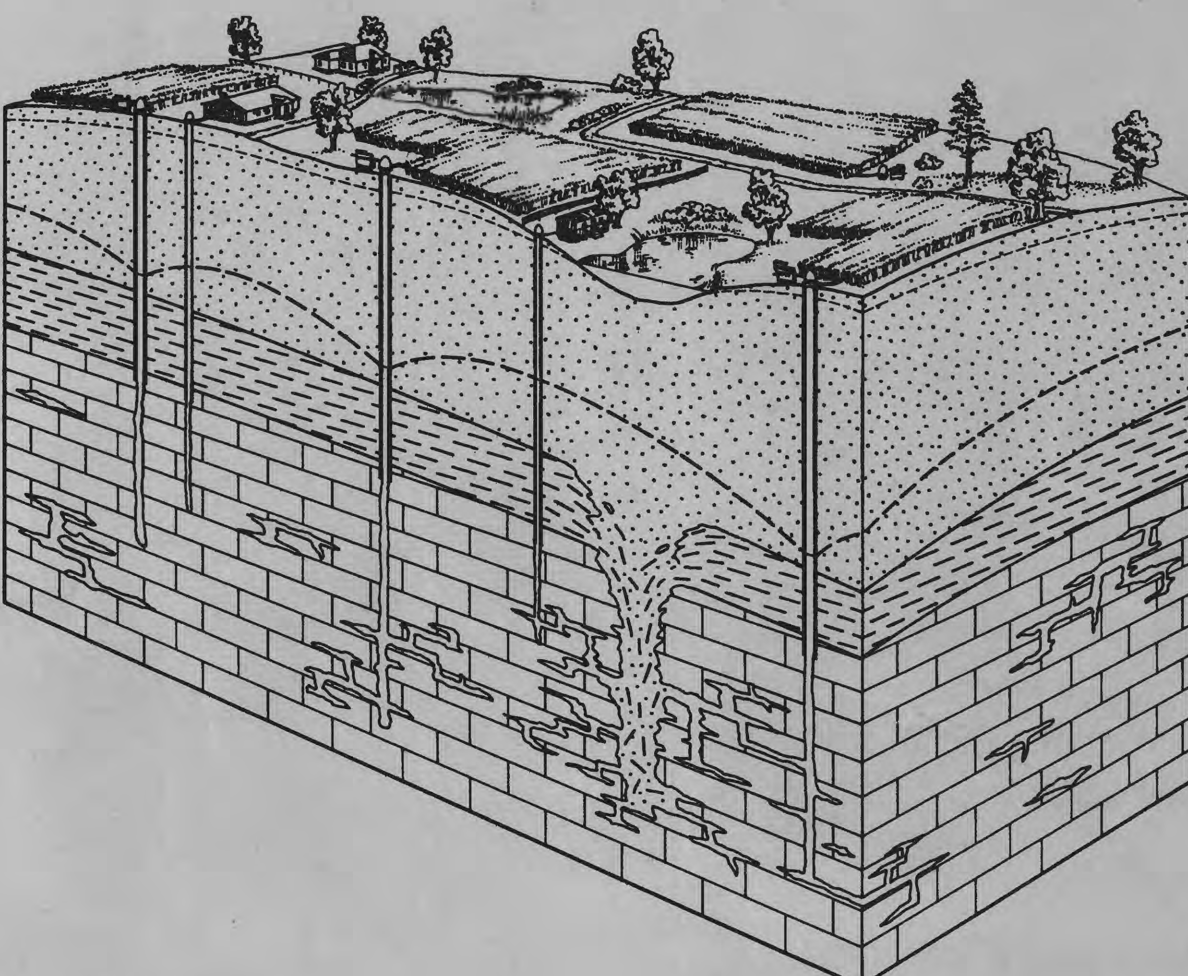
HYDROLOGY OF THE FLORIDAN AQUIFER IN NORTHWEST VOLUSIA COUNTY, FLORIDA



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 82-108

Prepared in cooperation with

VOLUSIA COUNTY and the

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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IN NORTHWEST VOLUSIA COUNTY, FLORIDA

By A. T. Rutledge

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1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than U.S. customary units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7636	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow	
gallon per minute (gal/min)	0.003785	cubic meter per minute (m^3/min)
million gallons per day (Mgal/d)	0.0438	cubic meter per second (m^3/s)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)

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

HYDROLOGY OF THE FLORIDAN AQUIFER
IN NORTHWEST VOLUSIA COUNTY, FLORIDA

By A. T. Rutledge

ABSTRACT

Northwest Volusia County, in east-central Florida, is a 262-square-mile area including the southern part of the Crescent City Ridge and the northern tip of the DeLand Ridge. The hydrogeologic units in the area include the Floridan aquifer, which is made up of parts of the Lake City Limestone, the Avon Park Limestone, and the Ocala Limestone, all of Eocene age; the confining bed, which is composed of clays of Miocene or Pliocene age; and the surficial aquifer, which is made up of Pleistocene and Holocene sands.

Ornamental fern growing is a $12 million per year industry in northwest Volusia County. Fern culture requires a large amount of good-quality water for irrigation, and more significantly, a large water withdrawal rate for freeze protection during winter months. The source of most water used is the Floridan aquifer. The large irrigation withdrawals, especially in winter months when spray irrigation is used for freeze protection of ferns, introduce problems such as the potential for saltwater intrusion, the temporary loss of water in domestic wells caused by large potentiometric drawdown, and increased sinkhole activity.

The water budget of the surficial layer consists of 55 inches per year rainfall, 39 inches per year evapotranspiration, 13 inches per year runoff, and a net downward leakage of 3 inches per year.

Average ground-water irrigational withdrawal is 8.1 million gallons per day, while the peak withdrawal rate is 300 million gallons per day during freeze-protection pumpage. The average irrigation well depth exceeds 300 feet.

Transmissivities of the Floridan aquifer range from 4,500 to 160,000 feet squared per day. Highest transmissivities are in the DeLeon Springs area and the lowest are in the east Pierson area. Storage coefficients range from 0.0003 to 0.0013.

The water budget of the Floridan aquifer under present conditions of withdrawal consists of 108 cubic feet per second recharge, 2 cubic feet per second horizontal ground-water inflow, 34 cubic feet per second direct discharge, 40 cubic feet per second upward leakage, 22 cubic feet per second horizontal outflow, and 14 cubic feet per second pumpage.

The Floridan aquifer contains good-quality water in most of the study area, but also contains brackish water underneath the stressed zones and in the upper zones along the western and southern limits of the area. The altitude of the fresh- saltwater interface varies in the area from 1,500 to 300 feet below sea level.

Areal drawdowns in the fern-growing areas of Pierson are 5 feet during growth irrigation periods and 20 to 30 feet during freeze-protection withdrawals. The drawdown in the Pierson area at the end of one intense period of pumpage exceeded 30 feet over a 4.4-square-mile area. A significant amount of the withdrawn water was replaced by leakage during the pumping period. Drawdowns in some pumping wells in northeast Pierson exceed 90 feet during freeze-protection withdrawals.

No long-term residual drawdown has occurred. The predominant effect of pumpage on the water budget of the Floridan aquifer has been an increase in recharge. Sinkhole activity has been increased by the temporary increase in load on the aquifer's skeletal structure during intense lowering of the potentiometric surface. There is no evidence of saltwater intrusion, but a monitoring network for future early detection is suggested.

INTRODUCTION

Description of Area and Problems

Northwest Volusia County in east-central Florida is a 262-square-mile area which is 10 miles west of Daytona Beach and 30 miles north of Orlando. The area is the northwestern fifth of Volusia County and includes the towns of Seville, Pierson, Emporia, Barberville, and DeLeon Springs (fig. 1). The area consists of approximately 35 percent flat to undulating upland terraces, 40 percent flatwoods, and 25 percent swamps. Numerous lakes are located throughout the area. The climate is subtropical, with an average temperature of 71°F and an average rainfall of 55 inches per year.

Ornamental fern growing is a $12 million per year industry in northwest Volusia County. Fern culture requires a large amount of good-quality water for irrigation, and more significantly, a large water withdrawal rate for freeze protection during winter months. The source of most water used is the Floridan aquifer.

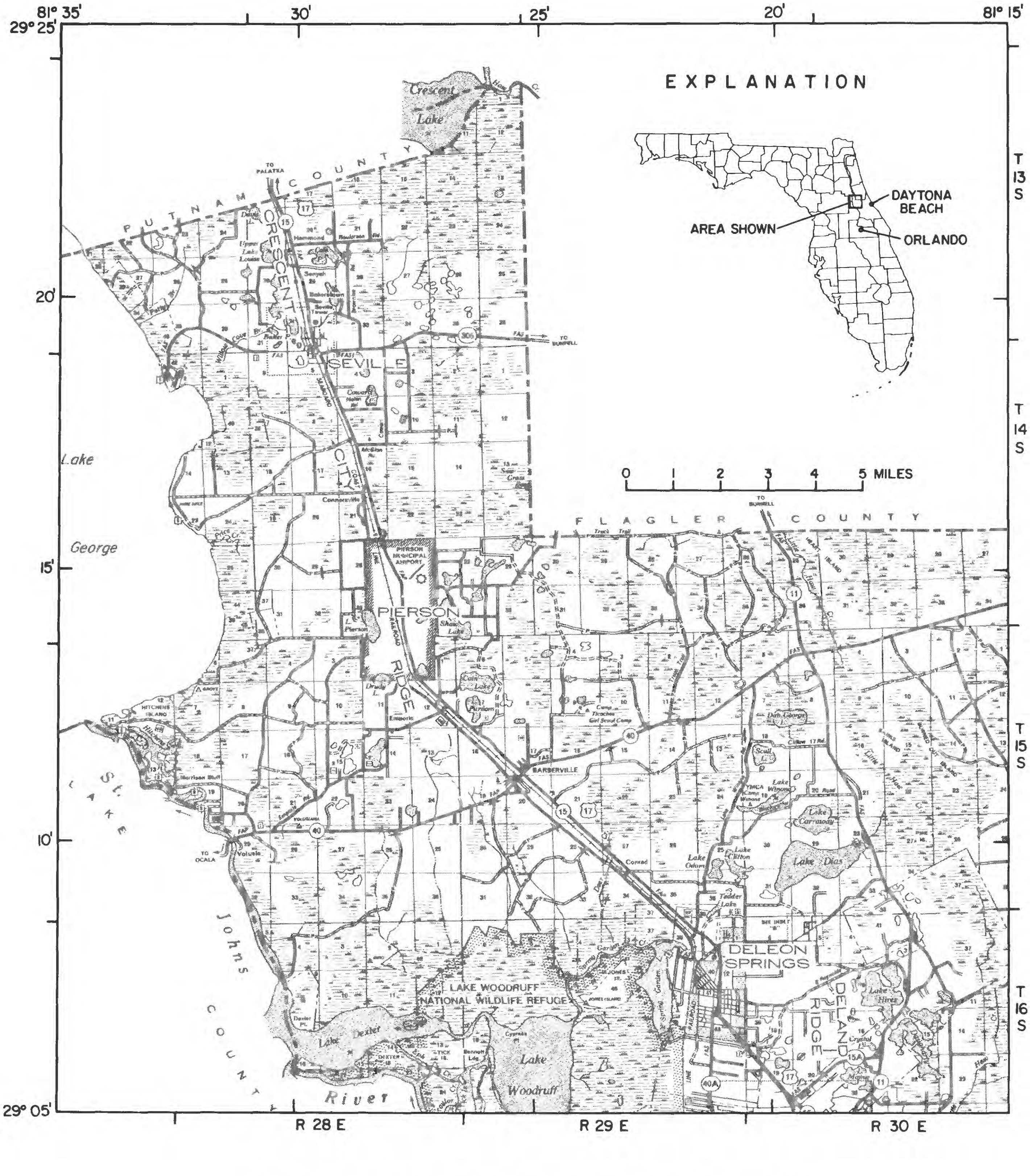


Figure 1.--Location of northwest Volusia County.

The problems related to ground-water withdrawals in northwest Volusia County include present withdrawals of brackish water in some areas, the potential for saltwater intrusion into other areas, the loss of water in domestic supplies caused by the lowering of the potentiometric surface below pump intakes in domestic wells, and increased sinkhole activity. Although the Floridan aquifer contains very good-quality water in most areas of northwest Volusia County, the upper part of the aquifer contains brackish water west of the fern-growing areas and saltwater is also present beneath the stressed zones of the aquifer throughout the area.

Purposes of Investigation

The primary purposes of the investigation are as follows:

1. Determine the physical properties and the water budget of the Floridan aquifer in northwest Volusia County.

2. Determine the rate of irrigational ground-water use, and the spacial distribution of irrigation wells in the study area. Investigate the temporal distribution of ground-water use.

3. Determine and describe the present extent of saltwater in the Floridan aquifer and the temporal variability of chloride concentration in the aquifer, including the variation during freeze-protection periods. Investigate the relation between ground-water irrigation withdrawals and saltwater intrusion. Set up a water-quality monitoring scheme for the purpose of early detection of vertical or horizontal saltwater migration into the stressed parts of the aquifer.

4. Describe and map the distribution of drawdown in the Floridan aquifer caused by freeze protection. Investigate the areas of maximum drawdown and the way in which this drawdown varies during freeze-protection pumping and also during the recovery period. Confirm estimates of the physical properties of the aquifer system by analyzing freeze-protection drawdown.

5. Describe past sinkhole activity in the northwest Volusia area. Investigate the relation of sinkhole activity to freeze-protection drawdown.

This is the first and final report of this investigation and is a description of the findings as they relate to the above purposes.

Scope of Investigation

The southern boundary of the study area is lat 29°05' and the eastern boundary is long 81°15'. The northern boundary and the southwestern boundary are the Volusia County line, and the remaining boundary is the eastern shore of Lake George. The study encompasses a 262-square-mile area, but most data were collected in the well-drained upland terraces where ferns are grown. Special emphasis is given to the Pierson area because of its large concentration of irrigation wells and the corresponding large magnitude of drawdown that occurs in that area. This investigation was performed during the 3-year period of 1978-80.

Some of the methods of analysis used in this investigation may be transferable to many areas where the effects of scattered pumping centers are being studied. Findings may be transferable to other areas where heavy transient withdrawal stresses are imposed on the Floridan aquifer.

It is not the purpose of this study to quantitatively predict saltwater intrusion. Such prediction would require data from a more extensive drilling, logging, and water-level observation effort supplemented by digital computer modeling of solute transport.

Previous Studies

The general ground-water hydrology of the study area was investigated and described by Wyrick (1960, 1961). His investigation was the first to describe the physical characteristics of the Floridan aquifer throughout Volusia County, and it, in effect, commenced accumulation of the historical water-level and water-quality data base which is needed to investigate the long-term effects of fernery irrigation. Knochenmus and Beard (1971) assessed the quality and quantity of both the surface- and ground-water resources of Volusia County; the ground-water assessment part resulted in the accumulation of new water-quality data for a number of wells that had been previously sampled by Wyrick. A map report by Knochenmus (1968) discussed drainage feasibility throughout the county. Bush (1978) presented a ground-water flow model of Volusia County.

Some water-quality data from 1950 to 1970 are available, including major-ion analyses of water from irrigation wells. Water levels have been measured periodically since the early 1950's in two wells in the flatwoods outlying the fern-growing areas.

Data Collection

Data collection included water-level measurements in wells, water-quality sampling from wells, and operation of water-level recorders to monitor variation of water level with time. The altitude of the measuring points of observation wells were determined so that accurate potentiometric maps and hydrographs could be constructed.

A considerable amount of information came from the inventory of irrigation wells. This detailed data-collection effort contributed to estimates of water use and to estimates of the spacial and temporal distribution of water use.

Geophysical logging, measurements of specific capacity of wells, and simple aquifer tests were used to give a better understanding of the physical properties of the aquifer system.

The great part of the water-level and water-quality data were collected just before, during, and immediately after freeze-protection periods. These types of data were also collected during high-water (September) and natural low-water (May) periods. Most water-level data were collected from wells that are not used for irrigation, whereas water-quality data were collected from irrigation wells. Geophysical logging, measurements of specific capacity, and aquifer tests were performed primarily at irrigation wells.

Base water-quality data from 1950 to 1970 were used to compare with present water-quality data to determine if chloride concentration has increased due to fernery irrigation. Historical water levels from a few observation wells were used to determine the historical change in water level and to determine if water levels have declined because of fernery irrigation.

Acknowledgments

This study was made in cooperation with Volusia County and with the St. Johns River Water Management District. The author gratefully acknowledges the assistance of William Hendrix and Barry Appleby of Volusia County, and Douglas Munch of St. Johns River Water Management District. This investigation could not have been done without the diligent work of many members of the staff of the U.S. Geological Survey, Orlando, Florida, especially Charles P. Laughlin.

Special thanks are given to the fern growers of northwest Volusia County who graciously allowed the use of their wells for aquifer testing, geophysical logging, water sampling, and water-level recording and who helped immensely in the compilation of the irrigation well inventory.

ENVIRONMENTAL SETTING

Geographic Setting

Land surface altitude varies from 3 to 115 feet in northwest Volusia County. The Seville area, the Pierson area, and the DeLeon Springs area are three topographic highs (fig. 2). From a broader perspective, the Seville high and the Pierson high together make up the southern end of the Crescent City Ridge, while the DeLeon Springs high is the northern segment of the DeLand Ridge. The topographic highs in northwest Volusia are surrounded by the lowlands around Lake George to the west, around Lake Woodruff to the south, in Flagler County to the northeast, and in the central Volusia flatwoods area to the east.

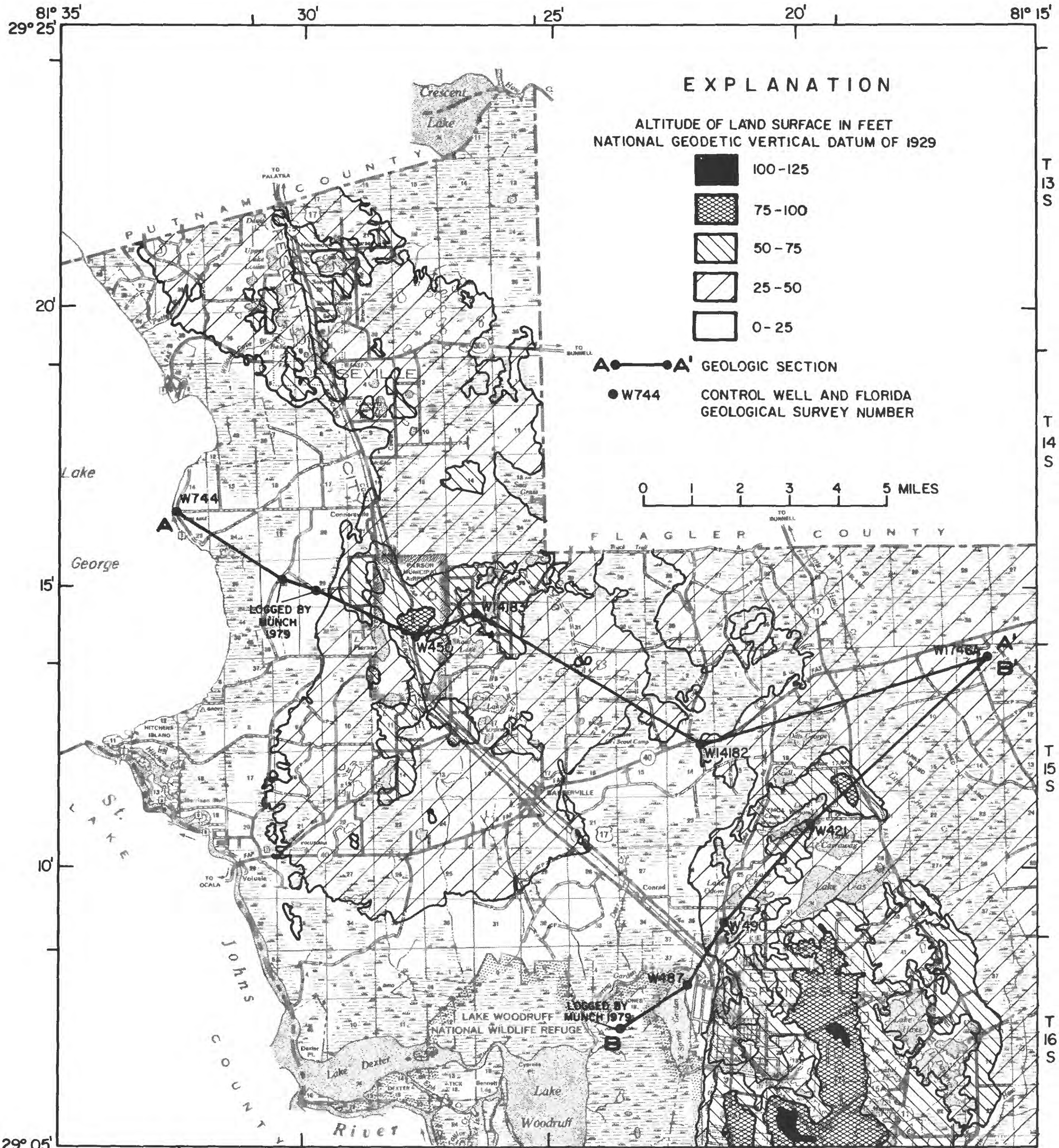


Figure 2.--Topography in northwest Volusia County.

Terrace formation during the Pleistocene played an important part in shaping the land surface in the northwest Volusia area (Cooke, 1945; Wyrick, 1960). The terraces of this area are expanses of land of relatively uniform altitude which were the sea floor while the sea level stood higher than present sea level. There are four recognizable terraces in northwest Volusia: (1) the Penholoway terrace, which was formed when the sea stood 70 to 80 feet above present level; (2) the Talbot terrace, which was formed when the sea stood 45 feet higher than present; (3) the Pamlico terrace, which was formed when the sea level stood 25 to 30 feet higher than present; and (4) the Silver Bluff terrace, which was formed when the sea stood 5 to 6 feet above its present level. The areas on figure 2 having land surface altitudes above 50 feet are remnants of the Penholoway terrace. The areas having altitudes between 25 and 50 feet are parts of the Talbot or Pamlico terraces while areas of less than 25-foot altitude are the Silver Bluff terrace. Terrace formation accounts for the flatness of the Seville and Pierson highs.

Karst topography is the name applied to the undulating, pitted land surface that occurs where sinkholes are numerous and drainage is underground. The Penholoway terrace is characterized by karst topography in northwest Volusia County. Karst topography is well developed in the DeLand Ridge and moderately developed in the Crescent City Ridge. This is evident from the greater relief in the DeLeon Springs area as compared to the Pierson and Seville areas and the absence of surface drainage features over a much larger part of the DeLeon Springs area. The terraces without karst topography remain flat and have well developed natural surface-drainage features. These stream systems are formed because the surplus of water that does not infiltrate into the ground must find a way out. Areas of karst topography are generally good recharge areas while non-karstic areas often have poor recharge or are areas of groundwater discharge.

Geologic Setting

Five stratigraphic units are discussed in the following paragraphs and are illustrated in figures 3 and 4. The Oldsmar Limestone of early Eocene age, although illustrated, is not discussed because no known water wells penetrate it in the study area and because it probably contains very little, if any, freshwater in the study area. Descriptions of the formations are from Wyrick (1960) and figures 3 and 4 were derived from geologic logs of the Florida Bureau of Geology. The lines of sections are shown in figure 2. Well numbers on these figures are assigned by the Florida Bureau of Geology.

The Lake City Limestone, of early middle Eocene age, consists of layers of dark brown dolomite separated by layers of chalky limestone. The dolomite is crystalline and contains few fossils while the limestone is very fossiliferous. The vertical extent of the Lake City Limestone at well W-1746A is from 420 feet below sea level at the top to 1,220 feet below sea level at the bottom (figs. 3 and 4). The top of this

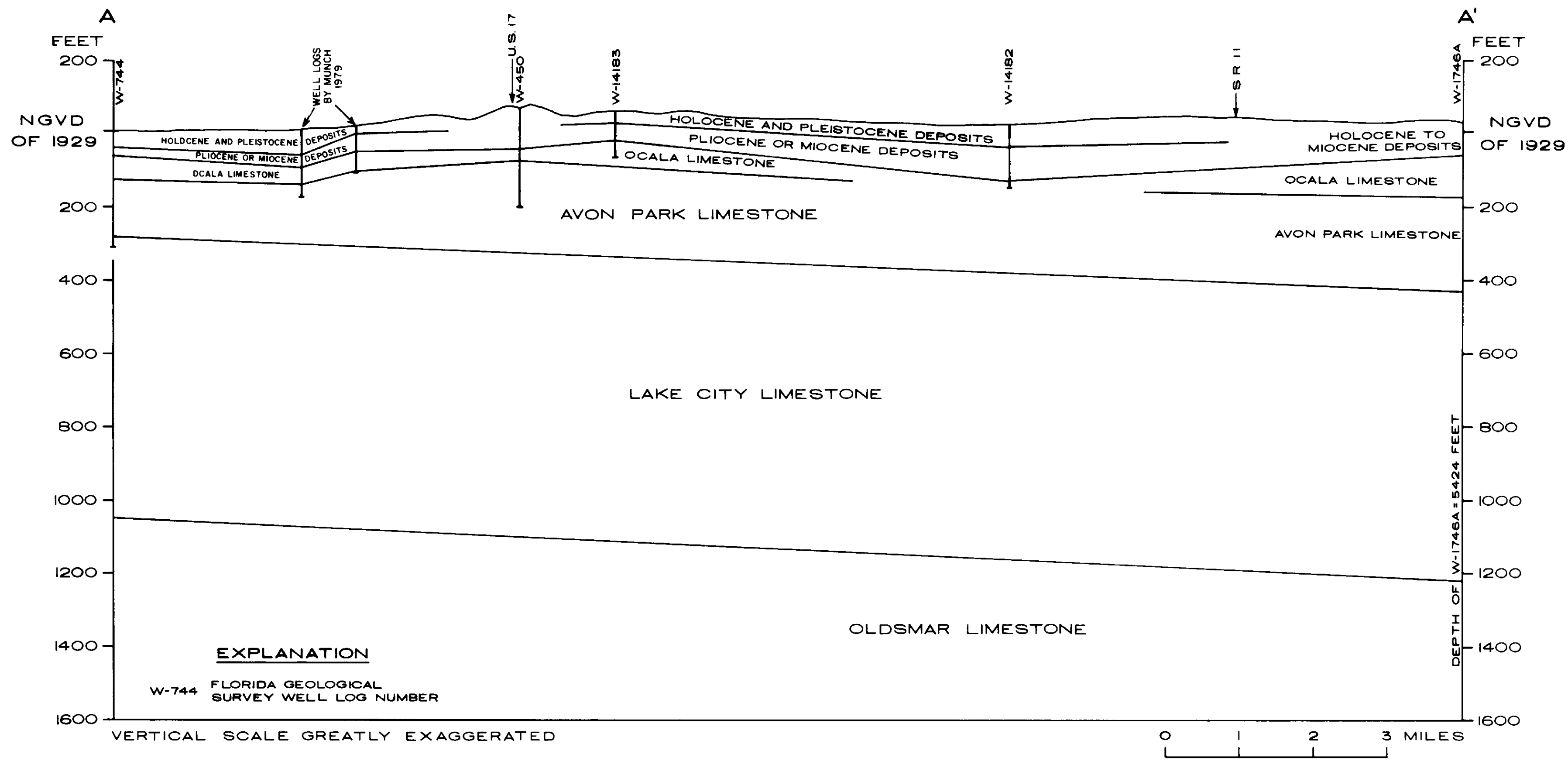


Figure 3.--Geologic section A-A' (trace of section in fig. 2).

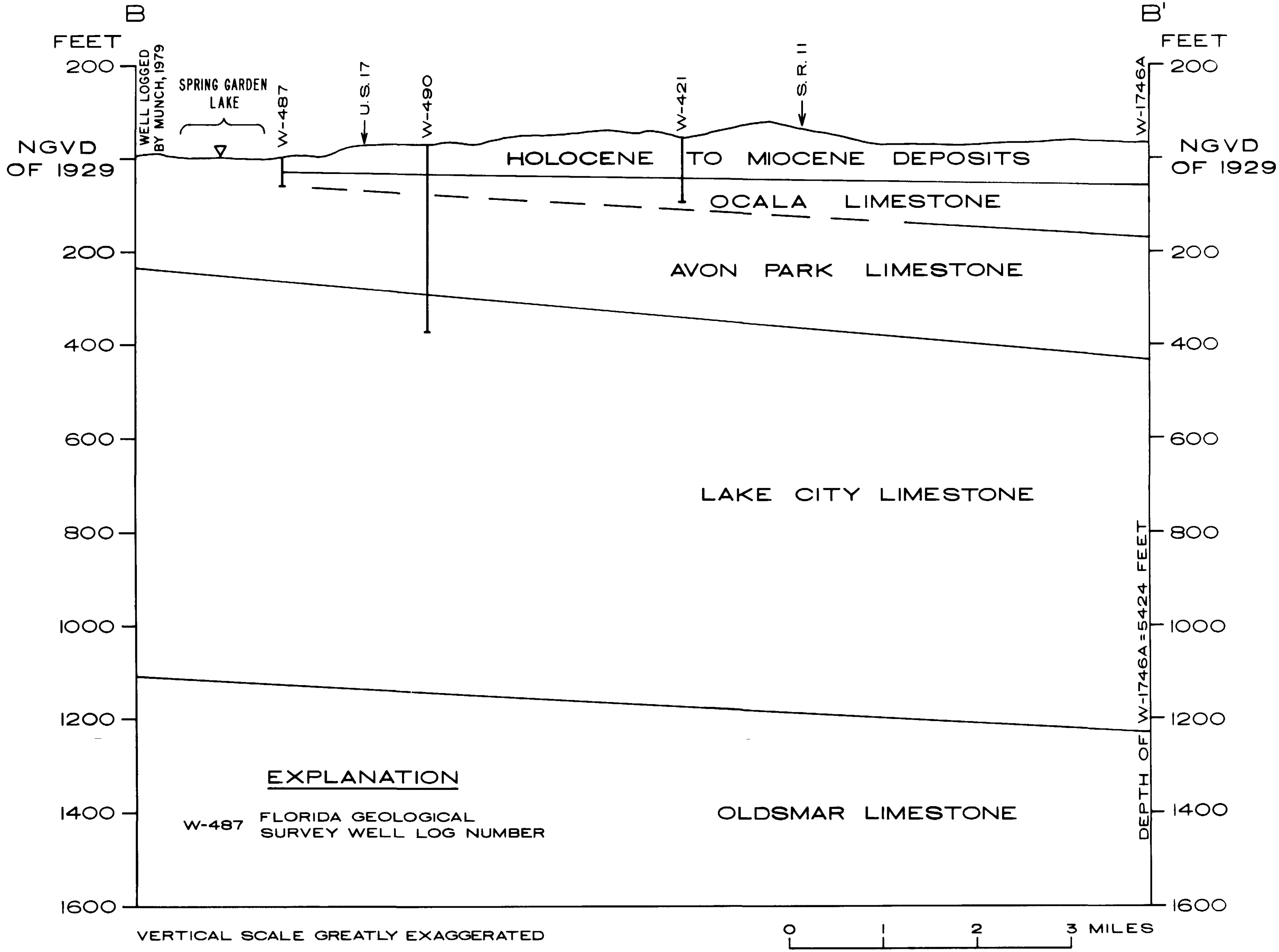


Figure 4.--Geologic section B-B' (trace of section in fig. 2).

formation is highest near Lake George, where its altitude is 280 feet below sea level. It has an eastward dip of approximately 8 feet per mile. The Lake City Limestone is tapped by at least 150 irrigation wells in northwest Volusia County.

The Avon Park Limestone, of late middle Eocene age, varies in color from chalky white to light brown or ashen gray, but most of it is tan. The limestone is extensively dolomitized. The formation is generally 180 to 250 feet thick in northwest Volusia. Some of the Avon Park Limestone was removed by erosion before the overlying Ocala Limestone was deposited. The Avon Park Limestone is thinnest in the extreme southern part of the study area, where the Ocala Limestone is absent. The highest altitude of the top of the Avon Park Limestone is approximately 10 feet near DeLeon Springs and the lowest altitude is approximately -150 feet near Seville. The formation, which has a slight eastward dip, is the principal source of water for irrigation in northwest Volusia. At least 400 irrigation wells tap it.

The Ocala Limestone, of late Eocene age, is composed of cream to white limestone mottled with gray zones. The Ocala Limestone is generally only slightly dolomitized in northwest Volusia County. Because of extensive erosion after deposition, the formation is very thin in most of northwest Volusia and absent at the southern limit of the study area. The formation is the main source of water for domestic use, but its importance for irrigation is secondary to the Avon Park Limestone because of its limited thickness.

The Miocene or Pliocene deposits which overlie the Ocala Limestone are made up of unconsolidated beds of fine sand, shells, and calcareous silty clays. Because the permeability of the clay beds in these deposits is low, they serve to confine water under pressure in the limestone formations below. The shell beds in these deposits supply small amounts of water to some domestic wells. The overall thickness of the Miocene or Pliocene deposits in northwest Volusia County is generally 20 to 70 feet.

The sediments of Pleistocene and Holocene age consist of fine- to medium-grained quartz sand, sandy clays, and locally, small amounts of shell. In some areas, the sand has been cemented into "hardpan" by deposition of iron oxide at the water table. The general thickness of the Pleistocene and Holocene deposits is 20 to 50 feet, but locally they can be as much as 100 feet thick. There is an abundance of small capacity irrigation wells producing water from these sediments in northwest Volusia, but the total withdrawal capacity is small in relation to that of the wells tapping the limestone formations.

Hydrologic Setting

Geohydrologic Units

The three geohydrologic units considered are the surficial aquifer, the confining bed, and the Floridan aquifer. The surficial aquifer is comprised of the sands of the Pleistocene and Holocene deposits; the confining bed generally consists of the clays of Miocene or Pliocene deposits; and the Floridan aquifer is made up of the Ocala, Avon Park, and Lake City Limestones of Eocene age.

The surficial aquifer is the layer of sand from land surface down to the first areally consistent and relatively impermeable layer of clay. If no clay is present it may be defined as the entire thickness of sand down to the Floridan aquifer. The surficial aquifer may contain zones of clay and hardpan. However, the clay zones are inconsistent enough and the hardpan is permeable enough that these do not significantly retard the flow of water in the aquifer. The surficial aquifer is generally 10 to 50 feet thick. Its thickness is greatest in the DeLeon Springs area, where it reaches 100 feet in a few places. The surficial aquifer is referred to as unconfined because its ground-water surface (water table) is the top of the zone of saturation and is free to rise and fall in the aquifer. Figure 5 shows fluctuations in the water table in eight shallow wells in the Crescent City Ridge part of the study area. In the Crescent City Ridge area the depth to water table averages 5 feet and exceeds 12 feet in very few places. In the DeLand Ridge the depth to the water table may average more than 20 feet. In swamps, the water table is close to land surface at all times.

Water enters the surficial aquifer by direct infiltration of rainfall and by upward leakage from the Floridan aquifer in areas of discharge from the Floridan aquifer. It leaves as evapotranspiration, runoff, and downward leakage in areas of recharge to the Floridan aquifer. Lateral movement into or out of the study area in the surficial aquifer is negligible because water-table gradients are small.

The importance of the surficial aquifer from a water-use standpoint is not so much its direct use for water supply but its function as a reservoir for recharge to the Floridan aquifer. Some recharge occurs to the Floridan aquifer in any area where the water table in the surficial aquifer is higher than the potentiometric surface in the Floridan. The surficial aquifer is most suitable as a source of recharge if (1) the depth to the water table is great, (2) the aquifer has a high specific yield, and (3) the thickness of the aquifer is great. The depth to the water table is important because a greater depth will reduce the loss of surficial aquifer water to evapotranspiration. A high specific yield will mean a greater storage of water for recharge and less loss of infiltrating water to unsaturated retention. A surficial aquifer with great thickness will provide a more consistent source of recharge during

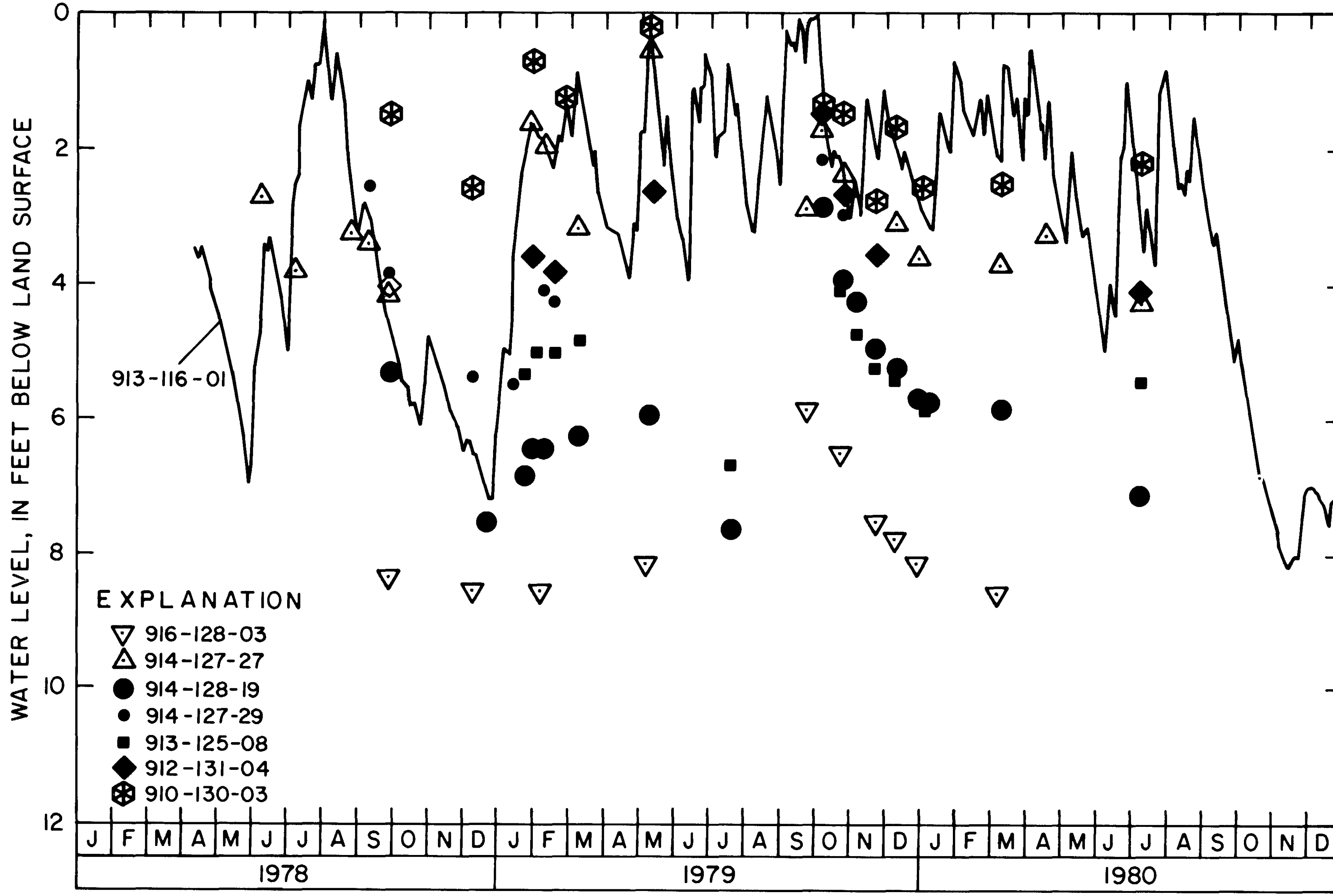


Figure 5.--Daily minimum depth below land surface to water level in shallow well 913-116-01 and periodic depths below land surface to water level in seven other shallow wells (well sites on fig. 9).

periods of drought. Because of the above-mentioned factors the deposits of the DeLand Ridge provide the best areas of recharge to the Floridan aquifer. The recharge rates vary in a descending order from ridges to flatwoods to swamps.

The confining bed is the composite of the clay layers that retard the flow of water between the surficial aquifer and the Floridan aquifer. The generalized thickness of clay map shown in figure 6 was compiled from drillers' logs, geologic logs, and geophysical logs. Areas of minimal clay thickness tend to be well suited to the vertical flow of water between the aquifers. Most of the DeLeon Springs area has very good recharge to the Floridan aquifer. The clay is also thin in the southern part of the Seville area and along the southeastern boundary of Lake George. Although the confining bed appears to be approximately 20 feet thick in the Pierson area, it may be extensively breached by sinkholes.

Figure 6 also shows the difference in hydraulic head between the surficial aquifer and the Floridan aquifer at several locations. This head difference is the driving force behind leakage and determines whether the leakage will be downward or upward. A positive head difference produces downward leakage, or Floridan aquifer recharge, while a negative head difference produces upward leakage, or Floridan aquifer discharge.

The rate of leakage at a given location is determined by the clay thickness, the head difference, and the hydraulic conductivity of the clay layer. The rate increases if the head difference or the hydraulic conductivity increases, while it decreases as the clay thickness is increased. It is relatively large in the DeLeon Springs area because the clay layer is thin. Leakage rates are low in the area between the Crescent City Ridge and the DeLand Ridge because the clay layer is thick and the head difference is relatively small.

The Floridan aquifer consists mainly of limestone of Eocene age. Its water-bearing capacity is derived from fissures and cavities within the limestone, and is constantly increased by the dissolution of the rock by slightly acidic rainwater recharging the aquifer. The top of the Floridan aquifer ranges between 30 and 150 feet below sea level (NGVD of 1929) in the study area but generally is 40 feet below sea level in the ridge areas (fig. 7). The depth to the Floridan at any point in the study area may be estimated by subtracting the altitude of the top of the Floridan aquifer (fig. 7) from land surface altitude. Because the head in the Floridan is higher than the top of the aquifer, and the aquifer is overlain by a confining bed, the aquifer is referred to as an artesian aquifer in northwest Volusia County. The bottom of the freshwater-containing zone in the Floridan may be as much as 1,400 feet below sea level in northwest Volusia County. Below this altitude are limestone and dolomite formations that are saturated with saltwater. The altitude of the top of this saltwater zone, which is the bottom of the freshwater zone, locally becomes higher than -300 feet along Lake George and near DeLeon Springs. The Floridan aquifer is discussed in greater detail in the later sections.

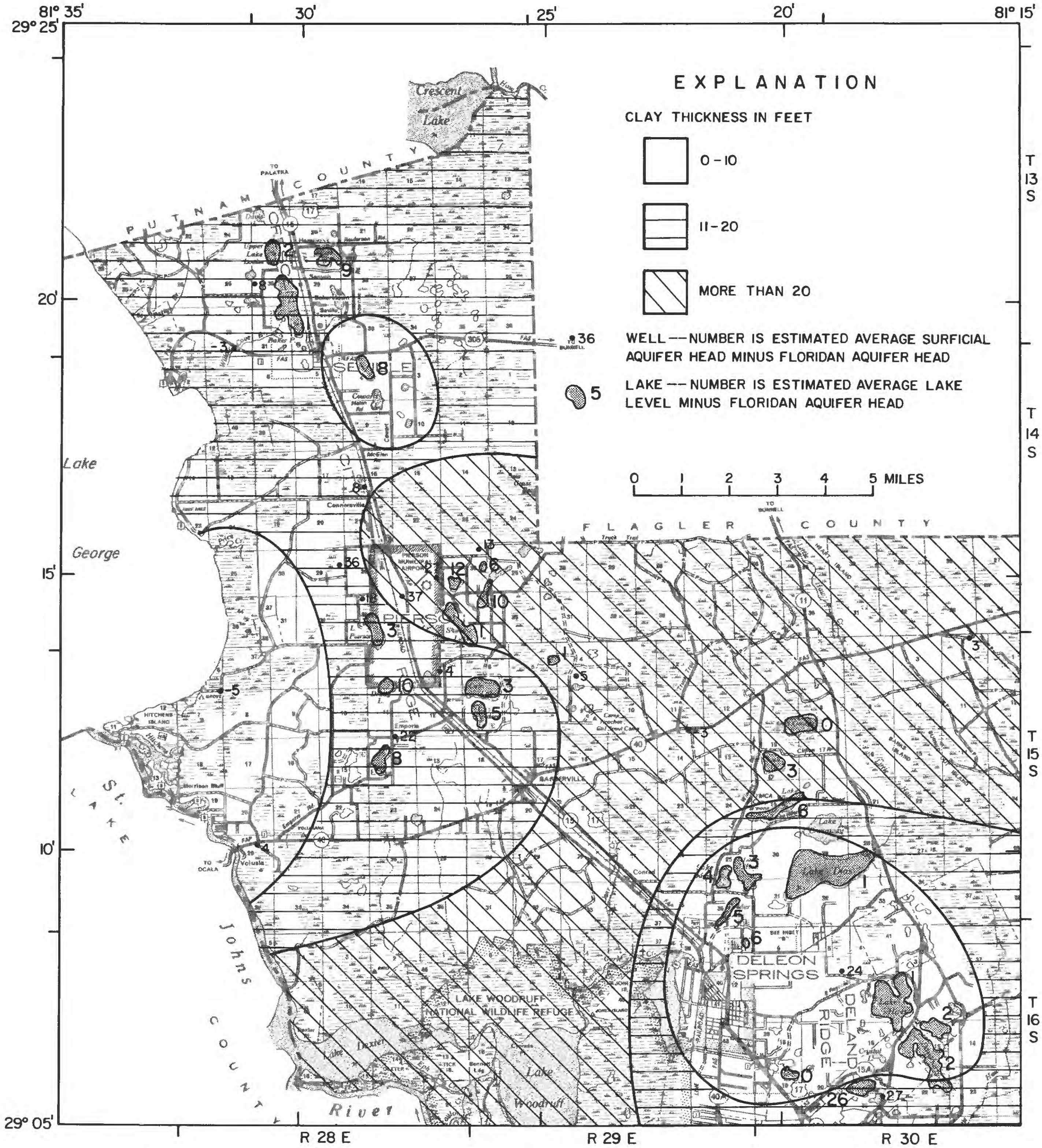


Figure 6.--Generalized clay-bed thickness and hydraulic head difference across the clay bed.

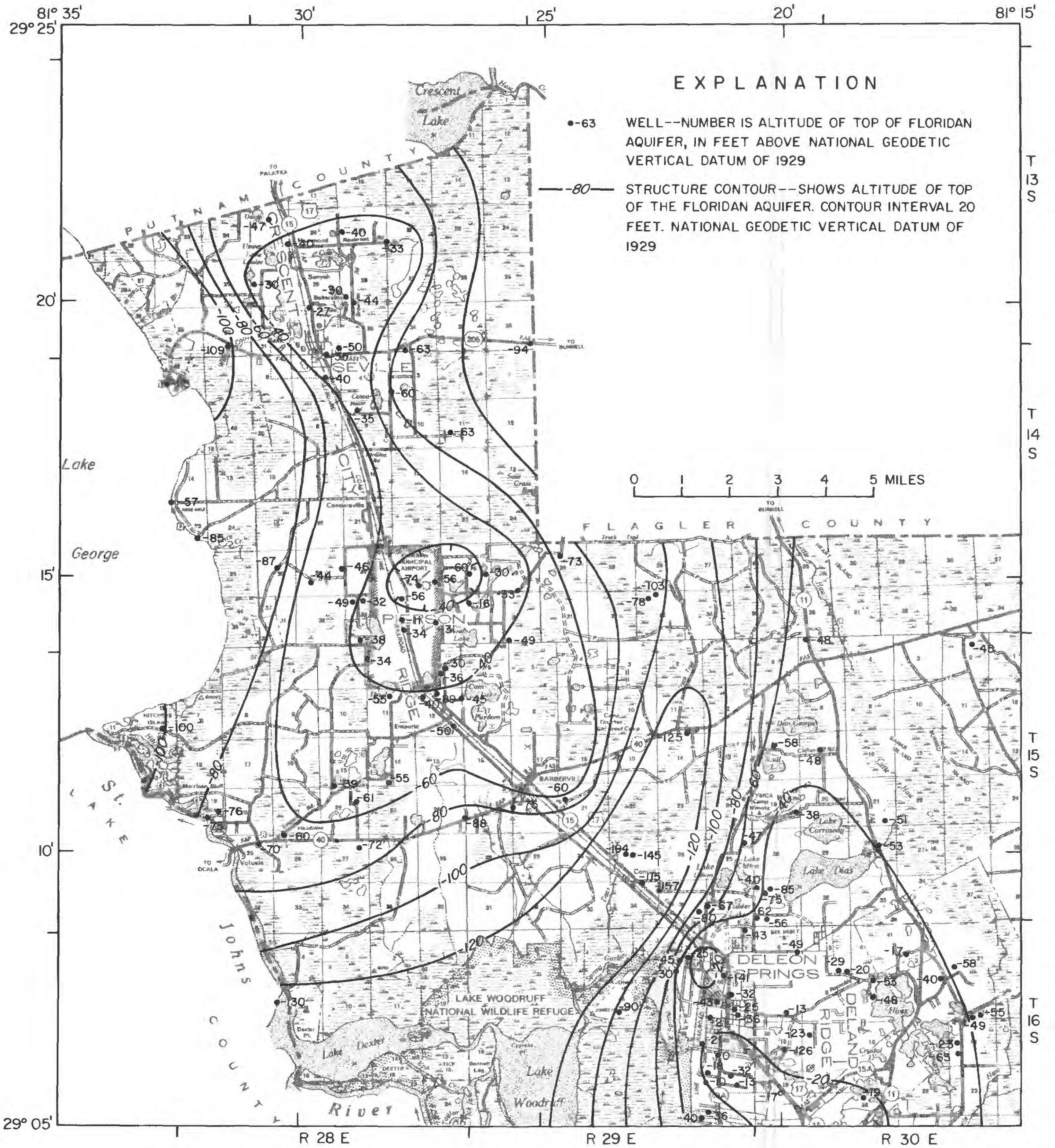


Figure 7.--Altitude of the top of the Floridan aquifer.

Rainfall and Evapotranspiration

The average annual rainfall in northwest Volusia County for the period 1941-70 was 54.8 inches. This is calculated from the long-term average rainfall figures for the U.S. Weather Bureau stations at Crescent City and DeLand. Approximately 64 percent of the annual rainfall occurs in the months of June-October. With the exceptions of surface-water inflow from the St. Johns River and Little Haw Creek and a small ground-water inflow from the south, rainfall is the only source of water entering the northwest Volusia County area.

Evapotranspiration is the return of water from the surface to the atmosphere. It is the sum of direct evaporation and transpiration. The average evapotranspiration for this study area is estimated at 39 inches per year based on values used by other investigators in central Florida. In Orange County, Lichtler and others (1968, p. 145) estimated that evapotransporation is 70 percent of rainfall, which in the case of northwest Volusia County, would be 38.5 inches per year. Knochenmus and Beard (1971, p. 45) estimated an evapotranspiration rate for Volusia County of 35 inches per year based on a rainfall rate of 52 inches per year. Grubb and Rutledge (1979, p. 21) calculated an average evapotranspiration of 40 inches per year in the Green Swamp, an area about 50 miles south-southwest of northwest Volusia County. The evapotranspiration rate is a function of temperature, rainfall, relative humidity, albedo, soil type, vegetative type, and depth to the water table. Assuming that temperature, rainfall, relative humidity, albedo, and vegetative type do not vary in the study area, it is evident that areal variations in the rate of evapotranspiration are caused mainly by variations in soil characteristics and the depth to the water table.

Figure 8 shows the three general soil types in northwest Volusia. The soils of the St. Johns River floodplain and other inland wetlands are very poorly-drained swamp and marsh soils. These areas are inundated by surface water for a large part of the year, and thus exhibit the maximum possible evapotranspiration. The soils of the flatwoods are medium- to poorly-drained soils. The flatwoods are inundated for only a small fraction of the year, but the water table generally remains within 3 feet of land surface. The sand ridge soils in the DeLeon Springs area probably allow significantly less evapotranspiration than do the soils of the other parts of the study area because the water table in the DeLeon Springs area is as much as 10 to 50 feet below land surface. In the Crescent City Ridge soils evapotranspiration is larger because the depth to the water table there is generally about 5 feet.

Runoff

After evapotranspiration, runoff is the second largest exit route of water from the surface in northwest Volusia County. The area is divided into two major surface drainage basins: The Little Haw Creek - Middle Haw Creek area and the St. Johns River - Lake George area (fig. 9).

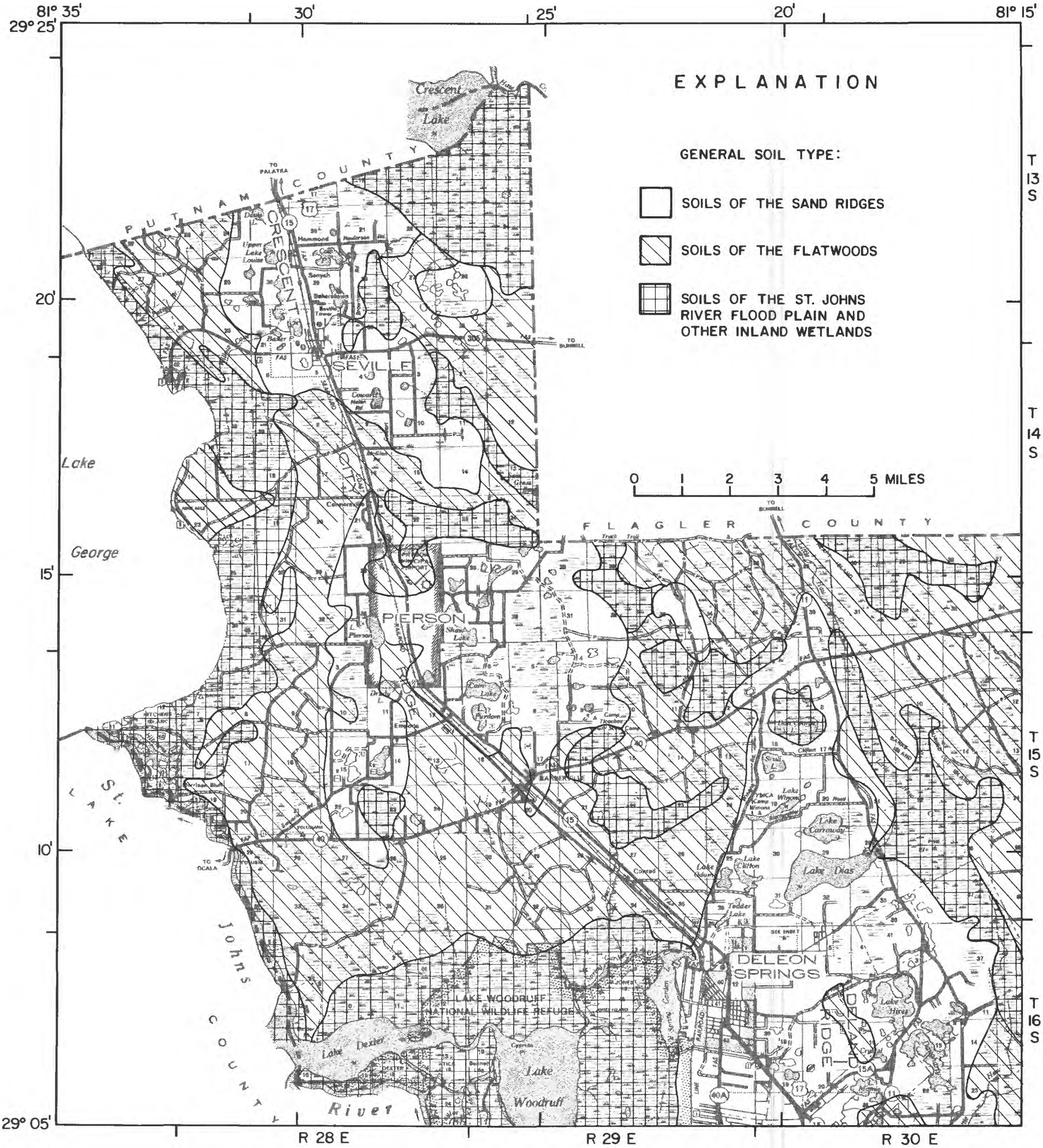


Figure 8.--General soil types (from soil survey of Volusia County, Florida, U.S. Soil Conservation Service, 1980).

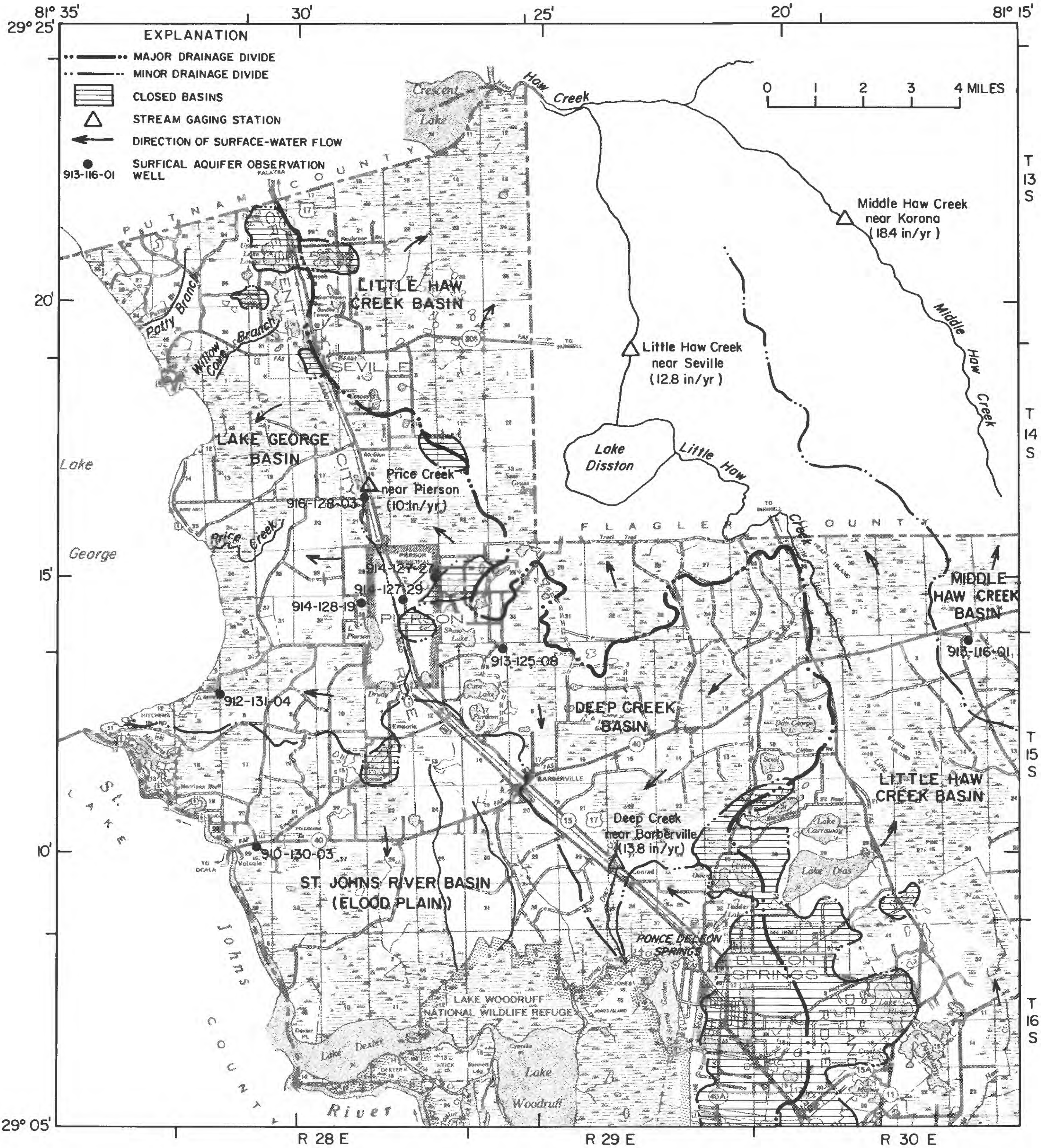


Figure 9.--Drainage basins, surface-water flow directions, stream-gaging stations, and surficial aquifer observation wells.

Although these major drainage areas are separate in northwest Volusia, their streams eventually converge north of the study area near Palatka. Middle Haw Creek, which drains much of the flatwoods and swamps of north-central Volusia County and southern Flagler County, drains a relatively small part of northwest Volusia. Little Haw Creek drains a large part of the DeLand Ridge in addition to many of the swamps and flatwoods of northwest Volusia. To the north, its drainage area includes part of the Crescent City Ridge. Its channel runs through Lake Disston in Flagler County and converges with Haw Creek before it flows into Crescent Lake. The St. Johns River - Lake George drainage area is subdivided into the Deep Creek drainage area, the St. Johns River floodplain, and the Lake George drainage area (fig. 9). Price Creek is part of the Lake George drainage basin. The ground-water discharge from Ponce de Leon Springs combines with water from Spring Garden Lake and Deep Creek, flows westward through Lake Woodruff and Lake Dexter, and enters the St. Johns River. From here, the flow becomes northward and enters Lake George. Lake George is simply a very wide section of the St. Johns River. This major stream continues northward from Lake George outside the study area. Other small channels that enter Lake George from northwest Volusia include Price Creek, Willow Cove Branch, and Patty Branch.

At four stream-gaging stations shown in figure 9 a daily recording of stream stage is obtained and periodic measurements of streamflow are made. When a relation between streamflow and stage is formulated, a daily streamflow record can be tabulated. Different amounts of streamflow data exist for these stations. Little Haw Creek near Seville has 27 years of daily discharge data from 1954 to 1980. The average for this record is assumed to be the long-term average runoff. This long-term record was used as an index for calculating the long-term averages for the other stations by statistical methods. The 5-year average discharge of the Middle Haw Creek near Korona for 1976-80, for example, was multiplied by the ratio of the 27-year average of Little Haw Creek over the 5-year average of Little Haw Creek for 1976-80 to obtain the long-term average of Middle Haw Creek. The same technique was used to project the long-term average discharge of Price Creek near Pierson, which has a continuous record from September 11, 1979, to the present time (1980). The estimation of the long-term runoff rate at Price Creek is subject to considerable error because it is based on such a short period of data. Graphical correlation was used to determine the long-term average runoff at Deep Creek near Barberville using 26 periodic discharge measurements at that station between September 1964 and January 1973 along with the corresponding daily discharge of Little Haw Creek. A curve of relation between the two stations was plotted on logarithmic paper and the 88 ft^3/s long-term average for Little Haw Creek corresponded to 36 ft^3/s for Deep Creek. The following is a summary of runoff data at the four stations:

	Drainage area (mi^2)	Average streamflow		
		(ft^3/s)	(Mgal/d)	(in/yr)
Little Haw Creek near Seville	93.0	88	57	12.8
Middle Haw Creek near Korona	78.3	107	69	18.4
Price Creek near Pierson	6	5	3	10
Deep Creek near Barberville	35.4	36	23	13.8

The last column represents the average runoff rate for the various basins in inches per year. A basin which includes more swamps than sand ridges will exhibit more average areal runoff than a basin that includes more ridges than swamps. For the purpose of estimating the runoff rates for the entire study area, assume that any part of northwest Volusia County can be placed into one of the following soil-hydrology types and that the characteristic runoff for that soil-hydrology type is as follows:

Soil-hydrology type	Runoff rate (in/yr)	Percentage of Price Creek basin	Percentage of Deep Creek basin
Swamp or flatwood soils in discharge areas	20	5	44
Swamp or flatwood soils in areas of no recharge or discharge	16	35	9
Flatwood soil in areas of recharge	12	18	5
Ridge soils in areas of surface drainage	6	30	39
Ridge soils in closed basins	0	12	3

An estimate of runoff for the Price Creek basin and the Deep Creek basin can be calculated as the weighted average of the runoff rates taking into consideration the percentages of each basin that is occupied by each of the soil-hydrology types. The runoff rate estimates are 11 inches per year for Price Creek near Pierson and 13 inches per year for Deep Creek near Barberville. Although estimates such as these are subject to considerable error, they may be useful in evaluating the water budget of the surficial layer over large areas. An understanding of the water budget of the surficial layer is a prerequisite to an understanding of the water budget of the Floridan aquifer.

Water Budget of the Surficial Layer

The surficial layer consists of the land surface, the lakes, streams, ditches, the surficial aquifer, and the vegetation. A water budget is the accounting of inflow and outflow. Because the long-term water budget is being considered here, changes in storage are considered negligible. Water enters the northwest Volusia surficial layer in the form of rainfall, stream inflow, and upward leakage from the Floridan aquifer. It leaves the system by evapotranspiration, stream outflow, and downward leakage to the Floridan aquifer. For the purpose of this analysis, it may be assumed that stream inflow can be ignored. This assumption is made because it is believed that the St. Johns River and Little Haw Creek, which are both areas of discharge from the surficial and the Floridan aquifers within the study area, probably exit the northern boundaries with the same amount of water they had when they entered the study area in addition to the amount each gains from runoff and ground-water discharge within the study area. Therefore stream inflow and stream outflow are not calculated. Instead, local runoff is calculated and used as part of the budget.

Table 1 gives estimates of the water budget of the surficial layer for the five different combinations of soil type and hydrology previously discussed. Rainfall is assumed to be uniform throughout the study area. Upward leakage from the Floridan aquifer into the surficial layer is zero with the exception of one soil-hydrology type. Evapotranspiration is assumed to be 39 inches per year for all but one soil-hydrology type. Ridge soils in closed basins exhibit lower evapotranspiration because the depth to the water table in these areas may reach 50 feet. Runoff rates vary from one soil-hydrology type to another as estimated previously. Runoff and downward leakage supplement each other in such a way that an area of high runoff will have low downward leakage and an area of low runoff will exhibit high downward leakage. The estimates of recharge used by Bush (1978, p. 26) agree with the downward leakage estimates of table 1. The average upward leakage for all areas of upward leakage in northwest Volusia County simulated in the Bush model is 4 to 5 inches per year. This compares well with the average upward leakage rate of 4 inches per year in discharge areas as shown on table 1. Downward leakage rates in the Bush model for the DeLand Ridge area reach 20 inches per year while those of the Crescent City Ridge reach 12 inches per year. These figures are in reasonable agreement with the downward leakage estimates for ridge soils on table 1.

A water budget of the surficial layer for the entire northwest Volusia area may be calculated using the percentage of study area occupied by the five different soil-hydrology types (table 1). The values given in the last row of table 1 are the weighted-average components of inflow and outflow for the study area. These represent the values of rainfall, upward leakage, evapotranspiration, runoff, and downward leakage averaged for the 262-square-mile study area. The downward leakage of 5 inches per year minus the upward leakage of 2 inches per year is equal to the net leakage, or recharge, to the Floridan aquifer: 3 inches per year, or approximately 60 ft^3/s.

Table 1.--Estimated water budget of the surficial layer (in inches per year)

Northwest Volusia area soils	Percentage of study area	Inflow		Outflow		
		Rainfall	Upward leakage	Evapo-transpiration	Runoff	Downward leakage
Swamp or flatwood soils in discharge areas	39	55	4	39	20	0
Swamp or flatwood soils in areas of little recharge or discharge	20	55	0	39	16	0
Flatwood soils in areas of recharge	9	55	0	39	12	4
Ridge soils with surface drainage	23	55	0	39	6	10
Ridge soils in closed basins	9	55	0	35	0	20
Areally weighted average		55	2	39	13	5

GROUND-WATER USE

Because irrigation water use makes up more than 90 percent of the total ground-water use in northwest Volusia County, it is the primary subject of this section. The total withdrawal rate for purposes other than irrigation is estimated from water-use data of the U.S. Geological Survey as 1 Mgal/d. Approximately 70 percent of this is domestic water use, with livestock, public, and industrial uses making up the remainder. The following discussion of irrigation water use in northwest Volusia is divided into (1) an irrigation well inventory, showing locations, construction details, and other data about wells, and (2) a section describing the distribution of irrigation well pumpage.

Irrigation Well Inventory

Irrigation wells were inventoried as part of this study so that locations, depths, and durations of pumping stress could be defined. Plate 1 (pocket) shows all irrigation wells inventoried for this study. Most irrigation wells are located on the well-drained soils of the sand ridges (fig. 8). The density of wells is greater in the Pierson area than it is in the Seville or DeLeon Springs areas. The greatest concentration of irrigation wells is in the northeast Pierson area. For the purpose of this report, the Pierson area may be defined as the town of Pierson and the areas within 2 miles of the town limits, in addition to the towns of Emporia and Barberville.

The irrigation well inventory was accomplished by visiting wells, identifying locations on maps with latitude-longitude coordinates, and interviewing owners about well construction and pumpage. The objective was to inventory all Floridan aquifer irrigation wells in use as of January 1980. Because the Floridan aquifer is by far the major source of ground-water use, irrigation wells open only to the surficial aquifer were not inventoried to any great extent. Included in plate 1 are new irrigation wells which had been drilled as of January 1980, but which were not yet in use. Abandoned irrigation wells were not included. Of the total wells for which this inventory was intended, the author believes that records were obtained for approximately 90 percent.

The supplementary data table at the end of this report gives information on all wells in northwest Volusia County for which data had been collected and stored in the computer files of the U.S. Geological Survey as of January 1980. Included are irrigation wells from plate 1.

Local well numbers are used to cross-reference between plate 1 and the data table (see plate 1, explanation). Local well numbers are based on latitude and longitude coordinates derived from a grid of 1-minute parallels of latitude and longitude. Wells within these quadrangles are assigned numbers that consist of the last digit of the degree and the two digits of the minute of the line of latitude on the south side of the quadrangle, the last digit of the degree and the two digits of the minute of the line of longitude on the east side of the quadrangle, and the two-digit sequence number assigned in the order in which the well within the quadrangle was inventoried. For example, well 905-116-02 was the second well inventoried in the 1-minute quadrangle north of lat 29°05' and west of long 81°16'. Local well numbers are shown unhyphenated on the well inventory table.

The well inventory (supplementary data) shows type of water use, and for irrigation wells, notes whether or not the well is used for freeze protection. The altitude of land surface at the well and the depth to water level in the well are also given. The last chloride concentration analysis, for each well having that data, is shown along with the date of sampling. Additional data for any well may be retrieved from the computer files of the U.S. Geological Survey using the well inventory table as a guide. This data, which may include additional water levels or chloride concentrations, for example, is retrieved by the 15-digit station numbers shown in the second column.

Depths of Floridan aquifer irrigation wells vary from 100 to 790 feet in northwest Volusia County. The altitude of the bottoms of irrigation wells in the Pierson area (fig. 10) shows no general pattern but indicates that the average depth exceeds 300 feet. The deepest irrigation wells are in northeast Pierson.

Irrigation Well Pumpage

To define the overall irrigation water-use rates in northwest Volusia County, data were collected on the amount of acres irrigated, the withdrawal rate per acre, and the pumpage per time. Also noted for this overall water-use calculation was whether or not each well is used for freeze protection. The term "growth irrigation" is used in this discussion to apply to all irrigation which is for purposes other than freeze protection.

Data from the irrigation well inventory indicate that a total of 1,470 acres of ferneries are growth irrigated in northwest Volusia County with 850 acres growth irrigated in the Pierson area alone. These estimates are based on acreage figures for early 1980. Data also indicate that acres freeze protected on March 3-4, 1980, were 1,260 for northwest Volusia County and 690 for the Pierson area alone. The mornings of March 3-4, 1980, made up the most severe freeze of winter 1979-80.

The average application rate for irrigation of ferneries in northwest Volusia County is approximately 160 (gal/min)/acre. This is the average rate for many measurements at individual wells which were made during freeze protection and growth irrigation.

The average total period of pumpage per time for irrigation wells in northwest Volusia County is 210 hours per year. The pumpage for the period November 15 to March 15 is 110 hours, which represents approximately 50 percent of the pumpage. These rates were derived from readings of

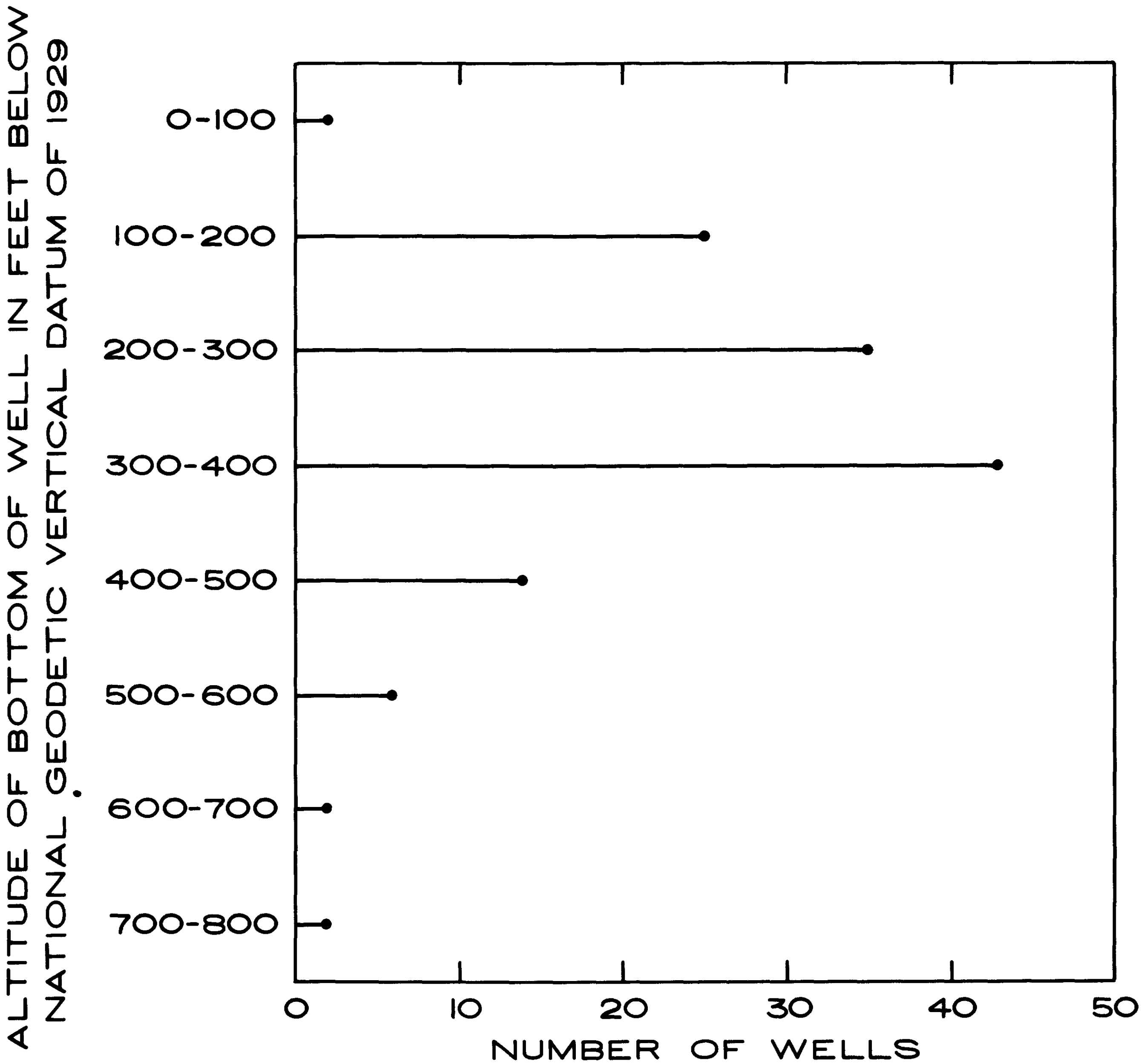


Figure 10.--Altitude of bottoms of irrigation wells in the Pierson area.

diesel hour meters on diesel-powered pumps and readings of kilowatt-hour meters on electrically-powered pumps during the period November 1978 through November 1980. A total of 60 pumps were monitored at locations throughout the study area. A greater number of pumps in Pierson were monitored than elsewhere. The metered time versus actual time was monitored for six diesel hour meters. All meters were accurate within 10 percent. Elapsed pumping time was determined for electrically-powered irrigation well pumps by calibrating the power consumption per time. Kilowatt-hour readings could then be converted to period of pumpage figures.

The long-term average ground-water irrigation use from the Floridan aquifer is 8.1 Mgal/d in northwest Volusia County, of which 4.7 Mgal/d is the use rate for the Pierson area alone. For the 4-month-long winter from November 15 to March 15, the figures are 13.0 Mgal/d for northwest Volusia County, of which 7.6 Mgal/d is for the Pierson area. The peak water-use rate calculated for March 3-4, 1980, was 300 Mgal/d for northwest Volusia County, of which 170 Mgal/d was for the Pierson area. These peak-use rates are slightly higher than the average rates would indicate because the estimate of acreage freeze protected is probably slightly smaller than the actual acreage.

TESTING OF PHYSICAL PROPERTIES OF THE FLORIDAN AQUIFER

Geophysical Logging of Wells

Geophysical logging was performed on wells as part of this study for the purposes of (1) defining well depths and depths of casing, (2) estimating thickness of the surficial aquifer, the thickness of the clay beds, and the depth to the Floridan aquifer, (3) defining formation characteristics such as altitude of permeable zones, and (4) determining the vertical flow regime in the Floridan aquifer. Figure 11 shows wells in northwest Volusia County for which geophysical logs are available. Most logging was performed by the U.S. Geological Survey during this investigation, although several logs were provided by the St. Johns River Water Management District. Geophysical logs were instrumental in providing data for other sections of this report.

Lithologic information, geologic information, and geophysical logs are shown in figure 12 for a well that is typical of the Pierson area. The top sand layer is the Holocene and Pleistocene deposits that make up the surficial aquifer. Next are the Pliocene and Miocene interbeds of clay, sand, and shell. These clay layers form the confining bed. Beginning at 120 feet below land surface are the limestone formations that, as a unit, make up the Floridan aquifer. The well casing has been driven through the unconsolidated layers of sand, clay, and shell of the surficial aquifer and the confining beds. From the top of the Floridan aquifer to the bottom of the well, the well consists of an open hole in limestone. It is from this interval of 120 to 480 feet that water is withdrawn. The highest peaks of the natural gamma log are the result of

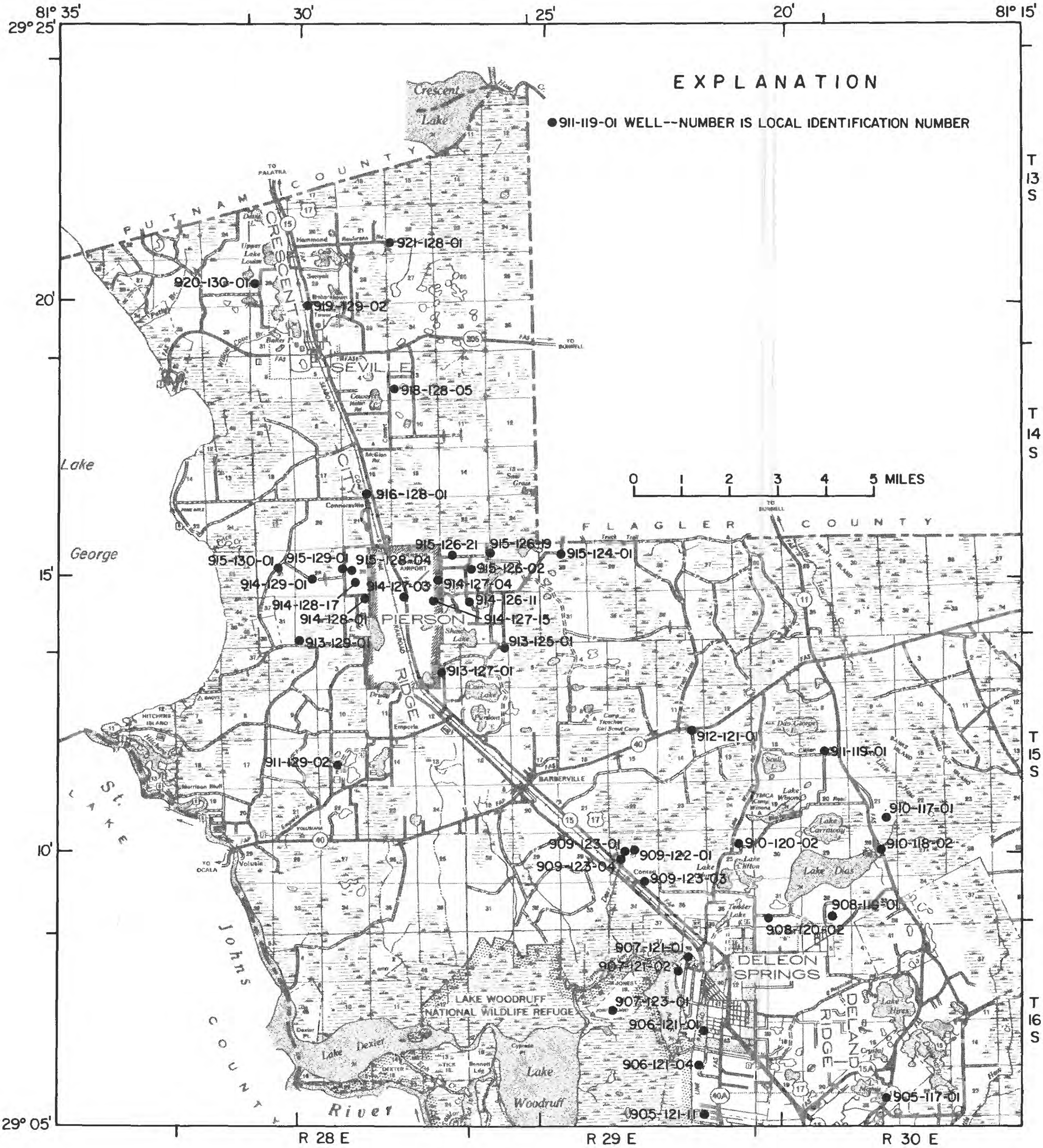


Figure 11.--Wells for which geophysical logs are available.

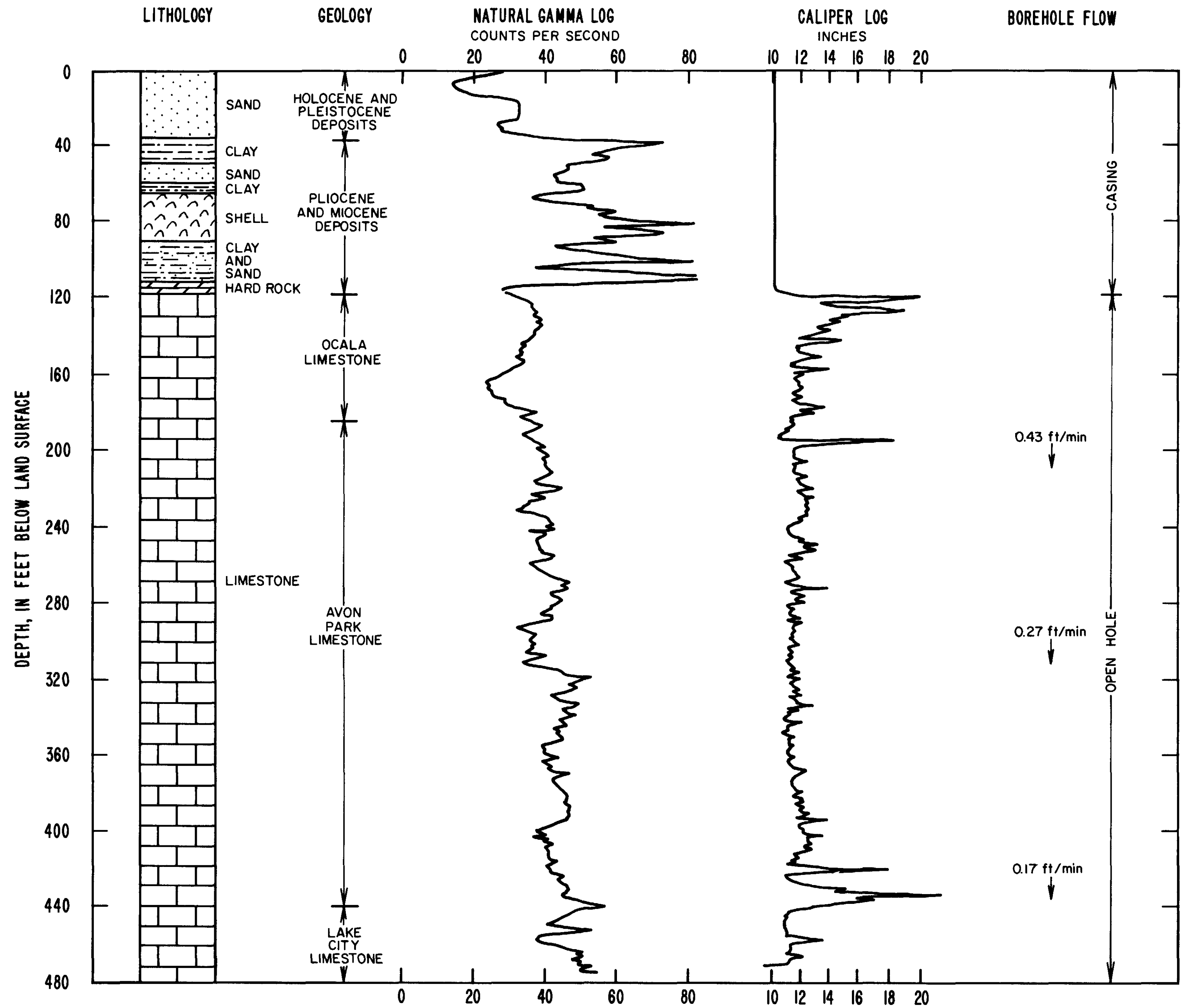


Figure 12.--Lithology, geology, and geophysical logs of well 914-127-15.

clay layers because the natural gamma activity of clay-bearing sediments is much higher than the activity of quartz sands and carbonate materials. The gamma activity, which is detectable through the iron casing of this well, shows that clay beds begin at 40 feet below land surface and end at 115 feet, and that the clay beds are interbedded with layers of relatively inactive materials. The caliper (hole-diameter) log shows that the 10-inch-diameter casing is 120 feet deep and also shows altitudes of the more porous zones in the limestone formations. These zones of greater hole diameter are centered around the 130-foot and the 440-foot depths. The values of borehole flow shown on figure 12 were derived from brine-trace logs. A plume of brine water was released in the borehole and its vertical movement under nonpumping conditions was recorded with an electrical conductance probe. The borehole flow apparently enters between 120 and 160 feet and exits farther down. This indicates that the head in the top of the Floridan is higher than the head farther down at this site.

Caliper logs of several wells in the study area (fig. 13) show that the altitudes of porous zones in the Floridan aquifer vary from one location to another. The first three logs are from wells in the DeLeon Springs area, followed by four from the Pierson area and one from the Seville area. Generally, the upper 50 feet of the Floridan is relatively permeable in the Pierson area. This zone is followed by 200 or more feet of less permeable rock, below which is another zone of higher permeability. Well 915-126-19, which is in the east Pierson area, was drilled deeper than most wells in the area because the driller did not penetrate zones of high permeability. The second and third logs in figure 13 are typical of the DeLeon Springs area. These logs show vertically extensive zones of high porosity.

Aquifer Tests

An aquifer test is a field experiment used in ground-water studies to determine physical characteristics of an aquifer such as its ability to transmit and store water. Depending on the amount of data collected and the amount of analytical methods used, a test can also yield quantitative information about the ratio of vertical to horizontal hydraulic conductivity in the aquifer and the water-transmitting capacity of the confining beds above the aquifer. The eight aquifer tests performed as part of this study are of simple design and are used only to give values of transmissivity and storage coefficient. A quantitative knowledge of transmissivity and storage coefficient aids in the understanding of the water budget of the aquifer and the effects of drawdown caused by ground-water withdrawals for freeze protection.

The test design for each of the eight aquifer tests consisted of one production well pumping at a constant known rate and one observation well 400 to 1,000 feet away in which water-level drawdown was measured during the pumping period. Most production and observation wells are fernery irrigation wells that penetrate at least 100 feet into the Floridan aquifer.

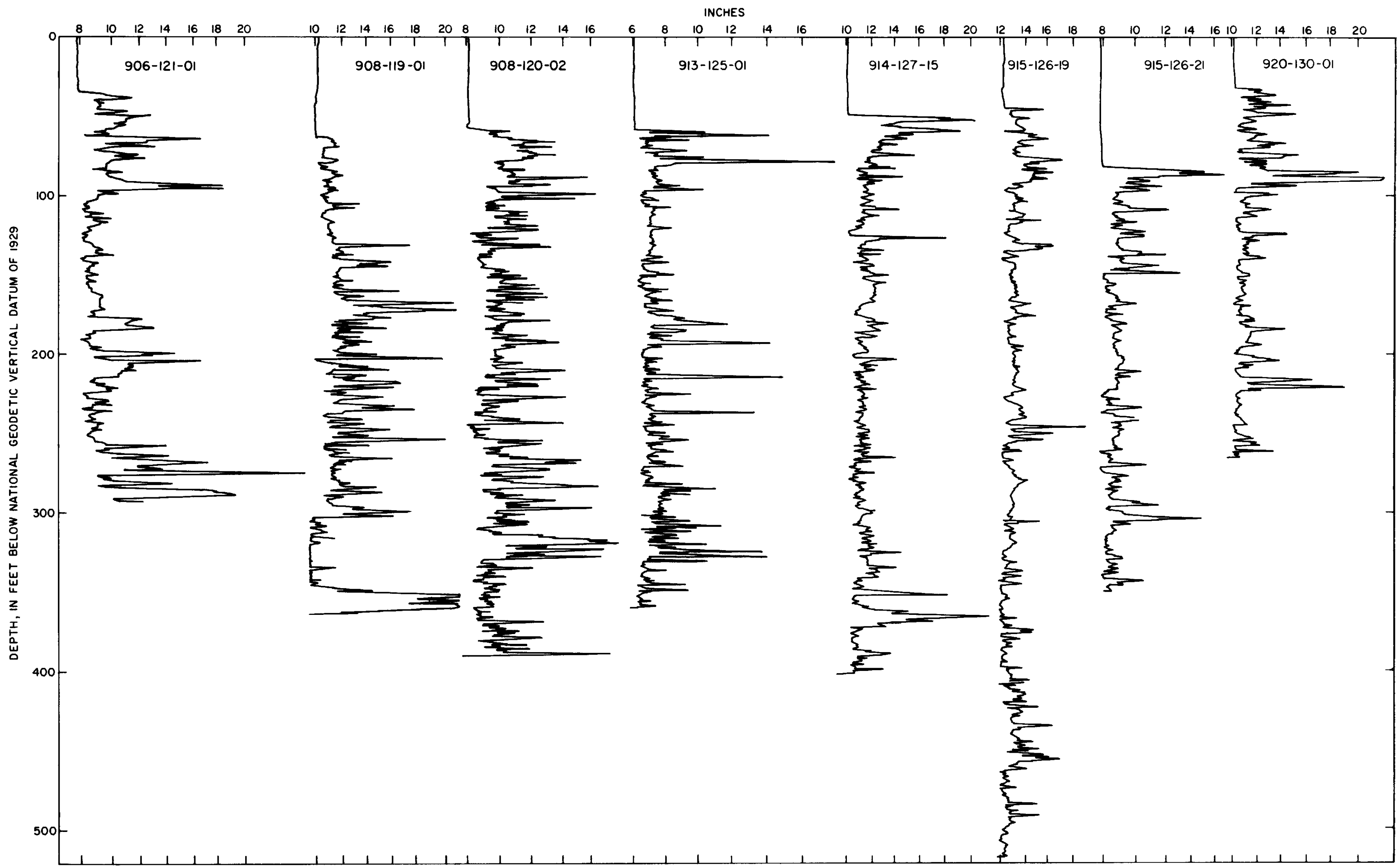


Figure 13.--Caliper logs of wells in northwest Volusia County.

The analytical methods used apply to isotropic, homogeneous, nonleaky artesian aquifers with fully penetrating production wells of constant discharge. The transmissivity of an aquifer is defined as the rate of flow of water at the prevailing kinematic viscosity through a unit width of the aquifer and extending the full saturated thickness of the aquifer under a unit hydraulic gradient (modified from Lohman and others, 1972, p. 13). The term "apparent transmissivity" is used because the conditions of isotropy and full penetration of wells generally are not met. Isotropy is defined as the condition in which all significant properties of the aquifer are independent of direction (Lohman and others, 1972, p. 9). The storage coefficient of an aquifer is the volume of water that is released from or taken into storage, per unit change in head per unit surface area of the aquifer (modified from Lohman and others, 1972, p. 13). Although the assumption that the aquifer is nonleaky is actually incorrect, it is a reasonable assumption for the purposes herein because the tests are short in duration and observation wells are relatively close to the production well in each test.

The data for each aquifer test were analyzed by two methods which are referred to here as the curve-matching method and the straight-line method. In the curve-matching method, the time-drawdown data are plotted on logarithmic paper and superimposed on a type curve for nonsteady radial flow without vertical movement (Lohman, 1972). A match point is selected, and match point values of s, t, W(u), and u are determined. These values are used to solve for transmissivity and storage coefficient from the following equations:

$$T = \frac{Q}{4\Pi s} W(u)$$

$$S = \frac{4Ttu}{r^2}$$

for $u = \frac{r^2 S}{4Tt}$

where

T = transmissivity (feet squared per day),

S = storage coefficient (dimensionless),

Q = discharge rate from pumping well (cubic feet per day)

s = drawdown (feet),

W(u) = the well function of u,

t = time after discharge started (days), and

r = distance from production well to observation well (feet).

In the straight-line method, drawdown is plotted against the log of time and transmissivity and storage coefficient are calculated from the following equations:

$$T = \frac{2.30\ Q}{4\Pi \Delta s/\Delta \log_{10} t}$$

$$S = 2.25T \left(\frac{t}{r^2}\right)_0$$

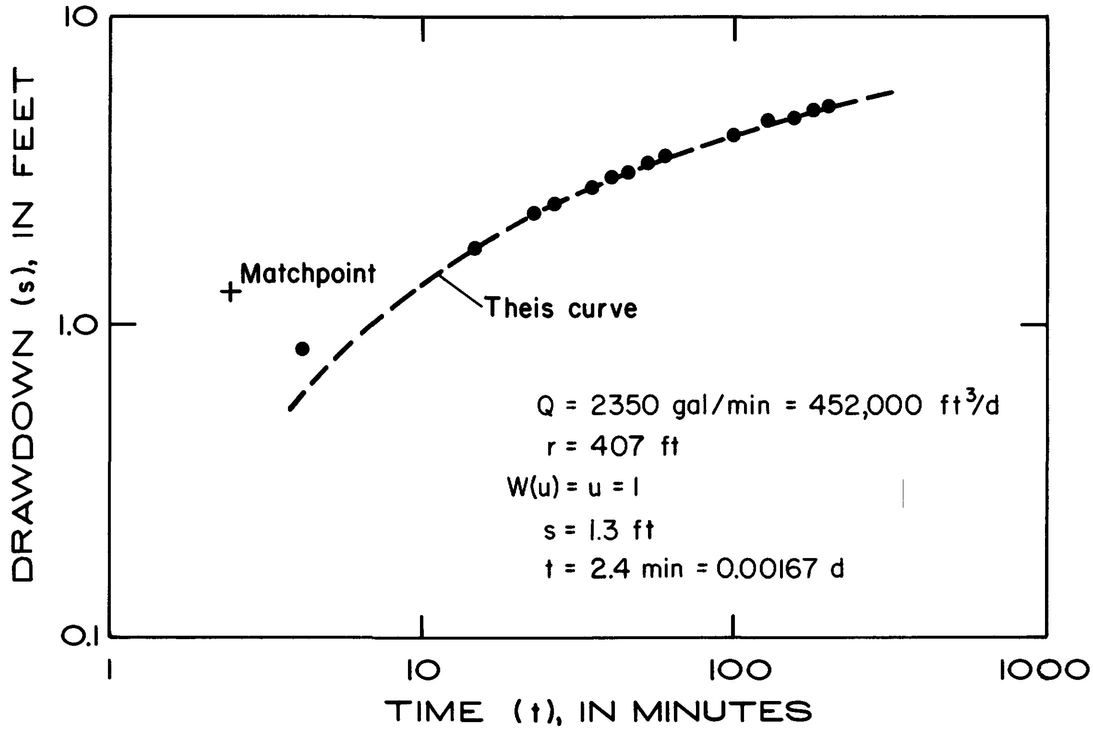
where all terms are as previously defined, and $\Delta s/\Delta \log_{10} t$ is the slope of the straight-line part of the curve and $(t/r^2)_0$ is the value of t/r^2 attained for the point where the straight-line projection intersects the line of zero drawdown.

The plots used for analysis of the eight aquifer tests are shown in figures 14-21. Each figure shows the plot used for the curve-matching method and the plot used for the straight-line method. For plots in which the curve-matching method was used, the values of w(u) u, s, and t, which define the match point, are shown. For plots in which the straight-line method was used, the value of $\Delta s/\Delta \log_{10} t$, which is the slope of the straight-line projection, is shown on the graph. Also shown for these plots is the value of t where the straight-line projection intersects the line of zero drawdown: t_0. The apparent values of transmissivity and storage coefficient are in table 2. Transmissivities range from 6,300 to 89,000 ft^2/d while storage coefficients range from 0.0003 to 0.0013.

The equations used for calculating T and S by the straight-line method should only be used when u is less than or equal to about 0.02. Considering that $u = r^2S/4Tt$, and solving this equation for t after substituting values of T and S obtained by the curve-matching method, a value of critical time is obtained for each aquifer test. Critical time is the time after which the data may be used for determination of transmissivity and storage coefficient using the straight-line method and the values thereof are:

Test No.	Critical time in minutes
1	120
2	170
3	250
4	630
5	260
6	115
7	550
8	140

Most of the tests were not run for periods of time that were long enough to reach critical time. For this reason, the results of the straight-line method may be unreliable in comparison with those of the curve-matching method. It is worthy of note, though, that corresponding results using



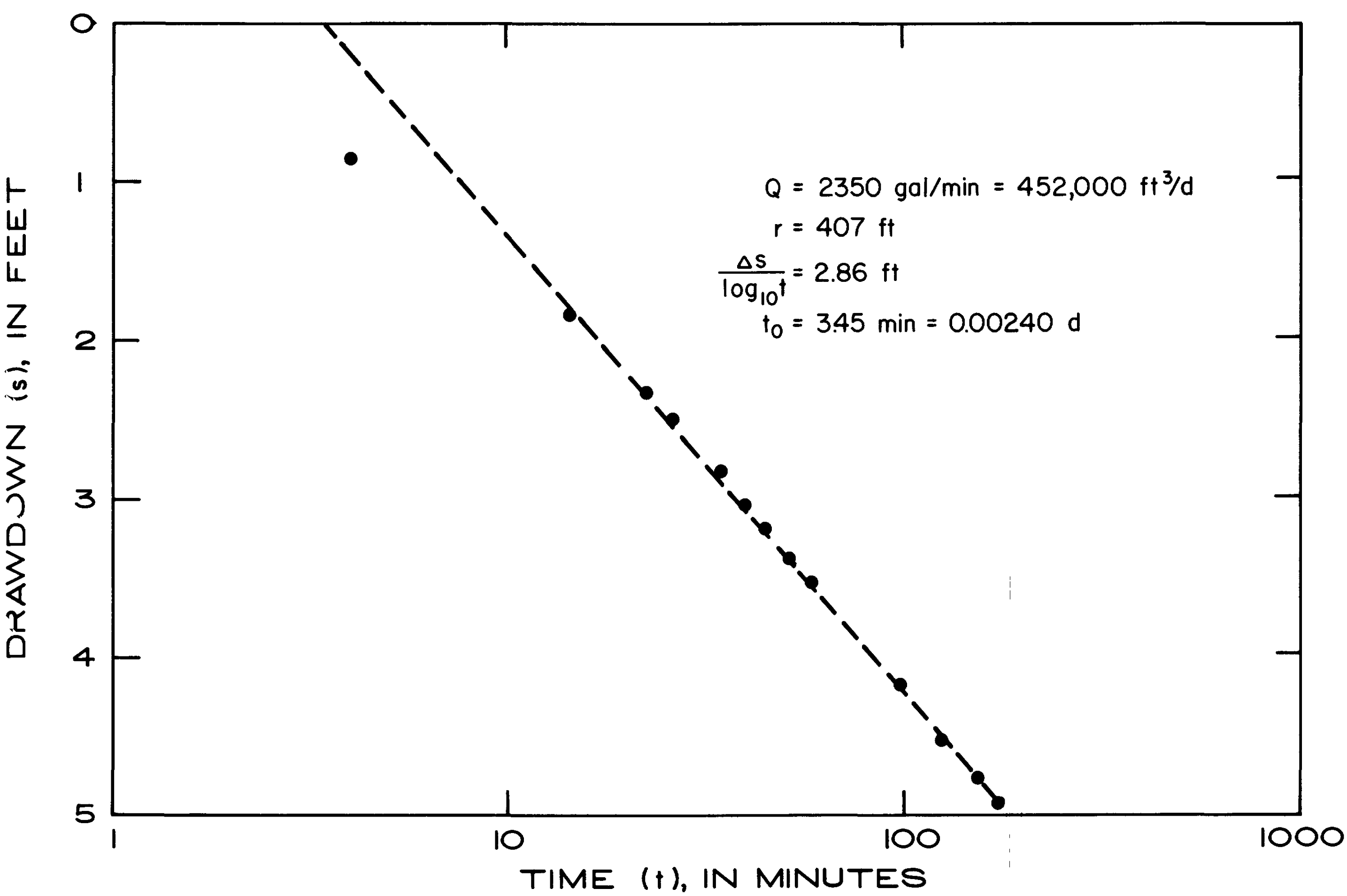


Figure 14.--Graph showing drawdown data, aquifer test 1.

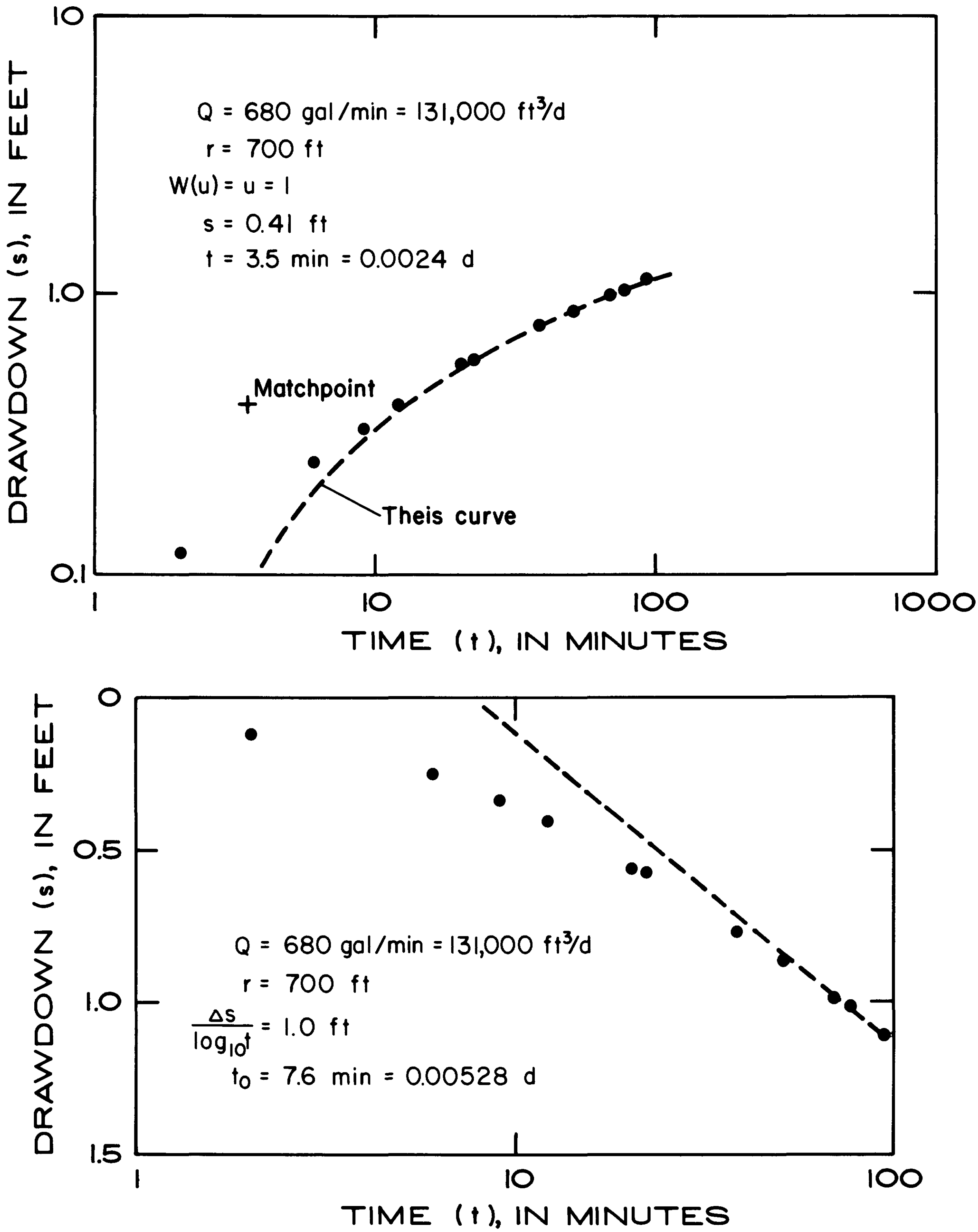
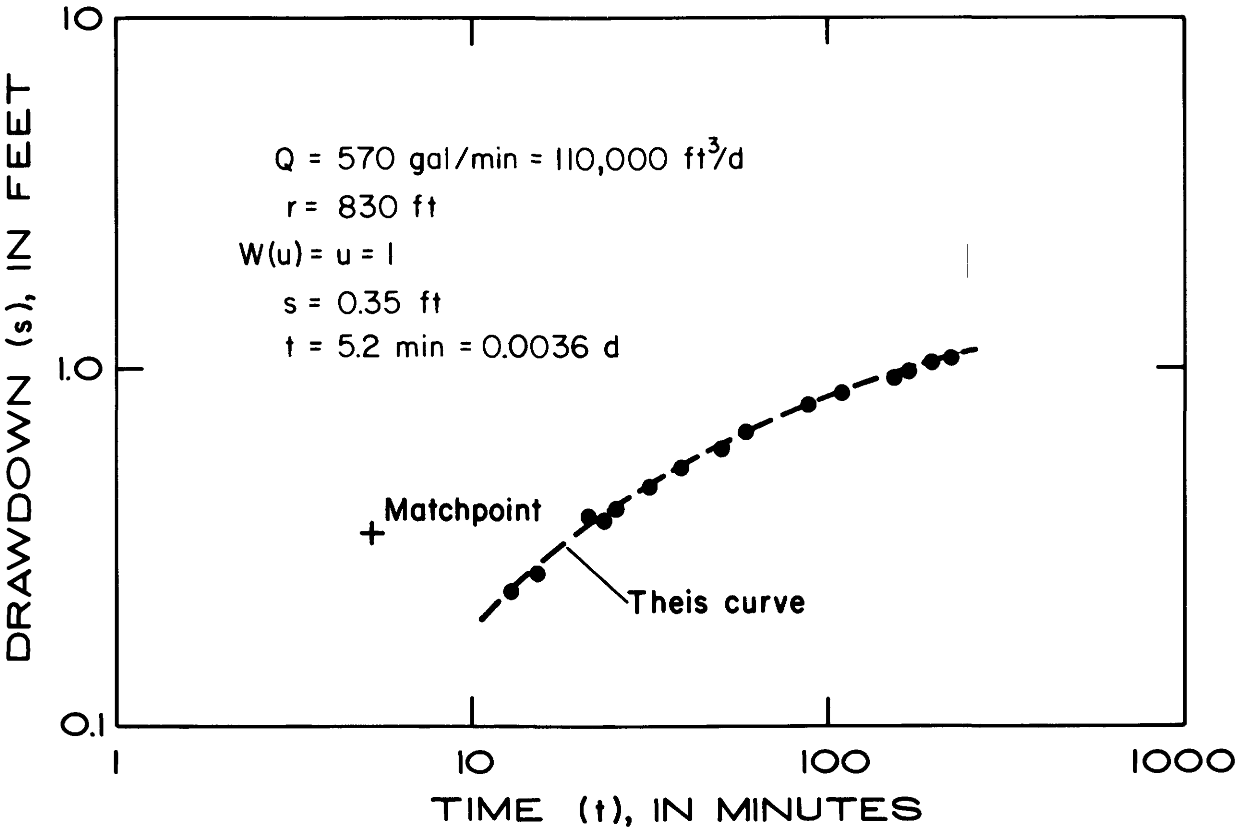


Figure 15.--Graph showing drawdown data, aquifer test 2.



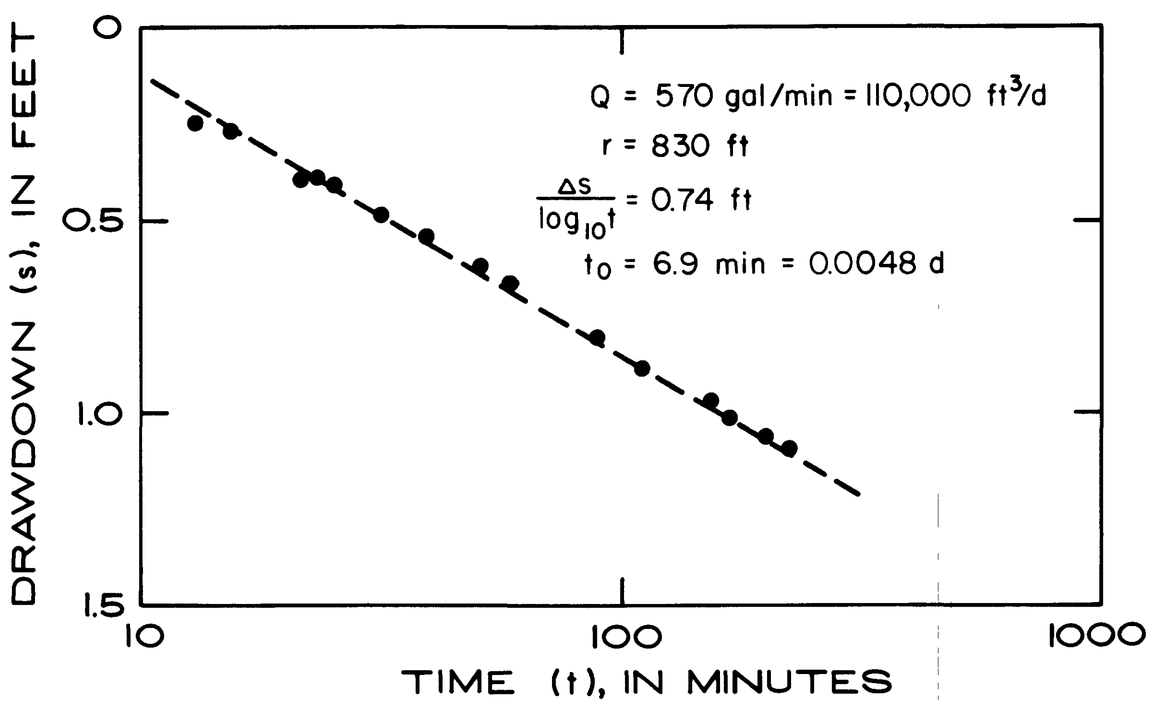
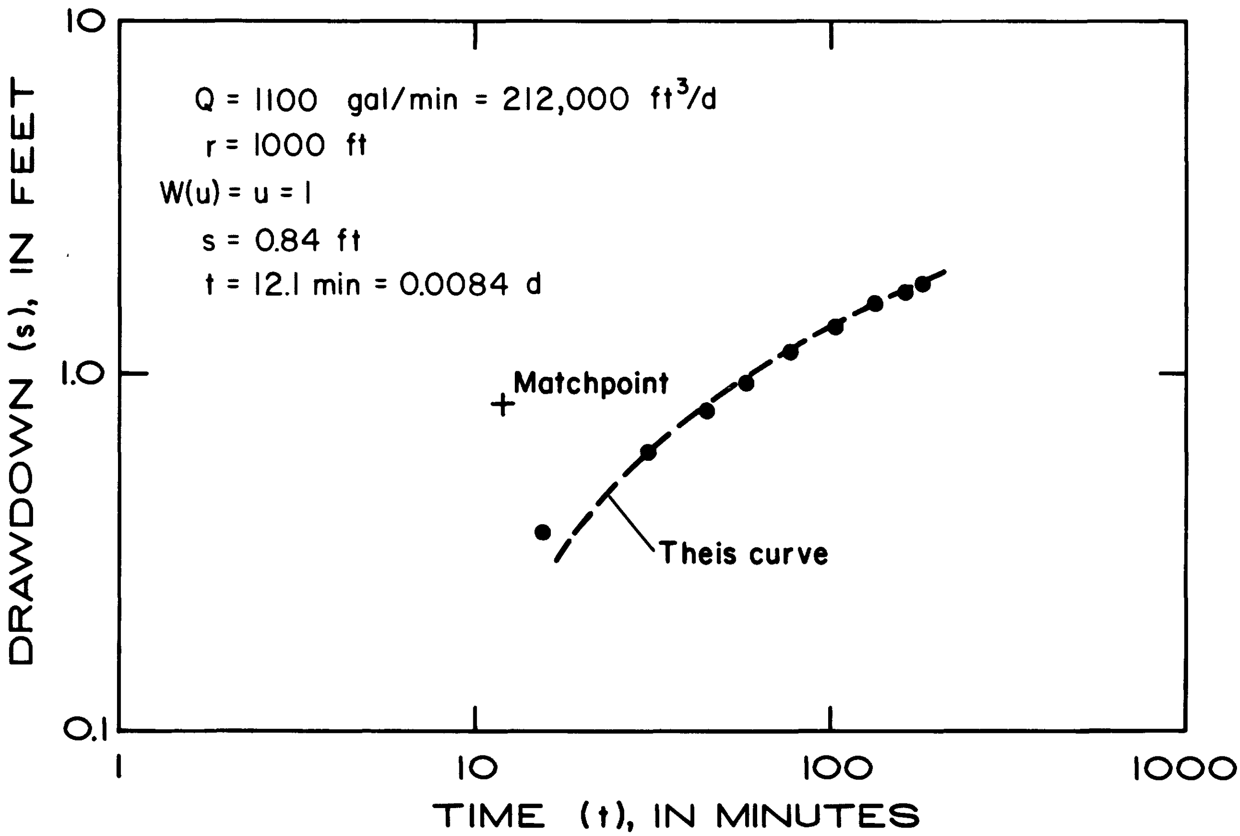


Figure 16.--Graph showing drawdown data, aquifer test 3.



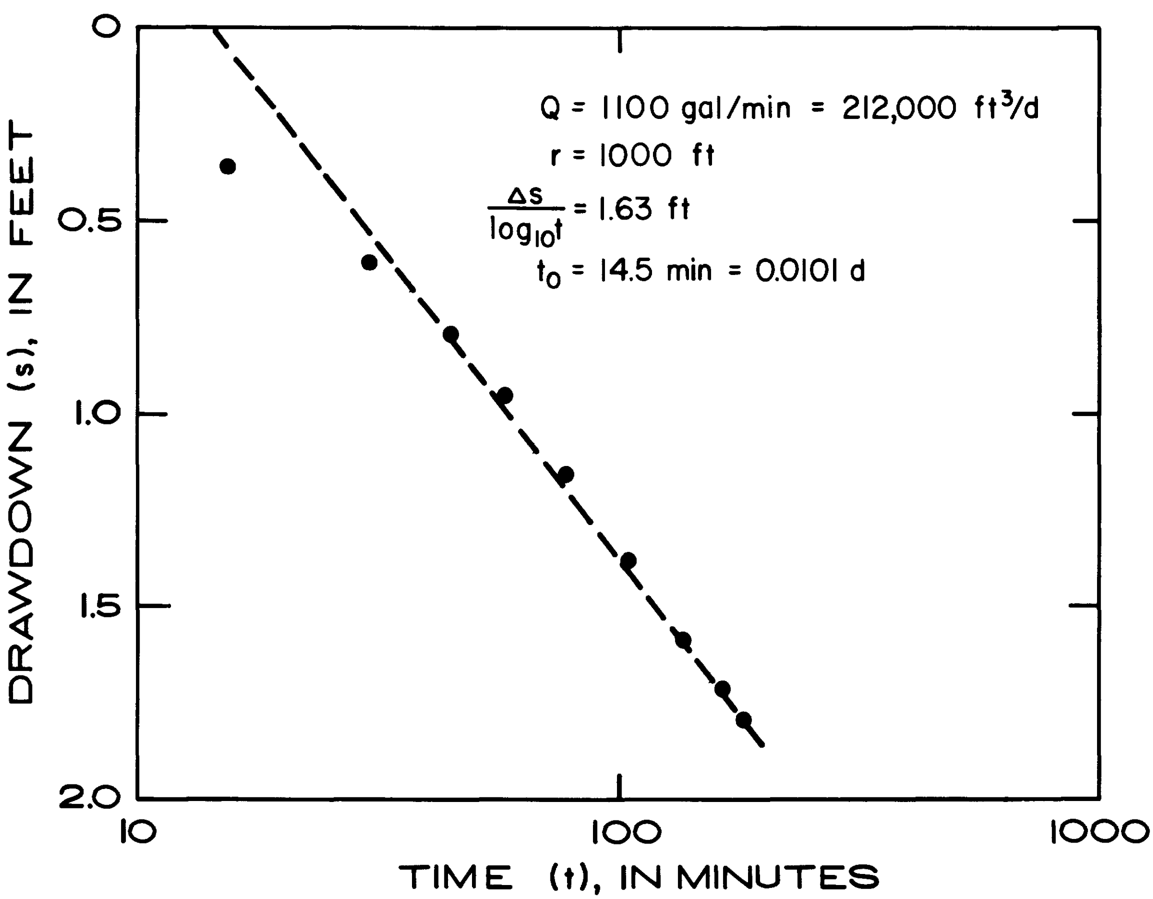
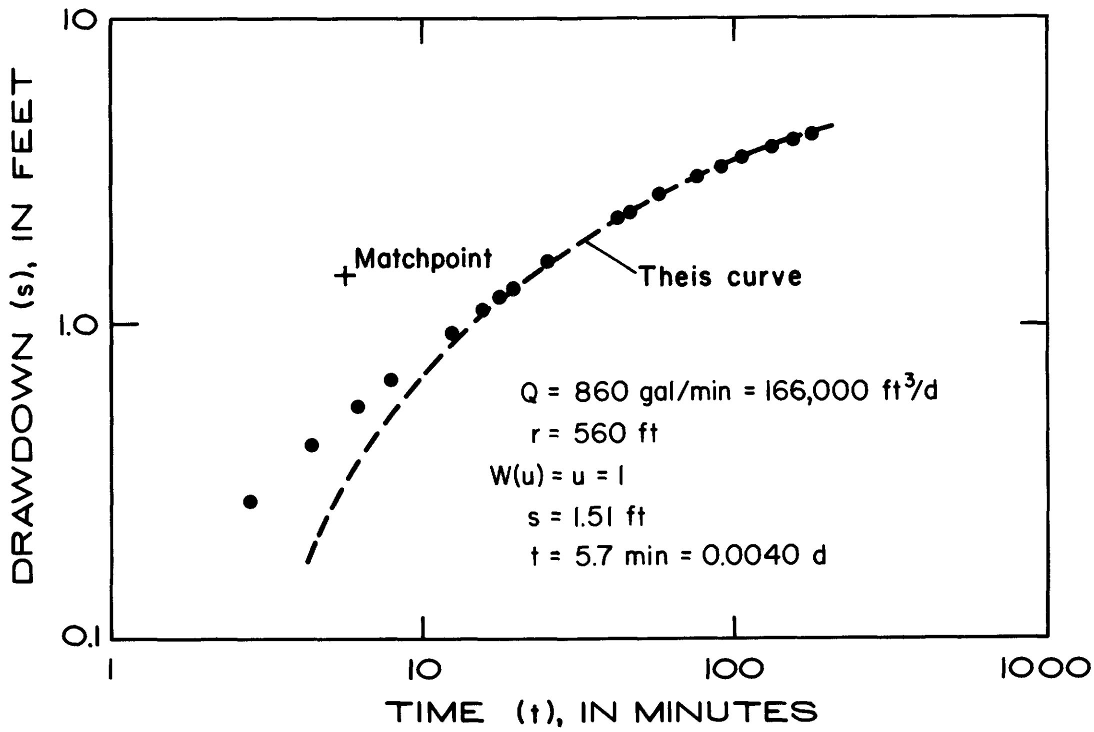


Figure 17.--Graph showing drawdown data, aquifer test 4.



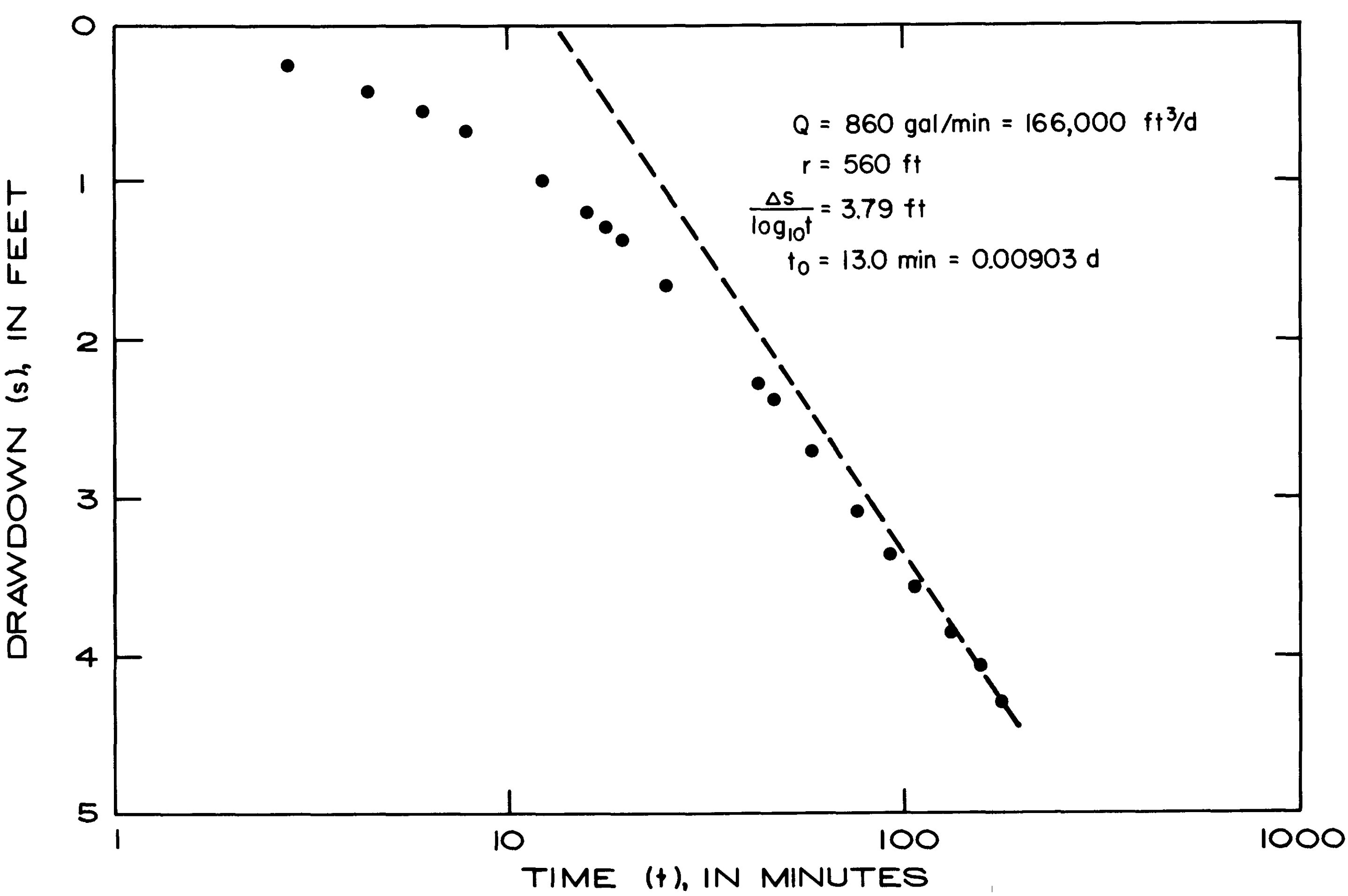
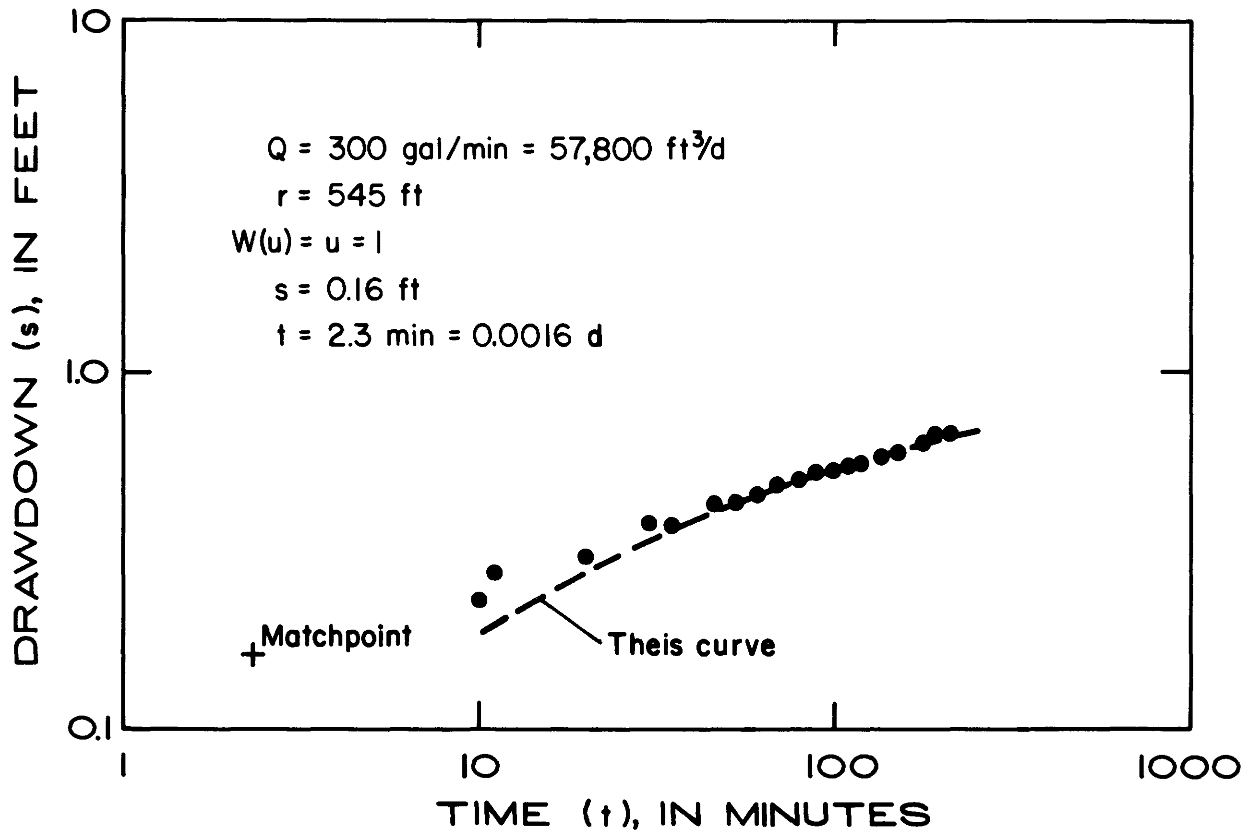


Figure 18.--Graph showing drawdown data, aquifer test 5.



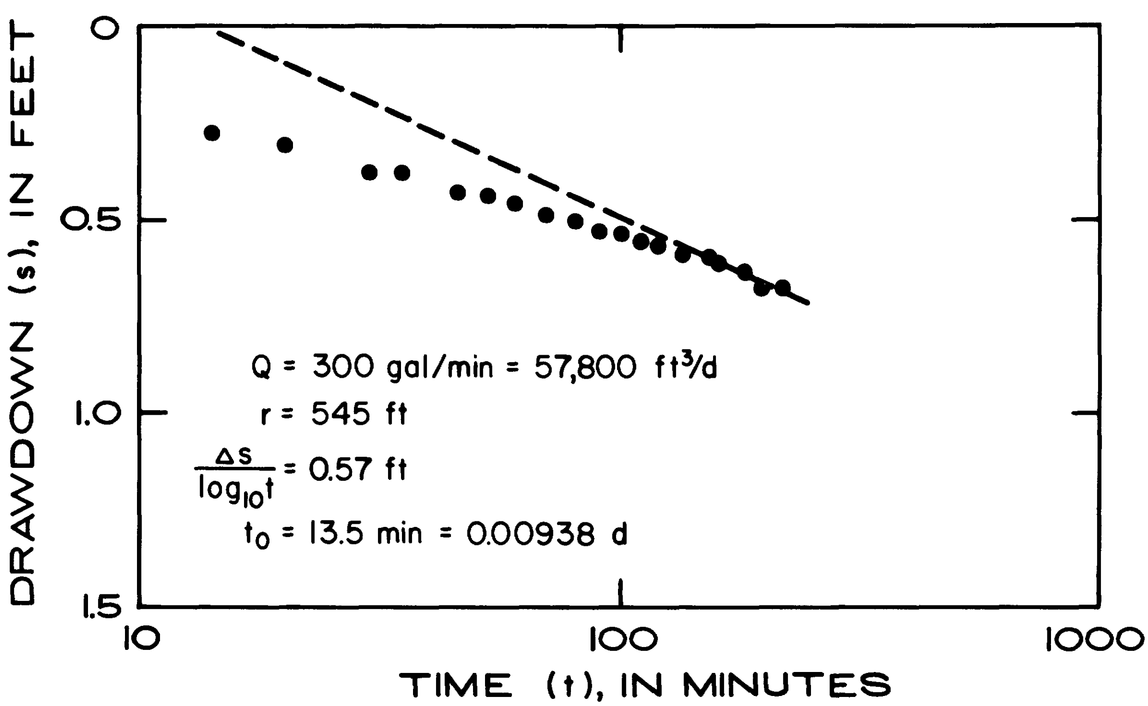


Figure 19.--Graph showing drawdown data, aquifer test 6.

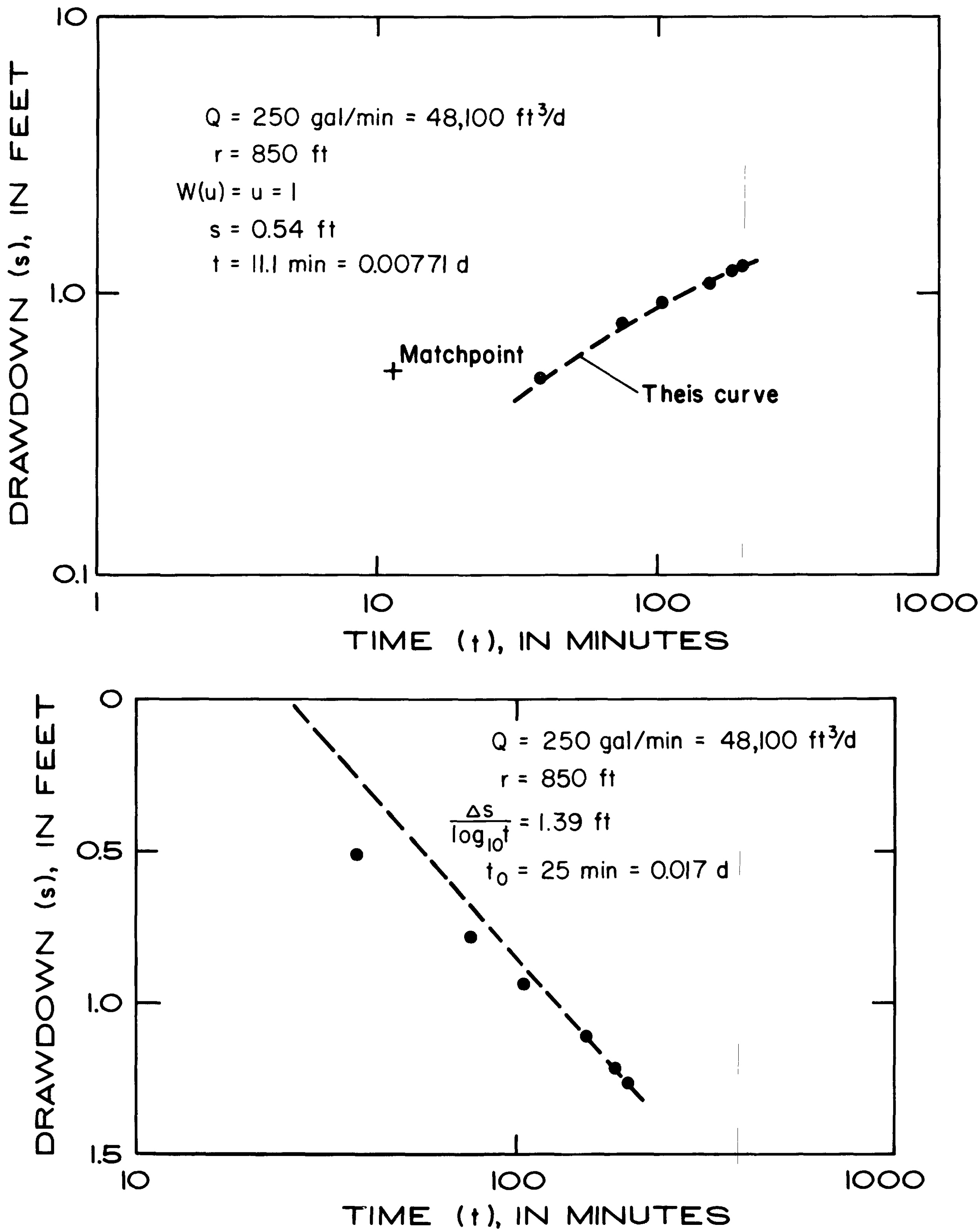


Figure 20.--Graph showing drawdown data, aquifer test 7.

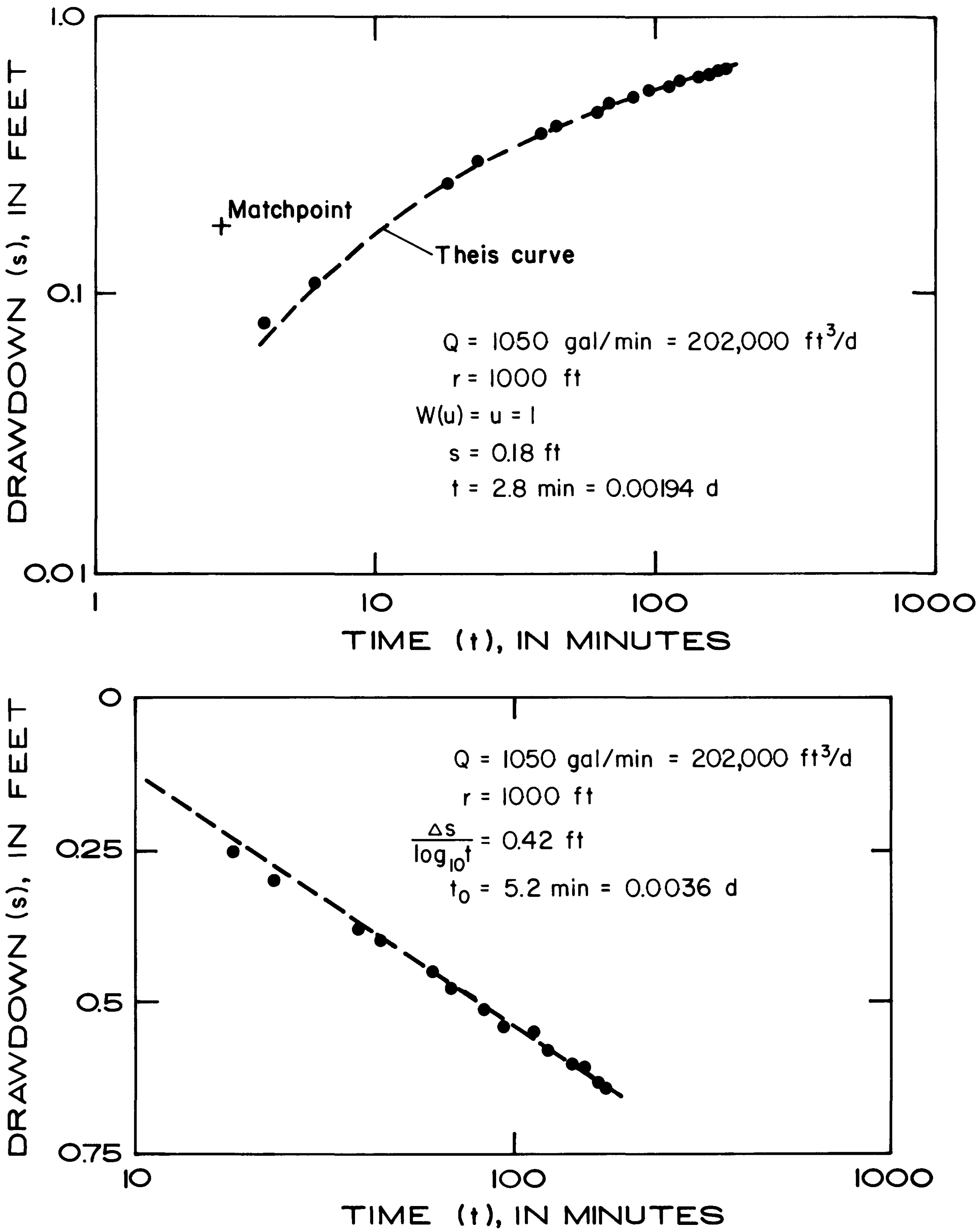


Figure 21.--Graph showing drawdown data, aquifer test 8.

Table 2.--Aquifer test data

Test No.	Local No.[1]	Well depth (ft)	Thickness of aquifer penetrated (ft)	Apparent hydrologic characteristics: Curve-matching method: Transmissivity (ft^2/d)	Curve-matching method: Storage coefficient	Straight-line method: Transmissivity (ft^2/d)	Straight-line method: Storage coefficient
1	919-128-04	338	191	28,000	0.0011	29,000	0.0009
	919-128-08	173	72				
2	917-127-03	476	371	25,000	0.0005	24,000	0.0006
	917-127-04	--	--				
3	915-128-04	424	304	25,000	0.0005	27,000	0.0004
	915-129-03	408	288				
4	914-128-04	--	--	20,000	0.0007	24,000	0.0005
	914-128-06	260	--				
5	915-125-02	510	400	8,800	0.0004	8,000	0.0005
	915-125-03	385	285				
6	909-121-01	253	169	29,000	0.0006	19,000	0.0013
	909-121-07	117	38				
7	908-120-02	450	342	7,100	0.0003	6,300	0.0003
	908-120-03	385	--				
8	905-121-01	--	--	89,000	0.0007	88,000	0.0007
	905-121-07	--	--				

[1]First well listed in each group is discharge well, followed by observation well.

the two different methods were in reasonable agreement (table 2). An explanation of this may be that the rule setting the upper limit of u as 0.02 may be conservative, and that higher values are acceptable within certain limits.

The semilog data plots for tests 2 and 7 (figs. 15 and 20) do not become straight close to the end of the tests. This may result, in part, from the fact that critical time had not been exceeded. For this reason, the results using the curve-matching method may be more reliable for these tests.

Specific Capacities

The specific capacity of a well is related to the ability of the aquifer the well penetrates to transmit water, and thus is related to the transmissivity of the aquifer. Specific capacity data were collected as part of this study for the purpose of adding to the understanding of transmissivity of the Floridan aquifer in the northwest Volusia County area. The specific capacity is the ratio of pumping rate from a well to the drawdown in the well. Following the assumptions of the previous section, specific capacity is related to transmissivity by the following equation:

$$\frac{Q}{s_w} = \frac{4\pi T}{2.30 \log_{10} 2.25Tt/r_w^{2}S} \qquad \text{(from Lohman, 1972)}$$

where

s_w = drawdown at production well, in feet,

r_w = radius of production well, in feet,

and other terms are as previously defined. The equation shows that specific capacity, Q/s_w, is nearly proportional to T at a given value of t, but gradually diminishes as t increases, by the amount $1/\log_{10} t$. The value of transmissivity calculated for a given test is sensitive to specific capacity but relatively insensitive to values of t, r_w, and S. The equation is based on the assumption that the well is 100 percent efficient. This assumption, which may be weak, was checked for a few of the specific capacity determinations by a comparison of the results with those of aquifer tests.

Table 3 shows specific capacity results for 10 wells. Four of the specific capacity tests were performed during the two-well aquifer tests described previously. The values of estimated borehole radius, r_w, were derived from a knowledge of casing diameter and of caliper logs for the area. An 8-inch-diameter well in Pierson, for example, will generally have an average borehole radius of 0.6 foot. Estimates of S came from results shown on table 2.

Table 3.--Specific capacity data

Local No.	Well depth (ft)	Thickness of aquifer penetrated (ft)	Pumping rate (gal/min)	Period of pumpage (min)	Drawdown (ft)	Specific capacity [(gal/min)/ft]	Estimated borehole radium (ft)	Apparent transmissivity (ft^2/d)	Aquifer test number (table 2)	Transmissivity from curve-matching method (ft^2/d)
919-128-02	135	55	480	180	13	37	0.5	8,900	--	--
918-127-02	475	385	810	120	14	58	0.6	15,000	--	--
915-128-04	424	304	570	181	7.76	73	0.6	19,000	3	25,000
914-128-02	249	147	800	180	14	57	0.6	16,000	--	--
914-128-04	--	--	1,100	91	7.21	153	0.7	42,000	4	20,000
914-125-05	789	--	464	120	24.6	19	0.6	4,500	--	--
910-128-02	500	390	500	--	8	62	0.6	18,000	--	--
908-120-02	450	342	250	190	8.28	30	0.6	7,800	7	7,100
906-120-03	350	190	1,400	180	2.45	571	0.6	160,000	--	--
905-121-01	--	--	1,050	160	7.55	139	0.6	37,000	8	89,000

Discussion of Physical Properties of the Floridan Aquifer

Apparent transmissivities from aquifer tests and specific capacities are shown in figure 22. The average of transmissivity values in the Seville and Pierson areas is approximately 20,000 ft^2/d while that of the DeLeon Springs area is 50,000 ft^2/d. These generalized transmissivity values agree reasonably well with the digital model by Bush (1978), which included an average transmissivity of 27,000 ft^2/d in the Seville and Pierson areas, and an average transmissivity of 50,000 ft^2/d in the DeLeon Springs area. The transmissivity distribution in the model was considerably more uniform in the Seville and Pierson areas than it was in the DeLeon Springs area. The difference in average transmissivity between the Crescent City Ridge area and the DeLand Ridge area is supported by caliper logs which show considerably larger cavities in the DeLeon Springs area. The highest apparent transmissivity of 160,000 ft^2/d was calculated from a specific capacity in the DeLeon Springs area. The lowest apparent transmissivity was the 4,500 ft^2/d calculated for a well in the east-central Pierson area. The deepest irrigation wells in the study area are located in this area of low transmissivity because drilling operations tend to continue until a desired well yield is obtained.

The aquifer test results generally show good correlations between transmissivity calculations performed by the various methods. Aquifer test 6 showed the only significant departure in results between the curve-matching method and the straight-line method. Because the straight-line method is sensitive to errors in the data which would cause an apparent change in the slope of the straight-line part of the plot, the result obtained by the curve-matching method, 29,000 ft^2/d, is probably more reliable.

The specific capacity results (table 3) agree reasonably well with those of the curve-matching method for tests 3 and 7. The corresponding results for test 4, on the other hand, show a considerable difference. This difference is not caused by well loss because well loss would create a lower calculated T value from specific capacity than that from the curve-matching method. The values of transmissivity calculated from aquifer test 8 are considerably larger than the value from the specific capacity, apparently because the pumping well is considerably less than 100 percent efficient. Unpublished drawdown data from two other observation wells monitored during the test support the two-well aquifer test results, and not the specific capacity results.

Apparent values for storage coefficient range from 0.0003 to 0.0013. The higher number may not be reliable because it was obtained from the straight-line analysis of test 6. Without it, the range of storage coefficient values is 0.0003 to 0.0011. The average of all values is 0.0006. The values of apparent storage coefficient for the Pierson area,

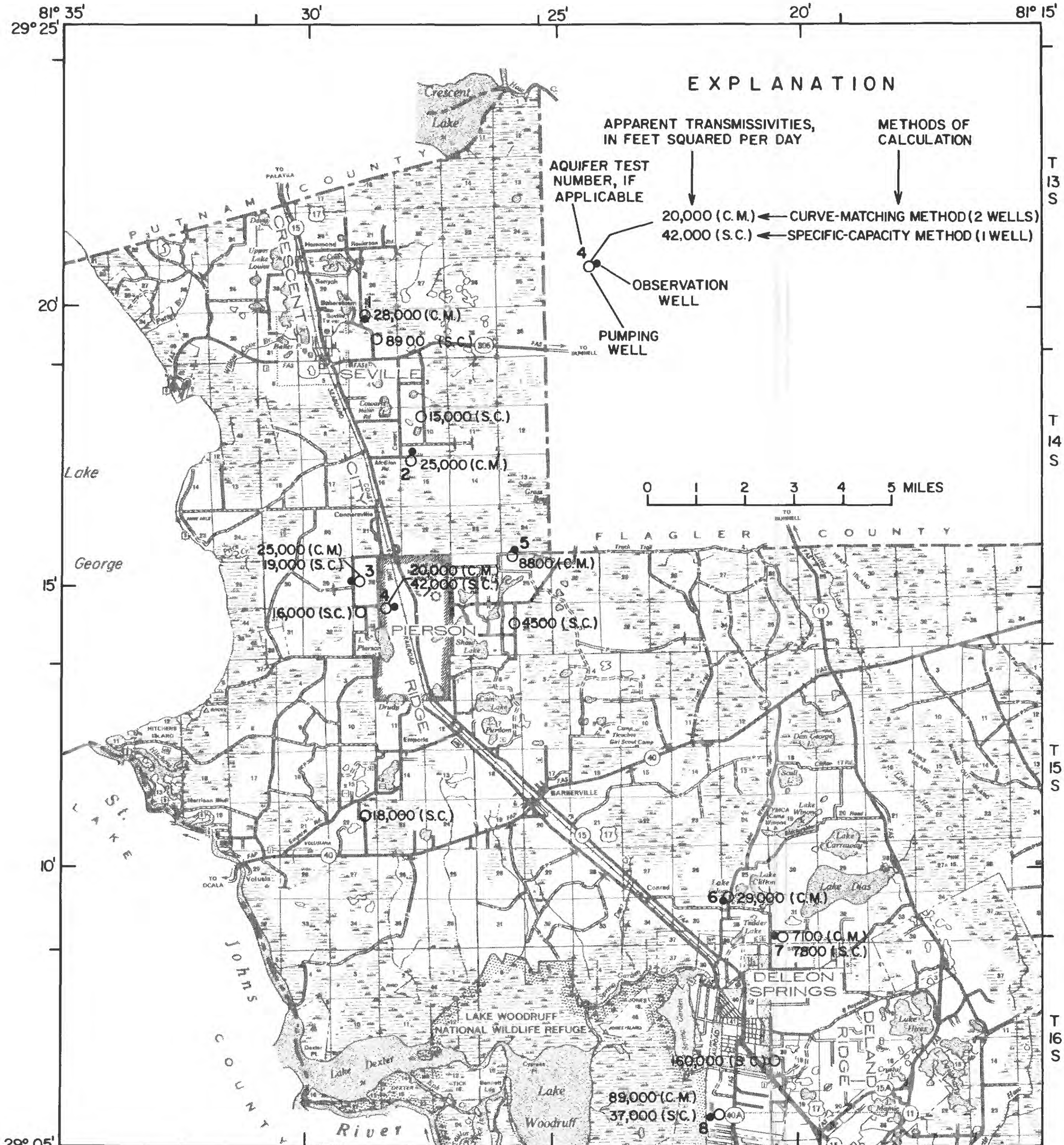


Figure 22.--Apparent transmissivity data from aquifer tests and specific capacities.

from tests 2-5, range from 0.0004 to 0.0007 and average 0.0005. Apparent storage coefficient values may be subject to error because of (1) lack of early data for most tests, and (2) divergence of early data, where available, from the Theis curve.

FLORIDAN AQUIFER FLOW SYSTEM

Potentiometric Surface

Potentiometric surface maps were constructed to understand the distribution of hydraulic head and the directions of flow within the Floridan aquifer. These are made with measurements of the altitude of the water surface in wells that are cased into the aquifer. The observation wells used for constructing potentiometric surface maps (fig. 23) are described, among other wells, in the well inventory table at the end of the report. The potentiometric surface is shown during a period of high water (fig. 24) and during a period of low water (fig. 25). Each map was constructed from approximately 60 water-level measurements.

The three potentiometric highs in northwest Volusia County are in the north Seville area, the east Pierson area, and the area east of DeLeon Springs. Potentiometric highs may be created by a combination of recharge, low transmissivity, and remoteness of discharge areas. A potentiometric high is not necessarily an area of high recharge, although some recharge must occur. The closed surficial drainage basins in the Seville and Pierson highs (fig. 9), because of their characteristic high recharge, probably play an important part in forming these areas of high potentiometric surface. The anomalously low transmissivity in the east Pierson area (fig. 22) accounts in part for this potentiometric high. The potentiometric high east of DeLeon Springs is the northwestern corner of the central Volusia potentiometric high. Most of this potentiometric dome is located southeast of the study area, and is outside the area shown on figures 24 and 25. This high exists mainly because of the remoteness of discharge areas. The potentiometric high of central Volusia is an area of low recharge although it is flanked on the west by the DeLand Ridge, which allows a relatively large downward leakage.

Potentiometric depressions in northwest Volusia County are caused by direct ground-water discharge in springs and by upward leakage through the confining bed. The 20 Mgal/d discharge from Ponce de Leon Springs accounts for the closed 10-foot contour in the southern part of the study area. This depression extends to the west because of upward leakage in the Lake Dexter - Lake Woodruff area. Another depression around Lake George indicates upward leakage. Upward leakage also occurs in the northern part of the study area near Crescent Lake. The potentiometric surface is generally above land surface in these areas of upward leakage through the confining bed.

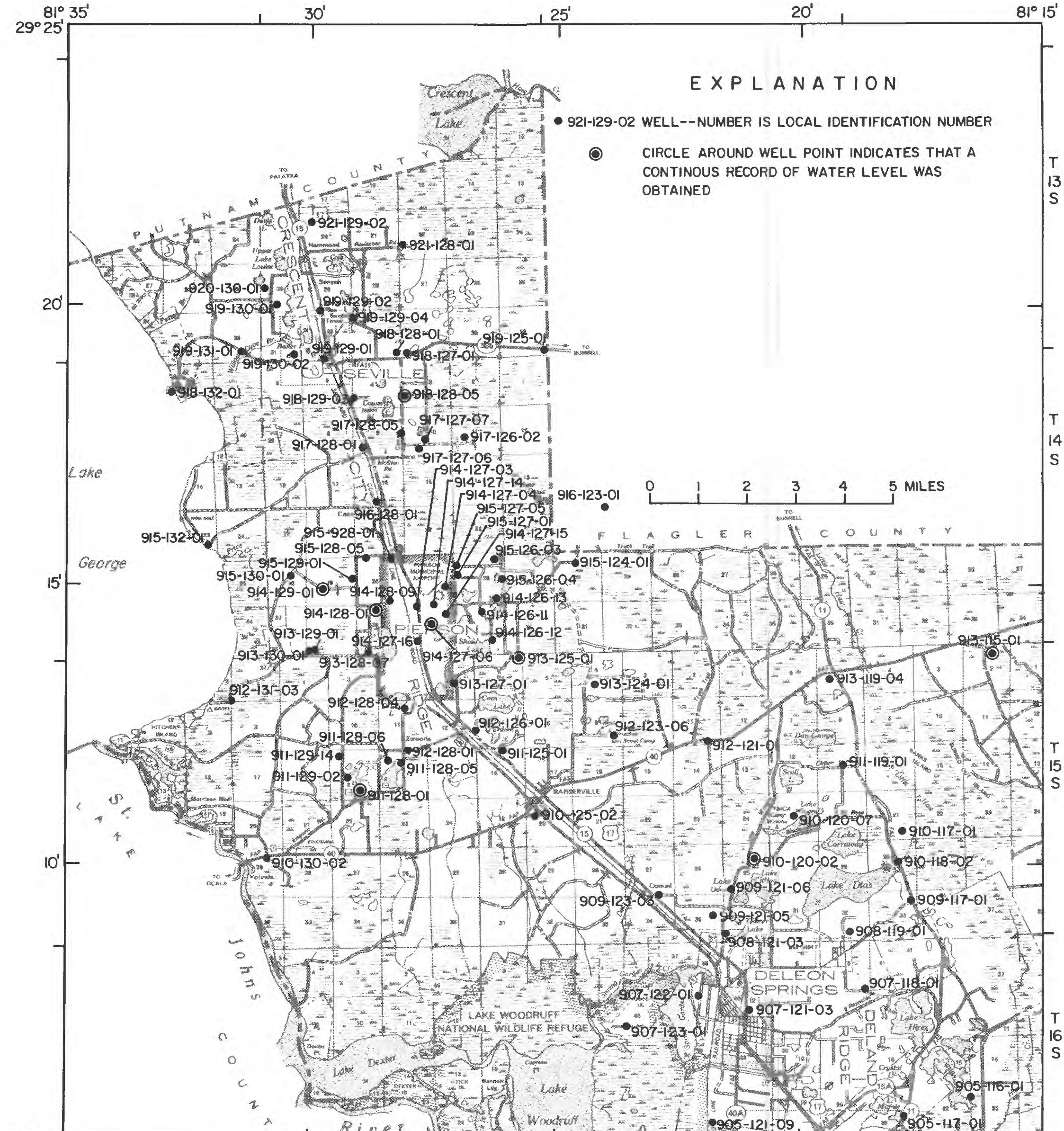


Figure 23.--Floridan aquifer water-level observation wells.

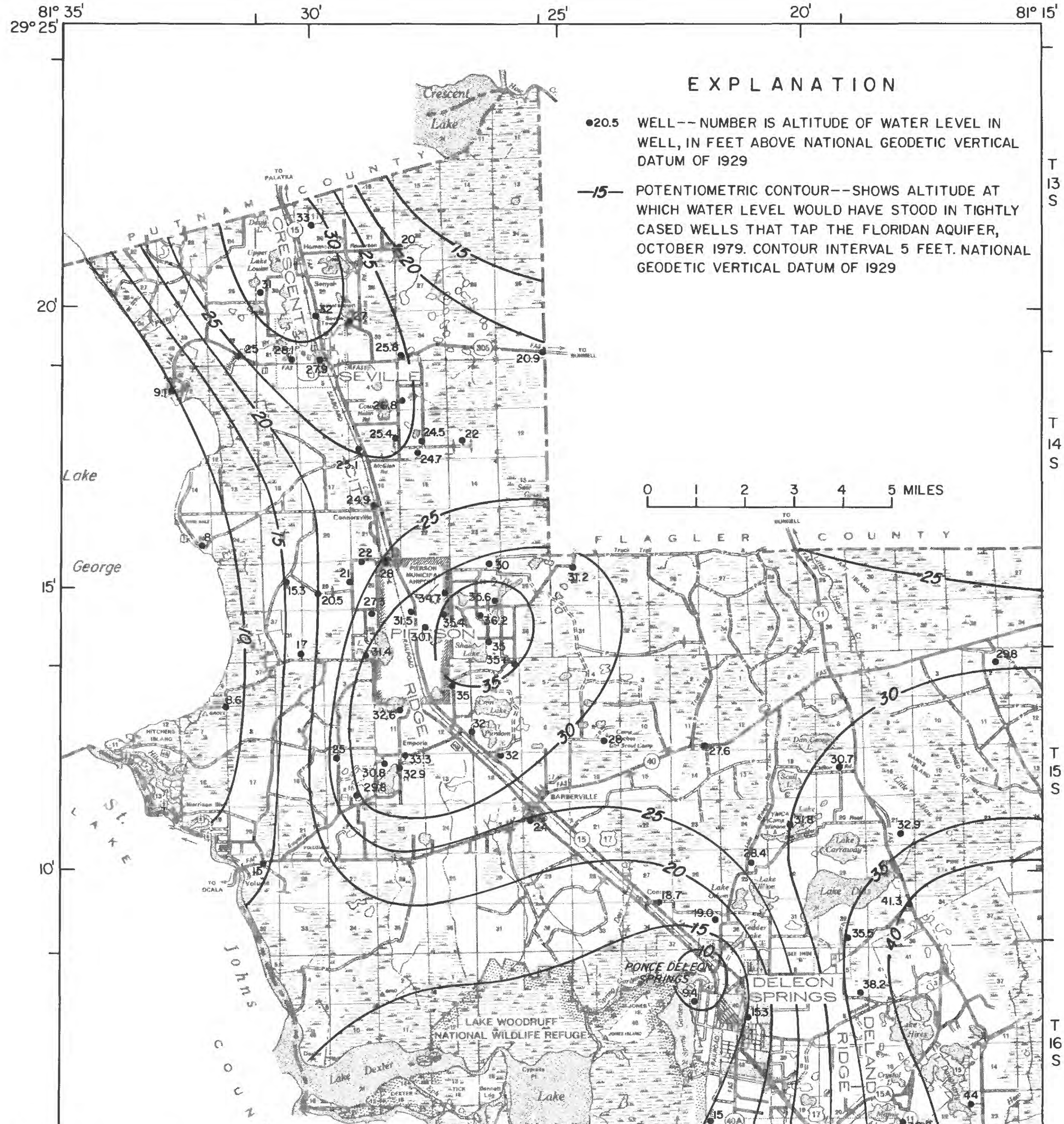


Figure 24.--Potentiometric surface of the Floridan aquifer, October 1979.

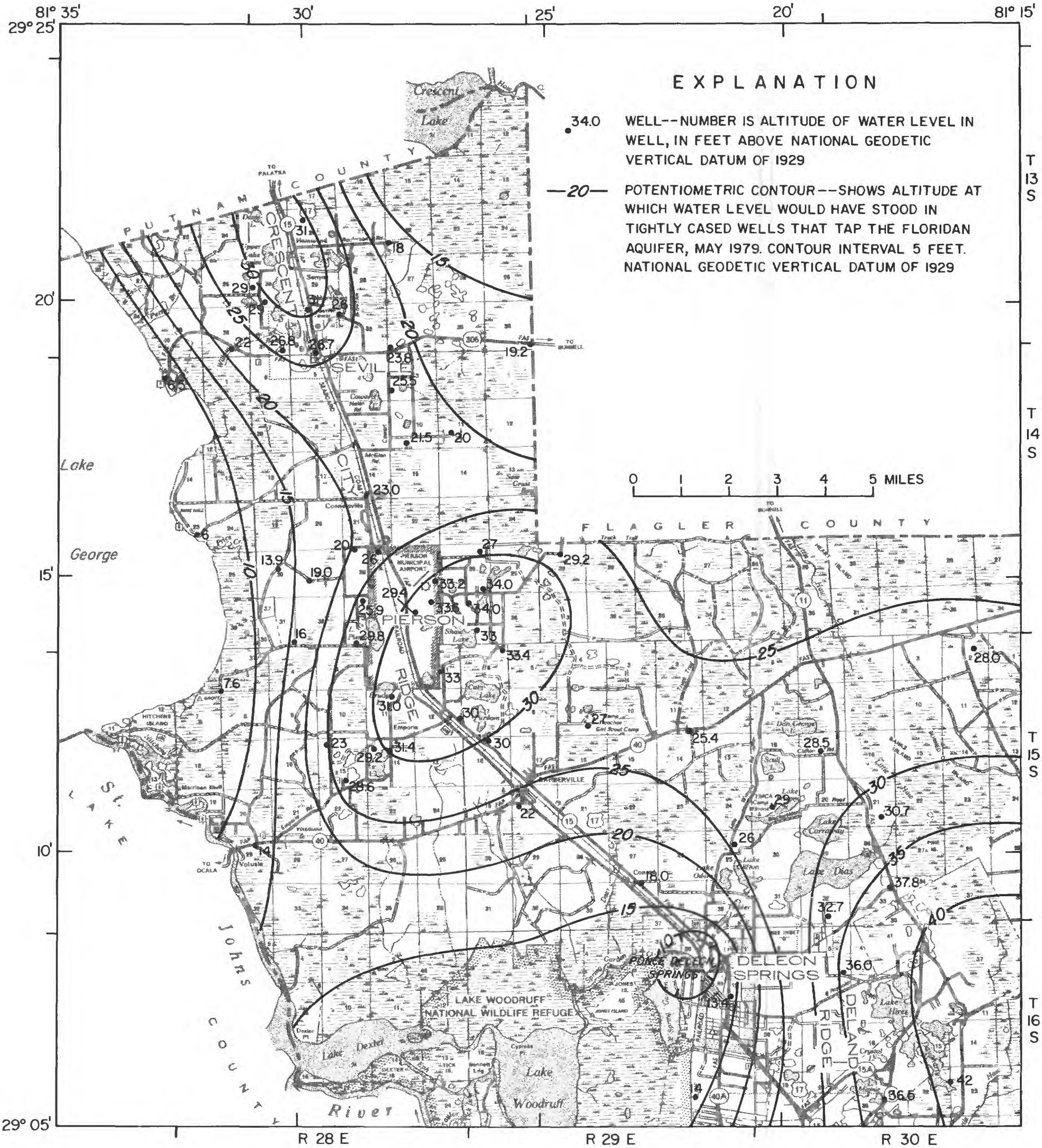


Figure 25.--Potentiometric surface of the Floridan aquifer, May 1979.

The potentiometric maps shown are for periods of little pumping stress. The head distribution may vary considerably during times of pumpage. A discussion of drawdowns due to pumpage is in a later section.

Flow Directions in the Floridan Aquifer

The flow of water in an aquifer is from a point of high head to low head. The flow may be thought of as having a horizontal component and a vertical component. If, for example, the head decreases in the aquifer in the northward direction and also decreases in the downward direction, then the ground-water flow has a northward component and a downward component. Farther along the path of flow, the vertical component may change to the upward direction as a discharge area is approached.

The horizontal component of flow is generally at right angles to potentiometric contours. Arrows showing these flow directions (fig. 26) radiate from recharge areas or potentiometric highs and converge on areas of ground-water discharge. The study area may be divided into three ground-water basins on the basis of flow directions. Flow in one basin is toward Lake George, flow in another is toward Flagler County, and in the third, to the Lake Woodruff and Ponce de Leon Springs area (fig. 26). Most of the water in these basins is recharged within the boundaries of the study area. The only ground-water inflow to the study area is along the southern boundary of the study area.

Figure 26 also gives information about the vertical component of flow in the Floridan aquifer. Downward borehole flow in a well indicates that the head is greater in the upper zone penetrated than in the lower zone penetrated and therefore indicates a downward vertical flow component. The downward flow in the aquifer would exist in the absense of the well. An upward borehole flow indicates an upward vertical flow component within the aquifer. If two adjacent wells open to different altitudes within the Floridan have dissimilar water levels, then the vertical component of ground-water flow is (1) downward if the shallow well head exceeds the deep well head, or (2) upward if the deeper well has greater head than the shallow well. The borehole-flow tests mentioned here were accomplished with brine-trace logs. Care was taken to insure that very little pumping stress was taking place during brine-trace logging and while determining head differences between adjacent wells.

The study area can be divided into areas with artesian flow and areas without artesian flow (fig. 27). In an area of artesian flow, the static water level in wells open to the Floridan aquifer is higher than land surface. These wells will flow without pumping if they are open at land surface. The potentiometric surface of October 1979 (fig. 24) was used to construct figure 27. The areas of artesian flow during low water periods will be less than that shown on the map, and especially so in the vicinity of Little Haw Creek.

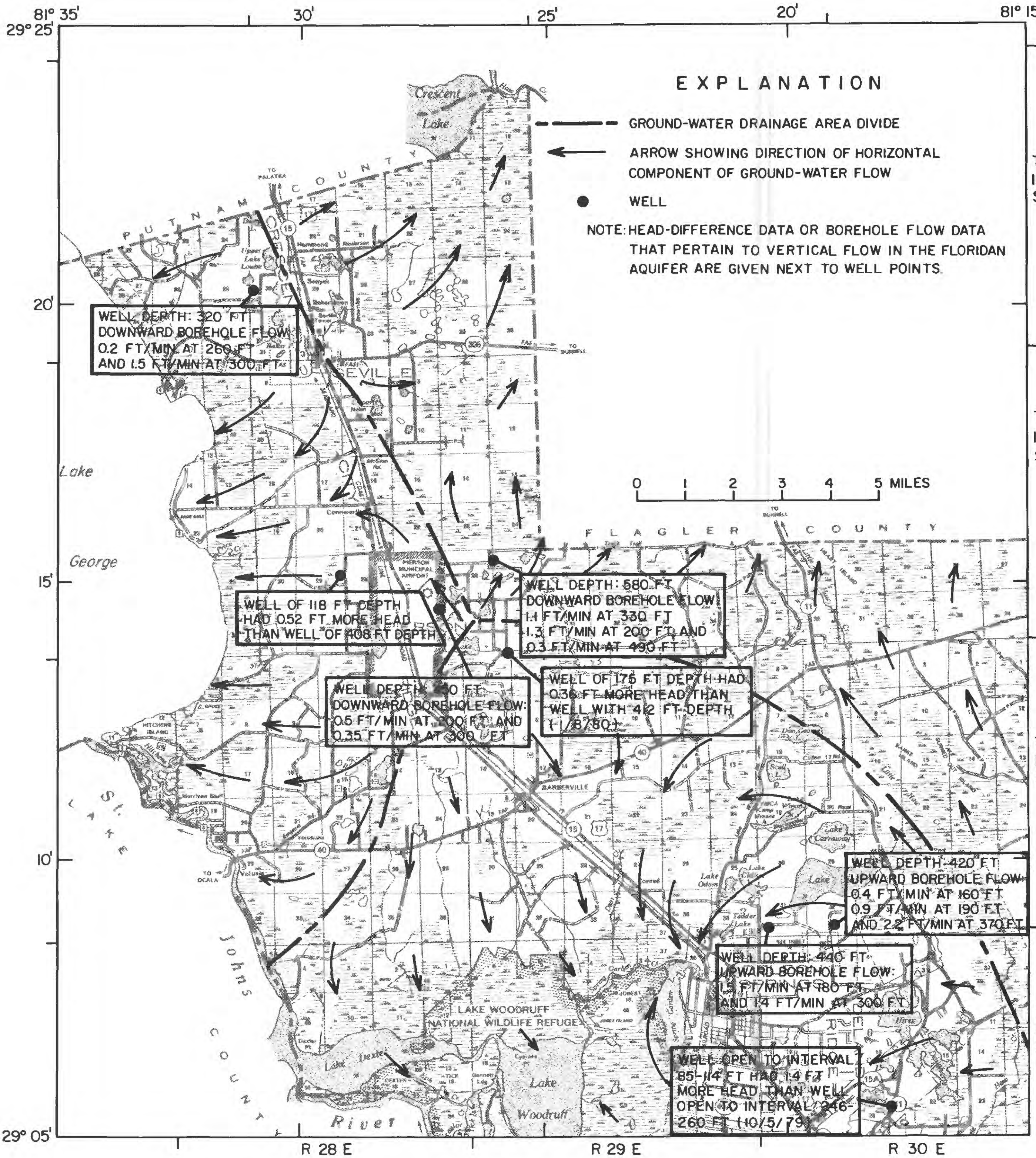


Figure 26.--Directions of ground-water flow in the Floridan aquifer, October 1979.

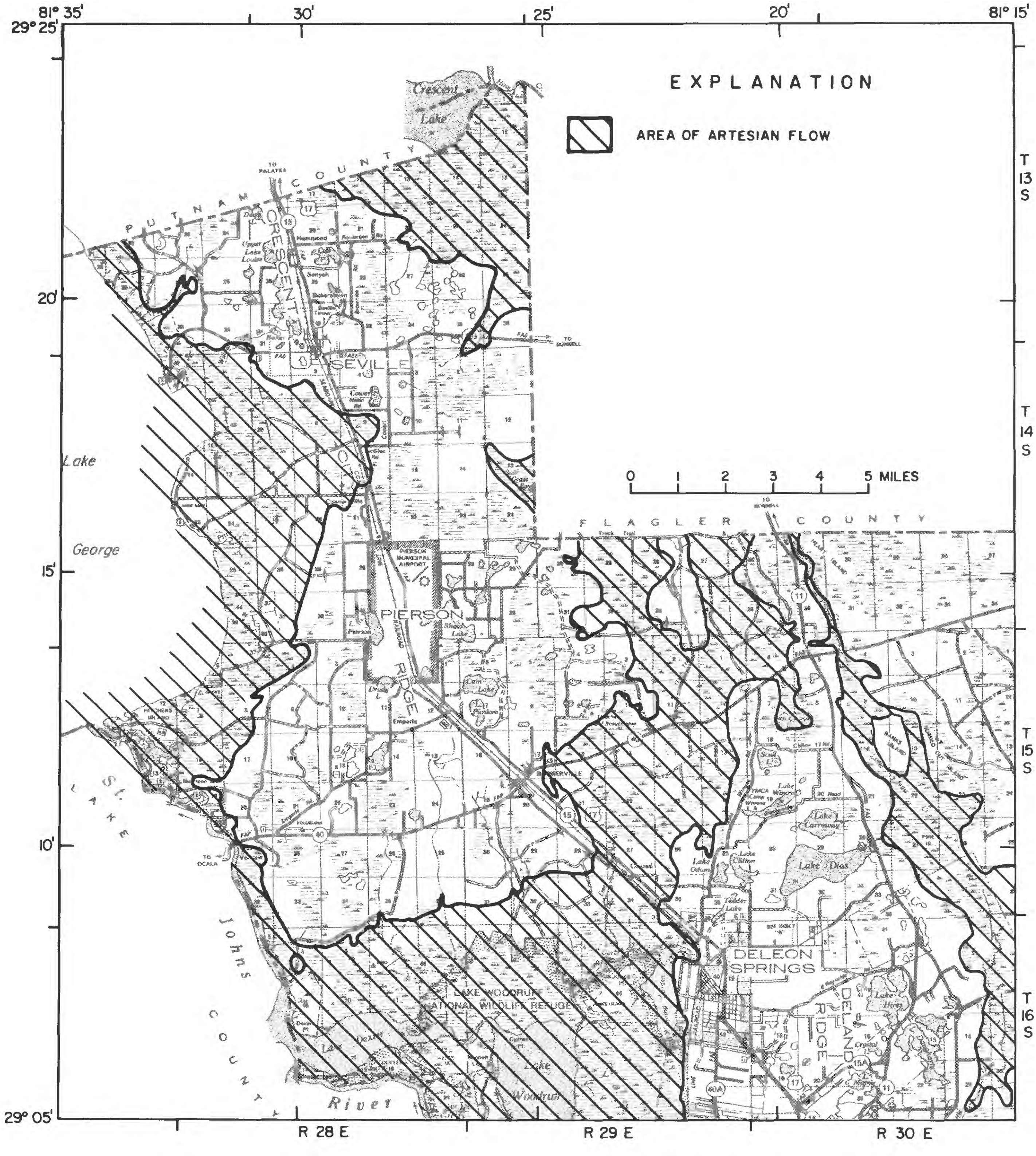


Figure 27.--Areas of artesian flow of Floridan aquifer in northwest Volusia County, October 1979.

Areas of artesian flow are usually areas of upward leakage, or discharge, from the Floridan aquifer while other areas exhibit downward leakage, or recharge, to the Floridan. The actual area of upward leakage may exceed that shown because some discharge may occur where the potentiometric surface is below land surface--as long as the potentiometric surface is higher than the water table in the surficial aquifer. Approximately 40 percent of the study area is characterized by discharge from the Floridan.

Flow-Net Analysis and Water Budget

If the potentiometric surface and the transmissivity of an aquifer are known, the flow rate may be calculated for any point in the system. It follows that if the head gradient across the outflow boundary of a recharge area is known and the transmissivity at that boundary is also known, then the total outflow rate for that recharge area may be calculated, and thus, so may the average recharge rate for the area assuming steady-state conditions. Flow-net analysis, when used in conjunction with known discharges, can yield an understanding of the water budget of an aquifer.

Using equation 137 from Lohman (1972, p. 47) that relates ground-water flow to the potentiometric surface and the transmissivity of the aquifer, the flow can be calculated from Darcy's Law:

$$Q = \frac{T \, \Delta h}{\Delta r} \times \frac{L_1 + L_2}{2}$$

where

Q = rate of flow perpendicular to a potentiometric contour, in cubic feet per day,

T = transmissivity of the aquifer in feet squared per day,

Δh = change in head between the two contours, in feet,

Δr = distance between the two contours, in feet,

L_1, L_2 = respective lengths of the two contours, in feet.

The flow-net diagram (fig. 28) was derived from the potentiometric surface map (fig. 24) and shows the outflow boundaries of areas A, B, C, D, E, and F as the midline between potentiometric contours. Each of the corresponding contours differ by 5 feet with the exception of the contours representing the outflow boundary of area B, in which case the contours used are the 15-foot contour and the inferred 17-foot contour. The areas between contours have been segmented into near-rectangular flow cells which are numbered 1 through 36. The flow equation above was applied to each

Figure 28.--Flow net of Floridan aquifer in northwest Volusia County (areas and flow cells derived from potentiometric surface map of October 1979 in figure 24; area names refer to tables 5 and 6).

cell in the simplified form Q = TIL wherein I represents $\Delta h/\Delta r$ and L represents $(L_1 + L_2)/2$. In calculations L was measured as the width of the segment midway between contours and Δr was measured as the average distance between contours for each cell. Results of the calculations are shown in table 4.

The estimated transmissivity at the outflow boundaries of areas A, B, E, and F was 15,000 ft^2/d, while the estimated transmissivity at the outflow boundary of area C was 20,000 ft^2/d and that of area D, 60,000 ft^2/d. These values are in reasonable agreement with observed transmissivities from figure 22.

The total outflow, and thus, the total recharge for areas A through F, is calculated as 63 ft^3/s (table 5) assuming steady-state conditions. This is equal to a net recharge rate of 3.9 in/yr. Because areas A through F include discharge areas (fig. 27), the total downward leakage to the Floridan is greater than 63 ft^3/s. The 63 ft^3/s net recharge is the algebraic sum of a larger number which represents downward leakage minus upward leakage within the area.

The calculated recharge rate of area A is relatively high. This could be because area A includes a large part of the Crescent City Ridge. Areas B and E, which include sections of the Crescent City Ridge, have net recharge rates between 2 and 3 inches per year. Area B is covered with flatwood soils in 80 percent of its expanse (fig. 8). Area E, on the other hand, includes ridge soils with good recharge capability over one-third of its area. The reason for the low calculated recharge rate of the latter is not readily apparent, although it may exist because of errors in the potentiometric map arising from sparse water-level data northeast of Seville. Areas C and F have very low net recharge rates because they are covered largely by flatwood and swamplands and because they include significant areas of discharge (fig. 27). Area D has a calculated recharge that is much larger than that of the other four areas, probably because of the coincidence of extensive closed basins (fig. 9) and low clay-bed thickness (fig. 6).

To describe the water budget of the Floridan aquifer for the entire northwest Volusia County area, the areas outside of areas A through F must also be analyzed. Areas G through L (fig. 28) which are covered almost entirely by discharge areas, are fed mainly by horizontal ground-water inflow from areas A through E. Area I is fed by horizontal inflow from outside the study area. Water leaves areas G, H, I, J, K, and L by upward leakage or horizontal outflow. Using the 4 in/yr upward leakage rate for discharge areas (table 1), the budget of these areas may be estimated (table 6). Horizontal outflow for each area is the difference between inflow from flow-net analysis and upward leakage. The upward leakage is assumed to be equal to inflow for area H because the 4 in/yr rate would exceed the horizontal inflow from area B. Area K, which is one-third discharge area and two-thirds upland ridge, has a net downward

Table 4.--Quantity of flow leaving areas A, B, C, D, E, and F, calculated from the equation Q = TIL

Cell No.	T (ft^2/d)	I (ft/ft)	L (ft)	Q (ft^3/s)
1	15,000	5/2,620	16,800	5.56
2	15,000	5/4,010	10,000	2.17
3	15,000	5/4,790	8,450	1.53
4	15,000	5/4,230	26,400	5.41
5	15,000	5/6,230	2,750	0.38
6	15,000	5/7,500	1,850	0.21
7	15,000	5/8,550	1,060	0.11
8	15,000	5/9,400	1,580	0.15
9	15,000	2/9,000	1,580	0.06
10	15,000	2/6,600	2,530	0.13
11	15,000	2/5,070	2,010	0.14
12	15,000	2/4,380	2,110	0.17
13	15,000	2/3,700	3,270	0.31
14	15,000	2/3,540	2,530	0.25
15	15,000	2/3,270	2,380	0.25
16	15,000	2/3,270	7,290	0.77
17	15,000	2/3,700	6,650	0.63
18	20,000	5/9,400	7,920	0.96
19	20,000	5/7,660	3,640	0.55
20	20,000	5/6,380	3,220	0.58
21	60,000	5/3,960	5,070	4.45
22	60,000	5/2,530	3,800	5.21
23	60,000	5/2,060	2,640	4.46
24	60,000	5/2,220	2,640	4.13
25	60,000	5/2,850	5,020	6.11
26	60,000	5/3,380	4,960	5.10
27	60,000	5/4,750	5,120	3.74
28	15,000	5/3,220	4,220	1.14
29	15,000	5/3,800	4,750	1.08
30	15,000	5/4,540	4,070	0.78
31	15,000	5/5,020	5,170	0.86
32	15,000	5/5,970	6,180	0.90
33	15,000	5/7,810	7,550	0.84
34	15,000	5/12,700	9,610	0.66
35	15,000	5/11,800	31,900	2.35
36	15,000	5/12,000	9,660	0.70

Table 5.--Flow-net summary

Area designation	Square miles	Outflow (ft^3/s)	Calculated recharge in/yr
A	48.61	15.5	4.3
B	18.46	2.7	2.0
C	30.78	2.1	0.9
D	33.76	33.2	13.4
E	29.32	5.6	2.6
F	55.59	3.7	0.9
Total	216.52	63	3.9

Table 6.--Residual areas of flow net

Area		Estimated inflow (ft^3/s)	Outflow		Remarks
Designation	Square miles		Upward leakage (ft^3/s)	Horizontal outflow (ft^3/s)	
G	11.93	15.5	3.5	12.0	Assume upward leakage = 4 in/yr
H	18.26	2.7	2.7	0	Assume upward leakage = inflow
I	5.74	1.7 (est.)	1.7	0	Assume upward leakage = 4 in/yr
J	5.15	2.1	1.5	0.6	Do.
K	6.81	33.2	-3.7	36.9	Assume area is one-third discharge area and two-thirds recharge area
L	9.11	4.8	2.7	2.1	Assume upward leakage = 4 in/yr
Total	57.00	60.0	8.4	51.6	

leakage of 3.7 ft^3/s. This was calculated by assuming that the 13 in/yr recharge rate for area D applies to the ridge portion of area K and that the 4 in/yr discharge rate applies for its discharge portion. Horizontal outflow is zero for area H and area I because their flows converge upon each other and turn into upward leakage. The horizontal outflows of areas J and K become direct ground-water discharge from Ponce de Leon Springs and the flowing wells near the spring. The spring discharge measured on November 2, 1979, was 30.9 ft^3/s. If an estimated 4 ft^3/s flow rate from flowing wells near the spring is added to the spring discharge, the rate of ground-water discharge becomes approximately 35 ft^3/s. This is in reasonable agreement with the 37.5 ft^3/s outflow of areas J and K. The 12.0 ft^3/s outflow from area G may be thought of as horizontal outflow from the study area although it ultimately leaves the ground-water system by upward leakage into Lake George. This may also be the case for the 2.1 ft^3/s outflow from area L, which ultimately leaves the system by upward leakage in Crescent Lake and in parts of Flagler County.

The estimated budget of the Floridan aquifer for areas A though L (table 7) was derived from the preceding flow-net analysis and from the analysis of the areas residual to the flow net. The net recharge rate is the total outflow of areas A though F minus the total upward leakage for areas G through L. This 55 ft^3/s rate, when applied to the 274-square-mile area, is 2.7 in/yr net recharge. The net downward leakage from the surficial layer estimated earlier (table 1) for the 262-square-mile study area was 3 in/yr. The 12-square-mile area difference exists because the present analysis includes a small part of Flagler County (fig. 28). The only remaining inflow to the system is the 2 ft^3/s estimated ground-water inflow from the south. After upward leakage, the only outflows from the Floridan aquifer from northwest Volusia are direct spring and flowing well discharges at Ponce de Leon Springs and horizontal outflow to Lake George, Crescent Lake, and Flagler County. Because this budget was derived from an unstressed potentiometric surface, it is probably only valid as a water budget of the Floridan aquifer in its natural unstressed condition. The water budget under present pumping stress will be described in a later section.

Flow-net analysis and the resulting assessment of the Floridan aquifer water budget in northwest Volusia County are not without probability of significant error. The observed values of transmissivity are the largest source of probable error, with local variation of at least 25 percent around average regional transmissivities. The determinations of I and L (table 4) have built-in inaccuracies of approximately 5 percent each. The 4 in/yr estimation of upward leakage in discharge areas is an approximate average of this rate for all discharge areas. The actual rate, though, ranges from a small fraction of an inch per year in areas of minimal hydraulic gradient through the confining layer to perhaps as much as 6 in/yr in areas of maximum gradient and minimum confining bed thickness. The cumulative flow-rate error resulting from the above-mentioned parameter errors may be considerably higher. Of importance, though, is the fact that many of the potential errors

Table 7.--Estimated budget of Floridan aquifer without pumping stress for areas A-L (fig. 28)

Inflow	Cubic feet per second
Net recharge	55
Horizontal inflow	2
Total	57

Outflow	Cubic feet per second
Spring discharge and flowing wells near spring	38
Horizontal outflow--	
to Crescent Lake and Flagler County	7
to Lake George	12
Total	57

mentioned represent "noise" between the values of each of these hydrologic parameters, and these errors may tend to cancel each other out when the entire flow system is considered. For example, the actual transmissivities along the outflow boundary of area A (fig. 28) might range from 10,000 ft^2/d to 20,000 ft^2/d, and these variations may result in flow-rate errors from site to site of as much as 33 percent. Nonetheless, the total actual flow rate through this large outflow boundary may be close to the calculated flow rate through the boundary because the average actual transmissivity is close to the 15,000 ft^2/d value used in the flow-net analysis. For these reasons, it is the final overall water budget (table 7) that has the most accuracy of all the estimations in this section and caution should be used when the specific estimations of tables 4 through 6 are utilized.

Occurrence of Brackish Water in the Floridan Aquifer

A considerable number of analyses of chloride concentration have been performed on water from the Floridan aquifer in northwest Volusia County. The reasons for this are that chloride concentration is a commonly used index of how brackish a water is, and brackish water contamination is a major potential water problem in the area. Water having a chloride concentration of not more than 250 mg/L is acceptable for public supply. A chloride concentration in irrigation water exceeding 700 mg/L may be damaging to ferns. Water having chloride concentrations in excess of 250 mg/L may be referred to as brackish. If the concentration approaches 19,000 mg/L, the water has a salt concentration close to that of the ocean, and is referred to as saltwater.

It is the purpose of this section to describe the present occurrence of brackish water. A later section will evaluate changes in salt concentration with the passage of time. Although the Floridan aquifer contains very good-quality water in most of the study area, it contains brackish water in its upper zones along the western and southern limits of the area and saltwater is also present in deeper zones of the aquifer throughout the area.

Concentrations of the principal chemical constituents of water from wells in northwest Volusia County are given in table 8. Twenty-five of these analyses were performed during November and December of 1978 as part of this study. Well 911-129-01 and well 914-127-01 were sampled in 1965 and 1978, while all others were sampled only once. All analyses are of Floridan aquifer wells except for that of 905-117-03, which is open to the surficial aquifer. More information about the wells sampled is available in the well inventory in the back of the report.

The chloride concentration of water in the upper part of the Floridan aquifer is very low in most of the study area (fig. 29). Areas of brackish water in the upper part of the aquifer are near Lake George and in the Lake Dexter - Spring Garden Lake area. Although the 26 to 250 mg/L chloride concentration range does not represent brackish water, it

STATION NUMBER	LOCAL NO.	DATE OF SAMPLE	SPECIFIC CONDUCTANCE (UMHOS)	PH (UNITS)	BICARBONATE FET-FLD (MG/L AS HCO3)	CARBONATE FET-FLD (MG/L AS CO3)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)
290520081211301	90512110	65-08-18	240	7.4	112	0	97	5	34	3.1	7.7
290534081175001	90511701	66-04-21	370	7.6	214	0	169	0	63	2.8	7.2
290534081175002	90511702	66-04-21	360	7.8	242	0	202	3	66	9.1	6.6
290534081175003	90511703	66-04-21	88	6.7	24	0	20	1	6.2	1.3	6.2
290538081213501	90512102	78-12-14	--	--	160	0	306	175	63	36	280
290550081162601	90511601	65-08-05	410	7.7	284	0	238	4	87	5.0	7.5
290551081180101	90511801	65-05-12	260	7.6	156	0	128	0	48	1.9	6.3
290552081161001	90511602	65-08-05	270	7.8	176	0	138	0	50	3.1	5.2
290612081214101	90612107	78-12-18	--	--	150	0	277	154	61	30	240
290625081201801	90612007	78-12-15	--	--	130	0	121	14	41	4.4	5.8
290635081202501	90612004	78-12-14	--	--	180	0	162	14	49	9.5	9.5
290646081213701	90612101	78-12-18	--	--	150	0	440	317	75	61	500
290704081155301	90711502	78-12-15	--	--	99	0	86	5	33	.9	4.7
290849081203101	90812001	65-08-13	400	7.5	190	0	154	0	45	10	22
291008081204801	91012001	65-08-20	195	7.5	104	0	87	1	30	3.0	5.6
291008081304801	90913001	65-08-12	588	--	344	0	282	0	93	12	6.0
291111081291401	91112915	78-12-13	--	--	200	0	169	4	58	5.8	6.0
291112081282601	91112802	78-12-14	--	--	140	0	120	5	39	5.5	5.2
291128081291501	91112901	65-08-12	268	7.7	136	0	125	13	45	3.0	4.5
	91112901	78-12-18	--	--	170	0	150	10	52	4.8	6.7
291222081243801	91212401	65-08-17	360	7.8	232	0	184	0	59	8.9	6.6
291258081313701	91213103	78-12-18	--	--	280	0	236	6	78	10	14
291339081192901	91311908	65-08-05	315	7.4	184	0	150	0	52	4.8	6.9
291340081192501	91311902	65-08-05	350	8.1	240	0	181	0	70	1.6	11
291347081295801	91312901	78-12-18	--	--	190	0	152	0	47	8.4	5.6
291422081254701	91412505	78-12-08	--	--	120	0	102	3	31	6.0	5.0
291426081224001	91412205	78-12-15	--	--	180	0	148	0	41	11	5.8
291431081272001	91412713	65-08-12	210	7.5	127	0	101	0	31	5.7	5.0
	91412713	78-12-15	--	--	130	0	110	3	34	6.0	4.8
291435081255301	91412509	78-12-14	--	--	120	0	102	3	30	6.5	5.0
291452081261701	91412610	78-12-20	--	--	120	0	108	9	32	6.8	5.0
291458081294201	91412901	78-12-20	--	--	210	0	178	5	53	11	5.6
291504081264801	91512608	78-12-18	--	--	140	0	137	22	40	9.0	5.7
291508081302801	91513001	78-12-20	--	--	160	0	150	18	48	7.3	6.2
291523081263101	91512606	78-11-21	--	--	120	0	112	13	33	7.1	5.1
291528081262001	91512614	78-12-15	--	--	180	0	146	0	43	9.3	5.0
291802081274101	91812702	78-11-30	--	--	180	0	154	6	52	5.8	5.8
291835081324201	91813201	65-08-17	3200	7.7	224	0	520	336	101	65	512
291838081280601	91812803	78-11-30	--	--	160	0	149	17	48	7.1	7.8
291851081304101	91813001	78-11-30	--	--	190	0	166	10	40	16	6.5
291910081312401	91913101	78-12-20	--	--	170	0	155	15	51	6.6	9.0
291955081304001	91913001	65-08-20	235	8.0	126	0	106	3	39	2.2	5.6

SAMPLES FROM WELLS

DATE OF SAMPLE	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SULFATE DIS-SOLVED (MG/L AS SO4)	SULFIDE TOTAL (MG/L AS S)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	STRON-TIUM, DIS-SOLVED (UG/L AS SR)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS NO3)	IRON, DIS-SOLVED (UG/L AS FE)	IRON (UG/L AS FE)	DEPTH OF WELL, TOTAL (FEET)
65-08-18	1.2	13	13	--	.1	7.0	2	134	.00	--	0	300
66-04-21	1.3	10	.0	--	.1	13	0	203	.00	2	--	--
66-04-21	.4	10	.0	--	.0	12	2	223	.10	--	900	260
66-04-21	.0	11	.0	--	.0	1.3	0	37	.10	--	390	11
78-12-14	12	500	--	.0	.1	7.1	760	--	--	30	--	--
65-08-05	.8	10	1.2	--	.1	8.7	--	260	1.6	--	1800	107
65-05-12	1.1	10	3.2	--	.1	10	--	157	.10	--	1700	120
65-08-05	.9	8.0	.0	--	.2	9.6	1	164	.10	--	20	240
78-12-18	10	450	63	--	.1	7.9	700	937	--	50	--	--
78-12-15	1.3	10	3.7	--	.1	6.5	230	137	--	<10	--	--
78-12-14	1.3	19	2.3	.3	.1	8.5	160	188	--	50	--	--
78-12-18	20	930	130	--	.1	7.8	1100	1799	--	30	--	--
78-12-15	.6	7.2	.3	--	.1	7.6	140	103	--	50	--	--
65-08-13	1.7	36	3.6	--	.2	12	1	224	.10	--	0	309
65-08-20	.7	10	.0	--	.2	8.2	--	109	.00	--	420	137
65-08-12	1.0	10	.0	--	.1	12	304	305	--	1300	--	--
78-12-13	1.2	11	2.2	.7	.1	7.0	110	190	--	440	--	--
78-12-14	2.3	11	5.7	.2	.1	7.5	100	145	--	180	--	--
65-08-12	2.1	8.0	12	--	.1	6.9	--	148	.10	--	100	128
78-12-18	1.8	11	15	--	.1	5.6	110	181	--	540	--	--
65-08-17	1.1	10	.0	--	.1	11	1	211	.00	--	40	155
78-12-18	1.2	27	.2	--	.1	9.5	230	278	--	260	--	--
65-08-05	.7	10	.8	--	.2	10	--	176	.10	--	370	130
65-08-05	1.6	10	.0	--	.1	21	--	233	.00	--	470	121
78-12-18	.9	7.8	1.1	--	.1	14	140	179	--	80	--	--
78-12-08	.9	8.0	1.5	.3	.1	8.1	120	120	--	110	--	--
78-12-15	1.2	10	.8	--	.1	9.2	120	168	--	30	--	--
65-08-12	.6	8.0	.0	--	.1	8.4	0	121	.00	--	0	250
78-12-15	.6	8.7	1.4	--	.1	8.1	130	128	--	30	--	--
78-12-14	1.1	9.0	.8	.6	.1	6.9	90	119	--	50	--	--
78-12-20	.9	8.4	3.4	--	.1	7.8	220	124	--	<10	--	--
78-12-20	.9	8.1	1.3	--	.2	15	250	199	--	60	--	--
78-12-18	2.8	13	17	--	.1	6.7	120	163	--	80	--	--
78-12-20	1.0	11	2.1	--	.1	11	250	166	--	<10	--	--
78-11-21	.9	8.5	2.0	.5	.1	8.3	100	124	--	<10	--	--
78-12-15	1.0	8.3	.3	--	.1	8.2	120	164	--	40	--	--
78-11-30	.9	9.3	1.5	.5	.1	8.8	130	173	--	<10	--	--
65-08-17	9.9	960	68	--	.2	10	2	1836	1.2	--	170	155
78-11-30	.9	12	3.0	1.0	.1	13	100	171	--	50	--	--
78-11-30	.9	11	3.5	1.0	.1	8.4	80	180	--	<10	--	--
78-12-20	.6	17	1.4	--	.1	7.9	180	177	--	50	--	--
65-08-20	.7	7.0	3.6	--	.2	13	--	133	.00	--	250	135

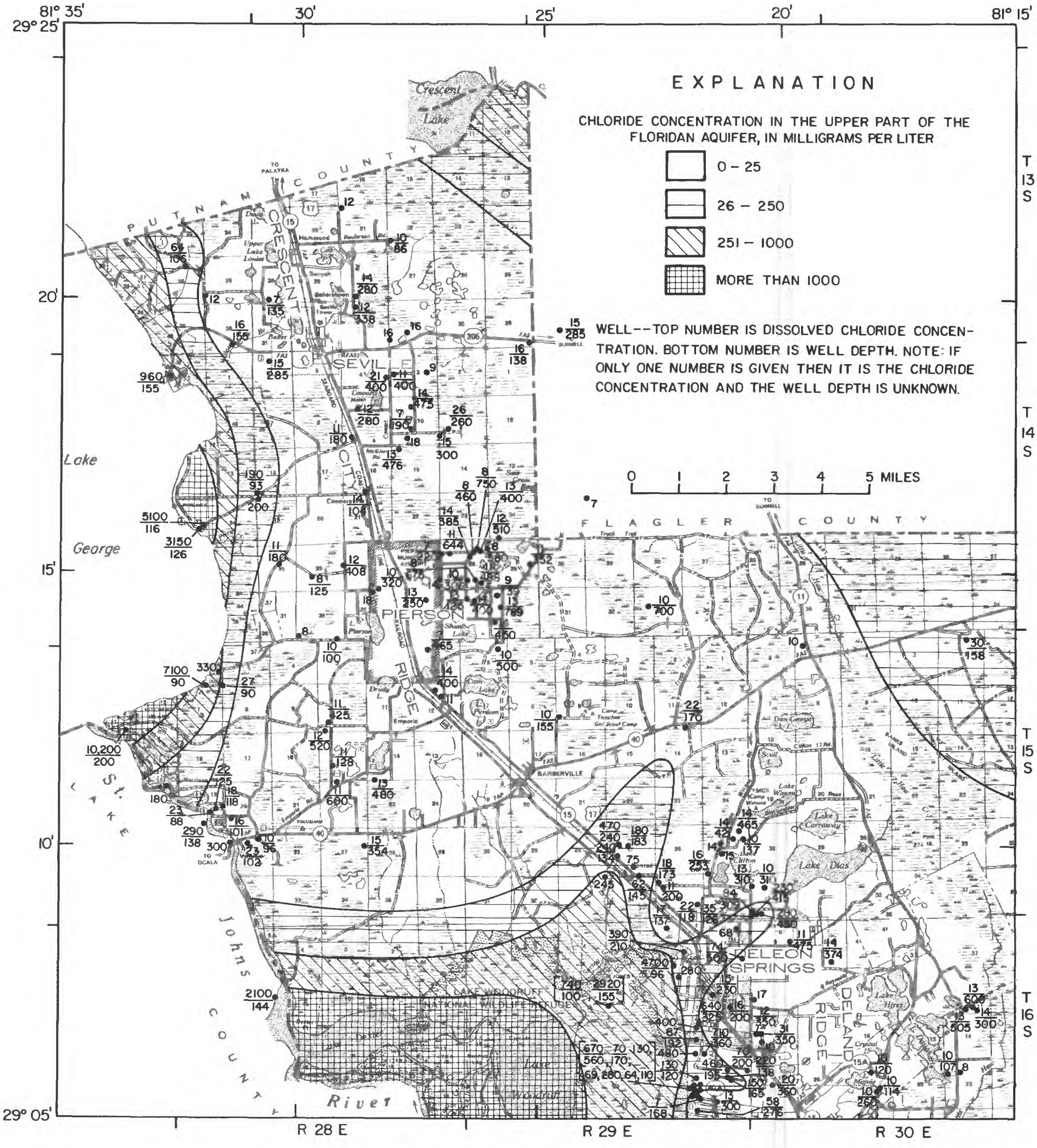


Figure 29.--Chloride concentration in water from wells that tap the upper part of the Floridan aquifer and well locations showing chloride concentrations and depths of wells.

is shown as a separate unit on the map merely to define with greater clarity the occurrence of brackish water in the aquifer. The water in the upper part of the Floridan becomes brackish in Flagler County. Because the chloride-concentration range areas shown on figure 29 are for the upper part of the Floridan aquifer only, a well in an area showing a low chloride range may actually yield water of higher chloride concentration if the well is drilled below the upper parts of the aquifer. Such is especially the case for irrigation wells in the west DeLeon Spring area. Because of the large water-yielding capacity needed, irrigation wells here tend to be drilled more than 100 feet into the Floridan.

The potentiometric surface map was used in conjunction with the Ghyben-Herzberg principle, as modified by Hubbert (1940) to estimate the altitude of the freshwater-saltwater interface (fig. 30). The principle states generally that when freshwater in an aquifer is in static equilibrium with the underlying saltwater, the altitude of the interface between them is -40 times the altitude of the head of the freshwater system. Because the freshwater system is not static, it is the freshwater head immediately above the fresh- saltwater interface that determines the vertical position of this interface. Furthermore, because the head within the freshwater flow system is known to vary with depth, the freshwater heads as indicated by the known potentiometric surface of the upper zones of the Floridan aquifer (fig. 24) were modified slightly before the interface calculations were performed. The average head in the upper part of the Floridan in east-central Pierson, for example, is approximately 34 feet. The head deep in the freshwater flow system near the interface is estimated to be 30 feet, and the altitude of the interface is thus calculated to be at altitude -1,200 feet. Saltwater head was assumed to be zero everywhere because of lack of data.

Care should be exercised in using figure 30 for areas where the modified Ghyben-Herzberg principle was used to estimate the altitude of the top of the saltwater zone. The principle provides an estimate of the altitude of the fresh- saltwater interface in an ideal condition in which this interface is sharp. In the real system, the transition from freshwater to saltwater occurs gradually with depth, so that the altitude of the top of brackish water may be significantly higher than the altitude of the top of saltwater.

Figures 31 and 32 are generalized hydrogeologic cross sections showing the chloride concentration in the Floridan aquifer. These were constructed using the data and principles discussed previously with respect to figures 29 and 30. Figure 31 is a hydrogeologic cross section at latitude 29°15' from Lake George, through Pierson, and into the central Volusia flatwoods and swamps east of State Road 11. Figure 32 is a hydrogeologic cross section at latitude 29°06' which begins east of Lake Woodruff, extends across the DeLeon Springs area, and ends near Little Haw Creek.

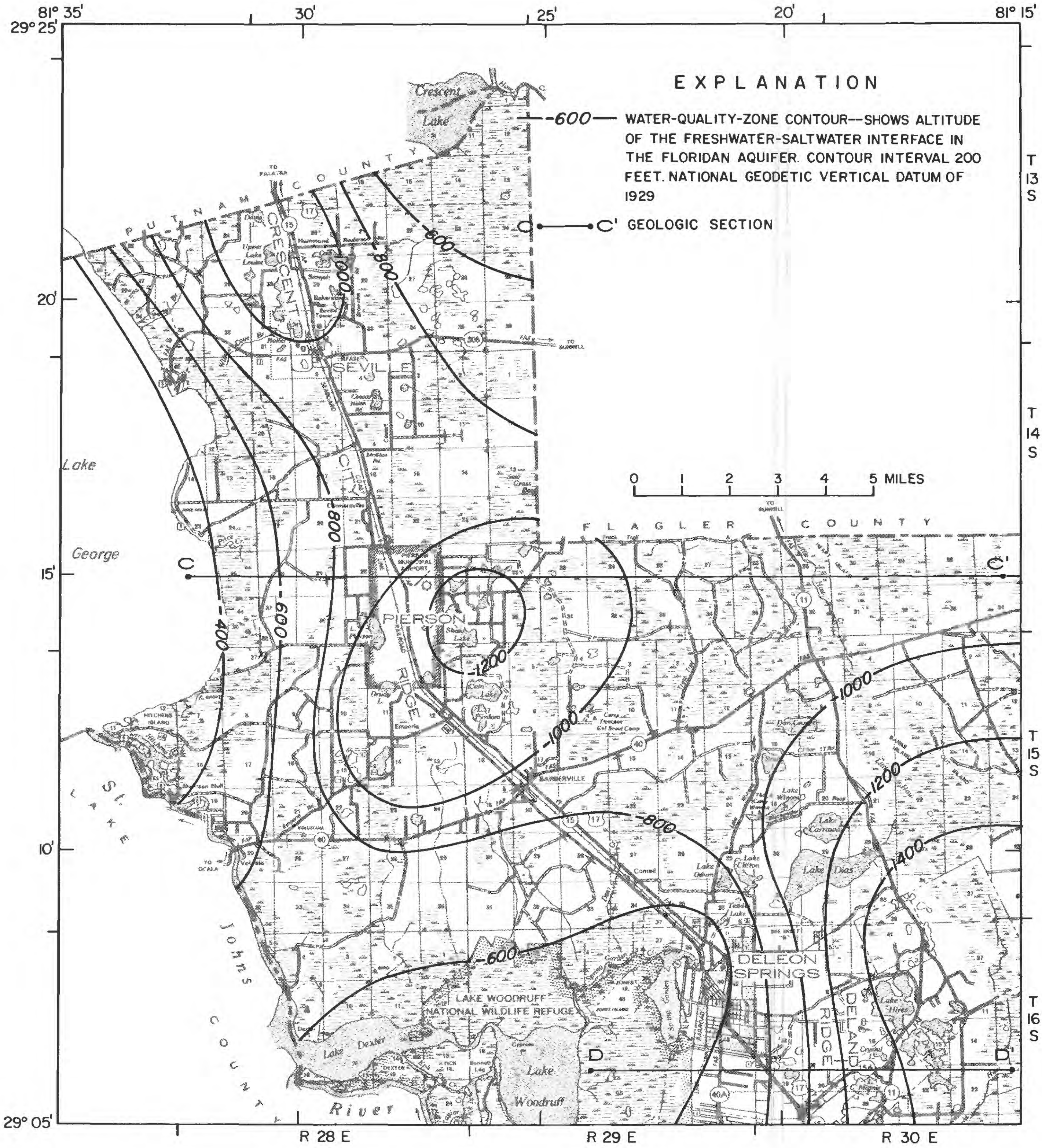


Figure 30.--Altitude of the freshwater-saltwater interface as estimated from the modified Ghyben-Herzberg principle.

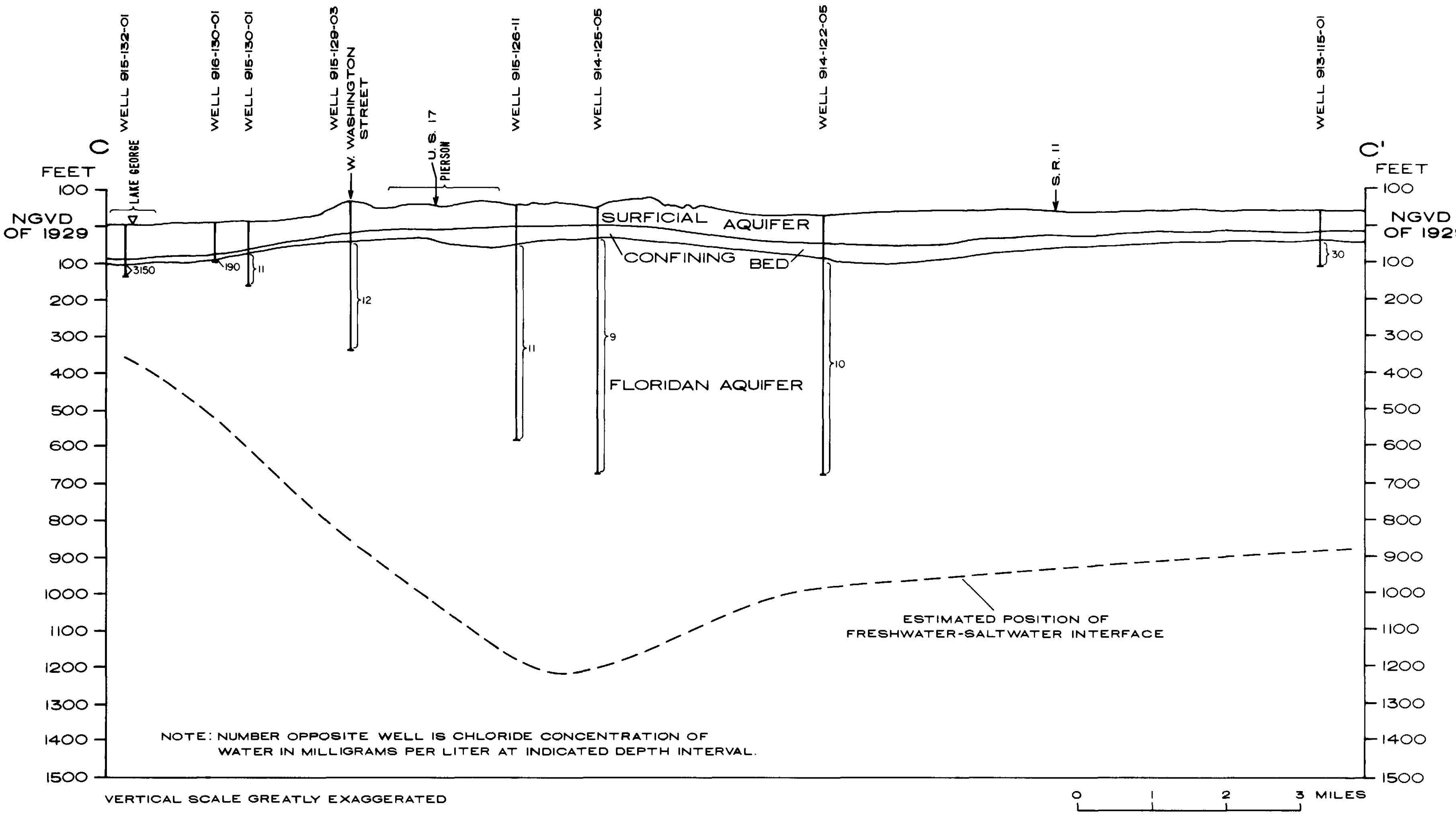


Figure 31.--Chloride concentration in Floridan aquifer wells and estimated position of freshwater-saltwater interface along line C-C' in figure 30.

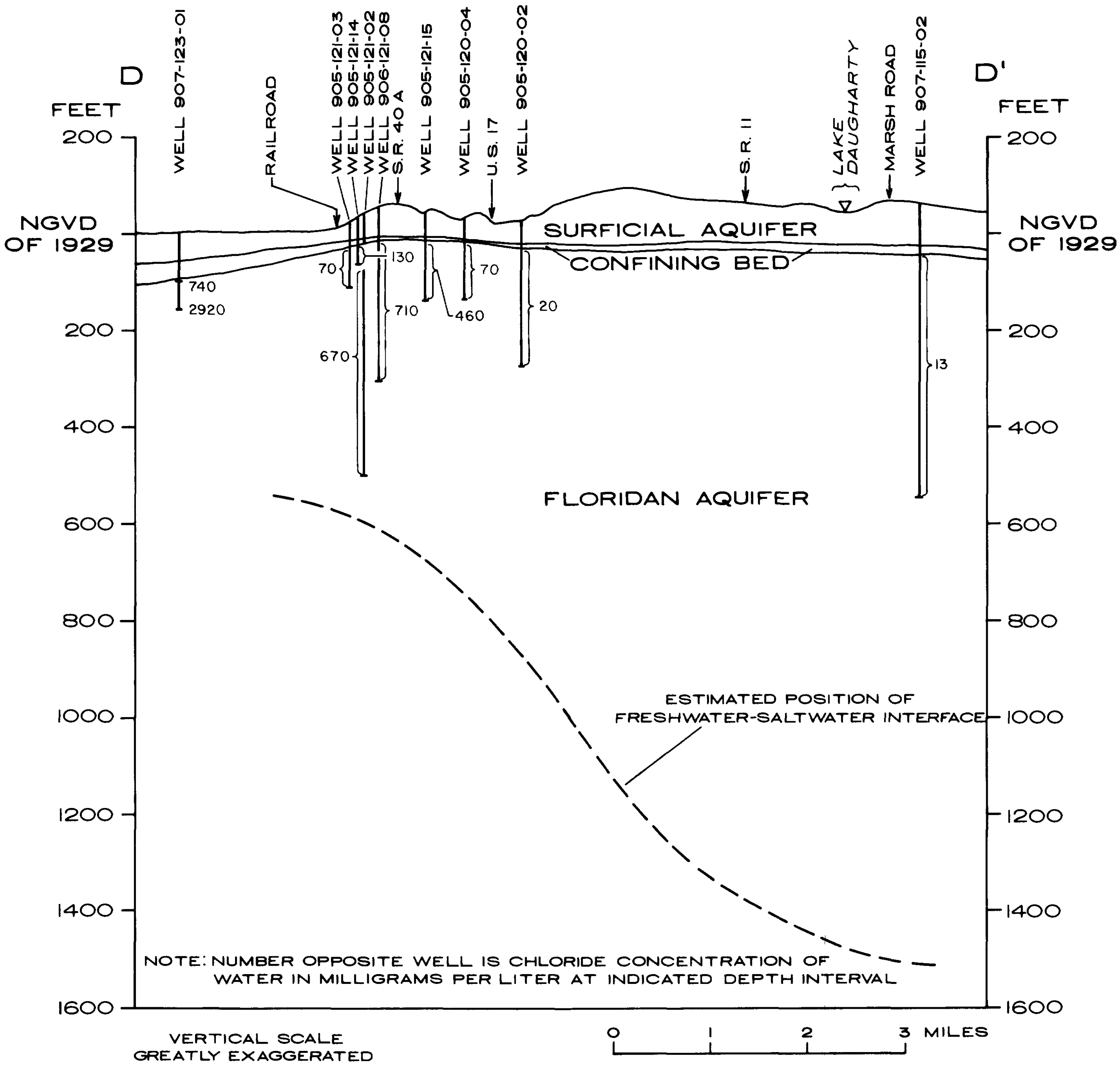


Figure 32.--Chloride concentration in Floridan aquifer wells and estimated position of freshwater-saltwater interface along line D-D' in figure 30.

EFFECTS OF FERNERY IRRIGATION WITHDRAWALS

Drawdown

The following discussion of drawdown caused by irrigational ground-water use in northwest Volusia County begins with a description of the theoretical drawdown created by one pumping well. This is necessary for an understanding of drawdown as measured in the field which is described in following sections. The discussion of measured drawdowns includes the short-term effects during growth irrigation and freeze-protection irrigation. Analyses of freeze-protection drawdowns are used to confirm various estimates of the physical properties of the aquifer which were made in previous sections of this report. Long-term effects of withdrawals on the potentiometric surface are then assessed.

Effects of One Pumping Well

Figure 33 shows calculations of drawdowns that would be produced by one well discharging at a rate of 1,200 gal/min from an infinitely extensive, homogeneous, and isotropic aquifer with a transmissivity of 15,000 ft^2/d and a storage coefficient of 0.0005. Because the drawdowns in the aquifer vary directly with the discharge, drawdowns for greater or lesser rates of discharge can be computed from these curves. For example, the drawdown 100 feet from a well discharging 1,200 gal/min would be 8.2 feet after 3 hours of discharge. If the well had discharged 600 gal/min for the same length of time, the drawdown at the same distance would have been only one-half as much, 4.1 feet.

The curves are useful for estimating drawdowns during growth irrigation in much of the Seville and Pierson areas since the transmissivity and storage coefficient are typical of these areas. Also, growth irrigation pumpage is very scattered: the chances are good that for a given growth irrigation pumpage from a given well, no other wells nearby will be pumped, causing interference, and the curves are thus an accurate estimate of drawdowns around the well.

The method used (Theis, 1963) is based on the assumptions that the aquifer is homogeneous, isotropic, and infinitely extensive and that there is zero leakage. The estimates of drawdown are least accurate for large pumping periods and large distances from the pumping well.

Short-Term Effects of Irrigation Withdrawals

From a water-use perspective, the year may be divided into three parts: the dry season (March-May), when growth irrigation is at its maximum; the rainy season (June-October), when the least irrigation is needed; and the winter (November-February), when large withdrawal rates for freeze-protection are needed. Figure 34 consists of three hydrographs showing the short-term changes in the water level at well 914-128-01, west

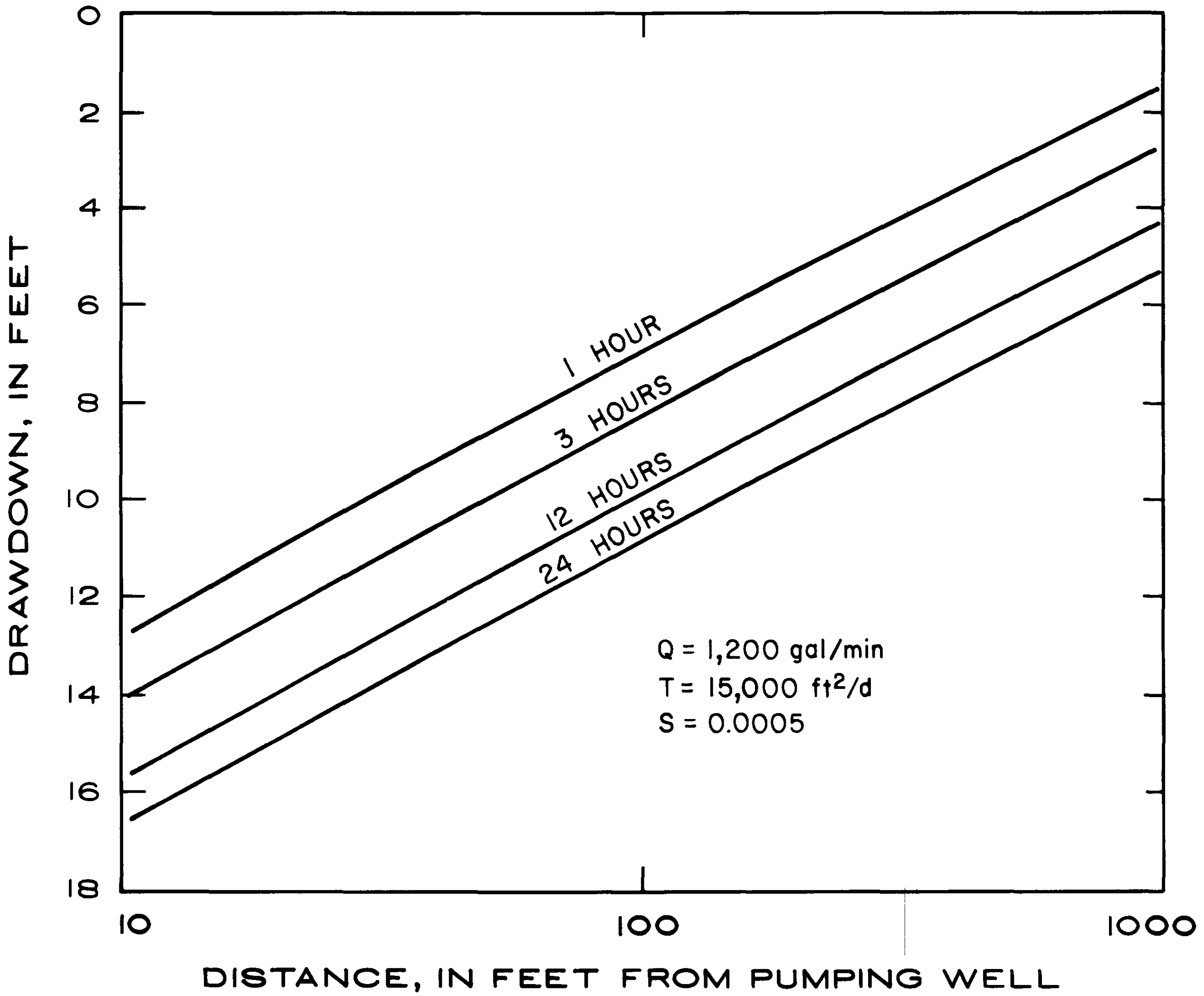


Figure 33.--Predicted drawdown in vicinity of a well discharging 1,200 gal/min for selected time periods.

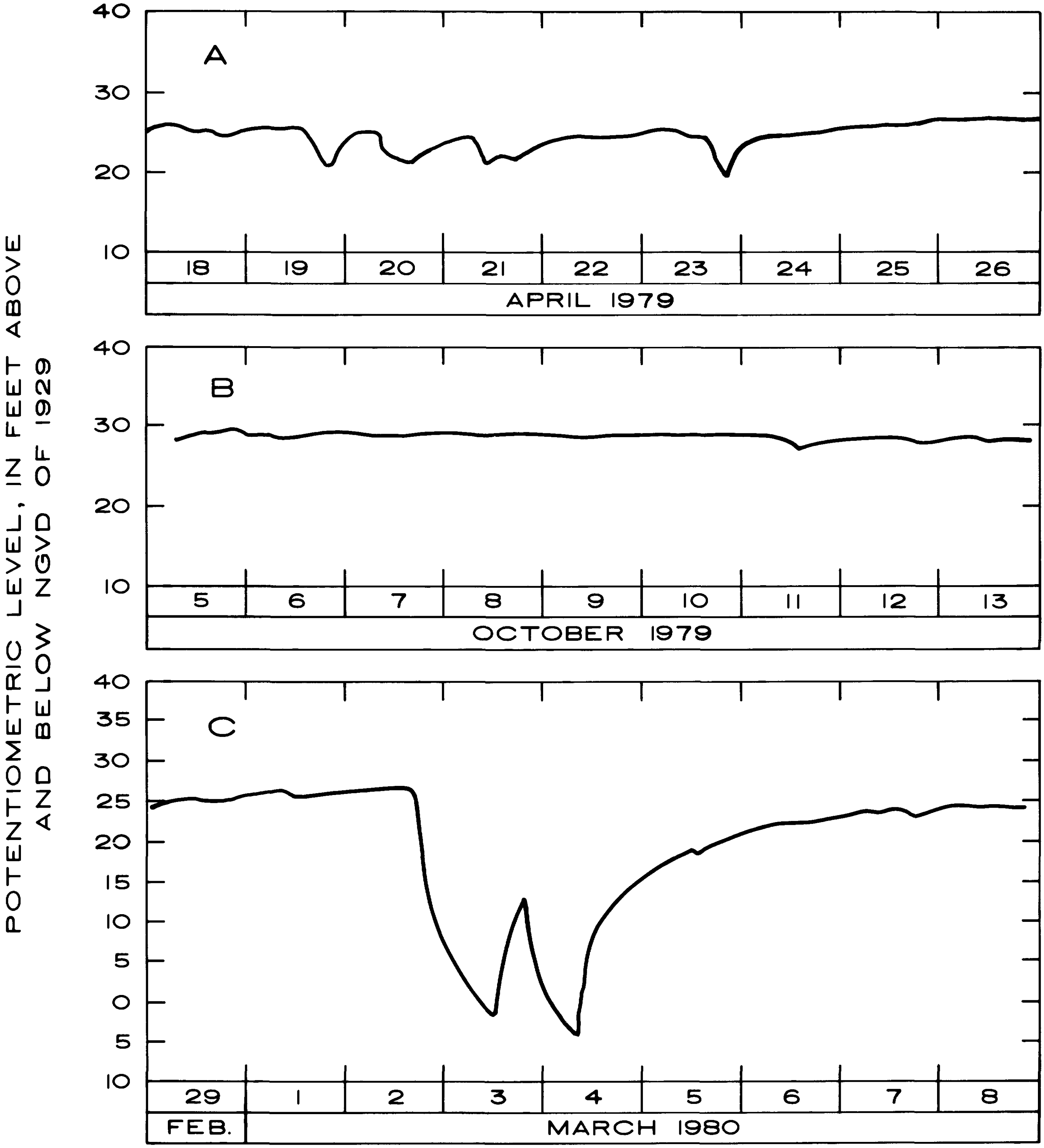


Figure 34.--Water level in well 914-128-01 during (a) a period of growth irrigation, (b) a period of little irrigation, and (c) a period of time including freeze-protection pumpage.

of Pierson, during (a) a dry period during which growth irrigation occurs, (b) a period of frequent rainfall during which very little irrigation occurs, and (c) a period of time including a severe freeze and the resulting freeze-protection irrigation. Well 914-128-01 is approximately 900 feet from the nearest active irrigation well and is in an area having a large concentration of irrigation wells (plate 1). The drawdown at this well is typical for wells in an approximately 7-square-mile area in and near Pierson. Drawdowns caused by growth irrigation commonly exceed 5 feet at this well (fig. 34a). In east Pierson, where transmissivities are lower and the concentration of irrigation wells is greater, drawdowns caused by growth irrigation exceed 10 feet. In the area of DeLeon Springs, where transmissivity is higher and the irrigation well concentration is lower, typical growth irrigation drawdowns may not exceed 1 foot. The above-mentioned drawdown figures are for locations which are at least 500 feet from irrigation wells. Growth irrigation drawdown generally reaches a maximum in the early evening hours. Because of frequent rainfall, the amount of drawdown during the late summer months is generally small (fig. 34b).

The greatest drawdown measured during the 3-year study period was during the freeze of March 3-4, 1980 (fig. 34c). Pumpage for freeze protection for most wells used began at 4:30 p.m. on March 2, stopped at 11 a.m. on March 3, started again at 7 p.m. on March 3, and stopped at 8:30 a.m. on March 4. The maximum drawdown at well 914-128-01 on the first morning was 29 feet and on the second morning, 33 feet. Drawdown in 914-128-01 and two other wells is shown in figure 35.

A map showing drawdown in the Pierson area at 8 a.m., March 4, 1980, is shown in figure 36. Water levels were measured between 4 a.m. and 9 a.m. in 21 wells. These measurements, combined with data from water-level recorders on six other wells, were used to construct figure 36. A knowledge of the locations of pumping wells aided the author in contouring the distribution of drawdown. Because water-level measurements were not made on the morning of March 4, 1980, in the Seville or DeLeon Springs areas, figure 36 does not show drawdown in these areas.

The drawdown at the end of this severe freeze exceeded 30 feet for an area of about 4.4 square miles and exceeded 15 feet for an area of about 23 square miles. The area of maximum drawdown was northeast of Pierson, where a water-level measurement in one observation well showed a drawdown of 50 feet. The drawdown on figure 36 and the drawdowns discussed above are intended to represent areal drawdown and not the drawdown in the pumping wells.

A map showing the drawdown in the northwest Volusia County area at 9 a.m. on February 2, 1979, another freeze-protection pumping period, is shown in figure 37. This map was compiled from approximately 60 water-level measurements. Drawdowns were less severe during this freeze-protection pumping period than they were during March 4, 1980 (fig. 36). Figure 37 shows that the Pierson area has considerably more drawdown than does the Seville or the DeLeon Springs area.

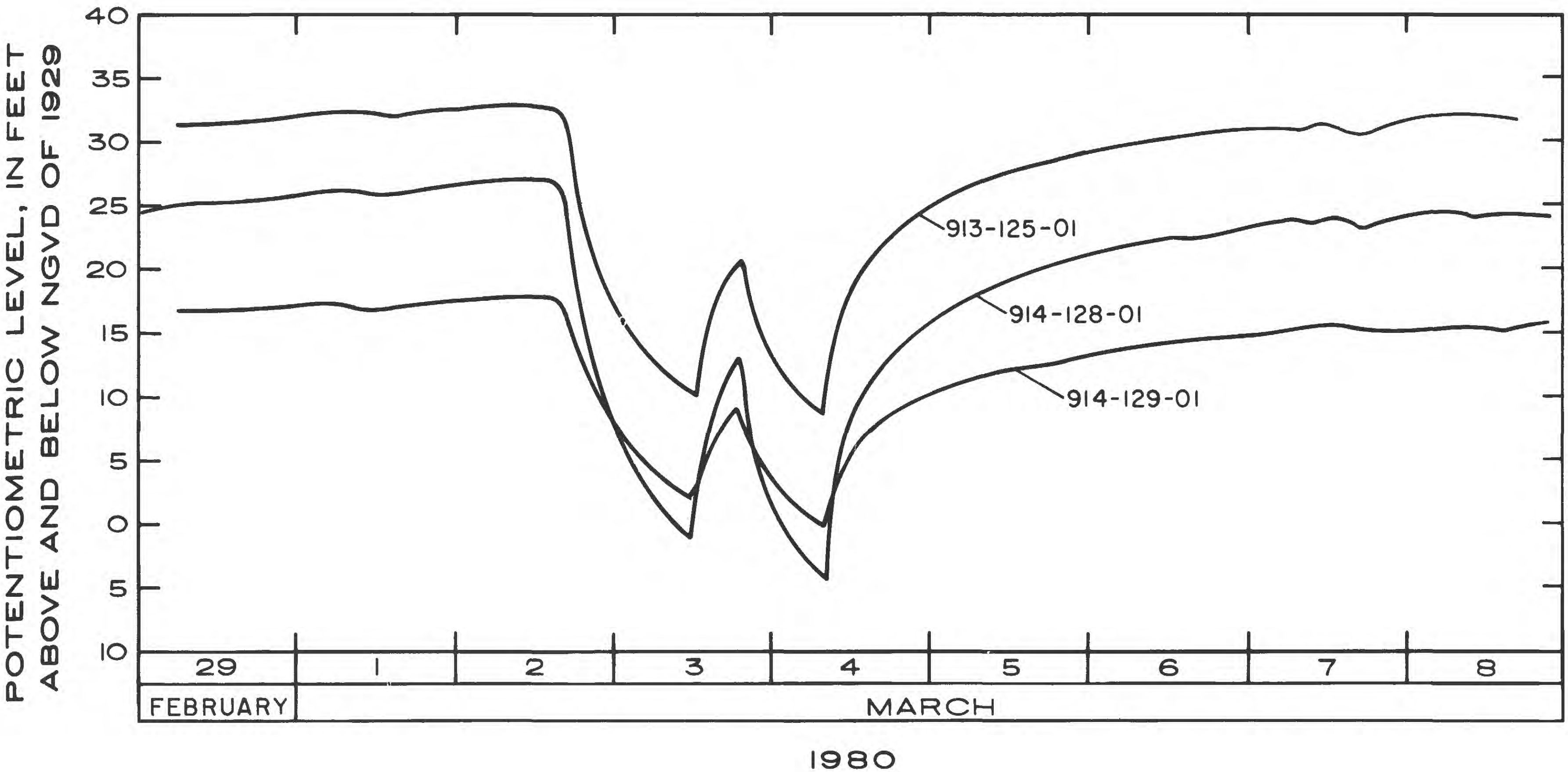


Figure 35.--Water levels in wells 913-125-01, 914-128-01, and 914-129-01, February 29-March 8, 1980.

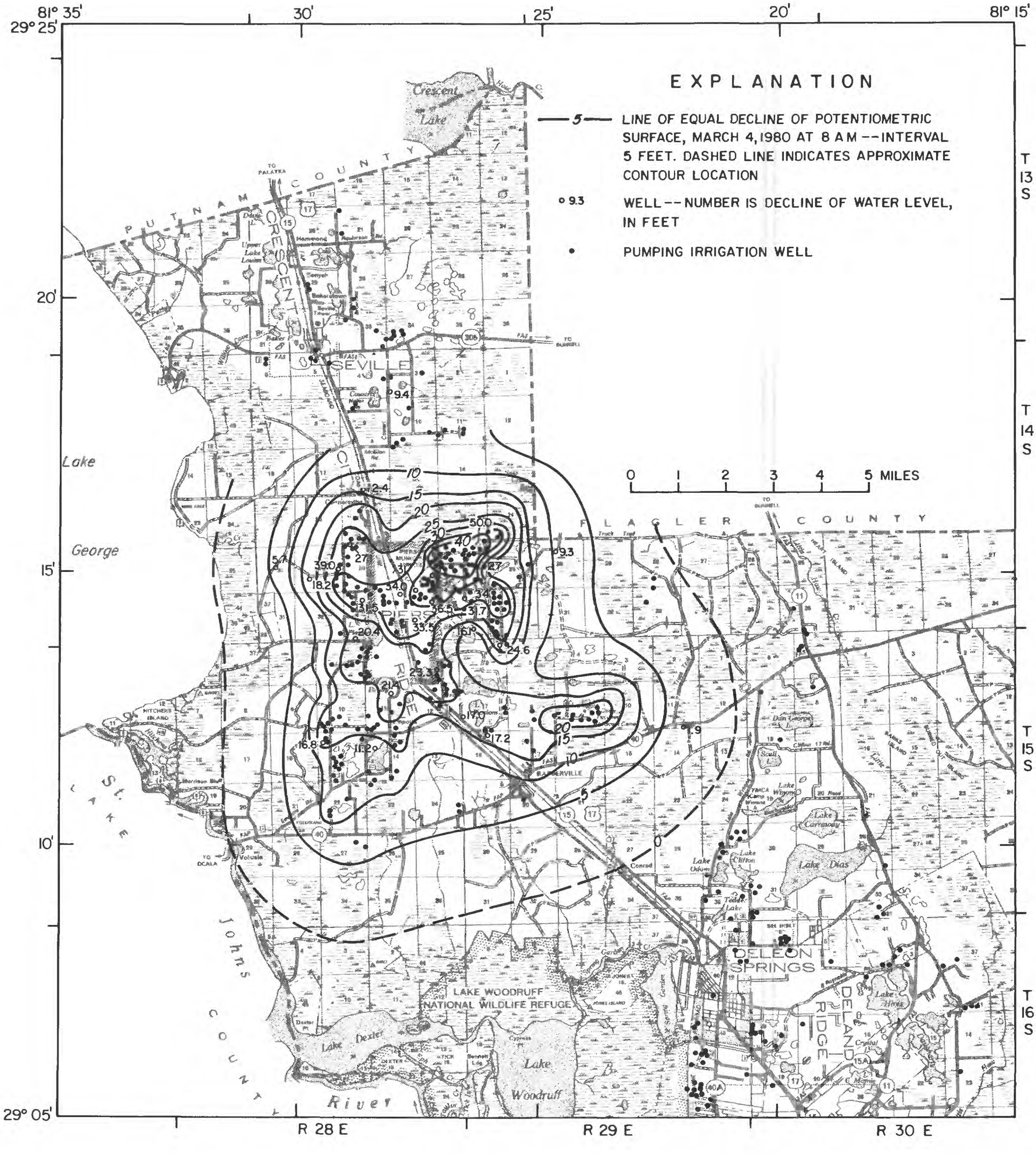


Figure 36.--Drawdown of potentiometric surface of the Floridan aquifer in the Pierson area at the end of a period of freeze protection, March 4, 1980. (Water level declines were not measured in the Seville or DeLeon Springs areas.)

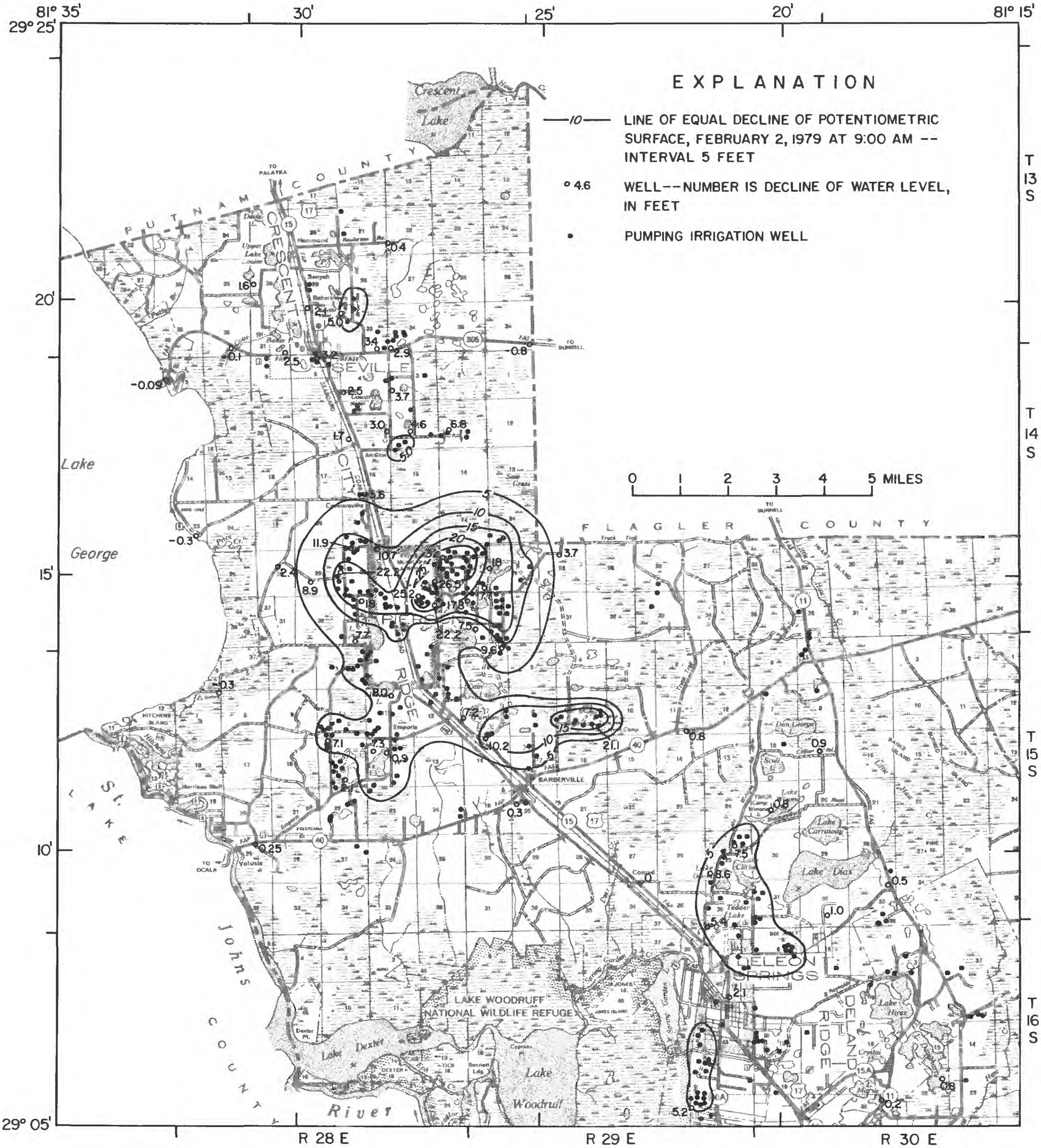


Figure 37.--Drawdown of potentiometric surface of the Floridan aquifer in northwest Volusia County at the end of a period of freeze protection, February 2, 1979.

The drawdown caused by freeze-protection pumpage is relatively small in the DeLeon Springs area because of the high transmissivity of that area. The measurement of 5.2 feet of drawdown near the southern limit of figure 37 is close to aquifer test site 8, which yielded a transmissivity of 89,200 ft^2/d (fig. 22). Another reason for small drawdown in the DeLeon Springs area may be that pumpage is temporarily capturing spring discharge.

The drawdown close to a pumping irrigation well may be thought of as the sum of the areal drawdown shown on the maps and the drawdown caused by the pumping from the individual well. The drawdown caused by the well may be calculated from the relationship shown on figure 33. Consider, for example, an irrigation well which is located on the 40-foot drawdown contour of figure 36 and which was pumping 1,200 gal/min. If the transmissivity and storage coefficient are 15,000 ft^2/d and 0.0005 respectively, then the total drawdown at a location 10 feet from the pumping well is 40 ft + 17 ft = 57 ft. This calculation was made assuming that the amount of drawdown caused by the single irrigation well at 8 a.m. March 4, 1980, can be approximated as the drawdown created by 24 hours of continuous pumping from that well, and deriving 17 feet from figure 33.

Using the same approach outlined above but assuming that a well northeast of Pierson close to the 40-foot contour on figure 36 was discharging 1,700 gal/min and that the aquifer properties for that area are, from aquifer test 5, T = 8,700 ft^2/d and S = 0.0004 (table 2), then the total drawdown within the well was more than 90 feet at 8 a.m., March 4, 1980. It is assumed that the drawdown within the well mentioned is equal to the drawdown at r = 1 foot.

Drawdowns in pumping wells are greater than drawdowns in observation wells. Measured drawdowns in several pumping wells during freeze-protection pumping are listed below:

Well	Drawdown (ft)	Time	Date	Pumping rate from measured well (gal/min)
905-121-01	11	7:30 a.m.	2-5-80	800
906-120-03	3.5	8:55 a.m.	2-5-80	1,400
910-128-02	10	10:15 a.m.	2-2-80	450
914-125-05	more than 71	7:30 a.m.	1-3-80	1,000
914-126-15	25	9:10 a.m.	2-2-80	480
915-125-03	34	8:45 a.m.	1-3-80	550
915-126-15	56	8:55 a.m.	1-3-80	800
917-127-04	more than 30	7:35 a.m.	3-3-80	400
918-127-02	24	7:00 a.m.	3-3-80	700

Most of these drawdown measurements were made close to the end of relatively mild freeze-protection pumpages. The drawdowns in these wells close to the end of a severe freeze would exceed the drawdowns shown.

The maximum drawdowns are in wells in east Pierson while the minimum drawdowns are in the DeLeon Springs area. Because of the great difficulties associated with making water-level measurements in pumping irrigation wells in freezing weather, few measurements were made. The maximum drawdown is thus unknown, although the analytical approach of the preceding paragraph indicates that several large-capacity irrigation wells in east Pierson might have drawdowns exceeding 90 feet at the end of severe freeze-protection pumpages.

Drawdown of the potentiometric surface gives rise to the problem of water loss in domestic wells during freeze-protection pumping. Domestic wells are generally cased to the top of the Floridan aquifer and drilled a short distance into the formation. Water is pumped out of the well at a pump intake which may be located at any level in the casing or in the open hole part of the well. If the pump intake is not positioned deep enough below the static water level, then the water level in the well may decline below the intake during freeze-protection pumping, and the well temporarily will not pump water.

The information given here may be used as a guide to alleviate the problem of domestic water loss. At the very least, pump intakes should be positioned below the static water level by an amount as large as the drawdowns shown in figure 36. If a domestic well in the fern-growing areas of Pierson is located within 500 feet of an irrigation well, however, the drawdowns during severe freezes may become more intense than figure 36 indicates, and additional lowering of the intake may be necessary.

An estimate of the amount of water removed from storage in the aquifer can be calculated using a drawdown map and an estimate of the storage coefficient of the aquifer. The volume of water removed from storage is equal to the volume of the cone of depression multiplied by the storage coefficient. Approximating the volume of the cone of depression of figure 36 as the summation:

V = (area within zero drawdown contour) x 2.5 feet,

+ (area within 5-foot drawdown contour) x 5 feet,

+ (area within 10-foot drawdown contour) x 5 feet,

+ .... up to 40-foot drawdown contour,

and estimating that the area within the zero drawdown contour is 2.8×10^9 ft^2, then the total volume is 2.6×10^{10} ft^3. Estimating S = 0.0005 from table 2, aquifer tests 2 through 5, the total volume removed from storage in the Pierson area as of March 4, 1980, at 8 a.m. is about 100 Mgal.

Assuming that the withdrawal rate for freeze-protection pumping for the Pierson area is 170 Mgal/d and noting that the total pumping period for the March 3-4, 1980, freeze was 32 hours, the total amount of water withdrawn from the aquifer is approximately 230 Mgal. The difference between this quantity of water and the amount that has come out of storage in the aquifer, 130 Mgal/d, is the amount of water which has reentered the aquifer in the Pierson area by leakage or by increased horizontal inflow due to the change in the potentiometric gradient. This indicates that significant amounts of the water removed from storage in the aquifer during this freeze-protection period had been replaced by leakage during the pumping period.

The drawdown at an observation well caused by freeze-protection pumpage may be simulated by determining which irrigation wells in its vicinity are affecting drawdown in the observation well. When this is known, the individual drawdowns caused by each of the irrigation wells can be added to calculate the total drawdown at the observation well. Figure 38 is a semilog plot of drawdown versus time for well 914-128-01 assuming that pumping began at 4 p.m. March 2, 1980. Using the equation for straight-line aquifer test analysis discussed earlier and solving for Q:

$$Q = 1.74\Pi T \frac{\Delta s}{\Delta \log_{10} t}$$

where all terms are as previously defined. Transmissivity is estimated to be 15,000 ft^2/d and $\Delta s/\Delta \log_{10} t$ is 22 feet (fig. 38). The total discharge causing the drawdown at well 914-128-01 is thus estimated as 9,400 gal/min.

It is now possible to compare measured drawdowns with calculated drawdowns by superimposing drawdowns caused by all wells affecting 914-128-01. Irrigation wells are tabulated in the order of increasing distance from 914-128-01 (table 9). The tabulation was stopped when total discharge exceeded 9,400 gal/min. All wells involved in this analysis are shown on plate 1 including 914-128-01, which is shown as an unused irrigation well. Wells not used for freeze-protection withdrawal were not included. The estimates of drawdown caused by each pumping well (table 9) are calculated from Theis (1963) using T = 15,000 ft^2/d and S = 0.0005. The total estimated drawdowns from table 9 compare reasonably with measured drawdowns of 19.91 feet at 8 hours and 28.13 feet at 19 hours.

The drawdown at well 914-129-01 was subjected to the same analysis given for 914-128-01 above. Well 914-129-01 is approximately 1.1 miles west-northwest of well 914-128-01 and is more than one-half mile from the nearest irrigation well. The plot of figure 39 yielded an effective discharge rate of 7,000 gal/min and 10 pumping irrigation wells in the vicinity were simulated as 2 pumping wells: one 3,200 feet away pumping 3,760 gal/min and another 4,500 feet away pumping 3,070 gal/min. Assuming T = 15,000 ft^2/d and S = 0.0003, the calculated drawdowns are 8.07 feet at 8 hours and 13.87 feet at 19 hours. Measured drawdowns were 10.02 feet at 8 hours and 15.75 feet at 19 hours.

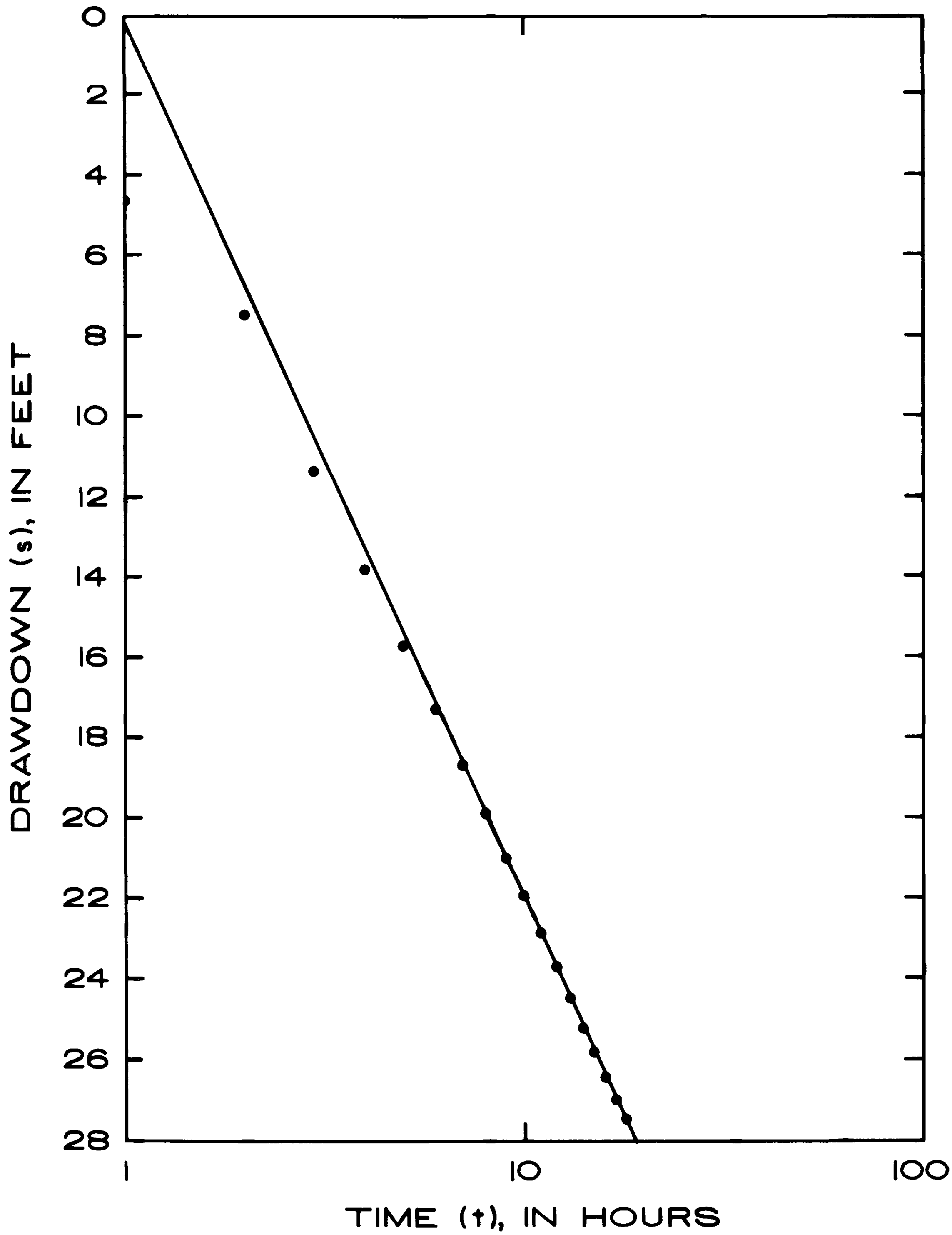


Figure 38.--Drawdown data for well 914-128-01 from freeze-protection pumpage of March 2-3, 1980.

Table 9.--Irrigation wells causing drawdown at well 914-128-01, March 2-3, 1980

Well	Discharge (gal/min)	Distance from 914-128-01 (ft)	Estimated drawdown (ft) t=8 hr	Estimated drawdown (ft) t=19 hr
914-128-02	720	900	2.43	3.14
914-128-21	320	800	1.14	1.42
914-128-22	160	1,000	0.49	0.64
914-128-16	480	1,000	1.55	1.98
914-128-04	1,280	1,300	3.36	4.56
914-128-15	600	1,400	1.48	2.01
914-128-07	320	1,900	0.60	0.88
914-128-23	480	2,200	0.82	1.21
914-128-17	1,600	2,300	2.56	3.83
914-128-06	640	2,300	1.03	1.57
914-128-05	320	2,800	0.38	0.64
914-129-02	480	2,800	0.60	0.99
914-128-03	640	3,200	0.66	1.14
914-129-03	1,600	3,300	1.56	2.77
Total	9,640		18.66	26.78

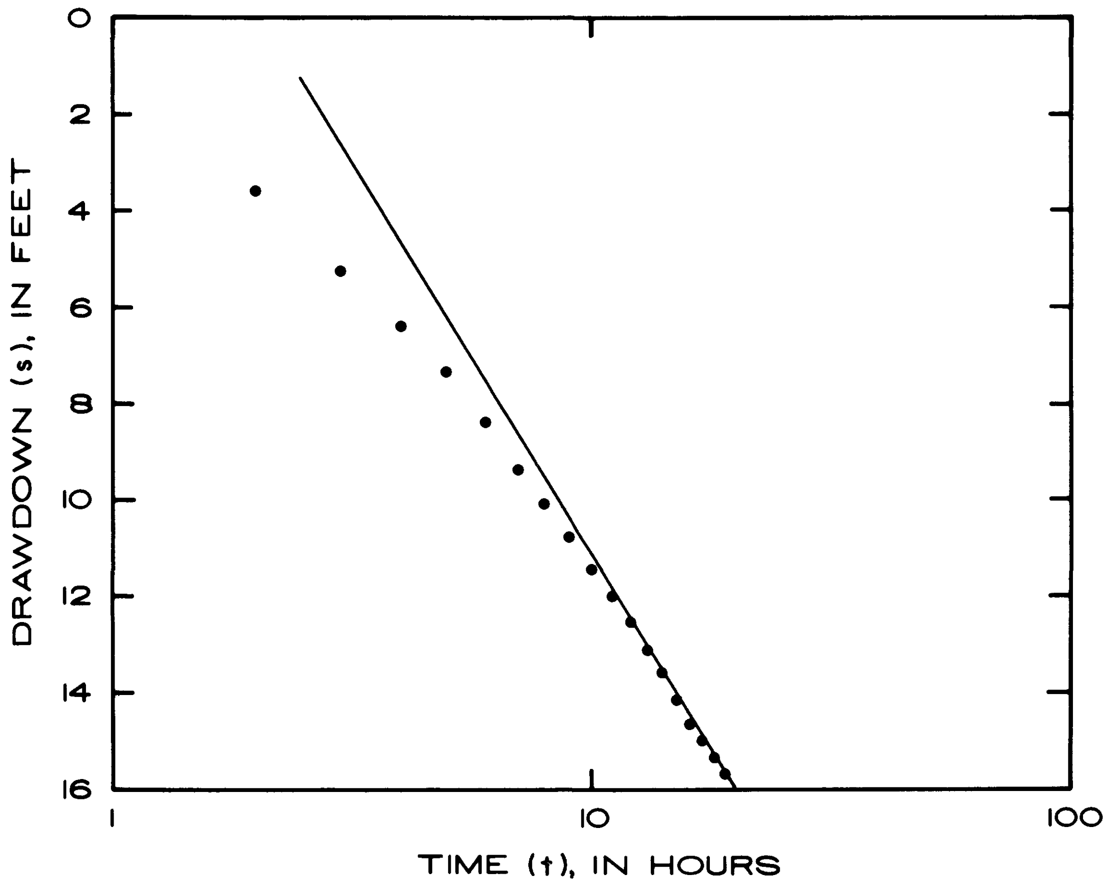


Figure 39.--Drawdown data for well 914-129-01 from freeze protection pumpage of March 2-3, 1980.

The foregoing analyses show that drawdowns caused by freeze-protection withdrawals from numerous wells can be approximated as the sum of the individual drawdowns created by each. The percent of the drawdown at a given observation well which is caused by a certain irrigation well can be estimated. The analysis is limited to areas close to irrigation wells because errors caused by leakage become great as the distance increases.

Long-Term Effects of Irrigation Withdrawals

Daily fluctuations of water levels in wells 914-128-01 and 913-125-01 for the study period are shown in figures 40 and 41. Each hydrograph shows two records: (1) consecutive daily maximum water levels and (2) consecutive daily minimum water levels. Both wells, located in figure 23 and on plate 1, are in areas of heavy irrigational ground-water use. Well 914-128-01 is 900 feet from the nearest active irrigation well. Well 913-125-01 is 200 feet from a relatively small-capacity irrigation well and 550 feet from a large-capacity well.

The fluctuations in water levels shown in figures 40 and 41 are typical of the Pierson area. The largest changes are between November 15 and March 15 because of freezing temperatures and freeze-protection irrigation withdrawals while the smallest are between July and October because of frequent rainfall and moderate irrigational withdrawals. The hydrographs show that recovery after freeze-protection withdrawals is rapid.

Figure 42 shows the water level changes in well 913-125-01, which is in the fern-growing areas of Pierson, and well 913-115-01 (fig. 23), which is in an area of very little water use. The two records show the same general seasonal water-level changes, although the record for well 913-125-01 is interrupted by downward spikes caused by irrigational withdrawals.

The long-term water-level trend in northwest Volusia County, including years of little irrigational water use, is shown on figures 43 and 44. Figure 43 represents the potentiometric level 1 mile south of Seville whereas figure 44 represents the potentiometric level 3 miles east of Seville. Neither well is located within the fern-growing areas. No records of this type are available for wells in the fern-growing areas. The potentiometric trend shown is similar to that in other areas of east-central Florida. Figure 45 represents the potentiometric trend at a well in south-central Volusia County in an area of relatively small present-day (1980) pumpage. A comparison of the potentiometric trend of figure 45 with those of figures 43 and 44 shows that the general decline of the potentiometric surface that occurred from 1961 to 1975 in northwest Volusia County is mainly the result of deficient rainfall. Water use by the fern industry probably became significant in the 1970's. Before that time, the water use for freeze-protection was a very small fraction of what it is now (1980).

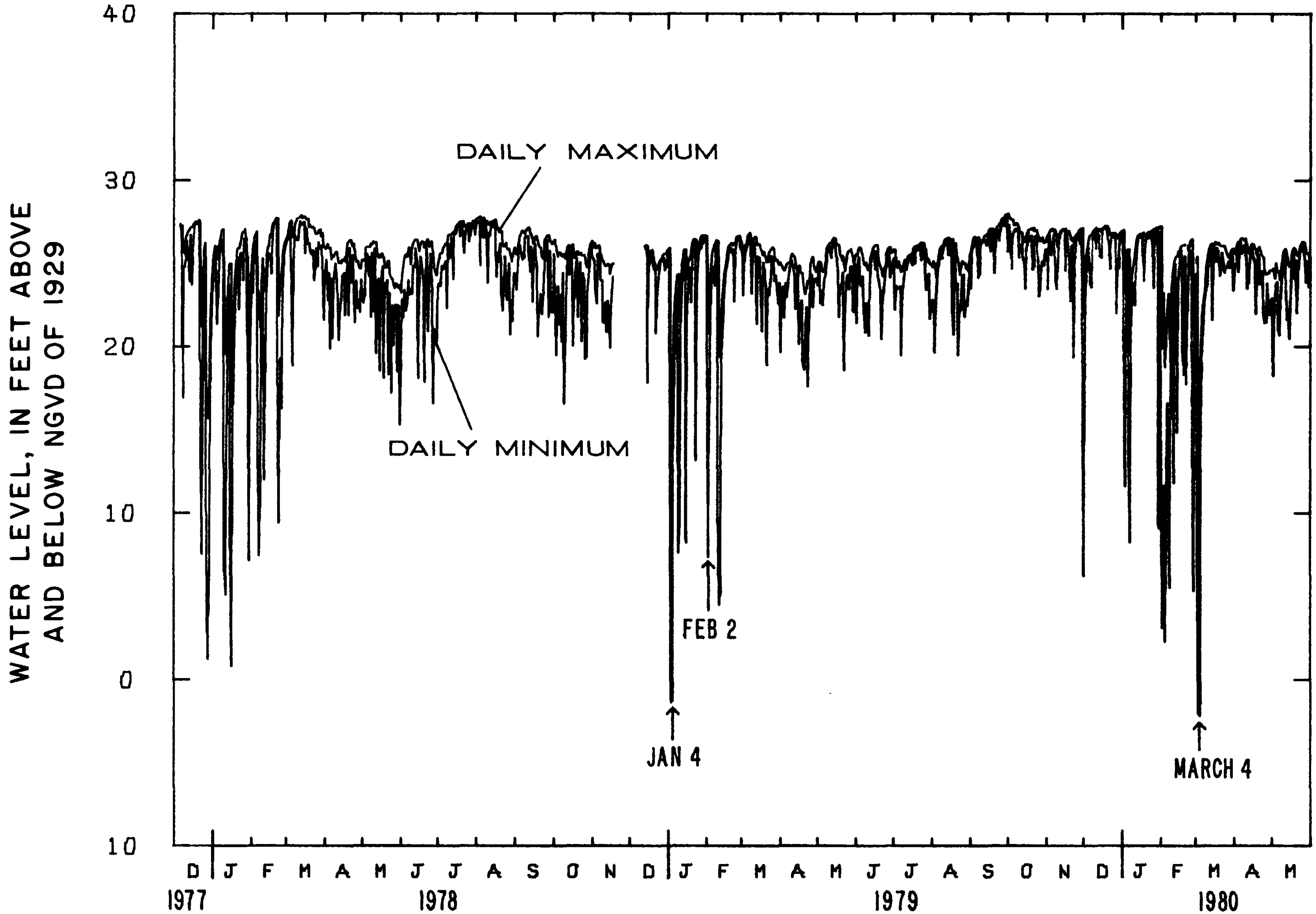


Figure 40.--Daily maximum and daily minimum water levels in well 914-128-01, December 1977-May 1980.

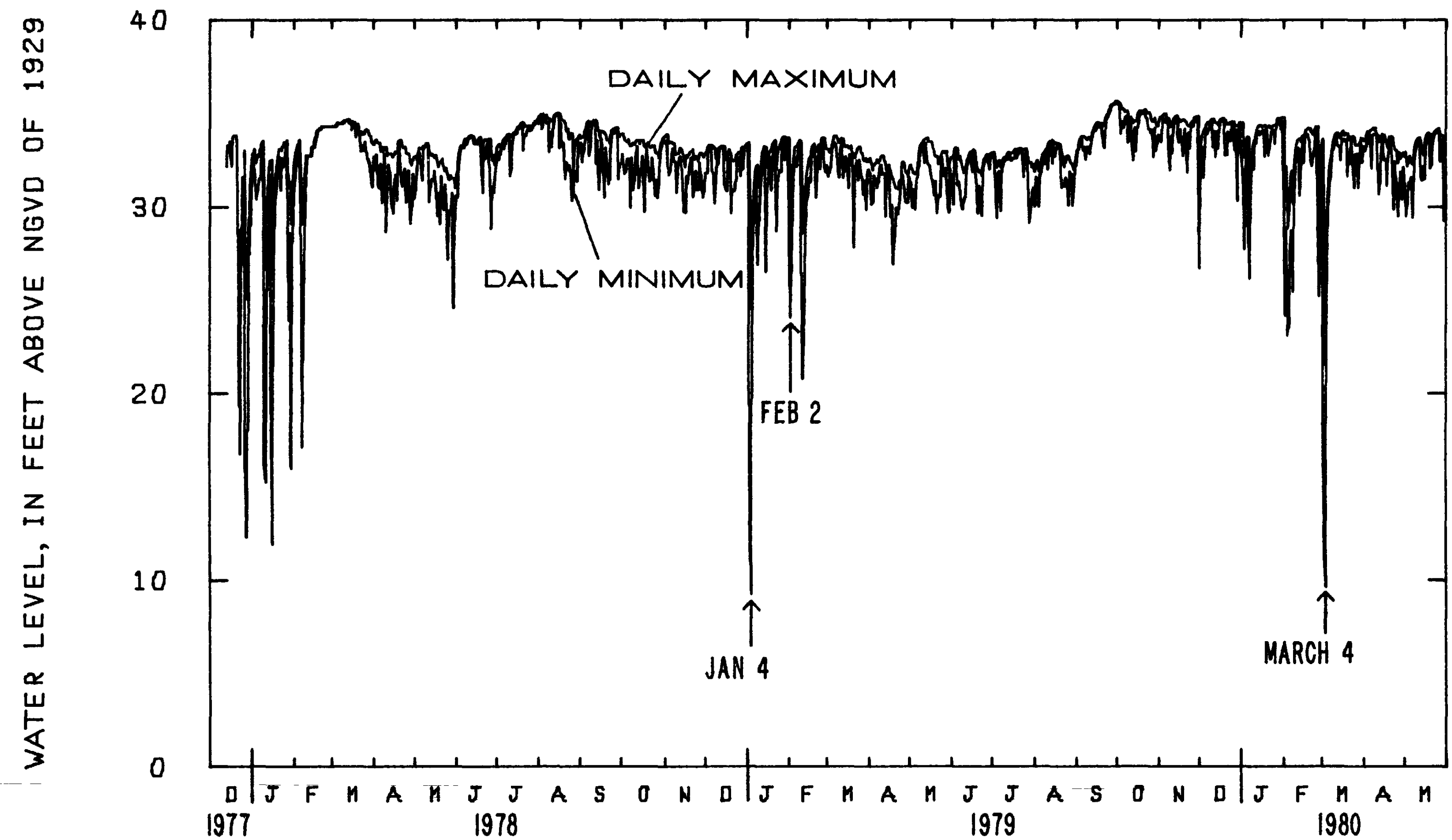


Figure 41.--Daily maximum and daily minimum water levels in well 913-125-01, December 1977-May 1980.

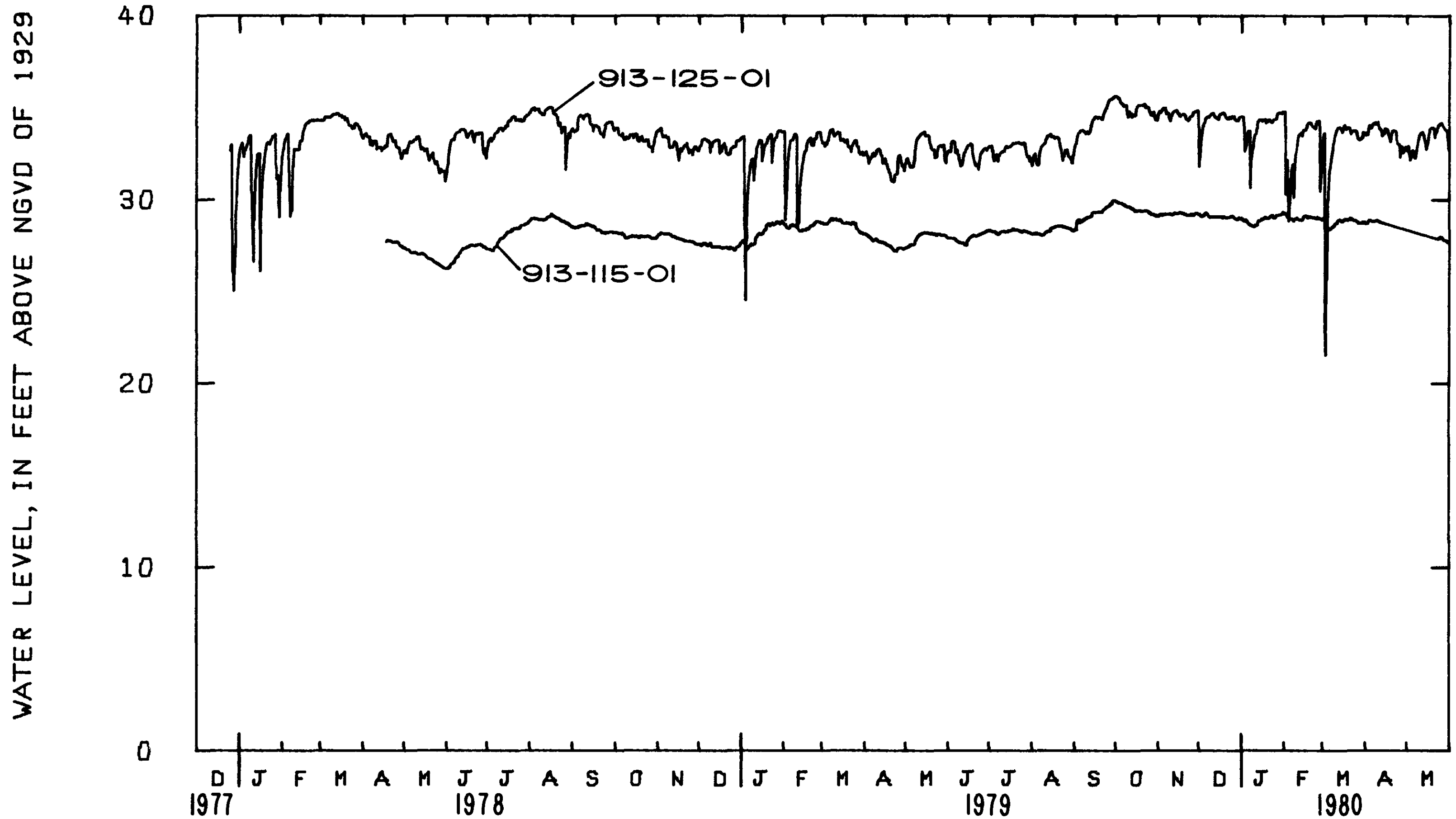


Figure 42.--Daily maximum water levels in wells 913-125-01 and 913-115-01, December 1977-May 1980.

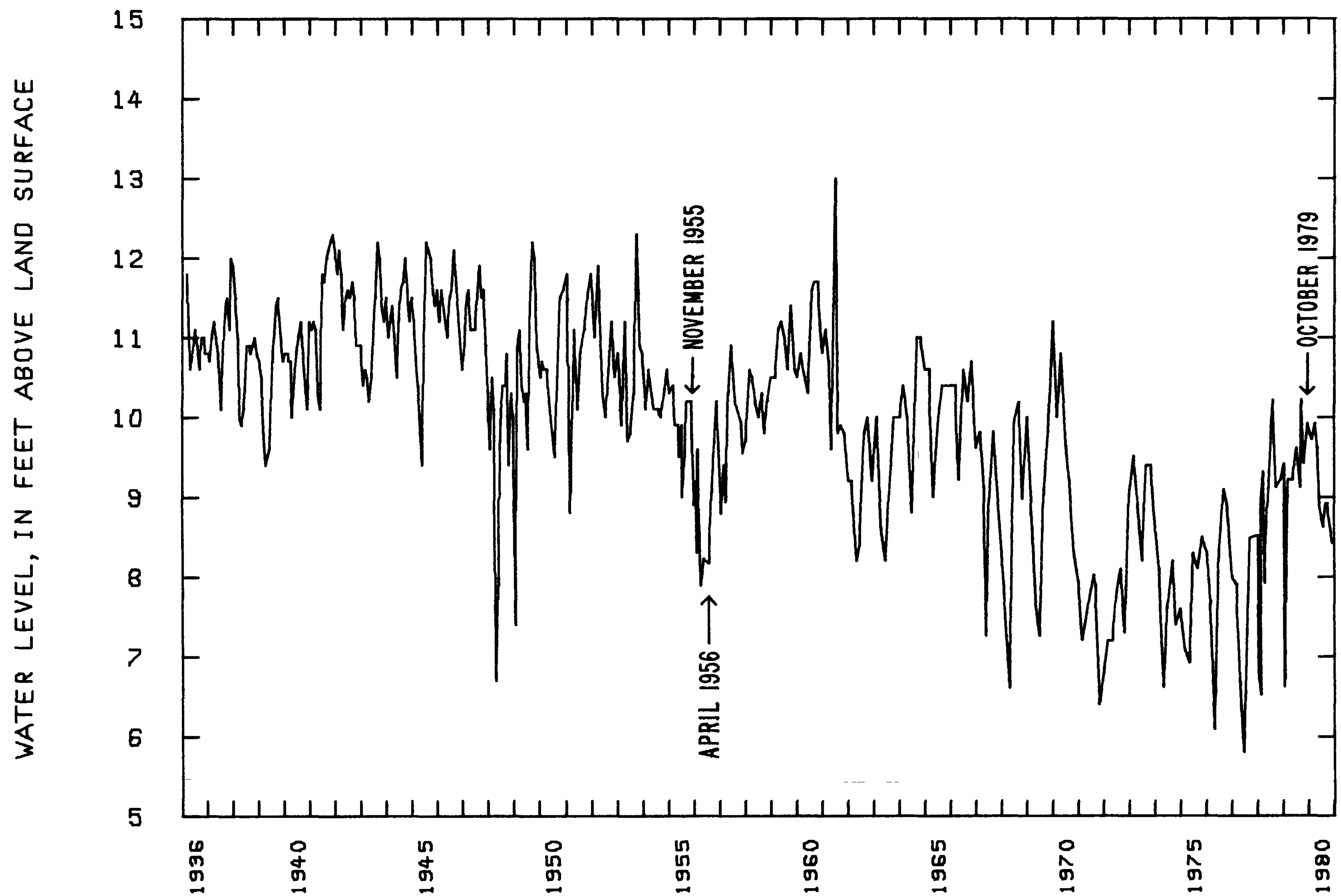


Figure 43.--Periodic water level record of well 917-128-01, 1936-80.

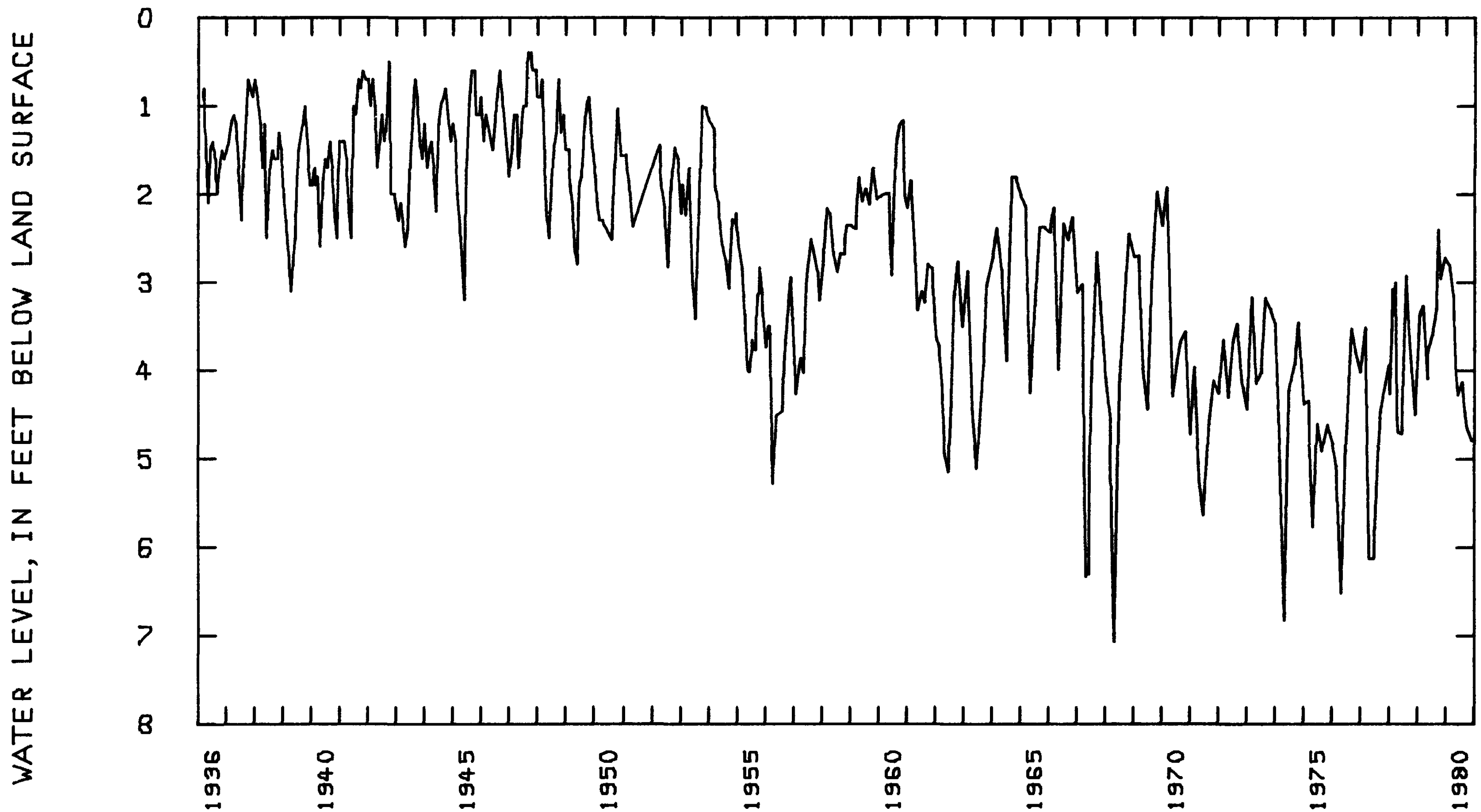


Figure 44.--Periodic water level record of well 919-125-01, 1936-80.

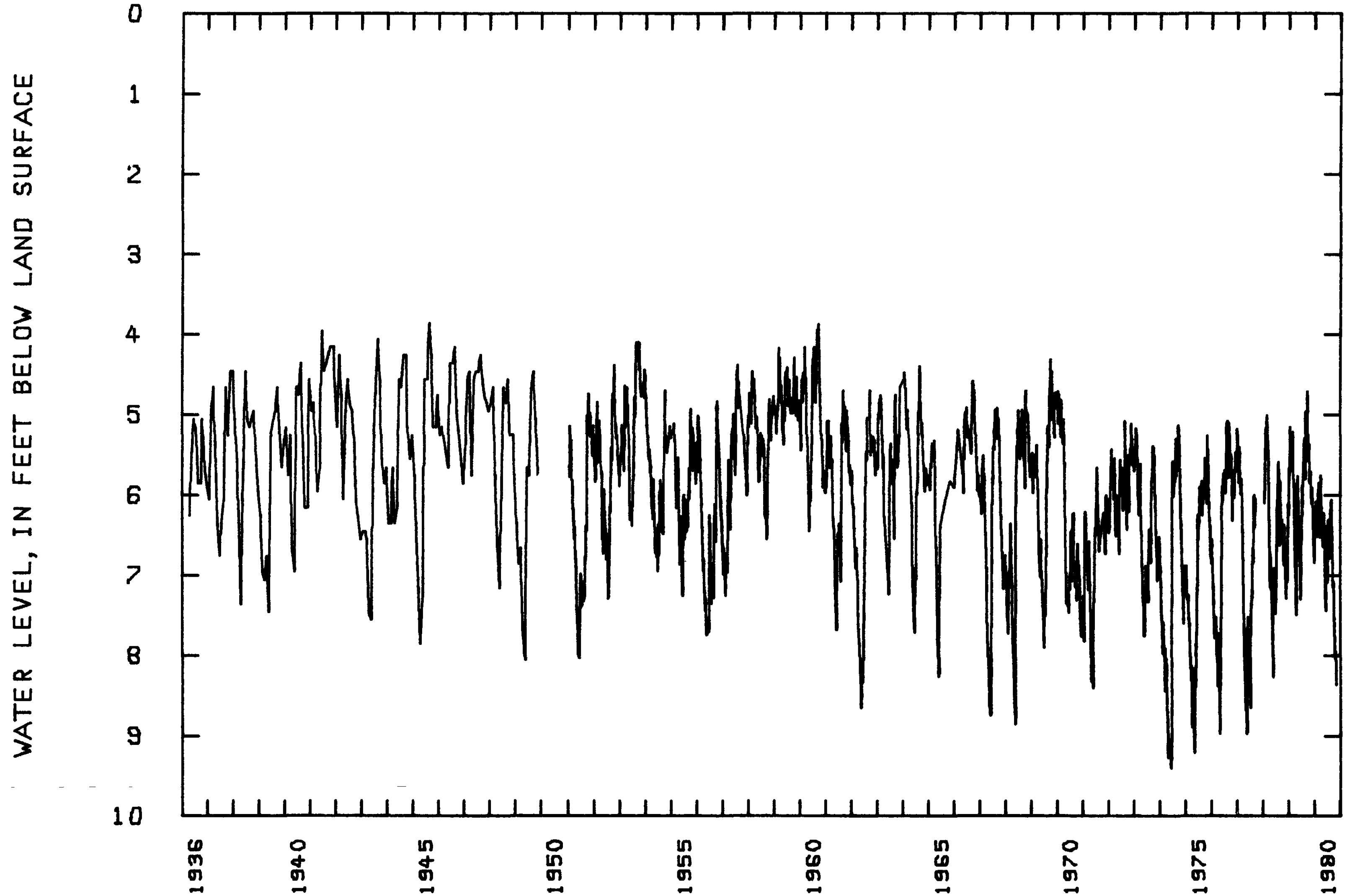


Figure 45.--Periodic water level record of well in Alamana, Florida, south-central Volusia County, 1936-80.

The potentiometric surface map of November 1955 (fig. 46) can be compared with the October 1979 potentiometric surface map (fig. 24) to evaluate long-term changes caused by the fern industry. Long-term records such as those shown in figures 43 and 44 indicate that the potentiometric surface had approximately the same level in October 1979 as it did in November 1955 in areas of little pumping stress. It is also evident from the potentiometric maps that the nonpumping head in the aquifer has not changed in the heavily-stressed Pierson area. It should be noted that the contours on the November 1955 map were drawn with only 19 water-level measurements while those of the October 1979 map were drawn using 66 measurements. The contours of figure 46 are drawn exactly as they were in the 1960 report (Wyrick, 1960). Most of the differences between the shapes of the contours on these potentiometric maps result from the lesser concentration of data from November 1955.

Effects on the Water Budget

Because the water budget discussed previously was derived from the static, unstressed potentiometric surface, it is necessary to consider the changes in the budget caused by fernery irrigation. Changes considered are only the long-term changes caused by fernery irrigation withdrawals. Fluctuations in water levels and ground-water discharges caused by rainfall trends are ignored. Pumpage from the Floridan aquifer would increase the outflow in the budget of table 7 from 57 ft^3/s to 71 ft^3/s. This additional 14 ft^3/s is derived from the sum of 8.1 Mgal/d irrigational pumpage and the 1 Mgal/d pumpage for all other uses.

If pumpage is introduced into a ground-water budget, the change must be balanced by any number of the following alterations in the flow system: (1) an increase in recharge, (2) a decrease in upward leakage, (3) an increase in horizontal inflow, (4) a decrease in discharge from springs or flowing wells or both, (5) a decrease in horizontal ground-water outflow, or (6) a long-term change in aquifer storage. By the process of elimination, it will be shown that, of the above-mentioned changes in the ground-water budget, most change has occurred in the form of an increase in recharge.

A decline in upward leakage would necessitate a lowering of the potentiometric surface in areas of upward leakage. The potentiometric maps of November 1955 (fig. 46) and October 1979 (fig. 24), along with the long-term hydrograph of a well in a discharge area (fig. 43) showing the potentiometric surface at these dates, show that no general decline has occurred over and above that which occurred because of the natural water level decline resulting from deficient rainfall (fig. 45).

An increase in horizontal inflow, a decrease in horizontal outflow, or a long-term change in aquifer storage could be created only by significant long-term changes in the potentiometric surface. If an increase in ground-water inflow occurred, it would do so at the present

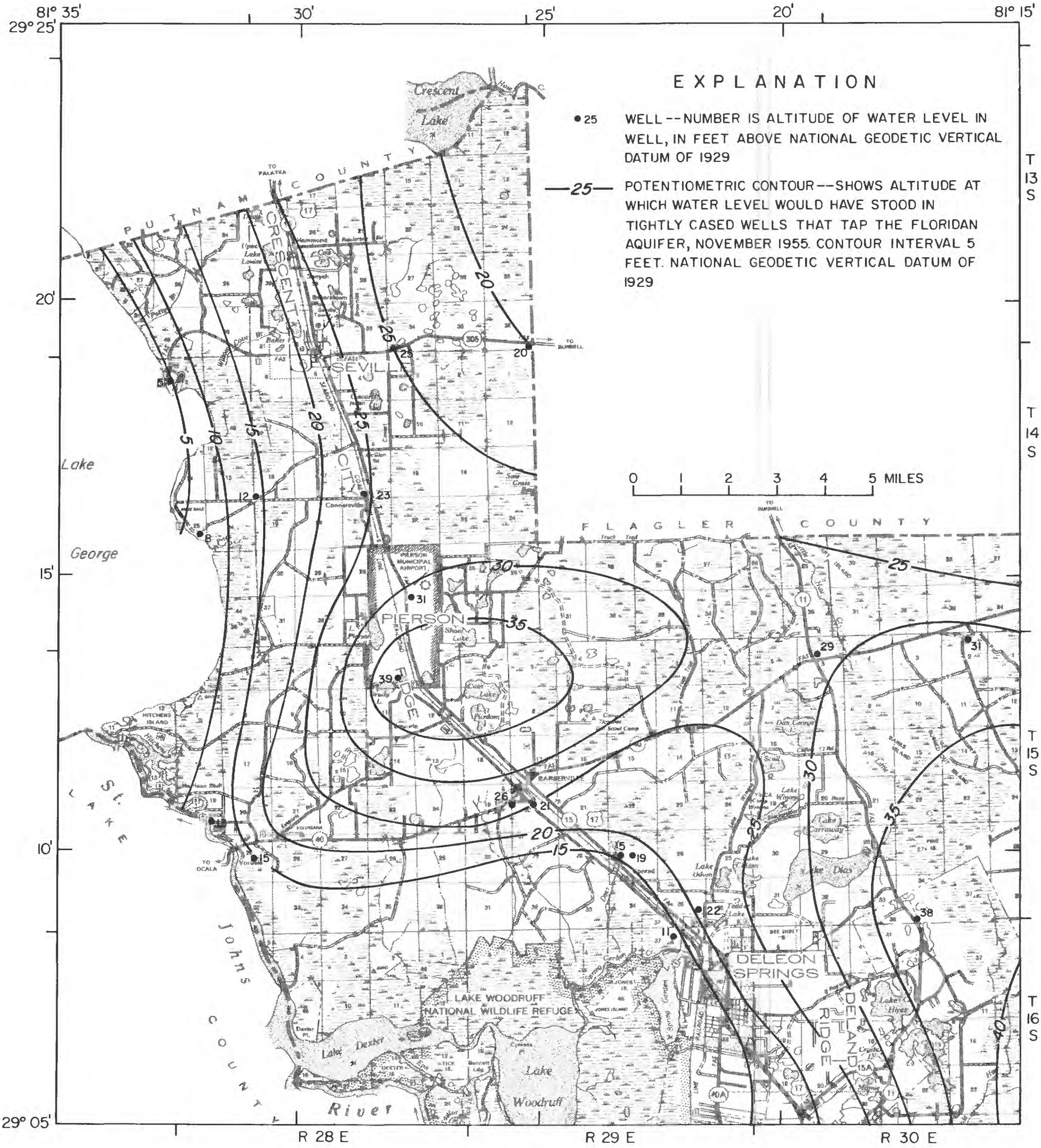


Figure 46.--Potentiometric surface of the Floridan aquifer in northwest Volusia County, November 1955 (from Wyrick, 1960).

site of ground-water inflow; the southern limit of the study area west of State Road 40A. Because of the low concentration of fernery irrigation wells, a large increase in inflow at this boundary is not likely. A decline in horizontal outflow would require a change in the potentiometric gradient at the outflow boundaries. Because the unstressed horizontal outflow is approximately 20 ft^3/s (table 7), the gradient would have to be altered noticeably to account for even a small fraction of the 14 ft^3/s pumpage. The potentiometric maps of November 1955 (fig. 46) and October 1979 (fig. 24) do not show such a hydraulic gradient change. The only time that the hydraulic gradient at the horizontal outflow boundaries is significantly altered is during severe transient drawdowns caused by freeze-protection withdrawals, which occur approximately 1 percent of the time. The comparison of the November 1955 and the October 1979 potentiometric maps also shows that no long-term change in aquifer storage has occurred. As figures 40 and 41 show, large transient storage changes occur in the fern-growing areas, but these may be thought of as the driving force for very large recharge events, and not as the long-term source of pumped water.

A decrease in discharge from springs or flowing wells or both, if it has occurred, could only account for pumpage in the DeLeon Springs area and not in the Seville or Pierson areas. No springs discharge water from the Seville or Pierson areas within the study area. Few flowing wells are in the Crescent City Ridge area, but if flowing well discharge has changed at all, it has increased and not decreased during the past several years. It is reasonable to assume that more flowing wells exist now than existed 15 years ago.

When pumping occurs, there is a decline in the potentiometric surface in the pumped zone, and this can induce an increase in recharge from the confining bed above the aquifer. Because this additional leakage comes from water storage in the confining layer, there usually is not a measurable decline in the water table in the surficial aquifer. Water lost from the Floridan aquifer is replenished by water from the confining layer, and this is in turn replenished eventually by water from the surficial aquifer. Although the immediate source of pumped water is storage in the aquifer, the long-term source is increased recharge.

The discussion in the previous section pertaining to the pumpage from the Pierson area during a severe freeze and the corresponding change in aquifer storage indicates that induced leakage could be very large. A significant amount of the 230 Mgal withdrawal from the aquifer in the Pierson area during the 39-hour time period may have been replenished to the aquifer by leakage during the 39-hour time period.

The following generalized water budget of the Floridan aquifer in northwest Volusia County is based on the assumption that the water withdrawn by pumpage is replaced entirely by induced leakage. Recharge is thus equal to the net recharge from table 7 plus the upward leakage from table 1 plus the total pumping rate. The total discharge of the spring and the flowing wells near the spring is equal to the long-term average discharge of Ponce de Leon Springs (30 ft^3/s) plus an estimated 4 ft^3/s from flowing wells. The upward leakage estimate is 40 ft^3/s, based on the 2 in/yr from table 1. The discussion in the flow-net section indicated that the outflow from area E was anomalously low. The estimate of outflow to Crescent Lake and Flagler County given here is thus higher than that of table 7 by 3 ft^3/s. The outflow to Lake George is unchanged from table 7.

Inflow		Cubic feet per second
Recharge		108
Horizontal inflow		2
	Total	110

Outflow		Cubic feet per second
Discharge of spring and flowing wells near spring		34
Upward leakage		40
Horizontal outflow:		
to Crescent Lake and Flagler County		10
to Lake George		12
Pumpage		14
	Total	110

Figure 47 shows that there is no apparent increase in runoff caused by the freeze-protection withdrawals from the Floridan aquifer, although large volumes of water are transferred to the surficial layer. The Price Creek drainage area (fig. 9) includes 40 active irrigation wells while the Middle Haw Creek drainage area includes none.

Sinkhole Activity

Sinkholes are common in areas such as northwest Volusia County that are underlain by limestone formations. Rainfall combines with carbon dioxide from the atmosphere to form weak carbonic acid. As the recharge water flows through the limestone, dissolution takes place and cavities are formed. When this dissolution of the formation weakens the roof of a large cavity to the extent that it can no longer support the saturated sand and clay layers above, the roof collapses, the sands and clays fall into the cavity, and a sinkhole depression is formed at land surface. Most of the natural lakes, ponds, and topographic depressions in northwest Volusia County were formed in this way. Larger lakes are often formed by the coalescence of several sinkholes.

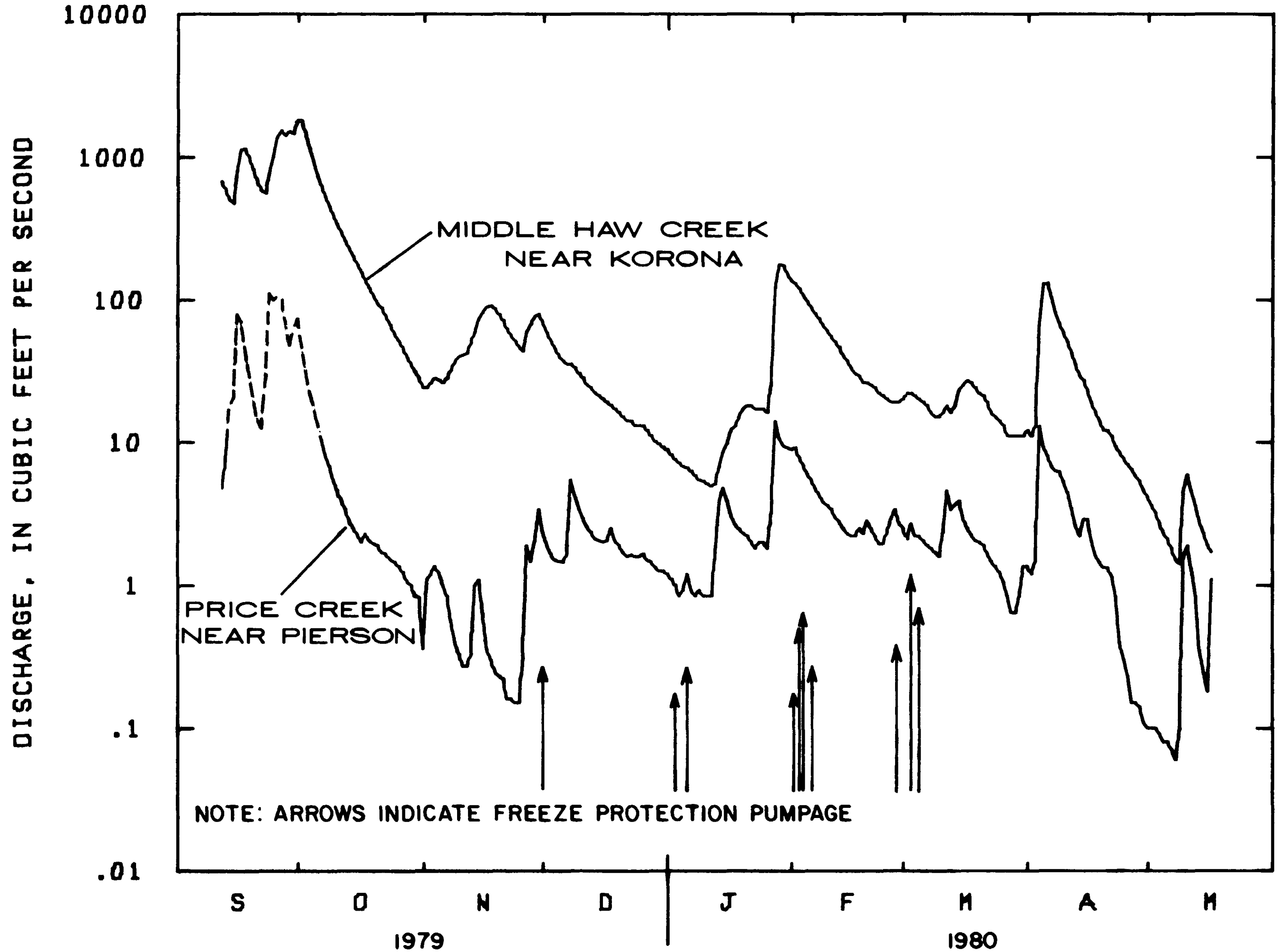


Figure 47.--Daily mean discharges at Middle Haw Creek near Korona and Price Creek near Pierson, September 11, 1979-May 23, 1980.

Sinkholes are most likely to occur in areas of active ground-water recharge, because the dissolving action of the water is greatest when it first enters the limestone aquifer. The water tends to become neutralized after moving through and reacting with the limestone. Caliper logs of wells in Pierson show a prevalance of larger cavities at the top of the formation, followed at depth by zones of smaller hole diameter (figs. 12 and 13). The larger cavities are formed at the top because the "new water" is highly reactive. Areas having shallow cavities in the limestone formation may have a greater potential for sinkhole activity.

There is a relationship between the lowering of the head, or potentiometric surface, in an artesian limestone aquifer and sinkhole formation. This is because part of the weight of the saturated sand and clay layers above the Floridan aquifer is supported by the pressure of the water in the aquifer. As drawdown of the potentiometric surface causes a decline in water pressure in the aquifer, the skeletal structure of the aquifer must bear an increase in weight. Ground-water withdrawals thus impose structural stress increases and sinkhole formation may result.

Tibbals (written commun., 1974) studied the relationship between drawdown in the Floridan and the formation of a sinkhole east of Pierson on December 12, 1973. The depth to the Floridan aquifer at the sinkhole site is 90 feet and the drawdown, which was caused by freeze-protection irrigation, was 18 to 23 feet at the time of the collapse. The increase in load on the skeletal structure of the aquifer was calculated as 15 to 19 percent.

Figure 48 shows locations of known recent sinkhole sites. The date of the sinkhole formation is shown for each. Also shown are contours of drawdown in the Floridan for 8 a.m., March 4, 1980, a time of large ground-water withdrawals for freeze-protection use. The contour interval is 15 feet. Although drawdown measurements were only made in the Pierson area at that time it is considered unlikely that areal drawdowns exceeded 15 feet in the remainder of the study area.

Most of the sinkholes located in figure 48 are known to have occurred during periods of drawdown caused by freeze-protection irrigation. The remainder of these formed in secluded locations but were discovered soon after periods of freeze protection. One of these formed 300 feet from observation well 914-128-01 and its collapse is considered to have caused a "spike" in the water-level record of that well (fig. 49). The sinkhole apparently occurred at 11 a.m. on January 3, 1979, during a period of intense freeze protection. The water surface in 914-128-01 had reached 1 foot above sea level, a level to which it probably had not declined for at least 2 years, when the collapse occurred.

The volume of cavities, and thus, the potential for sinkhole development, is slowly being increased by the dissolution of limestone formations by flowing ground water. It may be assumed that the rate of natural flushing through the Floridan aquifer in northwest Volusia County

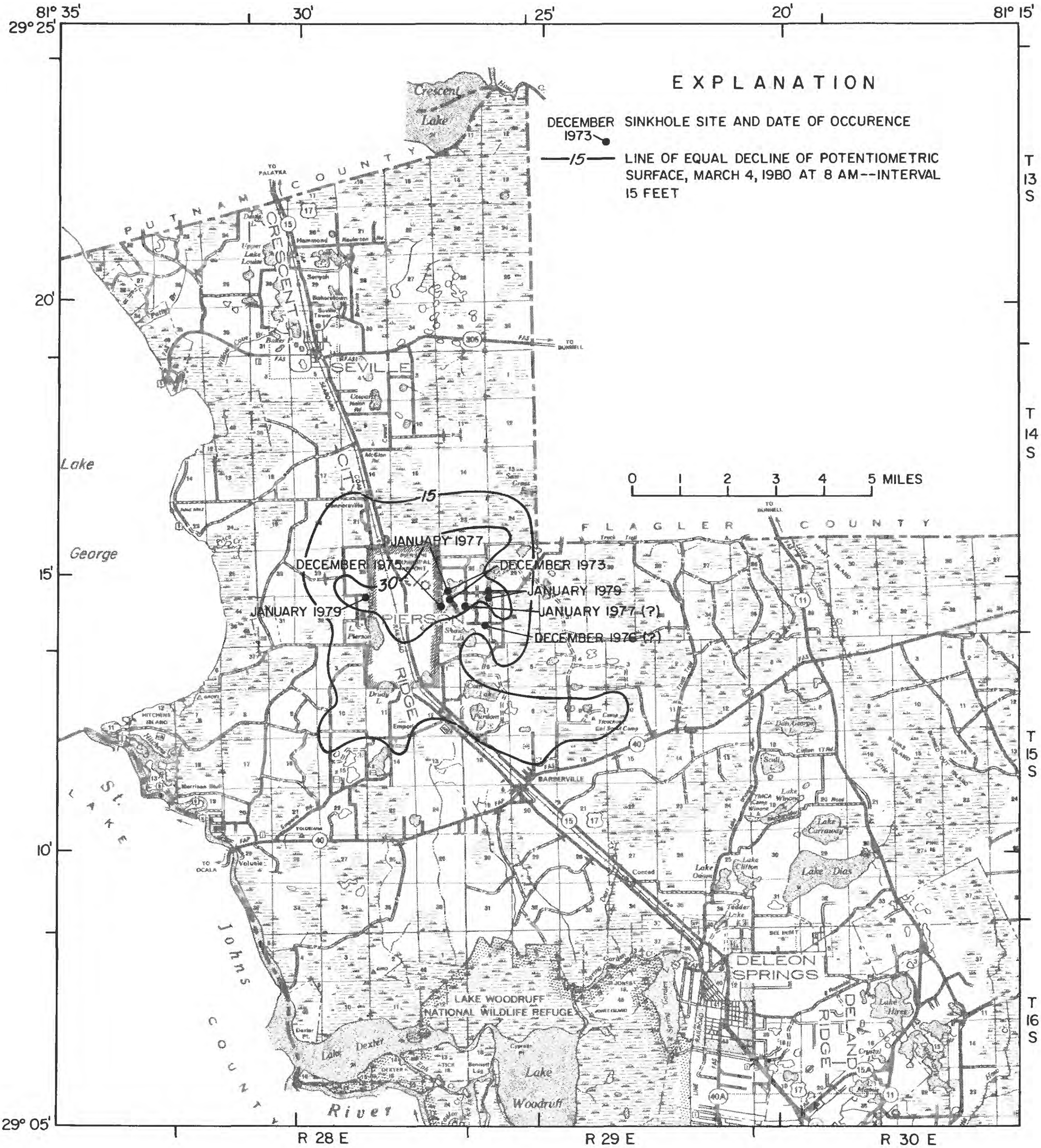


Figure 48.--Locations and dates of occurrences of sinkholes.

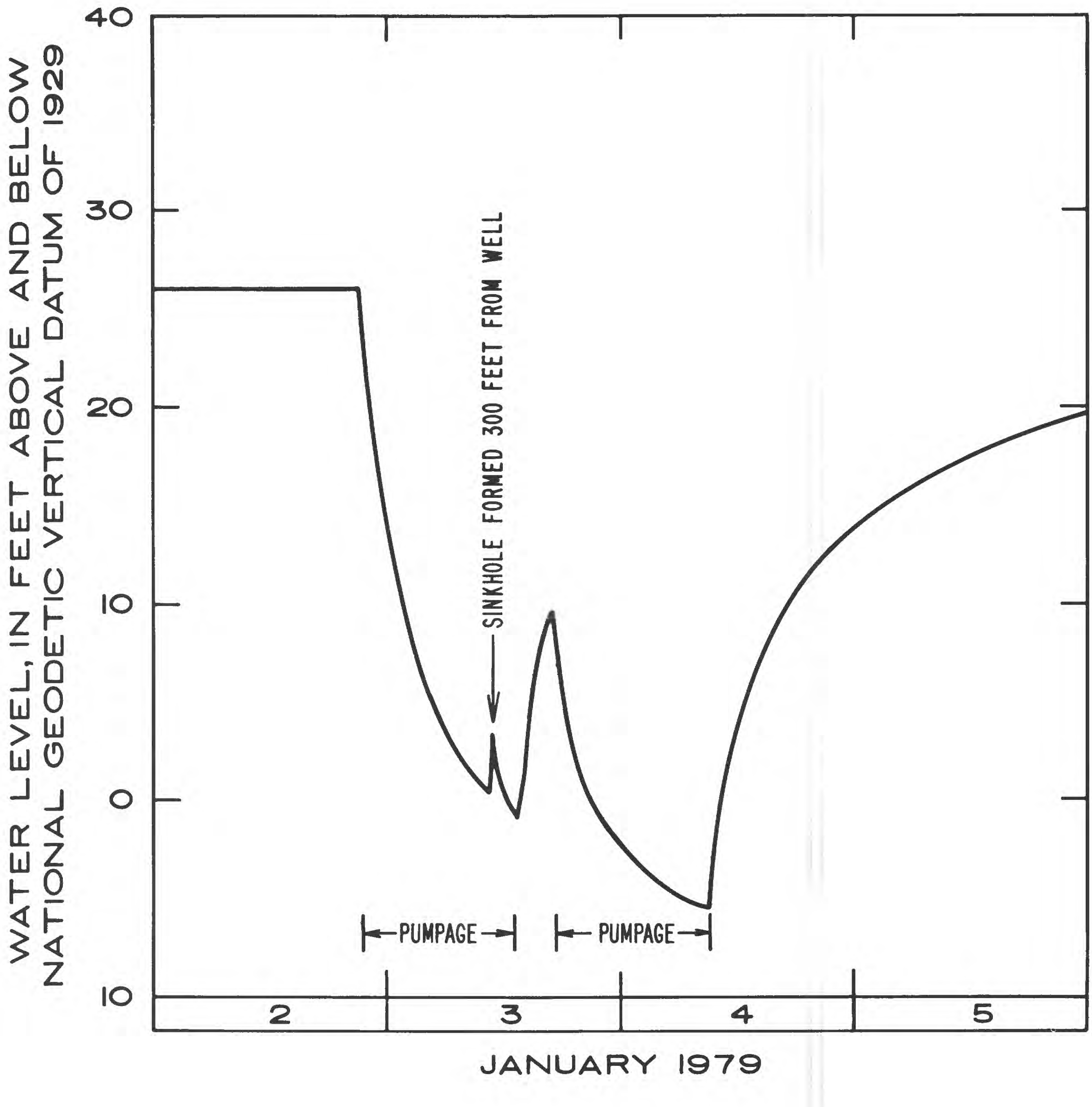


Figure 49.--Water level in well 914-128-01, January 2-5, 1979.

is the sum of the net recharge rate of 55 ft^3/s (from table 1) and an estimate of 40 ft^3/s upward leakage and that all of this water attains a dissolved solids concentration, from dissolution of the formation, of 170 mg/L. If the density of the limestone is 2.8 g/cm^3, then an amount of limestone equivalent to 360,000 ft^3, or 13,000 yd^3, is dissolved annually.

In areas where the potential for sinkhole occurrence exists in northwest Volusia County, large ground-water withdrawals may accelerate the development of collapse features. Drawdowns induce increased recharge of relatively reactive water, thus increasing the dissolution rate of aquifer material. Also, drawdowns may dewater cavities and remove part of the support for cavity roofs, thus increasing the likelihood of collapse. Nonetheless, sinkholes would continue to occur to some extent in northwest Volusia County even in the absence of irrigation withdrawals.

Saltwater Intrusion

The following discussion has two parts. The first is a discussion of data that pertain to the subject of saltwater intrusion. The second is a presentation of a water-sampling network for early detection of saltwater intrusion. The term "saltwater intrusion," where used here, refers to a significant increase in chloride concentration, with time, at given monitoring sites.

Changes in Chloride Concentration

Long-term changes in the chloride concentration of wells in northwest Volusia County are shown in table 10. These are the only wells for which chloride concentration records span more than 10 years. For this reason, the chloride concentration record for Ponce de Leon Springs is also shown (fig. 50) so that the fluctuations in salt concentration of wells can be put into perspective. Chloride analyses of water were made in the period 1953-56 for the report by Wyrick (1960), while chloride analyses made in the period 1965-68 were for the report by Knochenmus and Beard (1971). Samplings of wells for the present study were during 1978-80. The chloride concentration and discharge for Ponce de Leon Springs have been determined periodically from 1929 to the present time (1980) as part of a hydrologic monitoring network of the U.S. Geological Survey.

The chloride concentration data show no evidence of saltwater intrusion during 1953-80 in northwest Volusia County. The chloride concentration in brackish-water wells and in Ponce de Leon Springs show large fluctuations, but these are apparently related to seasonal or yearly water-level fluctuations, and do not represent a general trend of incline or decline.

Table 10.--Long-term chloride concentration changes in Floridan aquifer wells

[Given are month-day-year; chloride concentrations are in milligrams per liter]

907-121-01	
4-29-57	390
1- -66	670
6-15-79	438
9-10-79	678
12-10-79	810
2- 5-80	780

907-121-02	
4-30-57	7200
9-10-79	4275
12-10-79	4800
2- 5-80	4700

909-122-01	
4-16-56	90
12-10-79	180
1-23-80	180

909-122-02	
4-16-56	75
9- -79	97

909-122-03	
4-23-56	14
- -66	11
12- 5-79	11

909-123-01	
11- 6-53	326
9-13-66	478
1- 4-68	435
3- 8-68	430
5- 3-68	370
9-26-70	455
11- 4-70	455
5-10-72	300
9- 6-72	450
12-10-79	470
1-23-80	470

909-130-01	
1-16-56	16
- -66	10
9-10-79	9

911-129-01	
8-12-65	8
12-18-78	11

914-127-13	
8-12-65	8
12-15-78	9
2-10-79	13

917-128-01	
5-22-56	20
- -66	10
9- 6-79	10
1- 8-80	11

918-132-01	
2-27-56	510
8-17-65	960
9- 6-79	505

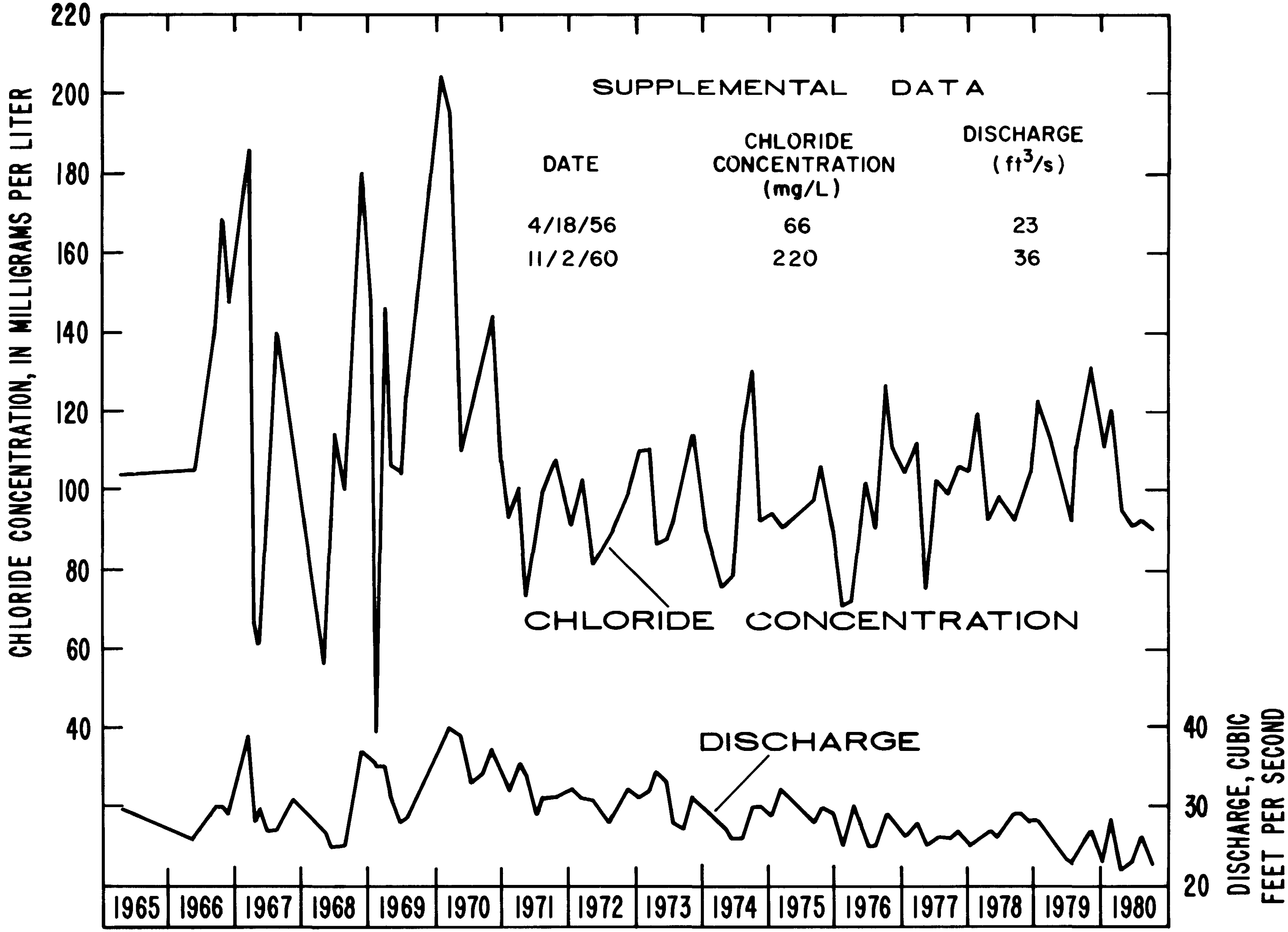


Figure 50.--Chloride concentration and discharge of Ponce de Leon Springs, 1965-80.

The fluctuations of chloride concentrations in fresh ground water where the average concentration is less than about 50 mg/L is generally not related to the movement of the saltwater interface. These small chloride concentrations may originate from rainwater and the changes of such may be related to such varied factors as street runoff and septic tank effluent.

The variations in chloride concentration of brackish ground water, though, may be related to general movements of the saltwater interface. In most areas close to the saltwater interface, the chloride concentration of the brackish water in the aquifer will decrease during periods of high water level and high ground-water discharge, and will increase during periods of low water level and low discharge. The relationship is roughly opposite to the above for brackish ground water in the DeLeon Springs area. The chloride concentration in wells 909-122-01 and 909-122-02 and in Ponce de Leon Springs during April 1956 were 90, 75, and 66 mg/L, which are all relatively low concentrations for each site. The water level (fig. 43) and the spring discharge (fig. 50) at that time were low. The relationship between chloride concentration in brackish ground water in the DeLeon Springs area and ground-water levels is not a simple one, but generally concentrations increase with increasing water levels and decrease with declining water levels.

One possible explanation for the high discharge, high water levels, and high chloride concentration is related to the existence of another freshwater system beyond the saltwater system that adjoins northwest Volusia to the southwest. Usually, an increase in discharge and water levels in a freshwater system will effectively push the saltwater interface and cause wells tapping the interface to pump fresher water. During general periods of high water level, the other, larger freshwater system displaces the saltwater system to the northeast. The saltwater interface thus moves toward the DeLeon Springs area, and wells near it pump water of higher salt concentration.

The following is a list of chloride concentrations in irrigation wells that tap brackish water in the Floridan aquifer in the DeLeon Springs area. Samples were generally taken during periods of freeze-protection withdrawals from these wells. Chloride concentration changes are apparently related to regional water-level changes discussed previously, and not to the heavy withdrawals of ground water.

Well	Date	Time	Chloride concentration (mg/L)
905-121-02	12-14-78	4:10 p.m.	550
	1-23-79	--	665
	2-10-79	5:35 a.m.	655
	2-10-79	8:18 a.m.	650
	12-27-79	6:30 a.m.	360
	1- 2-80	5:55 a.m.	800
	2- 5-80	6:00 a.m.	670
	3- 3-80	6:40 a.m.	620
906-121-07	12-18-78	9:15 a.m.	450
	1-23-79	--	490
	2-10-79	6:03 a.m.	478
	2-10-79	8:04 a.m.	480
	12- 1-79	6:45 a.m.	470
	12-27-79	6:15 a.m.	400
	1- 2-80	5:40 a.m.	500
	3- 3-80	6:25 a.m.	440
906-121-01	12-18-78	10:00 a.m.	930
	1-23-79	--	790
	2-10-79	6:08 a.m.	920
	2-10-79	7:58 a.m.	880
	12- 1-79	7:00 a.m.	790
	2- 5-80	6:35 a.m.	700
	3- 3-80	6:10 a.m.	640

Samples taken in many other irrigation wells also indicate that no upward chloride concentration change has occurred in pumping wells because of irrigational withdrawals. The reasons for the apparent absence of saltwater intrusion are not well known, but it is reasonable to assume that the temporary nature of freeze-protection pumpage has avoided intrusion up to the present time.

Suggested Monitoring Network

Although saltwater intrusion has not occurred in northwest Volusia County to a detectable extent, the irrigational pumping stresses, especially during winter months, make future intrusion a possibility. An early warning at the beginning of saltwater intrusion is desirable so that pumping can be stopped, or reduced, before intrusion becomes more severe.

Figure 51 is a suggested ground-water monitoring network for future warning of saltwater intrusion in northwest Volusia County. Most of these wells are used for freeze-protection withdrawals. These wells were chosen because of factors such as (1) present high concentration of chloride, (2) proximity to the saltwater interface, (3) well depth, or (4) large withdrawal rate, or (5) because of a combination of these factors. Other wells in the network include free-flowing wells and domestic-supply wells near the saltwater interface.

SUMMARY

Northwest Volusia County, in east-central Florida, is a 262-square-mile area including the southern part of the Crescent City Ridge and the northern tip of the DeLand Ridge. The hydrogeologic units in the area include the Floridan aquifer, which is made up of parts of the Lake City Limestone, the Avon Park Limestone, and the Ocala Limestone; the confining bed, which is composed of clays of Miocene or Pliocene age; and the surfical aquifer, which is made up of Pleistocene and Holocene age sands.

Under natural conditions, the surficial layer water budget for the study area includes rainfall of 55 in/yr, evapotranspiration of 39 in/yr, runoff of 13 in/yr, and a net downward leakage, or recharge to the Floridan aquifer, of 3 in/yr. Recharge is estimated to be 20 in/yr in some of the areas of DeLeon Springs and 10 in/yr in the Pierson and Seville Ridge areas. Upward leakage in the discharge areas surrounding the ridges is estimated to be 4 in/yr.

Average yearly ground-water irrigational use from the Floridan aquifer is 8.1 Mgal/d for the entire study area of which 4.8 Mgal/d is for the Pierson area alone. Peak ground-water use rates from the Floridan aquifer, which occur during freeze-protection pumpage in winter months, are 300 Mgal/d for northwest Volusia County and 170 Mgal/d for the Pierson area alone. Application rates average 160 gal/min per acre of fernery. The greatest concentration of irrigation wells is in the northeast Pierson area. The average depth of irrigation wells in northwest Volusia County exceeds 300 feet.

Apparent transmissivities of the Floridan aquifer range from 4,500 ft^2/d to 160,000 ft^2/d while storage coefficients range from 0.0003 to 0.0013. Transmissivity is higher in the DeLeon Springs area than it is in the Seville and Pierson areas. The average for the DeLeon Springs area is 50,000 ft^2/d while that of the Seville and Pierson areas is 20,000 ft^2/d. The deepest irrigation wells in the study area, with some depths exceeding 700 feet, are in the east Pierson area mainly because this area has the lowest transmissivities in the study area.

The areal drawdowns in the Floridan aquifer in the fern-growing areas of Pierson are approximately 5 feet for growth irrigation pumpages and 20 to 30 feet for freeze-protection irrigational withdrawals. At the end

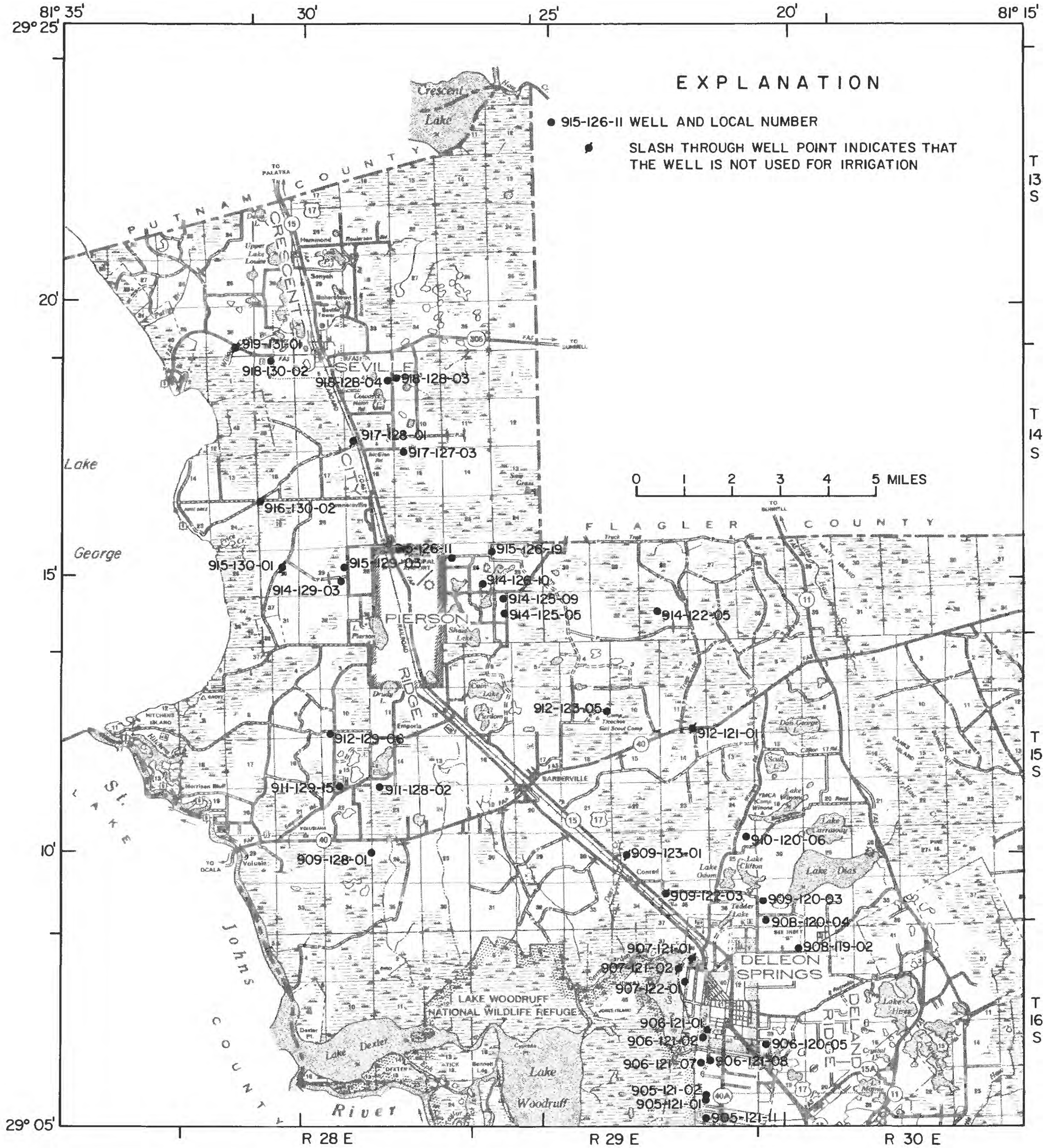


Figure 51.--Suggested monitoring network for future warning of saltwater intrusion.

of one severe freeze-protection pumping period in March 1980, the Pierson drawdown exceeded 30 feet over a 4.4-square-mile area and exceeded 15 feet over a 23-square-mile area. This pumping period consisted of 19 hours of pumpage followed by 7 hours of recovery followed by another 13 hours of pumpage. Evidence indicates that significant amounts of the water withdrawn during this 39-hour period may have been replaced by leakage during the 39 hours. For observation wells in fern-growing areas, the freeze-protection drawdowns caused by many wells can be approximated as the sum of individual drawdowns created by each. Because of leakage effects, this simulation is limited to observation wells relatively close to pumping wells. Drawdowns are significantly smaller in the Seville and DeLeon Springs areas than they are in the Pierson area. Drawdowns in pumping irrigation wells during freeze-protection pumpages are greatest in the northeast Pierson area, where some may exceed 90 feet.

Drawdowns caused by freeze protection are large, but temporary, and there has been no long-term residual drawdown. The predominant effect of these withdrawals on the Floridan aquifer water budget has been increased recharge. The budget under present conditions of withdrawal consists of 108 ft^3/s recharge, 2 ft^3/s horizontal ground-water inflow, 34 ft^3/s direct discharge, 40 ft^3/s upward leakage, 22 ft^3/s horizontal outflow, and 14 ft^3/s pumpage.

Northwest Volusia County is an area of natural sinkhole activity, but this activity has been increased by the temporary increase in load on the aquifer's skeletal structure during intense drawdowns in the Floridan aquifer and by the increased dissolution of the limestone formation caused by induced leakage.

The Floridan aquifer contains good-quality water in most of the study area, but also contains brackish water underneath the stressed zones and also in the upper zones along the western and southern limits of the area. The altitude of the fresh- saltwater interface varies in the area from -1,500 to -300 feet. There is no evidence to indicate that saltwater intrusion has occurred to date, but a monitoring network for early detection of such intrusion is suggested.

Future monitoring should consist of a continuous record of water level in a Floridan aquifer well in the Pierson area and chloride sampling using the monitoring network listed. Sampling should be most rigorous during freeze-protection periods.

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TABLE OF SUPPLEMENTAL DATA--WELL INVENTORY

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN-TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
90511601	290550081162601	107	70	4	LAWRENCE	UNUSED		50.00	7.21	08/05/65	10	08/05/65
90511602	290552081161001	240	225	8	LAWRENCE	IRRIGATION	F	64.00	.	.	8	08/05/65
90511701	290534081175001	114	85	4	U S GEOL S	UNUSED		63.10	24.35	10/21/65	10	04/21/66
90511702	290534081175002	260	246	4	U S GEOL S	UNUSED		63.16	26.00	10/21/65	10	04/21/66
90511703	290534081175003	11	11	4	U S GEOL S	UNUSED		63.02	1.93	10/21/65	11	04/21/66
90511801	290551081180101	120	90	2	S J WOLF	DOMESTIC		70.00	45.00	.	10	05/12/65
90511902	290517081193601	212	116	4	MCDONALD	PUBLIC		94.00	68.20	12/07/78	.	.
90512002	290538081200501	360	110	8	LOADHOLTZ	IRRIGATION	F	93.00	.	.	20	01/02/80
90512003	290556081202601	345	79	8	BUTKIS	IRRIGATION		67.00	.	.	.	.
90512004	290553081203501	200	.	6	OTT	IRRIGATION	F	64.00	.	.	70	12/05/79
90512005	290546081205701	165	94	2	PAISH	DOMESTIC		65.00	.	.	150	12/05/79
90512101	290532081213501	.	.	8	CONTINENTA	IRRIGATION	F	43.00	35.42	12/02/78	65	03/03/80
90512102	290538081213501	560	.	10	CONTINENTA	IRRIGATION	F	52.00	28.85	12/02/78	620	03/03/80
90512103	290539081214201	170	.	8	CONTINENTA	IRRIGATION	F	57.00	.	.	73	02/05/80
90512104	290528081214501	.	.	6	CONTINENTA	IRRIGATION		50.00	.	.	69	01/02/80
90512105	290528081213101	.	.	6	CONTINENTA	IRRIGATION		65.00	.	.	280	01/02/80
90512106	290527081213801	.	.	8	CONTINENTA	IRRIGATION	F	66.00	48.38	12/02/78	64	02/05/80
90512107	290535081214801	.	.	8	CONTINENTA	IRRIGATION	F	37.00	17.20	12/02/78	110	01/02/80
90512108	290535081214301	.	.	10	CONTINENTA	IRRIGATION	F	61.00	46.43	12/02/78	.	.
90512109	290527081215001	.	.	4	ADAMS	DOMESTIC		25.37	12.73	05/07/76	17	05/13/80
90512110	290520081211301	300	70	6	A H DUVAL	PUBLIC		.	.	.	13	08/18/65
90512111	290512081213801	276	109	8	BOOKER	IRRIGATION	F	69.00	.	.	58	03/03/80
90512112	290517081213001	180	100	2	HALL	IRRIGATION		64.00	.	.	.	.
90512113	290517081212501	.	.	6	CLARK	IRRIGATION	F	78.00	.	.	.	.
90512114	290545081213901	120	62	4	SORG	DOMESTIC		57.00	33.00	04/01/79	130	12/05/79
90512115	290557081210201	.	97	4	THOMAS	DOMESTIC		65.00	55.00	08/01/78	460	12/05/79
90512116	290557081210101	195	90	2	THOMAS	DOMESTIC		67.00	.	.	7	12/05/79
90512117	290524081213501	168	146	2	SCHORR	DOMESTIC		57.00	38.00	08/01/76	7	12/13/79
90512118	290549081210201	138	79	4	SENECA	DOMESTIC		74.00	58.00	09/01/78	220	12/13/79
90611602	290616081162101	300	119	6	POWELL	IRRIGATION		56.00	21.60	12/02/78	.	.
90611901	290647081192201	150	115	8	STRAHAN	IRRIGATION	F	92.00	60.00	09/21/77	.	.
90611902	290623081195601	270	169	6	KINNEY	IRRIGATION	F	43.00	36.00	08/14/78	.	.
90612002	290653081200301	48	45	1	U S GEOL S	UNUSED		31.00	12.69	02/27/67	8	04/14/82
90612003	290635081202701	350	.	8	RICHARDSON	IRRIGATION	F	71.00	60.39	12/14/78	10	03/03/80
90612004	290635081202501	400	160	.	RICHARDSON	IRRIGATION	F	72.00	.	.	12	12/27/79
90612005	290635081202101	350	.	.	RICHARDSON	IRRIGATION	F	67.00	.	.	31	12/27/79
90612006	290643081201201	.	.	6	RICHARDSON	IRRIGATION	F	39.00	32.00	.	.	.
90612007	290625081201801	.	.	.	HARPER	IRRIGATION	F	67.00	.	.	10	12/15/78
90612101	290646081213701	353	92	8	WARD	IRRIGATION	F	57.00	.	.	640	03/03/80
90612102	290642081214001	.	.	6	LAWERENCE	IRRIGATION	F	55.00	.	.	400	03/03/80
90612103	290602081213201	.	.	6	BENNETT	IRRIGATION		57.00	.	.	.	.
90612104	290602081214501	225	53	8	DUBELL	IRRIGATION		37.00	15.00	08/07/78	.	.
90612105	290610081213501	.	.	8	HASSTROM	IRRIGATION	F	50.00	.	.	.	.
90612106	290610081213201	.	.	.	HAGSTROM	IRRIGATION	F	60.00	.	.	.	.
90612107	290612081214101	.	.	8	HAGSTROM	IRRIGATION	F	46.00	.	.	440	03/03/80
90612108	290613081213001	343	105	8	LUCAS	IRRIGATION	F	58.00	46.86	12/18/78	710	02/05/80
90612109	290629081214001	192	83	8	MEAD	IRRIGATION	F	62.00	.	.	87	12/01/79
90711501	290703081155001	300	107	8	JAMES	IRRIGATION	F	52.00	.	.	14	02/01/79
90711502	290704081155301	600	.	10	HAGSTROM	IRRIGATION	F	54.00	.	.	13	02/01/79
90711602	290755081161501	618	105	12	SHELDON	IRRIGATION	F	47.00	14.84	08/17/78	.	.
90711603	290703081160401	505	107	8	HAGSTROM	IRRIGATION	F	58.00	.	.	13	02/01/79
90711604	290748081163301	.	.	12	SHELDON	IRRIGATION	F	60.00	.	.	.	.

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN-TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
90711701	290749081171801	.	.	8	LUNDGREN	IRRIGATION	F	52.00	.	.	.	.
90711702	290749081173701	.	.	8	HERRING	IRRIGATION	F	50.00	.	.	.	.
90711703	290751081175201	.	.	.	HERRING	IRRIGATION	F	55.00	.	.	.	.
90711801	290748081184201	250	94	5	THOMAS	DOMESTIC		73.55	.	.	.	.
90711802	290753081185001	374	.	8	FLEMING	IRRIGATION	F	82.00	55.00	04/08/76	14	02/01/79
90711803	290740081180801	350	110	8	HESTER	IRRIGATION	F	57.00	24.00	08/27/77	.	.
90711901	290704081194801	123	86	4	POWSENSE	IRRIGATION		73.00	16.00	01/01/77	.	.
90712001	290756081204001	250	.	6	COTTAM	IRRIGATION	F	62.00	45.00	01/01/75	.	.
90712002	290756081204401	500	.	8	FRANKLIN	IRRIGATION	F	67.00	43.84	12/12/78	11	03/03/80
90712003	290712081203001	.	.	8	LAWERENCE	IRRIGATION	F	64.00	.	.	17	02/01/79
90712004	290705081205901	200	89	4	VOL.COUNTY	FIRE		53.00	34.00	12/01/75	16	12/13/79
90712101	290804081215601	169	38	12	SAMS	UNUSED		5.00	.	.	720	04/14/82
90712102	290752081220901	96	28	8	SAMS	UNUSED		5.00	.	.	4000	04/14/82
90712103	290723081210601	200	87	4	DELEON SPG			45.80	31.09	03/24/78	.	.
90712104	290731081212401	168	70	4	LEVAN	IRRIGATION		55.00	40.00	09/28/77	.	.
90712105	290730081213401	.	.	.	LEVAN	IRRIGATION	F	50.00	.	.	.	.
90712106	290718081212001	230	90	8	ALMAND	IRRIGATION	F	47.00	30.00	01/01/77	15	03/03/80
90712201	290737081220301	.	.	.	HAGSTROM	IRRIGATION	F	20.00	12.12	11/18/78	280	05/13/80
90712202	290743081221101	.	.	6		UNUSED		4.00	.	.	1900	04/15/80
90712203	290745081221101	.	.	2		UNUSED		5.00	.	.	1000	04/15/80
90712301	290708081233101	156	100	4	SJRWMD	UNUSED		8.00	-2.38	05/20/80	2700	09/10/80
90811702	290808081172501	312	92	8	CAMPBELL	IRRIGATION	F	44.00	15.00	03/24/76	.	.
90811703	290853081175201	.	.	10	SHELDON	IRRIGATION	F	42.00	6.95	11/28/78	.	.
90811704	290843081175501	87	.	4	PETERSON	IRRIGATION	F	40.00	.	.	.	.
90811705	290847081174801	98	.	4	PETERSON	IRRIGATION	F	45.00	.	.	.	.
90811901	290850081190101	510	151	10	FLORAL GRE	IRRIGATION		70.05	36.28	08/17/78	.	.
90811902	290815081194801	475	.	8	FLORAL GRN	IRRIGATION	F	66.00	47.99	11/28/78	11	03/03/80
90811903	290815081195101	.	6	.	FLORAL GRN	IRRIGATION	F	70.00	.	.	10	01/02/80
90811904	290817081195201	.	.	6	FLORAL GRN	IRRIGATION	F	64.00	.	.	8	01/02/80
90811905	290819081195001	.	.	.	FLORAL GRN	IRRIGATION	F	68.00	.	.	.	.
90811906	290818081194701	.	.	8	FLORAL GRN	IRRIGATION	F	70.00	.	.	9	01/02/80
90811907	290810081194701	190	.	6	JONES	IRRIGATION		77.00	51.00	01/01/77	.	.
90811908	290801081194001	245	134	4	BRADLEY	IRRIGATION	F	85.00	57.00	11/26/76	.	.
90812001	290849081203101	309	.	6	HOBLICK	IRRIGATION	F	45.00	25.40	11/30/78	84	06/21/79
90812002	290850081202101	450	108	8	HOBLICK	IRRIGATION		54.67	33.60	11/30/78	280	12/28/79
90812003	290847081203001	385	.	8	HOBLICK	IRRIGATION	F	45.00	31.60	11/30/78	.	.
90812004	290849081202601	415	.	6	HOBLICK	IRRIGATION	F	45.00	.	.	260	03/03/80
90812005	290829081203001	400	.	8	HOBLICK	IRRIGATION		47.00	.	.	.	.
90812006	290843081205601	.	.	10	ABBOTT	IRRIGATION		45.00	18.84	11/30/78	.	.
90812007	290830081205101	.	.	6	LENNON	IRRIGATION	F	50.00	.	.	68	12/27/79
90812008	290807081205201	.	.	6	KING	IRRIGATION	F	65.00	46.89	12/01/78	150	03/03/80
90812009	290813081203101	.	.	6	SYLVESTER	IRRIGATION	F	54.00	32.63	11/30/78	.	.
90812010	290849081203201	126	102	4	HOBLICK	DOMESTIC		40.00	.	.	35	12/05/79
90812103	290846081213301	.	.	2	WOLF	UNUSED		30.61	.	.	.	.
90812201	290801081220501	55	50	2				4.00	.	.	1600	04/16/80
90911701	290923081174301	128	.	4	O.DIEAS	UNUSED		52.17	15.47	05/10/76	.	.
90911702	290937081174501	.	.	6	TEDDER	IRRIGATION	F	53.00	.	.	14	02/01/79
90912001	290918081203201	310	95	8	CAMPBELL	IRRIGATION	F	55.00	15.00	03/24/76	13	02/10/79
90912002	290917081202101	295	130	6	HIRES	IRRIGATION	F	55.00	49.00	09/16/76	.	.
90912003	290910081202801	350	145	6	CRIBBS	IRRIGATION	F	60.00	32.00	07/16/76	10	03/03/80
90912004	290906081204201	.	.	8	HARPER	IRRIGATION	F	44.00	.	.	.	.
90912101	290929081212501	253	84	12	SHUMAN	IRRIGATION	F	34.38	12.00	11/15/76	16	06/22/79
90912102	290901081213101	242	101	8	SHUMAN	IRRIGATION	F	34.00	22.00	01/01/77	.	.
90912103	290955081210901	.	.	8	SHUMAN	IRRIGATION	F	45.00	.	.	15	02/01/79

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN- TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
90912104	290948081211301	.	.	6	SHUMAN	IRRIGATION		34.00	.	.	.	.
90912105	290906081214801	180	.	8	FIESER	STOCK		27.82	8.86	09/05/78	.	.
90912106	290935081212201	140	.	2	BRACKET	UNUSED		34.09	10.31	05/10/79	.	.
90912107	290927081212801	117	79	8	SHUMAN	IRRIGATION		34.03	15.00	02/21/77	.	.
90912108	290910081211501	200	100	8	SHUMAN	IRRIGATION	F	32.25	16.66	06/28/79	.	.
90912201	290959081230601	183	155	4	SUNNY HILS	UNUSED		15.00	.	.	180	01/23/80
90912203	290917081222201	200	.	4	FIESER	UNUSED		10.00	-8.00	12/13/79	11	04/14/82
90912205	290921081223301	173	168	2	NICHOLSON	DOMESTIC		11.00	.	05/01/79	18	12/13/79
90912301	290959081231601	241	206	4	SUNNY HILS	UNUSED		12.00	4.20	11/06/53	440	04/14/82
90912303	290930081230201	145	143	2		UNUSED		15.94	-2.35	02/03/78	62	12/10/79
90912304	290948081232001	135	124	4	SUNNY HILS	UNUSED		14.00	.	.	240	01/23/80
90912801	290959081283501	354	.	8	TURNER	IRRIGATION	F	45.00	12.00	12/07/58	15	02/10/79
90913001	291008081304801	96	90	2	GALZERANO	IRRIGATION		20.00	6.00	01/01/53	9	09/10/79
90913003	290946081305101	150	.	6	UNDERWOOD	UNUSED		8.08	-10.30	12/14/79	.	.
91011701	291036081175801	180	95	4	HENDRIX	STOCK		43.93	13.27	05/11/79	9	02/17/82
91011801	291003081180301	98	95	1	U S GEOL S	UNUSED		37.90	4.68	02/28/67	.	.
91011802	291004081180001	162	.	4	VOLUSIA	PUBLIC		37.00	7.59	06/01/78	.	.
91011803	291035081180501	420	92	6	BARNHILL	IRRIGATION	F	52.00	16.00	04/05/76	.	.
91012001	291008081204801	137	80	4	M BLACKWEL	DOMESTIC		55.00	24.00	05/01/65	10	08/20/65
91012002	291009081205801	450	200	10	BLACKWELDE	UNUSED		38.20	10.85	03/27/78	.	.
91012003	291009081204801	400	99	8	BLACKWELD	IRRIGATION	F	52.00	28.00	02/09/76	.	.
91012004	291010081205801	421	192	10	BLACKWELDE	IRRIGATION	F	41.00	9.00	02/23/77	14	06/23/79
91012005	291017081204001	395	.	.	BLACKWELDE	IRRIGATION	F	52.00	.	.	.	.
91012006	291017081205001	465	.	.	BLACKWELDE	IRRIGATION	F	46.00	.	.	14	02/01/79
91012007	291052081200901	.	.	2	YMCA	UNUSED		65.96	35.85	09/27/78	.	.
91012101	291002081211001	.	.	.		IRRIGATION	F	40.00	.	.	14	02/10/79
91012501	291053081253401	107	.	6	CLEM NASSA	STOCK		40.50	15.00	02/18/36	.	.
91012502	291056081252401	.	.	2		STOCK		42.15	22.13	05/01/76	.	.
91012601	291044081263701	320	156	8	WOODS	IRRIGATION	F	42.00	18.00	01/01/77	.	.
91012602	291038081263801	225	129	4	SEYMOUR	IRRIGATION	F	42.00	20.00	01/01/77	.	.
91012801	291052081285801	338	138	8	HARPER	IRRIGATION	F	46.00	21.00	01/01/77	.	.
91012802	291055081285001	500	110	8	TURNER	IRRIGATION	F	42.00	12.11	07/20/78	.	.
91012803	291005081284701	279	109	6	WARENSFORD	IRRIGATION	F	37.00	21.00	01/01/68	.	.
91012901	291035081292001	.	.	6	JONES	IRRIGATION	F	37.00	.	.	.	.
91012902	291037081292001	.	.	6	JONES	IRRIGATION	F	47.00	.	.	.	.
91013002	291009081305401	99	.	1		UNUSED		20.00	6.44	02/03/78	.	.
91013003	291009081305402	.	3	2	USGS	UNUSED		20.00	0.68	01/31/79	70	03/03/82
91013201	291057081324101	.	.	2		UNUSED		6.00	-2.98	02/28/80	.	.
91111901	291149081190801	240	118	8	BEATTY	IRRIGATION		73.56	43.95	03/27/78	.	.
91111902	291158081195401	408	100	12	SHELDON	IRRIGATION	F	42.00	9.18	08/28/78	.	.
91112501	291203081260701	101	.	3	LAW	IRRIGATION		50.00	19.10	09/05/78	.	.
91112502	291157081250701	.	.	.	HARPER	IRRIGATION	F	51.00	.	.	.	.
91112701	291154081275201	410	107	8	PRIDGEON	IRRIGATION	F	56.00	28.20	12/06/78	.	.
91112702	291152081275901	396	130	8	TURNER	IRRIGATION	F	58.00	24.00	10/01/77	.	.
91112703	291123081275701	300	180	8	LUCAS	IRRIGATION	F	54.00	.	.	.	.
91112801	291118081285901	366	102	8	HARPER	IRRIGATION		43.20	19.00	01/01/77	.	.
91112802	291112081282601	480	140	8	RICHARDSON	IRRIGATION	F	52.00	26.59	11/18/78	13	02/10/79
91112803	291107081283101	185	120	8	RICHARDSON	IRRIGATION	F	45.00	15.03	11/18/78	.	.
91112804	291158081284001	265	110	8	WARD	IRRIGATION	F	35.00	.	.	.	.
91112805	291150081280601	.	.	2	TURNER	UNUSED		46.83	15.71	12/07/78	.	.
91112806	291150081282501	303	129	8	HARPER	IRRIGATION		48.54	19.93	11/27/78	.	.
91112807	291123081283401	.	.	4	TURNER	IRRIGATION	F	45.00	.	.	.	.
91112808	291116081280101	200	120	6	SAULS	IRRIGATION	F	51.00	21.50	12/06/78	.	.

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN-TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91112901	291128081291501	250	97	4	ED REIM	IRRIGATION	F	43.00	10.00	08/01/64	11	12/18/78
91112902	291137081291501	120	90	2	EVANS	UNUSED		45.00	18.40	01/13/78	.	.
91112903	291123081291001	310	115	8	HARPER	IRRIGATION	F	45.00	24.00	01/01/77	.	.
91112904	291116081291701	194	79	4	LONG	IRRIGATION		41.00	16.00	01/01/77	.	.
91112905	291118081291701	.	.	4	LONG	IRRIGATION		44.00	.	.	.	.
91112906	291138081290701	300	95	6	HARPER	IRRIGATION	F	41.00	.	.	.	.
91112907	291133081291301	.	.	4	EVANS	IRRIGATION	F	46.00	.	.	.	.
91112908	291136081290701	.	.	4	EVANS	IRRIGATION	F	40.00	.	.	.	.
91112909	291136081291501	.	.	2	EVANS	IRRIGATION		45.00	.	.	.	.
91112910	291137081291701	.	.	4	EVANS	IRRIGATION		45.00	15.28	11/27/78	.	.
91112911	291131081290501	317	.	8	ED REIM	IRRIGATION	F	40.00	13.70	11/27/78	.	.
91112912	291159081292401	.	.	8	SMITH	IRRIGATION	F	37.00	.	.	.	.
91112913	291153081292301	325	90	8	PRIDGEON	IRRIGATION	F	41.00	16.50	11/27/78	.	.
91112914	291157081292201	101	.	2	PRIDGEON	UNUSED		41.00	16.74	09/07/78	.	.
91112915	291111081291401	600	.	8	MCCOLLOUGH	IRRIGATION	F	42.00	12.79	12/13/78	11	12/13/78
91112916	291117081291701	301	93	8	LONG	IRRIGATION	F	42.00	14.00	12/01/78	.	.
91113201	291105081324501	180	.	.	HOBBS			6.00	-1.50	02/28/80	.	.
91211901	291257081191301	145	71	8	SPENCE	IRRIGATION	F	44.00	12.70	08/11/78	.	.
91212001	291225081202001	.	.	10	CONE	IRRIGATION	F	40.00	.	.	.	.
91212101	291216081215601	170	131	4	SJWMD	UNUSED		24.12	-0.78	02/02/79	22	02/09/79
91212301	291223081235501	350	.	8	RICHARDSON	IRRIGATION	F	27.00	.	.	.	.
91212302	291221081234901	.	120	8	RICHARDSON	IRRIGATION	F	37.00	.	.	.	.
91212303	291228081234901	380	.	8	RICHARDSON	IRRIGATION	F	44.00	.	.	.	.
91212304	291229081234501	390	.	8	RICHARDSON	IRRIGATION	F	40.00	.	.	.	.
91212305	291233081234401	400	.	8	RICHARDSON	IRRIGATION	F	40.00	.	.	.	.
91212306	291221081235101	100	.	4	RICHARDSON	UNUSED		36.00	9.75	11/13/78	.	.
91212401	291222081243801	155	.	4	PEDERSON	IRRIGATION	F	40.00	11.00	01/01/63	10	08/17/65
91212402	291221081240701	300	.	8	RICHARDSON	IRRIGATION	F	41.00	.	.	.	.
91212403	291224081243501	400	100	4	PEDERSEN	IRRIGATION	F	41.00	.	.	.	.
91212501	291229081250701	403	105	8	HARPER	IRRIGATION	F	36.00	13.21	07/21/78	.	.
91212502	291201081250801	.	.	.	HARPER	IRRIGATION	F	53.00	.	.	.	.
91212503	291227081254201	370	120	8	RICHARDSON	IRRIGATION	F	50.00	.	.	.	.
91212504	291229081254201	370	120	8	RICHARDSON	IRRIGATION	F	49.00	.	.	.	.
91212505	291219081250401	332	140	8	STRICKLAND	IRRIGATION	F	39.00	.	.	.	.
91212601	291219081263701	.	.	3	TURNER	UNUSED		56.41	26.11	08/29/78	.	.
91212604	291247081264301	233	97	8	SHARR	IRRIGATION	F	52.00	24.00	01/01/76	.	.
91212605	291257081265601	300	120	6	RICHARDSON	IRRIGATION	F	53.00	.	.	.	.
91212606	291207081260001	.	.	6	T.TAYLOR	IRRIGATION	F	56.00	.	.	.	.
91212607	291206081260401	.	.	6	T.TAYLOR	IRRIGATION	F	54.00	.	.	.	.
91212608	291246081265401	.	.	.	RICHARDSON	IRRIGATION	F	60.00	26.00	.	.	.
91212609	291248081265401	.	.	.	RICHARDSON	IRRIGATION	F	59.00	26.00	.	.	.
91212704	291250081271101	366	110	6	RICHARDSON	IRRIGATION		57.00	25.00	01/01/78	.	.
91212705	291242081270301	.	.	.	RICHARDSON	IRRIGATION	F	61.00	.	.	11	01/10/78
91212706	291218081271201	400	120	8	RICHARDSON	IRRIGATION	F	57.00	.	.	14	02/10/79
91212707	291209081275701	400	120	8	PETERSON	IRRIGATION	F	59.00	37.00	09/22/77	.	.
91212708	291236081275201	357	90	8	SPENCE	IRRIGATION	F	56.00	27.00	01/01/76	.	.
91212801	291205081280301	.	.	4	SIRMEN	DOMESTIC		60.35	30.84	01/13/78	.	.
91212802	291224081283101	364	122	8	RICHARDSON	IRRIGATION	F	37.00	9.95	07/20/78	.	.
91212803	291214081282201	350	78	8	SAUL	IRRIGATION	F	55.00	27.85	07/20/78	.	.
91212804	291248081280301	.	.	3	TURNER	UNUSED		55.55	23.87	09/05/78	.	.
91212805	291210081284701	.	147	4	PETERSON	IRRIGATION	F	35.00	.	.	.	.
91212806	291212081282501	360	78	8	GUESS	IRRIGATION	F	54.00	27.00	11/01/78	.	.
91212807	291209081282801	246	80	6	GUESS JR	IRRIGATION	F	52.00	.	.	.	.

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN- TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91212808	291231081281801	206	117	8	VAN HOOSE	IRRIGATION	F	57.00	28.00	12/01/78	.	.
91212809	291209081283401	.	100	2	GUESS SR	IRRIGATION		50.00	27.00	12/14/78	.	.
91212810	291204081280001	.	.	2	KIRBY	IRRIGATION	F	61.00	32.00	.	.	.
91212811	291230081280501	340	90	4	BLACKBURN	IRRIGATION	F	55.00	.	.	.	.
91212901	291220081291701	.	.	8	RICHARDSON	IRRIGATION	F	42.00	16.70	11/27/78	13	02/10/79
91212902	291223081290901	400	.	8	RICHARDSON	IRRIGATION	F	40.00	12.95	11/27/78	.	.
91212903	291215081292201	425	85	8	YORK&SONS	IRRIGATION	F	46.00	.	.	11	01/10/78
91212904	291214081292801	425	85	.	YORK&SONS	IRRIGATION	F	40.00	.	.	.	.
91212905	291216081293001	.	.	.	MONTGOMERY	IRRIGATION	F	37.00	.	.	.	.
91212906	291208081292501	520	.	.	SMITH	IRRIGATION	F	43.00	.	.	12	02/10/79
91212907	291208081291901	.	79	6	SMITH	IRRIGATION	F	41.00	.	.	.	.
91212908	291214081290101	.	.	.	PETERSON	IRRIGATION	F	40.00	.	.	.	.
91213103	291258081313701	90	80	4	EZEL	DOMESTIC		7.91	0.51	01/18/78	29	04/12/82
91213104	291258081313702	8	6	2	USGS	UNUSED		8.00	3.60	01/31/79	27	04/12/82
91311501	291344081155701	151	74	6	UNION CAMP	UNUSED		32.90	5.20	04/17/78	30	01/18/55
91311502	291330081150901	93	.	4	U S GEOL S	UNUSED		36.00	.	.	28	02/02/55
91311601	291353081160401	20	20	4	USGS	UNUSED		34.10	3.45	04/13/78	200	02/23/82
91311902	291340081192501	121	113	2	M B BAILEY	DOMESTIC		43.00	.	.	10	08/05/65
91311903	291332081191001	128	.	2	PAULK	DOMESTIC		41.00	11.36	05/14/77	20	04/12/56
91311904	291323081192803	94	.	2	CLIFTON	UNUSED		45.00	18.30	05/07/76	.	.
91311905	291357081192701	440	125	6	CLIFTON	IRRIGATION	F	47.00	.	.	.	.
91311906	291355081192601	144	.	4	CLIFTON	IRRIGATION	F	47.00	.	.	.	.
91311907	291340081192801	130	100	4	BAILEY	IRRIGATION	F	47.00	.	.	.	.
91311908	291339081192901	130	103	6	M B BAILEY	IRRIGATION	F	.	16.00	08/05/65	10	02/14/66
91312401	291309081241101	175	90	4	BENNINGTON	DOMESTIC		37.00	9.67	01/13/78	.	.
91312501	291343081254601	412	108	6	JONES	IRRIGATION		51.88	18.64	12/12/77	.	.
91312502	291354081254101	323	109	8	GAY	IRRIGATION	F	53.00	28.00	01/01/77	.	.
91312503	291343081254001	.	90	.	WIGGINS	IRRIGATION	F	48.00	15.98	11/01/78	.	.
91312504	291345081254501	175	90	6	WIGGINS	IRRIGATION	F	54.00	.	.	.	.
91312505	291353081254801	.	.	6	J.TAYLOR	IRRIGATION	F	55.00	21.86	11/01/78	.	.
91312506	291357081255301	.	.	.	J.TAYLOR	IRRIGATION	F	59.00	.	.	.	.
91312507	291338081254901	500	.	8	JONES	IRRIGATION	F	46.00	.	.	10	01/10/78
91312508	291343081254602	8	6	2	USGS	UNUSED		52.00	5.35	01/23/79	.	.
91312601	291317081265901	210	80	6	J.WARD	IRRIGATION	F	42.00	.	.	.	.
91312602	291319081265601	260	80	8	J.WARD	IRRIGATION	F	42.00	.	.	.	.
91312701	291315081270301	103	80	2	MCLAUGHLIN	UNUSED		47.27	26.70	01/10/78	.	.
91312702	291335081272001	465	115	8	HAGSTROM	IRRIGATION	F	57.00	30.00	01/01/76	7	01/02/80
91312703	291307081270401	.	.	8	RICHARDSON	IRRIGATION	F	44.00	.	.	.	.
91312704	291304081270201	280	120	6	RICHARDSON	IRRIGATION	F	40.00	.	.	.	.
91312705	291359081272501	.	.	.	HAGSTROM	IRRIGATION	F	60.00	.	.	.	.
91312706	291343081271501	411	119	8	HAGSTROM	IRRIGATION	F	59.00	.	.	.	.
91312707	291323081273601	300	.	6	SOMERFORD	IRRIGATION	F	57.00	23.65	11/28/79	.	.
91312801	291324081283601	120	80	4	JAMES	UNUSED		52.00	22.86	12/28/77	.	.
91312802	291321081284701	270	92	8	HARPER	IRRIGATION	F	47.00	.	.	.	.
91312803	291329081283601	170	102	4	T.SWAFFORD	IRRIGATION		52.00	15.09	07/21/78	.	.
91312804	291334081283301	203	102	4	J.W.WARD	IRRIGATION		52.00	19.14	07/21/78	.	.
91312805	291317081283901	.	.	4	TAYLOR	IRRIGATION	F	50.00	.	.	.	.
91312806	291333081283301	.	.	.	J.WARD	IRRIGATION	F	49.00	.	.	.	.
91312807	291347081284701	100	87	3	CLINE	DOMESTIC		41.31	11.97	08/31/78	.	.
91312808	291318081285501	222	105	6	SMITH	IRRIGATION	F	41.00	12.30	12/12/78	.	.
91312809	291326081282401	200	120	6	WHIDDEN	IRRIGATION	F	48.00	15.00	.	.	.
91312810	291310081283601	280	.	6	SOMERFORD	IRRIGATION	F	49.00	.	.	.	.
91312811	291336081283101	300	120	6	NORTH	IRRIGATION	F	46.00	.	.	.	.

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN- TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91312812	291318081285801	.	.	6	SMITH	IRRIGATION	F	42.00	.	.	.	.
91312813	291336081284101	300	100	4	NORTH	IRRIGATION	F	51.00	.	.	.	.
91312814	291308081283401	.	.	4	BARNHART	IRRIGATION	F	48.00	.	.	.	.
91312815	291327081284501	350	114	8	HANSEN	IRRIGATION	F	50.00	20.00	.	.	.
91312816	291305081284101	425	78	8	PETERSON	IRRIGATION	F	45.00	23.00	.	.	.
91312817	291329081283501	.	.	6	HUTCHINSON	IRRIGATION	F	51.00	.	.	.	.
91312901	291347081295801	120	.	2	PIKE	DOMESTIC		21.00	7.25	12/28/77	8	12/18/78
91312902	291347081291501	100	84	2	SMITH	IRRIGATION		35.00	8.00	01/01/76	10	01/10/78
91312903	291319081291901	.	.	4	YORK&SONS	IRRIGATION	F	35.00	.	.	.	.
91313001	291347081300501	112	83	2	SORENSON	DOMESTIC		21.00	5.05	09/28/78	.	.
91411901	291423081193501	400	86	8	JONES	IRRIGATION	F	40.00	15.31	08/11/78	.	.
91412201	291426081222501	.	.	6	UNDERHILL	UNUSED		40.00	.	.	.	.
91412202	291442081222901	.	.	6	UNDERHILL	UNUSED		46.00	.	.	.	.
91412203	291451081223201	520	140	8	UNDERHILL	IRRIGATION	F	37.00	13.40	11/27/78	.	.
91412204	291441081223301	340	120	8	UNDERHILL	IRRIGATION	F	42.00	17.58	11/27/78	.	.
91412205	291426081224001	700	.	10	UNDERHILL	IRRIGATION	F	33.00	4.00	01/01/64	10	12/15/78
91412206	291426081224101	.	.	4	UNDERHILL	UNUSED		33.00	.	.	.	.
91412501	291439081253901	550	94	8	HAGSTROM	IRRIGATION	F	62.00	.	.	.	.
91412502	291409081255501	450	110	8	BRADDOCK	IRRIGATION	F	62.00	.	.	14	01/10/78
91412503	291408081255101	396	110	.	BRADDOCK	IRRIGATION	F	62.00	.	.	.	.
91412504	291441081255401	355	130	.	JONES	IRRIGATION	F	64.00	39.00	.	.	.
91412505	291422081254701	789	.	8	TAYLOR	IRRIGATION	F	62.00	.	.	13	02/10/79
91412506	291428081255401	584	.	.	HAGSTROM	IRRIGATION	F	64.00	.	.	.	.
91412507	291428081254601	500	.	.	HAGSTROM	IRRIGATION	F	64.00	.	.	.	.
91412508	291421081254101	555	.	8	HAGSTROM	IRRIGATION	F	62.00	.	.	.	.
91412509	291435081255301	739	.	8	JONES	IRRIGATION	F	65.00	.	.	9	12/14/78
91412510	291435081254801	350	.	6	JONES	IRRIGATION	F	69.00	.	.	.	.
91412511	291411081255901	.	.	4	BRADDOCK	UNUSED		62.00	.	.	.	.
91412602	291439081265301	85	85	2	MR JEAN RO	DOMESTIC		52.53	17.78	12/20/73	.	.
91412603	291448081261301	488	160	8	HAGSTROM	IRRIGATION	F	55.00	31.30	08/28/78	11	01/10/78
91412604	291450081263001	306	133	6	TAYLOR	IRRIGATION	F	70.00	.	.	10	01/10/78
91412605	291443081262401	450	168	8	TAYLOR	IRRIGATION	F	60.00	28.00	05/01/72	.	.
91412606	291457081265601	.	.	.	TAYLOR	IRRIGATION	F	61.00	26.84	11/02/78	.	.
91412607	291446081264201	240	120	6	PITTMAN	IRRIGATION	F	56.00	25.00	01/01/68	.	.
91412608	291402081260001	450	.	6	BURNSED	IRRIGATION	F	55.00	.	.	.	.
91412609	291432081262201	400	159	8	HAGSTROM	IRRIGATION	F	57.00	.	.	14	01/02/80
91412610	291452081261701	675	.	8	JONES	IRRIGATION	F	65.00	.	.	8	12/20/78
91412611	291431081263101	125	85	4	SJWMD	UNUSED		58.85	24.35	12/12/78	18	12/11/78
91412612	291404081261901	185	80	4	B.SMITH	DOMESTIC		44.00	12.77	11/16/78		
91412613	291446081261001	438	.	8	HAGSTRAM	UNUSED		54.94	22.54	12/08/78	.	.
91412614	291421081263201	500	100	8	TURNER	IRRIGATION	F	50.00	19.30	12/06/78	.	.
91412615	291443081263401	.	.	6	SOWELL	IRRIGATION	F	60.00	25.35	11/27/78	.	.
91412616	291453081265401	11	9	2	USGS	UNUSED		59.00	8.69	04/08/80	.	.
91412617	291453081265402	22	19	2	USGS	UNUSED		59.00	8.94	04/08/80	.	.
91412618	291453081265403	.	16	2	JOHNSON	IRRIGATION	F	59.00	.	.	30	03/03/82
91412702	291437081271901	134	.	2	CHAS B LUC	DOMESTIC		74.00	36.32	04/09/70	.	.
91412703	291437081274901	148	112	3	PIERSON	UNUSED		74.65	69.16	01/10/78	.	.
91412704	291457081270901	145	130	4	USGS	UNUSED		65.19	28.38	09/07/78	.	.
91412705	291407081275101	214	84	4	HARTLEY	IRRIGATION	F	75.00	44.00	01/01/76	.	.
91412706	291418081273401	198	110	4	RICHARDSON	UNUSED		77.32	46.40	08/08/78	.	.
91412707	291452081270501	.	.	.	JONES	IRRIGATION	F	65.00	.	.	14	01/11/78
91412708	291441081271001	311	.	6	RICHARDSON	IRRIGATION	F	70.00	.	.	.	.
91412709	291430081272701	268	110	6	BRADDOCK	IRRIGATION	F	65.00	.	.	.	.

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN-TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91412710	291436081272701	.	.	.	BRADDOCK	IRRIGATION	F	75.00	.	.	.	.
91412711	291434081270601	240	.	.	GREENLAND	IRRIGATION	F	66.00	.	.	.	.
91412712	291430081270001	240	.	6	A.PETERSON	IRRIGATION	F	65.00	.	.	.	.
91412713	291431081272001	250	116	4	TAYLOR	IRRIGATION	F	76.00	45.00	04/01/63	13	02/10/79
91412714	291440081272801	72	.	2	SMITH	UNUSED		72.33	42.67	11/13/78	.	.
91412715	291433081271501	479	118	10	HANSEN	IRRIGATION		70.33	37.40	02/06/79	.	.
91412716	291400081274801	.	.	4	C.BENNETT	PUBLIC		69.00	35.65	12/07/78	.	.
91412717	291446081272401	.	.	6	FLOWERS	IRRIGATION	F	70.00	.	.	.	.
91412718	291453081272201	310	125	6	ADAMS	IRRIGATION	F	68.00	.	.	.	.
91412719	291449081271101	.	.	6	JONES	IRRIGATION		69.00	.	.	.	.
91412720	291445081271001	.	.	6	JONES	IRRIGATION		70.00	.	.	.	.
91412721	291451081271701	.	.	6	ADAMS	IRRIGATION	F	68.00	.	.	.	.
91412722	291445081271801	452	.	6	CADE	IRRIGATION	F	72.00	.	.	.	.
91412723	291441081271501	456	.	8	CADE	IRRIGATION	F	72.00	.	.	.	.
91412724	291433081273101	260	.	6	ZIEBARTH	IRRIGATION	F	77.00	50.00	.	.	.
91412725	291426081274301	428	.	8	PETERSON	IRRIGATION	F	78.00	46.80	11/28/79	.	.
91412726	291425081273701	.	.	6	FISHER	IRRIGATION	F	78.00	.	.	.	.
91412727	291457081270902	10	10	2	USGS	UNUSED		65.00	1.60	01/29/79	.	.
91412728	291425081275601	357	133	8	SMITH	IRRIGATION	F	77.00	.	.	.	.
91412729	291437081274902	8	4	2	USGS	UNUSED		75.00	2.57	09/11/78	.	.
91412730	291427081273401	9	7	2	USGS	UNUSED		78.00	4.57	04/08/80	.	.
91412731	291427081273402	24	16	2	USGS	UNUSED		78.00	4.59	04/08/80	.	.
91412732	291427081273403	.	13	2	ZIEBARTH	IRRIGATION		78.00	.	.	26	04/12/82
91412801	291433081284101	128	83	8	J.TAYLOR	IRRIGATION		51.50	24.32	12/05/77	.	.
91412802	291433081285201	249	102	8	TAYLOR	IRRIGATION	F	52.00	24.45	07/20/78	.	.
91412803	291426081281201	.	138	6	TAYLOR	IRRIGATION	F	74.00	.	.	.	.
91412804	291440081282801	.	.	.	TAYLOR	IRRIGATION	F	53.00	25.60	11/13/78	18	02/10/79
91412805	291424081281201	260	100	6	TALTON	IRRIGATION	F	71.00	.	.	.	.
91412806	291439081281701	260	.	.	GREENLAND	IRRIGATION	F	63.00	.	.	.	.
91412807	291442081282301	320	.	.	GREENLAND	IRRIGATION	F	58.00	.	.	10	01/11/78
91412808	291434081281301	.	.	4	GREENLAND	IRRIGATION		67.00	.	.	.	.
91412809	291442081282401	.	.	4	GREENLAND	UNUSED		58.00	28.46	12/12/78	.	.
91412810	291438081285601	.	.	6	TURNER	IRRIGATION		55.00	.	.	.	.
91412811	291406081280401	351	80	6	GRIFFIN	IRRIGATION	F	70.00	.	.	.	.
91412812	291404081280401	.	.	4	RICHARDSON	IRRIGATION	F	68.00	.	.	.	.
91412813	291413081284601	.	90	4	HALLMAN	IRRIGATION		47.00	16.00	.	.	.
91412814	291419081284901	130	80	3	HALLMAN	IRRIGATION		49.00	.	.	.	.
91412815	291433081283301	.	.	6	JONES	IRRIGATION	F	57.00	.	.	.	.
91412816	291442081284501	.	.	6	JONES	IRRIGATION	F	55.00	.	.	.	.
91412817	291453081285401	394	105	10	JONES	IRRIGATION	F	56.00	45.00	06/01/78	.	.
91412818	291433081284102	367	246	4	SJRWMD	UNUSED		52.90	28.77	09/10/80	.	.
91412819	291433081284103	9	7	2	USGS	UNUSED		51.62	7.53	12/20/78	.	.
91412820	291433081284104	.	.	4	SJRWMD	UNUSED		51.96	.	.	.	.
91412821	291428081285001	.	.	4	BARFIELD	IRRIGATION	F	52.00	.	.	.	.
91412822	291424081284901	.	.	4	CLARK	IRRIGATION	F	50.00	.	.	.	.
91412823	291448081285901	.	.	6	MAYRE	IRRIGATION	F	58.00	.	.	.	.
91412901	291458081294201	125	63	4	SJRWMD	UNUSED		21.23	2.20	12/07/78	8	12/20/78
91412902	291444081291201	565	127	8	POWELL	IRRIGATION	F	49.00	33.00	.	.	.
91412903	291454081291101	.	.	8	TAYLOR	IRRIGATION	F	58.00	.	.	.	.
91512401	291524081243501	135	108	2		UNUSED		39.93	16.45	12/28/77	.	.
91512501	291509081251201	352	122	8	TAYLOR	IRRIGATION	F	62.00	28.79	11/01/78	11	02/10/79
91512502	291537081255001	510	110	8	POWELL	IRRIGATION	F	43.00	.	.	12	02/10/79
91512503	291541081254601	385	100	.	POWELL	IRRIGATION	F	39.00	16.18	11/18/78	.	.

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN- TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91512601	291507081263101	.	.	8	JONES	IRRIGATION	F	58.00	25.96	09/19/75	.	.
91512602	291508081263001	400	150	8	JONES	IRRIGATION	F	58.00	26.25	.	20	04/24/79
91512603	291527081261701	.	.	4	R.BURNSED	DOMESTIC		50.00	29.14	01/18/78	.	.
91512604	291509081260401	220	96	4	D.SCUDDER	DOMESTIC		64.30	29.51	09/27/78	.	.
91512605	291518081263401	385	90	8	BENNETT	IRRIGATION	F	55.00	25.36	11/02/78	14	02/10/79
91512606	291523081263101	460	95	6	BENNETT	IRRIGATION	F	52.00	.	.	9	11/21/78
91512607	291513081263101	.	.	6	TAYLOR	IRRIGATION	F	55.00	.	.	.	.
91512608	291504081264801	225	135	8	L.JONES	IRRIGATION	F	60.00	.	.	16	02/10/79
91512609	291543081260201	.	.	4	TAYLOR	IRRIGATION	F	37.00	.	.	.	.
91512610	291506081263601	.	.	8	R.HARPER	IRRIGATION	F	66.00	.	.	.	.
91512611	291522081265201	644	100	8	WORTHINGTO	IRRIGATION	F	47.00	30.00	.	11	02/10/79
91512612	291535081260801	500	.	.	R.BURNSED	IRRIGATION	F	44.00	.	.	.	.
91512613	291519081262201	580	.	8	R.BURNSED	IRRIGATION	F	57.00	.	.	.	.
91512614	291528081262001	750	.	8	R.BURNSED	IRRIGATION	F	48.00	.	.	8	12/15/78
91512615	291525081261201	345	100	.	R.BURNSED	IRRIGATION	F	60.00	31.00	.	13	02/10/79
91512616	291504081265701	220	90	4	J.WARD	IRRIGATION	F	60.00	.	.	12	01/10/78
91512617	291503081265701	220	90	4	J.WARD	IRRIGATION	F	60.00	.	.	.	.
91512618	291503081263101	.	.	8	JONES	IRRIGATION	F	63.00	.	.	.	.
91512619	291525081260601	580	102	12	CARTER	IRRIGATION	F	60.00	.	.	8	01/02/80
91512620	291519081262501	.	.	8	BURNSED	IRRIGATION	F	56.00	.	.	.	.
91512621	291519081265401	425	140	8	PARKER	IRRIGATION	F	55.00	.	.	.	.
91512622	291526081265501	445	144	6	WHITE	IRRIGATION	F	43.00	.	.	.	.
91512623	291525081264601	.	.	8	FISHER	IRRIGATION	F	46.00	.	.	.	.
91512701	291511081270201	.	.	4	M.SANDERSO	DOMESTIC		57.00	78.20	12/28/77	.	.
91512702	291507081270501	555	166	8	L.JONES	IRRIGATION	F	58.00	30.00	.	.	.
91512703	291514081270601	417	.	6	L.BURNSED	IRRIGATION	F	53.00	.	.	.	.
91512704	291505081270001	387	85	8	H.BENNETT	IRRIGATION	F	59.00	.	.	.	.
91512705	291521081270301	220	.	6	GRUBBS	IRRIGATION	F	46.00	21.37	02/06/79	7	01/02/80
91512706	291504081271101	400	150	8	JONES	IRRIGATION		62.00	.	.	.	.
91512707	291502081270801	400	150	8	JONES	IRRIGATION	F	62.00	.	.	.	.
91512708	291511081271001	.	.	4	COUNCIL	IRRIGATION	F	55.00	.	.	.	.
91512801	291529081282001	192	.	4	W.THOMPKIN	DOMESTIC		55.00	48.20	12/28/77	.	.
91512802	291534081283901	.	.	4	HARPER	IRRIGATION	F	53.00	.	.	.	.
91512803	291535081284201	500	.	8	HARPER	IRRIGATION	F	53.00	.	.	.	.
91512804	291506081285701	424	120	8	BRADDOCK	IRRIGATION	F	66.00	45.26	11/09/78	.	.
91512805	291531081285101	.	105	.	A.PRICE	DOMESTIC		56.00	34.82	01/31/79	.	.
91512901	291506081290601	116	108	2	D.CARLYLE	UNUSED		66.00	50.37	12/01/77	.	.
91512902	291541081290101	406	105	8	CAL NORTH	IRRIGATION	F	40.00	21.09	08/04/78	.	.
91512903	291507081290601	408	120	8	BRADDOCK	IRRIGATION	F	65.00	45.64	11/09/78	12	02/10/79
91512904	291530081290101	408	.	4	BRADDOCK	IRRIGATION	F	55.00	.	.	.	.
91513001	291508081302801	180	97	4	SJRWMD	UNUSED		11.52	-1.20	01/23/79	11	12/18/79
91513201	291543081320601	116	.	.	UNION BAG	UNUSED		6.00	-0.55	09/19/75	3200	12/16/81
91612801	291626081283601	104	100	2		UNUSED		38.86	15.37	09/19/75	14	03/18/56
91612802	291607081284101	260	97	6	WILSON	IRRIGATION	F	42.00	15.91	08/03/78	.	.
91612803	291626081283602	9	7	2	USGS	UNUSED		39.00	8.58	02/06/79	.	.
91613002	291621081304901	.	.	2	KELLY	DOMESTIC		10.00	.	.	200	12/18/79
91712601	291738081265501	260	113	8	BOCK	IRRIGATION	F	50.00	34.00	06/01/76	26	02/10/79
91712602	291737081265501	.	.	4	BOCK	UNUSED		50.00	30.60	12/22/78	.	.
91712701	291735081271701	268	124	8	SMITH	IRRIGATION	F	47.00	25.00	11/01/76	.	.
91712702	291727081274801	.	.	8	J.WARD	IRRIGATION	F	46.00	.	.	18	06/19/79
91712703	291724081275701	476	105	8	SMITH	IRRIGATION	F	43.00	20.90	11/30/78	13	01/29/79
91712704	291725081275601	.	113	8	COHEN	IRRIGATION	F	47.00	25.00	11/30/78	.	.
91712705	291734081270401	300	.	4	BOCK	IRRIGATION	F	47.00	21.57	11/30/78	15	01/11/78

WELL INVENTORY--CONTINUED

LOCAL NUMBER	STATION NUMBER	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN)	OWNER	WATER USE	F INDICATES FREEZE PROTECTION USE	LAND SURFACE ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT (MO/DAY/YR)	CHLORIDE CONCEN-TRATION (MG/L)	DATE OF SAMPLING (MO/DAY/YR)
91712706	291728081274501	.	.	2		UNUSED		44.82	22.69	12/22/78	.	.
91712707	291737081273801	190	100	4	YELVINGTON	UNUSED		47.87	24.79	08/29/78	7	01/08/80
91712801	291715081281801	180	.	4	USCE	UNUSED		14.90	-9.50	08/08/50	11	01/08/80
91712803	291719081280001	560	105	6	SMITH	IRRIGATION	F	44.00	.	.	.	.
91712804	291726081281101	340	.	4	J.BELL	IRRIGATION		42.00	.	.	.	.
91712805	291739081280901	400	1	4	TUCKER'S M	INDUSTRIAL		39.11	15.22	08/29/78	.	.
91812701	291908081280901	132	.	2	LEVINE	UNUSED		44.48	20.65	05/28/56	.	.
91812702	291802081274101	475	90	8	F.CADE	IRRIGATION	F	46.00	21.95	11/29/78	14	01/29/79
91812703	291842081273401	.	.	.	PRICE	IRRIGATION		41.00	.	.	.	.
91812704	291840081272401	.	.	6	COWART	IRRIGATION	F	32.00	.	.	9	01/02/80
91812801	291907081281901	134	.	3	DOUTSOS	DOMESTIC		44.00	20.49	02/27/56	17	01/18/66
91812802	291801081285201	280	106	8	NOLAN	IRRIGATION		45.00	.	.	12	01/11/78
91812803	291838081280601	400	.	6	COLMAN	IRRIGATION	F	47.00	.	.	11	01/02/80
91812804	291834081281101	400	.	6	COLMAN	IRRIGATION	F	53.00	.	.	21	01/02/80
91812805	291823081280801	166	113	4	SJRWMD	UNUSED		49.42	26.62	09/27/79	.	.
91812806	291804081285001	380	92	12	NOLAN	IRRIGATION	F	51.00	.	.	.	.
91812902	291851081292301	.	83	6	MCCORMICK	IRRIGATION	F	51.00	22.62	11/29/78	.	.
91812903	291823081290901	.	.	6	M.MCBRIDE	DOMESTIC		48.00	22.85	09/27/78	.	.
91812904	291857081294501	.	.	5	MAYRES	IRRIGATION	F	52.00	.	.	.	.
91813001	291851081304101	285	118	8	COLMAN	IRRIGATION	F	35.00	.	.	15	01/29/79
91813002	291857081304101	526	130	.	PREVATT	IRRIGATION	F	41.00	.	.	.	.
91813201	291835081324201	155	.	.	U S C E	UNUSED		4.36	-1.30	05/05/76	505	09/06/79
91912501	291905081251001	138	.	6	U S C E	STOCK		23.30	2.52	08/08/78	16	12/26/79
91912701	291921081275901	180	.	4	SMITH	IRRIGATION	F	41.00	.	.	.	.
91912702	291920081275901	180	.	4	SMITH	IRRIGATION	F	42.00	.	.	.	.
91912703	291923081274901	350	145	8	F.CADE	IRRIGATION	F	38.00	.	.	.	.
91912704	291922081274901	.	145	.	F.CADE	IRRIGATION	F	38.00	.	.	16	01/29/79
91912801	291938081285701	280	100	8	MYLES	IRRIGATION	F	35.00	10.28	08/04/78	.	.
91912802	291929081284001	135	80	6	CADE	IRRIGATION	F	45.00	22.43	08/28/78	.	.
91912803	291926081282201	396	192	12	CADE	IRRIGATION	F	43.00	26.00	.	.	.
91912804	291952081285401	338	147	12	PREVATT	IRRIGATION	F	43.00	.	.	12	01/11/78
91912805	291908081281301	.	.	4	C.LEVINE	IRRIGATION		45.00	22.96	11/29/78	.	.
91912806	291917081280801	.	.	8	LEVINE	IRRIGATION	F	45.00	20.99	11/29/78	16	02/10/79
91912807	291917081280201	.	.	4	SMELT	IRRIGATION	F	44.00	.	.	.	.
91912808	291948081285501	173	101	6	PREVATT	INDUSTRIAL		43.00	16.92	06/18/79	.	.
91912901	291903081294601	.	.	.	WATERS	UNUSED		52.60	29.05	05/06/76	.	.
91912902	291952081294901	99	89	2		UNUSED		56.00	25.32	01/20/78	.	.
91912903	291951081295301	.	.	4	C.MEW	IRRIGATION		53.00	.	.	.	.
91912904	291945081290901	.	.	2		UNUSED		39.00	13.52	05/10/79	.	.
91913001	291955081304001	135	85	8	F P CADE	IRRIGATION		52.00	23.03	09/27/78	7	08/20/65
91913002	291904081301901	.	.	3	WATERS	IRRIGATION		53.02	27.22	01/18/78	.	.
91913101	291910081312401	155	135	8	J.MILLICAN	PUBLIC		26.00	3.27	08/29/78	16	01/29/79
92012801	292002081285501	358	90	12	PREVATT	IRRIGATION	F	46.00	19.30	11/29/78	14	02/10/79
92013001	292016081305401	320	83	12	MCBRIDE	IRRIGATION		53.00	23.74	01/20/78	.	.
92013202	292004081320101	.	.	6	STONE	STOCK		28.00	.	.	12	01/08/80
92112801	292105081281201	85	.	2		UNUSED		32.33	13.85	01/20/78	10	12/31/79
92112902	292128081295401	140	.	4	HERREN	DOMESTIC		55.04	23.62	01/20/78	.	.
92112903	292138081290901	.	.	8	CADE	IRRIGATION	F	50.00	.	.	12	01/02/80
92112904	292114081290601	135	90	8	CADE	IRRIGATION		50.00	24.16	11/29/78	.	.