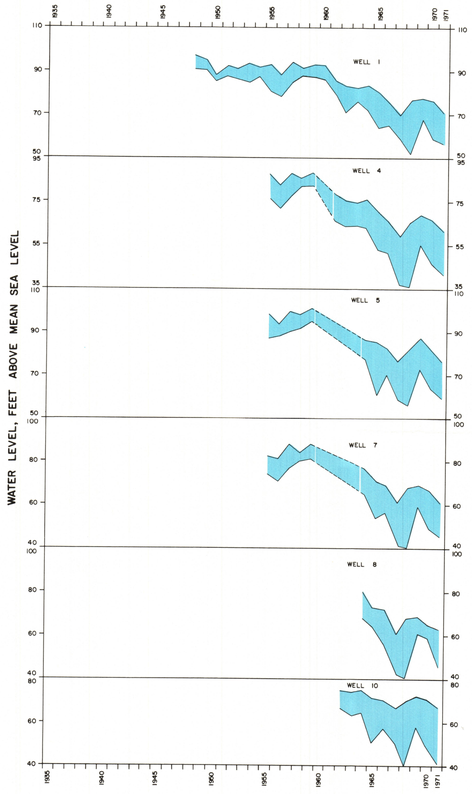


Figure 8. Range of water-level fluctuations in selected wells which penetrate the Floridan Aquifer, 1948-71. The highest and lowest water levels during the year are shown where data are available. Numbered wells are shown on figures 1 and 2.

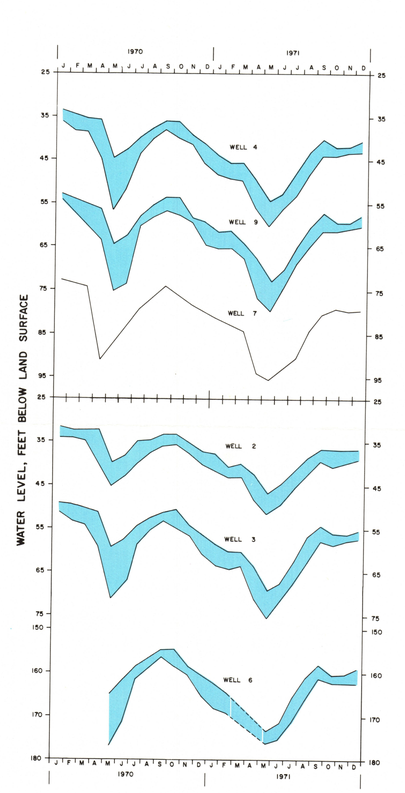


Figure 9. Range of water-level fluctuations in selected wells which penetrate the Floridan Aquifer, 1970-71. The highest and lowest water levels in each month are shown where data are available from recorder charts. Well 7 is measured periodically. Numbered wells are shown on figures 1 and 2.