Relation of Change in Water Levels in Surficial and Upper Floridan Aquifers and Lake Stage to Climatic Conditions and Well-Field Pumpage in Northwest Hillsborough, Northeast Pinellas, and South Pasco Counties, Florida

By M.A. Lopez and J.D. Fretwell

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
foot per day per foot [(ft/d)/ft]	1.0000	meter per day per meter
mile (mi)	1.609	kilometer
acre	0.4047	hectare
foot squared per day (ft^2/d)	0.09294	square meter per day
square mile (mi^2)	2.590	square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9\ (°F - 32)$$

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 both the United States and Canada, formerly called Sea Level Datum of 1929.

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Abstract

In response to a rapidly growing demand for water, pumpage from six municipal water-supply well fields that tap the Upper Floridan aquifer in the study area may increase. The effect of this increase in ground-water withdrawal on the water levels in the Upper Floridan and surficial aquifers and lake stage was assessed. Multiple linear-regression analyses were used to define the relation of well-field pumpage, rainfall, and potential evaporation to changes in monthly average water levels in 29 Upper Floridan aquifer wells. The regression coefficient of determination and root mean square error of the relations ranged from 0.40 to 0.90 and 0.18 to 2.20 feet, respectively.

The change in average monthly water levels in surficial aquifer wells and lake stage was related to rainfall, water level in a nearby Upper Floridan aquifer well, and potential evaporation. For 14 of the 24 lakes, regression relations were developed for two seasons, June through October and November through May. The regression coefficient of determination and root mean square error for all relations ranged from 0.42 to 0.85 and 0.11 to 0.77 foot, respectively. These same parameters for three surficial aquifer wells ranged from 0.65 to 0.84 and 0.43 to 0.67 foot, respectively.

The change in water level in the surficial aquifer and lake stage also was related to well-field pumpage, rainfall, and potential evaporation. The root mean square error of the set of relations using water level in an Upper Floridan well was generally lower than for the relations using well-field pumpage. Because neither set of relations was universally superior, both sets of relations were used in the application of the regressions to demonstrate the effect of varying rainfall or pumpage. Examples of the effects of varying the monthly rainfall or pumpage rates from 50 to 150 percent of the average are shown for October 1984 through September 1985 at James deep well 11, Berger deep well, Van Dyke shallow well, St. Petersburg shallow well 105, Lake Alice, and Starvation Lake.

INTRODUCTION

In 1982, the Florida State Legislature delegated authority to the Water Management Districts to determine the availability of ground water in areas where overdrafts are likely to occur because of current or projected development and to establish minimum seasonal surface- and ground-water levels. There has been public concern that well-field pumpage from the Floridan aquifer system in the rapidly developing area north of Tampa Bay has contributed to excessive, long-term lowering of lake levels and the water table in the surficial aquifer. Some scientific credence has been given to the argument in an analysis by the Southwest Florida Water Management District of water levels for a few selected lakes and well-field pumpage that indicated lake levels and pumpage are related (Patricia Dooris, Southwest Florida Water Management District, oral commun., 1985). Climatic factors also affect lake levels and the water table in the surficial aquifer. A need existed, therefore, to define further the degree of interaction between rainfall, evapotranspiration, and water levels in lakes; the water table in the surficial aquifer; and the potentiometric surface in the Upper Floridan aquifer so that water-management decisions can be based on a scientific understanding of the hydrologic system.

In response to this need, the U.S. Geological Survey, in cooperation with the Southwest Florida Water Management District and Pinellas County, began a study of existing hydrologic data in 1986 to determine the relation of lake stage and well water levels to well-field pumpage and climatic factors.

This report summarizes the data used in the hydrologic analysis and presents the relation of change in lake stage and well water levels to well-field pumpage, rainfall, and evaporation.

Purpose and Scope

The purpose of this report is: (1) to show the relation of well-field pumpage and rainfall to lake stage and water levels in wells that tap the surficial and Upper Floridan aquifers and (2) to describe a method for evaluating the effects of well-field pumpage and rainfall on lake stage and water levels in the surficial and Upper Floridan aquifers. The area of study is in northwest Hillsborough, northeast Pinellas, and south Pasco Counties. Within this area there are six municipal well fields; the first one began pumping in 1931. A daily rainfall gage was installed in 1931, and as other well fields were developed, additional daily rainfall data were collected. Periodic observations or continuous records of water levels in wells and lake stage began as early as 1943, but most analyses were made during periods of concurrent record after 1970.

Much of the rainfall, well water-level, and lake-stage data up through 1984 had been summarized by month by the Southwest Florida Water Management District and was available for this study. Because this area experienced a severe drought in 1985, the data were extended through September 1985 by the U.S. Geological Survey.

The monthly data provided a suitable time period to determine seasonal variations in the hydrologic conditions. The monthly data also were suitable for statistical evaluation through regression analysis. Multiple linear-regression analysis was used to determine the relation of the dependent variable, the change in lake stage or water level in a well, to the explanatory variables, rainfall, evaporation, and well-field pumpage.

Previous Studies

Discussions of the hydrogeology of the study area are found in many publications of the U.S. Geological Survey, the Florida Geological Survey, and private organizations. Stewart (1968) described the hydrologic effects of pumping from the Floridan aquifer in northwest Hillsborough, northeast Pinellas, and southwest Pasco Counties. Cherry and others (1970) described the general hydrology of the middle gulf area. Wetterhall (1964) reported on a geohydrologic reconnaissance of Pasco County.

Many authors have discussed various hydrologic aspects of northwest Hillsborough County. Cherry and Brown (1973) discussed the hydrogeology at a proposed landfill site, Sinclair (1974) described the hydrogeology of the surficial aquifer, Stewart and Hughes (1974) described the hydrologic consequences of augmenting lakes with well water, and Corral and Thompson (1988) described the hydrogeology of the Citrus Park quadrangle.

General ground-water resource studies, which include parts of the study area, were done by Heath and Smith (1954) in Pinellas County, Menke and others (1961) in Hillsborough County, and Fretwell (1988) in Pasco County. Ryder (1982) made use of a regional flow model to describe the ground-water hydrology of the study area, and Hutchinson (1984) presented a more detailed model study of the well-field areas near Tampa.

DESCRIPTION OF STUDY AREA

The approximately 100-mi^2 study area (fig. 1), northwest of Tampa on the west-central coast of Florida, is bounded on the east by Dale Mabry Highway (State Road 597), on the north by State Road 54 and the Pasco County line, on the west by Lake Tarpon, and on the south by 28 degrees, 2 minutes, and 30 seconds north latitude. The study area is largely rural; however, the area is rapidly becoming urban with residential growth along Dale Mabry Highway, Gunn Highway, and East Lake Road. In the Hillsborough-Pinellas-Pasco tricounty area, population has increased 44 percent in the last decade. This upward growth trend is expected to continue at least through 2020 (University of Florida, 1985).

Rainfall

Rainfall data are collected at stations within and near the study area (fig. 1 and table 1). The amount of rainfall varies considerably between stations because of its convective nature. Annual rainfall recorded in and around the study area ranged from 28.89 in. in 1956 at Tampa south of the study area to 77.78 in. in 1957 at Tarpon Springs (table 1). The wide variations in rainfall among three stations, Cosme-Odessa, Tampa, and Tarpon Springs, are shown in figure 2. Average annual rainfall for a 30-year period of record (1956-85) was 54.96 in. at Cosme-Odessa, 46.19 in. at Tampa, and 53.44 in. at Tarpon Springs.

The wide monthly variations of rainfall and mean monthly rainfall at these same three stations are shown in figure 3. Fifty-seven percent of the rainfall occurs in the summer months between June and September. Figure 3 also shows the comparison of rainfall in 1981 to the extremes. Rainfall in July 1981 at Tampa is the minimum rainfall recorded at that station for the month of July. Monthly rainfall has varied from as little as zero in some spring and fall months at all sites (table 1) to as much as 23.97 in. in June 1974 at Cosme-Odessa. Months of lowest rainfall are generally November and April. Total monthly rainfall at four stations within the study area, Cosme-Odessa, Section 21, South Pasco, and Eldridge-Wilde, was used in the regression analyses.

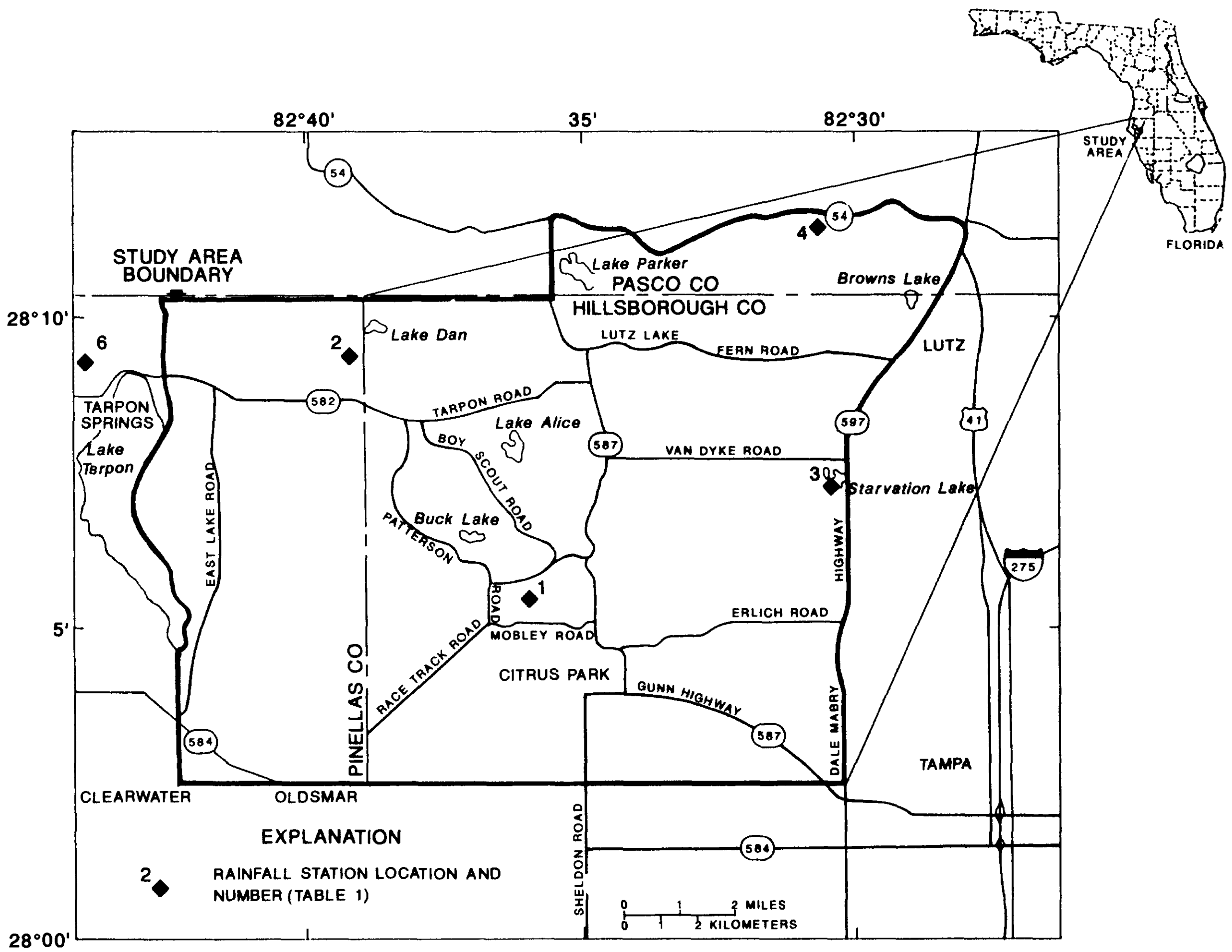


Figure 1. Location of the study area and rainfall stations.

Evapotranspiration

Evapotranspiration (ET) is the natural loss of water vapor to the atmosphere from soil, vegetation, and open-water surfaces (Jones and others, 1984). Values of ET vary locally with climate, soil conditions, and vegetation and seasonally with changes in temperature, vegetative cover, precipitation, and soil moisture. Cherry and others (1970), in their study of the middle gulf area (conducted between 1964 and 1966), found that ET was greatest in July and August when rainfall and temperature were also greatest. On the basis of residuals in a water-balance equation and adjusting values for seasonal and areal variations by use of the Thornthwaithe method (Thornthwaithe and Mather, 1957), ET for the middle gulf area, which includes the study area, was estimated to average 38.5 in. annually.

Dohrenwend (1977) calculated 44.29 in. of potential ET and estimated actual ET to average 34.84 in. In contrast, Farnsworth and others (1982) estimated average annual potential evaporation to be 47 to 48 in. in the study area. The difference in rainfall and potential evaporation is about 5 in.

Mean monthly temperatures in the study area range from a low of about 59 °F in January to a high of about 82 °F in August. The mean annual temperature is about 72 °F.

Pan evaporation from stations at Lake Alfred, about 45 mi east of the study area, and Lake Padgett, just northeast of the study area, was available for analyses; however, potential evaporation was used in this study because it could be used as input for predictive equations. Monthly potential evaporation was calculated on the basis of solar radiation at latitude 28 degrees north (Chow, 1964, p. 11-29). The midmonth daily value in millimeters of water evaporated per day was converted to the monthly total, in inches, as indicated below.

January	10.9	July	19.6
February	11.9	August	18.7
March	17.2	September	16.2
April	17.6	October	14.2
May	19.4	November	11.2
June	19.4	December	10.2

Geohydrology

Sedimentary deposits several hundred feet in thickness form the aquifers and confining units in the study area. The principal potable water-bearing units in the study area are the surficial aquifer and the Upper Floridan aquifer. These aquifers are separated by a discontinuous intermediate confining unit of the Floridan aquifer system in some areas. Where the

Table 1. Summary of rainfall data within and near the study area
[—, no data]

Station number and name	Period of record (number of years)	Minimum monthly rainfall Inches	Minimum monthly rainfall Date	Maximum monthly rainfall Inches	Maximum monthly rainfall Date	Minimum annual rainfall Inches	Minimum annual rainfall Year	Maximum annual rainfall Inches	Maximum annual rainfall Year	Average annual rainfall for period of record Inches	Average annual rainfall for period of record Years	Average annual rainfall for 30-year period 1956-85 (inches)
1 Cosme-Odessa	54	0.00	Nov. 1931	23.97	June 1974	33.19	1956	73.77	1937	54.23	1932-85	54.96
		.00	Nov. 1942									
		.00	Nov. 1960									
		.00	Apr. 1967									
		.00	Nov. 1978									
		.00	Apr. 1981									
2 Eldridge-Wilde	12	.00	Nov. 1978	21.22	July 1974	40.76	1984	63.05	1983	51.60	1974-85	—
		.00	Apr. 1981									
		.00	Dec. 1984									
3 Section 21	13	.00	Nov. 1978	19.94	Aug. 1979	34.46	1984	74.76	1979	51.31	1973-85	—
		.00	Apr. 1981									
4 South Pasco	10	.00	Oct. 1974	16.82	Aug. 1979	30.83	1980	67.77	1979	49.15	1976-85	—
		.00	Nov. 1978									
		.00	Apr. 1981									
5 Tampa	33	.00	Jan. 1950	20.59	July 1960	28.89	1956	76.57	1959	46.41	1951-85	46.19
		.00	Nov. 1960									
		.00	Apr. 1967									
6 Tarpon Springs	55	.00	May 1927	23.60	Aug. 1949	32.89	1956	77.78	1957	53.09	1938-85 (missing 1944, 1948-49, 1972, 1978)	53.44
		.00	Nov. 1931									
		.00	Nov. 1939									
		.00	Jan. 1950									
		.00	Apr. 1967									

intermediate confining unit is missing, the surficial aquifer and the Upper Floridan aquifer are hydraulically connected. The Upper Floridan aquifer is separated from the Lower Floridan aquifer by the middle confining unit. The Lower Floridan aquifer contains saline water and, therefore, is not considered in this study. The Lower Floridan aquifer is underlain by the lower confining unit, which is the base of the Floridan aquifer system. A generalized hydrogeologic section of the Floridan aquifer system is shown in table 2.

Hydrogeologic Framework

The locations of three hydrogeologic sections in the study area, based on drillers' logs and well permit applications, are shown in figure 4. The surficial aquifer, which contains the water table, is composed of unconsolidated quartz sand, clay, and shells (fig. 5). Thickness ranges from less than 5 ft to 70 ft, but it generally is 20 to 60 ft thick. Deposits that form the aquifer range in age from Pliocene to Holocene. Water from the aquifer is used for lawn irrigation and stock water, and wells open to the aquifer are generally less than 25 ft deep (Corral and Thompson, 1988). Transmissivity of the aquifer is about 300 ft^2/d (Hutchinson, 1984).

The intermediate confining unit is composed of sandy clay and ranges from 0 to 60 ft thick. The intermediate confining unit is discontinuous, but where present, retards the movement of water between the surficial and the Upper Floridan aquifers. Leakance values for the intermediate confining unit used in Hutchinson's model (1984) in the well-field area ranged from 0.0003 to 0.0004 (ft/d)/ft.

Miller (1986) defined the Floridan aquifer system as a vertically continuous sequence of carbonate rocks of Tertiary age of generally high permeability that are hydraulically connected in varying degrees and whose permeability is several orders of magnitude greater than that of the rocks that bound the system above and below. The Floridan aquifer system in west-central Florida consists of an upper and a lower unit separated by a highly impermeable confining unit. The upper unit, referred to as the Upper Floridan aquifer, is the major water-producing unit in central Florida.

The Upper Floridan aquifer consists of the Tampa Limestone, the Suwannee Limestone, the Ocala Limestone, and the upper part of the Avon Park Formation (table 2). The Tampa Limestone of early Miocene age varies in thickness from 100 to 240 ft (Corral and Thompson, 1988) and is the major stratigraphic unit that contributes water to production

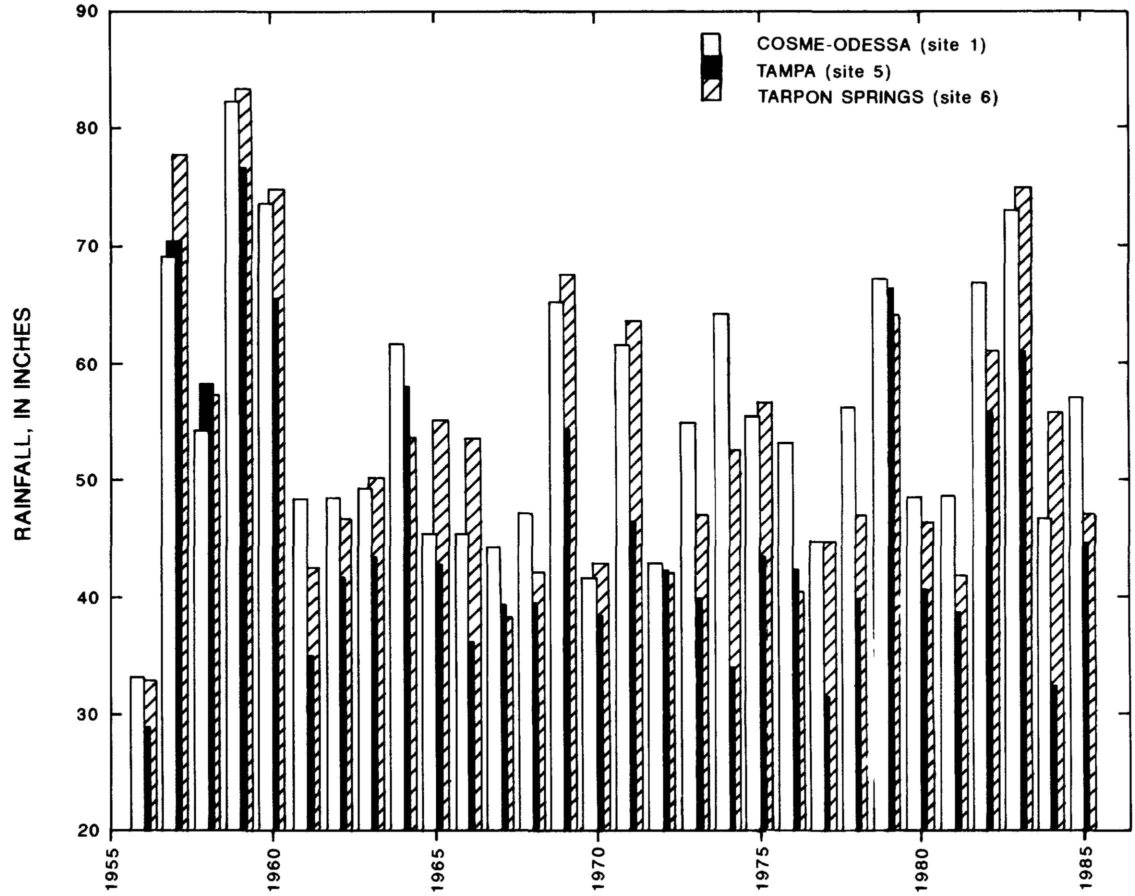


Figure 2. Total annual rainfall at Cosme-Odessa, Tampa, and Tarpon Springs, 1956-85.

wells in the study area. The Tampa Limestone is underlain by the Suwannee Limestone of Oligocene age, which is about 200 ft thick and acts as a semiconfining unit in the study area. The Suwannee Limestone is, in turn, underlain by the Ocala Limestone of late Eocene age, which is also about 200 ft thick in the study area. The lowermost unit of the Upper Floridan aquifer is the Avon Park Formation of middle Eocene age. Thickness of the entire Upper Floridan aquifer ranges from 950 to 1,100 ft (Miller, 1982) in the study area. Transmissivity of the Upper Floridan aquifer in the study area ranges from 25,900 to 57,000 ft^2/d (Hutchinson, 1984).

The middle confining unit of the Floridan aquifer system separates the Upper and Lower Floridan aquifers. It consists of low permeability gypsiferous dolomite and dolomitic limestone and is virtually a nonleaky confining bed that prevents saline water of the permeable limestone of the Oldsmar and Cedar Keys Formations of the Lower Floridan aquifer from mixing with fresher water in the Upper Floridan aquifer (Miller, 1986, p. B56). Anhydrite beds within the Cedar Keys Formation of Paleocene age form an effective confining unit at the base of the Floridan aquifer system (Miller, 1986, p. B22).

Ground Water

The water table of the surficial aquifer marks the top of the saturated zone, and water in the pores of the aquifer at this point is at atmospheric pressure. The elevation of the water table in May 1981, a period of low rainfall, is shown in figure 6. The direction of ground-water flow in the surficial aquifer is generally south and west. Wells used for measuring the elevation of the water table in the surficial aquifer are listed in table 3.

The potentiometric surface of the Upper Floridan aquifer is an imaginary surface that represents points to which water will rise above sea level in tightly cased wells. The potentiometric surface, as it existed prior to development (fig. 7), was defined by Johnston and others (1980). Flow generally is to the south and west toward Tampa Bay and the Gulf of Mexico. The lowest potentiometric surface in recent years occurred in May 1981 and represents the effects of both well-field pumpage and low rainfall (fig. 8). Wells used for measuring the potentiometric surface of the Upper Floridan aquifer also are listed in table 3.

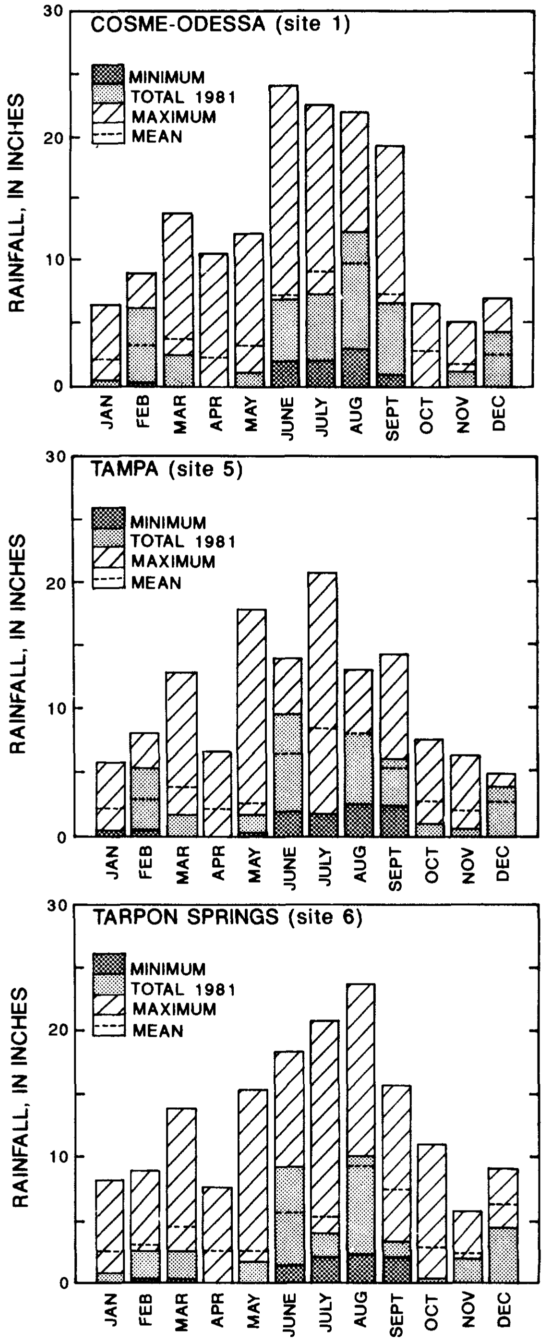


Figure 3. Total monthly rainfall for 1981 and mean, minimum, and maximum rainfall for the period of record at Cosme-Odessa, Tampa, and Tarpon Springs.

The water table of the surficial aquifer and the potentiometric surface of the Upper Floridan aquifer fluctuate seasonally in response to rainfall. The water table of the surficial aquifer generally is above the potentiometric surface of the Upper Floridan aquifer (fig. 9). Locations of wells used to measure water levels are shown in figure 4, and descriptions of these wells are in table 3.

Soils

Most of the study area is covered by poorly to somewhat poorly drained, fine sands that contain organic materials (fig. 10). There are, however, large areas of well-drained, fine, deep sand, especially in the central part of the study area and at the northern end of Lake Tarpon. Mucky soil is found near swamps and streams (Leighty and others, 1958; U.S. Department of Agriculture, 1972; Stankey, 1982).

A generalized soil-infiltration index has been determined by the U.S. Soil Conservation Service using a runoff-curve number and taking into consideration land use and soil type (Chow, 1964; Seijo and others, 1979). This index is defined as the value of potential maximum infiltration during the mean annual storm under average soil-moisture conditions. Throughout most of the area, the index number is 2.05 in. Exceptions are in the extreme western part of the study area near Lake Tarpon, where the index number is 5.38 in., and the extreme northeastern part of the area, where the index number is 3.89 in. Although soil types or indices were not used directly in the regression analyses, they were used to interpret the relative effect of infiltration (recharge) on the regression coefficient of rainfall.

Drainage

Seven drainage basins are within the study area (fig. 11). They are the Anclote River, South Branch Anclote River, Brooker Creek, Double Branch, Rocky Creek, Sweetwater Creek, and Lake Tarpon basins. Some of these are subdivided into smaller drainage areas and internally drained areas. Some of the smaller streams and channels that drain parts of the study area are Hollins Creek in the Anclote River basin and Brushy Creek in the Rocky Creek basin (fig. 11).

Lakes

There are about 90 named lakes and numerous small unnamed lakes or ponds in the study area (fig. 12). Mean monthly lake levels for 24 of these lakes were used in the regression analyses (table 4). Most lakes are naturally or artificially connected to streams. Some lakes, however, do not have well defined outlets and may have outflow only at high flood stage. Lakes vary in size, from less than an acre for many of the unnamed lakes to 417 acres for Keystone Lake. Some lakes are augmented with ground water pumped from nearby deep wells to maintain lake levels, and other lakes are pumped for irrigation.

Water levels in lakes formed by depressions in a surficial aquifer are generally about the same as the water table. Water-level observations in surficial aquifer wells near lakes in northwest Hillsborough County verify that the lakes are hydraulically connected to the surficial aquifer. Hunn and

Table 2. Geohydrologic framework of Floridan aquifer system
[Modified from Ryder, 1985, table 1]

System	Series	Stratigraphic unit	General lithology	Major lithologic unit	Hydrogeologic unit
Quaternary	Holocene and Pleistocene	Surficial sand, terrace sand, phosphorite	Predominantly fine sand; interbedded clay marl, shell, and phosphorite.	Sand	SURFICIAL AQUIFER SYSTEM
Tertiary	Pliocene	Undifferentiated deposits	Clayey and pebbly sand; clay, marl, shell, phosphatic.	Clastic	Confining unit (INTERMEDIATE AQUIFER SYSTEM)
	Miocene	Hawthorn Formation	Dolomite, sand, clay, and limestone; silty, phosphatic.	Carbonate and clastic	Aquifer (INTERMEDIATE AQUIFER SYSTEM)
		Tampa Limestone	Limestone, sandy, phosphatic, fossiliferous; sand and clay in lower part in some areas.		Confining unit (INTERMEDIATE AQUIFER SYSTEM)
	Oligocene	Suwannee Limestone	Limestone, sandy limestone, fossiliferous.	Carbonate	FLORIDAN AQUIFER SYSTEM: Upper Floridan aquifer
	Eocene	Ocala Limestone	Limestone, chalky, foraminiferal, dolomitic near bottom		
		Avon Park Formation	Limestone and hard brown dolomite; intergranular evaporite in lower part in some areas.		Middle confining unit
		Oldsmar Formation	Dolomite and limestone with intergranular gypsum in most areas.		Lower Floridan aquifer
	Paleocene	Cedar Keys Formation	Dolomite and limestone with beds of anhydrite.	Carbonate with evaporites	Sub-Floridan confining unit

Reichenbaugh (1972) described the relation of the surficial aquifer water table and water levels in Lake Magdalene, just east of the study area. Reichenbaugh (1977) made a similar comparison for Keystone Lake, and more recently, Henderson (1986a) related the gradient in the surficial aquifer to the water level in Hunters Lake.

The degree of hydraulic connection between lakes and the underlying Upper Floridan aquifer has not been as well documented. Earlier studies of the losses by leakage from lakes by Stewart and Hughes (1974) and Sinclair (1977) attempted to use an annual water budget to estimate these quantities.

Bathymetry of Lakes

Two factors that control the connection between a lake and the Upper Floridan aquifer are whether the aquifer is penetrated by the lake and the vertical hydraulic conductivity of the bottom sediments. The configuration of lake bottoms in the study area has been defined for Keystone Lake (Reichenbaugh, 1977) and Island Ford Lake (Henderson, 1986b). These lakes are in the chain of lakes that form the headwaters of Brooker Creek.

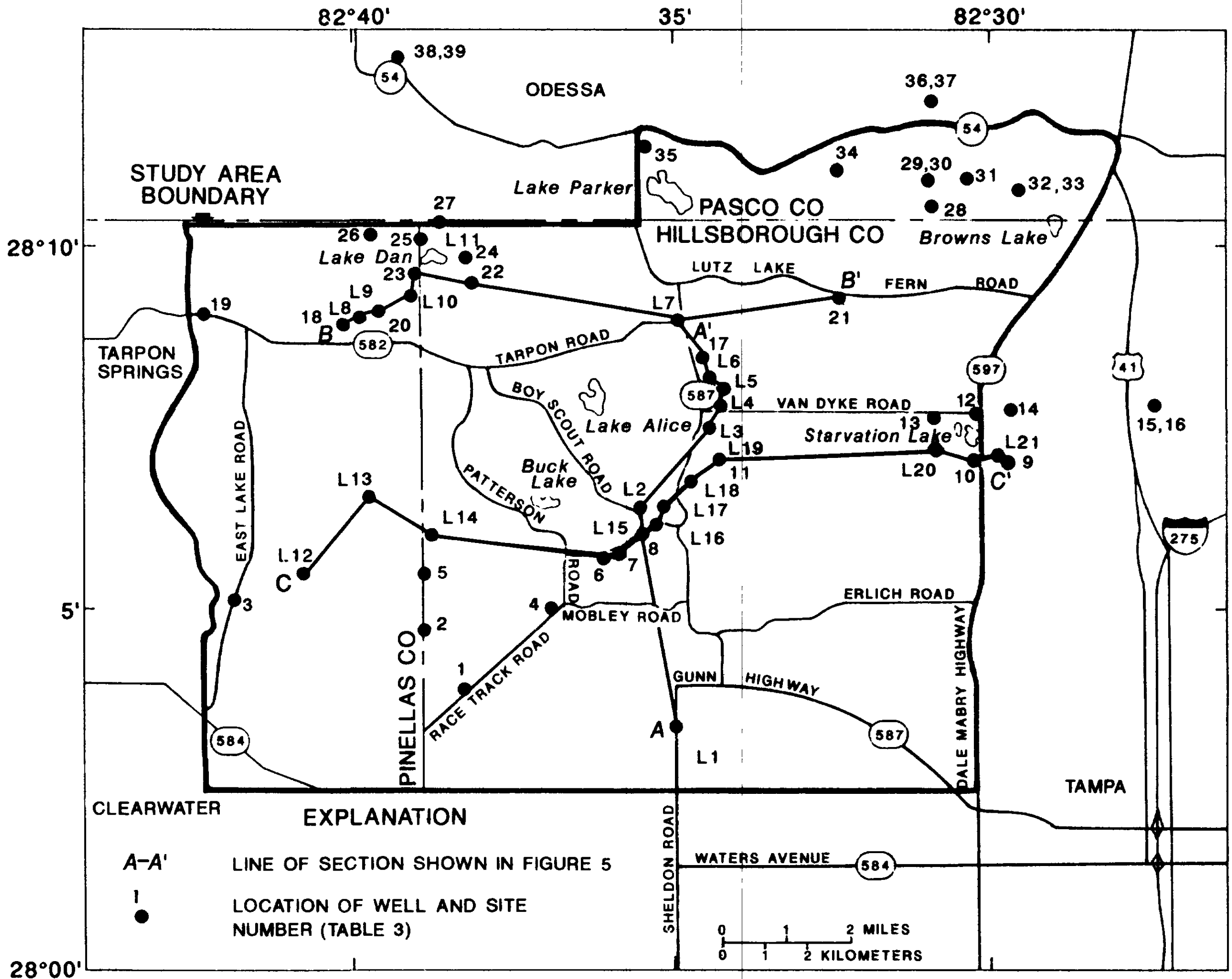


Figure 4. Locations of wells and hydrogeologic sections.

Bathymetry to define the bottom configuration of lakes typical of other parts of the study area was done in cooperation with the Southwest Florida Water Management District and was undertaken to determine if there were bottom features that could explain differences in the relation of lake stage to ground-water levels or pumpage. The five lakes selected for additional surveys were Lake Alice, Browns Lake, Buck Lake, Lake Dan, and Parker Lake.

Lake Alice

Lake Alice is near the center of the study area, about one-quarter mile west of Keystone Lake. Surface area is about 93 acres at an elevation of 39 ft above sea level. The bathymetric survey was made on October 28, 1986, when the lake stage was 39.13 ft above sea level. Fathometer transects were located by Loran C[1], a navigation positioning system, every second of longitude. There was heavy hydrilla growth over most of the lake bottom, except for the shallow shelf less than 6 ft deep at the narrow section that separates the northern one-quarter of the lake from the main body.

Depth below water surface is contoured every 2 ft in figure 13. The greatest depth of 25 ft was near the center of the lake. Near the shoreline, there are several depressions more than 20 ft deep that may be dredge holes. The numerous small holes along the southwest shore most probably were formed by sand pumps. The geologic section *B-B'*, about 1.5 mi north of Lake Alice, shows that the surficial aquifer is about 40 to 50 ft thick (fig. 5). The surficial aquifer is about 60 ft deep at section *A-A'*, 2 mi east of Lake Alice. The lake bottom probably is within the surficial aquifer.

Browns Lake

Browns Lake is near the northeast corner of the study area, about 2.3 mi east of South Pasco well field. Surface area of the lake is about 30 acres at an elevation of 62 ft above sea level, and the drainage area is about 1,060 acres, not including the lake. The shoreline is completely developed, but most of the drainage basin is in pastureland and orange groves.

[1]The use of brand or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

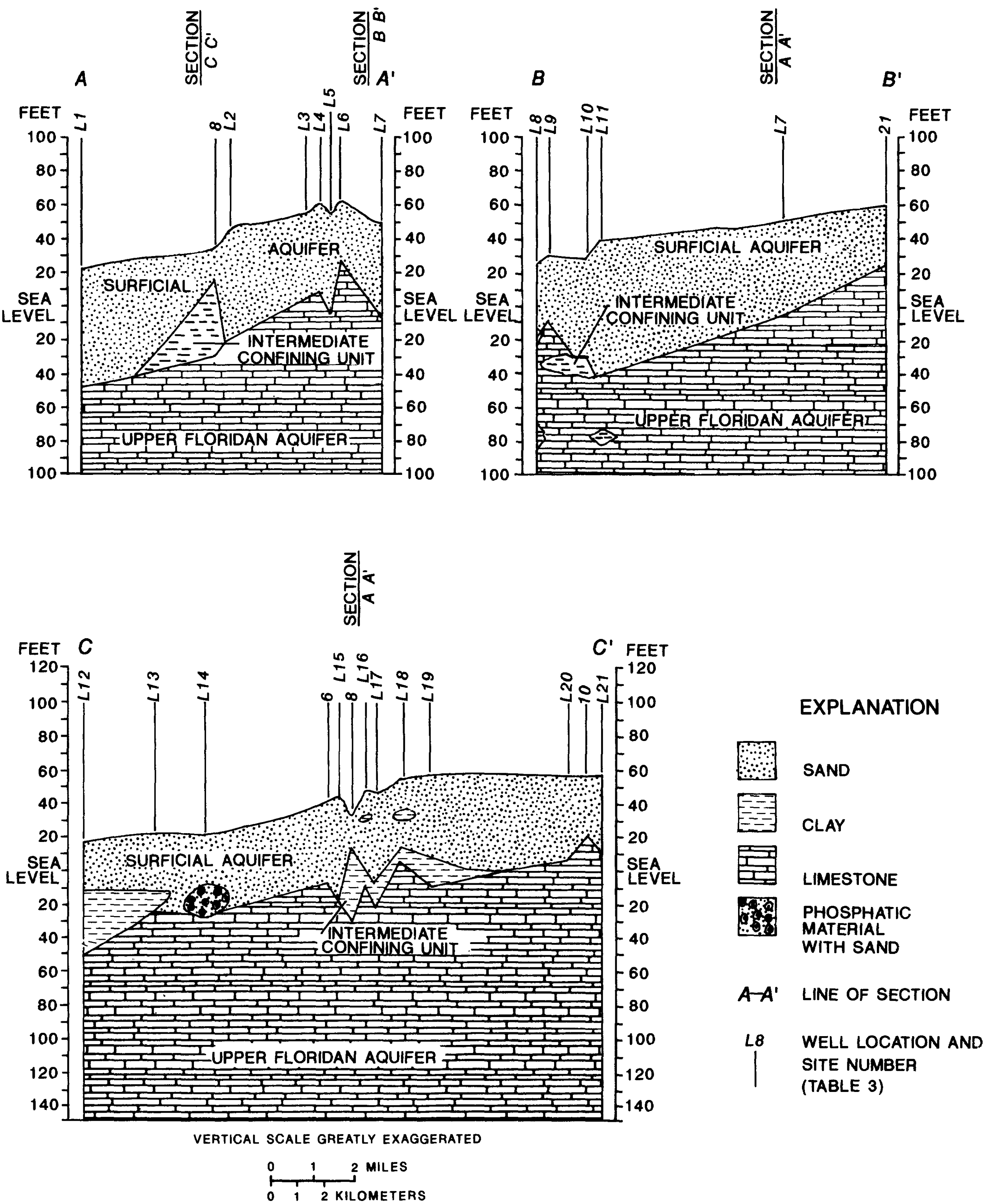


Figure 5. Hydrogeologic sections *A-A'*, *B-B'*, and *C-C'*.

The bathymetric survey was made on February 10, 1987, when the lake stage was 61.93 ft above sea level. Fathometer transects were located by Loran C every second of latitude. Measurements of depth below water surface were erratic from 50 to 250 ft from the shoreline where sand was dredged. Depth below water surface was contoured every 2 ft along the undisturbed shoreline. Point depths only are plotted for the dredged areas where detailed contouring was not possible. The dredge holes range in depth from 15 to 24 ft. The lake contours and point depths are shown in figure 14. The maximum natural depth may have been about 17 ft based on the location of a firm soil interface beneath the soft muck near the center of the lake. An estimated natural depth is shown at section *A-A′* in figure 14. The thickness of the surficial sands is about 25 ft in this area (Wolansky and others, 1979).

Buck Lake

Buck Lake is at the southwest edge of the lakes in the study area (fig. 4). Surface area is about 37 acres at an elevation of 32 ft above sea level, and the drainage area is about 155 acres, not including the lake. There are only three homes on the lakeshore, and most of the drainage basin is in pastureland and orange groves.

The bathymetric survey was made on November 4, 1986, when the lake stage was 32.23 ft above sea level. Fathometer transects were located by Loran C every second of longitude. Depth below water surface is contoured every foot in figure 15. The maximum depth is 22 ft near the north shore in a area that probably was dredged. Three smaller depressions near the north shore, at the east end of the lake, also may have been formed by dredging. The natural lake

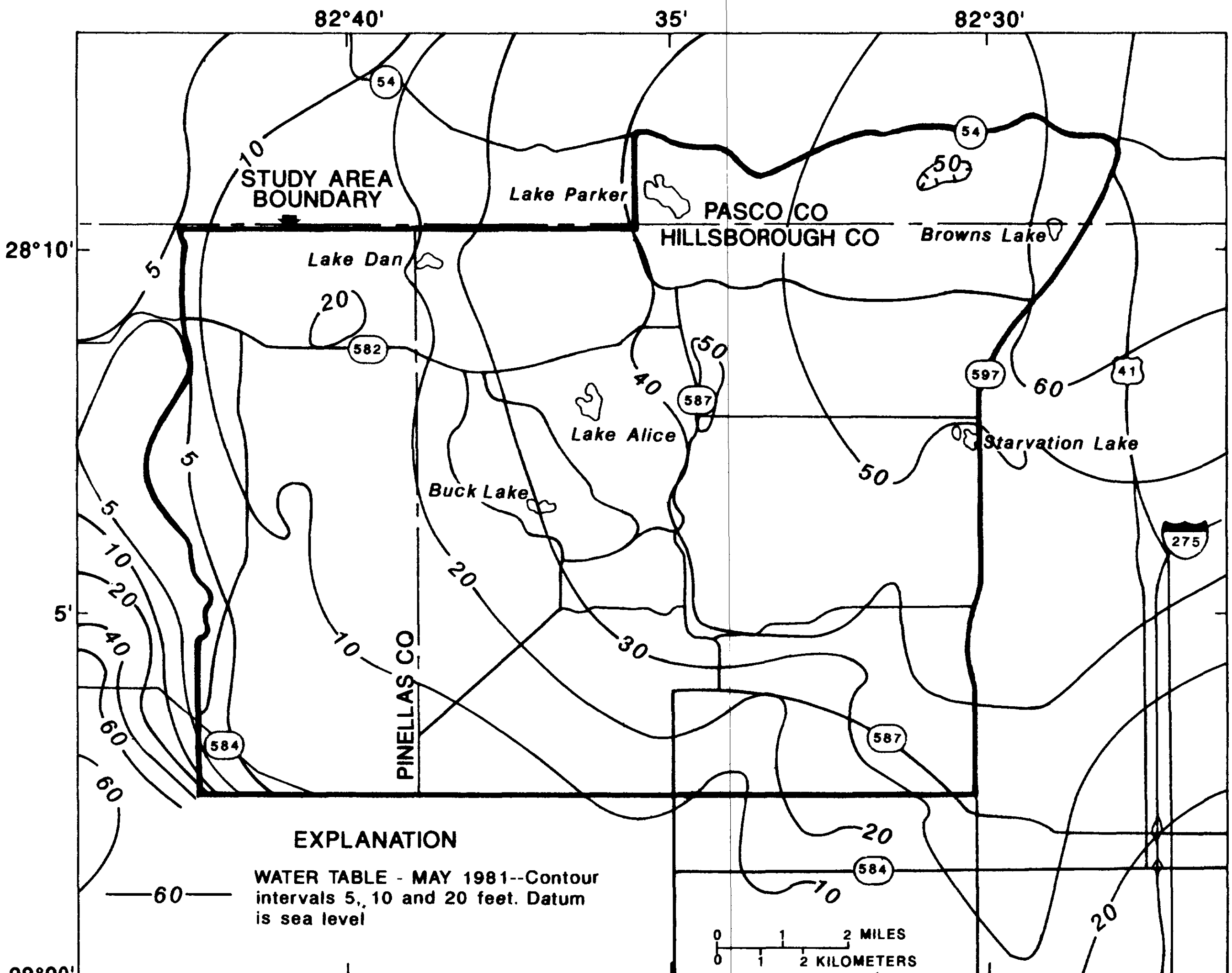


Figure 6. Position of the water table in the surficial aquifer, May 1981. (Modified from Yobbi and Woodham, 1981.)

Table 3. Summary of well data

[FAS, Floridan aquifer system (designation used for wells open to both the Upper Floridan aquifer and the lower confining unit); R, used in regression; H, used in hydrograph; L, used to describe lithologic sections; MX, the arithmetic average of the maximum values recorded for each day of the month; MO, one measurement made during the month; WM, monthly mean calculated from weekly measurements; —, no data; <, less than]

Site No.	Well name	Identification number[1]	Depth of well, in feet below land surface	Depth of casing, in feet below land surface	Hydrologic unit	Elevation of land surface, in feet above sea level	Elevation of measuring point, in feet above sea level	Range in water level, in feet above sea level	How used	Value used in regression	Period of record
1	ROMP TR13-3 deep well	280354082381901	807	710	Upper Floridan	15.00	19.54	13.59 – 18.17	R	MX	1972-83
2	East Lake deep well 17	280446082390701	305	57	Upper Floridan	17.97	18.87	12.87 – 19.00	R	MO	1977-85
3	Brooker Creek well	280457082420402	310	300	Upper Floridan	6.46	10.08	5.25 – 9.04	R	MX	1969-85
4	St. Petersburg deep well E-102	280504082365501	1,200	697	FAS	29.00	31.28	15.19 – 25.55	R	MX	1972-82
5	East Lake deep well 14	280546082390701	305	57	Upper Floridan	22.53	23.73	13.17 – 21.40	R	MO	1977-85
6	St. Petersburg deep well E-100	280548082355701	1,200	656	FAS	41.23	42.83	16.27 – 32.14	R,L	MX	1972-85
7	St. Petersburg shallow well 1C-6	280550082355002	23	21	Surficial	43.07	44.67	31.91 – 41.53	R	MX	1974-85
8	St. Petersburg Comse well 3	280607082353001	354	79	Upper Floridan	46.74	47.68	16.21 – 33.51	R,L	MX	1974-85
9	Berger deep well	280659082294302	134	44	Upper Floridan	57.25	59.87	33.20 – 51.71	R	MX	1965-85
10	Hillsborough deep well 13	280702082302801	347	46	Upper Floridan	55.82	56.86	24.04 – 50.90	R,L	MX	1944-85
11	James deep well 11	280703082341701	300	76	Upper Floridan	57.37	59.65	19.00 – 39.87	R	MX	1972-85
12	St. Petersburg deep well 21-7	280728082301101	1,250	718	FAS	56.66	60.87	28.24 – 51.30	R	MX	1973-85
13	St. Petersburg deep well 26A	280732082305801	300	142	Upper Floridan	56.87	57.87	20.50 – 48.45	R	MX	[2]1972-85
14	Van Dyke shallow well	280739082294202	22	18	Surficial	59.59	63.39	48.30 – 60.71	R	MX	1964-85
15	Debuel Road deep well	280740082271001	300	118	Upper Floridan	63.68	66.78	50.03 – 60.13	H		1965-85
16	Debuel Road shallow well	280740082271002	25	22	Surficial	63.61	66.61	53.31 – 63.21	H		1965-85
17	St. Petersburg well 33A	280833082343601	359	81	Upper Floridan	56.64	57.64	18.11 – 40.30	R	MX	[2]1972-85
18	Eldridge-Wilde well 2	280856082401201	290	61	Upper Floridan	27.70	30.52	0.35 – 21.26	R	MX	[2]1972-85
19	Tarpon Road deep well	280907082424801	305	205	Upper Floridan	21.77	25.00	8.20 – 13.06	R	MX	1965-85
20	Eldridge-Wilde monitor well 5	280908082394601	229	58	Upper Floridan	29.00	31.40	11.19 – 21.38	R	MX	1974-85
21	Lutz-Lake Fern deep well	280920082322101	375	65	Upper Floridan	59.32	62.32	33.71 – 48.43	R,L	MX	1963-85
22	Eldridge-Wilde deep well N-4	280944082380501	350	100	Upper Floridan	41.00	43.04	18.20 – 31.70	R	MX	1977-85
23	Eldridge-Wilde well 113A	280946082391301	114	58	Upper Floridan	34.34	36.04	2.59 – 22.87	R	MX	1973-85
24	Eldridge-Wilde deep well 139G	280956082381801	195	44	Upper Floridan	40.76	43.36	11.43 – 29.32	R	MX	[2]1973-85
25	Eldridge-Wilde well N2	281010082390601	292	62	Upper Floridan	38.14	39.94	4.84 – 23.75	R	WM	[2]1973-85
26	Eldridge-Wilde deep well N3	281022082400201	350	100	Upper Floridan	28.78	31.88	8.51 – 22.74	R	MX	1977-85
27	Eldridge-Wilde Mitchell well	281025082384601	608	42	Upper Floridan	36.42	38.18	5.07 – 25.49	R	MX	1973-85
28	St. Petersburg well 42	281035082305701	398	70	Upper Floridan	58.61	60.11	32.56 – 53.40	R	MX	[2]1973-85
29	St. Petersburg deep well 105	281053082310401	1,360	1,012	FAS	58.45	62.05	32.76 – 52.10	R	MX	1973-82
30	St. Petersburg shallow well 105	281053082310402	20	18	Surficial	57.82	61.02	51.12 – 59.18	R	MX	1973-85
31	St. Petersburg well 45	281055082302401	707	59	Upper Floridan	61.10	62.10	39.68 – 56.10	R	MX	[2]1973-85
32	Harry Matts deep well	281101082292501	60	59	Upper Floridan	68.03	69.53	54.41 – 61.32	H		1972-85
33	Harry Matts shallow well	281101082292502	10	8	Surficial	68.09	69.59	<58.09 – 65.45	H		1972-85
34	Doyles Ranch deep well	281103082322601	438	38	Upper Floridan	56.50	57.71	37.70 – 50.23	R	MX	1970-81

Table 3. Summary of well data–Continued

[FAS, Floridan aquifer system (designation used for wells open to both the Upper Floridan aquifer and the lower confining unit); R, used in regression; H, used in hydrograph; L, used to describe lithologic sections; MX, the arithmetic average of the maximum values recorded for each day of the month; MO, one measurement made during the month; WM, monthly mean calculated from weekly measurements; —, no data; <, less than]

Site No.	Well name	Identification number[1]	Depth of well, in feet below land surface	Depth of casing, in feet below land surface	Hydrologic unit	Elevation of land surface, in feet above sea level	Elevation of measuring point, in feet above sea level	Range in water level, in feet above sea level	How used	Value used in regression	Period of record
35	Swains well	281124082353001	316	65	Upper Floridan	50.69	54.39	30.90 – 42.08	R	MO	1963-85
36	State Highway 54 deep well	281143082304702	345	178	Upper Floridan	59.40	61.90	37.35 – 57.28	R,H	MX	1965-85
37	State Highway 54 shallow well	281143082304703	5	3	Surficial	59.54	61.53	<54.54 – 59.67	H		1965-85
38	Seven Springs deep well	281222082393401	301	76	Upper Floridan	34.42	36.81	14.51 – 25.43	H		1965-85
39	Seven Springs shallow well	281222082393403	11	9	Surficial	35.04	36.04	27.14 – 34.78	H		1968-85
Wells used only to describe lithologic sections											
L1	St. Petersburg deep well E-104	2803160823458	1,145	115	FAS	22	—	—	L	—	—
L2	St. Petersburg Cosme well 21	2806220823535	320	80	Upper Floridan	47	—	—	L	—	—
L3	St. Petersburg Cosme well 25	W-3081	350	98	Upper Floridan	55	—	—	L	—	—
L4	St. Petersburg well 26	W-4117	300	—	Upper Floridan	61	—	—	L	—	—
L5	St. Petersburg well 28	W-4115	300	—	Upper Floridan	54	—	—	L	—	—
L6	St. Petersburg well 31	W-4120	374	102	Upper Floridan	62.5	—	—	L	—	—
L7	YMCA well	W-2570	97	60	Upper Floridan	50	—	—	L	—	—
L8	Eldridge-Wilde well 2A	2808510824013	400	113	Upper Floridan	—	—	—	L	—	—
L9	Eldridge-Wilde well 3B	2809020824006	410	78	Upper Floridan	—	—	—	L	—	—
L10	Eldridge-Wilde well 10A	2809170823914	550	99	Upper Floridan	—	—	—	L	—	—
L11	Eldridge-Wilde well 122	2809200823906	291	123	Upper Floridan	38.72	—	—	L	—	—
L12	Skinner block 7 #1	W-2144	3,563	3,540	Lower confining	30	—	—	L	—	—
L13	Skinner block 10 #1	W-2475	1,449	101	FAS	21	—	—	L	—	—
L14	St. Petersburg deep well E-103	2806030823854	1,138	608	FAS	21	—	—	L	—	—
L15	Pinellas well 2	2805530823542	305	65	Upper Floridan	44	—	—	L	—	—
L16	Pinellas new well 4	2806110823515	345	65	Upper Floridan	49	—	—	L	—	—
L17	St. Petersburg Cosme well 6	W-241	333	83	Upper Floridan	47	—	—	L	—	—
L18	Pinellas well 8	W-133	345	82	Upper Floridan	54	—	—	L	—	—
L19	St. Petersburg Cosme well 1	2807100823414	299	56	Upper Floridan	56.6	—	—	L	—	—
L20	Section 21 well 3	2807080823058	411	72	Upper Floridan	56.33	—	—	L	—	—
L21	St. Petersburg well 21-10	W-5645	411	71	Upper Floridan	57.39	—	—	L	—	—

[1]Florida Geological Survey identification number substituted when the latitude and longitude were uncertain.
[2]Southwest Florida Water Management District, 1983-85.

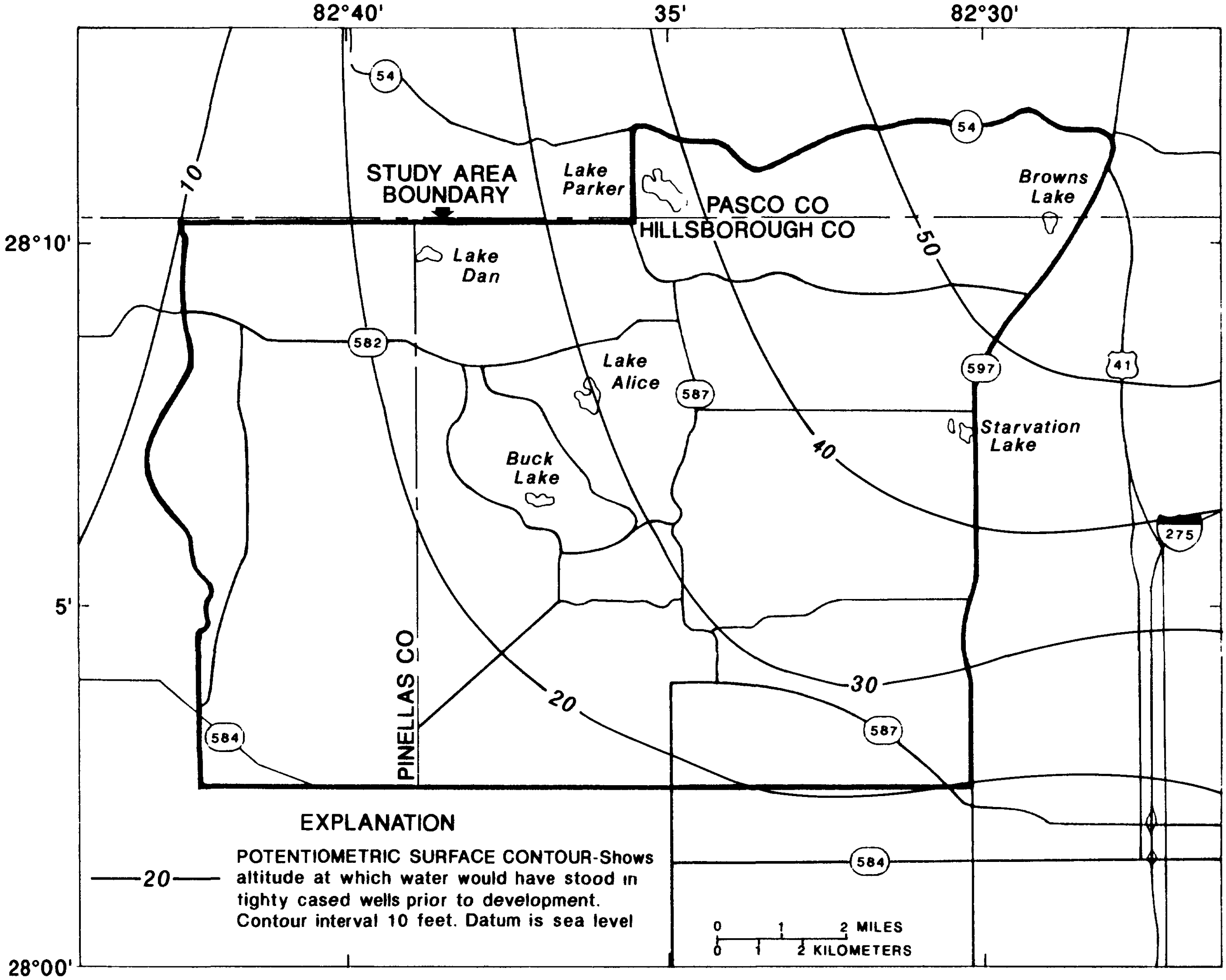


Figure 7. Position of the potentiometric surface of the Upper Floridan aquifer prior to development. (Modified from Johnston and others, 1980.)

depth seems to be about 10 to 12 ft. Lithologic section *C-C'*, 0.5 mi to the south of Buck Lake, indicates that the surficial sands are about 40 to 50 ft deep in this area. The deepest points in the lake bottom are probably still within the surficial aquifer.

Lake Dan

Lake Dan is at the northwest edge of the lakes in the study area (fig. 4). Surface area is about 35 acres at an elevation of 30 ft above sea level. The drainage area of the lake is about 350 acres, not including the lake. The lake and contributing drainage basin are in the Eldridge-Wilde well field, and land use is mostly pasture and wetlands.

The bathymetric survey was made on December 8, 1986, when the lake stage was 26.96 ft above sea level. Transects were located by Loran C every second of longitude. Depth below water surface is contoured every foot in figure 16. The greatest depth is a little over 12 ft in two depressions near the north shore. Most of the bottom is 7 to 8 ft below the water surface. Lithologic section *B-B'*, 0.25 mi south of Lake Dan, indicates that the surficial sands are about 50 ft thick in this area.

Parker Lake

Parker Lake is at the north-central edge of the group of lakes in the study area. Surface area is about 93 acres at an elevation of 48 ft above sea level. Development is mostly on the east and north shore of the lake. The drainage basin is about 1,920 acres, not including the lake, and most of the land is in pasture or orange groves.

The bathymetric survey was made on February 17, 1987. Water level of the lake was 47.11 ft above sea level. Transects were located by Loran C every 2 seconds of longitude. Depth below water surface is contoured every 2 ft in figure 17. The maximum depth of the undisturbed bottom near the center of the lake is 16 ft. There are several irregular depressions with depths to 24 ft that probably were caused by dredging along the east and north shore. The thickness of the surficial sands is between 25 and 50 ft in this area (Wolansky and others, 1979), so the deeper holes may be near the bottom of the surficial aquifer.

Well-Field Development

Six well fields are within the study area (fig. 18): Cosme-Odessa, Eldridge-Wilde, Section 21, East Lake, South Pasco, and Northwest Hillsborough. Almost all water withdrawn within the study area is pumped by pipeline to other parts of Pinellas and Hillsborough Counties.

Cosme-Odessa is by far the oldest well field, having been on line since 1931 (table 5). It was supplemented in 1957 when Eldridge-Wilde came on line. The number of well fields has increased fairly regularly since that time. The latest

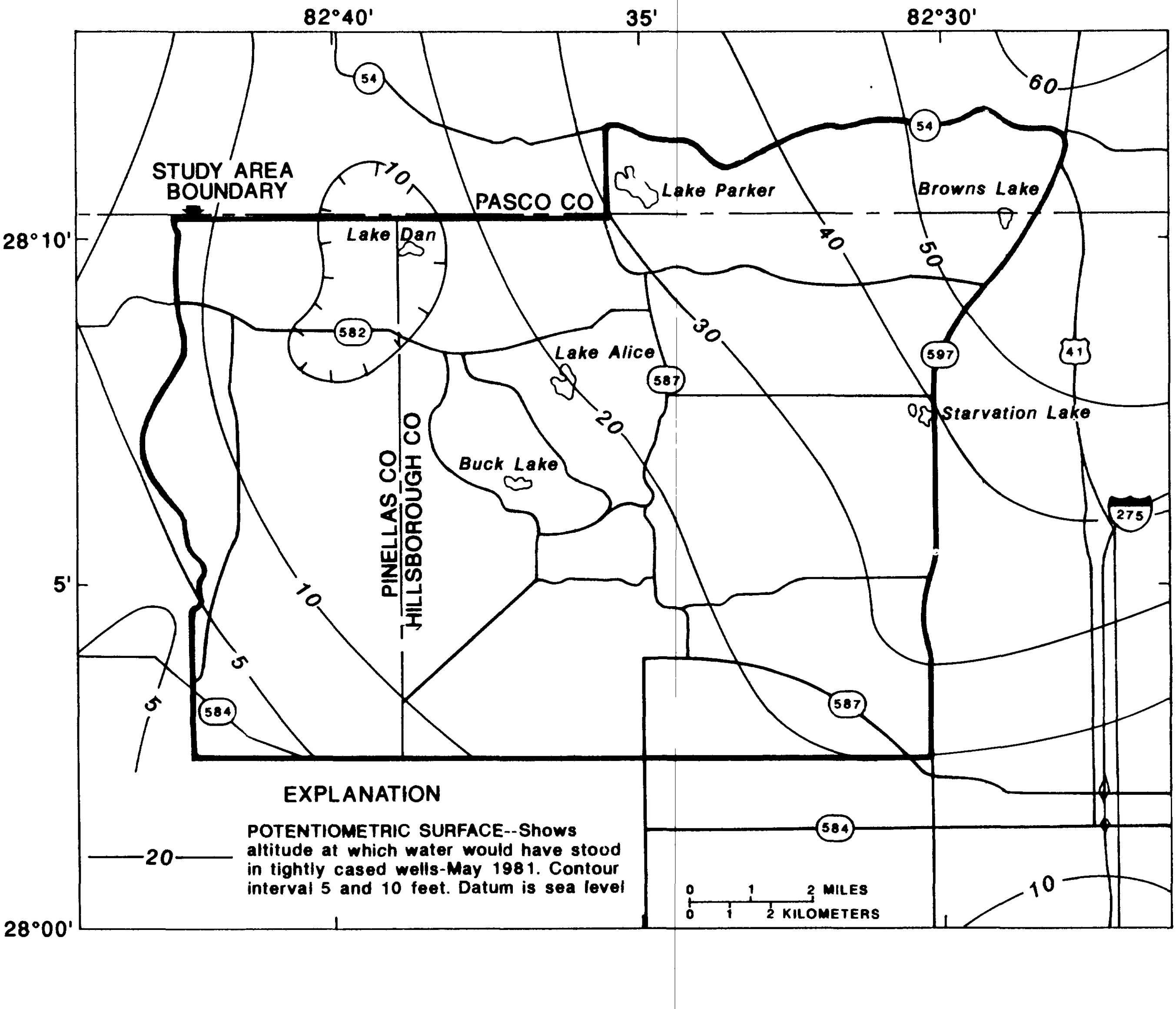


Figure 8. Position of the potentiometric surface of the Upper Floridan aquifer, May 1981. (Modified from Yobbi and others, 1981.)

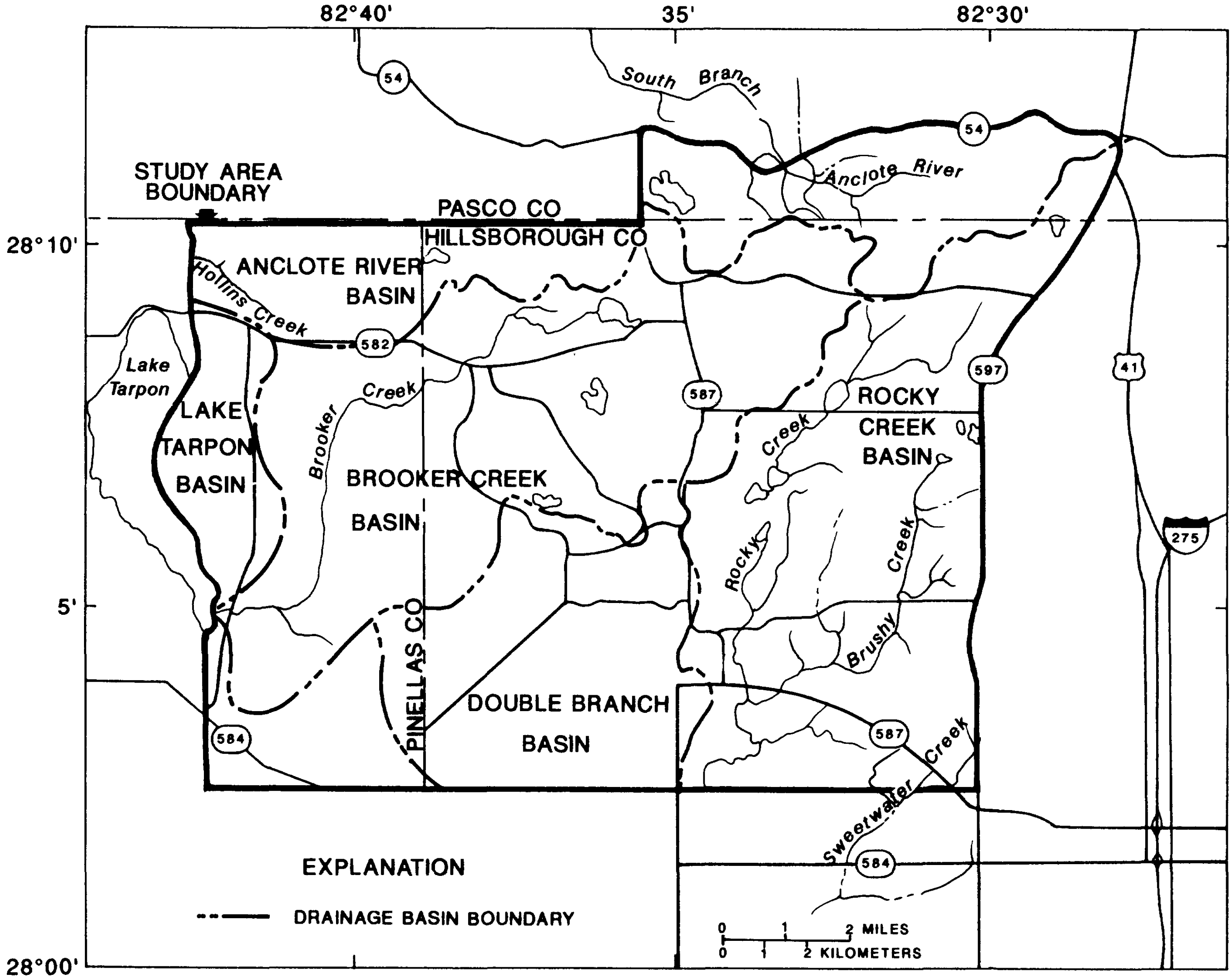


Figure 11. Drainage boundaries of streams within the study area.

record, 1969-85, was from 5.25 to 9.04 ft above sea level (table 3). The largest RMSE is 2.20 ft for the Eldridge-Wilde Mitchell well (table 6). The range in monthly average water levels during the period of record, 1973-85, was from 5.07 to 25.49 ft above sea level (table 3).

The absolute value of the t statistic indicates the relative influence of each explanatory variable in the regression relation. The explanatory variables that appear in the regression relations were rainfall, potential evaporation, well-field pumpage, and the previous month's water level in the well. These variables were listed in this order for consistency and were not ranked by their relative influence. Pumpage most often has the highest value of t and is a significant variable in all the regression relations. Pumpage during the current month in nearby well fields has a negative coefficient. Rainfall often has a high value of t and always has a positive coefficient. Potential evaporation always has a negative coefficient.

When pumpage the previous month is also in the regression relation, the coefficient is positive, but the t value is usually less than the t value for current month's pumpage. This positive coefficient is explained as follows. The Upper Floridan aquifer is confined and under pressure. With all other variables being equal, when pumpage increases, the pressure decreases and is reflected in lower water levels. Conversely, when pumpage decreases, the pressure increases and water levels rise (J.J. Hickey, U.S. Geological Survey, oral commun., 1988).

Pumpage at nearby well fields generally exerts an influence directly proportional to the distance from the well. For example, James deep well 11 (no. 11, fig. 4) is at the south end of a line of wells that are part of the Cosme-Odessa well field (fig. 18), approximately 2 mi northeast of the center of the main well field and 4 mi west of the Section 21 well field. The absolute values of the t statistic for COSME_Q and LAGCOS_Q are larger than those for SEC21_Q and

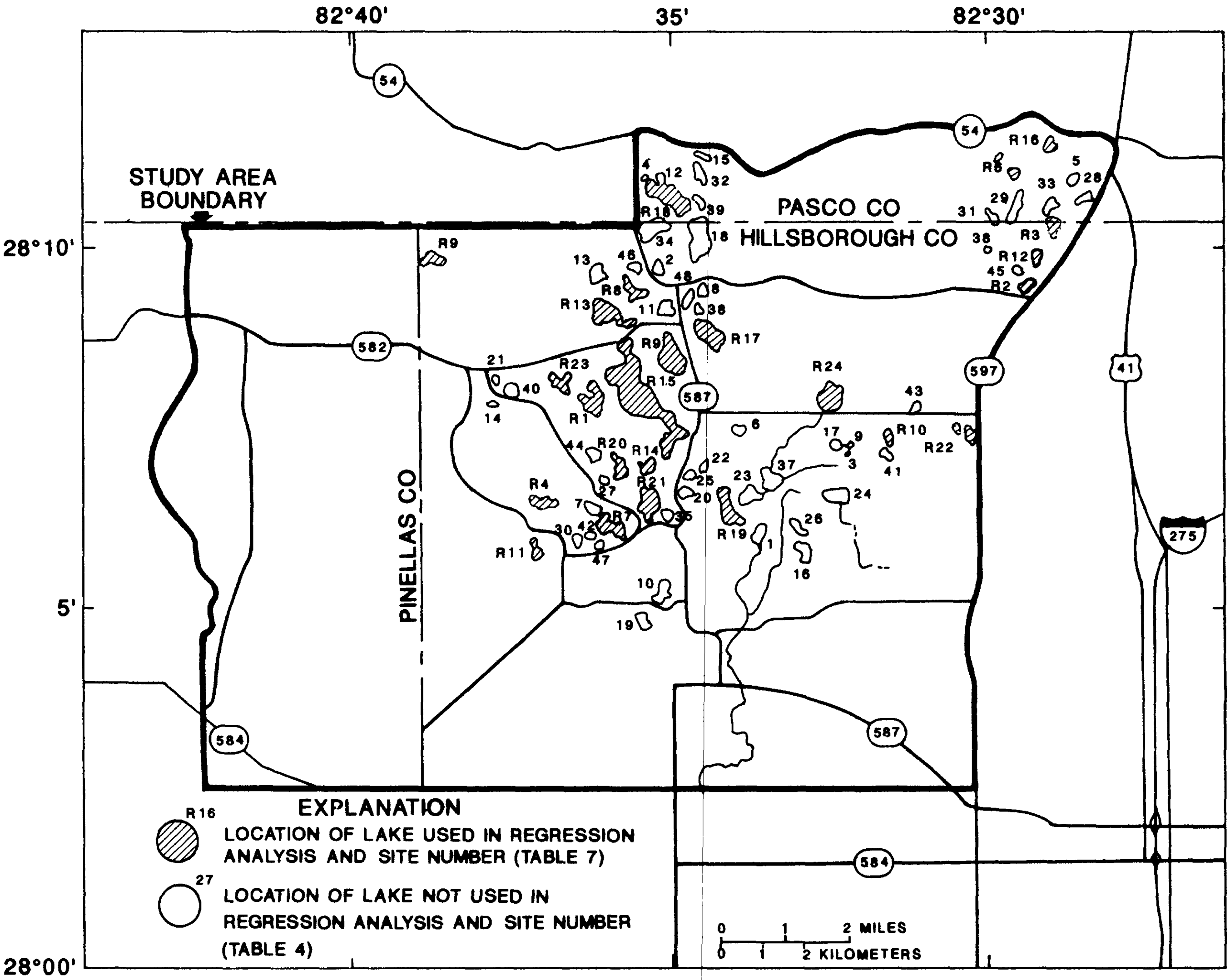


Figure 12. Locations of named lakes in the study area.

LAG21_Q. As the distances from the well fields increase, the influence of pumpage decreases.

The coefficient of water level in the well the previous month is always negative and is generally one of the more influential explanatory variables. This indicates that, with other variables being equal, the higher the water level the previous month, the greater the negative influence of this variable, and conversely, the lower the previous month's water level, the lesser the negative influence of this variable.

Change in Lake Stage

Lake stage and volume change in response to precipitation, evaporation, surface-water inflow and outflow, and ground-water inflow and outflow. The change in volume is reflected by the change in stage and is the difference between inflow and outflow. The inflow can be composed of rainfall directly on the lake, surface runoff, or ground-water inflow. The outflow can be evaporation from the lake surface, surface outflow, and ground-water outflow or leakage. None of these components of the water budget are measured directly, but suitable surrogates are rainfall at a nearby rain gage (for direct rainfall), the theoretical potential evaporation for the latitude of the study area, lake stage (for volume), and the potentiometric-surface altitude (for ground-water flow patterns).

The change in monthly average lake stage was related by the use of regression analyses to rainfall, potential evaporation, the monthly average water level of a nearby observation well in the Upper Floridan aquifer, and the previous month average lake stage (table 7). Because there is a seasonal variation in rainfall, the data were partitioned by season: June through October and November through May. The procedure described in "Development of Regression Relations" was used to select the best all-year or seasonal periods for estimating the change in monthly average lake stage.

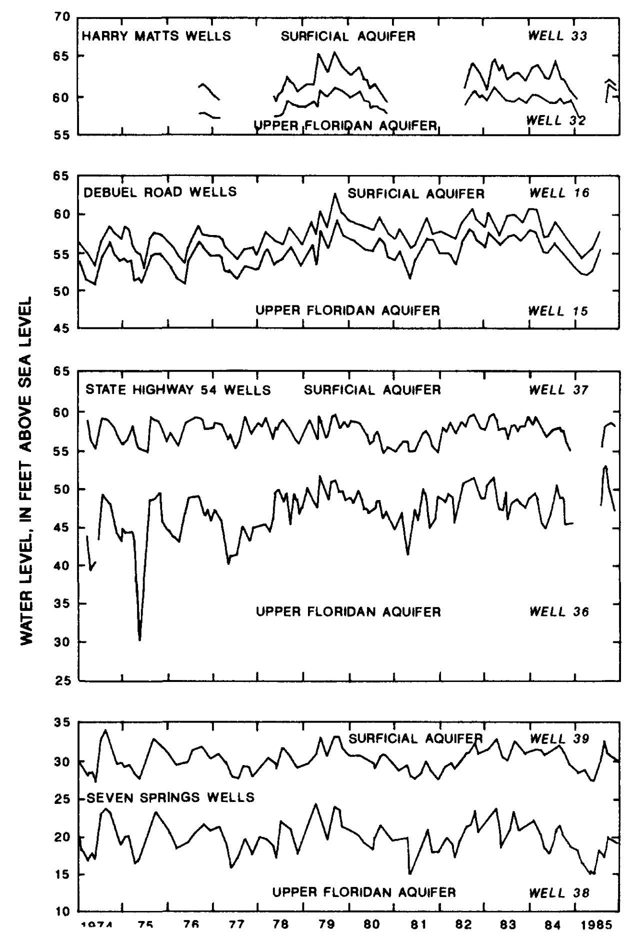


Figure 9. Water levels in pairs of wells representing the surficial aquifer and the Upper Floridan aquifer.

one, Northwest Hillsborough, began to withdraw water in 1977. The large increase in ground-water withdrawals that began in 1956 is shown in figure 19. Well-field pumpage has fluctuated between 60 and 80 Mgal/d since 1972, averaging somewhat less than 70 Mgal/d. In the low rainfall year of 1981, well-field pumpage totaled 58.69 Mgal/d. In 1985, well fields represented a combined average permitted pumping rate of 89.9 Mgal/d, of which 72.99 Mgal/d was actually withdrawn. Monthly average pumpage at each of these well fields was used in the regression analysis.

DEVELOPMENT OF REGRESSION RELATIONS FOR ESTIMATING CHANGES IN WATER LEVELS AND LAKE STAGE

Although we are dealing with multiple time series data, modeling the change in well water levels or lake stage can be used to approximate the sequence of dependent variable values. Time series analysis would satisfy some desirable optimal criteria, and better estimates of the uncertainty of the results could be presented. However, the simpler regression approach would give a first approximation of the relation of changes in water level or lake stage to well-field pumpage and climatic conditions.

Multiple linear-regression analysis was selected by the authors to meet the objectives of the study. Monthly time increments were selected for analysis because data for rainfall, pumpage, water levels, and lake stage were readily available. The monthly time increments also would be representative of seasonal fluctuations.

The Statistical Analysis System (SAS) was used to perform the multiple linear-regression analysis (Statistical Analysis System Institute, Inc., 1985). The relation of the dependent variable to a set of explanatory (independent) variables can be expressed as a mathematical relation:

$$y = a + b_i x_i . . . . . b_n x_n, \tag{1}$$

where

- y is the dependent variable,
- a is constant,
- b is the regression coefficient,
- x is the value of the explanatory variable,
- i is the identity of the variable from 1 to n, and
- n is the total number of variables in the model.

The selection of the set of explanatory variables to be considered in each relation was determined by the following steps:

1. All likely candidates of explanatory variables were used in a preliminary screening relation. For instance, the relation to determine the change in water level in a well would include rainfall at the nearest rain gage or the average of two nearby gages, pumpage from the nearest well fields (some models included pumpage from four well fields), potential evaporation, and water level the previous month.
2. PROC RSQUARE was used to find subsets of explanatory variables that best predict a dependent variable by linear regression. The regression coefficient of determination (R^2) is the criteria for ranking subsets. The value of R^2 multiplied by 100 is the percentage of the variation in the dependent variable estimated by the explanatory variables in the relation. Subsets consisted of models with all combinations of explanatory variables.
3. The most promising relations from each subset were selected on the basis of the Mallow's Cp statistic being equal to or less than the number of explanatory variables plus one. Mallow's Cp is adjusted for the number of variables in each relation so that comparison between relations that have different numbers of variables can be made.
4. Collinearity of independent variables was evaluated by the VIF and COLLIN options in PROC REG. VIF values exceeding 10, which would indicate a high degree of collinearity (E.J. Gilroy, U.S. Geological Survey, oral commun., 1988), were not found in any of the models.
5. A final selection of a relation was made on the basis of the minimum root mean square error (RMSE) statistic and consideration of the plausible functional form of the relevant explanatory variables. The root mean square error is approximately equal to the standard deviation of the difference between the observed value and the model estimate. About two-thirds of the differences will be within one standard deviation of the true value.

6. A simplified test to determine whether relations for different seasonal periods should be used was made by comparing the mean square error of the all-year relation to the sum of two seasonal model sums of squares divided by the sum of their degrees of freedom. If the mean square error of the all-year relation was greater than 10 percent more than the seasonal relations average, the seasonal relations were used; if not, the all-year relation was used.

Change in Water Levels in the Upper Floridan Aquifer

The change in monthly average water levels in wells completed in the Upper Floridan aquifer was related by use of regression analysis to rainfall, potential evaporation, pumping at nearby well fields, and the average water level in the well the previous month. The number of data points (N), intercept of the regression relation, R^2, and RMSE are listed on the same line with the well name in table 6. The regression coefficient of each explanatory variable, t statistic, and the probability of a greater t statistic (p>|t|) are listed on following lines.

How well the regression relation estimates the change in monthly average water level can be evaluated from the R^2 statistic. An important factor that influences the derived R^2 statistic seems to be the method of determining the monthly average water level (table 3). Generally, the regression relations for wells with continuous water-level recorders had higher R^2 than that for wells that were measured periodically. The regression R^2 ranged from 0.40 at the Eldridge-Wilde Mitchell well to 0.90 at St. Petersburg well 42 and State Highway 54 deep well (table 6).

The RMSE is a measure of the error in the estimate of change in water level and is a function of the range in water-level fluctuation, as well as the accuracy of the computation of monthly average water level. The smallest RMSE is 0.18 ft for Brooker Creek deep well (table 6). The range in monthly average water levels in this well during the period of

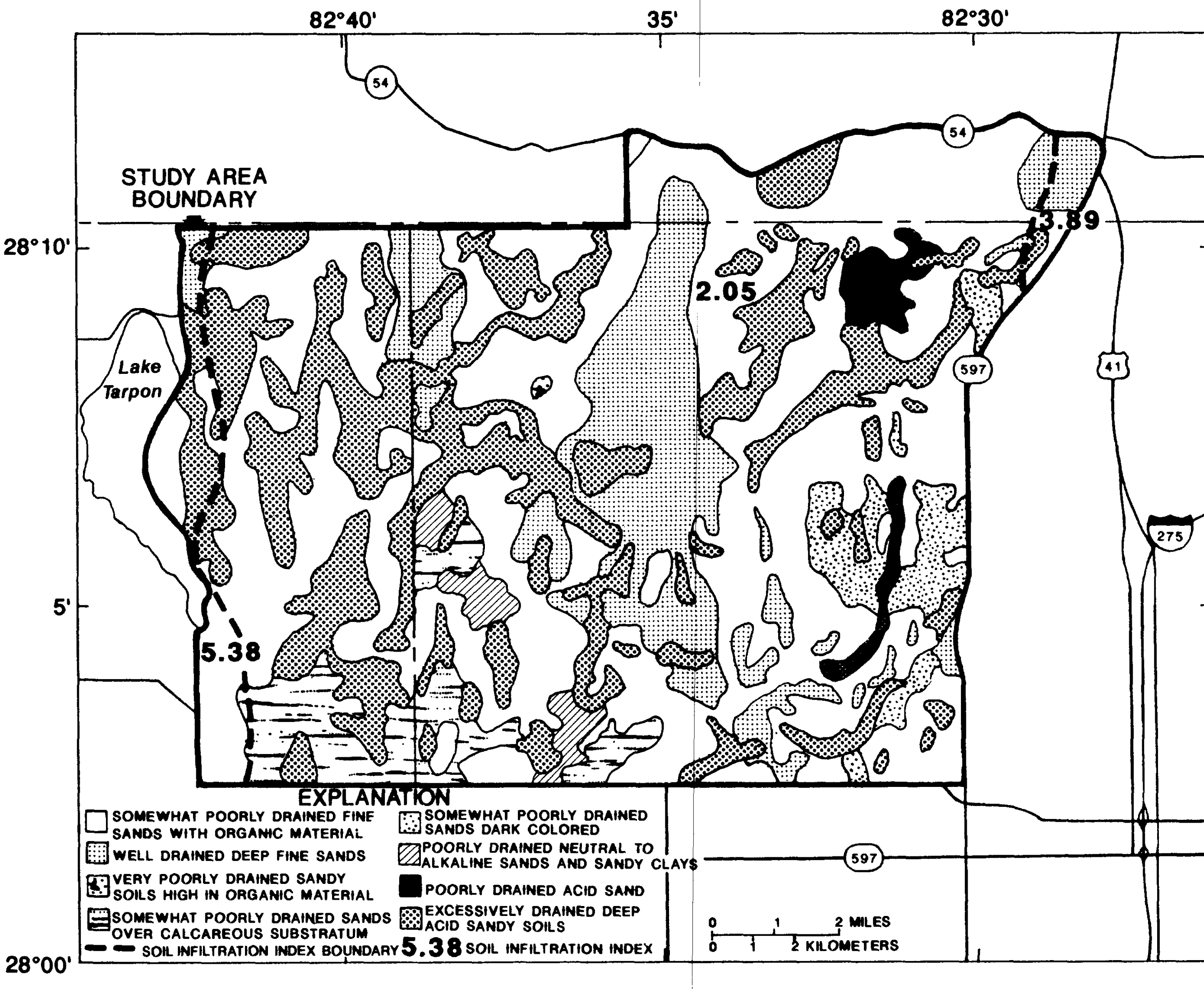


Figure 10. Soil types and soil-infiltration indices within the study area. (Modified from Seijo and others, 1979.)

Table 4. Summary of lakes

[T-R-S, Township-Range-Section; I, internally drained; P, pumped for irrigation; A, augmented; R, used in regression analysis; 1, well-drained deep sands; 2, somewhat poorly drained fine sands with organic material; 3, very poorly drained sandy soils high in organic material; 4, excessively drained deep acid sandy soil; 5, somewhat poorly drained sands, dark colored]

Site No.	Lake	Period of record	County	Quadrangle sheet	Location (T-R-S)	Size (acres)	Basin	Soil type	Remarks
R1	Alice, Lake	1971-85	Hillsborough	Odessa	27-17-16	93	Brooker Creek	1,2	,I
R2	Allen, Lake	1971-85	Hillsborough	Lutz	27-18-10	28	Rocky Creek	2	
1	Armistead, Lake		Hillsborough	Citrus Park	27-17-25	35	Rocky Creek	2,1	
2	Artillery, Lake		Hillsborough	Odessa	27-17-3	19	Brooker Creek	1	P
3	Barbara, Lake		Hillsborough	Citrus Park	27-18-19	2	Rocky Creek	2	
4	Bass (Holiday) Lake		Pasco	Odessa	26-17-34	10	S. Branch Anclote	2	
R3	Browns Lake	1971-85	Hillsborough	Lutz	27-18-2	30	Rocky Creek	3	
R4	Buck Lake	1972-85	Hillsborough	Citrus Park	27-17-29	37	Brooker Creek	1,2	P,I
R5	Calm, Lake	1965-85	Hillsborough	Odessa	27-17-14	127	Brooker Creek	1	I
R6	Camp Lake	1968-85	Pasco	Lutz	26-18-34	19	S. Branch Anclote	2	I
R7	Church Lake	1957-85	Hillsborough	Citrus	27-17-28	68	Brooker Creek	3	P,I
5	Como Lake		Pasco	Lutz	26-18-35	24	Rocky Creek	1	
R8	Crescent Lake	1971-85	Hillsborough	Odessa	27-17-10	46	Brooker Creek	1,2	
6	Cypress Lake		Hillsborough	Odessa	27-17-24	17	Rocky Creek	1	
R9	Dan, Lake	1965-85	Hillsborough	Elfers	27-17-6	35	Anclote River	1	
R10	Dosson Lake	1971-85	Hillsborough	Citrus Park	27-18-20	11	Rocky Creek	3	I
7	Echo Lake		Hillsborough	Citrus Park	27-17-28	27	Brooker Creek	3,1	
8	Elizabeth, Lake		Hillsborough	Odessa	27-17-11	22	S. Branch Anclote	2	
9	Ellen, Lake		Hillsborough	Citrus Park	27-18-19	5	Rocky Creek	2	
10	Fairy Lake		Hillsborough	Citrus Park	27-17-34	52	Double Branch	3,1	
11	Fern, Lake		Hillsborough	Odessa	27-17-11	33	Brooker Creek	1	
12	Fishing Lake		Pasco	Odessa	26-17-34	13	S. Branch Anclote	2	
13	Frances, Lake		Hillsborough	Odessa	27-17-4	43	Anclote River	3	
14	Garden Lake		Hillsborough	Elfers	27-17-17	13	Brooker Creek	3,2	A
15	Geneva, Lake		Pasco	Odessa	26-17-26	13	S. Branch Anclote	2	
R11	Glass Lake	1976-85	Hillsborough	Citrus Park	27-17-32	17	Double Branch	1	I
16	Halfmoon Lake		Hillsborough	Citrus Park	27-18-31	32	Rocky Creek	2	
R12	Harvey, Lake	1970-85	Hillsborough	Lutz	27-18-3	24	Rocky Creek	3	I
17	Helen, Lake		Hillsborough	Citrus Park	27-18-19	18	Rocky Creek	2	
18	Hiawatha, Lake		Hillsborough	Odessa	27-17-2	136	S. Branch Anclote	2,1	P
19	Hixon Lake		Hillsborough	Citrus Park	27-17-3	21	Double Branch	1	
20	Horse Lake		Hillsborough	Citrus Park	27-17-26	28	Rocky Creek	1	
R13	Island Ford Lake	1971-85	Hillsborough	Odessa	27-17-10	96	Brooker Creek	2	
21	Jackson Lake		Hillsborough	Elfers	27-17-17	10	Brooker Creek	2	
22	James Lake		Hillsborough	Citrus Park	27-17-23	16	Brooker Creek	1	
23	Josephine, Lake		Hillsborough	Citrus Park	27-17-25	51	Rocky Creek	1	
R14	Juanita, Lake	1971-85	Hillsborough	Citrus Park	27-17-22	24	Brooker Creek	3	I
R15	Keystone, Lake	1946-85	Hillsborough	Odessa	27-17-15	417	Brooker Creek	1	P
24	LeClare, Lake		Hillsborough	Citrus Park	27-18-30	44	Rocky Creek	5	
R16	Linda, Lake	1969-85	Pasco	Lutz	26-18-26	19	S. Branch Anclote	1	
25	Little Lake		Hillsborough	Citrus Park	27-17-23	18	Brooker Creek	1	P
26	Little Halfmoon Lake		Hillsborough	Citrus Park	27-17-25	10	Rocky Creek	2	
27	Little Moon Lake		Hillsborough	Citrus Park	27-17-28	12	Brooker Creek	2	
28	Little Moss Lake		Pasco	Lutz	26-18-35	24	Rocky Creek	1	
29	Long Sun Lake		Pasco	Lutz	26-18-34	44	S. Branch Anclote	2	
30	Marlee Lake		Hillsborough	Citrus Park	27-17-28	16	Double Branch	1,2	
31	Mary Lou Lake		Pasco	Lutz	26-18-34	34	S. Branch Anclote	2	
32	Minniola, Lake		Pasco	Odessa	26-17-35	30	S. Branch Anclote	2	
33	Moss Lake		Pasco	Lutz	26-18-35	33	Rocky Creek	1	
R17	Mound Lake	1972-85	Hillsborough	Odessa	27-17-11	79	Brooker Creek	2	P,I
34	Osceola Lake		Hillsborough	Odessa	27-17-3	64	Brooker Creek	2,1	
R18	Parker (Ann) Lake	1969-85	Pasco	Odessa	26-17-35	93	S. Branch Anclote	2,1	
R19	Pretty Lake	1971-85	Hillsborough	Citrus Park	27-16-26	80	Rocky Creek	2	P
R20	Rainbow Lake	1971-85	Hillsborough	Citrus Park	27-17-22	47	Brooker Creek	3	I
35	Raleigh, Lake		Hillsborough	Citrus Park	27-17-27	24	Double Branch	1	
36	Rebel Lake		Hillsborough	Odessa	27-17-11	10	Brooker Creek	2	
37	Rock Lake		Hillsborough	Citrus Park	27-17-25	53	Rocky Creek	1,3	
R21	Rogers, Lake	1973-85	Hillsborough	Citrus Park	27-17-27	93	Double Branch	2	
38	Ruth, Lake		Hillsborough	Lutz	27-18-3	15	Rocky Creek	2	
39	Seminole, Lake		Pasco	Odessa	26-17-35	14	S. Branch Anclote	1	

Table 4. Summary of lakes–Continued

[T-R-S, Township-Range-Section; I, internally drained; P, pumped for irrigation; A, augmented; R, used in regression analysis; 1, well-drained deep sands; 2, somewhat poorly drained fine sands with organic material; 3, very poorly drained sandy soils high in organic material; 4, excessively drained deep acid sandy soil; 5, somewhat poorly drained sands, dark colored]

Site No.	Lake	Period of record	County	Quadrangle sheet	Location (T-R-S)	Size (acres)	Basin	Soil type	Remarks
R22	Starvation Lake	1961-85	Hillsborough	Citrus Park	27-18-21	52	Rocky Creek	2	
40	Sunset Lake		Hillsborough	Odessa	27-17-17	37	Brooker Creek	2	I,A
41	Sunshine Lake		Hillsborough	Citrus Park	27-18-20	17	Rocky Creek	3,2	
R23	Taylor, Lake	1971-85	Hillsborough	Odessa	27-17-16	44	Brooker Creek	3,2	
42	Thorpe Lake		Hillsborough	Citrus Park	27-17-28	13	Brooker Creek	2	
R24	Turkey Ford Lake	1970-85	Hillsborough	Odessa	27-18-18	93	Brooker Creek	3	
43	Van Dyke Lake		Hillsborough	Odessa	27-18-17	12	Rocky Creek	3	
44	Velburton Lake		Hillsborough	Citrus Park	27-17-21	26	Brooker Creek	2	
45	Virginia, Lake		Hillsborough	Lutz	27-18-3	21	Rocky Creek	3	
46	Wastena, Lake		Hillsborough	Odessa	27-17-3	20	Brooker Creek	2	
47	Williams Lake		Hillsborough	Citrus Park	27-17-33	17	Brooker Creek	2	
48	Wood, Lake		Hillsborough	Odessa	27-17-11	20	Brooker Creek	1	

Different combinations of logarithmic transforms of dependent and explanatory variables did not improve the accuracy of the regression models; therefore, untransformed values of all variables were used in the regression analysis. Model bias was not apparent from plots of estimated changes in lake stage contrasted with observed changes. Residuals of estimated changes were plotted as a function of each of the independent variables and time. These scatter plots indicated that residual departures from zero were distributed uniformly throughout the range of explanatory variable values and time.

Because some of the same rainfall and potential evaporation explanatory variables are used along with well-field pumpage to estimate change in water level in the Upper Floridan aquifer (table 6), it could be argued that the change in lake stage can be estimated by using that set of explanatory variables also. The regression relations for change in lake stage using rainfall, potential evaporation, well-field pumpage, and previous month lake stage are presented in table 8. In four out of five of the comparisons between the regression relations that use either well-field pumpage or water level in the Upper Floridan aquifer, the RMSE of the regression relation that includes pumpage was higher than the RMSE of the regression relation that includes Upper Floridan aquifer water levels. Both the regression relation that includes water levels in the Upper Floridan aquifer (table 7) and the relation that includes well-field pumpage (table 8) are presented. The site number, lake name, months that the regression relation is applicable, the number of data points, the regression intercept, regression coefficient of determination, and RMSE for both regression relations are listed on the first line. An additional column, SD (standard deviation), appears in the regression relation that includes water levels in the Upper Floridan aquifer (table 7). The regression coefficient of each explanatory variable, the t statistic, and the probability of a greater t statistic are listed on following lines.

To evaluate the error to be expected in predicting change in lake stage using an estimated Upper Floridan aquifer well water level, the estimated instead of the observed water level was used in the computations for change in lake stage (table 7). All other independent variables were observed data. The SD of the differences between the estimated and observed changes in lake stage was then computed. For example, an estimated water level for James deep well 11, PREDW11, is computed by adding the regression estimate of change in water level, RCHNDW11, in table 6 to the previous month's average water level, LAGDW11.

$$PREDW11 = LAGDW11 + RCHNDW11 \qquad (2)$$

PREDW11 was used instead of JAMEDW11 in the regression relation given in table 7 to compute the estimated change in stage of Lake Alice, RCHSTGW. The SD of the difference between the observed change in lake stage and PCHSTGW is comparable to the RMSE of a regression. The SD of the all-year regression relation for Lake Alice is 0.16 ft and slightly larger than the RMSE of the regression relation that includes observed well water levels, 0.15 ft.

The difference in SD and RMSE depends on the influence of the well water level in the regression relation for change in lake stage and the RMSE of the regression estimate of change in water level for the well that is used in the regression relation for change in lake stage. The more accurate the estimate of change in well water level, the closer the SD of the estimate of change in lake stage will be to the RMSE when using observed well water level.

One regression relation is applicable all year for 10 lakes when using the relation that includes the water level in an Upper Floridan well (table 7) and for 12 lakes when using the relation that includes well-field pumpage (table 8). Neither well water levels nor well-field pumpage reduced the RMSE statistic in the regression relation for Lake Rogers. Well-field pumpage did not reduce the RMSE statistic in the regression relation for Buck Lake.

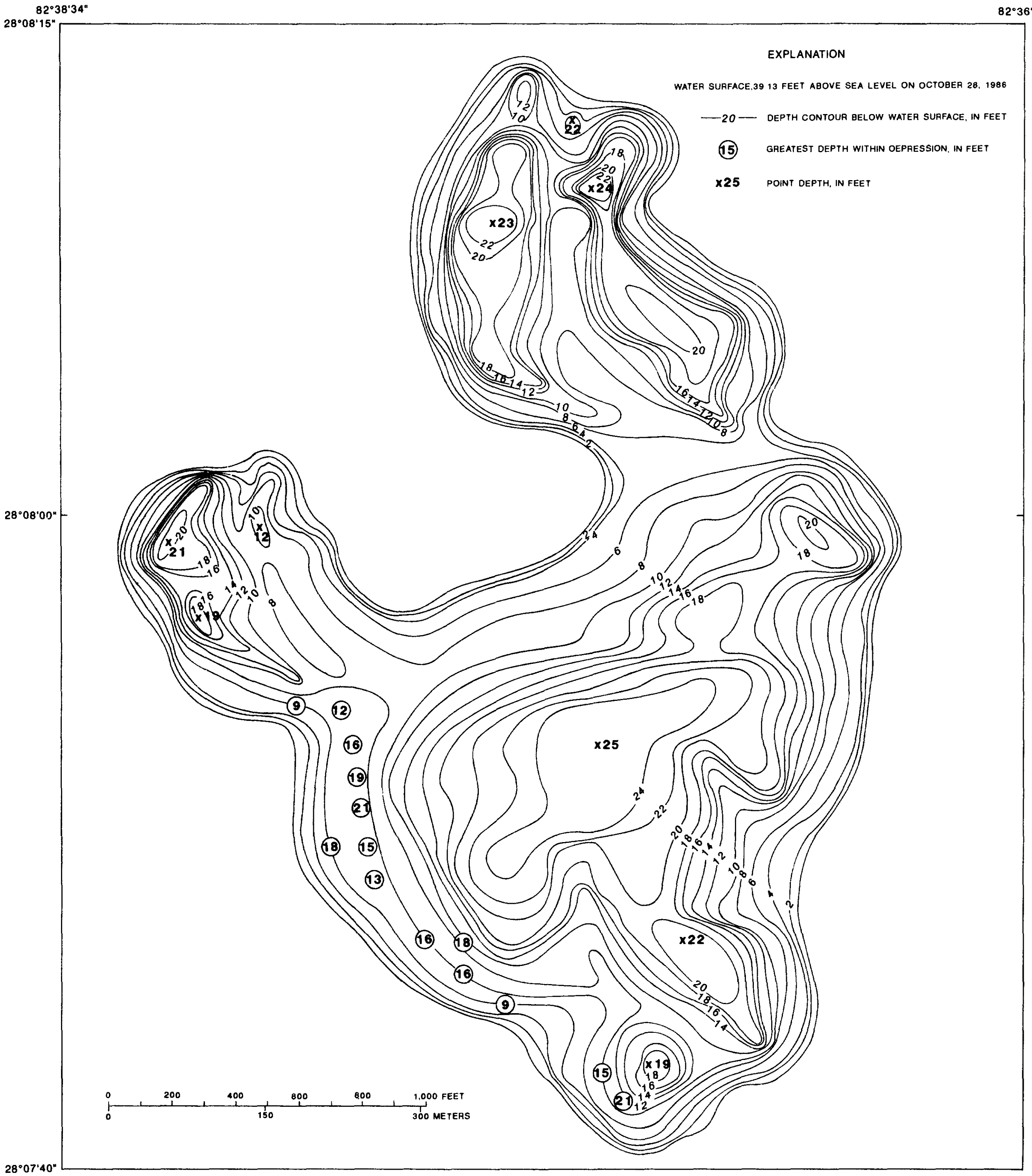


Figure 13. Bathymetry of Lake Alice.

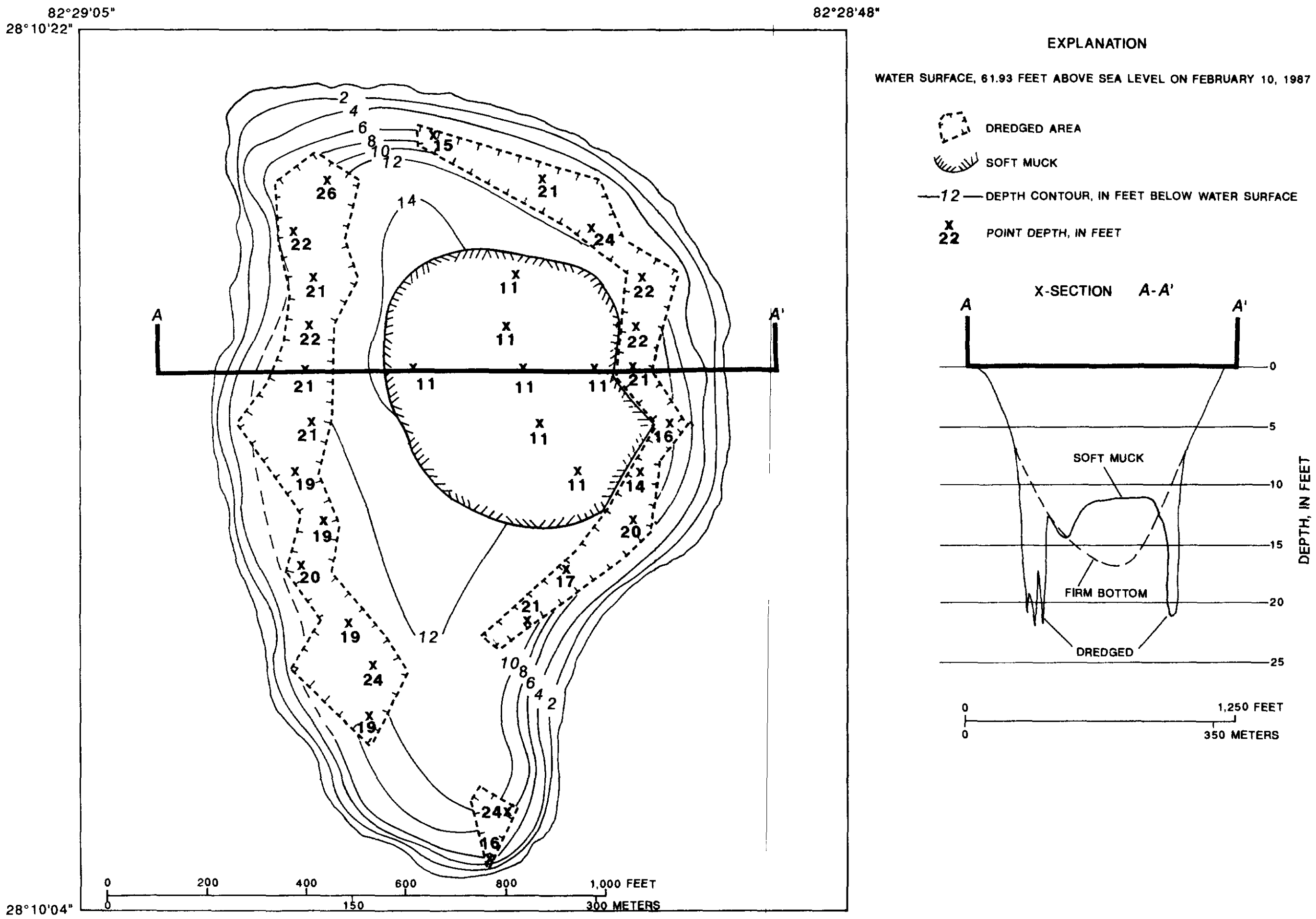


Figure 14. Bathymetry of Browns Lake.

The regression analyses that include water levels in an Upper Floridan aquifer well (table 7) for the June through October period indicated that the relations for 11 lakes included well water level as an explanatory variable that reduces the RMSE; the relations for Glass Lake, Island Ford Lake, and Keystone Lake do not. The relations for the November through May period for 13 lakes included well water levels as an explanatory variable that reduces the RMSE; the relation for Pretty Lake does not.

The regression analyses that include well-field pumpage (table 8) for the June through October period indicated that the relations for seven lakes included well-field pumpage as a variable that reduces the RMSE; the relations for Church Lake, Crescent Lake, Glass Lake, Lake Juanita, and Keystone Lake do not. The relations for the November through May period for 10 lakes include well-field pumpage as an explanatory variable that reduces the RMSE; the relations for Lake Allen and Crescent Lake do not.

The all-year regression relations that include Upper Floridan aquifer well water levels (table 7) had R^2 that varied from 0.62 for Lake Dosson to 0.86 for Lake Alice. The RMSE varied from 0.15 ft for Lake Alice to 0.51 ft for Lake Dan. The all-year regression relations that include well-field pumpage (table 8) had R^2 that varied from 0.47 for Lake Harvey to 0.85 for Rainbow Lake. The RMSE varied from 0.20 ft for Lake Alice to 0.53 ft for Lake Dan.

The June through October season regression relations that include the water level in an Upper Floridan aquifer well (table 7) had R^2 that varied from 0.62 for Lake Harvey to 0.87 for Rainbow Lake. The RMSE varied from 0.22 ft for Lake Calm to 0.46 ft for Pretty Lake. The June through October season regression relations that include well-field pumpage (table 8) had R^2 that varied from 0.52 for Lake Allen to 0.81 for Lake Calm. The RMSE varied from 0.21 ft for Lake Calm to 0.51 ft for Lake Allen.

The regression relations with the highest R^2 and lowest RMSE were for lakes that had little surface inflow or outflow. The June through October regression relation for Island Ford Lake was improved significantly when the stage in Keystone Lake, which flows into it, was included in the relation.

The November through May regression relations that include the water level in an Upper Floridan aquifer well (table 7) had R^2 that varied from 0.58 at Crescent Lake to

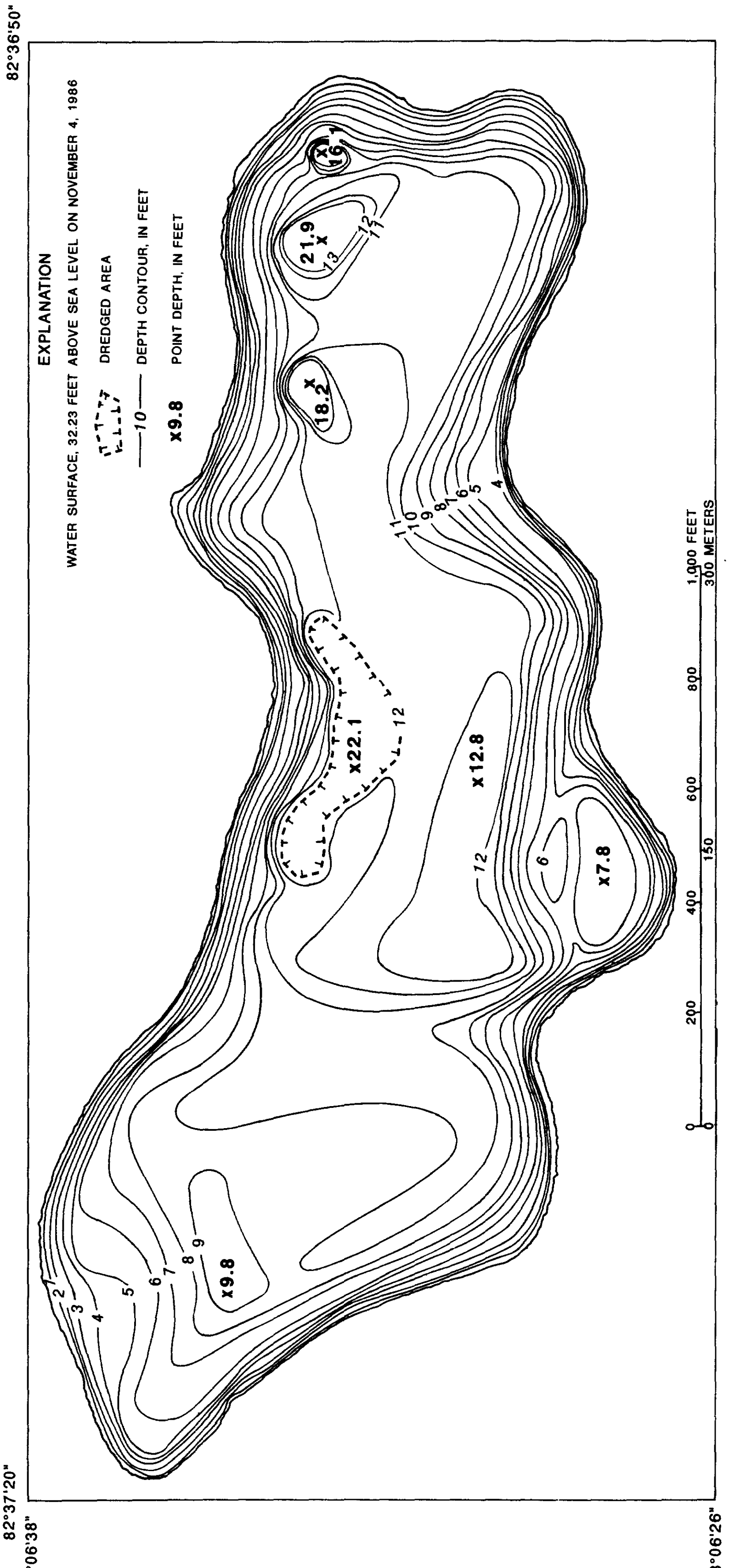


Figure 15. Bathymetry of Buck Lake.

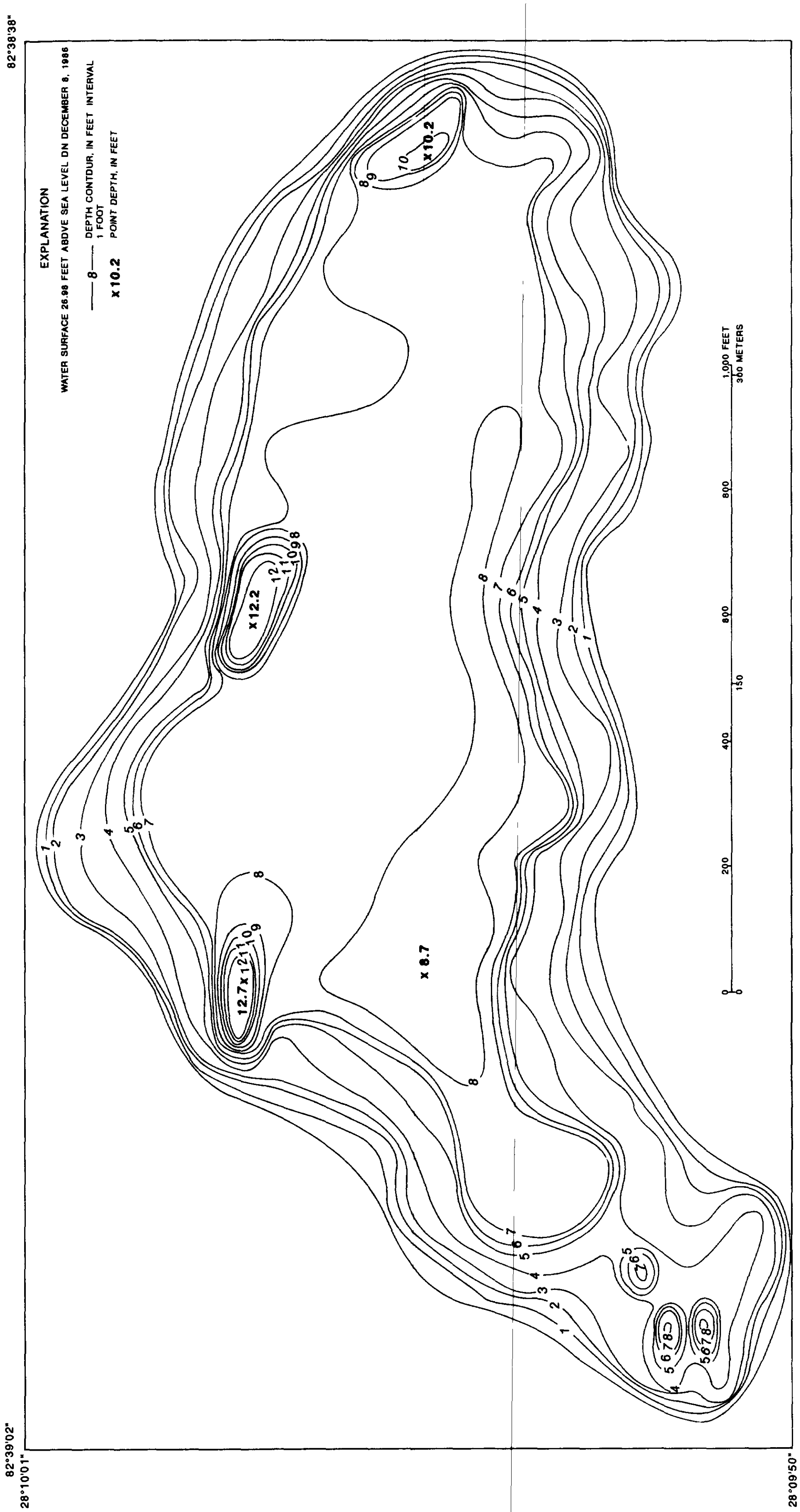


Figure 16. Bathymetry of Lake Dan.

0.86 for Church Lake and Lake Taylor. The RMSE varied from 0.12 ft at Lake Calm, Church Lake, and Lake Taylor to 0.35 ft at Pretty Lake. The November through May regression relations that include well-field pumpage (table 8) had R^2 that varied from 0.56 for Island Ford Lake to 0.84 for Lake Calm. The RMSE varied from 0.11 ft for Lake Calm to 0.27 ft for Turkey Ford Lake.

The June through October season regression relations have larger RMSE than those for the November through May season. The larger RMSE in the June through October season can be attributed to the greater variability of rainfall and the higher range in lake stage.

Rainfall generally had the most influence on the variation of lake stage in all the regression relations, as seen in the relative ranking of the absolute value of t of the explanatory variables. The previous month's lake stage also was an important explanatory variable for the June through October season, whereas the water level in the Upper Floridan aquifer became more important during November through May.

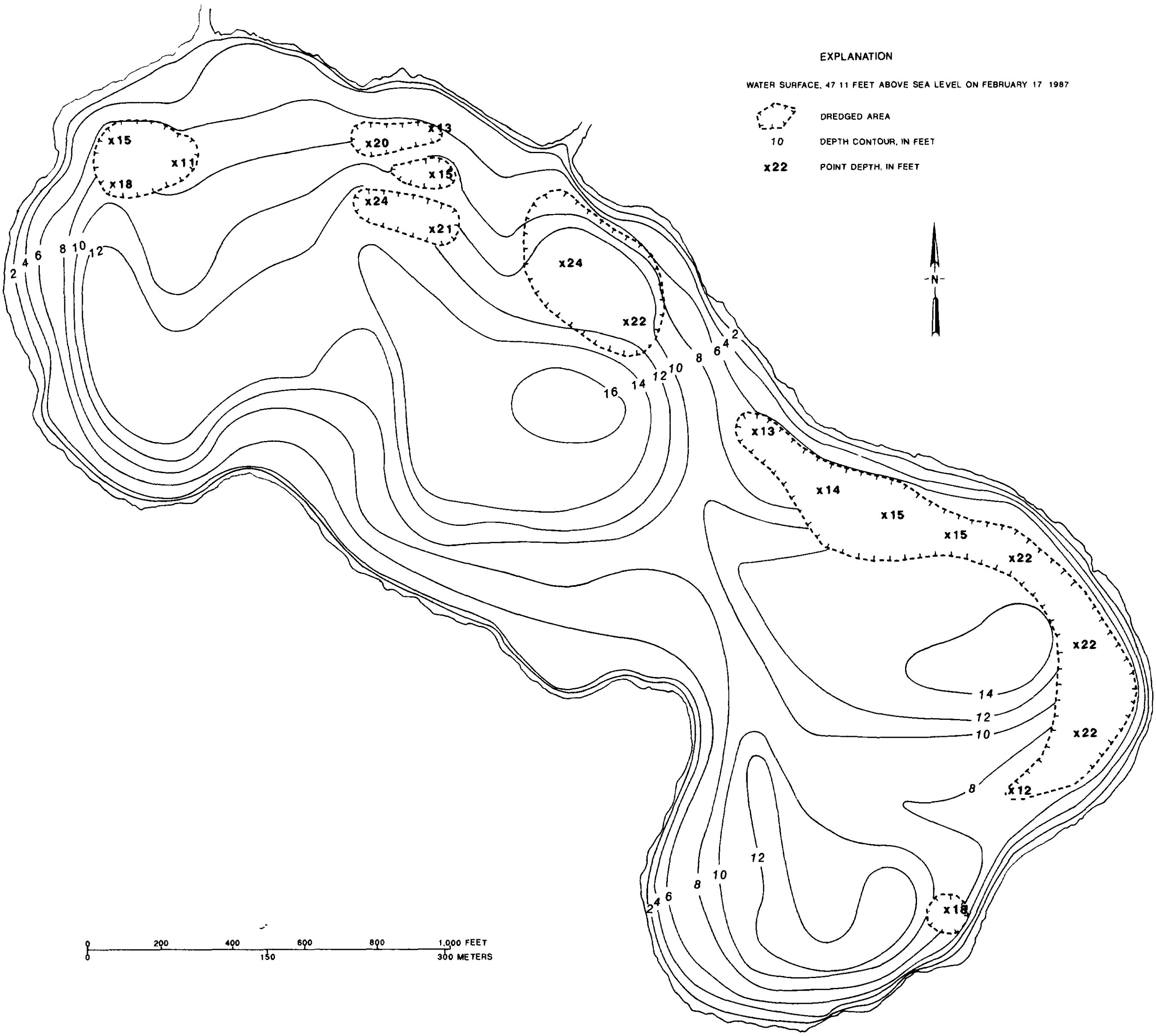


Figure 17. Bathymetry of Parker Lake.

Change in Water Levels in the Surficial Aquifer

Change in the water-table altitude in a surficial aquifer is indicative of the change of volume in storage during a time period. The change in storage is due to the difference between inflow and outflow. The inflow may be composed of infiltration of rainfall directly on the soil surface or lateral movement of water through the aquifer. The outflow may be composed of evapotranspiration from the land surface, leakage to the underlying aquifer, and lateral movement of water through the aquifer. Because of these similarities with the factors that influence change in lake stage, the same approach was used as in the analysis of change in lake stage.

There were only three shallow aquifer observation wells with sufficient data to compute monthly average water levels (table 3). The change in monthly average water level in the surficial aquifer was related to rainfall, potential evaporation, the monthly average water level in a nearby Upper Floridan aquifer well, and the previous month's average water level (table 9). A second set of explanatory variables that include well-field pumpage instead of Upper Floridan well water level was used in a regression analysis (table 10).

One regression relation that includes the water level in an Upper Floridan aquifer well (table 9) is applicable all year for St. Petersburg shallow well 1C-6 (site 7, table 3) and Van Dyke shallow well (site 14, table 3). Two seasonal regressions are applicable for St. Petersburg shallow well 105 (site 30, table 3).

One regression relation that includes well-field pumpage (table 10) is applicable all year for St. Petersburg shallow well 105 and two seasonal relations are applicable for St. Petersburg shallow well 1C-6 and Van Dyke shallow well. The absolute value of the t statistic for rainfall is greater than that of the water level in the Upper Floridan aquifer well in the relations for St. Petersburg shallow well 1C-6 and St. Petersburg shallow well 105 (table 9). The absolute value

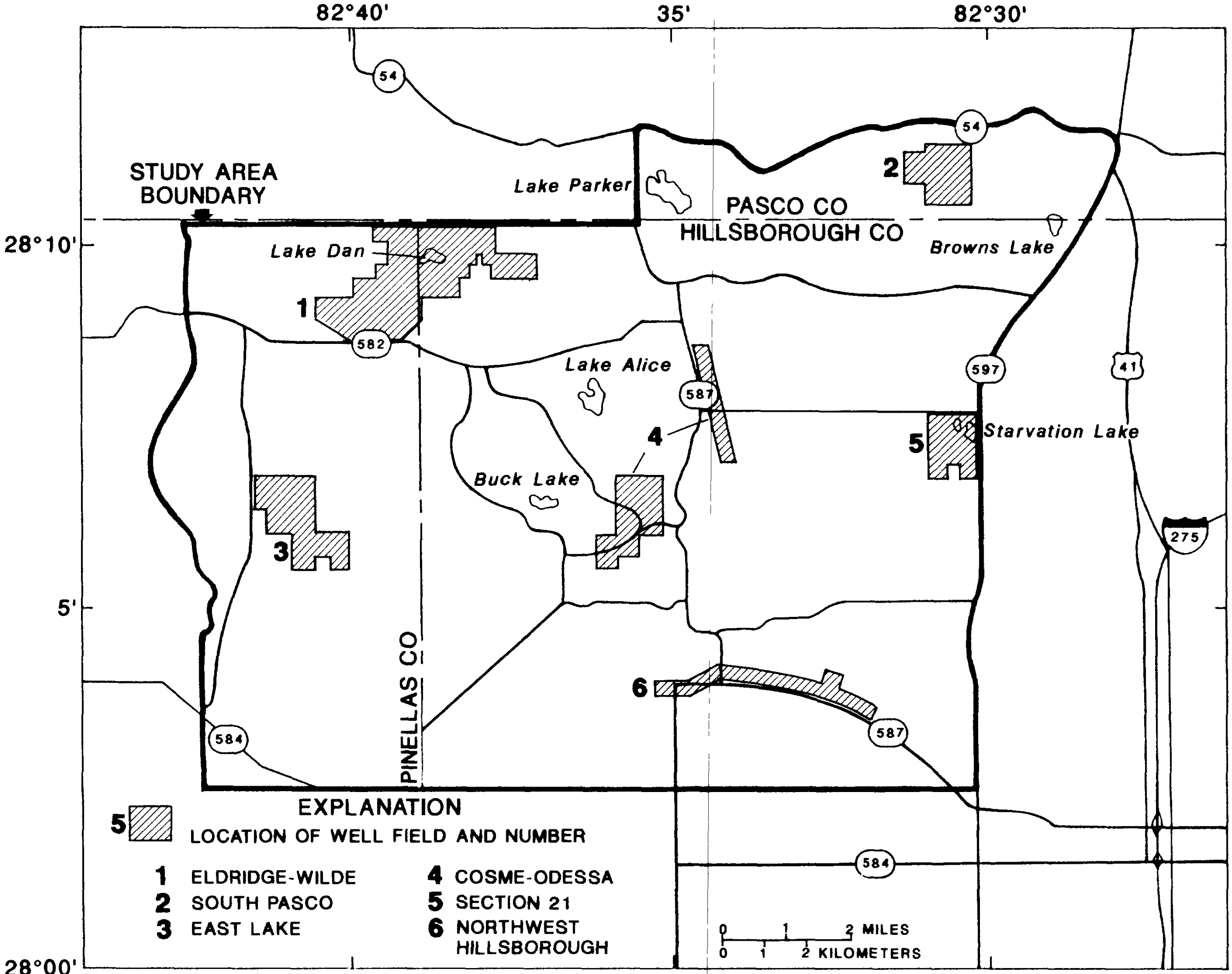


Figure 18. Locations of well fields.

Table 5. Well-field statistics
[Mgal/d, million gallons per day]

Well field	Year online	Average permitted pumping rate in 1985 (Mgal/d)	Maximum permitted pumping rate in 1985 (Mgal/d)	Actual pumpage in 1981 (Mgal/d)	Actual pumpage in 1985 (Mgal/d)	County served	Remarks
Cosme-Odessa	1931	13	22	8.19	12.07	Pinellas	Pumpage decreased in 1963 when Section 21 came online.
Eldridge-Wilde	1957	35.2	55	23.27	31.20	Pinellas	Has been the largest producer in the study area since 1964.
Section 21	1963	13	22	8.29	7.05	Pinellas	Was the second largest producer until South Pasco came online in 1973.
East Lake	1974	3	5	1.52	1.72	Pinellas	The smallest producer in the study area.
South Pasco	1973	16.9	24	11.87	11.53	Pinellas	Has been the second largest producer since coming online.
Northwest Hillsborough	1977	8.8	18.4	5.55	9.42	Hillsborough	Second smallest producer. Water used in Hillsborough County. Many wells spread out over a very large area in the Citrus Park area. Delineated in figure 18.

of the t statistic for the water level in an Upper Floridan aquifer well is greater than that of rainfall in the relation for Van Dyke shallow well. The absolute value of the t statistic for rainfall is highest in the relations that include well-field pumpage (table 10).

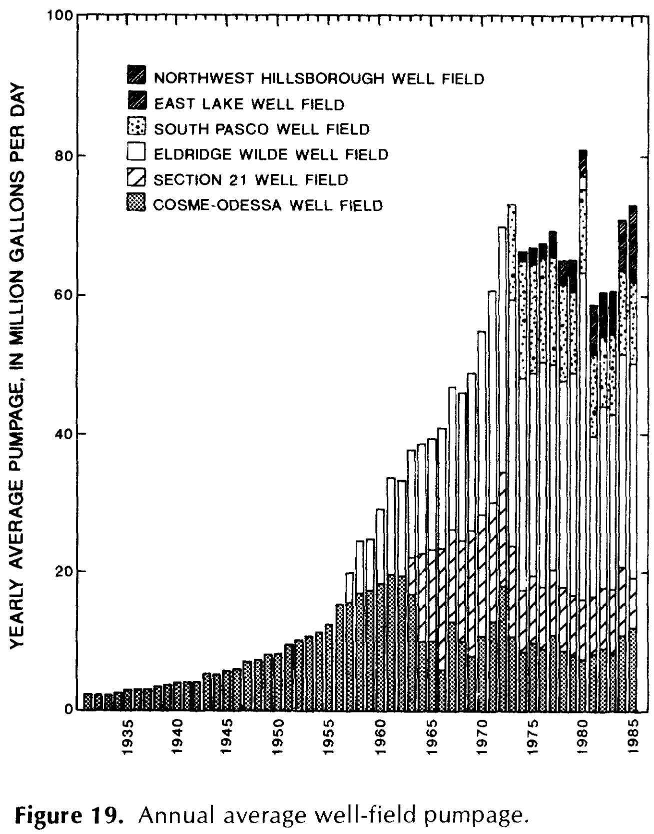


Figure 19. Annual average well-field pumpage.

The range in the R^2 statistic of the all-year relations was from 0.65 for Van Dyke shallow well to 0.78 for St. Petersburg shallow well 1C-6 (table 9). The RMSE ranged from 0.43 ft for St. Petersburg shallow well 1C-6 to 0.67 ft for Van Dyke shallow well (table 9). The R^2 statistic of the June through October season relation varied from 0.48 for Van Dyke shallow well (table 10) to 0.84 for St. Petersburg shallow well 105 (table 9). The RMSE varied from 0.46 ft for St. Petersburg shallow well 105 (table 9) to 0.97 ft for Van Dyke shallow well (table 10). The R^2 of the November through May regression relations varied from 0.63 for Van Dyke shallow well (table 10) to 0.73 for St. Petersburg shallow well 105 (table 9). The RMSE varied from 0.38 ft for St. Petersburg shallow well 1C-6 to 0.60 ft for Van Dyke shallow well (table 10).

APPLICATION OF REGRESSION RELATIONS FOR ESTIMATING CHANGES IN WELL WATER LEVELS AND LAKE STAGE

Regression relations were developed by using the monthly means that were computed from observed data. In order to use these relations to estimate changes in well water levels and lake stage for subsequent months, assumed values for the explanatory variables must be used for each succeeding month. These regression relations can be used for estimating sequential months by using the estimate of the previous month to add to the computed monthly change. The farther into the future an estimate is made, however, the greater the chance of increasing the error of estimate. Comparisons of estimates for 1 month at a time and sequential months of the 1985 water year (October 1984 through September 1985) follow.

Table 6. Regression relations to determine change in monthly average water level in Upper Floridan aquifer wells
[N is number of observations used to determine regression relations; R^2 is regression coefficient of determination; RMSE is the square root of the regression mean square error statistic; t is the t test that the parameter is zero; p>|t| is the probability that a t statistic would obtain a greater absolute value than that observed, given that the true value of t is zero]

Site No. (fig. 4)	Well name	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|
1	ROMP TR13-3 deep well	62	9.03	+0.0749 × COSME_R	0.85	0.61	0.26	0.0001
				+0.0749 × COSME_R		5.61		.0001
				+0.0679 × LAGCOS_R		5.23		.0001
				+0.0287 × LAG2COSR		2.19		.0326
				–0.0643 × LAGPVAP		–4.00		.0002
				–0.0502 × COSME_Q		–2.30		.0257
				–0.2518 × NW_HILLQ		–4.76		.0001
				+0.1821 × LAGHILLQ		3.19		.0024
				–0.5127 × LAGTR13		–5.71		.0001
2	East Lake deep well 17	76	10.39	+0.0666 × AVRAIN1	.69	2.49	.53	.0152
				+0.0791 × LAGAV_R1		3.62		.0006
				–0.0472 × LAGPVAP		–1.87		.0653
				–0.0190 × EW_PUMP		–1.67		.0991
				–0.1520 × NW_HILLQ		–4.56		.0001
				–0.1630 × EASTLK_Q		–2.13		.0369
				–0.5205 × LAGE_L17		–6.30		.0001
3	Brooker Creek deep well	97	3.88	+0.0537 × AVRAIN1	.84	6.85	.18	.0001
				+0.0494 × LAGAV_R1		5.79		.0001
				+0.0168 × LAG2AVR1		1.94		.0557
				–0.0314 × LAGPVAP		–3.28		.0015
				–0.1081 × EASTLK_Q		–4.37		.0001
				–0.0656 × NW_HILLQ		–3.71		.0004
				+0.0375 × LAGHILLQ		2.02		.0470
				–0.0148 × EW_PUMP		–3.29		.0014
				+0.0072 × LAGEW_Q		1.52		.0133
				–0.4866 × LAGBRKCR		–6.95		.0001
4	St. Petersburg deep	62	12.09	+0.1724 × COSME_R	.84	5.94	.57	.0001
				+0.1192 × LAGCOS_R		4.08		.0001
				+0.0522 × LAG2COSR		1.94		.0579
				–0.1516 × LAGPVAP		–4.26		.0001
				–0.1210 × COSME_Q		–2.47		.0166
				–0.5389 × NW_HILLQ		–4.41		.0001
				+0.4671 × LAGHILLQ		3.67		.0006
				–0.4700 × LAGE_102		–5.33		.0001
5	East Lake deep well 14	72	12.49	+0.0987 × AVRAIN1	.70	2.54	.78	.0134
				+0.1135 × LAGAV_R1		3.28		.0017
				–0.0726 × LAGPVAP		–1.89		.0632
				–0.0504 × EW_PUMP		–2.92		.0048
				–0.1696 × NW_HILLQ		–3.67		.0005
				–0.2164 × EASTLK_Q		–1.95		.0555
				–0.5409 × LAGE_L14		–6.58		.0001
6	St. Petersburg deep well E-100	97	10.07	+0.1750 × COSME_R	.80	4.94	.88	.0001
				+0.1607 × LAGCOS_R		4.16		.0001
				–0.1633 × LAGPVAP		–4.03		.0001
				–0.3538 × COSME_Q		–5.09		.0001
				+0.2434 × LAGCOS_Q		3.21		.0019
				–0.2919 × NW_HILLQ		–3.19		.0020
				+0.2542 × LAGHILLQ		2.82		.0060
				–0.0557 × EW_PUMP		–2.29		.0242
				+0.0405 × LAGEW_Q		1.66		.0999
				–0.2898 × LAGE_100		–4.34		.0001
8	St. Petersburg Cosme well 3	97	10.51	+0.1892 × COSME_R	.80	4.95	.95	.0001
				+0.1623 × LAGCOS_R		3.88		.0002
				–0.1705 × LAGPVAP		–3.90		.0002
				–0.4662 × COSME_Q		–6.23		.0001
				+0.3148 × LAGCOS_Q		3.74		.0003
				–0.2328 × NW_HILLQ		–2.38		.0197
	Footnote is at end of table.			+0.2151 × LAGHILLQ		2.25		.0269

Table 6. Regression relations to determine change in monthly average water level in Upper Floridan aquifer wells–Continued

Site No. (fig. 4)	Well name	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|
				−0.0576 × EW_PUMP		−2.19		0.0309
				+0.0463 × LAGEW_Q		1.77		.0809
				−0.2952 × LAGCOS_3		−4.31		.0001
9	Berger deep well	97	9.64	+0.2077 × SEC21_R	0.83	8.61	0.71	.0001
				+0.1025 × LAG21_R		4.09		.0001
				+0.0482 × LAG2_21R		1.82		.0717
				−0.1114 × LAG2PVAP		−3.66		.0004
				−0.1447 × SPASCO_Q		−2.86		.0053
				+0.1110 × LAGSP_Q		2.14		.0355
				−0.3268 × NW_HILLQ		−4.90		.0001
				+0.2786 × LAGHILLQ		3.97		.0001
				−0.3950 × SEC21_Q		−7.06		.0001
				+0.3433 × LAG21_Q		6.38		.0001
				−0.0281 × EW_PUMP		−2.04		.0446
				−0.1735 × LAGBERG		−4.01		.0001
10	Hillsborough deep well 13	97	12.60	+0.1824 × SEC21_R	.86	6.57	.83	.0001
				+0.1272 × LAG21_R		4.22		.0001
				−0.0960 × LAG2PVAP		−3.12		.0024
				−0.1215 × COSME_Q		−2.35		.0208
				−0.3823 × NW_HILLQ		−4.51		.0001
				+0.3308 × LAGHILLQ		3.95		.0002
				−0.2654 × SPASCO_Q		−4.64		.0001
				+0.1811 × LAGSP_Q		2.93		.0043
				−0.6691 × SEC21_Q		−10.24		.0001
				+0.4748 × LAG 21_Q		6.87		.0001
				−0.2225 × LAGDW13		−4.47		.0001
11	James deep well 11	97	11.78	+0.2033 × COSME_R	.85	5.82	.89	.0001
				+0.2148 × LAGCOS_R		5.60		.0001
				−0.1107 × LAGPVAP		−1.97		.0518
				−0.1054 × LAG2PVAP		−2.12		.0372
				−0.5730 × COSME_Q		−8.51		.0001
				+0.4081 × LAGCOS_Q		5.23		.0001
				−0.2093 × SPASCO_Q		−3.38		.0011
				+0.1669 × LAGSP_Q		2.54		.0128
				−0.2428 × SEC21_Q		−3.34		.0012
				+0.1952 × LAG21_Q		2.93		.0043
				−0.2420 × NW_HILLQ		−2.59		.0113
				+0.2465 × LAGHILLQ		2.73		.0077
				−0.2517 × LAGDW11		−4.29		.0001
12	St. Petersburg deep well 21-7	97	15.44	+0.2268 × SEC21_R	.84	7.76	.83	.0001
				+0.1043 × LAG21_R		3.41		.0010
				−0.0921 × LAGPVAP		−2.51		.0140
				−0.5517 × SEC21_Q		−8.14		.0001
				+0.4011 × LAG21_Q		5.98		.0001
				−0.0915 × SPASCO_Q		−1.98		.0511
				−0.4311 × NW_HILLQ		−5.78		.0001
				+0.3338 × LAGHILLQ		4.00		.0001
				−0.0984 × LAGCOS_Q		−1.81		.0738
				−0.2806 × LAG21_7		−5.16		.0001
13	St. Petersburg deep well 26A	80	24.72	+0.1875 × SEC21_R	.80	5.94	.99	.0001
				+0.0685 × LAG21_R		2.15		.0348
				−0.5784 × SEC21_Q		−6.45		.0001
				+0.1713 × LAG21_Q		1.81		.0742
				−0.2222 × SPASCO_Q		−3.91		.0002
				−0.3390 × NW_HILLQ		−5.54		.0001
				−0.1611 × LAGCOS_Q		−2.67		.0094
				−0.4321 × LAGDW26A		−7.19		.0001
17	St. Petersburg deep well 33A	103	18.76	+0.2020 × AVRAIN1	.83	16.37	.02	.0001
				+0.2442 × LAGAV_R1		7.33		.0001
				−0.1728 × LAG2PVAP		−4.25		.0001
				−0.6387 × COSME_Q		−10.30		.0001

Table 6. Regression relations to determine change in monthly average water level in Upper Floridan aquifer wells–Continued

Site No. (fig. 4)	Well name	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|
				+0.3170 × LAGCOS_Q		3.94		0.0002
				–0.2368 × SEC21_Q		–3.16		.0022
				–0.2644 × SPASCO_Q		–4.16		.0001
				+0.2327 × LAGSP_Q		3.53		.0006
				–0.4040 × LAG_33A		–6.95		.0001
18	Eldridge-Wilde deep well 2	139	14.31	+0.0190 × EW_RAIN	0.78	2.99	1.23	.0034
				+0.1685 × LAGEW_R		4.47		.0001
				–0.1071 × LAGPVAP		–2.56		.0117
				–0.2613 × EW_PUMP		–9.58		.0001
				+0.1199 × LAGEW_Q		3.43		.0008
				–0.2699 × COSME_Q		–4.30		.0001
				–0.0759 × SPASCO_Q		–1.71		.0898
				–0.0990 × LAG21_Q		–1.52		.1301
				–0.4979 × LAGE_W2		–8.27		.0001
19	Tarpon Road deep well	132	3.77	+0.0571 × EW_RAIN	.82	8.78	.21	.0001
				+0.0618 × LAGEW_R		8.82		.0001
				–0.0210 × LAG2PVAP		–3.22		.0017
				–0.0254 × EW_PUMP		–5.37		.0001
				+0.0122 × LAGEW_Q		2.54		.0123
				–0.0320 × COSME_Q		–3.16		.0020
				–0.0509 × EASTLK_Q		–2.70		.0080
				–0.3046 × LAGTARRD		–8.34		.0001
20	Eldridge-Wilde monitor well 5	139	15.33	+0.1370 × EW_RAIN	.79	2.92	1.64	.0041
				+0.1587 × LAGEW_R		3.36		.0010
				–0.1162 × LAGPVAP		–2.12		.0360
				–0.3896 × EW_PUMP		–10.87		.0001
				+0.1810 × LAGEW_Q		3.89		.0002
				–0.2988 × COSME_Q		–3.84		.0002
				–0.1338 × SPASCO_Q		–2.25		.0258
				–0.4835 × LAGMON5		–7.98		.0001
21	Lutz-Lake Fern deep well	97	12.09	+0.1853 × AVRAIN4	.88	8.53	.61	.0001
				+0.1027 × LAGAV_R4		4.51		.0001
				–0.0697 × LAG2PVAP		–3.11		.0026
				–0.3276 × SEC21_Q		–6.88		.0001
				+0.2603 × LAG21_Q		5.64		.0001
				–0.3254 × SPASCO_Q		–7.73		.0001
				+0.2241 × LAGSP_Q		4.68		.0001
				–0.0362 × LAGEW_Q		–3.03		.0032
				–0.3691 × NW_HILLQ		–6.46		.0001
				+0.2530 × LAGHILLQ		4.02		.0001
				–0.2073 × LAGLZ_LF		–4.94		.0001
22	Eldridge-Wilde deep well N-4	96	7.34	+0.1683 × EW_RAIN	.87	6.25	.73	.0001
				+0.2072 × LAGEW_R		6.98		.0001
				–0.1211 × LAG2PVAP		–4.40		.0001
				–0.2231 × EW_PUMP		–11.09		.0001
				+0.1578 × LAGEW_Q		7.18		.0001
				–0.1929 × COSME_Q		–3.43		.0009
				+0.1081 × LAGCOS_Q		1.86		.0658
				–0.1734 × LAGDWN_4		–4.09		.0001
23	Eldridge-Wilde well 113A	139	8.66	+0.1476 × EW_RAIN	.83	4.33	1.17	.0001
				+0.2006 × LAGEW_R		5.98		.0001
				–0.0667 × LAGPVAP		–1.70		.0907
				–0.3689 × EW_PUMP		–14.80		.0001
				+0.2121 × LAGEW_Q		6.41		.0001
				–0.0872 × COSME_Q		–1.56		.1202
				–0.2883 × LAG113A		–5.87		.0001
24	Eldridge-Wilde deep well 139G	130	9.52	+0.1556 × EW_RAIN	.83	5.22	.95	.0001
				+0.2171 × LAGEW_R		6.80		.0001
				–0.0963 × LAG2PVAP		–3.17		.0019
				–0.2723 × EW_PUMP		–12.14		.0001
				+0.1893 × LAGEW_Q		7.64		.0001

Table 6. Regression relations to determine change in monthly average water level in Upper Floridan aquifer wells–Continued

Site No. (fig. 4)	Well name	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|
				−0.1703 × EASTLK_Q		−2.02		0.0455
				−0.1575 × COSME_Q		−3.29		.0013
				−0.2491 × LAG139G		−5.66		.0001
25	Eldridge-Wilde deep well N2	138	6.19	+0.1356 × EW_RAIN	0.85	5.21	0.93	.0001
				+0.2038 × LAGEW_R		7.45		.0001
				−0.0705 × LAG2PVAP		−2.34		.0208
				−0.3225 × EW_PUMP		−15.64		.0001
				−0.1425 × COSME_Q		−2.59		.0108
				+0.0757 × LAGCOS_Q		−1.32		.1895
				−0.1804 × LAGE_WN2		−4.31		.0001
26	Eldridge-Wilde deep well N3	97	6.20	+0.1383 × EW_RAIN	.89	5.93	.64	.0001
				+0.2018 × LAGEW_R		7.79		.0001
				−0.1036 × LAG2PVAP		−4.29		.0001
				−0.2013 × EW_PUMP		−11.11		.0001
				+0.1298 × LAGEW_Q		6.62		.0001
				−0.1853 × COSME_Q		−3.80		.0003
				+0.1081 × LAGCOS_Q		2.18		.0323
				−0.1264 × SPASCO_Q		−2.84		.0056
				+0.1035 × LAGSP_Q		2.23		.0286
				−0.1931 × LAGDWN3		−4.81		.0001
27	Eldridge-Wilde Mitchell	120	14.72	+0.1574 × LAGEW_R	.40	3.12	2.20	.0023
				−0.1477 × EW_PUMP		−3.94		.0001
				−0.3050 × COSME_Q		−2.89		.0046
				−0.4864 × LAGMITCH		−7.63		.0001
28	St. Petersburg well 42	115	15.90	+0.1504 × SPASCO_R	.90	7.05	.70	.0001
				+0.1696 × LAGSP_R		7.53		.0001
				−0.0974 × LAGPVAP		−3.84		.0002
				−0.8568 × SPASCO_Q		−20.18		.0001
				+0.6299 × LAGSP_Q		10.97		.0001
				−0.0972 × LAGCOS_Q		−2.53		.0127
				−0.2705 × LAGDW42		−6.78		.0001
29	St. Petersburg deep well 105	97	15.75	+0.1494 × SPASCO_R	.88	5.46	.79	.0001
				+0.1703 × LAGSP_R		6.45		.0001
				−0.1297 × LAGPVAP		−4.50		.0001
				−0.7845 × SPASCO_Q		−15.57		.0001
				+0.6046 × LAGSP_Q		9.45		.0001
				−0.0914 × COSME_Q		−2.28		.0247
				−0.2781 × LAGDW105		−5.92		.0001
31	St. Petersburg well 45	115	14.53	+0.1569 × SPASCO_R	.88	8.57	.60	.0001
				+0.1519 × LAGSP_R		7.90		.0001
				−0.0942 × LAGPVAP		−4.33		.0001
				−0.6034 × SPASCO_Q		−16.74		.0001
				+0.4420 × LAGSP_Q		9.88		.0001
				−0.0848 × LAGCOS_Q		−2.60		.0105
				−0.2362 × LAGDW45		−6.85		.0001
34	Doyles Ranch deep well	68	17.61	+0.2083 × SPASCO_R	.84	7.52	.67	.0001
				+0.1541 × LAGSP_R		5.74		.0001
				−0.1476 × LAGPVAP		−4.97		.0001
				−0.3195 × SPASCO_Q		−6.51		.0001
				+0.1834 × LAGSP_Q		3.27		.0017
				−0.1149 × COSME_Q		−2.37		.0209
				−0.3108 × LAGDOYLE		−5.69		.0001
35	Swains	124	10.39	+0.1307 × EW_RAIN	.77	5.89	.75	.0001
				+0.2192 × LAGEW_R		9.80		.0001
				−0.1152 × LAG2PVAP		−4.85		.0001
				−0.1744 × SPASCO_Q		−4.03		.0001
				+0.1317 × LAGSP_Q		2.92		.0042
				−0.0545 × EW_PUMP		−3.08		.0026
				+0.0406 × LAGEW_Q		2.34		.0210

Table 6. Regression relations to determine change in monthly average water level in Upper Floridan aquifer wells–Continued

Site No. (fig. 4)	Well name	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|
				−0.1248 × COSME_Q		−3.24		0.0015
				−0.2131 × LAGSWAIN		−5.36		.0001
36	State Highway 54 deep	115	15.48	+0.1615 × SPASCO_R	0.90	8.60	0.59	.0001
				+0.1527 × LAGSP_R		8.21		.0001
				−0.1017 × LAGPVAP		−5.17		.0001
				−0.6750 × SPASCO_Q		−19.01		.0001
				+0.4930 × LAGSP_Q		10.60		.0001
				−0.0698 × COSME_Q		−2.42		.0174
				−0.2603 × LAG54DW		−7.13		.0001

[1]Definitions of abbreviations for explanatory variables are as follows:
AVRAIN1 = average of Cosme-Odessa well field and Eldridge-Wilde well field rainfall for month, in inches;
AVRAIN4 = average of Section 21 well field and South Pasco well field rainfall for month, in inches;
BERGERDW = monthly average water level in Berger deep well, in feet above sea level;
COSME_Q = monthly average pumpage from Cosme-Odessa well field, in million gallons per day;
COSME_R = monthly rainfall at Cosme-Odessa well field rain gage, in inches;
EASTLK_Q = monthly average pumpage from East Lake well field, in million gallons per day;
EW_PUMP = monthly average pumpage from Eldridge-Wilde well field, in million gallons per day;
EW_RAIN = monthly total rainfall in Eldridge-Wilde well field rain gage, in inches;
LAG113A = previous month average water level in Eldridge-Wilde 113A, in feet above sea level;
LAG139G = previous month average water level in Eldridge-Wilde 139G, in feet above sea level;
LAG21_7 = previous month average water level in St. Petersburg deep well 21-7, in feet above sea level;
LAG21_Q = previous month average pumpage from Section 21 well field, in million gallons per day;
LAG21_R = previous month total rainfall in Section 21 well field rain gage, in inches;
LAG2AVR1 = lag 2 month average rainfall at Cosme-Odessa well field and Eldridge-Wilde well field rainfall, in inches;
LAG2COSR = lag 2 month total rainfall in Cosme-Odessa well field rain gage, in inches;
LAG2PVAP = lag 2 month potential evaporation, in inches;
LAG2_21R = lag 2 month total rainfall in Section 21 well field rain gage, in inches;
LAG54DW = previous month average water level in State Road 54 deep well, in feet above sea level;
LAGAV_R1 = previous month average rainfall at Cosme-Odessa well field and Eldridge-Wilde well field rainfall, in inches;
LAGAV_R4 = previous month average rainfall at Section 21 well field and South Pasco well field rainfall, in inches;
LAGBERG = previous month average water level in Berger deep well, in feet above sea level;
LAGBRKCR = previous month average water level in Brooker Creek deep well, in feet above sea level;
LAGCOS_3 = previous month average water level in Cosme-3 well, in feet above sea level;
LAGCOS_Q = previous month average pumpage from Cosme-Odessa well field, in million gallons per day;
LAGCOS_R = previous month total rainfall at Cosme-Odessa well field rain gage, in inches;
LAGDOYLE = previous month water level in Doyles Ranch deep well, in feet above sea level;
LAGDW105 = previous month water level in St. Petersburg deep well 105, in feet above sea level;
LAGDW11 = previous month average water level in James deep well 11, in feet above sea level;
LAGDW13 = previous month average water level in Hillsborough deep well 13, in feet above sea level;
LAGDW26A = previous month average water level in St. Petersburg deep well 26A, in feet above sea level;
LAGDW42 = previous month average water level in St. Petersburg deep well 42, in feet above sea level;
LAGDW45 = previous month water level in St. Petersburg deep well 45, in feet above sea level;
LAGDWN3 = previous month water level in Eldridge-Wilde deep well N3, in feet above sea level;
LAGDWN_4 = previous month water level in Eldridge-Wilde deep well N-4, in feet above sea level;
LAGELK_Q = previous month average pumpage from East Lake well field, in million gallons per day;
LAGEW_Q = previous month average pumpage from Eldridge-Wilde well field, in million gallons per day;
LAGEW_R = previous month total rainfall in Eldridge-Wilde well field rain gage, in inches;
LAGE_100 = previous month average water level in St. Petersburg deep well E-100, in feet above sea level;
LAGE_102 = previous month average water level in St. Petersburg deep well E-102, in feet above sea level;
LAGE_L14 = previous month average water level in East Lake deep well 14, in feet above sea level;
LAGE_L17 = previous month average water level in East Lake deep well 17, in feet above sea level;
LAGE_W2 = previous month average water level in Eldridge-Wilde well 2, in feet above sea level;
LAGE_WN2 = previous month average water level in Eldridge-Wilde well N2, in feet above sea level;
LAGHILLQ = previous month average pumpage from Hillsborough County well field, in million gallons per day;
LAGLZ_LF = previous month average water level in Lutz-Lake Fern well, in feet above sea level;
LAGMITCH = previous month average water level in Mitchell well, in feet above sea level;
LAGMON5 = previous month average water level in Eldridge-Wilde monitor well 5, in feet above sea level;
LAGPVAP = previous month total potential evaporation, in inches;
LAGSP_Q = previous month average pumpage from South Pasco well field, in million gallons per day;
LAGSP_R = previous month total rainfall in South Pasco well-field rain gage, in inches;
LAGSWAIN = previous month average water level in Swains well, in feet above sea level;
LAGTARRD = previous month average water level in Tarpon Road well, in feet above sea level;
LAGTR13 = previous month average water level in ROMP well TR13-3, in feet above sea level;
LAG_33A = previous month average water level in St. Petersburg deep well 33A, in feet above sea level;
NW_HILLQ = monthly average pumpage from Northwest Hillsborough well field, in million gallons per day;
SEC21_Q = monthly average pumpage from Section 21 well field, in million gallons per day;
SEC21_R = monthly rainfall in Section 21 well-field rain gage, in inches;
SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day;
SPASCO_R = monthly rainfall at South Pasco well-field rain gage, in inches.

Table 7. Regression relations to determine change in monthly average lake stage due to climatic factors and water level in the Upper Floridan aquifer

[N is number of observations used to determine regression relation; R^2 is regression coefficient of determination; RMSE is the square root of the regression mean square error statistic, in feet; t is the t test that the parameter is zero; p>|t| is the probability that the t statistic would obtain a greater absolute value than that observed given that the true value of t is zero; SD is the standard deviation of the residuals, in feet, when the estimated water level in the Upper Floridan aquifer well computed using the regression relation in table 6 is used instead of the observed water level]

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|	SD
R1	Lake Alice	All year	97	0.42	+0.0567 × AVRAIN1	0.86	7.73	0.15	0.0001	0.16
					+0.0641 × LAGAV_R1		10.29		.0001	
					+0.0114 × LAG2AVR1		1.85		.0670	
					–0.0158 × LAGPVAP		–1.75		.0836	
					–0.0299 × LAG2PVAP		–3.58		.0006	
					+0.0359 × JAMEDW11		3.53		.0007	
					–0.0377 × LAGSTAGE		–2.22		.0288	
R2	Lake Allen	June-October	58	17.27	+0.1613 × SH54DW	.67	3.05	.43	.0035	.51
					+0.1246 × LZ_LFDW		2.03		.0476	
					–0.4957 × LAGSTAGE		–9.34		.0001	
R2	Lake Allen	November-May	79	6.59	+0.0725 × SEC21_R	.79	7.70	.19	.0001	.24
					+0.0352 × LAG21_R		2.72		.0080	
					–0.0387 × LAG2PVAP		–3.86		.0002	
					+0.0825 × LZ_LFDW		5.43		.0001	
					–0.1647 × LAGSTAGE		–4.16		.0001	
R3	Browns Lake	All year	112	17.65	+0.0310 × SPASCO_R	.68	3.40	.28	.0010	.30
					+0.0283 × LAGSP_R		2.97		.0037	
					–0.0158 × LAG2PVAP		–1.76		.0820	
					+0.0482 × SH54DW		2.02		.0460	
					+0.0873 × LZ_LFDW		3.00		.0034	
					–0.3827 × LAGSTAGE		–8.29		.0001	
R4	Buck Lake	All year	80	8.15	+0.0653 × COSME_R	.69	5.55	.29	.0001	.30
					+0.0466 × LAGCOS_R		3.94		.0002	
					+0.0195 × LAG2COSR		1.54		.1277	
					–0.0582 × LAG2PVAP		–4.47		.0001	
					+0.1231 × E_L14DW		4.03		.0001	
					–0.3213 × LAGSTAGE		–5.50		.0001	
R5	Lake Calm	June-October	58	–1.93	+0.0573 × AVRAIN1	.80	7.63	.22	.0001	.21
					+0.0713 × LAGAV_R1		8.22		.0001	
					+0.0138 × LAG2AVR1		1.68		.0988	
					+0.0361 × DW_33A		2.29		.0258	
R5	Lake Calm	November-May	81	–1.43	+0.0544 × AVRAIN1	.82	9.24	.12	.0001	.13
					+0.0282 × LAGAV_R1		3.30		.0015	
					–0.0124 × LAGPVAP		–1.82		.0726	
					–0.0218 × LAG2PVAP		–3.24		.0018	
					+0.0363 × LZ_LFDW		4.72		.0001	
R6	Camp Lake	All year	108	– .89	+0.0623 × SPASCO_R	.72	6.88	.27	.0001	.29
					+0.0515 × LAGSP_R		5.12		.0001	
					–0.0310 × LAG2PVAP		–3.56		.0006	
					+0.1013 × SH54DW		6.31		.0001	
					–0.0663 × LAGSTAGE		–4.98		.0001	
R7	Church Lake	June-October	58	2.04	+0.0380 × COSME_R	.82	3.45	.27	.0011	.29
					+0.0985 × LAGCOS_R		7.61		.0001	
					+0.0702 × DW_E100		2.45		.0175	
					–0.1352 × LAGSTAGE		–3.38		.0014	
R7	Church Lake	November-May	79	1.03	+0.0385 × COSME_R	.86	6.37	.12	.0001	.15
					+0.0432 × LAGCOS_R		6.05		.0001	
					–0.0314 × LAG2PVAP		–5.44		.0001	
					+0.0740 × DW_E100		8.96		.0001	
					–0.0835 × LAGSTAGE		–5.96		.0001	

Footnotes are at end of table.

Table 7. Regression relations to determine change in monthly average lake stage due to climatic factors and water level in the Upper Floridan aquifer–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|	SD
R8	Crescent Lake	June-October	35	29.27	+0.0451 × LAGAV_R1	0.77	1.57	0.42	0.1263	0.46
					–0.2482 × LAGPVAP		–3.87		.0006	
					+0.0825 × DWN_4		1.64		.1115	
					+0.1890 × SWAINSWL		2.14		.0408	
					–0.8381 × LAGSTAGE		–7.94		.0001	
R8	Crescent Lake	November-May	65	4.46	–0.0315 × LAGPVAP	.58	–2.49	.27	.0156	.32
					+0.1925 × SWAINSWL		7.48		.0001	
					–0.2788 × LAGSTAGE		–5.26		.0001	
R9	Lake Dan	All year	95	1.16	+0.0852 × EW_RAIN	.66	4.47	.51	.0001	.51
					+0.1182 × LAGEW_R		5.76		.0001	
					–0.0595 × LAGPVAP		–3.08		.0027	
					+0.0977 × E_WN2		3.90		.0002	
					–0.0947 × LAGSTAGE		–3.55		.0006	
R10	Dosson Lake	All year	138	9.65	+0.0760 × SEC21_R	.62	5.94	.46	.0001	.49
					+0.0562 × LAG21_R		4.11		.0001	
					–0.0408 × LAG2PVAP		–3.03		.0029	
					+0.1168 × LZ_LFDW		4.80		.0001	
					–0.2772 × LAGSTAGE		–6.50		.0001	
R11	Glass Lake	June-October	33	4.21	+0.0867 × COSME_R	.70	3.18	.39	.0035	—
					+0.1073 × LAGCOS_R		4.74		.0001	
					–0.1033 × POTEVAP		–2.42		.0221	
					–0.1155 × LAGSTAGE		–2.27		.0311	
R11	Glass Lake	November-May	46	3.14	+0.0523 × COSME_R	.67	3.45	.25	.0013	.27
					+0.1124 × LAGCOS_R		5.18		.0001	
					+0.0575 × DW_E100		2.66		.0111	
					–0.1657 × LAGSTAGE		–3.37		.0016	
R12	Lake Harvey	June-October	45	12.41	+0.0354 × AVRAIN4	.62	2.02	.37	.0495	.43
					+0.1951 × SH54DW		5.42		.0001	
					–0.3584 × LAGSTAGE		5.49		.0001	
R12	Lake Harvey	November-May	66	6.43	+0.0552 × AVRAIN4	.70	5.30	.23	.0001	.25
					+0.0457 × LAGAV_R4		2.77		.0073	
					+0.0853 × DW21_7		6.20		.0001	
					–0.1702 × LAGSTAGE		–4.88		.0001	
R13	Island Ford Lake	June-October	55	–3.65	+0.0362 × LAGAV_R1	.85	2.37	.34	.0215	[2].45
					+0.8197 × KEYSTONE		9.72		.0001	
					–0.7452 × LAGSTAGE		–13.19		.0001	
R13	Island Ford Lake	November-May	78	3.45	+0.0397 × AVRAIN1	.59	3.44	.22	.0010	.25
					–0.0325 × LAG2PVAP		–2.82		.0061	
					+0.0919 × LZ_LFDW		5.20		.0001	
					–0.1785 × LAGSTAGE		–3.66		.0005	
R14	Lake Juanita	June-October	55	2.75	+0.0631 × AVRAIN1	.78	3.38	.42	.0014	.44
					+0.1498 × LAGAV_R1		8.22		.0001	
					+0.0602 × JAMEDW11		1.71		.0935	
					–0.1472 × LAGSTAGE		–2.45		.0179	
R14	Lake Juanita	November-May	79	2.06	+0.0462 × AVRAIN1	.77	5.28	.17	.0010	.20
					+0.0231 × LAGAV_R1		2.24		.0283	
					–0.0335 × LAG2PVAP		–4.05		.0001	
					+0.0784 × DW_E100		6.62		.0001	
					–0.0984 × LAGSTAGE		–5.06		.0001	
R15	Keystone Lake	June-October	58	12.04	+0.0469 × AVRAIN1	.62	3.55	.39	.0008	—
					+0.0949 × LAGAV_R1		7.24		.0001	
					+0.0402 × LAG2AVR1		2.79		.0073	
					–0.3234 × LAGSTAGE		–4.78		.0001	

Table 7. Regression relations to determine change in monthly average lake stage due to climatic factors and water level in the Upper Floridan aquifer–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|	SD
R15	Keystone Lake	November-May	79	5.42	+0.0256 × AVRAIN1	0.59	2.44	0.21	0.0172	0.22
					–0.0323 × LAGPVAP		–2.93		.0045	
					–0.0242 × LAG2PVAP		–2.17		.0329	
					+0.0644 × LZ_LFDW		3.98		.0002	
					–0.1860 × LAGSTAGE		–3.34		.0013	
R16	Lake Linda	June-October	48	12.00	+0.0410 × SPASCO_R	.66	2.74	.36	.0088	.41
					+0.1776 × SH54DW		6.29		.0001	
					–0.3174 × LAGSTAGE		–6.07		.0001	
R16	Lake Linda	November-May	66	4.63	+0.0717 × SPASCO_R	.83	9.49	.16	.0001	.18
					+0.0268 × LAGSP_R		2.26		.0276	
					–0.0388 × LAG2PVAP		–4.23		.0001	
					+0.0640 × LZ_LFDW		5.06		.0001	
					–0.1112 × LAGSTAGE		–4.00		.0002	
R17	Mound Lake	All year	136	13.98	+0.0446 × AVRAIN1	.78	7.70	.19	.001	.20
					+0.0405 × LAGAV_R1		7.25		.0001	
					–0.0305 × LAG2PVAP		–5.12		.0001	
					+0.0509 × DW_33A		5.92		.0001	
					–0.3121 × LAGSTAGE		–8.63		.0001	
R18	Parker (Ann) Lake	June-October	52	18.49	+0.0273 × LAGAV-R1	.78	1.65	.32	.1055	.37
					+0.2716 × SWAINSWL		5.98		.0001	
					–0.6117 × LAGSTAGE		–8.74		.0001	
R18	Parker (Ann) Lake	November-May	66	8.44	+0.0459 × AVRAIN1	.84	5.96	.14	.0001	.16
					+0.0149 × LAGAV_R1		1.57		.1221	
					–0.0294 × LAG2PVAP		–3.47		.0010	
					+0.1291 × SWAINSWL		7.00		.0001	
					–0.2789 × LAGSTAGE		–6.16		.0001	
R19	Pretty Lake	June-October	49	16.48	+0.0710 × AVRAIN2	.66	3.62	.46	.0008	.46
					+0.0348 × LAGAV_R2		1.88		.0671	
					–0.1049 × LAGPVAP		–1.53		.1326	
					+0.1830 × COSME_3		4.68		.0001	
					–0.4688 × LAGSTAGE		–6.41		.0001	
R19	Pretty Lake	November-May	75	3.36	+0.0872 × AVRAIN2	.46	5.41	.35	.0001	—
					–0.0593 × LAGPVAP		–3.44		.0010	
					–0.0422 × LAG2PVAP		–2.20		.0312	
					–0.0562 × LAGSTAGE		–1.20		.2330	
R20	Rainbow Lake	June-October	50	2.11	+0.0624 × COSME_R	.87	5.97	.25	.0001	.24
					+0.1150 × LAGCOS_R		9.91		.0001	
					+0.0376 × LAG2COSR		3.53		.0010	
					–0.1699 × LAG2PVAP		–2.92		.0054	
					+0.0592 × JAMEDW11		2.24		.0300	
					–0.0570 × LAGSTAGE		–1.89		.0659	
R20	Rainbow Lake	November-May	70	1.12	+0.0534 × COSME_R	.80	4.87	.19	.0001	.21
					+0.0732 × LAGCOS_R		5.45		.0001	
					–0.0178 × LAGPVAP		–1.44		.1548	
					–0.0282 × LAG2PVAP		–2.49		.0154	
					+0.0547 × JAMEDW11		3.82		.0003	
					–0.0735 × LAGSTAGE		–3.58		.0007	
R21	Lake Rogers	All year	42	2.61	+0.1088 × COSME_R	.83	9.13	.26	.0001	—
					+0.0386 × LAGCOS_R		2.92		.0059	
					–0.0653 × POTEVAP		–4.52		.0001	
					–0.0323 × LAG2PVAP		–1.96		.0571	
					–0.0499 × LAGSTAGE		–1.75		.0883	

Table 7. Regression relations to determine change in monthly average lake stage due to climatic factors and water level in the Upper Floridan aquifer–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p|t|	SD
R22	Starvation Lake	All year	138	3.38	+0.0561 × SEC21_R	0.68	3.86	0.46	0.0002	0.49
					+0.0944 × LAG21_R		6.20		.0001	
					+0.0279 × LAG2_21R		2.09		.0384	
					–0.0529 × LAGPVAP		–3.10		.0024	
					+0.1124 × BERGERDW		3.78		.0002	
					–0.1631 × LAGSTAGE		–5.38		.0001	
R23	Lake Taylor	June-October	41	4.64	+0.0418 × AVRAIN1	.77	2.93	.25	.0058	.25
					+0.0665 × LAGAV_R1		4.73		.0001	
					+0.0681 × DWN_4		2.37		.0232	
					–0.1880 × LAGSTAGE		–3.13		.0034	
R23	Lake Taylor	November-May	79	3.87	+0.0394 × AVRAIN1	.86	6.03	.12	.0001	.17
					+0.0404 × LAGAV_R1		5.30		.0001	
					–0.0324 × LAG2PVAP		–5.06		.0001	
					+0.0808 × DW_E100		8.47		.0001	
					–0.1572 × LAGSTAGE		–5.79		.0001	
R24	Turkey Ford Lake	All year	115	15.31	+0.0962 × AVRAIN4	.68	7.29	.38	.0001	.38
					+0.0510 × LAGAV_R4		3.96		.0001	
					–0.0443 × LAGPVAP		–3.38		.0010	
					+0.0654 × DW_33A		3.56		.0005	
					–0.3370 × LAGSTAGE		–7.12		.0001	

[1]Definitions of abbreviations for explanatory variables are as follows:
AVRAIN1 = average of Cosme-Odessa well field and Eldridge-Wilde well field rainfall for month, in inches.
AVRAIN2 = average of Cosme-Odessa well field and Section 21 well field rainfall for month, in inches.
AVRAIN4 = average of Section 21 well field and South Pasco well field rainfall for month, in inches.
BERGERDW = monthly average water level in Berger deep well, in feet above sea level.
COSME_3 = monthly average water level in St. Petersburg Cosme deep well 3, in feet above sea level.
COSME_R = monthly rainfall at Cosme-Odessa well-field rain gage, in inches.
DW21_7 = monthly average water level in St. Petersburg deep 21-7, in feet above sea level.
DWN_4 = monthly average water level in Eldridge-Wilde deep well N-4, in feet above sea level.
DW_33A = monthly average water level in St. Petersburg deep well 33A, in feet above sea level.
DW_E100 = monthly average water level in St. Petersburg deep well E–100, in feet above sea level.
EW_RAIN = monthly total rainfall at Eldridge-Wilde well-field rain gage, in inches.
E_L14DW = monthly average water level in East Lake deep well 14, in feet above sea level.
E_WN2 = monthly average water level in Eldridge-Wilde well N2, in feet above sea level.
JAMEDW11 = monthly average water level in James deep well 11, in feet above sea level.
KEYSTONE = monthly average stage in Keystone Lake, in feet above sea level.
LAG21_R = previous month total rainfall at Section 21 well-field rain gage, in inches.
LAG2AVR1 = lag 2 average of Cosme-Odessa well field and Eldridge-Wilde well field rainfall for month, in inches.
LAG2AVR1 = lag 2 average of Cosme-Odessa well field and Section 21 well field rainfall for month, in inches.
LAG2AVR4 = lag 2 average of Section 21 well field and Eldridge-Wilde well field rainfall for month, in inches.
LAG2COSR = lag 2 month total rainfall at Cosme-Odessa well-field rain gage, in inches.
LAG2PVAP = second previous month potential evaporation, in inches.
LAG2SP_R = lag 2 month total rainfall at South Pasco well-field rain gage, in inches.
LAG2_21R = lag 2 month total rainfall at Section 21 well-field rain gage, in inches.
LAGAV_R1 = previous month average rainfall at Cosme-Odessa well-field and Eldridge-Wilde well-field rain gages, in inches.
LAGAV_R2 = previous month average rainfall at Cosme-Odessa well-field and Section 21 well-field rain gages, in inches.
LAGAV_R4 = previous month average rainfall at Section 21 well-field and South Pasco well-field rain gages, in inches.
LAGCOS_R = previous month total rainfall at Cosme-Odessa well-field rain gage, in inches.
LAGEW_R = previous month total rainfall at Eldridge-Wilde well-field rain gage, in inches.
LAGPVAP = previous month total potential evaporation, in inches.
LAGSP_R = previous month total rainfall at South Pasco well-field rain gage, in inches.
LAGSTAGE = previous month average lake stage, in feet above sea level.
LZ_LFDW = monthly average water level in Lutz-Lake Fern deep well, in feet above sea level.
POTEVAP = monthly potential evaporation, in inches.
SEC21_R = monthly rainfall at Section 21 well-field rain gage, in inches.
SH54DW = monthly average water level in State Highway 54 deep well, in feet above sea level.
SPASCO_R = monthly rainfall at South Pasco well-field rain gage, in inches.
SWAINSWL = monthly average water level in Swains well, in feet above sea level.

[2]SD was computed with estimated stage in Keystone Lake.

Table 8. Regression relations to determine change in monthly average lake stage due to climatic factors and well-field pumpage

[N is number of observations used to determine regression relation; R^2 is regression coefficient of determination; RMSE is the square root of the regression mean square error statistic, in feet; t is the t test that the parameter is zero; p>|t| is the probability that the t statistic would obtain a greater absolute value than that observed given that the true value of t is zero]

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|
R1	Lake Alice	All year	126	0.36	+0.0683 × AVRAIN1	0.83	12.04	0.20	0.0001
					+0.0811 × LAGAVR_1		15.21		.0001
					+0.0293 × LAG2AVR1		5.24		.0002
					–0.0178 × LAGPVAP		–1.72		.0875
					–0.0436 × LAG2PVAP		–4.40		.0001
					–0.0219 × COSME_Q		–2.27		.0251
R2	Lake Allen	June–October	48	14.10	+0.0496 × AVRAIN4	.52	2.30	.51	.0261
					+0.0514 × LAGAV_R4		2.56		.0140
					+0.0315 × LAG2AVR4		1.53		.1329
					–0.1076 × SPASCO_Q		–2.62		.0120
					–0.2210 × LAGSTAGE		–3.62		.0008
R2	Lake Allen	November–May	79	.41	+0.0989 × SEC21_R	.75	11.24	.21	.0001
					+0.0624 × LAG21_R		4.79		.0001
					–0.0368 × LAGPVAP		–3.62		.0005
					–0.0394 × LAG2PVAP		–3.34		.0013
R3	Browns Lake	All year	112	12.17	+0.0570 × SPASCO_R	.62	5.98	.30	.0001
					+0.0638 × LAGSP_R		6.87		.0001
					+0.0265 × LAG2SPR		2.58		.0111
					–0.0302 × LAGPVAP		–1.97		.0518
					–0.0262 × LAG2PVAP		–1.75		.0831
					–0.0670 × SPASCO_Q		–3.59		.0005
					+0.0478 × LAGSP_Q		–2.46		.0157
					–0.1889 × LAGSTAGE		–4.89		.0001
R4	Buck Lake	All Year	131	7.45	+0.0744 × COSME_R	.72	9.41	.29	.0001
					+0.0893 × LAGCOS_R		11.59		.0001
					–0.0531 × LAGPVAP		–4.11		.0001
					–0.0319 × LAG2PVAP		–2.50		.0136
					–0.2198 × LAGSTAGE		–5.93		.0001
R5	Lake Calm	June–October	58	– .030	+0.0591 × AVRAIN1	.81	8.19	.21	.0001
					+0.0812 × LAGAV_R1		11.48		.0001
					+0.0224 × LAG2AVR1		3.10		.0031
					–0.0250 × COSME_Q		–1.63		.1092
					–0.0418 × SEC21_Q		–2.22		.0310
R5	Lake Calm	November–May	81	.34	+0.0583 × AVRAIN1	.84	10.15	.11	.0001
					+0.0415 × LAGAV_R1		5.38		.0001
					+0.0135 × LAG2AVR1		2.41		.0187
					–0.0159 × LAGPVAP		–2.42		.0178
					–0.0316 × LAG2PVAP		–4.44		.0001
					–0.0197 × LAGCOS_Q		–2.68		.0091
					–0.0377 × SPASCO_Q		–4.44		.0001
					+0.0376 × LAGSP_Q		4.25		.0001
R6	Camp Lake	All year	107	1.85	+0.0869 × SPASCO_R	.66	8.86	.31	.0001
					+0.0780 × LAGSP_R		7.54		.0001
					+0.0268 × LAG2SP_R		2.68		.0087
					–0.0292 × LAGPVAP		–1.89		.0619
					–0.0359 × LAG2PVAP		–2.40		.0180
					–0.0194 × SPASCO_Q		–1.37		.1744
					–0.0246 × LAGSTAGE		–2.04		.0438
R7	Church Lake	June–October	58	1.36	+0.0511 × COSME_R	.80	5.08	.29	.0001
					+0.1209 × LAGCOS_R		12.68		.0001
					–0.0691 × LAGSTAGE		–2.23		.0296

Table 8. Regression relations to determine change in monthly average lake stage due to climatic factors and well-field pumpage–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|
R7	Church Lake	November–May	55	0.49	+0.0599 × COSME_R	0.82	7.01	0.14	0.0001
					+0.0482 × LAGCOS_R		4.70		.0001
					–0.0187 × LAGPVAP		–2.05		.0454
					–0.0418 × LAG2PVAP		–4.26		.0001
					–0.0282 × NW_HILLQ		–3.19		.0025
R8	Crescent Lake	June–October	45	34.47	+0.1233 × AVRAIN1	.67	3.54	.77	.0010
					+0.0804 × LAGAV_R1		2.73		.0093
					–0.3610 × LAGPVAP		–3.35		.0018
					–0.7072 × LAGSTAGE		–6.45		.0001
R8	Crescent Lake	November–May	71	.26	+0.0584 × AVRAIN1	.42	3.49	.31	.0008
					+0.0601 × LAGAV_R1		3.25		.0018
					–0.0631 × LAGPVAP		–4.74		.0001
R9	Lake Dan	All year	95	.69	+0.1049 × EW_RAIN	.62	5.47	.53	.0001
					+0.1449 × LAGEW_R		7.67		.0001
					–0.0685 × LAGPVAP		–3.47		.0008
					–0.0257 × EW_PUMP		–2.57		.0118
R10	Dosson Lake	All year	139	10.12	+0.1015 × SEC21_R	.59	7.92	.48	.0001
					+0.0831 × LAG21_R		6.22		.0001
					–0.0550 × LAGPVAP		–3.37		.0010
					–0.0387 × LAGCOS_Q		–1.58		.1161
					–0.1855 × LAGSTAGE		–5.01		.0001
R11	Glass Lake	June–October	33	4.21	+0.0867 × COSME_R	.70	3.18	.39	.0035
					+0.1073 × LAGCOS_R		4.74		.0001
					–0.1033 × POTEVAP		–2.42		.0221
					–0.1155 × LAGSTAGE		–2.27		.0311
R11	Glass Lake	November–May	46	3.17	+0.0619 × COSME_R	.63	3.96	.26	.0003
					+0.1332 × LAGCOS_R		6.31		.0001
					–0.0240 × COSME_Q		–1.21		.2346
					–0.1154 × LAGSTAGE		–2.46		.0183
R12	Lake Harvey	All year	112	6.84	+0.0701 × AVRAIN4	.47	6.55	.37	.0001
					+0.0399 × LAGAV_R4		3.68		.0004
					–0.0306 × SPASCO_Q		–1.97		.0513
					–0.1143 × LAGSTAGE		–3.30		.0013
R13	Island Ford Lake	June–October	55	14.72	+0.0476 × AVRAIN1	.70	2.64	.50	.0112
					+0.1306 × LAGAV_R1		7.53		.0001
					+0.0622 × LAG2AVR1		3.33		.0017
					–0.0796 × SPASCO_Q		–1.68		.0999
					+0.0546 × LAGSP_Q		1.26		.2121
					–0.3968 × LAGSTAGE		–5.16		.0001
R13	Island Ford Lake	November–May	78	1.00	+0.0513 × AVRAIN1	.56	4.52	.23	.0001
					–0.0642 × LAG2PVAP		–5.94		.0001
					–0.0315 × COSME_Q		–2.56		.0126
					–0.0473 × SPASCO_Q		–2.73		.0078
					+0.0317 × LAGSP_Q		1.73		.0871
R14	Lake Juanita	June–October	55	3.12	+0.0802 × AVRAIN1	.78	4.87	.43	.0001
					+0.1653 × LAGAV_R1		11.12		.0001
					+0.0237 × LAG2AVR1		1.58		.1204
					–0.1168 × LAGSTAGE		–2.22		.0307
R14	Lake Juanita	November–May	79	2.10	+0.0652 × AVRAIN1	.73	7.29	.18	.0001
					+0.0423 × LAGAV_R1		3.71		.0004
					+0.0148 × LAG2AVR1		1.60		.1145
					–0.0566 × LAG2PVAP		–6.02		.0001
					–0.0426 × COSME_Q		–4.46		.0001
					–0.0226 × SEC21_Q		–2.01		.0483
					–0.0321 × LAGSTAGE		–1.83		.0711

Table 8. Regression relations to determine change in monthly average lake stage due to climatic factors and well-field pumpage–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer				R^2	t	RMSE	p>|t|
		Applicable period	N	Intercept	Coefficient × explanatory variable[1]				
R15	Keystone Lake	June–October	58	12.04	+0.0469 × AVRAIN1	0.62	3.55	0.39	0.0001
					+0.0949 × LAGAV_R1		7.24		.0001
					+0.0402 × LAG2AVR1		2.79		.0073
					–0.3234 × LAGSTAGE		–4.78		.0001
R15	Keystone Lake	November–May	55	4.08	+0.0328 × AVRAIN1	.60	2.45	.23	.0178
					–0.0451 × LAGPVAP		–3.28		.0019
					–0.0399 × LAG2PVAP		–2.78		.0077
					–0.0327 × NW_HILLQ		–2.29		.0263
					–0.0743 × LAGSTAGE		–1.47		.1483
R16	Lake Linda	All year	114	7.66	+0.0754 × SPASCO_R	.63	8.04	.31	.0001
					+0.0562 × LAGSP_R		6.02		.0001
					+0.0188 × LAG2SP_R		1.81		.0725
					–0.0426 × LAG2PVAP		–4.07		.0001
					–0.0533 × SPASCO_Q		–2.83		.0056
					+0.0288 × LAGSP_Q		1.46		.1469
					–0.1131 × LAGSTAGE		–3.81		.0002
R17	Mound Lake	June–October	58	12.39	+0.0577 × AVRAIN1	.77	7.11	.23	.0001
					+0.0589 × LAGAV_R1		7.39		.0001
					–0.0187 × SPASCO_Q		–1.28		.2060
					–0.2586 × LAGSTAGE		–5.55		.0001
R17	Mound Lake	November–May	77	5.09	+0.0560 × AVRAIN1	.71	7.44	.15	.0001
					+0.0436 × LAGAV_R1		4.40		.0013
					–0.0226 × LAGPVAP		–2.62		.0108
					–0.0284 × LAG2PVAP		–3.20		.0021
					–0.0225 × COSME_Q		–2.37		.0206
					–0.0924 × LAGSTAGE		–2.28		.0258
R18	Parker (Ann) Lake	June–October	53	9.77	+0.0450 × AVRAIN1	.69	3.06	.38	.0036
					+0.1030 × LAGAV_R1		7.78		.0001
					+0.0202 × LAG2AVR1		1.43		.1589
					–0.0011 × COSME_Q		– .03		.9743
					–0.0008 × EW_PUMP		– .07		.9417
					–0.2274 × LAGSTAGE		–3.92		.0003
R18	Parker (Ann) Lake	November–May		4.03	+0.0556 × AVRAIN1	.81	7.40	.15	.0001
					+0.0522 × LAGAV_R1		5.42		.0001
					–0.0567 × LAG2PVAP		7.81		.0001
					–0.0309 × COSME_Q		–3.79		.0003
					–0.0482 × SPASCO_Q		4.32		.0001
					+0.0393 × LAGSP_Q		3.33		.0014
					–0.0702 × LAGSTAGE		–2.52		.0143
R19	Pretty Lake	All year	125	11.47	+0.0888 × AVRAIN2	.50	7.01	.44	.0001
					+0.0536 × LAGAV_R2		3.95		.0001
					+0.0203 × LAG2AVR2		1.63		.1064
					–0.0785 × LAGPVAP		–4.50		.0001
					–0.0243 × LAGCOS_Q		–1.06		.2909
					–0.2515 × LAGSTAGE		–5.36		.0001
R20	Rainbow Lake	All year	121	1.66	+0.0621 × COSME_R	.85	8.84	.23	.0001
					+0.1096 × LAGCOS_R		16.42		.0001
					+0.0271 × LAG2COSR		3.93		.0001
					–0.0727 × LAG2PVAP		–7.99		.0001
					–0.0320 × COSME_Q		2.95		.0038
					–0.0314 × LAGSTAGE		–1.86		.0657
R21	Lake Rogers	All year	42	2.61	+0.1088 × COSME_R	.83	9.13	.26	.0001
					+0.0386 × LAGCOS_R		2.92		.0059
					–0.0653 × POTEVAP		–4.52		.0001
					–0.0323 × LAG2PVAP		–1.96		.0571
					–0.0499 × LAGSTAGE		–1.75		.0883

Table 8. Regression relations to determine change in monthly average lake stage due to climatic factors and well-field pumpage–Continued

Reference number (table 4)	Lake name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|
R22	Starvation Lake	All year	97	4.77	+0.0875 × SEC21_R	0.64	5.61	0.47	0.0001
					+0.0978 × LAG21_R		6.20		.0001
					+0.0438 × LAG2_21R		2.85		.0054
					–0.0784 × LAGPVAP		–4.20		.0001
					–0.1022 × SPASCO_Q		–3.23		.0017
					+0.0791 × LAGSP_Q		2.47		.0155
					–0.0330 × LAGHILLQ		–1.34		.1830
					–0.0816 × LAGSTAGE		–3.23		.0017
R23	Lake Taylor	June–October	56	3.88	+0.0602 × AVRAIN1	.78	5.98	.27	.0001
					+0.0970 × LAGAV_R1		10.24		.0001
					+0.0159 × LAG2AVR1		1.63		.1094
					–0.0194 × COSME_Q		–1.07		.2912
					–0.1249 × LAGSTAGE		–3.10		.0031
R23	Lake Taylor	November–May	79	1.30	+0.0619 × AVRAIN1	.78	8.27	.16	.0001
					+0.0644 × LAGAV_R1		6.75		.0001
					–0.0247 × LAGPVAP		–2.78		.0069
					–0.0392 × LAG2PVAP		–4.30		.0001
					–0.0146 × COSME_Q		–1.54		.1285
					–0.0222 × LAGSTAGE		.88		.3837
R24	Turkey Ford Lake	June–October	48	13.85	+0.1254 × AVRAIN4	.66	6.01	.48	.0001
					+0.0525 × LAGAV_R4		2.41		.0201
					+0.0376 × LAG2AVR4		1.75		.0872
					–0.0207 × LAGEW_Q		–1.70		.0958
					–0.2798 × LAGSTAGE		–3.48		.0012
R24	Turkey Ford Lake	November–May	67	11.37	+0.1134 × AVRAIN4	.73	9.51	.27	.0001
					–0.0280 × LAGPVAP		–1.63		.1084
					–0.0744 × LAG2PVAP		–4.52		.0001
					–0.0378 × COSME_Q		–1.98		.0528
					–0.1982 × LAGSTAGE		–3.96		.0002

[1]Definitions of abbreviations for explanatory variables are as follows:
AVRAIN1 = average of Cosme–Odessa well–field and Eldridge–Wilde well–field rainfall for month, in inches;
AVRAIN2 = average of Cosme–Odessa well–field and Section 21 well–field rainfall for month, in inches;
AVRAIN4 = average of Section 21 well–field and South Pasco well–field rainfall for month, in inches;
COSME_Q = monthly average pumpage from Cosme–Odessa well field, in million gallons per day;
COSME_R = monthly rainfall at Cosme–Odessa well–field rain gage, in inches;
EW_PUMP = monthly average pumpage from Eldridge–Wilde well field, in million gallons per day;
EW_RAIN = monthly total rainfall at Eldridge–Wilde well–field rain gage, in inches;
LAG21_Q = previous month average pumpage from Section 21 well field, in million gallons per day;
LAG21_R = previous month total rainfall at Section 21 well–field rain gage, in inches;
LAG2AVR1 = lag 2 average of Cosme–Odessa well–field and Eldridge–Wilde well–field rainfall for month, in inches;
LAG2AVR2 = lag 2 average of Cosme–Odessa well–field and Section 21 well–field rainfall for month, in inches;
LAG2AVR4 = lag 2 average of Section 21 well–field and Eldridge–Wilde well–field rainfall for month, in inches;
LAG2COSR = lag 2 monthly total rainfall at Cosme–Odessa well–field rain gage, in inches;
LAG2PVAP = lag 2 month potential evaporation, in inches;
LAG2SP_R = lag 2 monthly total rainfall at South Pasco well–field rain gage, in inches;
LAG2_21R = lag 2 monthly total rainfall at Section 21 well–field rain gage, in inches;
LAGAV_R1 = previous month average rainfall of Cosme–Odessa well–field and Eldridge–Wilde well–field rain gages, in inches;
LAGAV_R2 = previous month average rainfall of Cosme–Odessa well–field and Section 21 well–field rain gages, in inches;
LAGAV_R4 = previous month average rainfall of Section 21 well–field and South Pasco well–field rain gages, in inches;
LAGCOS_Q = previous month average pumpage from Cosme–Odessa well field, in million gallons per day;
LAGCOS_R = previous month total rainfall at Cosme–Odessa well–field rain gage, in inches;
LAGEW_Q = previous month average pumpage from Eldridge–Wilde well field, in million gallons per day;
LAGEW_R = previous month total rainfall at Eldridge–Wilde well–field rain gage, in inches;
LAGPVAP = previous month total potential evaporation, in inches;
LAGSP_Q = previous month average pumpage from South Pasco well field, in million gallons per day;
LAGSP_R = previous month total rainfall at South Pasco well–field rain gage, in inches;
LAGSTAGE = previous month average lake state, in feet above sea level;
NW_HILLQ = monthly average pumpage from Northwest Hillsborough well field, in million gallons per day;
POTEVAP = monthly potential evaporation, in inches;
SEC21_Q = monthly average pumpage from Section 21 well field, in million gallons per day;
SEC21_R = monthly rainfall at Section 21 well–field rain gage, in inches;
SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day;
SPASCO_R = monthly rainfall at South Pasco well–field rain gage, in inches.

Table 9. Regression relations to determine change in monthly average water level in selected wells completed in the surficial aquifer due to climatic factors and water level in the Upper Floridan aquifer

[N is number of observations used to determine regression relation; R^2 is regression coefficient of determination; RMSE is the square root of the regression mean square error statistic, in feet; t is the t test that the parameter is zero; p>|t| is the probability that the t statistic would obtain a greater absolute value than that observed given that the true value of t is zero; SD is the standard deviation of the residuals, in feet, when the estimated water level in the Upper Floridan aquifer well computed with regression relation in table 6 is used in the regression relation to compute the change in water level in the surficial aquifer]

Reference number (table 4)	Well name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|	SD
7	St. Petersburg shallow well IC-6	All year	138	8.34	+0.1148 × COSME_R	0.78	9.38	0.43	0.0001	0.44
					+0.1092 × LAGCOS_R		8.76		.0001	
					–0.0659 × LAGPVAP		–4.50		.0001	
					+0.1006 × DW_E100		4.27		.0001	
					–0.2981 × LAGSW1C6		–8.38		.0001	
14	Van Dyke shallow well	All year	138	9.36	+0.0692 × SEC21_R	.65	3.74	.67	.0003	.75
					+0.0675 × LAG21_R		3.42		.0008	
					–0.0439 × LAG2PVAP		–2.24		.0267	
					+0.2902 × BERGERDW		7.68		.0001	
					–0.3996 × LAGVDYKE		–9.12		.0001	
30	St. Petersburg shallow well 105	June–October	44	17.52	+0.1160 × SPASCO_R	.84	5.38	.46	.0001	.54
					+0.0745 × LAGSP_R		3.39		.0016	
					+0.0495 × LAG2SP_R		2.43		.0198	
					+0.2345 × STPDW105		3.98		.0003	
					–0.5150 × LAGSW105		–7.28		.0001	
30	St. Petersburg shallow well 105	November–May	56	10.51	+0.1585 × SPASCO_R	.73	6.92	.47	.0001	.51
					+0.1329 × LAGSP_R		3.30		.0018	
					–0.0811 × LAGPVAP		–3.06		.0035	
					+0.0934 × STPDW105		2.72		.0090	
					–0.2549 × LAGSW105		–4.81		.0001	

[1]Definitions of abbreviations for explanatory variables are as follows: BERGERDW = monthly average water level in Berger deep well, in feet above sea level; COSME_R = monthly rainfall at Cosme-Odessa well-field rain gage, in inches; DW_E100 = monthly average water level in St. Petersburg deep well E-100, in feet above sea level; LAG21_R = previous month total rainfall at Section 21 well-field rain gage, in inches; LAG2PVAP = lag 2 month potential evaporation, in inches; LAG2SP_R = lag 2 month total rainfall at South Pasco well-field rain gage, in inches; LAGCOS_R = previous month total rainfall at Cosme-Odessa well-field rain gage, in inches; LAGPVAP = previous month total potential evaporation, in inches; LAGSP_R = previous month total rainfall at South Pasco well-field rain gage, in inches; LAGSW105 = previous month average water level in St. Petersburg shallow well 105, in feet above sea level; LAGSW1C6 = previous month average water level in St. Petersburg shallow well 1C-6, in feet above sea level; LAGVDYKE = previous month average water level in Van Dyke shallow well, in feet above sea level; SEC21_R = monthly rainfall in Section 21 well-field rain gage, in inches; SPASCO_R = monthly rainfall at South Pasco well-field rain gage, in inches; STPDW105 = monthly average water level in St. Petersburg deep well 105, in feet above sea level.

Change in Water Levels in the Upper Floridan Aquifer

The estimated average water level in James deep well 11 for the next month can be found by adding the regression estimate of change in monthly average water level (eq. 2) that was computed using assumed rainfall and pumpage to the observed previous month's average. For sequential estimates of more than 1 month, the estimated change is added to the estimate of previous month's water level. Examples of these two estimates are shown for James deep well 11 for the 1985 water year. To evaluate the regression equations as predictive tools, the change in water level was computed using observed rainfall, pumpage, and potential evaporation data, and then, the estimated water levels were compared to observed water levels.

The 1-month-at-a-time estimated water level for James deep well 11 is computed by adding the estimated change in monthly average as computed by equation 2 to the observed previous month's level. For example, in table 11, the 1-month-at-a-time estimate for James deep well 11, PREDW11, in October 1984 is computed by adding RCHNDW11 to the previous month's average well water level in September, JAMEDW11 (I-1).

$$\text{October PREDW11} = 31.16 - 2.11 = 29.05.$$

Likewise, the predicted water level in June is computed by adding RCHNDW11 to the observed previous month's average water level in May.

$$\text{June PREDW11} = 25.06 + 2.78 = 27.84.$$

Table 10. Regression relations to determine change in monthly average water level in selected wells completed in the surficial aquifer due to climatic factors and well-field pumpage

[N is number of observations used to determine regression relation; R^2 is regression coefficient of determination; RMSE is the square root of the regression mean square error statistic, in feet; t is the t test that the parameter is zero; p>|t| is the probability that the t statistic would obtain a greater absolute value than that observed given that the true value of t is zero]

Reference number (table 4)	Well name	Regression relation including water level in the Upper Floridan aquifer: Applicable period	N	Intercept	Coefficient × explanatory variable[1]	R^2	t	RMSE	p>|t|
7	St. Petersburg shallow well IC-6	June-October	58	9.44	+0.1217 × COSME_R	0.79	7.26	0.50	0.0001
					+0.1522 × LAGCOS_R		9.01		.0001
					+0.0277 × LAG2COSR		1.52		.1341
					–0.3062 × LAGSW1C6		–5.65		.0001
7	St. Petersburg shallow well IC-6	November-May	79	5.33	+0.1710 × COSME_R	.70	9.70	.38	.0001
					+0.0550 × LAGCOS_R		2.27		.0261
					–0.1135 × LAG2PVAP		–6.42		.0001
					–0.1292 × LAGSW1C6		–3.44		.0009
14	Van Dyke shallow well	June-October	58	11.75	+0.0776 × SEC21_R	.48	2.35	.97	.0224
					+0.1439 × LAG21_R		4.54		.0001
					–0.0686 × SPASCO_Q		–1.12		.2672
					–0.2202 × LAGVDYKE		–3.64		.0006
14	Van Dyke shallow well	November-May	55	9.18	+0.1968 × SEC21_R	.63	6.22	.60	.0001
					–0.1427 × LAG2PVAP		–4.35		.0001
					–0.0888 × NW_HILLQ		–2.33		.0239
					–0.1401 × LAGVDYKE		–2.91		.0054
30	St. Petersburg shallow well 105	All year	114	16.49	+0.1737 × SPASCO_R	.71	10.89	.54	.0001
					+0.1221 × LAGSP_R		7.23		.0001
					+0.0460 × LAG2SP_R		2.36		.0203
					–0.0789 × LAGPVAP		–2.90		.0045
					–0.0564 × LAG2PVAP		–2.12		.0367
					–0.0430 × SPASCO_Q		–1.87		.0642
					–0.2718 × LAGSW105		–6.97		.0001

[1]Definitions of abbreviations for explanatory variables are as follows: COSME_R = monthly rainfall at Cosme-Odessa well-field rain gage, in inches; LAG21_R = previous month total rainfall at Section 21 well-field rain gage, in inches; LAG2COSR = lag 2 month total rainfall at Cosme-Odessa well-field rain gage, in inches; LAG2PVAP = lag 2 month potential evaporation, in inches; LAG2SP_R = lag 2 month total rainfall at South Pasco well-field rain gage, in inches; LAGCOS_R = previous month total rainfall at Cosme-Odessa well-field rain gage, in inches; LAGPVAP = previous month total potential evaporation, in inches; LAGSP_R = previous month total rainfall at South Pasco well-field rain gage, in inches; LAGSW105 = previous month average water level in St. Petersburg shallow well 105, in feet above sea level; LAGSW1C6 = previous month average water level in St. Petersburg shallow well 1C-6, in feet above sea level; LAGVDYKE = previous month average water level in Van Dyke shallow well, in feet above sea level; NW_HILLQ = monthly average pumpage from Northwest Hillsborough well field, in million gallons per day; SEC21_R = monthly rainfall at Section 21 well-field rain gage, in inches; SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day; SPASCO_R = monthly rainfall at South Pasco well-field rain gage, in inches.

The sequential estimates of monthly change in well water level, ECHNDWll, are computed using the estimated water level the previous month instead of the observed water level. The sequential estimate of change in water level, ECHNDW11, is computed by substituting the sequential estimate of water level for the previous month, ESTLAG11, for the variable LAGDW11 in the regression relation in table 6.

$$\begin{aligned} ECHNDW11 = {} & 11.78 + 0.2033 \times COSME\_R \\ & + 0.2148 \times LAGCOS\_R - 0.1107 \times LAGPVAP \\ & - 0.1054 \times LAG2PVAP - 0.5730 \times COSME\_Q \\ & + 0.4081 \times LAGCOS\_Q - 0.2093 \times SPASCO\_Q \\ & + 0.1669 \times LAGSP\_Q - 0.2428 \times SEC21\_Q \\ & + 0.1952 \times LAG21\_Q - 0.2420 \times NW\_HILLQ \\ & + 0.2465 \times LAGHILLQ - 0.2517 \times ESTLAG11 \end{aligned} \quad (3)$$

where

COSME_R is monthly rainfall at Cosme-Odessa well-field rain gage, in inches;
LAGCOS_R is previous month rainfall at Cosme-Odessa well-field rain gage, in inches;
LAGPVAP is previous month's potential evaporation, in inches;
LAG2PVAP is lag 2 month potential evaporation, in inches;
COSME_Q is monthly average pumpage from Cosme-Odessa well field, in million gallons per day;
LAGCOS_Q is previous month's average pumpage from Cosme-Odessa well field, in million gallons per day;
SPASCO_Q is monthly average pumpage from South Pasco well field, in million gallons per day;
LAGSP_Q is previous month's average pumpage from South Pasco well field, in million gallons per day;

Table 11. Estimates of water levels in James deep well 11, October 1984 through September 1985

JAMEDW11 is the observed monthly average water level in James deep well 11, in feet above sea level;

RCHNDW11 is the estimate of change in monthly average water level in James deep well 11 computed by regression relation in table 6, in feet;

PREDW11 is the estimate of monthly average water level in James deep well 11 computed by adding RCHNDW11 to the previous month observed average water level, JAMEDW11(I-1), in feet above sea level;

ECHNDW11 is the estimate of change in monthly average water level in James deep well 11 computed by regression relation in table 6 using previous month sequential estimate of water level, ESTDW11(I-1), in feet;

ESTDW11 is the sequential estimate of monthly average water level in James deep well 11 computed by adding ECHNDW11 to ESTDW11(I-1), the previous month sequential estimate of average water level (eq. 3), in feet above sea level.

Year	Month	JAMEDW11	RCHNDW11	PREDW11	ECHNDW11	ESTDW11
1984	September	31.16				
	October	30.33	-2.11	29.05	-2.11	29.05
	November	29.74	-.92	29.41	-.60	28.45
	December	28.77	-1.34	28.40	-1.01	27.44
1985	January	28.80	1.26	30.03	1.60	29.04
	February	28.84	.46	29.26	.40	29.44
	March	26.88	-2.61	26.23	-2.76	26.68
	April	27.10	.30	27.18	.35	27.03
	May	25.06	-2.12	24.98	-2.10	24.93
	June	27.26	2.78	27.84	2.81	27.74
	July	29.67	2.44	29.70	2.32	30.06
	August	31.60	2.43	32.10	2.33	32.39
	September	32.96	.88	32.48	.68	33.07
	Mean	28.92		28.88		28.78
	Minimum	25.06		24.98		24.93
	Maximum	32.96		32.48		33.07

SEC21_Q is monthly average pumpage from Section 21 well field, in million gallons per day;
LAG21_Q is previous month's average pumpage from Section 21 well field, in million gallons per day;
NW_HILLQ is monthly average pumpage from Northwest Hillsborough well field, in million gallons per day;
LAGHILLQ is previous month's average pumpage from Northwest Hillsborough well field, in million gallons per day; and
ESTLAG11 is the sequential estimate of water level in James deep well 11 the previous month, ESTDW11(I-1), in feet above sea level.

The first estimate of next month's average water level is computed by adding the change in water level computed with the observed water level the previous month. After the first month, the previous month's estimated well level, ESTDW11 (I-1), is used. For example, in table 11, the sequential estimate in October is computed exactly as the 1-month-at-a-time estimate.

$$\text{October ESTDW11} = 31.16 - 2.11 = 29.05.$$

For each following month, the computed sequential change in monthly average well water level is modified because the previous month's water level is one of the explanatory variables in equation 3. ESTDW11 for June 1985 is computed by adding ECHNDW11 to the estimated water level the previous month, ESTDW11(I-1).

$$\text{June ESTDW11} = 24.93 + 2.81 = 27.74.$$

The mean, minimum, and maximum of observed monthly average water level, JAMEDW11, and estimates of monthly average water level, PREDW11 and ESTDW11, are listed in table 11. Both the 1-month-at-a-time and sequential estimates of change in water level result in means and minimums within 0.14 ft of the observed. The observed minimum in May was 0.08 ft higher than PREDW11 and 0.13 ft higher than ESTDW11.

Plots of the observed and estimated monthly average water levels in James deep well 11 for the 1985 water year are shown in figure 20. Both the 1-month-at-a-time and sequential estimates of water levels in James deep well 11 were within 1 ft of the observed water level after January. The seasonal decline in water level was interrupted in January and February when Section 21 well-field pumpage was reduced from 7.3 Mgal/d in December to 3.7 Mgal/d in January and 0 in February.

The 1-month and sequential 1985 water-year estimates of water levels in Berger deep well are computed in a similar manner. Both estimates of water levels in Berger deep well followed the rise in the observed levels in January and February (fig. 21). Water levels declined from February through May. The minimum observed water level in May was 0.31 ft higher than the 1-month estimate of water level and 0.27 ft lower than the sequential estimate of water level.

Change in Lake Stage

The estimated change in monthly average stage in a lake is computed by adding the regression relation estimate of change to the previous month's average stage. Either of the two sets of regression relations in table 7 or 8 can be used, but to use the regression relation that includes the water level in an Upper Floridan aquifer well, an estimate of the water level in the well is required. For sequential estimates of more than 1 month, the estimated change is added to the stage that was computed for the previous month. Examples for these two estimates, computed by the two sets of regression relations, are shown for Lake Alice in table 12.

When the regression relation that includes the water level in an Upper Floridan aquifer well (table 7) is used to compute the change in stage for Lake Alice, the estimate of the water level in James deep well 11, PREDW11, must be computed first (eq. 2). Then, the estimated change in lake stage, RCHSTGW, is computed by substituting PREDW11 for JAMESDW11 in the regression relation in table 7.

$$\begin{aligned} RCHSTGW = {} & 0.42 + 0.0567 \times AVRAIN1 + 0.0641 \times LAGAV\_R1 \\ & + 0.0114 \times LAG2AVR1 - 0.0158 \times LAGPVAP \\ & - 0.0299 \times LAG2PVAP + 0.0359 \times PREDW11 \\ & - 0.0377 \times LAGSTAGE \end{aligned} \tag{4}$$

where

AVRAIN1 is average of Cosme-Odessa well-field and Eldridge-Wilde well-field rain gages for month, in inches;

LAGAV_R1 is previous month's average rainfall at Cosme-Odessa well-field and Eldridge-Wilde well-field rain gages, in inches;

LAG2AVR1 is lag 2 month average rainfall at Cosme-Odessa well-field and Eldridge-Wilde well-field rain gages, in inches;

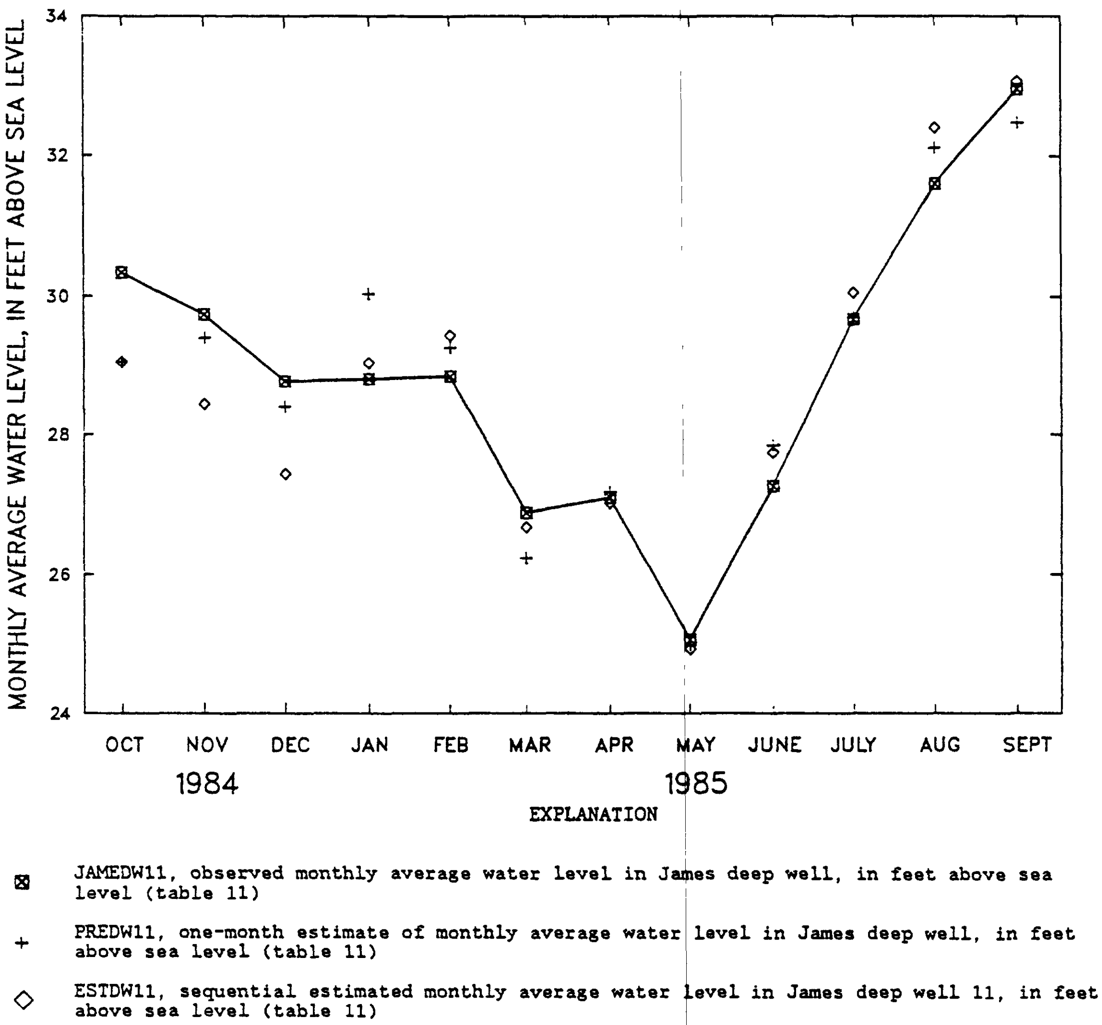


Figure 20. Observed and estimates of monthly average water level in James deep well 11, October 1984 through September 1985.

LAGPVAP is previous month's potential evaporation, in inches;
LAG2PVAP is lag 2 month potential evaporation, in inches;
PREDW11 is the estimate of monthly average water level in James Deep well 11, in feet above sea level;
LAGSTAGE is previous month's average lake stage, in feet above sea level.

The estimate of Lake Alice stage when using the regression relation that includes the water level in an Upper Floridan aquifer well, RSTAGEW, is computed by adding RCHSTGW to the previous month's stage.

$$RSTAGEW = LKALICE\ (I\text{-}1) + RCHSTGW \quad (5)$$

For example, the estimate of Lake Alice stage in May 1985 (table 12) is computed in two steps. First, the estimated water level for James Deep well 11, PREDW11, is computed using equation 2 (24.98 ft in table 11). Then, the value of PREDW11 is used in equation 4 to compute RCHSTGW for May. Equation 5 is used to compute the estimated stage, RSTAGEW.

$$\text{May } RSTAGEW = 37.68 - 0.76 = 36.92.$$

The estimate for Lake Alice stage when using the regression relation that includes well-field pumpage, RSTAGEP, is computed by adding the change computed by the regression relation that includes well-field pumpage (table 8), RCHSTGP, to the previous month's stage.

$$RSTAGEP = LKALICE\ (I\text{-}1) + RCHSTGP. \quad (6)$$

For example, the estimate of Lake Alice stage in May 1985 (table 12) as computed by equation 6 is

$$\text{May } RSTAGEP = 37.68 - 0.76 = 36.92.$$

The sequential estimates of monthly change in stage are computed using the previous month's estimated stage instead of the observed stage. Where the regression relation that includes the water level in an Upper Floridan aquifer well is used to compute the change in stage, the sequential estimate of the water level in that well is used.

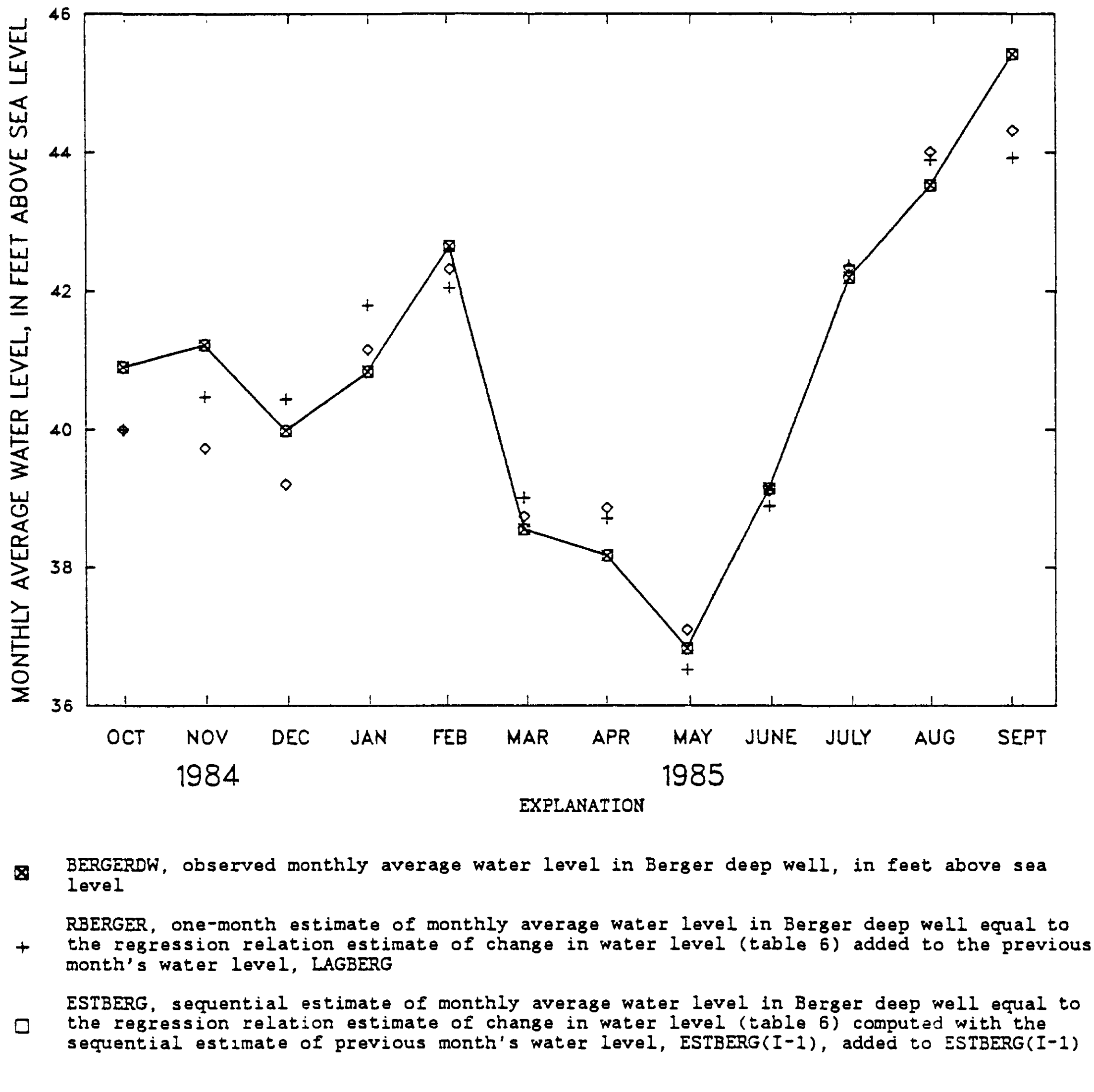


Figure 21. Observed and estimates of monthly average water level in Berger deep well, October 1984 through September 1985.

Table 12. Estimated Lake Alice stage, October 1984 through September 1985

LKALICE is the monthly average stage of Lake Alice, in feet above sea level.

RCHSTGW is the change in monthly average stage of Lake Alice computed by regression relation (table 7) using estimate of water level in James deep well 11 (PREDW11), in feet.

RSTAGEW is the estimate of monthly average stage of Lake Alice computed by adding RCHSTGW to the previous month's average stage, LKALICE(I-1), in feet above sea level.

RCHSTGP is the change in monthly average stage of Lake Alice computed by regression relation (table 8) using well-field pumpage, in feet.

RSTAGEP is the estimate of monthly average stage in Lake Alice computed by adding RCHSTGP to the previous month's average stage, LKALICE(I-1), in feet above sea level.

ECHSTGW is the sequential estimate of change in monthly average stage of Lake Alice (table 7) computed by using estimated water level in James deep well 11, ESTDW11, and previous month estimate of lake stage, ESTSTGW(I-1), in feet.

ESTSTGW is the sequential estimate of stage in Lake Alice computed by adding ECHSTGW to the previous month's estimated stage, ESTSTGW(I-1), in feet above sea level.

ECHSTGP is the sequential estimate of change in monthly average stage of Lake Alice computed by regression relation using well-field pumpage (table 8), in feet.

ESTSTGP is the sequential estimate of stage in Lake Alice computed by adding ECHSTGP to the previous month's estimate of stage, ESTSTGP(I-1), in feet above sea level.

Year	Month	LKALICE	RCHSTGW	RSTAGEW	RCHSTGP	RSTAGEP	ECHSTGW	ESTSTGW	ECHSTGP	ESTSTGP
1984	September	40.69								
	October	40.28	-0.50	40.19	-0.44	40.25	-0.50	40.19	-0.44	40.25
	November	39.73	- .63	39.65	- .63	39.65	- .66	39.53	- .63	39.62
	December	39.21	- .63	39.10	- .68	39.05	- .65	38.88	- .68	38.94
1985	January	38.80	- .38	38.83	- .44	38.77	- .40	38.48	- .44	38.50
	February	38.52	- .26	38.54	- .30	38.50	- .24	38.24	- .30	38.20
	March	38.16	- .36	38.16	- .30	38.22	- .33	37.91	- .30	37.90
	April	37.68	- .45	37.71	- .43	37.73	- .44	37.47	- .43	37.47
	May	37.00	- .76	36.92	- .76	36.92	- .75	36.72	- .76	36.71
	June	36.57	- .28	36.72	- .31	36.69	- .27	36.45	- .31	36.40
	July	36.56	.25	36.82	.19	36.76	.27	36.72	.19	36.59
	August	37.12	.88	37.44	.98	37.54	.88	37.60	.98	37.57
	September	38.39	.97	38.09	1.09	38.21	.97	38.57	1.09	38.66
	Mean	38.17		38.18		38.19		38.06		38.07
	Minimum	36.56		36.72		36.69		36.45		36.40
	Maximum	40.28		40.19		40.25		40.19		40.25

The sequential estimate of Lake Alice stage in table 12 is used as an example of the computations. The sequential estimate of change in stage, ECHSTGW, is computed by substituting in the regression relation in table 7, the sequential estimate of water level in James Deep well 11, ESTDW11, and the estimated stage in Lake Alice the previous month, ESTSTGW (I-1).

$$\begin{aligned} ECHSTGW = {} & 0.42 + 0.0567 \times AVRAIN1 + 0.0641 \times LAGAV\_R1 \\ & + 0.0114 \times LAG2AVR1 - 0.0158 \times LAGPVAP \\ & - 0.0299 \times LAG2PVAP + 0.0359 \times ESTDW11 \\ & - 0.0377 \times ESTSTGW(I\text{-}1). \end{aligned} \quad (7)$$

The sequential estimate of stage is computed by adding ECHSTGW to the previous month's sequential estimate of stage, ESTSTGW(I-1).

$$ESTSTGW = ESTSTGW(I\text{-}1) + ECHSTGW. \quad (8)$$

For example, the sequential estimate of stage in Lake Alice for May 1985 is computed using equation 8.

$$\text{May } ESTSTGW = 37.47 - 0.75 = 36.72.$$

ESTSTGP, the sequential estimate of stage computed with the regression relation that includes well-field pumpage for change in stage, ECHSTGP, is computed in a similar manner.

$$ESTSTGP = ESTSTGP(I\text{-}1) + ECHSTGP. \quad (9)$$

For example, the sequential estimate for stage of Lake Alice in May 1985 is computed by equation 9 as

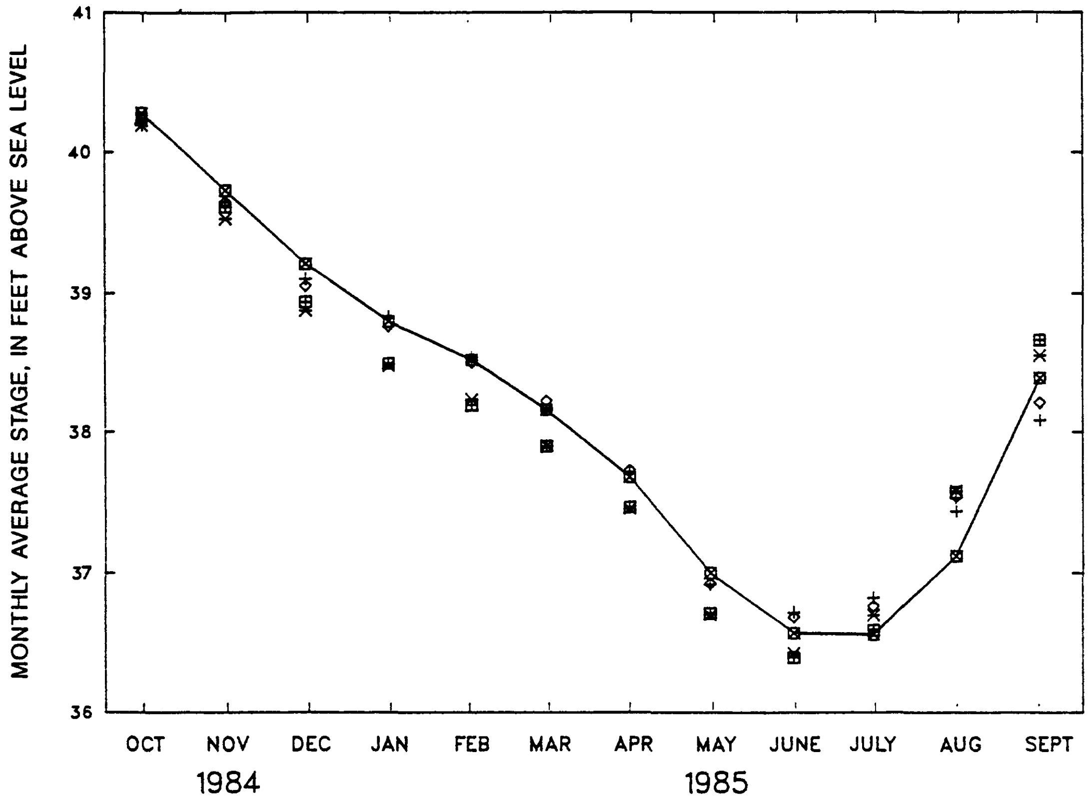
$$\text{May } ESTSTGP = 37.47 - 0.76 = 36.71.$$

Because the regression relation that includes pumpage for change in stage of Lake Alice does not include estimated stage the previous month, ECHSTGP is the same as RCHSTGP. The sequential estimates of stage are different because, whereas RSTAGEP is computed by adding RCHSTGP to the observed previous month's stage, LKALICE(I-1), ESTSTGP is computed by adding ECHSTGP to the sequential estimate of stage the previous month, ESTSTGP(I-1).

The mean, minimum, and maximum observed and estimated stages are listed under each respective column in table 12. The sequential estimates, ESTSTGW, computed by using the regression relation that includes sequential estimates of water levels in James Deep well 11, ESTDW11, simulated the mean stage and the minimum stage within 0.11 ft of the observed stage.

The observed and estimated 1985 water-year stages for Lake Alice are shown in figure 22. All estimates followed the decline in lake stage from October through June within 0.33 ft. All estimates produced a rise in stage of 0.19 to 0.27 ft in July, but the observed stage declined 0.01 ft. As the summer rains increased, all estimated stages continued higher than those observed in August. The maximum difference between the sequential estimate and observed stage was 0.45 ft in August. In September, the 1-month-at-a-time estimates were slightly lower than the observed, and the sequential estimates were less than three-tenths of a foot higher than the observed.

Similarly, 1-month-at-a-time and sequential estimates for monthly average stage of Starvation Lake were computed for the 1985 water year using the regression relations for change in stage in tables 7 and 8. The observed and estimated stages for October 1984 through September 1985 are shown in figure 23. All estimates of monthly average stage followed the decline through May within 0.35 ft. The 1-month estimates computed by using the regression relation that includes estimates of the water level in Berger deep well and the relation that includes well-field pumpage were 0.20 and 0.29 ft higher, respectively, than the minimum stage in June. The two sequential estimates were 0.51 ft higher and 0.10 ft



EXPLANATION

⊠ LKALICE, observed monthly average stage in Lake Alice, in feet above sea level(table 12)

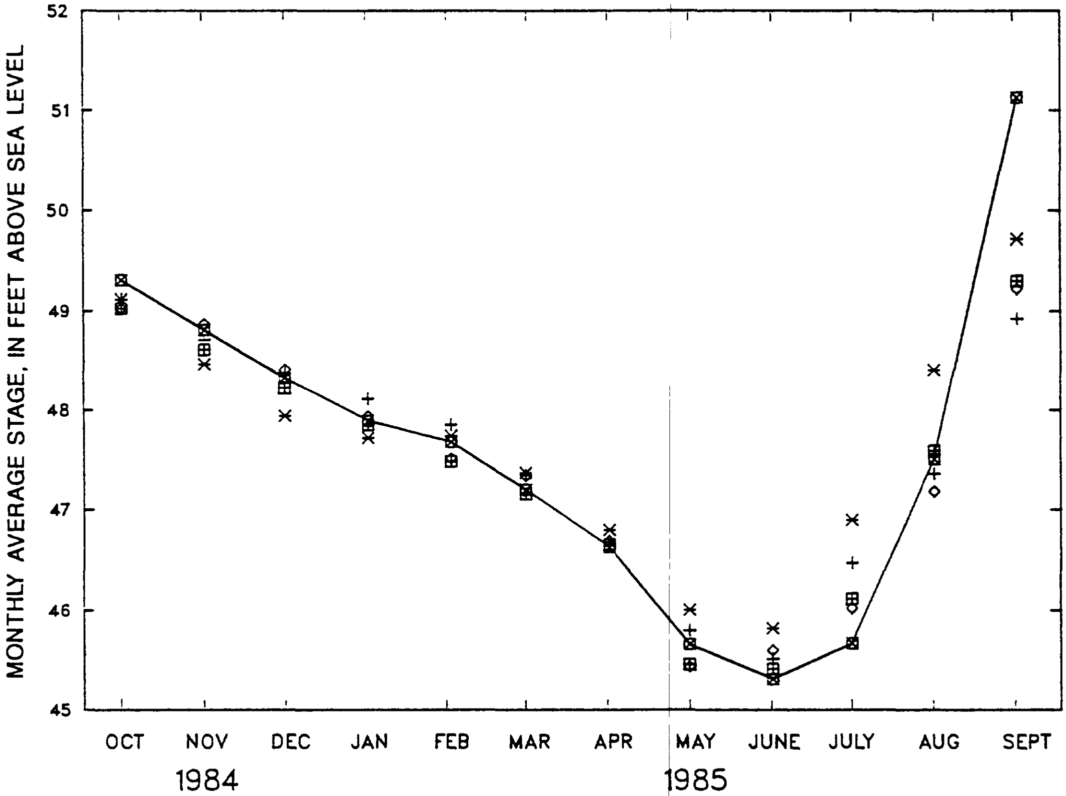
\+ RSTAGEW, estimated monthly average stage in Lake Alice equal to the regression relation estimate of change in stage (table 7) computed with estimated water level in James deep well (PREDW11) added to the previous month's stage, LKALICE(I-1) (table 12)

× ESTSTGW, sequential estimate of monthly average stage equal to the regression estimate of change in stage (table 7) computed with estimated water level in James deep well 11, PREDW11, and sequential estimate of previous month's stage, ESTSTGW(I-1), added to ECHSTGW (table 12)

◇ RSTAGEP, estimate of monthly average stage equal to the regression estimate of change in stage (table 8) computed with well-field pumpage added to the previous month's stage, LKALICE(I-1) (table 12)

⊞ ESTSTGP, sequential estimate of monthly average stage equal to the regression estimate of change in stage (table 8) computed with well-field pumpage added to the sequential estimate of previous month's stage, ESTSTGP(I-1) (table 12)

Figure 22. Observed and estimates of monthly average stage in Lake Alice, October 1984 through September 1985.



EXPLANATION

⊠ STARVLK, observed monthly average stage in Starvation Lake, in feet above sea level

\+ RSTARVW, estimate of monthly average stage in Starvation Lake equal to the regression relation estimate of change in stage using estimated water level in Berger deep well (table 7) added to previous month's stage, STARVLK(I-1)

◇ RSTARVP, estimate of monthly average stage in Starvation Lake equal to the regression relation estimate of change in stage using well-field pumpage (table 8) added to previous month's stage, STARVLK(I-1)

* ESTARVW, sequential estimate of monthly average stage in Starvation Lake equal to the regression relation estimate of change in stage using sequential estimate of water level in Berger deep well, ESTBERG (table 7), added to sequential estimate of previous month's stage, ESTARVW(I-1)

⊞ ESTARVP, sequential estimate of monthly average stage in Starvation Lake equal to the regression relation estimate of change in stage using well-field pumpage (table 8) added to sequential estimate of previous month's stage, ESTARVP(I-1)

Figure 23. Observed and estimates of monthly average stage in Starvation Lake, October 1984 through September 1985.

higher than the observed stage in June. As the rains increased, all estimates diverged from 0.35 (RSTARVP) to 1.23 ft (ESTARVW) above the observed in July to from 1.41 (ESTARVW) to 2.21 ft (RSTARVW) below the observed in September.

Change in Water Levels in the Surficial Aquifer

The estimated monthly average water level in a surficial aquifer well is computed by adding the regression relation estimate of change in water level (tables 9 or 10) to the previous month's average water level. For sequential estimates of more than 1 month, the estimated change in water level is added to the previous month's sequential estimate of water level. Example for 1-month and sequential estimates of water levels in surficial aquifer wells are shown for Van Dyke shallow well in table 13.

When the regression relation that includes the water level in the Upper Floridan aquifer (table 9) is used to estimate the change in water level in Van Dyke shallow well, the estimate of the change in water level in Berger deep well, RCHBERG, is computed first. The estimate of monthly average water level in Berger deep well, RBERGER, is computed by adding RCHBERG to the previous month's average water level, BERGEDW(I-1).

Table 13. Estimated Van Dyke shallow well water level, October 1984 through September 1985

VDYKESW is monthly average water level in Van Dyke shallow well, in feet above sea level.

RCHVDYKW is the estimate of change in monthly average water level in Van Dyke shallow well computed by regression relation including water level in Upper Floridan aquifer (table 9) using the estimated water level in Berger deep well, RBERGER (fig. 21) instead of BERGERDW, in feet.

RVDYKEW is the estimate of monthly average water level in Van Dyke shallow well computed by adding RCHVDYKW to the previous month's average water level, VDYKESW(I-1), in feet above sea level.

RCHVDYKP is the estimate of change in monthly average water level in Van Dyke shallow well computed by regression relation including well-field pumpage (table 10), in feet.

RVDYKEP is the estimate of monthly average water level in Van Dyke shallow well computed by adding RCHVDYKP to the previous month's average water level, VDYKESW(I-1), in feet above sea level.

ECHVDYKW is the sequential estimate of change in monthly average water level in Van Dyke shallow well computed by regression relation including water level in Upper Floridan aquifer (table 9) using sequential estimate of water level in Berger deep well, ESTBERG, (fig. 21) and sequential estimate of previous month's average water level, ESTVDYKW(I-1) instead of BERGERDW and LAGVDYKE, in feet.

ESTVDYKW is the sequential estimate of monthly average water level in Van Dyke shallow well computed by adding ECHVDYKW to the sequential estimate of the previous month's average water level, ESTVDYKW(I-1), in feet above sea level.

ECHVDYKP is the sequential estimate of change in monthly average water level in Van Dyke shallow well computed by regression relation including well-field pumpage (table 10) using sequential estimate of previous month's average water level, ESTVDYKP(I-1), in feet above sea level.

ESTVDYKP is sequential estimate of monthly average water level in Van Dyke shallow well computed by adding ECHVDYKP to the sequential estimate of the previous month's average water level, ESTVDYKP(I-1), in feet above sea level.

Year	Month	VDYKESW	RCHVDYKW	RVDYKEW	RCHVDYKP	RVDYKEP	ECHVDYKW	ESTVDYKW	ECHVDYKP	ESTVDYKP
1984	September	53.00								
	October	52.33	-0.77	52.23	-0.36	52.64	-0.78	52.22	-0.36	52.64
	November	52.01	- .34	51.99	-1.01	51.32	- .51	51.71	-1.05	51.59
	December	51.55	- .20	51.81	-1.02	50.99	- .44	51.27	- .97	50.62
1985	January	51.15	.51	52.06	- .07	51.48	.43	51.70	.06	50.68
	February	50.93	.90	52.05	.15	51.30	.75	52.45	.21	50.89
	March	50.77	.10	51.03	- .04	50.89	- .59	51.86	- .04	50.85
	April	50.41	.02	50.79	- .18	50.59	- .37	51.49	- .19	50.66
	May	49.80	- .81	49.60	-1.56	48.85	-1.08	50.41	-1.59	49.07
	June	49.96	.62	50.42	.65	50.45	.43	50.84	.81	49.88
	July	50.60	2.16	52.12	2.03	51.99	1.80	52.64	2.05	51.93
	August	52.06	2.51	53.11	2.23	52.83	1.72	54.36	1.94	53.87
	September	56.17	1.79	53.85	2.11	54.17	.98	55.34	1.71	55.58
	Mean	51.48		51.75		51.46		52.20		51.52
	Minimum	49.80		49.60		48.85		50.41		49.07
	Maximum	56.17		53.85		54.17		55.34		55.58

$$RBERGER = BERGERDW(I\text{-}1) + RCHBERG. \quad (10)$$

Then, the estimated change in water level in Van Dyke shallow well, RCHVDYKW, is computed by substituting RBERGER for BERGERDW in the regression relation in table 9.

$$RCHVDYKW = 9.36 + 0.0692 \times SEC21\_R + 0.0675 \times LAG21\_R - 0.0439 \times LAG2PVAP + 0.2902 \times RBERGER - 0.3996 \times LAGVDYKE. \quad (11)$$

The estimate of monthly average water level in Van Dyke shallow well, RVDYKEW, is computed by adding RCHVDYKW to the previous month's average water level

$$RVDYKEW = VDYKESW(I\text{-}1) + RCHVDYKW. \quad (12)$$

For example, the estimate of average water level in May 1985 in table 13 was computed by equation 12.

$$\text{May } RVDYKEW = 50.41 - 0.81 = 49.60.$$

The estimate of monthly average water level using the regression relation that includes well-field pumpage, RVDYKEP, is computed by adding the change estimated by the regression relation that includes well-field pumpage in table 10, RCHVDYKP, to the previous month's water level.

$$RVDYKEP = VDYKESW(I\text{-}1) + RCHVDYKP. \quad (13)$$

For example, the estimate of change in average water level in May 1985 is computed by the regression relation in table 10.

$$RCHVDYKP = 9.18 + 0.1968 \times SEC21\_R - 0.1427 \times LAG2PVAP - 0.0888 \times NW\_HILLQ - 0.1401 \times LAGVDYKE. \quad (14)$$

Then, equation 13 is used to estimate the water level in May.

$$\text{May } RVDYKEP = 50.41 - 1.56 = 48.85.$$

The sequential estimates of change in monthly average water level are computed using the previous month's sequential estimate of water level instead of the observed water level. When the regression relation estimate of change in water level that includes water level in the Upper Floridan aquifer is used, the sequential estimate of the water level in the Upper Floridan aquifer is used. The sequential estimate of Van Dyke shallow well in table 13 is used as an example of the computations. The sequential estimate of change in water level, ECHVDYKW, is computed by substituting the sequential estimate of water level in Berger deep well, ESTBERG, and the sequential estimate of water level the previous month, ESTVDYKW(I-1), in the regression relation in table 9.

$$\begin{aligned} ECHVDYKW = {} & 9.36 + 0.0692 \times SEC21\_R + 0.0675 \times LAG21\_R \\ & - 0.0439 \times LAGPVAP + 0.2902 \times ESTBERG \\ & - 0.3996 \times ESTVDYKW(I\text{-}1). \end{aligned} \quad (15)$$

The sequential estimate of monthly average water level, ESTVDYKW, is equal to ECHVDYKW added to the sequential estimate of average water level the previous month, ESTVDYKW(I-1)

$$ESTVDYKW = ESTVDYKW(I\text{-}1) + ECHVDYKEW. \quad (16)$$

For example, the sequential estimate of average water level in Van Dyke shallow well for May 1985 is computed using equation 16.

$$\text{May } ESTVDYKW = 51.49 - 1.08 = 50.41.$$

The sequential estimate of water level, ESTVDYKP, estimated with the regression relation that includes well-field pumpage, ECHVDYKP, is computed by adding ECHVDYKP to the sequential estimate of water level the previous month, ESTVDYKP(I-1).

$$ESTVDYKP = ESTVDYKP(I\text{-}1) + ECHVDYKP. \quad (17)$$

For example, the sequential estimate of change in monthly average water level in May 1985 is computed by using the regression relation that includes well-field pumpage in table 10, substituting ESTVDYKP(I-1) for LAGVDYKE.

$$\begin{aligned} ECHVDYKP = {} & 9.18 + 0.1968 \times SEC\ 21\_R - 0.1427 \times LAG2PVAP \\ & - 0.0888 \times NW\_HILLQ - 0.1401 \\ & \times ESTVDYKP(I\text{-}1) = -1.59. \end{aligned} \quad (18)$$

Then, equation 17 is used to estimate the average water level for May 1985.

$$\text{May } ESTVDYKP = 50.66 - 1.59 = 49.07.$$

The mean, minimum, and maximum observed and estimated water levels are listed at the bottom of each column in table 13. The observed and estimated monthly average water levels in Van Dyke shallow well from October 1984 through September 1985 are shown in figure 24. The 1-month and sequential estimates of water level that were computed by using the water level in Berger deep well, RVDYKEW and ESTVDYKW, rose in January and February because of the rise in Berger deep well water levels (fig. 21) in response to the reduction in Section 21 well-field pumpage. But, the water level in Van Dyke shallow well continued to decline through January and February, reaching the minimum in May. RVDYKEW, the 1-month-at-a-time estimate of water level using the regression relation that includes the water level in Berger deep well was 0.20 ft lower than the observed May water level, and RVDYKEP was 0.95 ft lower than the observed. ESTVDYKW remained higher than the observed after January and was 0.61 ft higher in May. ESTVDYKP estimated the observed water level for February through April within +0.25 ft, but was 0.73 ft lower than the water level observed in May. Van Dyke shallow well is about 1 mi east of the center of the Section 21 well field and about 0.75 mi north of Berger deep well.

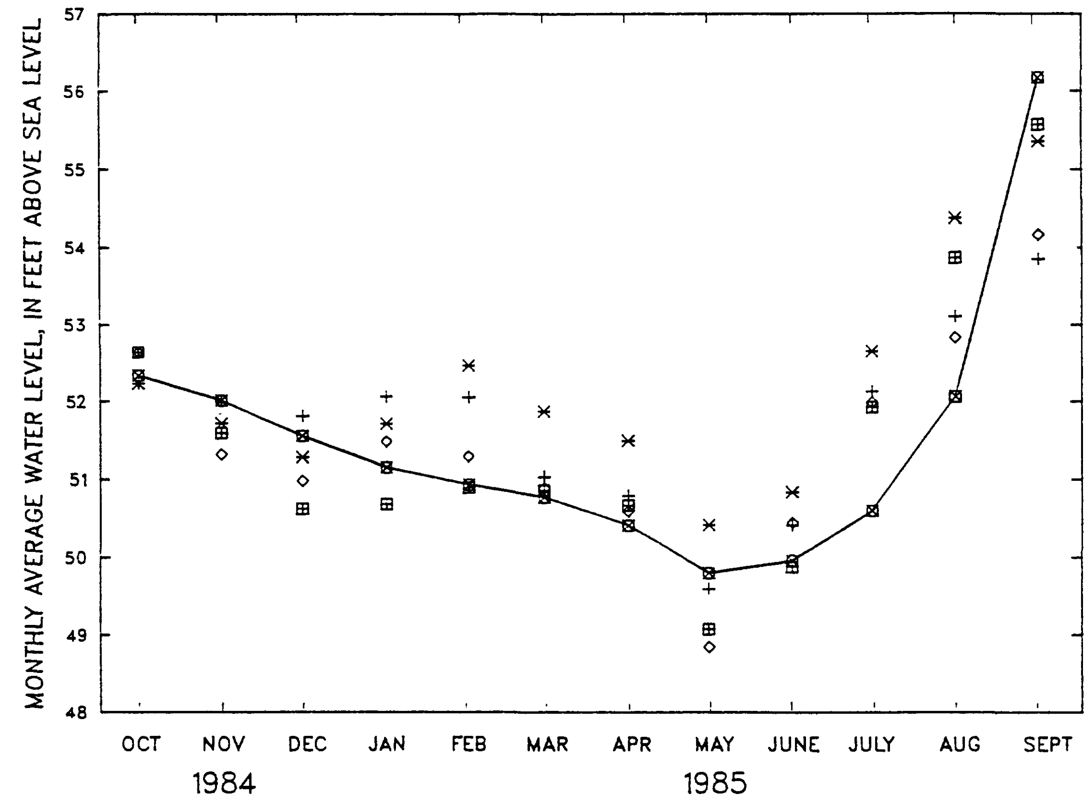
The proximity of the surficial aquifer well to the Upper Floridan aquifer well used in the regression relation to compute change in water level is a significant factor in the accuracy of estimates of water level. To illustrate the difference in accuracy of estimating change in a surficial aquifer well, a comparison is made with a surficial aquifer well near an Upper Floridan aquifer well.

Estimates of water levels in an Upper Floridan aquifer well, St. Petersburg deep well 105, and an adjacent surficial aquifer well, St. Petersburg shallow well 105, are listed in table 14. The observed and estimated monthly average water levels in St. Petersburg deep well 105 and St. Petersburg shallow well 105 from October 1984 through September 1985 are shown in figure 25. The estimates of change in water levels that were computed by the regression relation in table 6 were used to compute the 1-month and sequential estimates of water level in St. Petersburg deep well 105. Both estimates are within 0.07 ft of the minimum water level observed in May. The regression relation of change in water level in surficial aquifer wells (tables 9 and 10) was used to estimate the water levels in St. Petersburg shallow well 105. The 1-month and sequential estimates that use estimates of water levels in St. Petersburg deep well 105 were 0.02 and 0.48 ft higher, respectively, than the observed minimum in May. The 1-month and sequential estimates that use well-field pumpage were 0.21 and 1.14 ft higher, respectively, than the observed minimum in May.

APPLICATION OF REGRESSION RELATIONS FOR ESTIMATING CHANGES IN WATER LEVELS AND LAKE STAGE IN RESPONSE TO CHANGES IN RAINFALL OR PUMPAGE

Limitations of Regression Relations

The multiple linear-regression relations that were developed during this study are the "best-fit" models to represent the generally complex natural processes that determine changes in water levels in aquifers and lake stages. The regression constants and explanatory variable coefficients are determined by the input data. Application of these equations, based on input data that extend beyond the range of the explanatory variables, may lead to erroneous results. The reader is cautioned that the variable by variable range may not adequately define the range of application of the model because of the multidimensional space encompassed by the multivariate relations.



EXPLANATION

⊠ VDYKESW, monthly average water level in Van Dyke shallow well, in feet above sea level

\+ RVDYKEW, estimate of monthly average water level in Van Dyke shallow well equal to the regression relation estimate of change in water level (table 9) added to previous month's water level, VDYKESW(I-1) (table 13)

◇ RVDYKEP, estimate of monthly average water level in Van Dyke shallow well equal to the regression relation estimate of change in water level including well-field pumpage (table 10) added to previous month's water level, VDYKESW(I-1)

* ESTVDYKW, sequential estimate of monthly average water level in Van Dyke shallow well equal to the regression relation estimate of change in water level including water level in Upper Floridan aquifer (table 9) using ESTBERG (fig. 21) and ESTVDYKW(I-1) in place of BERGERDW and LAGVDYKE, respectively, added to the sequential estimate of water level the previous month, ESTVDYKW(I-1) (table 13)

⊞ ESTVDYKP, sequential estimate of monthly average water level in Van Dyke shallow well equal to the regression relation estimate of change in water level, including well-field pumpage (table 10), using the sequential estimate of the previous month's water level, ESTVDYKP(I-1), in place of LAGVDYKE added to the sequential estimate of water level the previous month, ESTVDYKP(I-1) (table 13)

Figure 24. Observed and estimates of monthly average water level in Van Dyke shallow well, October 1984 through September 1985.

The range in values of the explanatory variables in regression relations for estimating change in water levels in wells completed in the Upper Floridan aquifer (table 6) is listed in table 15. The explanatory variables include monthly rainfall, potential evaporation, well-field pumpage, and water level the previous month. The range in rainfall is applicable to rainfall for the month and previous months. Similarly, the range in well-field pumpage applies to the current and previous month. The range in potential evaporation is not listed because it is the same for all relations.

The range in values of explanatory variables in regression relations for estimating change in lake stage (tables 7 and 8) is listed in table 16. The explanatory variables include monthly rainfall, potential evaporation, water level in an Upper Floridan aquifer well, well-field pumpage, and lake stage the previous month. The range in potential evaporation is not listed because it is the same for all relations.

The range in explanatory variables in regression relations for change in water level in a surficial aquifer well (tables 9 and 10) is listed in table 17. The explanatory variables

Table 14. Estimated St. Petersburg deep well 105 and St. Petersburg shallow well 105 water levels, October 1984 through September 1985

STPDW105 is monthly average water level in St. Petersburg deep well 105, in feet above sea level.

RDW105 is estimate of monthly average water level in St. Petersburg deep well 105 equal to the regression relation estimate of change in water level (table 6) added to previous month's water level, STPDW105(I-1).

ESTDW105 is sequential estimate of monthly average water level in St. Petersburg deep well 105 equal to the change computed by regression relation (table 6) using sequential estimate of previous month's water level

ESTDW105(I-1) instead of LAGDW105 added to the sequential estimate of previous month's water level.

STPSW105 is monthly average water level in St. Petersburg shallow well 105, in feet above sea level.

RSW105W is estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including water level in Upper Floridan aquifer (table 9) using estimated water level, RDW105, instead of STPDW105 added to the previous month's water level, STPSW105(I-1).

RSW105P is estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including well-field pumpage (table 10) added to previous month's water level, STPSW105(I-1).

ESW105W is sequential estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including water level in Upper Floridan aquifer (table 9) using ESTDW105 and ESW105(I-1) instead of STPDW105 and LAGSW105, respectively, added to the sequential estimate of water level the previous month, ESW105W(I-1).

ESW105P is sequential estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including well-field pumpage (table 10) using the sequential estimate of the previous month's water level, ESW105P(I-1), instead of LAGSW105 added to sequential estimate of water level the previous month, ESW105P (I-1).

Year	Month	STPDW105	RDW105	ESTDW105	STPSW105	RSW105W	RSW105P	ESW105W	ESW105P
1984	October	41.02	40.14	40.14	54.60	54.65	55.09	54.65	55.09
	November	41.49	41.75	41.12	53.70	54.15	54.04	54.13	54.39
	December	42.01	41.76	41.50	53.22	53.65	53.59	53.95	54.09
1985	January	41.61	41.71	41.34	53.00	53.48	53.64	53.99	54.28
	February	40.76	40.42	40.22	53.06	53.24	53.45	53.96	54.38
	March	38.61	39.67	39.28	52.80	53.19	53.48	53.82	54.44
	April	39.99	39.48	39.97	52.63	52.45	52.72	53.26	53.92
	May	35.90	35.85	35.83	51.73	51.75	51.94	52.21	52.87
	June	38.59	39.29	39.24	52.29	52.68	52.36	52.90	53.19
	July	41.48	40.49	40.96	53.69	53.71	53.48	54.11	54.14
	August	43.30	44.52	44.14	56.15	56.75	56.48	56.87	56.81
	September	47.79	47.94	48.55	57.66	58.02	57.52	58.51	58.00
	Mean	41.05	41.09	41.03	53.71	53.98	53.98	54.36	54.63
	Minimum	35.90	35.85	35.83	51.73	51.75	51.93	52.21	52.87
	Maximum	47.79	47.94	48.55	57.66	58.02	57.52	58.51	58.00

include monthly rainfall, potential evaporation, water level in an Upper Floridan aquifer well, well-field pumpage, and water level the previous month.

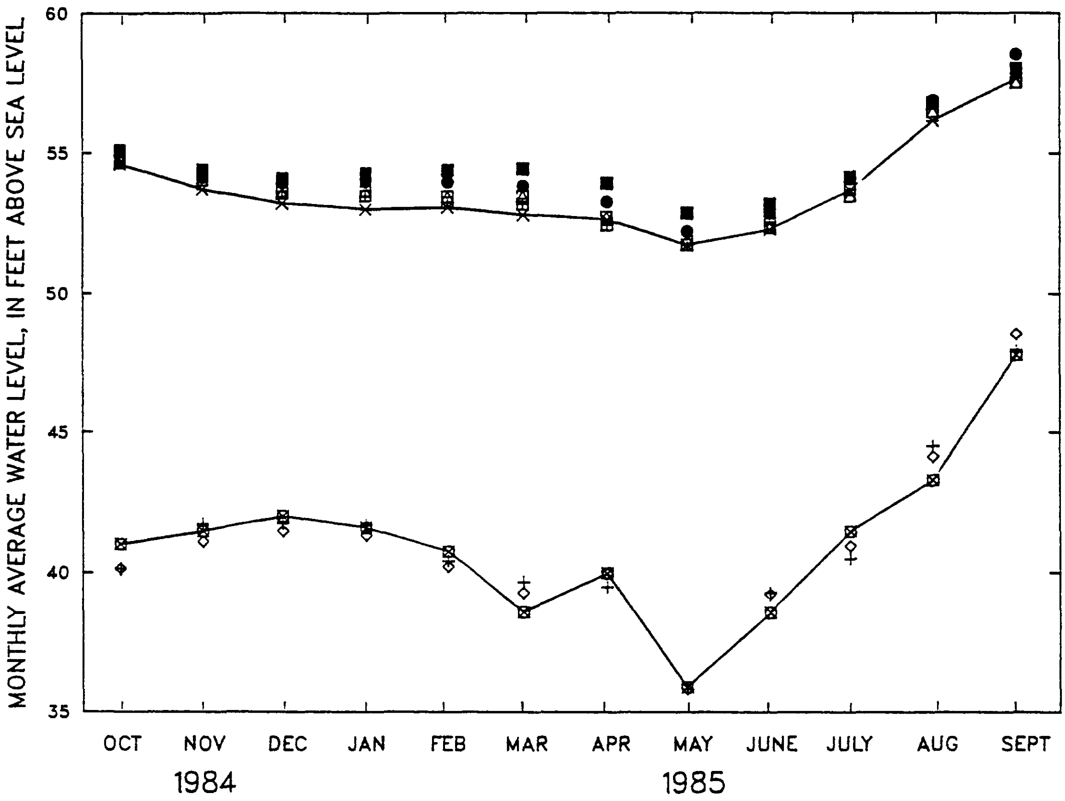
The relative influence of the explanatory variables on the computation of the dependent variable in a regression relation can be inferred from the absolute magnitude of the t statistic in tables 6 through 10. To determine the magnitude of the change in the dependent variable due to a change in one of the explanatory variables, a sensitivity analysis can be made. The usual procedure is to vary the value of one of the explanatory variables while holding the others constant and computing the corresponding change in the dependent variable.

Because the effects of changing rainfall or pumpage on water levels in the aquifer and stages in lakes is cumulative, a different procedure was used. To determine the effect of changing rainfall, actual well-field pumpage was used with varying percentages of average rainfall in the regression relations for change in water level in wells and change in lake stage to estimate the sequential changes. These sequential changes were then used to estimate the water level in the aquifer and the stage in the lakes from October 1984 through September 1985.

To evaluate the effect of changing well-field pumpage, actual rainfall was used with varying percentages of average monthly well-field pumpage in the regression relations for change in water levels in wells and lake stages to estimate the sequential changes. These sequential changes were used to estimate the water levels in the aquifer and the stages in selected lakes from October 1984 through September 1985. The October 1984 through September 1985 monthly rainfall and the average monthly rainfall are listed in table 18. The monthly pumpage and average pumpage for the same period are listed in table 19.

Effect of Changing Rainfall on Water Levels in the Upper Floridan Aquifer

An illustration of the effect of changing rainfall on water levels in the Upper Floridan aquifer is obtained by varying the monthly rainfall that is used in computing the changes in water levels, keeping all other explanatory variables unchanged. The 1985 water year, October 1984 through September 1985, was used as an example.



EXPLANATION

⊠ STPDW105, monthly average water level in St. Petersburg deep well 105, in feet above sea level (table 14)

\+ RDW105, estimate of monthly average water level in St. Petersburg deep well 105 equal to the regression relation estimate of change in water level (table 6) added to previous month's water level, STPDW105(I-1) (table 14)

◇ ESTDW105, sequential estimate of monthly average water level in St. Petersburg deep well 105 equal to the regression relation estimate of change in water level (table 6) using the sequential estimate of the previous month's water level, ESTDW105(I-1) instead of LAGDW105 added to the sequential estimate of the previous month's water level (table 14)

✱ STPSW105, monthly average water level in St. Petersburg shallow well 105, in feet above sea level (table 14)

⊞ RSW105W, estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including water level in Upper Floridan aquifer (table 9) using RDW105 instead of STPDW105 added to previous month's water level, LAGSW105 (table 14)

⧅ RSW105P, estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including well-field pumpage (table 10) added to previous month's water level, LAGSW105 (table 14)

● ESW105W, sequential estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including water level in Upper Floridan aquifer (table 9) using ESTDW10-5 and ESW105W(I-1) in place of STPDW105 and LAGSW105, respectively, added to the sequential estimate of water level the previous month, ESW105W(I-1) (table 14)

■ ESW105P, sequential estimate of monthly average water level in St. Petersburg shallow well 105 equal to the regression relation estimate of change in water level including well-field pumpage (table 10) using the sequential estimate of the previous month's water level, ESW105P(I-1), in place of LAGSW105 added to the sequential estimate of water level the previous month, ESW105P(I-1) (table 14)

Figure 25. Observed and estimates of monthly average water level in St. Petersburg deep well 105 and St. Petersburg shallow well 105, October 1984 through September 1985.

Table 15. Range of values for variables used in regression analysis to determine change in monthly average water level in selected wells completed in the Upper Floridan aquifer

Map number (fig. 4)	Well name	Explanatory variable[1]	Mean	Minimum	Maximum
1	Romp TR13-3 deep well	LAGTR13	15.87	13.97	17.73
		COSME_R	4.92	.00	16.60
		COSME_Q	9.0	4.3	13.5
		NW_HILLQ	5.1	1.0	14.2
2	East Lake deep well 17	LAGE_L17	16.88	12.87	19.00
		AVRAIN1	4.45	.00	16.44
		EW_PUMP	28.6	14.8	41.3
		NW_HILLQ	5.1	1.0	14.2
		EASTLK_Q	1.3	.0	5.0
3	Brooker Creek deep well	LAGBRKCR	7.08	5.68	8.43
		AVRAIN1	4.56	.00	22.60
		EASTLK_Q	1.3	.00	5.0
		NW_HILLQ	5.1	1.0	14.2
		EW_PUMP	29.5	14.8	41.3
4	St. Petersburg deep well E102	LAGE_102	21.33	17.16	24.67
		COSME_R	4.95	.00	16.60
		COSME_Q	8.4	4.3	12.6
		NW_HILLQ	4.0	1.0	8.2
5	East Lake deep well 14	LAGE_L14	18.05	13.17	20.89
		AVRAIN1	4.69	.00	16.44
		EASTLK_Q	1.3	.0	5.0
		EW_PUMP	28.6	14.8	41.3
		NW_HILLQ	4.0	1.0	8.2
6	St. Petersburg deep well E100	LAGE_100	25.85	19.40	30.74
		COSME_R	4.92	.00	16.60
		COSME_Q	9.0	4.3	13.5
		EW_PUMP	28.6	14.8	41.3
		NW-HILLQ	4.0	1.0	8.2
8	St. Petersburg Cosme well 3	LAGCOS_3	26.12	20.00	31.79
		COSME_R	4.78	.00	23.97
		COSME_Q	9.2	4.3	14.2
		NW_HILLQ	5.1	1.0	14.2
		EW_PUMP	29.5	14.8	41.3
9	Berger deep well	LAGBERG	42.94	36.83	48.73
		SEC21_R	4.30	.00	19.94
		EW_PUMP	29.2	14.8	41.3
		NW_HILLQ	4.0	1.0	8.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	13.3	9.3	20.9
10	Hillsborough deep well 13	LAGDW13	37.48	31.64	43.68
		SEC21_R	4.30	.00	19.94
		COSME_Q	9.2	4.3	14.2
		NW_HILLQ	4.0	1.0	8.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	12.9	6.9	20.9
11	James deep well 11	LAGDW11	31.64	25.06	38.01
		COSME_R	4.95	.00	16.60
		COSME_Q	8.4	4.3	12.6
		NW_HILLQ	5.1	1.0	14.2
		SEC21_Q	8.8	.0	11.4
12	St. Petersburg deep well 21-7	LAG21_7	40.90	34.54	47.54
		SEC21_R	4.26	.00	19.94
		COSME_Q	9.2	4.3	14.2
		NW_HILLQ	5.1	1.0	14.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	13.3	9.3	20.9
13	St. Petersburg deep well 26A	LAGDW26A	37.22	31.74	44.10
		SEC21_R	4.26	.00	19.94
		COSME_Q	9.2	4.3	14.2
		NW_HILLQ	4.0	1.0	8.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	13.3	9.3	20.9
17	St. Petersburg deep well 33A	LAG_33A	31.24	23.74	37.90
		AVRAIN1	4.76	.00	22.60
		COSME_Q	9.2	4.3	14.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	13.3	6.9	20.9
18	Eldridge-Wilde deep well 2	LAGE_W2	10.69	4.55	18.02
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.4	14.8	41.3
		SEC21_Q	18.8	.0	11.4
		SPASCO_Q	13.3	6.9	20.9
19	Tarpon Road deep well	LAGTARRD	10.51	8.72	12.00
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.5	14.8	41.3
		EASTLK_Q	1.3	.0	5.0
20	Eldridge-Wilde monitor well 5	LAGMON5	8.53	.46	17.94
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.4	14.8	41.3
		SPASCO_Q	13.3	6.9	20.9
21	Lutz-Lake Fern deep well	LAGLZ_LF	41.92	35.19	46.85
		AVRAIN4	5.86	.02	18.38
		EW_PUMP	29.4	14.8	41.3
		NW_HILLQ	5.1	1.0	14.2
		SEC21_Q	8.8	.0	11.4
		SPASCO_Q	13.2	6.9	20.9
22	Eldridge-Wilde deep well N-4	LAGDWN_4	25.67	19.89	30.42
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.5	14.8	41.3
23	Eldridge-Wilde well 113A	LAG113A	12.61	2.76	18.80
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.5	14.8	41.3
24	Eldridge-Wilde deep well 139G	LAG139G	22.25	16.10	27.26
		EW_RAIN	4.37	.00	18.82
		COSME_Q	9.2	4.3	14.2
		EASTLK_Q	1.3	.0	5.0
		EW_PUMP	29.4	14.8	41.3
25	Eldridge-Wilde deep well N2	LAGE_WN2	15.21	7.40	21.43
		EW_RAIN	4.34	.00	21.22
		COSME_Q	9.2	4.3	14.2
		EW_PUMP	29.5	14.8	41.3
26	Eldridge-Wilde deep well N3	LAGDWN3	15.79	9.79	20.21
		EW_RAIN	4.47	.00	18.82
		COSME_Q	9.0	4.3	13.5
		EW_PUMP	28.6	14.8	41.3
		SPASCO_Q	13.3	6.9	20.9

Table 15. Range of values for variables used in regression analysis to determine change in monthly average water level in selected wells completed in the Upper Floridan aquifer–Continued

Map number (fig. 4)	Well name	Explanatory variable[1]	Mean	Mini-mum	Maxi-mum	Map number (fig. 4)	Well name	Explanatory variable[1]	Mean	Mini-mum	Maxi-mum
27	Eldridge-Wilde Mitchell well	LAGMITCH	16.74	8.54	23.31	34	Doyles Ranch deep well	LAGDOYLE	44.83	39.90	48.97
		EW_RAIN	4.34	.00	21.22			SPASCO_R	4.02	.00	16.82
		COSME_Q	9.2	4.3	14.2			COSME_Q	8.8	4.3	14.2
		EW_PUMP	29.4	14.8	41.3			SPASCO_Q	13.4	9.3	19.4
28	St. Petersburg well 42	LAGDW42	44.18	36.06	49.94	35	Swains well	LAGSWAIN	37.39	30.90	41.29
		SPASCO_R	4.12	.00	16.82			EW_RAIN	4.37	.00	21.22
		COSME_Q	9.0	4.3	13.5			COSME_Q	9.2	4.3	14.2
		SPASCO_Q	12.6	6.9	19.4			EW_PUMP	29.4	14.8	41.3
								SPASCO_Q	13.2	6.9	20.9
29	St. Petersburg deep well 105	LAGDW105	42.69	35.76	48.50						
		SPASCO_R	4.15	.00	16.82	36	State Highway 54 deep well	LAG54DW	47.06	39.77	52.56
		COSME_Q	8.8	4.3	14.2			SPASCO_R	4.12	.00	16.82
		SPASCO_Q	12.6	6.9	19.4			COSME_Q	9.0	4.3	13.5
								SPASCO_Q	12.6	6.9	19.4
31	St. Petersburg well 45	LAGDW45	48.65	41.84	53.43						
		SPASCO_R	4.15	.00	16.82						
		COSME_Q	8.8	4.3	14.2						
		SPASCO_Q	12.6	6.9	19.4						

[1]Definitions of abbreviations for explanatory variables are as follows:
AVRAIN1 = average of Cosme-Odessa well field and Eldridge-Wilde well field rainfall for month, in inches;
AVRAIN4 = average of Section 21 well field and South Pasco well field rainfall for month, in inches;
COSME_Q = monthly average pumpage from Cosme-Odessa well field, in million gallons per day;
COSME_R = monthly rainfall at Cosme-Odessa well field rain gage, in inches;
EASTLK_Q = monthly average pumpage from East Lake well field, in million gallons per day;
EW_PUMP = monthly average pumpage from Eldridge-Wilde well field, in million gallons per day;
EW_RAIN = monthly total rainfall at Eldridge-Wilde well field rain gage, in inches;
LAG113A = previous month average water level in Eldridge-Wilde well 113A, in feet above sea level;
LAG139G = previous month average water level in Eldridge-Wilde well 139G, in feet above sea level;
LAG21_7 = previous month average water level in St. Petersburg deep well 21-7, in feet above sea level;
LAG54DW = previous month average water level in State Road 54 deep well, in feet above sea level;
LAGBERG = previous month average water level in Berger deep well, in feet above sea level;
LAGBRKCR = previous month average water level in Brooker Creek deep well, in feet above sea level;
LAGCOS_3 = previous month average water level in Cosme well 3, in feet above sea level;
LAGCOS_Q = previous month average pumpage from Cosme-Odessa well field, in million gallons per day;
LAGDOYLE = previous month water level in Doyles Ranch deep well, in feet above sea level;
LAGDW105 = previous month water level in St. Petersburg deep well 105, in feet above sea level;
LAGDW11 = previous month average water level in James deep well 11, in feet above sea level;
LAGDW13 = previous month average water level in Hillsborough deep well 13, in feet above sea level;
LAGDW26A = previous month average water level in St. Petersburg deep well 26A, in feet above sea level;
LAGDW42 = previous month average water level in St. Petersburg deep well 42, in feet above sea level;
LAGDW45 = previous month water level in St. Petersburg deep well 45, in feet above sea level;
LAGDWN3 = previous month water level in Eldridge-Wilde deep well N3, in feet above sea level;
LAGDWN_4 = previous month water level in Eldridge-Wilde deep well N-4, in feet above sea level;
LAGE_100 = previous month average water level in St. Petersburg deep well E-100, in feet above sea level;
LAGE_102 = previous month average water level in St. Petersburg deep well E-102, in feet above sea level;
LAGE_L14 = previous month average water level in East Lake deep well 14, in feet above sea level;
LAGE_L17 = previous month average water level in East Lake deep well 17, in feet above sea level;
LAGE_W2 = previous month average water level in Eldridge-Wilde well 2, in feet above sea level;
LAGE_WN2 = previous month average water level in Eldridge-Wilde well N2, in feet above sea level;
LAGLZ_LF = previous month average water level in Lutz-Lake Fern well, in feet above sea level;
LAGMITCH = previous month average water level in Mitchell well, in feet above sea level;
LAGMON5 = previous month average water level in Eldridge-Wilde monitor well 5, in feet above sea level;
LAGSWAIN = previous month average water level in Swains well, in feet above sea level;
LAGTARRD = previous month average water level in Tarpon Road well, in feet above sea level;
LAGTR13 = previous month average water level in ROMP well TR13-3, in feet above sea level;
LAG_33A = previous month average water level in St. Petersburg deep well 33A, in feet above sea level;
NW_HILLQ = monthly average pumpage from Northwest Hillsborough well field, in million gallons per day;
SEC21_Q = monthly average pumpage from Section 21 well field, in million gallons per day;
SEC21_R = monthly rainfall at Section 21 well field rain gage, in inches;
SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day;
SPASCO_R = monthly rainfall at South Pasco well-field rain gage, in inches.

Table 16. Range of values for variables in regression analysis to determine change in monthly average stage in selected lakes

Reference No. (table 4)	Lake name	Regression relation including water level in Upper Floridan aquifer (table 7): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum	Regression relation including well-field pumpage (table 8): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum
R1	Lake Alice	All year	LAGSTAGE	38.49	36.56	40.84	All year	—	38.58	36.04	41.13
			AVRAIN1	4.63	0.00	16.44		AVRAIN1	4.56	.00	22.60
			JAMEDW11	31.89	25.06	38.01		COSME_Q	9.2	4.3	14.2
R2	Lake Allen	June-	LAGSTAGE	60.76	58.00	62.67	June-	LAGSTAGE	60.50	57.95	62.67
		October	SH54DW	47.48	41.54	52.56	October	AVRAIN4	5.86	.02	18.38
			LZ_LFDW	42.71	37.15	46.85		SPASCO_Q	12.7	6.9	17.0
R2	Lake Allen	November-	LAGSTAGE	60.32	57.95	61.97	November-	—	60.32	57.95	61.97
		May	SEC21_R	2.81	0.00	15.17	May	SEC21_R	2.81	.00	15.17
			LZ_LFDW	41.38	35.19	46.10					
R3	Browns Lake	All year	LAGSTAGE	61.60	59.07	62.89	All year	LAGSTAGE	61.60	59.07	62.89
			SPASCO_R	4.12	0.00	16.82		SPASCO_R	4.12	.00	16.82
			SH54DW	47.06	39.77	52.56		SPASCO_Q	12.6	6.9	19.4
			LZ_LFDW	42.10	35.19	46.85					
R4	Buck Lake	All year	LAGSTAGE	31.26	28.80	32.56	All year	LAGSTAGE	31.24	28.80	33.21
			COSME_R	4.92	0.00	16.60		COSME_R	4.78	.00	23.97
			E_L14DW	18.02	13.17	20.89					
R5	Lake Calm	June-	—	47.81	45.60	50.32	June-	—	47.81	45.60	50.32
		October	AVRAIN1	6.94	.14	22.60	October	AVRAIN1	6.94	.14	22.60
			DW_33A	32.26	25.65	37.90		COSME_Q	9.1	4.6	14.2
								SEC21_Q	8.9	5.1	11.2
R5	Lake Calm	November-	—	47.64	45.46	49.70	November	—	47.64	45.46	49.70
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			LZ_LFDW	41.38	35.19	46.10		COSME_Q	9.2	4.3	13.5
								SPASCO_Q	13.6	9.4	20.9
R6	Camp Lake	All year	LAGSTAGE	59.48	55.16	63.65	All year	LAGSTAGE	59.49	55.16	63.65
			SPASCO_R	4.12	0.00	16.82		SPASCO_R	4.12	.00	16.82
			SH54DW	47.06	39.77	52.56		SPASCO_Q	12.6	6.9	19.4
R7	Church Lake	June-	LAGSTAGE	34.19	30.06	36.39	June-	LAGSTAGE	34.19	30.06	36.39
		October	COSME_R	7.35	.14	23.97	October	COSME_R	7.35	.14	23.97
			DW_E100	26.35	20.70	30.74					
R7	Church Lake	November-	LAGSTAGE	34.41	30.30	36.43	November-	—	34.74	32.92	36.43
		May	COSME_R	2.92	0.00	12.09	May	COSME_R	3.26	.00	10.88
			DW_E100	25.19	19.40	29.14		NW_HILLQ	5.4	1.8	14.2
R8	Crescent Lake	June-	LAGSTAGE	40.87	38.86	41.95	June-	LAGSTAGE	40.95	37.97	43.35
		October	AVRAIN1	6.69	.14	16.44	October	AVRAIN1	6.94	.14	22.60
			SWAINSWL	37.84	30.90	41.29					
			DWN_4	26.07	20.63	30.17					
R8	Crescent Lake	November-	LAGSTAGE	40.73	36.27	42.11	November-	—	40.73	36.27	42.11
		May	SWAINSWL	36.92	32.02	40.55	May	AVRAIN1	2.84	.00	12.90
R9	Lake Dan	All year	LAGSTAGE	28.26	22.50	32.81	All year	—	28.26	22.50	32.81
			EW_RAIN	4.37	0.00	18.82		EW_RAIN	4.37	.00	18.82
			E_WN2	15.68	9.04	21.43		EW_PUMP	28.5	14.8	41.3
R10	Dosson Lake	All year	LAGSTAGE	52.26	48.14	54.35	All year	LAGSTAGE	52.26	48.14	54.35
			SEC21_R	4.30	0.00	19.94		SEC21_R	4.30	.00	19.94
			LZ_LFDW	41.94	35.19	46.85		COSME_Q	9.2	4.3	14.2
R11	Glass Lake	June-	LAGSTAGE	31.14	28.08	33.19	June-	LAGSTAGE	31.14	28.08	33.19
		October	COSME_R	7.02	.14	16.60	October	COSME_R	7.02	.14	16.60
R11	Glass Lake	November-	LAGSTAGE	31.10	29.29	32.68	November-	—	31.10	29.29	32.68
		May	COSME_R	3.16	0.00	12.09	May	COSME_R	3.16	.00	12.09
			DW_E100	25.37	19.40	29.14		COSME_Q	9.2	4.3	13.5
R12	Lake Harvey	June-	LAGSTAGE	60.85	57.96	62.76	All year	LAGSTAGE	60.56	57.96	62.76
		October	AVRAIN4	5.62	.02	18.38		AVRAIN4	4.09	.00	18.38
			SH54DW	47.56	41.54	51.30		SPASCO_Q	12.7	9.3	19.4
R12	Lake Harvey	November-	LAGSTAGE	60.36	58.14	61.98					
		May	AVRAIN4	3.05	0.00	15.61					
			DW21_7	40.65	34.54	45.42					
R13	Island Ford Lake	June-	LAGSTAGE	39.80	37.55	41.47	June-	LAGSTAGE	39.80	37.55	41.47
		October	AVRAIN1	6.94	.14	22.60	October	AVRAIN1	6.94	.14	22.60
			KEYSTONE	40.60	38.30	41.87		SPASCO_Q	12.7	6.9	17.0
R13	Island Ford Lake	November-	LAGSTAGE	40.02	37.46	41.35	November-	—	40.02	37.46	41.35
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			LZ_LFDW	41.38	35.19	46.10		COSME_Q	9.2	4.3	13.5
								SPASCO_Q	13.6	9.4	20.9

Table 16. Range of values for variables in regression analysis to determine change in monthly average stage in selected lakes–Continued

Reference No. (table 4)	Lake name	Regression relation including water level in Upper Floridan aquifer (table 7): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum	Regression relation including well-field pumpage (table 8): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum
R14	Lake Juanita	June-	LAGSTAGE	40.23	37.09	42.76	June-	LAGSTAGE	40.23	37.09	42.76
		October	AVRAIN1	6.94	.14	22.60	October	AVRAIN1	6.94	.14	22.60
			JAMEDW11	32.48	27.05	38.01					
R14	Lake Juanita	November-	LAGSTAGE	40.29	37.17	42.33	November-	LAGSTAGE	40.29	37.17	42.33
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			DW_E100	25.19	19.40	29.14		COSME_Q	9.2	4.3	13.5
								SEC21_Q	8.8	.0	11.4
R15	Keystone Lake	June-	LAGSTAGE	40.34	38.30	41.84	June-	LAGSTAGE	40.34	38.30	41.84
		October	AVRAIN1	6.94	.14	22.60	October	AVRAIN1	6.94	.14	22.60
R15	Keystone Lake	November-	LAGSTAGE	40.77	39.31	41.70	November-	LAGSTAGE	40.77	39.31	41.70
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			LZ_LFDW	41.38	35.19	46.10		NW_HILLQ	5.4	1.8	14.2
R16	Lake Linda	June-	LAGSTAGE	64.62	62.30	66.92	All year	LAGSTAGE	64.53	62.30	66.92
		October	SPASCO_R	5.56	0.00	16.82		SPASCO_R	4.12	.00	16.82
			SH54DW	47.56	41.54	51.30		SPASCO_Q	12.6	6.9	19.4
R16	Lake Linda	November-	LAGSTAGE	64.47	62.58	66.09					
		May	SPASCO_R	3.08	0.00	16.05					
			LZ_LFDW	41.67	35.19	46.10					
R17	Mound Lake	All year	LAGSTAGE	49.63	47.17	50.64	June-	LAGSTAGE	49.63	47.17	50.64
			AVRAIN1	4.56	0.00	22.60	October	AVRAIN1	6.94	.14	22.60
			DW_33A	31.25	23.74	37.90		SPASCO_Q	12.7	6.9	17.0
R17	Mound Lake						November-	LAGSTAGE	49.62	47.98	50.29
							May	AVRAIN1	2.84	.00	12.90
								COSME_Q	9.2	4.3	13.5
R18	Parker Lake	June-	LAGSTAGE	47.11	44.30	48.68	June-	LAGSTAGE	47.11	44.30	48.68
		October	AVRAIN1	6.94	.14	22.60	October	AVRAIN1	6.94	.14	22.60
			SWAINSWL	37.98	30.90	41.29		COSME_Q	9.1	4.6	14.2
								EW_PUMP	28.5	14.8	41.3
R18	Parker Lake	November-	LAGSTAGE	47.03	45.40	48.29	November-	LAGSTAGE	47.03	45.40	48.29
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			SWAINSWL	36.92	32.02	40.55		COSME_Q	9.2	4.3	13.5
								SPASCO_Q	13.6	9.4	20.9
R19	Pretty Lake	June-	LAGSTAGE	42.64	39.39	44.31	All year	LAGSTAGE	42.86	39.39	44.31
		October	AVRAIN2	6.86	.24	21.66		AVRAIN2	4.54	.00	21.66
			COSME_3	26.75	21.05	31.79		COSME_Q	9.2	4.3	14.2
R19	Pretty Lake	November-	LAGSTAGE	43.00	40.15	44.24					
		May	AVRAIN2	2.87	0.00	13.02					
R20	Rainbow Lake	June-	LAGSTAGE	37.18	34.41	40.06	All year	LAGSTAGE	37.42	34.41	40.06
		October	COSME_R	7.35	.14	23.97		COSME_R	4.85	.00	23.97
			JAMEDW11	32.48	27.05	38.01					
R20	Rainbow Lake	November-	LAGSTAGE	37.60	34.78	40.00					
		May	COSME_R	2.96	0.00	12.09					
			JAMEDW11	31.16	25.06	36.61					
R21	Lake Rogers	All year	LAGSTAGE	36.16	31.10	39.95	All year	LAGSTAGE	36.16	31.10	39.95
			COSME_R	4.78	0.00	23.97		COSME_R	4.78	.00	23.97
R22	Starvation Lake	All year	LAGSTAGE	49.88	45.31	53.62	All year	LAGSTAGE	49.99	45.31	53.62
			SEC21_R	4.30	0.00	19.94		SEC21_R	4.48	.00	19.94
			BERGERDW	42.95	36.83	48.73		NW_HILLQ	5.1	1.0	14.2
								SPASCO_Q	12.0	6.9	18.8
R23	Lake Taylor	June-	LAGSTAGE	37.10	34.41	38.67	June-	LAGSTAGE	37.12	34.41	38.68
		October	AVRAIN1	6.69	.14	16.44	October	AVRAIN1	6.94	.14	22.60
			DWN_4	26.07	20.63	30.17		SPASCO_Q	12.7	6.9	17.0
R23	Lake Taylor	November-	LAGSTAGE	37.24	35.46	38.59	November-	—	37.24	35.46	38.59
		May	AVRAIN1	2.84	0.00	12.90	May	AVRAIN1	2.84	.00	12.90
			DW_E100	25.19	19.40	29.14		COSME_Q	9.2	4.3	13.5
R24	Turkey Ford Lake	All year	LAGSTAGE	51.26	48.44	53.80	June-	LAGSTAGE	51.27	48.44	53.80
			AVRAIN4	4.23	0.00	18.38	October	AVRAIN4	5.86	.02	18.38
			DW_33A	31.30	23.74	37.90		EW_PUMP	28.4	14.8	41.3
R24	Turkey Ford Lake						November-	LAGSTAGE	51.25	49.19	52.88
							May	AVRAIN4	3.05	.00	15.61
								COSME_Q	9.1	4.3	13.5

Table 16. Range of values for variables in regression analysis to determine change in monthly average stage in selected lakes–Continued

[1]Definitions of abbreviations for explanatory variables are as follows:
AVRAIN1 = average of Cosme-Odessa well field and Eldridge-Wilde well field rainfall for month, in inches;
AVRAIN2 = average of Cosme-Odessa well field and Section 21 well field rainfall for month, in inches;
AVRAIN4 = average of Section 21 well field and South Pasco well field rainfall for month, in inches;
COSME_Q = monthly average pumpage from Cosme-Odessa well field, in million gallons per day;
COSME_R = monthly rainfall at Cosme-Odessa well field rain gage, in inches;
DW21_7 = monthly average water level in St. Petersburg deep well 21-7, in feet above sea level;
DWN_4 = monthly average water level in Eldridge-Wilde deep well N-4, in feet above sea level;
DW_33A = monthly average water level in St. Petersburg deep well 33A, in feet above sea level;
DW_E100 = monthly average water level in St. Petersburg deep well E-100, in feet above sea level;
EW_PUMP = monthly average pumpage from Eldridge-Wilde well field, in million gallons per day;
EW_RAIN = monthly total rainfall at Eldridge-Wilde well field rain gage, in inches;
E_L14DW = monthly average water level in East Lake deep well 14, in feet above sea level;
E_WN2 = monthly average water level in Eldridge-Wilde well N2, in feet above sea level;
JAMEDW11 = monthly average water level in James deep well 11, in feet above sea level;
KEYSTONE = monthly average stage in Keystone Lake, in feet above sea level;
LAGSTAGE = previous month average lake stage, in feet above sea level;
LZ_LFDW = monthly average water level in Lutz-Lake Fern deep well, in feet above sea level;
NW_HILLQ = monthly average pumpage from Northwest Hillsborough well field, in million gallons per day;
SEC21_Q = monthly average pumpage from Section 21 well field, in million gallons per day;
SEC21_R = monthly rainfall at Section 21 well field rain gage, in inches;
SH54DW = monthly average water level in State Highway 54 deep well, in feet above sea level;
SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day;
SPASCO_R = monthly rainfall at South Pasco well field rain gage, in inches;
SWAINSWL = monthly average water level in Swains well, in feet above sea level.

Table 17. Range of values for variables in regression analysis to determine change in monthly average water level in selected wells completed in the surficial aquifer

Site No. (table 3)	Well name	Regression relation including water level in Upper Floridan aquifer (table 9): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum	Regression relation including well-field pumpage (table 10): Applicable period	Explanatory variable[1]	Value of explanatory variable: Mean	Minimum	Maximum
7	St. Petersburg	All year	LAGSWIC6	36.67	33.40	39.90	June-	LAGSWIC6	37.34	33.93	39.90
	shallow well		COSME_R	4.78	0.00	23.97	October	COSME_R	7.35	.14	23.97
	1C-6		DW_E100	25.68	19.40	30.74	November-	LAGSWIC6	36.20	33.40	38.90
							May	COSME_R	2.92	0.00	12.09
14	Van Dyke	All year	LAGVDYKE	54.32	49.80	59.15	June-	LAGVDYKE	54.66	49.96	59.15
	shallow		SEC21_R	4.32	0.00	19.94	October	SEC21_R	6.37	.05	19.94
			BERGERDW	42.96	36.83	48.73		SPASCO_Q	12.7	6.9	17.0
							November-	LAGVDYKE	54.08	49.80	57.72
							May	SEC21_R	2.84	0.00	15.17
								NW_HILLQ	5.4	1.8	14.2
30	St. Petersburg	June-	LAGSW105	56.37	52.29	58.79	All year	LAGSW105	56.02	51.73	58.79
	shallow well	October	SPASCO_R	5.59	0.00	16.82		SPASCO_R	4.12	0.00	16.82
	105		STPDW105	43.16	37.77	46.79		SPASCO_Q	13.3	6.9	20.9
		November-	LAGSW105	55.77	51.73	58.43					
		May	SPASCO_R	3.08	0.00	16.05					
			STPDW105	41.78	35.16	48.50					

[1]Definition of abbreviations for explanatory variables are as follows:
BERGERDW = monthly average water level in Berger deep well, in feet above sea level;
COSME_R = monthly rainfall at Cosme-Odessa well field rain gage, in inches;
DW_E100 = monthly average water level in St. Petersburg deep well E-100, in feet above sea level;
LAGSW105 = previous month average water level in St. Petersburg shallow well 105, in feet above sea level;
LAGSW1C6 = previous month average water level in St. Petersburg shallow well 1C-6, in feet above sea level;
NW_HILLQ = monthly average pumpage from northwest Hillsborough well field, in million gallons per day;
SEC21_R = monthly rainfall at Section 21 well field rain gage, in inches;
SPASCO_Q = monthly average pumpage from South Pasco well field, in million gallons per day;
SPASCO_R = monthly rainfall at South Pasco well field rain gage, in inches;
STPDW105 = monthly average water level in St. Petersburg deep well 105, in feet above sea level;
STPSW105 = monthly average water level in St. Petersburg shallow well 105, in feet above sea level.

Table 18. Observed and average monthly rainfall at Cosme-Odessa, Eldridge-Wilde, Section 21, and South Pasco well fields, October 1984 through September 1985

Year	Month	Cosme-Odessa Observed	Cosme-Odessa 1974-85 average	Eldridge-Wilde Observed	Eldridge-Wilde 1974-85 average	Section 21 Observed	Section 21 1974-85 average	South Pasco Observed	South Pasco 1976-85 average
		Rainfall, in inches							
1984	October	0.61	2.05	0.90	2.21	0.95	1.52	0.38	1.38
	November	.53	1.53	.17	1.55	1.66	1.49	.99	1.70
	December	.06	2.77	.0	2.65	.03	2.40	.05	2.44
1985	January	1.55	2.28	1.76	2.41	1.53	2.22	1.53	2.50
	February	1.97	3.41	1.58	3.23	1.74	3.42	.91	3.50
	March	1.75	3.46	2.19	3.39	1.85	3.25	1.80	3.34
	April	1.26	1.92	1.42	1.59	1.65	1.84	.40	1.85
	May	.37	4.97	.60	4.43	.20	4.90	.30	5.97
	June	9.63	8.45	7.29	6.73	9.07	7.34	7.01	6.02
	July	8.68	8.09	8.38	7.13	10.28	6.73	6.84	6.36
	August	14.06	9.75	18.82	9.41	11.42	9.11	16.34	8.44
	September	9.65	7.98	8.31	6.80	8.38	6.73	4.07	5.58
Annual total		50.12	56.66	51.42	51.53	48.76	50.95	40.62	49.08

Sequential estimates of monthly average water level in James deep well 11 were computed by using the regression relation (table 6) using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall (table 18), keeping all other explanatory variables unchanged. The observed and sequential estimates of water level for October 1984 through September 1985 are listed in table 20 and are shown in figure 26. All sequential estimates of monthly average water levels are within the range in values of water level used in the regression relation (table 15).

The observed water levels are very close to or below the estimates computed using 50 percent of average rainfall from January through June. The minimum water level in May was 0.25 ft lower than the estimate computed by using the 50 percent of average rainfall. The cumulative rainfall through May was 8.10 in. at the Cosme-Odessa rain gage (table 18). This was 3.10 in. less than 50 percent of the cumulative average rainfall for the same period. The observed water level rose to 32.96 ft in September, slightly lower than the 110-percent rainfall estimate. The cumulative

Table 19. October 1984 through September 1985 monthly well-field pumpage and average monthly pumpage in the study area

Year	Month	Cosme-Odessa Observed	Cosme-Odessa 1974-85 average monthly	East Lake Observed	East Lake 1975-85 average monthly	Eldridge-Wilde Observed	Eldridge-Wilde 1974-85 average monthly	NW Hillsborough Observed	NW Hillsborough 1978-85 average monthly	Section 21 Observed	Section 21 1974-85 average monthly	South Pasco Observed	South Pasco 1974-85 average monthly
		Well-field pumpage, in million gallons per day											
1984	October	12.0	9.18	0.0	1.07	35.4	30.96	9.6	4.96	8.6	8.85	13.5	13.05
	November	11.4	8.66	.8	.85	32.0	30.21	9.8	4.89	7.8	8.90	11.6	12.72
	December	12.3	7.63	1.4	1.03	30.2	26.30	10.1	4.69	7.3	8.73	10.9	12.43
1985	January	11.9	7.71	1.0	.86	28.6	25.03	8.2	4.42	3.7	7.94	11.2	12.72
	February	12.7	8.73	.0	.84	32.2	27.58	8.5	4.66	.0	7.68	12.7	13.08
	March	13.5	10.06	1.4	1.43	31.9	31.80	10.1	5.38	7.3	9.33	13.8	13.88
	April	12.3	10.90	1.5	2.15	27.8	34.48	9.8	6.08	8.1	9.78	12.1	15.09
	May	11.5	10.60	1.3	1.85	31.1	34.45	14.2	7.45	5.1	9.04	16.4	15.07
	June	10.0	10.18	1.7	1.82	28.5	32.26	12.5	6.10	5.1	8.83	12.7	12.99
	July	11.8	9.16	2.0	1.58	30.1	27.59	7.3	4.42	5.6	8.92	12.0	12.74
	August	11.2	8.57	2.0	1.12	29.4	25.50	4.9	3.77	9.2	8.72	10.8	12.51
	September	12.6	8.55	1.0	.94	33.2	27.12	9.4	4.68	9.2	8.98	6.9	12.35
Annual average		11.93	9.16	1.18	1.30	30.87	29.44	9.53	5.12	6.42	8.81	12.05	13.22

Table 20. Observed and sequential estimates of monthly average water level in James deep well 11 computed by using regression relation assuming varying rainfall rates, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of average rainfall in regression relation in table 6: 50	75	90	100	110	125	150
1984	October	30.33	29.05	29.58	29.90	30.11	30.33	30.65	31.18
	November	29.74	28.58	29.17	29.52	29.76	29.99	30.34	30.93
	December	28.77	27.86	28.52	28.92	29.18	29.45	29.84	30.51
1985	January	28.80	29.55	30.31	30.77	31.07	31.38	31.83	32.59
	February	28.84	29.68	30.55	31.06	31.41	31.76	32.28	33.14
	March	26.88	26.80	27.81	28.41	28.81	29.21	29.82	30.82
	April	27.10	27.05	28.09	28.71	29.12	29.54	30.16	31.20
	May	25.06	25.31	26.44	27.12	27.57	28.03	28.70	29.84
	June	27.26	27.39	28.93	29.85	30.47	31.09	32.01	33.56
	July	29.67	27.69	29.71	30.92	31.73	32.53	33.75	35.77
	August	31.60	27.76	30.20	31.66	32.64	33.62	35.08	37.52
	September	32.96	26.48	29.23	30.89	31.99	33.09	34.75	37.50

rainfall from June through September was 42.02 in., slightly less than 125 percent of average rainfall for the same period, 42.84 in. The differences in estimated water levels that were computed by using 50 to 100 percent of average rainfall and 100 to 150 percent of average rainfall in estimated water levels in May are -2.26 and +2.27 ft, respectively. The differences in September are -5.51 and +5.51 ft, respectively.

The range in rainfall values used in the regression relation (table 15) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). All estimates of water level are within the range of values used in the regression relation (table 15).

In a similar manner, sequential estimates of monthly average water level in Berger deep well were computed using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall (table 18). The observed and sequential estimates of water level in Berger deep well for October 1984 through September 1985 are shown in figure 27.

The observed water levels are close to or below the estimates computed using 50 percent of average rainfall from January through June. The minimum in May was 0.45 ft lower than the 50-percent rainfall estimate. The cumulative Section 21 rainfall through May, 9.61 in., was 0.01 in. more than 50 percent of the average rainfall for the same period. The water level rose from May through September to 45.42 ft, which was between the estimates using 110 and 125 percent of average rainfall (fig. 27). The June through September rainfall at Section 21 (39.15 in.) was slightly more than the 125 percent of average rainfall for the same period (37.39 in.). The differences in estimated water levels in May using 50 to 100 percent of average rainfall and 100 to 150 percent of average rainfall are -2.37 and +2.37 ft, respectively. The differences in September are -5.06 and +5.06 ft, respectively.

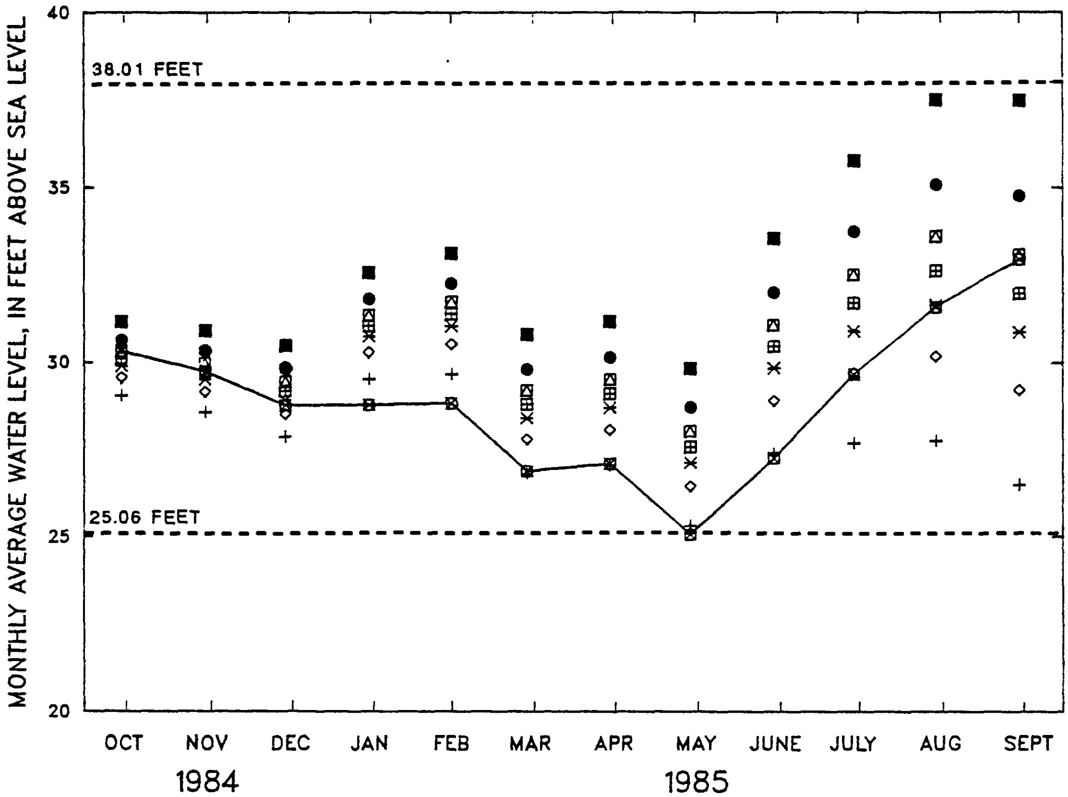
The range in rainfall values used in the regression relation (table 15) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). All estimates of water level are within the range of values used in the regression relation (table 15).

Effect of Changing Rainfall on Lake Stage

Estimates of lake stage can be computed by using either the regression relations that include the estimate of water level in an Upper Floridan aquifer well (table 7) or the regression relations that include well-field pumpage (table 8). The estimates of water levels in James deep well 11 (table 20) and Berger deep well (fig. 27) in the previous section will be used in this section to compute the estimates of stage in Lake Alice and Starvation Lake.

Sequential estimates of monthly average stage in Lake Alice were computed by using the regression relation (table 7) that includes the estimated water level in James deep well 11 using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19). The observed and estimated monthly average stages computed using varying percentages of average monthly rainfall at the Cosme-Odessa rain gage for October 1984 through September 1985 are listed in table 21 and are shown in figure 28. The range in rainfall values used in the regression relation (table 16) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). The values of estimated water levels in James deep well 11 (fig. 26) that were used in the computations were within the range of values used in the regression relation (table 16).

The observed stage is closely approximated by the estimate that was computed using 50 percent of average rainfall for October through June. As the rainfall increased after June, the observed stage rose until it was between the estimated stages that were computed using 75 and 90 percent of average rainfall. The estimates of stage that were computed using 50 percent of average rainfall from June through September were lower than the lowest stage used in the regression relation for change in stage (table 16). The estimates of stage that were computed using 150 percent of average rainfall for June through September and estimates that were computed using 125 percent of average rainfall for August and September were higher than the highest stage



EXPLANATION

-- Highest or lowest monthly average water level used in regression relation (table 15)

⊠ Observed monthly average water level in James deep well 11, in feet above sea level

+ Sequential estimate of monthly average water level (table 20) computed using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level (table 20) computed using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

× Sequential estimate of monthly average water level (table 20) computed using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

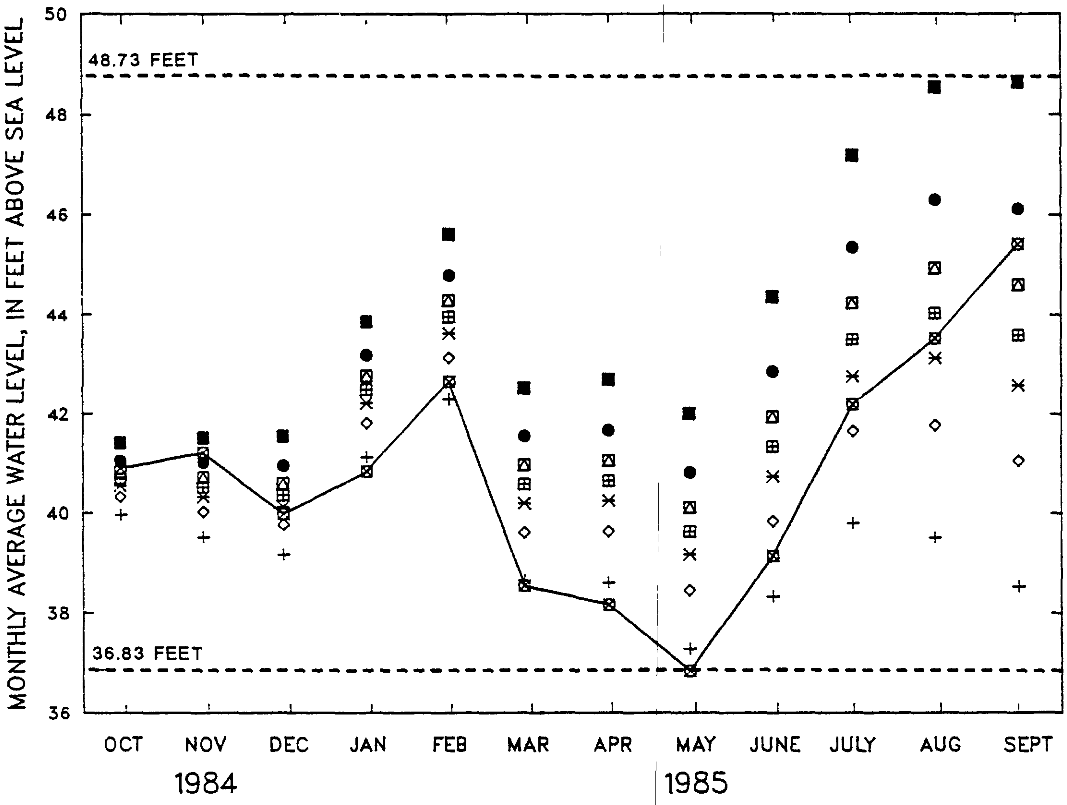
⊞ Sequential estimate of monthly average water level (table 20) computed using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⧄ Sequential estimate of monthly average water level (table 20) computed using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

● Sequential estimate of monthly average water level (table 20) computed using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average water level (table 20) computed using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 26. Observed and sequential estimates of monthly average water level in James deep well 11 assuming varying rainfall rates, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average water level in Berger deep well used in regression relation (table 15)

⊠ Observed monthly average water level in Berger deep well, in feet above sea level

+ Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

× Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

▨ Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average water level (table 21) computed with regression relation (table 6) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 27. Observed and sequential estimates of monthly average water level in Berger deep well assuming varying rainfall rates, October 1984 through September 1985.

Table 21. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation with sequential estimates of water level in James deep well 11 assuming varying rainfall rates, October 1984 through September 1985

Year	Month	Observed stage	Monthly average stage computed using indicated percent of average rainfall in regression relation in table 7						
			50	75	90	100	110	125	150
1984	October	40.28	40.16	40.35	40.47	40.55	40.62	40.74	40.94
	November	39.73	39.53	39.82	39.99	40.10	40.22	40.39	40.68
	December	39.21	39.00	39.37	39.59	39.74	39.88	40.10	40.47
1985	January	38.80	38.68	39.14	39.42	39.60	39.79	40.06	40.53
	February	38.52	38.41	38.98	39.32	39.55	39.78	40.12	40.68
	March	38.16	38.05	38.74	39.15	39.43	39.71	40.12	40.81
	April	37.68	37.56	38.35	38.82	39.14	39.46	39.93	40.72
	May	37.00	36.89	37.79	38.34	38.70	39.06	39.61	40.51
	June	36.57	36.45	37.57	38.24	38.69	39.14	38.81	40.93
	July	36.56	36.10	37.50	38.34	38.90	39.46	40.29	41.69
	August	37.12	35.82	37.54	38.57	39.25	39.94	40.97	42.68
	September	38.39	35.52	37.55	38.77	39.58	40.39	41.61	43.64

used in the regression relation (table 16). The differences in estimated stages that were computed using 50 to 100 percent of average rainfall and 100 to 150 percent of average rainfall in June are -2.24 and +2.24 ft, respectively. The differences in September are -4.06 and +4.06 ft, respectively (table 21).

In a similar manner, sequential estimates of monthly average stage were computed by using the regression relation that includes well-field pumpage (table 8) and uses 50, 75, 90, 100, 110, 125, and 150 percent of average rainfall and observed well-field pumpage. The observed and estimated monthly average stages for October 1984 through September 1985 are listed in table 22 and are shown in figure 29. The range in rainfall values used in the regression relation (table 16) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18).

The estimates of stage using 50 percent of average rainfall were lower than the lowest stage used in the regression relation (table 16) for June through September. The estimates of stage using 150 percent of average rainfall for February through September and estimates using 125 percent of average rainfall in August and September were higher than the highest stage used in the regression relation (table 16).

The observed stage and the estimate of stage using 50 percent of average rainfall are close for October through June. The observed stage in September is between the stages that were estimated by using 75 and 90 percent of average rainfall. The differences in estimated stage that were computed by using 50 to 100 percent of average rainfall and 100 to 150 percent of average rainfall in June are -2.71 and +2.71 ft, respectively. The differences in September are -4.86 and +4.86 ft, respectively.

The sequential estimates of monthly average stage in Starvation Lake were computed by using the regression relation (table 7) that includes estimated water levels in Berger deep well (fig. 27) and by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19). The observed and estimated stages for October 1984 through September 1985 are shown in figure 30.

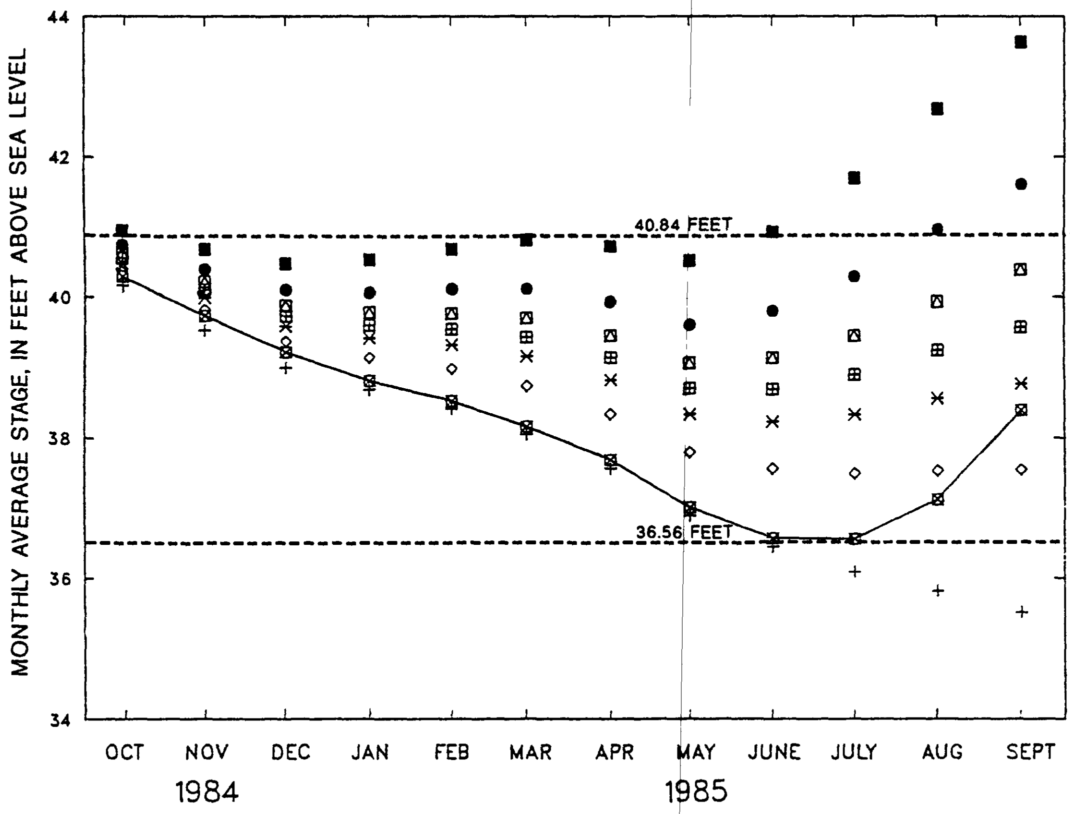
The range in rainfall values used in the regression relation (table 16) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). The values of estimated water levels in Berger deep well (fig. 27) that were used in the computations were within the range of values used in the regression relation (table 15). The estimate of stage that was computed using 150 percent of average rainfall in September was higher than the highest stage used in the regression relation (table 16).

The observed stage is closely approximated by the estimates computed using 50 percent of average monthly rainfall for October through July. By September, the observed stage was slightly higher than the estimate of stage using 110 percent of average rainfall.

The differences in estimates of stage that were computed by using 50 to 100 percent and 100 to 150 percent of average rainfall in June were -2.56 and +2.56 ft, respectively. The differences in September were -4.48 and +4.49 ft, respectively.

The sequential estimates of stage in Starvation Lake were computed by using the regression relation that includes well-field pumpage (table 8) and by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall and observed well-field pumpage. The observed and estimated monthly average stages for October 1984 through September 1985 are shown in figure 31.

The range in rainfall values used in the regression relation (table 16) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). The estimates of stage using 50 percent of average rainfall were lower than the lowest stage used in the regression relation (table 16) from June through August. The estimate of stage using 150 percent of average rainfall in September was higher than the highest stage value used in the regression relation (table 16).



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Lake Alice, in feet above sea level

\+ Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

* Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⊞ Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⊠ Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Lake Alice (table 21) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 20) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 28. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation with sequential estimates of water level in James deep well 11 assuming varying rainfall rates, October 1984 through September 1985.

Table 22. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985

Year	Month	Observed stage	Monthly average stage computed using indicated percent of average rainfall in regression relation in table 8						
			50	75	90	100	110	125	150
1984	October	40.28	40.20	40.45	40.61	40.71	40.81	40.97	41.22
	November	39.73	39.59	39.97	40.20	40.35	40.51	40.73	41.11
	December	39.21	39.05	39.53	39.81	40.00	40.19	40.47	40.95
1985	January	38.80	38.70	39.27	39.62	39.85	40.09	40.43	41.01
	February	38.52	38.39	39.09	39.51	39.79	40.07	40.50	41.20
	March	38.16	38.05	38.90	39.40	39.74	40.08	40.59	41.44
	April	37.68	37.56	38.53	39.12	39.50	39.89	40.47	41.44
	May	37.00	36.89	38.00	38.67	39.11	39.56	40.22	41.33
	June	36.57	36.40	37.76	38.57	39.11	39.65	40.47	41.82
	July	36.56	35.96	37.64	38.65	39.32	39.99	41.00	42.68
	August	37.12	35.63	37.69	39.92	39.74	40.56	41.80	43.85
	September	38.39	35.28	37.71	39.17	40.14	41.12	42.57	45.00

The observed stage and the estimate of stage using 50 percent of average rainfall are similar for October through June. The observed stage rose rapidly from July through September to a value between those computed using 110 and 125 percent of average rainfall. The differences between estimates of stage using 100 percent of average rainfall and estimates using 50 and 150 percent in June are -2.46 and +2.45 ft, respectively. In September, the differences are -4.25 and +4.24 ft, respectively.

Effect of Changing Rainfall on Water Levels in the Surficial Aquifer

Estimates of water levels in the surficial aquifer can be computed by using the regression relations that include the estimate of the water level in an Upper Floridan aquifer well (table 9) or the regression relations that include well-field pumpage (table 10). The estimates of water levels in Berger deep well that were computed in the previous section (fig. 27) will be used in this section to compute the estimates of water levels in Van Dyke shallow well.

Sequential estimates of monthly average water levels in Van Dyke shallow well were computed by using the regression relation (table 9) that includes estimated water levels in Berger deep well using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19). The observed and estimated monthly average water levels for October 1984 through September 1985 computed using varying percentages of average monthly rainfall at the Section 21 rain gage are listed in table 23 and are shown in figure 32.

The range in rainfall values used in the regression relation (table 17) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). The values of estimated monthly average water level in Berger deep well (fig. 27) that were used in the computations were within the range of values used in the regression relation (table 17).

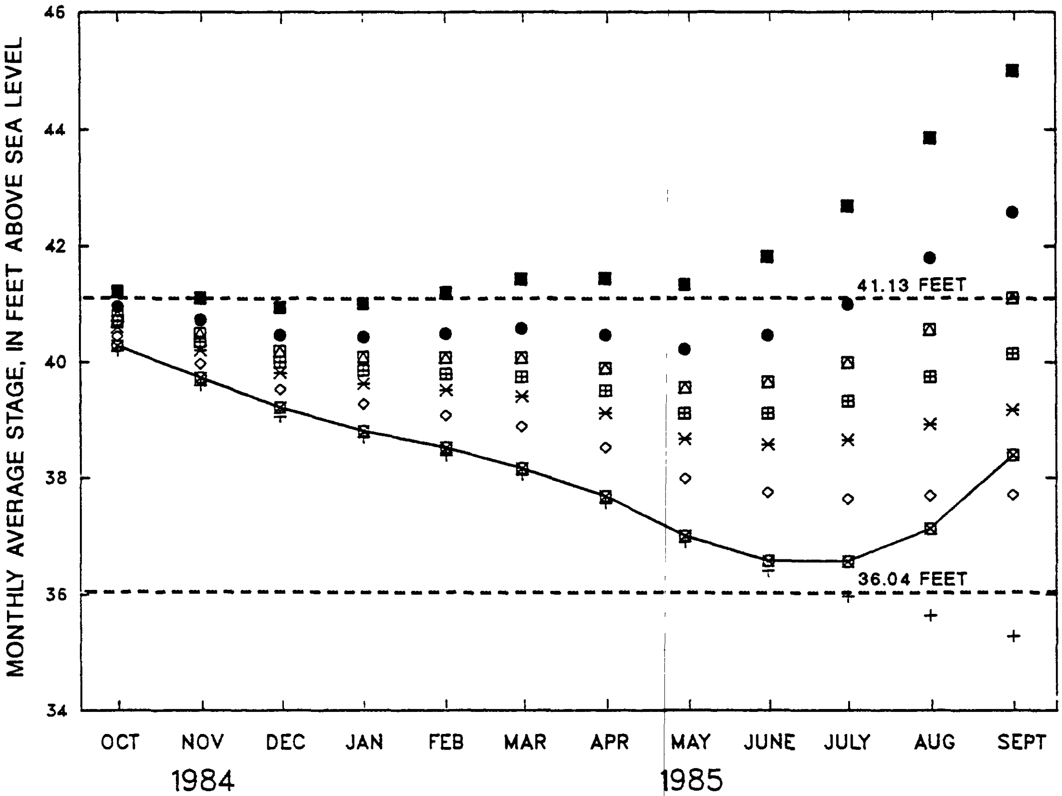
The observed water level was lower than the estimated water level that was computed using 50 percent of average rainfall for January through July. In September, the observed water level rose to 56.17 ft, slightly above the water level that was computed by using 110 percent of average rainfall. Only the estimated stage that was computed using 150 percent of average rainfall in September (fig. 32) exceeded the range of water-level values used in the regression relation (table 17).

The differences between the estimated stages that were computed using 100 and 50 percent of average rainfall were -1.95 ft in May and -4.22 ft in September. The differences between the estimated stages that were computed using 100 and 150 percent of average rainfall were 1.95 ft in May and 4.21 ft in September (table 23).

In a similar manner, sequential estimates of monthly average water levels were computed by using the regression relation that includes well-field pumpage (table 10) and by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall and observed well-field pumpage. The observed and estimated monthly average water levels for October 1984 through September 1985 are listed in table 24 and shown in figure 33.

The range in rainfall values at the Section 21 rain gage that were used in the regression relation (table 17) was not exceeded by the 50 to 150 percent of average monthly rainfall (table 18). Only the estimate of water level using 50 percent of average monthly rainfall in May exceeded the range of water-level values used in the regression relation.

The differences between the estimated water levels that were computed using 50 and 100 percent of average monthly rainfall are -1.56 ft in May and -2.93 ft in September. The differences between estimated water levels that were computed using 100 and 150 percent of average monthly rainfall are 1.57 ft in June and 2.93 ft in September.



EXPLANATION

- - Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Lake Alice, in feet above sea level (table 22)

\+ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

✱ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

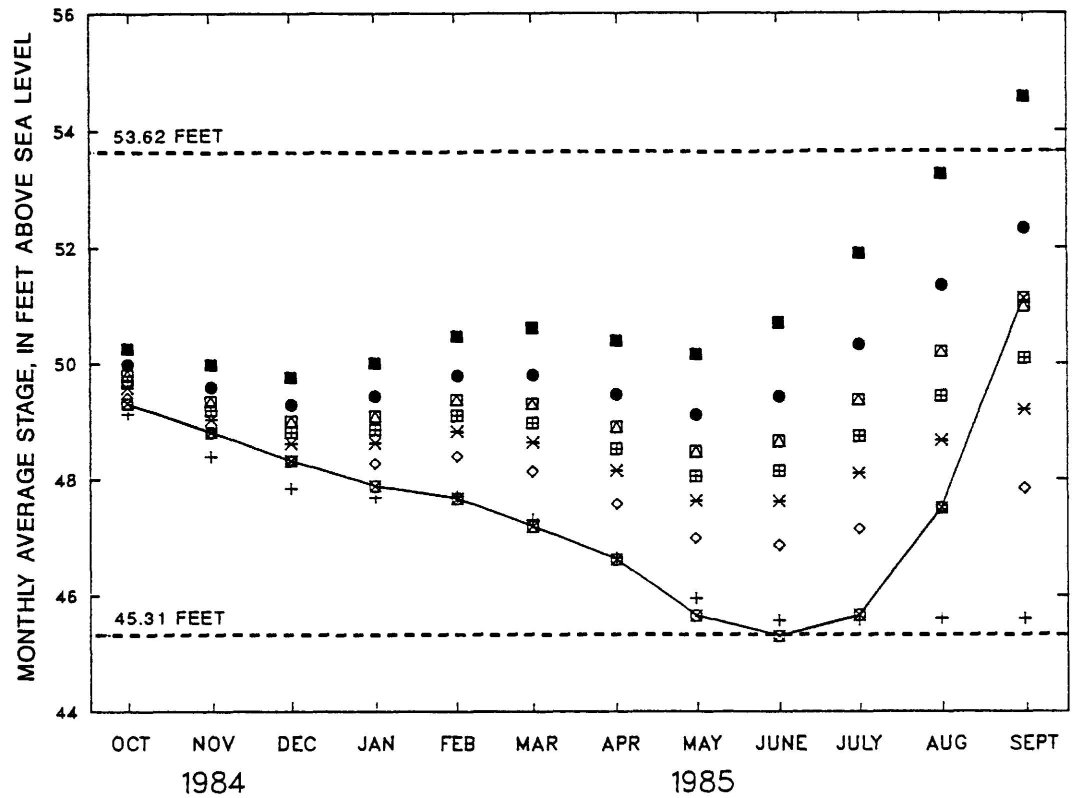
⊞ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⧅ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of average stage in Lake Alice (table 22) computed with regression relation including well-field pumpage (table 8) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 29. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Starvation Lake, in feet above sea level

\+ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 50 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 75 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

× Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 90 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

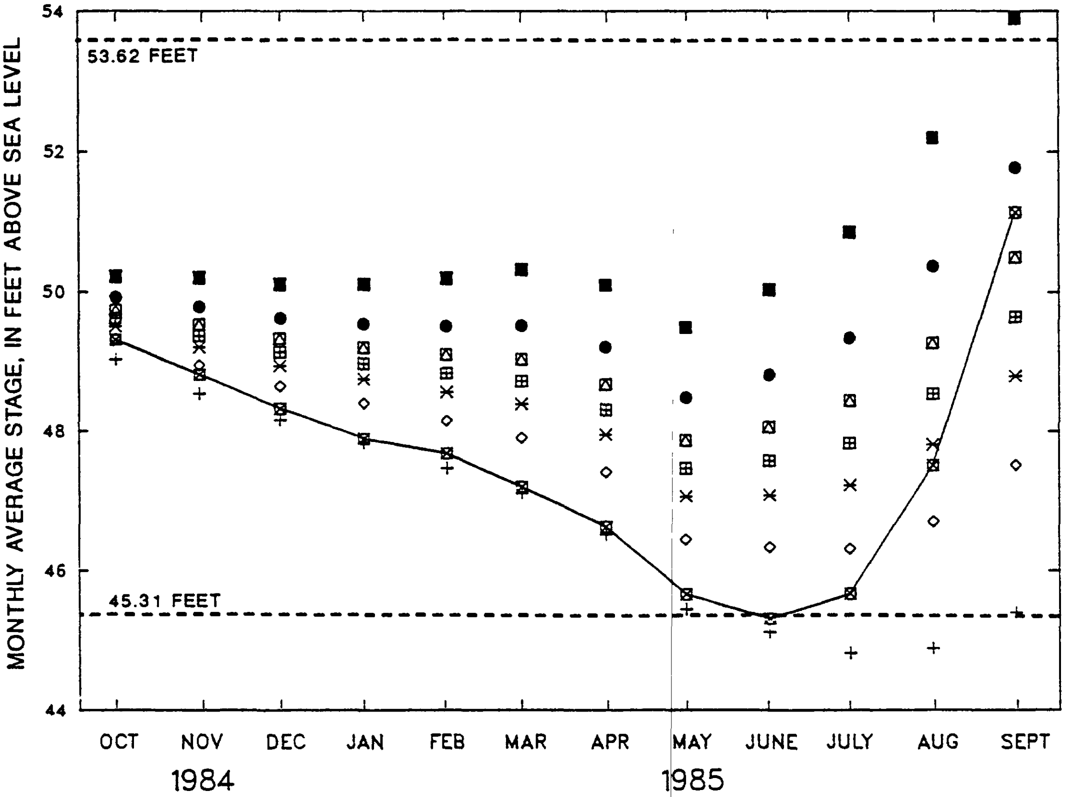
⊞ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 100 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

⧅ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 110 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 125 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation (table 7) including estimated water level in Berger deep well (fig. 27) using 150 percent of monthly average rainfall (table 18) and observed well-field pumpage (table 19)

Figure 30. Observed and sequential estimates of monthly average stage in Starvation Lake computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rainfall rates, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Starvation Lake, in feet above sea level

\+ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

✳ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⊞ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⧄ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 31. Observed and sequential estimates of monthly average stage in Starvation Lake computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985.

Table 23. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rainfall rates, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of average rainfall in regression relation in table 9						
			50	75	90	100	110	125	150
1984	October	52.33	52.24	52.48	52.63	52.73	52.83	52.97	53.22
	November	52.01	51.59	51.93	52.14	52.27	52.41	52.62	52.96
	December	51.55	51.21	51.66	51.92	52.10	52.28	52.54	52.99
1985	January	51.15	51.71	52.25	52.60	52.80	53.01	53.34	53.88
	February	50.93	52.43	53.09	53.49	53.75	54.02	54.42	55.08
	March	50.77	51.80	52.60	53.07	53.39	53.71	54.18	54.98
	April	50.41	51.32	52.18	52.69	53.04	53.38	53.90	54.76
	May	49.80	50.47	51.44	52.03	52.42	52.81	53.39	54.37
	June	49.96	50.43	51.66	52.40	52.90	53.39	54.13	55.36
	July	50.60	50.82	52.34	53.25	53.85	54.46	55.37	56.88
	August	52.06	51.03	52.87	53.97	54.71	55.44	56.54	58.38
	September	56.17	50.86	52.97	54.23	55.08	55.92	57.18	59.29

The observed and estimated water levels in St. Petersburg shallow well 105 were computed by using the regression relation (table 9) that includes the estimate of water levels in St. Petersburg deep well 105 (fig. 34). All estimates of water levels are within the range in values of water levels that were used in the regression relation (table 17) except for the estimate that uses 125 percent of average rainfall in September and the estimates that use 150 percent of average rainfall in August and September (fig. 34). The observed water levels are about 1 ft lower than the estimates that were computed by using 50 percent of average rainfall for December through May. The observed rainfall at South Pasco well field through May, 6.36 in., is only 28 percent of the average rainfall for the same period (table 18). Water levels rose from June through September in response to above average rainfall, 34.26 in., which was 130 percent of the average for the same period (table 18). The water level in September, 57.66 ft above sea level, was slightly below the estimates of water levels computed with 100 percent of average rainfall. When the relation that includes well-field pumpage was used (table 10), all estimates were in the range in water levels used in the regression relation (table 17), except the estimate that uses 125 percent of average rainfall in September and the estimates that use 150 percent of average rainfall in August and September (fig. 35).

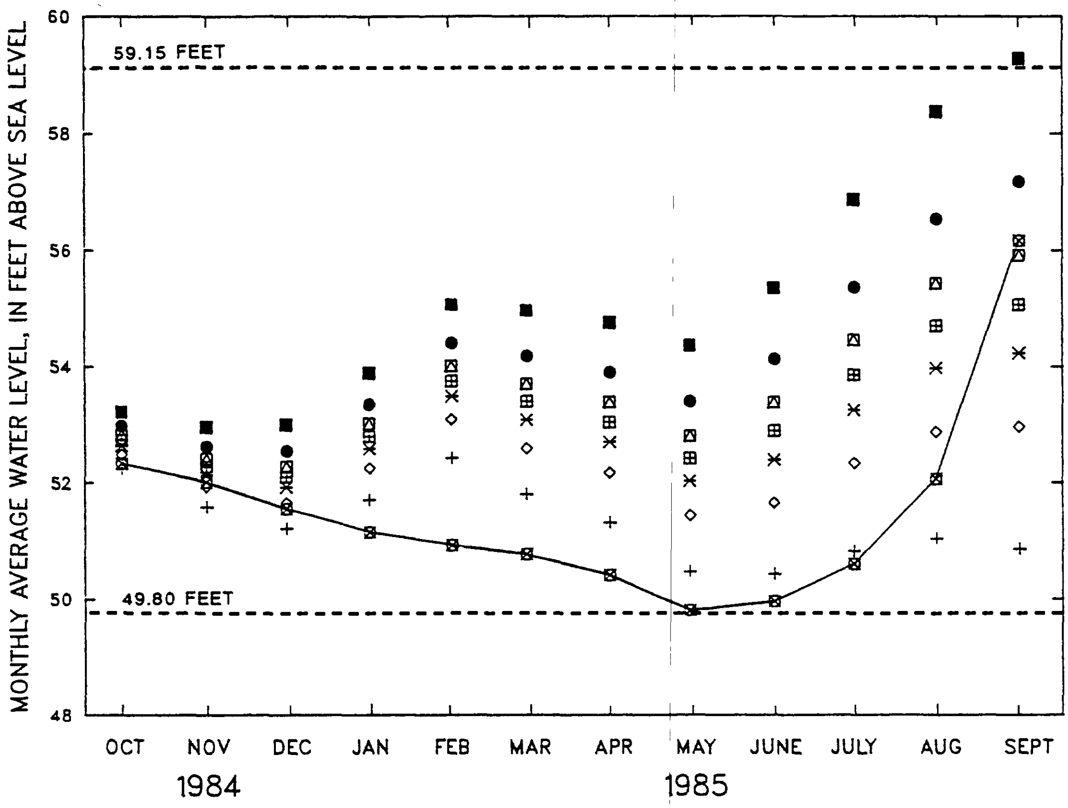
The differences in estimated water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average monthly rainfall are ±2.05 ft in May and ±2.89 ft in September when using the regression relation that includes estimated water levels in St. Petersburg deep well 105. When using the regression relation that includes well-field pumpage (fig. 35), these differences in estimated water levels are ±1.84 ft in May and ±3.50 ft in September.

Effect of Changing Pumpage Rates on Water Levels in the Upper Floridan Aquifer

To illustrate the effect of changing well-field pumpage on water levels in the Upper Floridan aquifer, the change in monthly average water levels are computed with varying pumpage rates, keeping all other explanatory variables unchanged. The 1985 water year, October 1984 through September 1985, is used in the examples.

Sequential estimates of monthly average water levels in James deep well 11 were computed by using the regression relation (table 6) that uses 50, 75, 90, 100, 110, 125, and 150 percent of average monthly well-field pumpage (table 19), keeping all other explanatory variables unchanged. The observed and sequential estimates of water level for October 1984 through September 1985 are listed in table 25 and are shown in figure 36.

The pumpage rates that exceeded the range in values used in the regression relation that was used to compute the estimated monthly average water levels are noted in figure 36. The estimated water level that was computed by using 50 percent of average monthly pumpage in September exceeded the highest water level used in the regression relation (table 15) by 1.21 ft (table 25). Estimated water levels that were computed by using 150 percent of pumpage rates in March through June and the April through June water level that was computed by using 125 percent of pumpage rate exceeded the lowest water level used in the regression relation (table 15). The water level that was estimated by using 150 percent of pumpage rate was 4.88 ft lower than the lowest water level used to develop the regression relation (table 15) in May.



EXPLANATION

-- Highest or lowest monthly average water level used in regression relation (table 17)

⊠ Observed monthly average water level in Van Dyke shallow well, in feet above sea level

\+ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

✱ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⧄ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

● Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in Van Dyke shallow well (table 23) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 27) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 32. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rainfall rates, October 1984 through September 1985.

Table 24. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of average rainfall in regression relation in table 10						
			50	75	90	100	110	125	150
1984	October	52.33	52.70	52.97	53.13	53.24	53.35	53.51	53.78
	November	52.01	51.46	51.77	51.95	52.07	52.19	52.38	52.69
	December	51.55	50.74	51.12	51.35	51.51	51.66	51.89	52.27
1985	January	51.15	50.71	51.14	51.41	51.58	51.76	52.02	52.46
	February	50.93	50.91	51.45	51.78	52.00	52.21	52.54	53.09
	March	50.77	50.82	51.45	51.83	52.08	52.33	52.71	53.34
	April	50.41	50.50	51.13	51.50	51.76	52.01	52.39	53.02
	May	49.80	49.37	50.15	50.62	50.93	51.25	51.72	52.50
	June	49.96	50.01	50.94	51.50	51.87	52.24	52.80	53.73
	July	50.60	50.72	51.84	52.51	52.96	53.40	54.07	55.19
	August	52.06	51.40	52.69	53.46	53.98	54.50	55.27	56.56
	September	56.17	52.27	53.74	54.62	55.20	55.79	56.67	58.13

The sum of the cumulative observed pumpage rates for October through May at Cosme-Odessa well field, 97.6 Mgal/d, and at Section 21 well field, 47.9 Mgal/d, were slightly higher than the sum of the average pumpage rates for the same period, 143.72 Mgal/d (table 19). Consequently, the estimated water level using 100 percent of average pumpage in May, 25.53 ft, is slightly higher than the observed water level, 25.06 ft. The sum of annual average observed pumpage rates at Cosme-Odessa and Section 21 well fields, 18.35 Mgal/d, is only 2 percent greater than the sum of the annual averages, 17.97 Mgal/d, but the estimated water level using average pumpage rates is 1.78 ft higher than the observed water level in September.

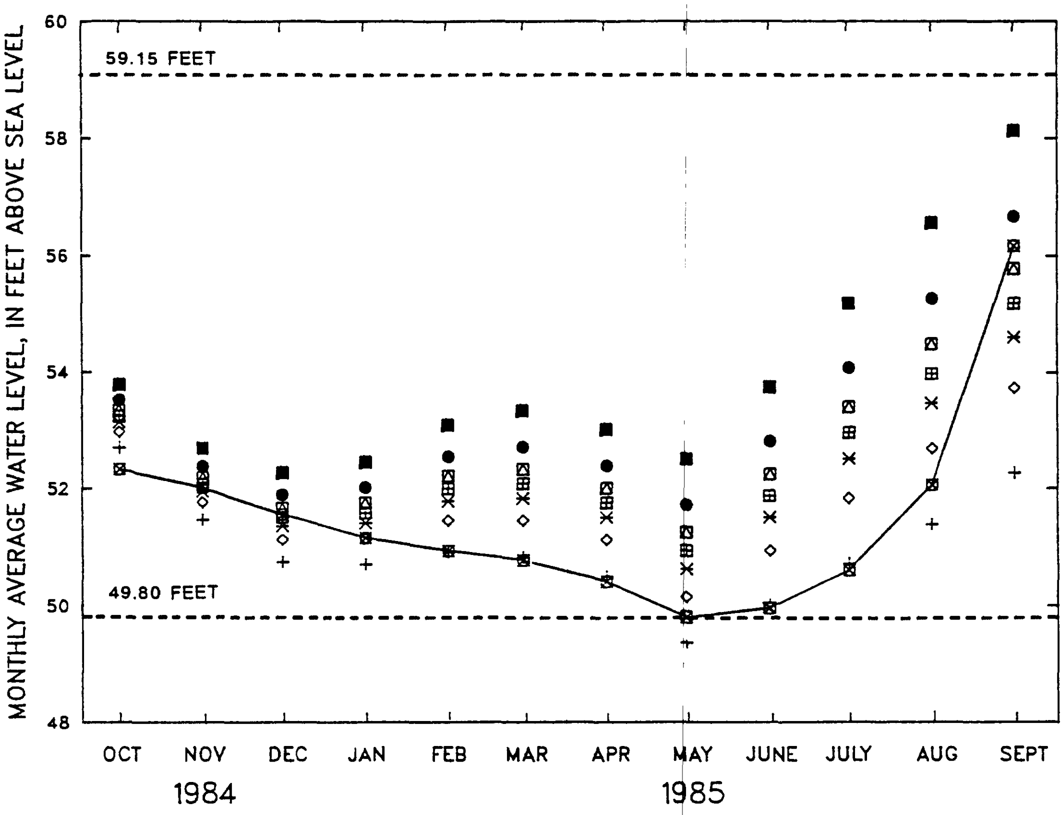
The differences in estimates of water levels that were computed by using 50 to 100 percent of average pumpage and 100 to 150 percent of average rates are ±5.35 ft in May and ±4.48 ft in September. Apparently, the cumulative effect of varying pumpage rates is greater when rainfall is low, such as in October through May; and, as rainfall amounts increase, such as in June through September, varying pumpage rates have less effect on changes in water levels.

In the next example, sequential estimates of monthly average water level in Berger deep well were computed by using the regression relation (table 6) that uses 50, 75, 90, 100, 110, 125, and 150 percent of average monthly well-field pumpage (table 19), keeping all other explanatory variables unchanged. The observed and sequential estimates of monthly average water level for October 1984 through September 1985 are shown in figure 37.

All of the 50 and 150 percent of average pumpage rates at one or more well fields exceeded the range in values in the regression relation (table 15). The 75-percent pumpage rate for South Pasco well field in September and the 125 percent of average pumpage rates at one or more well fields in March, April, and May exceeded the range in values in the regression relation (table 15). The range in water levels that was used in the regression relation (table 15) was exceeded by estimates of the water levels that were computed by using the following percentage of average pumpage rates: 50 percent in August and September; 110 percent in May; 125 percent in April, May, and June; and 150 percent in February through June.

The sum of the cumulative pumpage rates for October through May of the four well fields in the regression relation for change in water level in Berger deep well (Eldridge-Wilde, Northwest Hillsborough, Section 21, and South Pasco) was 479.6 Mgal/d. This sum was slightly more than the sum of average pumpage rates for the same period, 461.63 Mgal/d. The estimate of water level that was computed by using 100 percent of average pumpage was 0.75 ft higher than the observed water level in May. The sum of average annual observed pumpage rates, 58.87 Mgal/d, is about 4 percent greater than the sum of the annual average for the same four well fields, 56.59 Mgal/d. At the end of the water year in September, the estimated water level that was computed by using 100 percent of average well-field pumpage was only 0.43 ft from the observed water level.

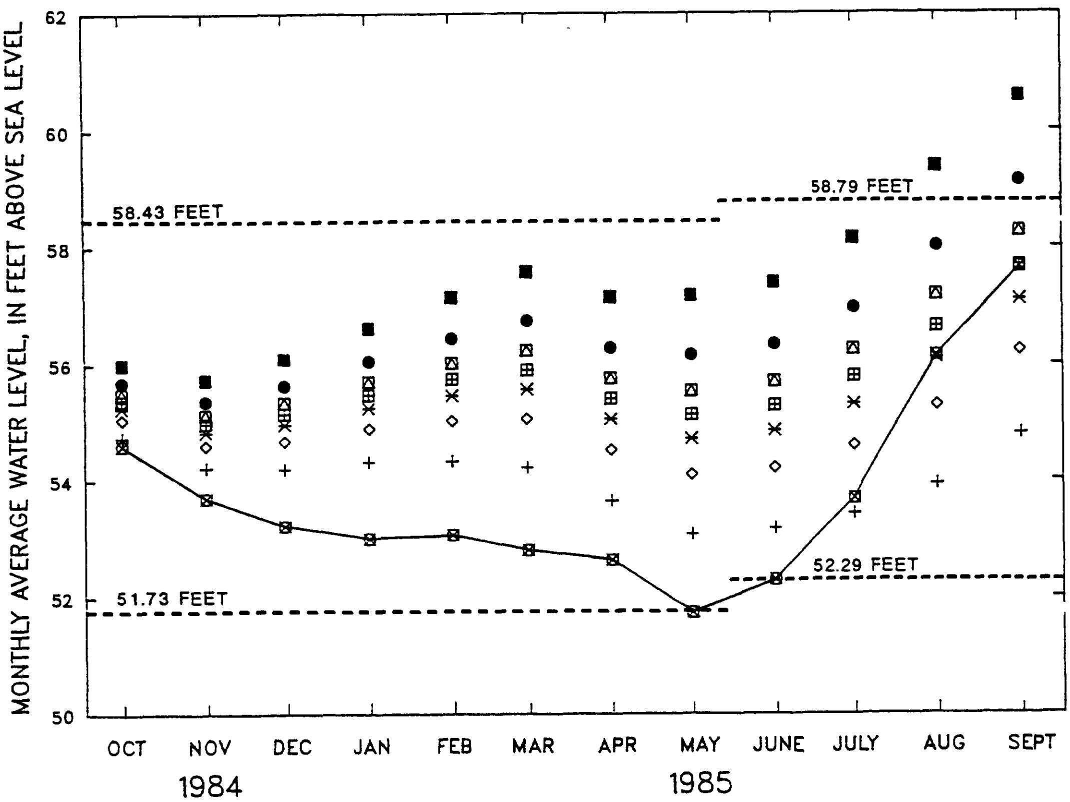
The differences between the May water levels that were estimated by using 100 percent of average pumpage rates and those estimated by using 50 and 150 percent of average pumpage rates were +5.12 and -5.12 ft, respectively. These same differences in September were +5.11 and -5.11 ft, respectively. The increase in the differences in estimated water levels from October through May did not continue from June through September because of the influence of above average rainfall from June through September.



EXPLANATION

- -- Highest or lowest monthly average water level used in regression relation (table 17)
- ⊠ Observed monthly average water level in Van Dyke shallow well, in feet above sea level
- \+ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- ◇ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- ✱ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- ⊞ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- ⧄ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- • Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)
- ■ Sequential estimate of monthly average water level in Van Dyke shallow well (table 24) computed with regression relation including well-field pumpage (table 10) using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 33. Observed and sequential estimates of water level in Van Dyke shallow well computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average water level used in regression relation (table 17)

⊠ Observed monthly average water level in St. Petersburg shallow well 105, in feet above sea level

+ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 50 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 75 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

✳ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 90 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

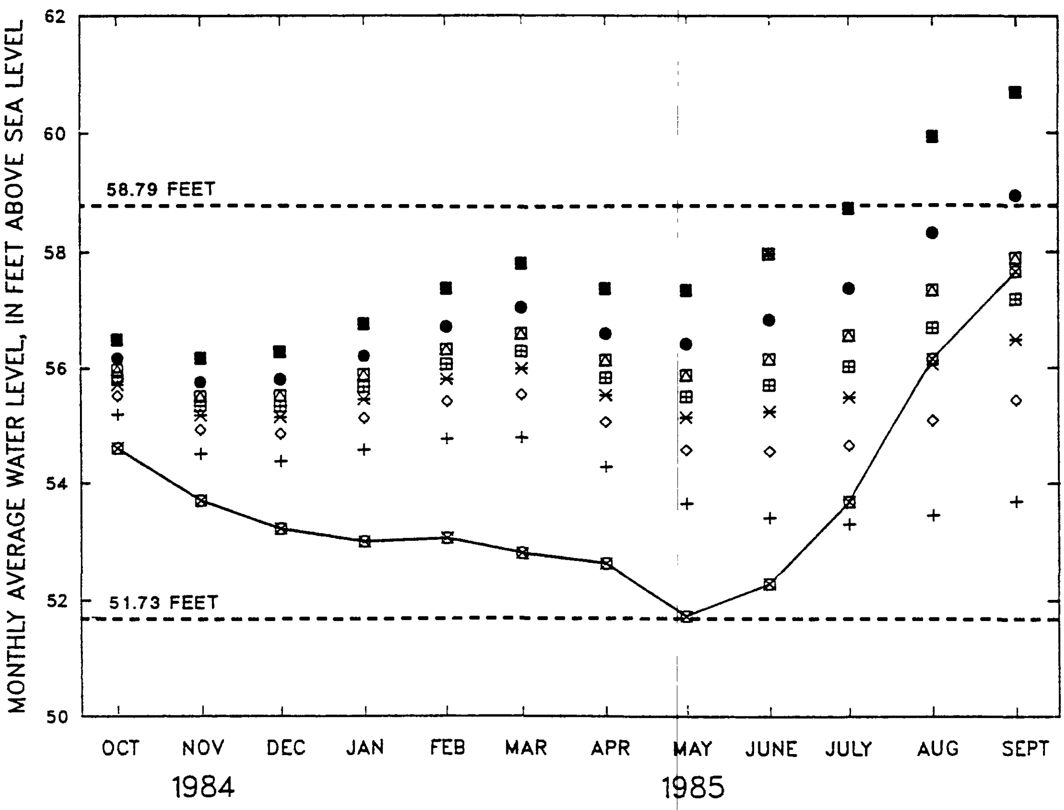
⊞ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 100 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

⧄ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 110 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

• Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 125 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation (table 9) including estimate of monthly average water level in St. Petersburg deep well 105 using 150 percent of average monthly rainfall (table 18) and observed well-field pumpage (table 19)

Figure 34. Observed and sequential estimates of water level in St. Petersburg shallow well 105 computed by using regression relation with sequential estimates of water level in St. Petersburg deep well 105 assuming varying rainfall rates, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average water level used in regression relation (table 17)

⊠ Observed monthly average water level in St. Petersburg shallow well 105, in feet above sea level

\+ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 50 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 75 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

✱ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 90 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 100 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

⧄ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 110 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

• Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 125 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed by regression relation including well-field pumpage (table 10) using 150 percent of average monthly rainfall (table 18) and observed monthly well-field pumpage (table 19)

Figure 35. Observed and sequential estimates of monthly average water level in St. Petersburg shallow well 105 computed by using regression relation that includes well-field pumpage assuming varying rainfall rates, October 1984 through September 1985.

Table 25. Observed and sequential estimates of monthly average water level in James deep well 11 computed by using regression relation assuming varying rates of well-field pumpage, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of average monthly well-field pumpage in regression relation in table 6						
			50	75	90	100	110	125	150
1984	October	30.33	30.96	30.23	29.80	29.51	29.23	28.79	28.07
	November	29.74	30.86	29.79	29.16	28.73	28.31	27.67	28.60
	December	28.77	31.45	30.24	29.52	29.04	28.56	27.84	26.63
1985	January	28.80	32.31	30.91	30.06	29.50	28.94	28.09	26.69
	February	28.84	33.00	31.24	30.19	29.48	28.78	27.72	25.97
	March	26.88	32.87	30.59	29.22	28.31	27.40	26.03	23.76
	April	27.10	32.01	29.38	27.81	26.76	25.71	24.14	21.51
	May	25.06	30.89	28.21	26.61	25.53	24.47	22.86	20.18
	June	27.26	32.06	29.63	28.17	27.19	26.22	24.76	22.32
	July	29.67	34.61	32.39	31.06	30.17	29.28	27.95	25.72
	August	31.60	37.26	35.13	33.85	33.00	32.15	30.85	28.74
	September	32.96	39.22	36.98	35.64	34.74	33.85	32.50	30.26

Effect of Changing Pumpage Rates on Lake Stage

An estimate of the effect of changing pumpage rates on lake stage can be obtained by varying the pumpage rates while keeping all other explanatory variables unchanged for a period of time. Estimates of water level in an Upper Floridan aquifer well will be computed with the regression relation in table 6 using varying pumpage rates. These estimated water levels are then used in the regression relation for change in lake stage in table 7. Another estimate of the effect of varying pumpage rates will be shown by using the regression relation for change in lake stage that includes the pumpage rates in table 8.

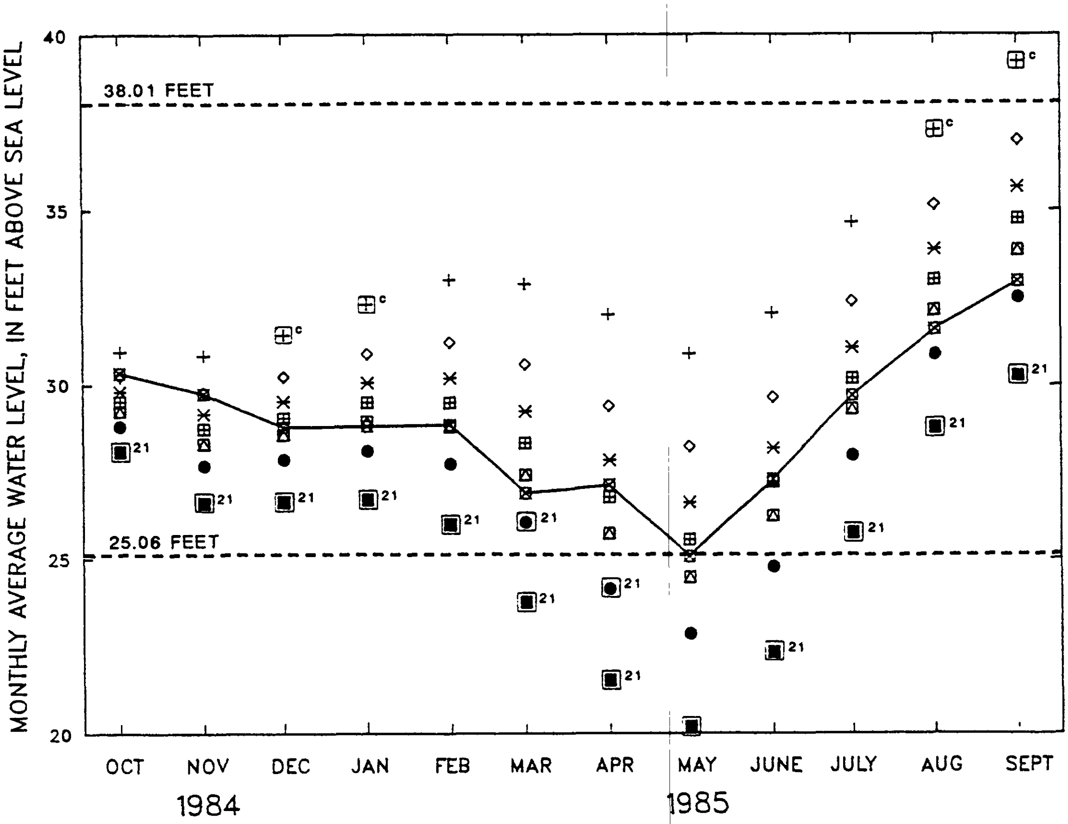
The sequential estimates of monthly average water level in James deep well 11 that were computed by using the varying pumpage rates in the previous section were used to compute the estimates of monthly average stage in Lake Alice. The observed and estimated monthly average stages in Lake Alice for October 1984 through September 1985 were computed by using the regression relation in table 7 using 50, 75, 90, 100, 110, 125, and 150 percent of average well-field pumpage and observed rainfall (table 26 and fig. 38).

The estimates of water levels in James deep well 11 that were used in the regression relation for change in stage exceeded the range of values (table 16) that were computed using the following percentages of average pumpage rates: 50 percent in September, 110 percent in May, 125 percent for April through June, and 150 percent for March through June. Only the estimated stages that were computed using 150 percent of average monthly pumpage in May, June, and July exceeded the range in stage used in the regression relation (table 16).

The estimates of stage that were computed by using 100 percent of average monthly well-field pumpage closely approximate the observed stage through June. In June, the estimated stage, 36.55 ft, is only 0.02 ft from the observed stage, 36.57 ft (table 26). The estimated water level in James deep well 11 in June was 0.07 ft lower than the observed water level (table 25). The differences in estimated stages between those computed using 50 to 100 percent and 100 to 150 percent of average monthly well-field pumpage were +1.04 and -1.03 ft, respectively, in June (table 26).

At the end of the estimated period in September, the observed stage, 38.39 ft, was close to the estimated stage that was computed by using 110 percent of average well-field pumpage, 38.47 ft (table 26). The differences in estimated stage that were computed by using 50 to 100 percent and 100 to 150 percent of average well-field pumpage were +1.38 and -1.38 ft, respectively, in September (table 26).

In a similar manner, sequential estimates of monthly average stage in Lake Alice were computed by using the regression relation that includes well-field pumpage (table 8) and by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly well-field pumpage and observed rainfall. The observed and estimated monthly average stages for October 1984 through September 1985 are listed in table 27 and are shown in figure 39. The range in the Cosme-Odessa well-field pumpage (table 16) was exceeded by 50 percent of average pumpage in October, November, August, and September and by 150 percent of average pumpage from March through June. Only the estimated stage that was computed by using 150 percent of average well-field pumpage in June exceeded the range in stage used in the regression relation (table 16).



EXPLANATION

-- Highest or lowest monthly average water level used in regression relation (table 15)

⊠ Observed monthly average water level in James deep well 11, in feet above sea level

\+ Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

× Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

⊠ Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

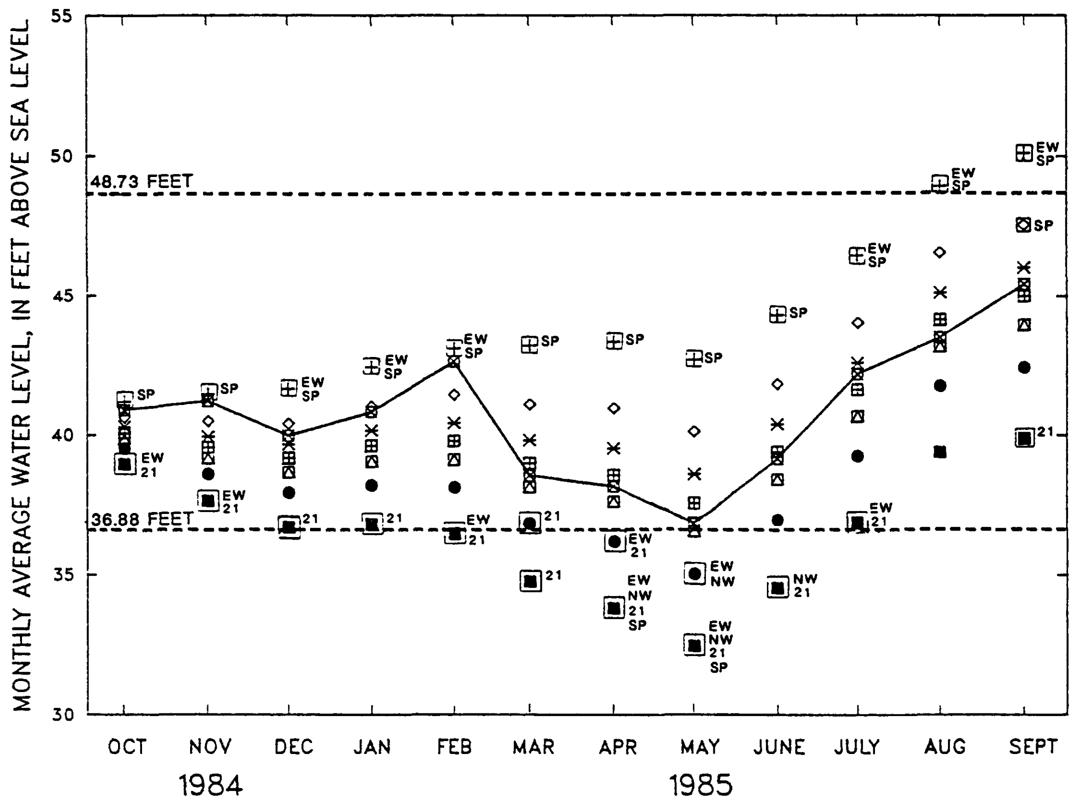
● Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in James deep well 11 (table 25) computed with regression relation in table 6 using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

One or more of the well-field pumpage variables exceeded the range of values used in the regression relation (table 15)

⊞ c C = Cosme-Odessa well-field pumpage
▣ 21 21 = Section 21 well-field pumpage

Figure 36. Observed and sequential estimates of monthly average water level in James deep well 11 computed by using regression relation assuming varying rates of well-field pumpage, October 1984 through September 1985.



EXPLANATION

- -- Highest or lowest monthly average water level used in regression relation (table 15)
- ⊠ Observed monthly average water level in Berger deep well, in feet above sea level
- \+ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)
- ◇ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)
- ✳ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)
- ⊞ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)
- ◪ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)
- • Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)
- ■ Sequential estimate of monthly average water level in Berger deep well computed with regression relation in table 6 using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

One or more average monthly well-field pumpage veriables exceeded range of values used in regression relation (table 15)

⊞ EW SP

■ EW NW 21 SP

EW = Eldridge-Wilde well field
NW = Northwest Hillsborough well field
21 = Section 21 well field
SP = South Pasco well field

Figure 37. Observed and sequential estimates of monthly average water level in Berger deep well computed by using regression relation assuming varying rates of well-field pumpage, October 1984 through September 1985.

Table 26. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation with sequential estimate of water level in James deep well 11 assuming varying rates of well-field pumpage, October 1984 through September 1985

Year	Month	Observed stage	Monthly average stage computed using indicated percent of well-field pumpage in regression relation in table 7						
			50	75	90	100	110	125	150
1984	October	40.28	40.26	40.24	40.22	40.21	40.20	40.18	40.16
	November	39.73	39.69	39.62	39.58	39.56	39.53	39.49	39.43
	December	39.21	39.17	39.06	39.00	38.96	38.92	38.86	38.75
1985	January	38.80	38.87	38.72	38.63	38.57	38.51	38.42	38.27
	February	38.52	38.74	38.54	38.41	38.33	38.24	38.12	37.91
	March	38.16	38.61	38.33	38.16	38.05	37.94	37.77	37.49
	April	37.68	38.32	37.96	37.74	37.59	37.44	37.22	36.86
	May	37.00	37.75	37.30	37.03	36.85	36.67	36.41	35.96
	June	36.57	37.59	37.07	36.76	36.55	36.35	36.04	35.52
	July	36.56	37.98	37.40	37.05	36.82	36.59	36.24	35.67
	August	37.12	38.99	38.36	37.98	37.73	37.47	37.09	36.46
	September	38.39	40.13	39.44	39.02	38.75	38.47	38.06	37.37

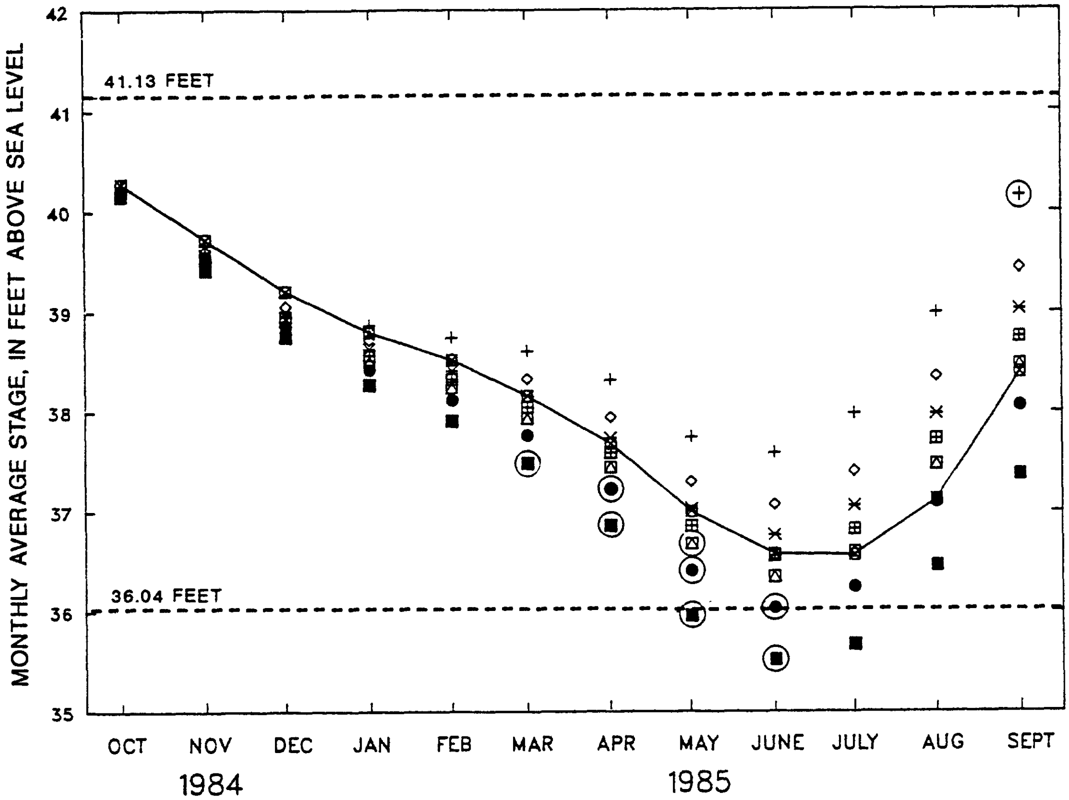
The cumulative sum of average pumpage at the Cosme-Odessa well field through June is 83.65 Mgal/d; the cumulative sum of observed pumpage for the same period is 107.6 Mgal/d. This difference in pumpage accounts for the +0.35-ft difference between the stage that was computed by using 100 percent of average pumpage and the observed stage in June (table 27). The differences in estimated stages between those computed by using 50 to 100 percent and 100 to 150 percent of average pumpage were +0.92 and -0.91 ft, respectively (table 27). By the end of the estimated period in September, the observed stage, 38.39 ft, is slightly higher than the estimated stage that was computed by using 150 percent of average pumpage, 38.19 ft. The annual average of observed pumpage at the Cosme-Odessa well field, 11.93 Mgal/d, is 130 percent of the annual average of monthly pumpage, 9.16 Mgal/d (table 19). The differences in estimated stages that were computed by using 50 to 100 percent and 100 and 150 percent of average well-field pumpage were +1.21 and -1.20 ft, respectively, in September (table 27).

Another illustration of the effect of changing pumpage rates on lake stage follows for Starvation Lake. The sequential estimates of monthly average stage were computed by using the regression relation (table 7) that includes estimated water levels in Berger deep well (fig. 37) using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly pumpage rates (table 19) and observed rainfall (table 18). The observed and estimated stages for October 1984 through September 1985 are shown in figure 40.

The estimates of monthly average water level in Berger deep well that were used in the regression relation for change in stage (table 7) exceeded the range in values for the following percentages of average pumpage: 50 percent in August and September, 125 percent in April and May, and 150 percent for February through June. The estimates of stage that were computed by using 125 percent of average pumpage in May and June and those computed by using 150 percent of average pumpage for April through July exceeded the range in stage used in the regression relation (table 16).

The estimated stage that was computed by using 100 percent of average monthly well-field pumpage in June, 45.68 ft, is 0.37 ft higher than the observed stage. The estimated water level in Berger deep well in June that was computed by using 100 percent of well-field pumpage is 0.75 ft higher than the observed water level (fig. 37). The differences between the estimated stages that were computed by using 50 to 100 percent and 100 to 150 percent of average monthly pumpage are +2.19 and -2.19 ft, respectively, in June. At the end of the estimated period in September, the observed stage, 51.13 ft, was slightly above the stage computed using 75 percent of average pumpage, 51.01 ft (fig. 40). The differences between estimated stages that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +2.68 and -2.68 ft, respectively.

When the regression relation that includes well-field pumpage (table 8) is used, only the estimated stages that were computed by using 150 percent of average pumpage in May and June exceeded the range in stage used in the regression relation (table 16). The observed and sequential estimates of stage that were computed by using 50, 75, 90, 100, 110, 125, and 150 percent of average well-field pumpage for October 1984 through September 1985 are shown in figure 41. The estimated stage that was computed by using 100 percent of average well-field pumpage gradually diverges from the observed stage for October through June. In June, the estimated stage is 1.06 ft higher than the observed stage. The differences between estimated stages that were computed by using 50 to 100 percent and 100 to 150 percent of average well-field pumpage are ±1.61 ft in June.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Lake Alice, in feet above sea level

\+ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

✳ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

◪ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (tabla 25) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Lake Alice (table 26) computed with regression relation (table 7) including estimated water level in James deep well 11 (table 25) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

◉⊕◙ Estimated monthly average water level in James deep well 11 (table 26) exceeded range of values used in regression relation (table 15)

Figure 38. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation with sequential estimates of water level in James deep well 11 assuming varying rates of well-field pumpage, October 1984 through September 1985.

Table 27. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985

Year	Month	Observed stage	Monthly average stage computed using indicated percent of well-field pumpage in regression relation in table 8						
			50	75	90	100	110	125	150
1984	October	40.28	40.41	40.36	40.33	40.31	40.29	40.26	40.21
	November	39.73	39.93	39.83	39.78	39.74	39.70	39.64	39.54
	December	39.21	39.44	39.30	39.22	39.16	39.11	39.02	38.88
1985	January	38.80	39.17	38.99	38.88	38.81	38.74	38.63	38.45
	February	38.52	39.06	38.83	38.69	38.60	38.51	38.37	38.14
	March	38.16	38.95	38.66	38.49	38.38	38.26	38.09	37.81
	April	37.68	38.66	38.32	38.11	37.98	37.84	37.63	37.29
	May	37.00	38.04	37.64	37.40	37.24	37.08	36.84	36.44
	June	36.57	37.84	37.38	37.10	36.92	36.74	37.46	36.01
	July	36.56	38.19	37.68	37.38	37.17	36.97	36.66	36.16
	August	37.12	39.32	38.77	38.43	38.21	37.99	37.66	37.10
	September	38.39	40.60	40.00	39.63	39.39	39.15	38.79	38.19

The observed stage rapidly rose from July through September in response to above average rainfall. During this same period, the estimated stages did not rise as quickly, and, in September, the estimated stage that was computed by using 100 percent of average pumpage was 1.36 ft lower than the observed stage (fig. 41). The differences between the estimated stages that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +1.84 and -1.84 ft, respectively, in September.

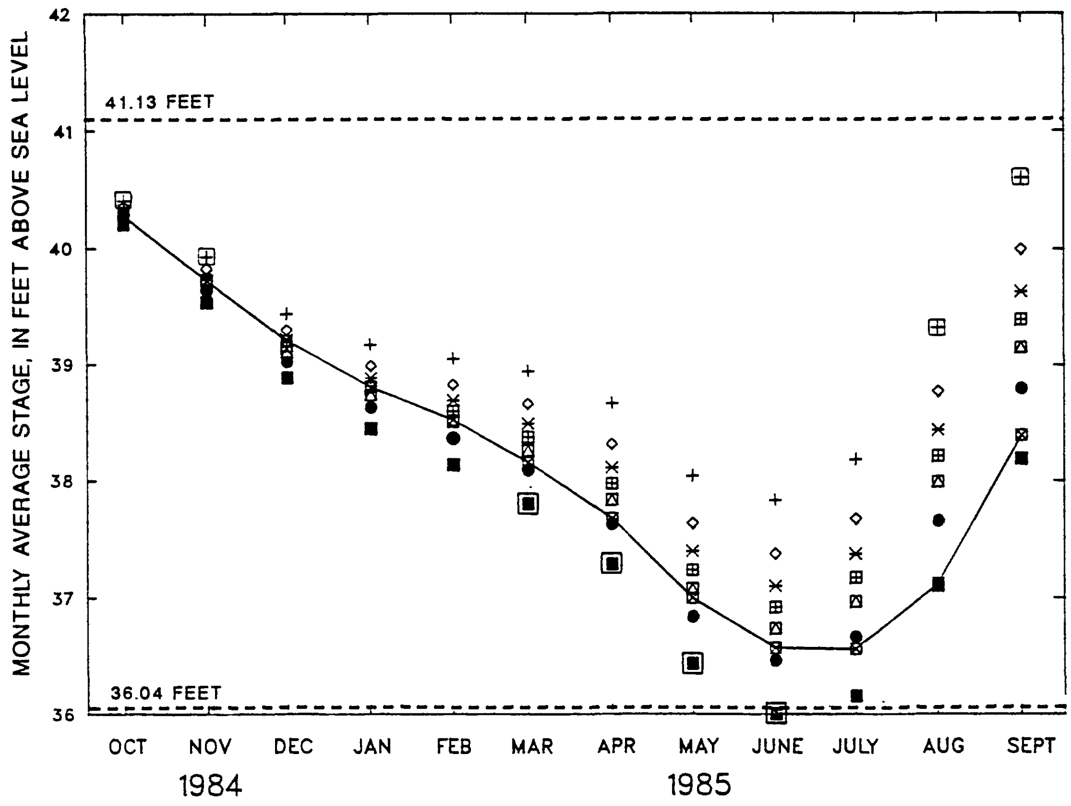
Effect of Changing Pumpage Rates on Water Levels in the Surficial Aquifer

An estimate of the effect of changing pumpage rates on water levels in the surficial aquifer can be obtained by varying the pumpage rates while keeping all other explanatory variables unchanged for a period of time. Estimates of water levels in an Upper Floridan aquifer well will be computed by using the regression relation in table 6 using varying pumpage rates. These estimated water levels are then used in the regression relation for change in water levels in the surficial aquifer (table 9). Another estimate of the effect of varying pumpage rates will be shown by using the regression relation that includes well-field pumpage rates (table 10).

The sequential estimates of monthly average water levels in Berger deep well that were computed by using varying pumpage rates in the previous section (fig. 37) were used to compute the estimates of monthly average water levels in Van Dyke shallow well. The observed and estimated monthly average water levels in Van Dyke shallow well for October 1984 through September 1985 were computed by using the regression relation (table 9) that includes estimates of water levels in Berger deep well when using 50, 75, 90, 100, 110, 125, and 150 percent of average well-field pumpage (table 28 and fig. 42). The estimated water levels that were computed by using 110 percent of average pumpage rate in May, 125 percent of average pumpage rate in April, May, and June, and 150 percent of average pumpage rate for February through July exceeded the range in water levels used in the regression relation (table 17).

The observed water level in May, 49.80 ft, is 0.12 ft higher than the water level estimated when using the 110 percent of average well-field pumpage rate. The sum of observed pumpage in Eldridge-Wilde, Northwest Hillsborough, Section 21, and South Pasco well fields that were used in the regression relation for change in water levels in Berger deep well (table 6) was 104 percent of the average pumpage for the same period. The differences between the estimates of water levels in May that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +3.17 ft and -3.17 ft, respectively.

The water level rose rapidly from July through September because of above average rainfall (table 18). The observed water level in September, 56.17 ft, was 0.05 ft lower than the estimated water level that was computed by using 90 percent of average pumpage. The sum of annual averages of observed pumpage at the four well fields that were used in the regression relation for change in water levels in Berger deep well, 58.87 Mgal/d, was 104 percent of the sum of the annual average pumpage, 56.59 Mgal/d (table 19). The differences in the estimated water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage were +3.53 and -3.53 ft, respectively, in September.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Lake Alice, in feet above sea level

\+ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

✱ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

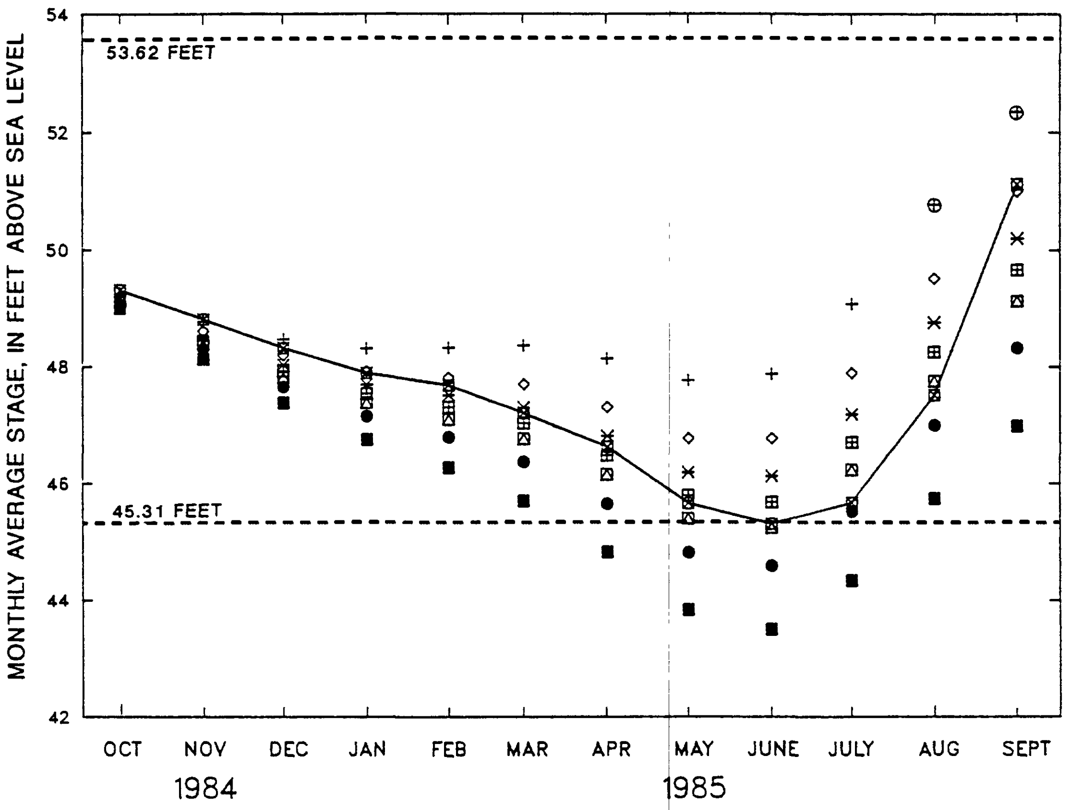
⧄ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

e Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Lake Alice (table 27) computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

▣ ⊞ Cosme well field average monthly pumpage exceeded the range of values used in the regression relation (table 16)

Figure 39. Observed and sequential estimates of monthly average stage in Lake Alice computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Starvation Lake, in feet above sea level

\+ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

✳ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

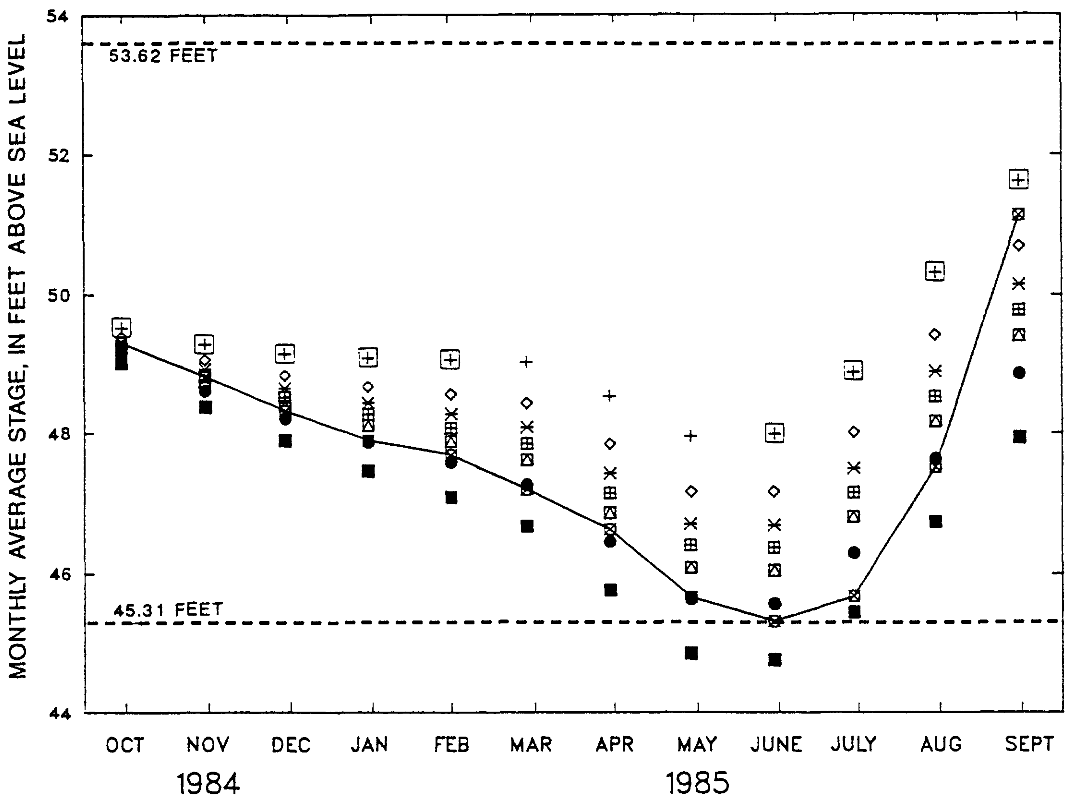
⧅ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including estimated water level in Berger deep well (table 8) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

⊕ Estimated monthly average water level in Berger deep well (fig. 37) exceeded range of values used in regression relation (table 15)

Figure 40. Observed and sequential estimates of monthly average stage in Starvation Lake computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rates of well-field pumpage, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average stage used in regression relation (table 16)

⊠ Observed monthly average stage in Starvation Lake, in feet above sea level

\+ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

✳ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

□ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

▨ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average stage in Starvation Lake computed with regression relation including well-field pumpage (table 8) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

⊞ South Pasco well field average monthly pumpage exceeded the range of values used in regression relation (table 16)

Figure 41. Observed and sequential estimates of monthly average stage in Starvation Lake computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985.

Table 28. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rates of well-field pumpage, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of well-field pumpage in regression relation in table 9						
			50	75	90	100	110	125	150
1984	October	52.33	52.57	52.41	52.31	52.25	52.18	52.09	51.92
	November	52.01	52.43	52.05	51.83	51.68	51.53	51.30	50.93
	December	51.55	52.42	51.83	51.48	51.25	51.01	50.66	50.07
1985	January	51.15	52.77	52.01	51.55	51.24	50.94	50.48	49.72
	February	50.93	53.33	52.39	51.83	51.45	51.07	50.51	49.57
	March	50.77	53.69	52.51	51.80	51.33	50.86	50.15	48.98
	April	50.41	53.90	52.49	51.65	51.09	50.53	49.69	48.29
	May	49.80	53.48	51.90	50.95	50.31	49.68	48.73	47.14
	June	49.96	54.19	52.53	51.54	50.87	50.21	49.21	47.55
	July	50.60	55.84	54.15	53.14	52.46	51.78	50.77	49.08
	August	52.06	57.71	56.01	54.99	54.30	53.62	52.60	50.89
	September	56.17	59.04	57.28	56.22	55.51	54.80	53.75	51.98

Another estimate of the effect of varying well-field pumpage on water levels in Van Dyke shallow well is obtained by using the regression relation that includes well-field pumpage (table 10). The observed and estimated monthly average water levels in Van Dyke shallow well for October 1984 through September 1985 were computed by using the regression relation in table 10 using 50, 75, 90, 100, 110, 125, and 150 percent of average well-field pumpage (table 29 and fig. 43). Only the estimated water levels that were computed by using 150 percent of average well-field pumpage in May and June were slightly lower than the range in water levels used in the regression relation (table 17).

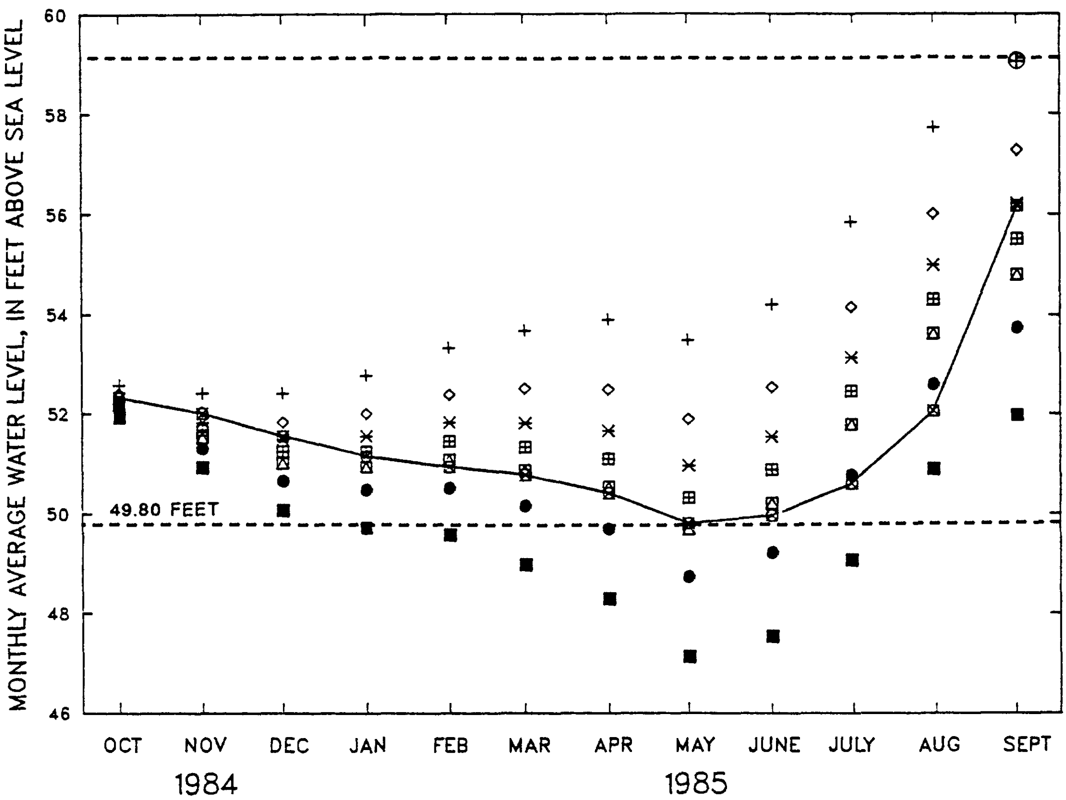
The observed water level in May, 49.80 feet, was only 0.04 ft higher than the estimated water level that was computed by using 150 percent of well-field pumpage. The observed pumpage rate for the Northwest Hillsborough well field that was used to compute the change in water levels in table 10 was 167 percent of the average pumpage for October through May. The differences between the estimates of water levels that were computed by using 50 to 100 percent of average pumpage and 100 to 150 percent of average pumpage in May were +1.32 and -1.32 ft, respectively (table 29).

The observed water level in September, 56.17 ft, was almost the same as the estimate that was computed by using 90 percent of average pumpage, 56.16 ft, (table 29). The sum of the annual averages of the observed pumpage at the Northwest Hillsborough and the South Pasco well fields, 21.58 Mgal/d, was 118 percent of the sum of the annual averages of the average monthly pumpage, 18.34 Mgal/d (table 19). The differences in estimated September water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage rates were +1.72 and -1.72 ft, respectively (table 29).

The changes in estimated water levels also were computed for St. Petersburg shallow well 105. As in the example for Van Dyke shallow well, the two regression relations in tables 9 and 10 were used to estimate the changes in water level caused by changes in well-field pumpage while holding all other explanatory variables unchanged.

The observed and estimated water levels in St. Petersburg shallow well 105 were computed by using the regression relations in table 9 that include the estimates of water levels in St. Petersburg deep well 105 when using 50, 75, 90, 100, 110, 125, and 150 percent of average pumpage (fig. 44). The observed water level in May, 51.73 ft, was between the estimates of water levels that were computed by using 110 and 125 percent of average well-field pumpage. The sum of the cumulative observed pumpage for October through May at Cosme-Odessa and South Pasco well fields that were used in the regression relation for change in St. Petersburg deep well 105, 199.8 Mgal/d, is 110 percent of the average pumpage for the same period, 181.51 Mgal/d. The difference in estimates of May water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +1.73 and -1.73 ft, respectively.

At the end of the estimated period in September, the observed water level, 57.66 ft, almost coincided with the estimate that was computed by using 100 percent of well-field pumpage, 57.71 ft. The sum of the annual averages of observed pumpage at the Cosme-Odessa and South Pasco well fields, 23.98 Mgal/d, is 107 percent of the sum of the average pumpage for the same period, 22.38 Mgal/d. The differences in estimates of September water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +2.40 and -2.40 ft, respectively.



EXPLANATION

-- Highest or lowest water level in Van Dyke shallow well used in regression relation (table 17)

⊠ Observed monthly average water level in Van Dyke shallow well, in feet above sea level

\+ Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

* Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

◩ Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in Van Dyke shallow well (table 28) computed with regression relation (table 9) including estimated water level in Berger deep well (fig. 37) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

⊕ Estimated monthly average water level in Berger deep well exceeded range of values used in regression relation (fig. 37)

Figure 42. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation with sequential estimates of water level in Berger deep well assuming varying rates of well-field pumpage, October 1984 through September 1985.

Table 29. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985

Year	Month	Observed water level	Monthly average water level computed using indicated percent of well-field pumpage in regression relation in table 10						
			50	75	90	100	110	125	150
1984	October	52.33	53.12	52.89	52.76	52.67	52.58	52.44	52.22
	November	52.01	52.65	52.35	52.17	52.05	51.93	51.75	51.45
	December	51.55	52.23	51.86	51.65	51.50	51.36	51.14	50.77
1985	January	51.15	52.60	52.19	51.94	51.78	51.61	51.37	50.96
	February	50.93	53.09	52.63	52.36	52.18	51.99	51.72	51.26
	March	50.77	53.40	52.89	52.58	52.38	52.17	51.86	51.35
	April	50.41	53.46	52.88	52.54	52.31	52.08	51.73	51.16
	May	49.80	52.40	51.74	51.34	51.08	50.82	50.42	49.76
	June	49.96	59.90	52.16	51.72	51.42	51.13	50.69	49.95
	July	50.60	54.67	53.87	53.40	53.08	52.76	52.29	51.49
	August	52.06	56.32	55.48	54.98	54.65	54.32	53.82	52.98
	September	56.17	57.53	56.67	56.16	55.81	55.47	54.95	54.09

Estimates of change in water levels that were computed by using the regression relation that includes well-field pumpage also were made for St. Petersburg shallow well 105. The observed and estimated monthly average stages were computed by using the regression relation that includes well-field pumpage (table 10) when using 50, 75, 90, 100, 110, 125, and 150 percent of average well-field pumpage (fig. 45).

The 50 percent of average pumpage rates for October through February and for June through September exceeded the range in pumpage values used in the regression relation (table 17). The 150 percent of average pumpage rates in April and May also exceeded the range in pumpage values used in the regression relation. None of the estimated water levels exceeded the range in values used in the regression relation.

The observed water levels are a little over a foot lower than the estimates that were computed by using 100 percent of average pumpage for February through May. In May, the estimate of water level that was computed by using 100 percent of average pumpage was 1.05 ft higher than the observed. The differences between the estimates of May water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +1.00 and -1.00 ft, respectively.

The observed and estimated water levels rose from June through September, and in September, the observed and estimated water levels that were computed by using 100 percent of average pumpage were the same. The differences between the estimates of September water levels that were computed by using 50 to 100 percent and 100 to 150 percent of average pumpage are +1.00 and -1.00 ft, respectively.

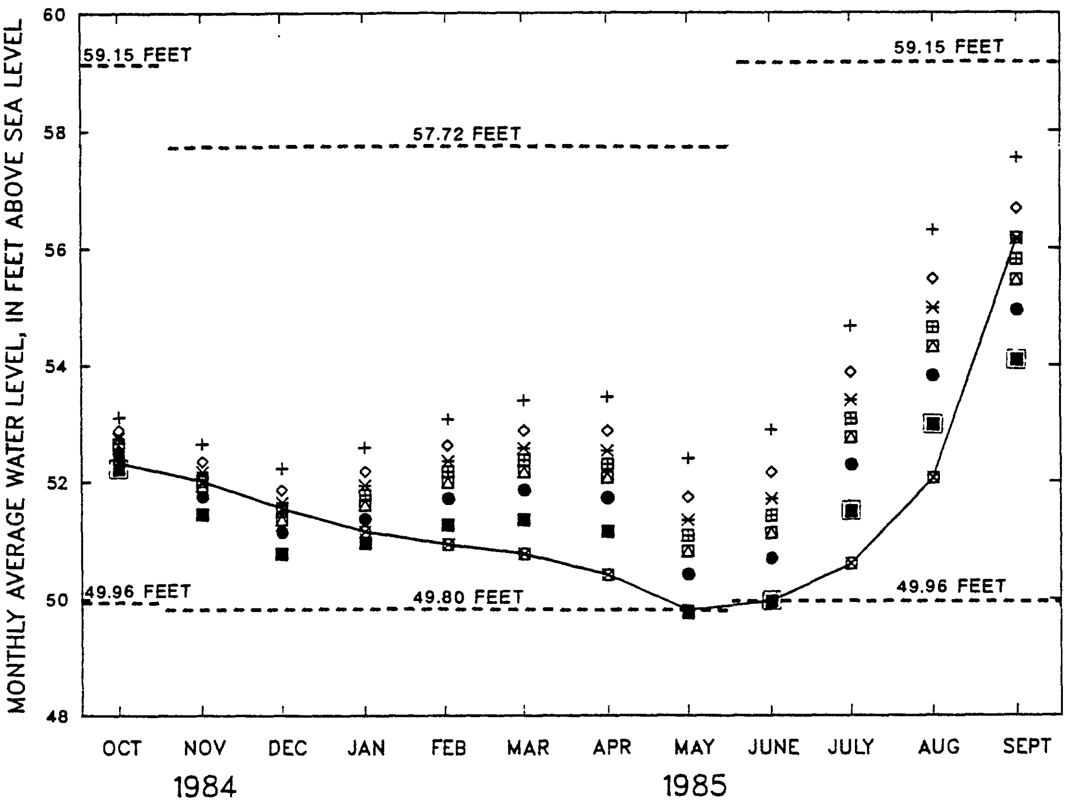
SUMMARY AND CONCLUSIONS

There are six municipal water-supply well fields in northwest Hillsborough, northeast Pinellas, and south Pasco Counties that have pumped a total of between 60 and 80 Mgal/d since 1972. Well-field pumpage from the Upper Floridan aquifer may increase in response to the rapidly growing water demand, and the effect of increased ground-water withdrawals on the lake levels and surficial aquifer needed to be assessed.

Regression analysis was used to determine the effects of well-field pumpage, rainfall, and potential evaporation on the change in monthly average water level in the Upper Floridan aquifer, in lakes, and in the surficial aquifer.

A stepwise multiple linear-regression analysis was used to relate the change in monthly average water level in 29 Upper Floridan aquifer wells to monthly rainfall, potential evaporation, and monthly average pumpage from nearby well fields. Pumpage generally was the most statistically significant explanatory variable. The regression coefficient of determination, R^2, which when multiplied by 100 indicates the percentage of the variation of the dependent variable that is explained by the explanatory variables, ranged from 0.40 to 0.90. The root mean square error ranged from 0.18 to 2.20 ft.

Changes in monthly average lake stage in 24 lakes were related to monthly rainfall, monthly potential evaporation, the previous month's average water level, and the water level in a nearby Upper Floridan aquifer well. Because rainfall characteristics are seasonal, regression relations for two periods, November through May and June through October,



EXPLANATION

-- Highest or lowest water level in Van Dyke shallow well used in regression relation (table 17)

⊠ Observed monthly average water level in Van Dyke shallow well, in feet above sea level

\+ Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

* Sequential estimate of monthly average water level in Van Dyke shallow well (taole 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

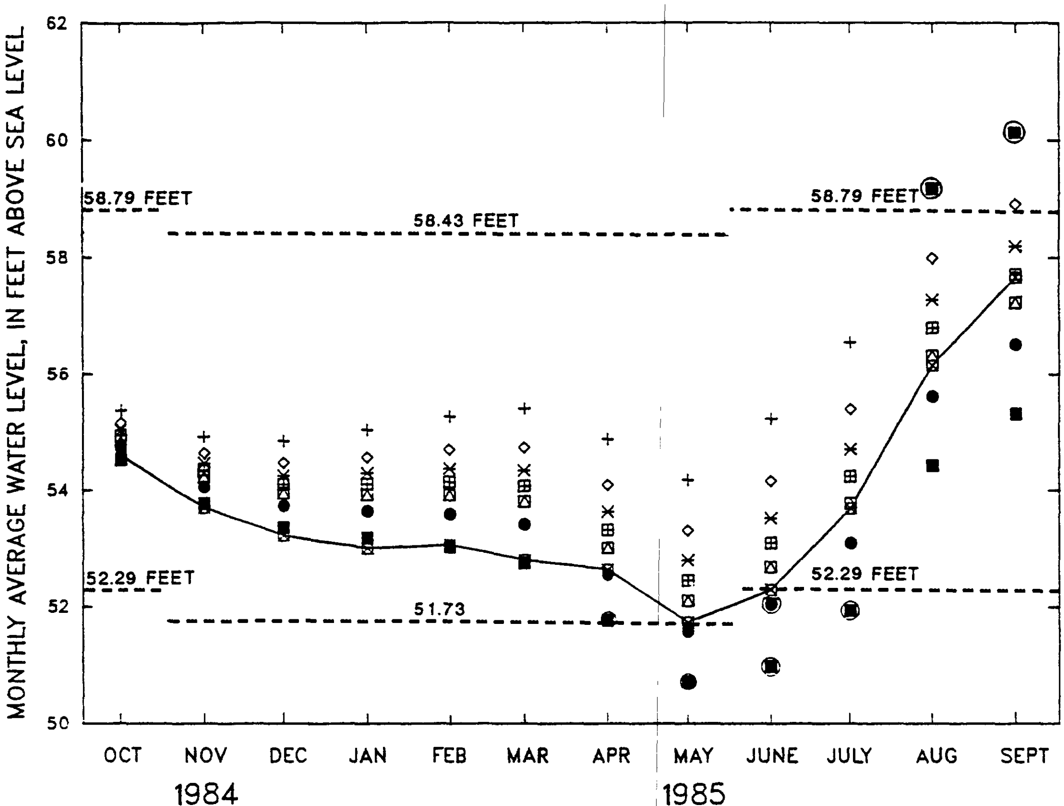
⧄ Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in Van Dyke shallow well (table 29) computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

▣ South Pasco well field average monthly pumpage exceeded the range of values used in regression relation (table 17)

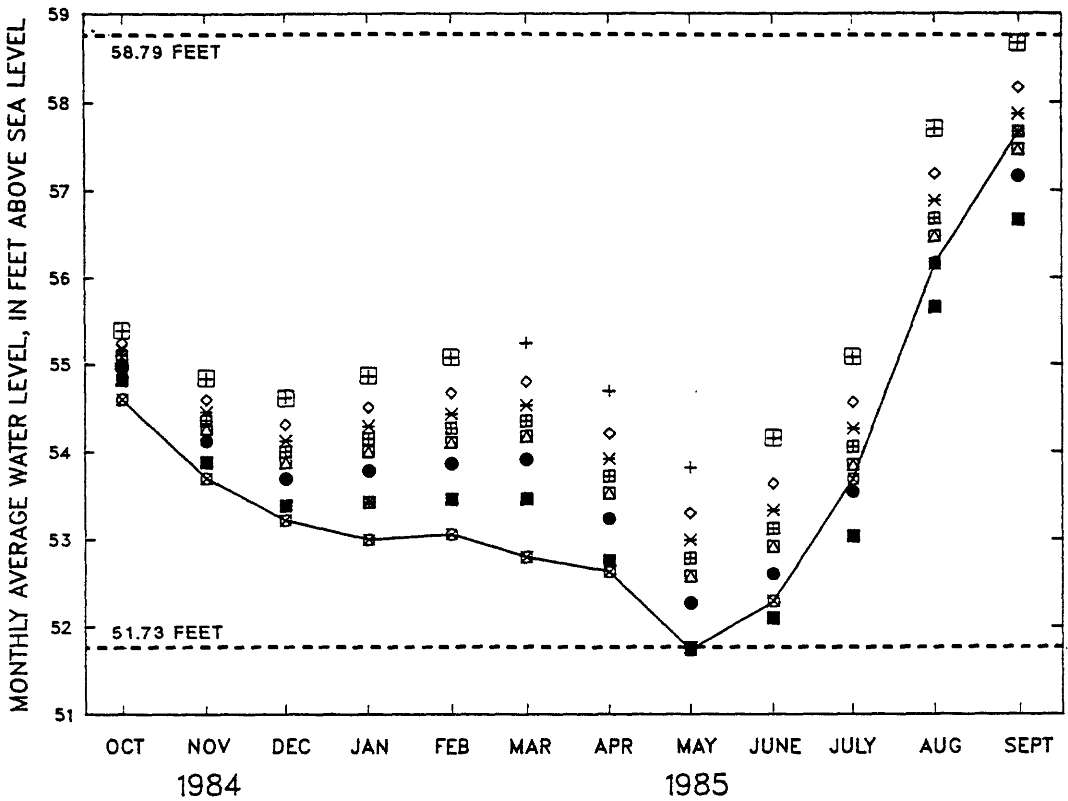
Figure 43. Observed and sequential estimates of monthly average water level in Van Dyke shallow well computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985.



EXPLANATION

- Highest or lowest monthly average water level in St. Petersburg shallow well 105 in regression relation (table 17)
- Observed monthly average water level in St. Petersburg shallow well 105, in feet above sea level
- \+ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)
- ◇ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)
- * Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)
- ⊞ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)
- Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)
- ● Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)
- ■ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including estimated monthly average water level in St. Petersburg deep well 105 (table 9) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)
- Estimated monthly average water level in St. Petersburg deep well 105 exceeded the range of values used in regression relation (table 17)

Figure 44. Observed and sequential estimates of monthly average water level in St. Petersburg shallow well 105 computed by using regression relation with sequential estimates of water level in St. Petersburg deep well 105 assuming varying rates of well-field pumpage, October 1984 through September 1985.



EXPLANATION

-- Highest or lowest monthly average water level in St. Petersburg shallow well 105 used in regression relation (table 17)

⊠ Observed monthly average water level in St. Petersburg shallow well 105, in feet above sea level

+ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 50 percent of average monthly well-field pumpage (table 19)

◇ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 75 percent of average monthly well-field pumpage (table 19)

✱ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 90 percent of average monthly well-field pumpage (table 19)

⊞ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 100 percent of average monthly well-field pumpage (table 19)

⧄ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 110 percent of average monthly well-field pumpage (table 19)

• Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 125 percent of average monthly well-field pumpage (table 19)

■ Sequential estimate of monthly average water level in St. Petersburg shallow well 105 computed with regression relation including well-field pumpage (table 10) using observed rainfall (table 18) and 150 percent of average monthly well-field pumpage (table 19)

▣ South Pasco well field average monthly pumpage exceeded the range of values used in regression relation (table 17)

Figure 45. Observed and sequential estimates of monthly average water level in St. Petersburg shallow well 105 computed by using regression relation that includes well-field pumpage assuming varying rates of well-field pumpage, October 1984 through September 1985.

were compared to a regression relation for all months. If the mean square error of the all-months regression relation was less than 10 percent greater than the weighted average of the mean square errors of the two seasonal regression relations, the all-months relation was used. Otherwise, the two seasonal regression relations were used in this report. The root mean square error for the 10 all-months regression relations varied from 0.15 to 0.51 ft. The root mean square error varied from 0.12 to 0.35 ft for the November through May season and from 0.22 to 0.46 ft for the June through October season.

Another set of regression relations was developed to relate the change in lake stage to well-field pumpage, rainfall, potential evaporation, and lake level the previous month. Regression relations applicable in all months were determined for 12 lakes. The root mean square error varied from 0.20 to 0.53 ft. The root mean square error for the two seasonal regression relations varied from 0.11 to 0.27 ft for the November through May season and from 0.21 to 0.51 ft for the June through October season.

The root mean square error of the regression relations for some lakes was not reduced by inclusion of water level in an Upper Floridan aquifer well or by well-field pumpage. The all-year regression relations for Lake Rogers included neither, and the all-year regression relations for Buck Lake did not include well-field pumpage. The root mean square error for these lakes varied from 0.26 to 0.29 ft. The November through May season regression relation for Pretty Lake did not include the water level in an Upper Floridan aquifer well, and the regression relations for Lake Allen and Crescent Lake did not include well-field pumpage. The root mean square error for these lakes varied from 0.21 to 0.35 ft. The June through October regression relations for Glass Lake and Island Ford Lake did not include the water level in an Upper Floridan aquifer well, and the regression relations for Church Lake, Crescent Lake, Glass Lake, Lake Juanita, and Keystone Lake did not include well-field pumpage. The root mean square error for these regression relations varied from 0.29 ft in Church Lake to 0.77 ft in Crescent Lake.

Rainfall is the most significant explanatory variable in most regression relations. During the drier November through May season, the influence of the water level in an Upper Floridan aquifer well or well-field pumpage increases. The regression relations for lakes with little or no surface inflow or outflow channels had the higher R^2 and lower root mean square error.

Only three wells in the surficial aquifer had sufficient data to compute monthly mean water levels during the 1972 through 1985 study period. Regression relations for the change in monthly average water levels, which included the water level in an Upper Floridan aquifer well as an explanatory variable, had R^2 that varied from 0.65 to 0.84 and RMSE that varied from 0.43 to 0.67 ft. The regression relations that included well-field pumpage as an explanatory variable had R^2 that varied from 0.48 to 0.79 and RMSE that varied from 0.38 to 0.97 ft.

The regression relations for change in water level in a well or change of stage in a lake were used to estimate the water level or lake stage for the next month. The estimate for 1 month is the previous month's observed water level or stage plus the change in water level or lake stage. A sequential estimate of more than 1 month is made by adding the change in water level or stage to the previous month's estimated water level or lake stage.

Applications of the regression relations in 1-month and sequential estimates for October 1984 through September 1985 were made for two Upper Floridan aquifer wells (James deep well 11 and Berger deep well), two lakes (Lake Alice and Starvation Lake), and two surficial aquifer wells (Van Dyke shallow well and St. Petersburg shallow well 105).

One-month and sequential estimates of the water level in James deep well 11 were within 1 ft of the observed water level after January. The 1-month estimate was 0.08 ft lower than the minimum water level in May, and the sequential estimate was 0.13 ft lower than the minimum water level in May.

One-month and sequential estimates of the water level in Berger deep well followed the rise in water levels in January and February that were caused by the reduction in pumpage from the Section 21 well field. The 1-month estimate of water level was 0.31 ft lower and the sequential estimate was 0.27 ft higher than the minimum water level observed in May.

One-month and sequential estimates of stage in Lake Alice, computed by using the regression relation that includes estimates of the water level in James deep well 11, followed the decline in stage through June within 0.33 ft. The estimate that was computed by using the regression relation that includes well-field pumpage also followed the decline in stage through June.

One-month and sequential estimates of stage in Starvation Lake, computed by using the regression relation that includes estimates of water level in Berger deep well and the relation that includes well-field pumpage, followed the decline in stage through May within 0.35 ft. The 1-month estimates of stage that uses these two regression relations were 0.20 and 0.29 ft higher, respectively, than the minimum stage observed in June. The sequential estimates were 0.51 and 0.10 ft higher, respectively, than the stage observed in June.

One-month and sequential estimates of the water level in Van Dyke shallow well, computed by using the regression relation that includes estimates of the water level in Berger deep well, were 0.20 ft lower and 0.61 ft higher, respectively, than the minimum observed water level in May. The 1-month and sequential estimates, computed by using the regression relation that includes well-field pumpage, were 0.95 and 0.73 ft lower, respectively, than the minimum water level in May.

The 1-month and sequential estimates of water level in St. Petersburg shallow well 105, computed by using the regression relation that includes estimates of the water level in St. Petersburg deep well 105, were 0.02 and 0.48 ft higher, respectively, than the minimum water level observed in May.

The 1-month and sequential estimates that were computed by using the regression equation that includes well-field pumpage were 0.21 and 1.14 ft higher, respectively, than the minimum water level observed in May.

The application of the regression relations for change in water level or change in stage may not give reliable estimates of water level or stage when the values of the explanatory variables are beyond the range of values used to determine the regression relation. Tables listing the range in values of each explanatory variable used in the regression relations, including water level in an Upper Floridan aquifer well or well-field pumpage, are presented in this report as a guide for application of these relations.

To illustrate the effect of changing rainfall on the estimates of change in water levels in wells and the estimates of change in lake stages, sequential estimates of changes from October 1984 through September 1985 were computed to estimate water levels in four wells and stages in two lakes by using varying percentages of average rainfall while maintaining other explanatory variables as unchanged. The average monthly rainfall for the period of time that was used to determine most of the regression relations, 1974 through 1985, was used in the computations. Sequential estimates were computed by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly rainfall. The range in rainfall values that was used in the computations did not exceed the range in values that was used to determine the regression relations.

The sequential estimate of the water level in James deep well 11, computed by using 50 percent of average monthly rainfall at the Cosme-Odessa well-field rain gage, was 0.25 ft higher than the observed water level in May. The cumulative rainfall through May was 3.10 in. less than the 50 percent of the cumulative monthly average rainfall for the same period. The difference in estimates of water level in May, which were computed by using 50 and 100 percent of average monthly rainfall is -2.26 ft. The difference computed using 100 and 150 percent of average monthly rainfall is +2.27 ft.

The sequential estimate of the water level in Berger deep well, computed by using 50 percent of average monthly rainfall at the Section 21 well-field rain gage, was 0.45 ft higher than the minimum monthly average water level in May. The cumulative observed rainfall through May was 0.01 in. more than the cumulative average monthly rainfall for the same period. The differences in estimates of water level in May, which were computed by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall, are -2.37 and +2.37 ft, respectively.

Sequential estimates of stage in Lake Alice were computed by using the regression relation that includes estimates of the water level in James deep well 11 and by using the regression relation that includes well-field pumpage when varying percentages of average monthly rainfall. The estimate of stage, which was computed by using the regression relation that includes estimates of the water level in James deep well 11 when using 50 percent of average monthly rainfall, was 0.13 ft lower than the observed stage in June. The differences in estimates of stage in June, computed by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall, are -2.24 and +2.24 ft, respectively. The estimates of stage, which were computed by using the regression relation that includes well-field pumpage when using 50 percent of average monthly rainfall, was 0.17 ft lower than the observed stage in June. The differences between estimates of stage in June, computed by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall, are -2.71 and +2.71 ft, respectively.

Sequential estimates of change in stage in Starvation Lake were computed by using the regression relation that includes estimates of the water level in Berger deep well and by using the regression relation that includes well-field pumpage and varying percentages of average monthly rainfall. The differences in estimates of stage in June that were computed by using the regression that includes estimates of the water level in Berger deep well when using 50 and 100 percent and 100 and 150 percent of average monthly rainfall are -2.56 and +2.56 ft, respectively. The differences in estimates of stage in June, which were computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall, are -2.46 and +2.45 ft, respectively.

Sequential estimates of the water level in Van Dyke shallow well were computed by using the regression relation that includes estimates of the water level in Berger deep well and by using the regression relation that includes well-field pumpage and varying percentages of average monthly rainfall. The differences in estimates of the May water level that were computed by using the regression relation that includes estimates of the water level in Berger deep well and by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall are -1.95 and +1.95 ft, respectively. The differences in estimates of the water level in May computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall are -1.56 and +1.57 ft, respectively.

The differences in estimates of the May water level in St. Petersburg shallow well 105, which were computed by using the regression relation that includes estimates of the water level in St. Petersburg deep well 105 and by using 50 and 100 percent and 100 and 150 percent of average monthly rainfall, are -2.05 and +2.05 ft, respectively. These differences in May water levels, when using the regression relation that includes well-field pumpage, are -1.84 and +1.84 ft, respectively.

To illustrate the effect of changing well-field pumpage rates on the estimates of water levels in wells and lake stages, sequential estimates of changes from October 1984 through September 1985 were computed to estimate water levels in four wells and stages in two lakes by using varying percentages of average monthly well-field pumpage rates while maintaining the other explanatory variables as unchanged. The average monthly pumpage rate for 1974 through 1985 was used in the computations. Sequential estimates were computed by using 50, 75, 90, 100, 110, 125, and 150 percent of average monthly pumpage rates.

The sum of the cumulative observed monthly pumpage for October through May in the Cosme-Odessa and Section 21 well fields was slightly higher than the sum of the average pumpage rate for the same period. Consequently, the estimate of the water level in James deep well 11 that was computed by using 100 percent of average monthly pumpage was slightly higher than the observed water level in May. The differences in estimates of water level that were computed by using 50 and 100 percent and 100 and 150 percent of average pumpage rates are ±5.35 ft in May and ±4.48 ft in September.

The sum of the cumulative pumpage for October through May from the four well fields used in the regression relation for change in water level in Berger deep well was about the same as the average pumpage rate for the same period. The estimate of the water level that was computed by using 100 percent of average pumpage rate was 0.75 ft higher than the water level in May. The differences in the water levels computed by using 50 and 100 percent and 100 and 150 percent of average pumpage rates are ±5.12 ft in May and ±5.11 ft in September.

The estimates of stage in Lake Alice, which were computed by using the regression relation that includes the estimated water level in James deep well 11 and by using 100 percent of average well-field pumpage, closely approximates the observed stages through June. In June, the estimate of stage is only 0.02 ft lower than the observed. The differences in estimates of stage, computed by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage, are +1.04 and -1.03 ft, respectively, in June. The differences in estimates of stage, which were computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of average pumpage are +0.92 and -0.91 ft, respectively, in June.

In a similar manner, the effect of changing well-field pumpage on stages in Starvation Lake is illustrated. The differences in estimates of stage, computed by using the regression relation that includes estimates of the water level in Berger deep well and by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage, are ±2.19 ft in June. The differences in estimated stages that were computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of well-field pumpage were ±1.61 ft in June.

Sequential estimates of the water level in Van Dyke shallow well were computed by using the regression relation that includes estimates of the water level in Berger deep well and by using the regression relation that includes well-field pumpage and varying percentages of average well-field pumpage. The differences in estimates of water level, computed by using the regression relation that includes estimates of the water level in Berger deep well and by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage, were ±3.17 ft in May. The differences between estimates of stage that were computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage were ±1.32 ft in May.

Sequential estimates of water levels in St. Petersburg shallow well 105 were computed by using the regression relation that includes estimates of water levels in St. Petersburg deep well 105 and by using the regression relation that includes well-field pumpage and varying percentages of average well-field pumpage. The differences between estimates of water levels that were computed by using the regression relation that includes estimates of water levels in St. Petersburg deep well 105 and by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage were ±1.73 ft in May. The differences between estimates of water levels that were computed by using the regression relation that includes well-field pumpage and by using 50 and 100 percent and 100 and 150 percent of average well-field pumpage were ±1.00 ft in May.

The following conclusions are drawn from this study:

- The regression relations in this report can be used to evaluate the effect of changing rainfall or pumpage rates on water levels in wells and stage in lakes studied in this report.
- Changes in pumpage rates affect water levels in wells penetrating the Upper Floridan aquifer more than the same percent change in rainfall. The relative effects of changing pumpage rates and rainfall are related to the distance from the well to the well fields. The closer the well is to the pumping center, the greater the influence of a change in pumpage rates.
- Changes in rainfall affect stage in lakes more than the same percent change in pumpage rate, but the closer the lake is to a pumping center, the greater the influence of pumpage.
- Sequential estimates of water levels in wells and stage in lakes can be simulated by using the regression relations with varying rates of pumpage and rainfall to evaluate the effects of changes in pumpage and rainfall or to changes in the distribution of pumpage.