HYDROLOGY OF THE FLORAL CITY POOL OF TSALA APOPKA LAKE, WEST-CENTRAL FLORIDA

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ABSTRACT

The chain of lakes known as Tsala Apopka Lake in west-central Florida has a surface area of approximately 19,000 acres. It is divided into three water-management pools: the Floral City Pool, the Inverness Pool, and the Hernando Pool, in downgradient order. The Floral City Pool has an extensive combination of lakes, wetlands, and connecting canals. Surface area of the pool is approximately 4,750 acres during years of average rainfall.

The main influence on changes in lake levels in the Floral City Pool is inflow from the Withlacoochee River through the Orange State and Leslie-Heifner Canals. Inflow is controlled through structures in the canals operated by the Southwest Florida Water Management District. Water flows from south to north through the Floral City Pool and exits through the Golf Course Canal control structure and the uncontrolled Moccasin Slough area.

Desired water-level fluctuation in the Floral City Pool is 2.0 feet, from 40.25 to 42.25 feet elevation, but lake levels stay below 40.25 feet elevation approximately 40 percent of the time. The Withlacoochee River, which supplies inflow to the lake, remains below 40.31 feet approximately 40 percent of the time. Virtually all inflow ceases when the river level drops below an elevation of 38.0 feet.

Less-than-normal rainfall occurred in 1984 and early 1985, resulting in reduced inflow to the Floral City Pool. During the time of little or no surface-water inflow in May and June 1985, the lake level dropped approximately 0.04 foot per day and surface area of the lake reduced to approximately 700 acres.

Heavy rainfall in August and September 1985 brought lake levels back to desired management levels. Surface-water inflow exceeded evapotranspiration and outflow between June 10 and September 27, 1985. At the same time, the lake surface area increased from 700 acres to 4,750 acres. By the end of September 1985, the surface-water outflow was 338 cubic feet per second and the surface-water inflow was 340 cubic feet per second.

Variable backwater conditions are present approximately 50 percent of the time in the two canals supplying inflow from the Withlacoochee River. Water levels decline faster on the river than they do on the lake following periods of heavy rainfall. This creates a potential for reverse flow from the lake to the river. Water-control structures are usually closed during periods of potential reverse flow, but are opened when a positive fall exists between the river and the lake.

Surface-water and ground-water levels are closely related in the study area. The overburden and confining layers above the Floridan aquifer system are thin or absent in places. These places have a large potential for recharge and discharge between the surficial and Floridan aquifer systems.

INTRODUCTION

Tsala Apopka Lake is in east-central Citrus County and in west-central Florida (fig. 1). It is physiographically bordered by the Withlacoochee River to the east and the hilly Brooksville Ridge to the west. The lake is actually a series of lakes and marshes connected by natural and manmade channels. For water management purposes, the lake is divided into three topographic basins containing upland, wetlands, and lakes. The water bodies are designated as pools, with water levels in the pools controlled to enhance the use of surrounding residential property.

The Floral City basin (fig. 2 and plate 1) is in the southern part of the lake chain and is most upgradient. It consists of several upland areas used for residential and agricultural purposes, as well as Floral City Lake (the largest lake), Lake Hampton, Tussock Lake, and connecting wetland areas. This combination of water bodies is designated as the Floral City Pool. Inverness and Hernando basins, which are in downgradient order, contain connecting lakes and wetlands that are designated the Inverness and Hernando Pools.

The U.S. Geological Survey and the Southwest Florida Water Management District (SWFWMD) recognized a need to understand the hydrology of the Floral City Pool after a series of extended dry spells caused water levels to fall below 39 feet elevation. Water levels in the chain of pools in Tsala Apopka Lake are influenced by inflow from the Withlacoochee River; therefore, the interaction between the river, the Floral City Pool, and connecting canals is an important consideration of water-level management. Ground-water influence also is a factor in water-level management of the pools, but quantity of the interaction may not be a controlling factor except in periods of little or no inflow.

Historical Background

The Tsala Apopka Lake area was settled in the 1800's and had a considerable population increase in the late 1800's due to railroads, mining, and citrus. Before the railroads extended to Floral City, the transportation needs of local residents included access from Floral City to the river. This access was provided by the Orange State Canal. "The Canal" was dug by the Orange Canal and Transit Company in 1884 to carry goods and people by steamboat from the Floral City Pool to the Withlacoochee River and then to Lake Panasoffkee (Morris, 1986), where the railroad was used for further travel.

Before that time, inflow to the lake was mainly from the swampy areas through which the Orange State Canal was dug. It is unknown whether the natural water-surface gradient was changed by digging the canal, but the topographic map prepared by the U.S. Geological Survey from an 1893 survey indicates that the water-surface gradient at that time was approximately a 0.5-foot drop per mile from south to north. The water-level gradient of Tsala Apopka Lake is less than 0.3-foot drop per mile from south to north with current water-management practices.

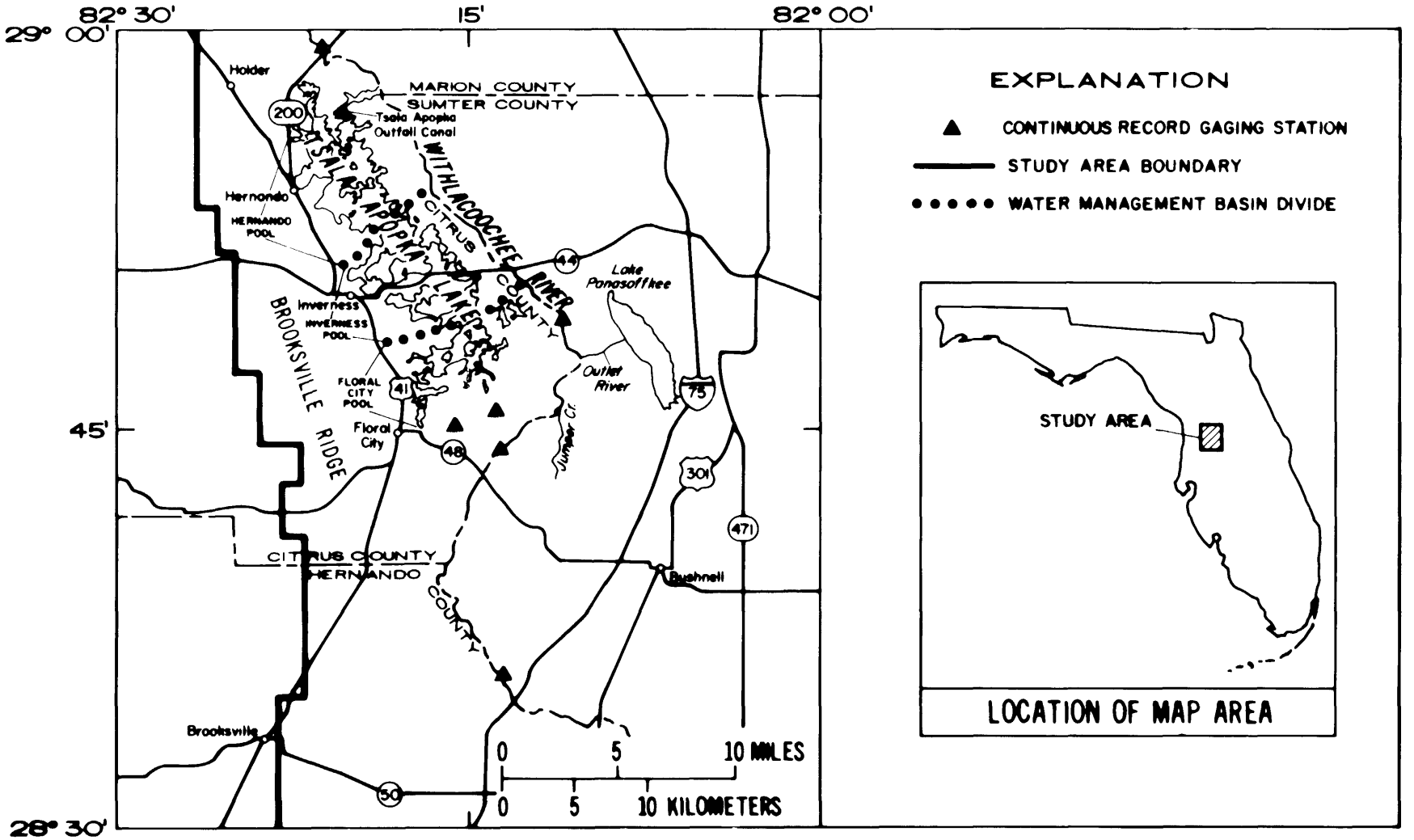

Figure 1.--Location of study area.

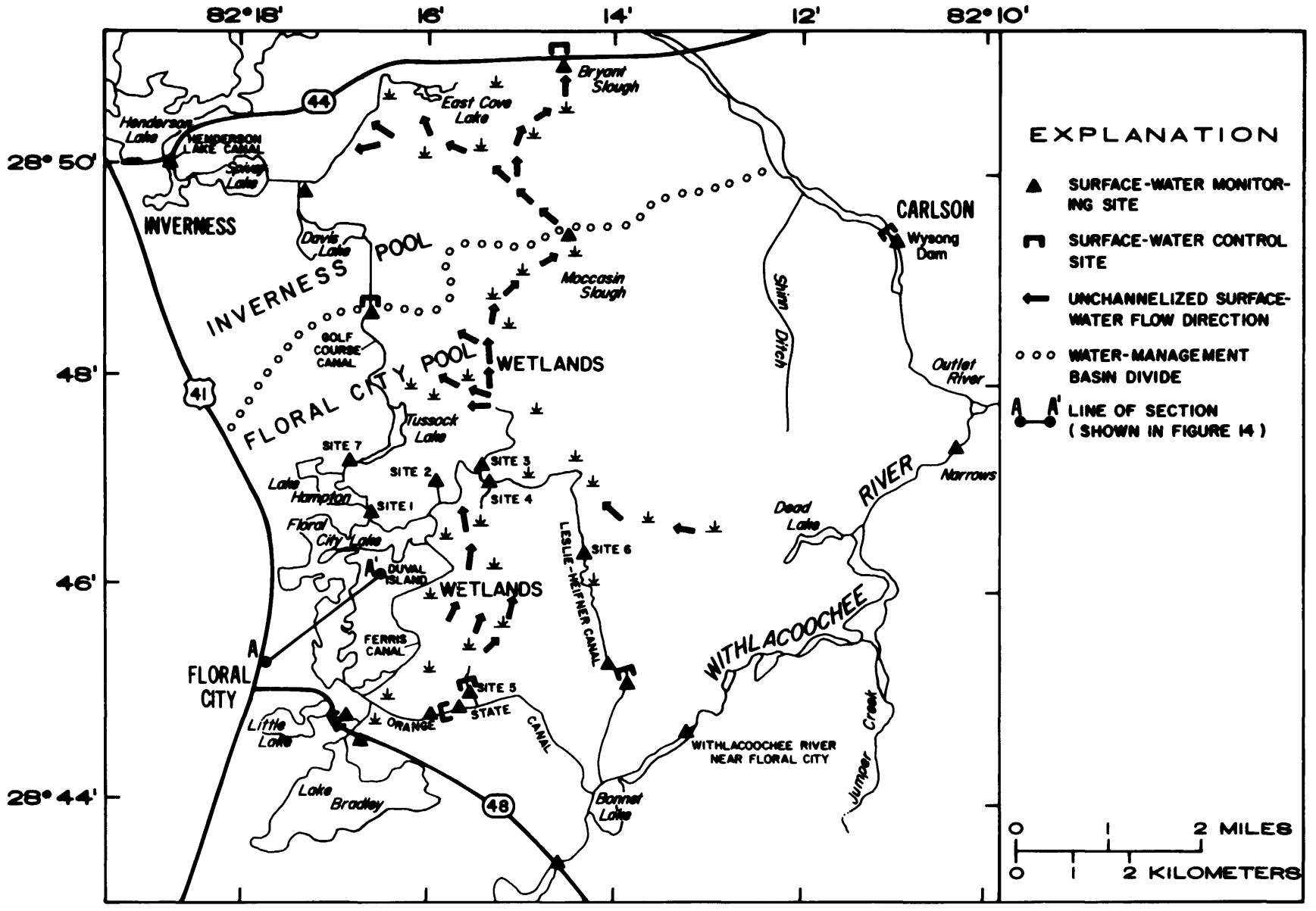

Figure 2.--Water-management system and data-collection sites near the Floral City Pool.

Residential development around the lake and recreational use rapidly increased in the 1950's, resulting in a public concern about lake levels and access. The lake was physically changed by dredging along the lake's edge for fill to improve lakefront property and by dredging canals through natural wetland areas for drainage and boat access (inferred from Morris (1986), and notes from the Tsala Apopka Water Control Authority).

Purpose and Scope

The purpose of this report is to describe the hydrologic conditions associated with the water-level fluctuations in the Floral City Pool and to explain the relations observed. The report also attempts to describe the entire flow system affecting the Floral City Pool by analyzing each streamflow site as well as defining ranges of water levels and streamflow. Additionally, the report attempts to present effects on water quality from water-level fluctuations.

Presented in the report are: hydrologic data collected during the investigation, analysis of inflow-outflow data for the Floral City Pool, comparison of these data to water-level fluctuations of the Floral City Pool, and a discussion of hydrologic conditions that most affect the water-level fluctuations. Also included are discussions of: the physical properties of the surface-water flow system, ground-water surface-water relations, and the comparison of the entire lake-river system as an integral whole unit or separate functioning subunits. Water-quality data are summarized in the report. Additionally, considerations for management of surface-water are presented.

Previous Studies

There have been at least two major investigations of Tsala Apopka Lake. Rutledge (1977) addressed the interrelations between the lake system and the Upper Floridan aquifer, along with a general reconnaissance of the entire lake. Attardi (1983) addressed water quality and aquatic vegetation of the lake, and outlined the water-level management practices that SWFWMD uses for the three pools.

Other studies concentrated on Citrus County or the Withlacoochee River basin. These studies did not consider the surface-water ground-water relations, but dealt mainly with the hydrogeology of the area. These studies include a geologic report of Citrus and Levy Counties by Vernon (1951), and hydrologic reports by Miller and others (1981), Ryder (1985), and Kimrey and Anderson (1987).

Acknowledgments

Appreciation is expressed to Jimmy Brooks, Craig Dye, and other staff of the Southwest Florida Water Management District. Special thanks are due to Patricia Dooris, formerly with SWFWMD, Jim Fenton of Ferris Groves, and the many residents in Floral City for information and access to the area.

GEOGRAPHY AND GEOLOGY

White (1970) shows Tsala Apopka Lake lying in the Tsala Apopka Plain, between the Brooksville Ridge to the west and the Withlacoochee River to the east. Land-surface elevation in the area ranges from 40 to 80 feet above sea level and there is less relief toward the Withlacoochee River. Thus, the lake-bottom surface also becomes flatter from open water in the main pool to the west side of the lake to the marshlands on the east side.

According to Vernon (1951), the geology of the Tsala Apopka Plain is closely tied to the Ocala Uplift, where the area was uplifted and eroded, leaving a thin veneer of unconsolidated deposits and locally exposing the limestone at the surface. The top of the limestone in the Floral City Pool area generally lies between 20 and 40 feet elevation, but has numerous depressions falling below an elevation of 20 feet due to sinkhole collapse. Vernon (1951) also describes a fault in the limestone in the Tsala Apopka area created by shearing of the limestone as it was uplifted. This fault, named the Inverness Fault, is partially located under the Floral City Pool area and is thought to be a contributing feature in the hydrology of the Floral City Pool by maintaining a higher potentiometric surface in the Upper Floridan aquifer to the east and limiting the recharge toward the west.

HYDROGEOLOGY

The limestone in the Tsala Apopka area is comprised of several extensive layers, each having different physical and water-bearing characteristics, that combine to form the Floridan aquifer system. The Upper Floridan aquifer is the most productive part of the Floridan aquifer system in the Tsala Apopka area, with transmissivities as great as 1,000,000 ft^2/d (Ryder, 1985, p. 20).

In the Inverness basin, there is a slight difference in water levels between the surficial aquifer system and the Floridan aquifer system, indicating separation of the two aquifer systems (Rutledge, 1977). However, in parts of the Floral City basin, water levels are the same in both aquifers due to the thin or missing confining layers. The area that includes the Floral City Pool and wetlands east to the Withlacoochee River is an area of moderate recharge to the Upper Floridan aquifer (Anderson and Laughlin, 1982).

WATER USE

Uses of the Upper Floridan aquifer in the area include agricultural, industrial, and public-water supply. Nearly all domestic wells in the Tsala Apopka area tap the Upper Floridan aquifer because of high yields and good water quality.

PHYSICAL PROPERTIES OF THE FLORAL CITY POOL

The physical layout of the canals and structures associated with the Floral City Pool of Tsala Apopka Lake is shown in figure 2 and plate 1 (in pocket). Structures regulating inflow to the Floral City Pool are located on the Orange State and Leslie-Heifner Canals and a small overflow canal extending north from the Orange State Canal. The structure regulating direct outflow from the Floral City Pool is located on the Golf Course Canal. A structure on Bryant Slough in the Inverness basin controls part of the flow from Moccasin Slough to the Withlacoochee River. Two other surface-water control structures regulate flow from the Orange State Canal to Little Lake and Lake Bradley at Floral City.

The drainage area for the Floral City Pool is indeterminate because much flow comes from the Withlacoochee River, whose headwaters include the Green Swamp. Approximately 995 mi^2 of drainage area contribute flow at the Withlacoochee River gaging station near Floral City, located about 1 mile downstream of the entrance to Orange State and Leslie-Heifner Canals at Bonnet Lake (fig. 2 and plate 1). Flow diverted through the canals is usually less than 10 percent of the total flow of the river. When the lake is not receiving water from the river, water in the area to the northeast of the main body of the Floral City Pool to the Moccasin Slough gaging site flows backwards toward the southwest and becomes part of the Floral City Pool's drainage area rather than that of the Inverness Pool.

Surface area of the Floral City Pool varies considerably with changes in water levels because of the flat land gradient surrounding the pool. When the lake level drops to 37.0 feet elevation, the surface area of the pool covers only 700 acres and mainly consists of Floral City Lake and Lake Hampton, leaving Tussock Lake isolated. The surface area of the Floral City Pool and connecting lakes and wetlands is approximately 4,750 acres when the lake water level is 41.0 feet elevation. Surface area of the Floral City Pool is delineated by several jeep trails that have been diked on the east side of the Leslie-Heifner Canal and the northeast part of the pool in Moccasin Slough. Further diking for an east-west jeep trail from the Leslie-Heifner Canal to the Withlacoochee River, and over a drainage canal called Shinn Ditch, have separated the east area of the Floral City Pool into small sections. The additional surface area is actually a group of separate areas, connected only when overflow levels at different control points are reached. When water levels on the Withlacoochee River and the Floral City Pool increase to more than 44.0 feet elevation, the surface area is greatly expanded to the area east of the Leslie-Heifner Canal and extends into the flood plain of the Withlacoochee River. Under this condition, the surface area of the pool may exceed 9,100 acres; however, this acreage was not used in calculations for this report.

Figure 3 shows pool depths in the Floral City Lake when water levels are 40.25 feet elevation, the minimum desired level for the pool set by SWFWMD. Features too small to show on the map included depressions 2 to 3 feet deeper around the edge of the lake and in some coves that were probably caused by dredging. The 5-foot contour line shown in figure 3 was the approximate shoreline in 1962 and 1981, years of little rainfall. Local residents report that sinkholes have formed in the lake bottom during extended dry spells, but depth soundings did not show any depressions deeper than 14 feet. These may be sinkholes that have filled in or dredge holes.

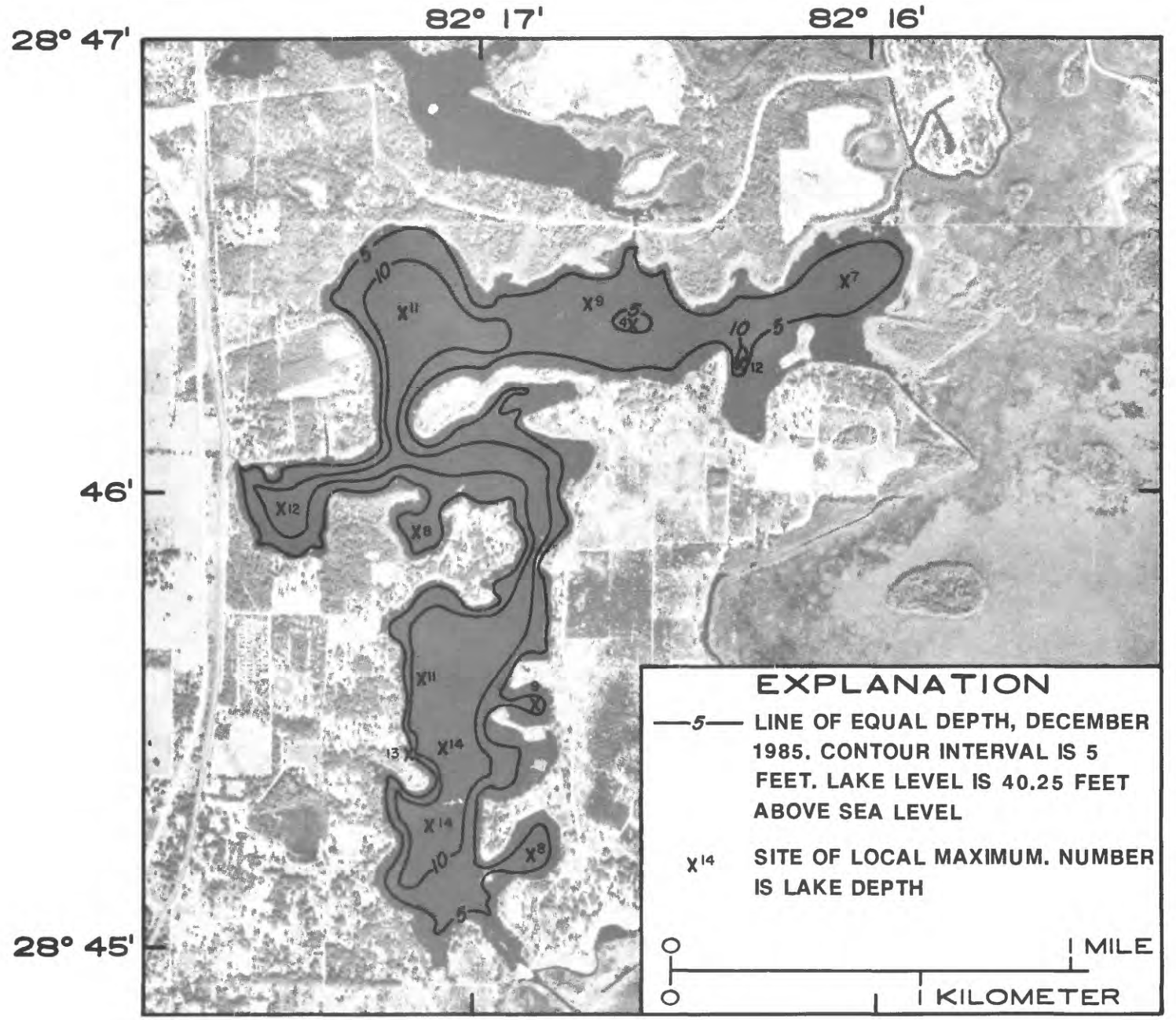

Figure 3.--Depth contours of Floral City Lake, December 1985.

HYDROLOGIC CONDITIONS

Rainfall and Evaporation

The average rainfall (1950-80) was 54.68 in/yr at Inverness and 51.41 in/yr at Bushnell (National Oceanic and Atmospheric Administration, 1986). The rainfall total at Inverness from July 1984 through June 1985 was 40.61, a deficit of 14.07 inches for the year. The Tsala Apopka chain is not dependent solely on rainfall in the area, but also receives inflow from the Withlacoochee River. With extremely heavy rains in the Green Swamp area (Withlacoochee River headwaters), the pools in the lake could rise without having any rain in the immediate vicinity.

Evaporation is variable throughout the year, depending mainly on temperature, wind speed, and humidity, but is highest in extremely hot, dry weather. Free-water surface evaporation averages approximately 48 in/yr for central Florida (Farnsworth and others, 1982) with May being one of the highest evaporation months. In May 1985, when inflow to and outflow from the Floral City Pool were minimal, the lake level dropped an average of 0.04 ft/d. This drop was caused by a combination of evapotranspiration and seepage out the bottom of the lake. Because of freezes the previous two winters, most of the groves adjacent tc the Floral City Pool had no trees to be irrigated. Effects from withdrawals from wells or the lake itself probably were minimal on decreasing lake levels during May 1985. The evaluation of evapotranspiration and seepage values for other times throughout the year are complicated by inflow from the river and adjoining wetlands and outflows through the Golf Course Canal and Moccasin Slough.

Surface Water

Water-Level Fluctuations

Floral City Pool.--Figure 4 shows hydrographs of the Floral City Pool and the Withlacoochee River near Floral City from 1957 to 1986. Notable differences in the long-term hydrograph include the dry spells of 1962, 1981, and 1985, and the flood of 1960. Although there are no recorded daily water levels for the pool or the Withlacoochee River near Floral City prior to 1957, water-level records of the Withlacoochee River at State Road 48 can be used to give approximate high levels. There were no water-level controls on the Orange State Canal until 1962, so prior to 1962, water levels of the Floral City Pool probably reflected those of the Withlacoochee River. Records show several high-water seasons, but none equals the 1934 flood when the river reached an estimated stage of 48.4 feet elevation at State Road 48 (U.S. Army Corps of Engineers, 1974).

Levels in the pool during dry years are more difficult to correlate with levels in the river, but years of low water can be detected by noting the length of time the river stayed below 39 feet elevation. In figure 4, the 1962, 1981-82, and 1985 extended dry spells are seen to occur when the level of the Withlacoochee River near Floral City remained below an elevation of 39 feet for several weeks. The Wysong Dam (fig. 2) was installed in 1965 and water levels in the reach between State Road 48 and Wysong Dam have been affected by dam manipulation since that time.

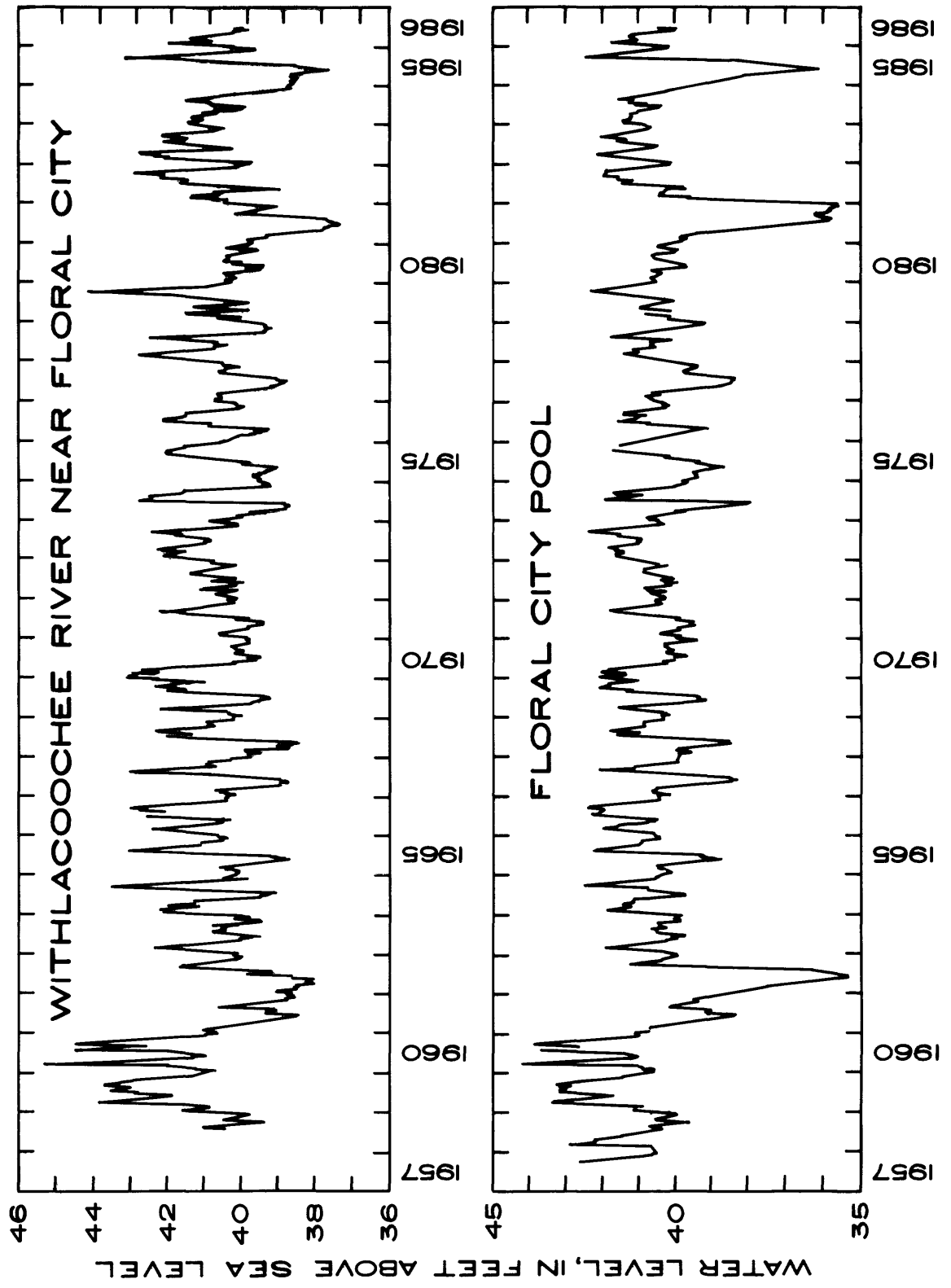

Figure 4.--Water levels of the Withlacoochee River near Floral City and the Floral City Pool, 1957-86.

An extended dry spell occurred in the basin from August 1984 through June 12, 1985, with very little inflow from the river until August 1985. Deficit rainfall amounts occurred in every month from August 1984 through May 1985, except November. Rainfall amounts totaled 19.98 inches at Inverness during this time, with a cumulative deficit of 19.41 inches by the end of May. The water level of the pool dropped during this period to about 36 feet elevation (fig. 5), within 0.8 foot of the minimum water level of 35.24 feet elevation which occurred in 1962 at the same location. Rainfall amounts totaled 39.8 inches from June through September 1985, increasing inflow to nearly record highs. After August 1985, there was enough inflow to the lake to keep the water levels within a range needed by SWFWMD for operational purposes. Lake levels rose 6.2 feet from June through September 1985.

Streams.--The hydrograph for the Withlacoochee River near Floral City from 1958 through 1986 is shown in figure 4. The maximum observed water level was 45.24 feet elevation on March 25, 1960, however, the 1934 flood marks indicated levels as high as 48.4 feet elevation at the State Road 48 bridge, about 2 miles upstream of the Floral City station. The minimum observed water level was 37.48 feet elevation on July 8, 1981, at the Floral City station; however, water levels could have been lower prior to establishment of the gaging station.

During the study period, July 1984 through June 1986, Orange State Canal and Leslie-Heifner Canal both hydraulically isolated the river from the lake for May and part of June 1985, with canal water levels dropping below the bottom of the recording gage. The Withlacoochee River dropped to 37.85 feet elevation at the Floral City gage on June 9, 1985 (fig. 5), within 0.37 foot of the 1981 minimum. Rapidly fluctuating water levels in both canals from September 1-3, 1985, are the result of manipulation of the lift gates in the structures.

Streamflow

Discharge hydrographs of the Withlacoochee River, Orange State Canal, and Leslie-Heifner Canal are shown in figures 6 and 7. Previously, daily streamflow data had been computed but not published for the Withlacoochee River near Floral City because of the variety of influences on the river flow. The discharge in the river near Floral City is affected by the Wysong Dam about 7 miles downstream, reverse slope effects from upstream during low flow (reverse flow can occur), and unknown amounts of diversions through Orange State and Leslie-Heifner Canals during high water. By increasing data-collection sites and number of streamflow measurements, more accurate data was possible.

For purposes of this investigation, daily flow data on Orange State Canal were estimated using stage data and several streamflow measurements. Flow in Leslie-Heifner Canal was not estimated because of problems in measuring the quantity and direction of low flow. When the lake has a higher water level than the river, there is reverse flow in the canals if the structures are not closed. During the 1985 water year (October 1, 1984, through September 30, 1985), these conditions occurred, but the structures were closed after October 7, 1984, stopping flow back toward the river. Between October 7, 1984, and the latter part of June 1985, there was little or no flow in the canals.

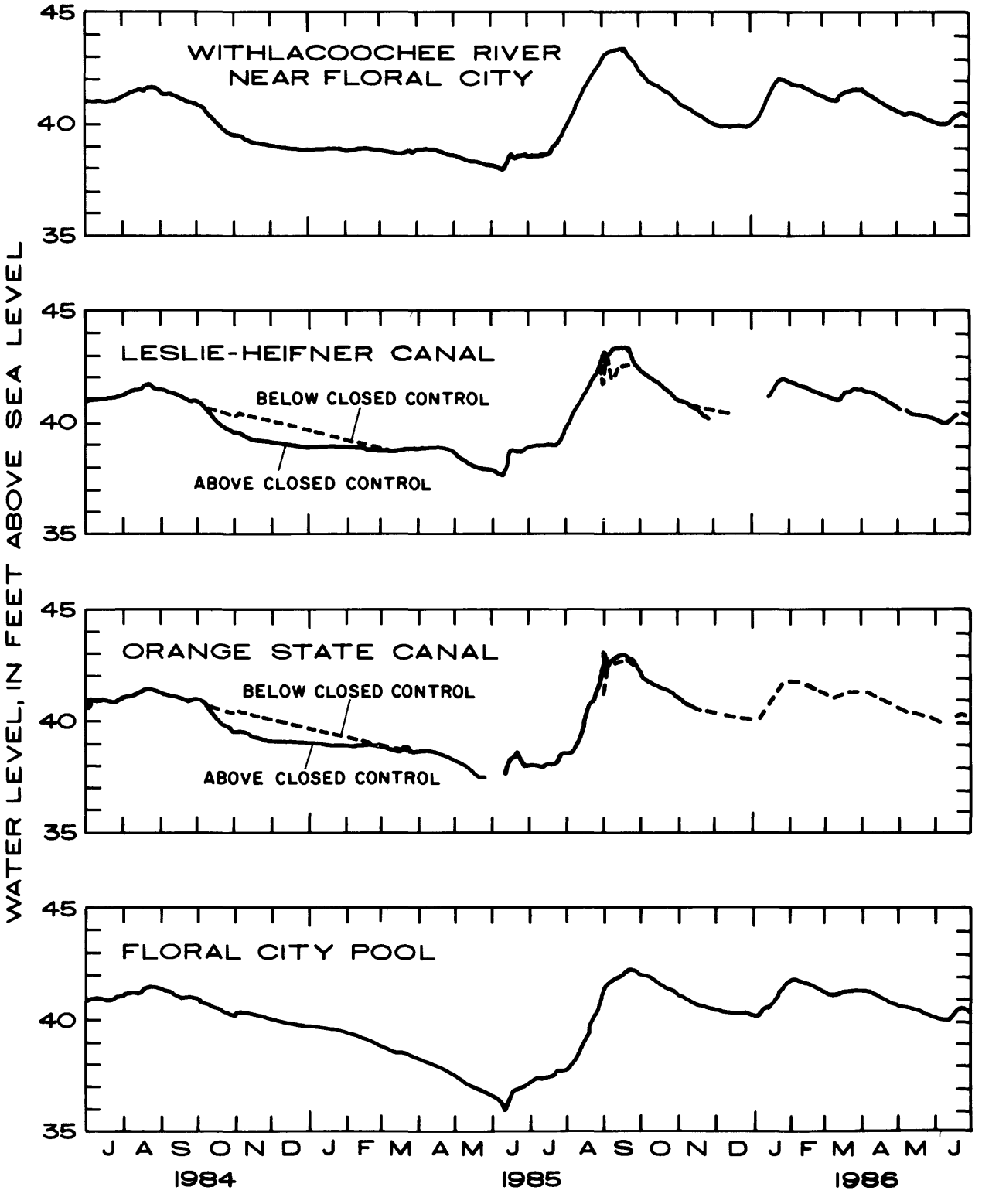

Figure 5.--Water levels of the Withlacoochee River near Floral City, the Leslie-Heifner Canal, the Orange State Canal, and the Floral City Pool, July 1984 through June 1986.

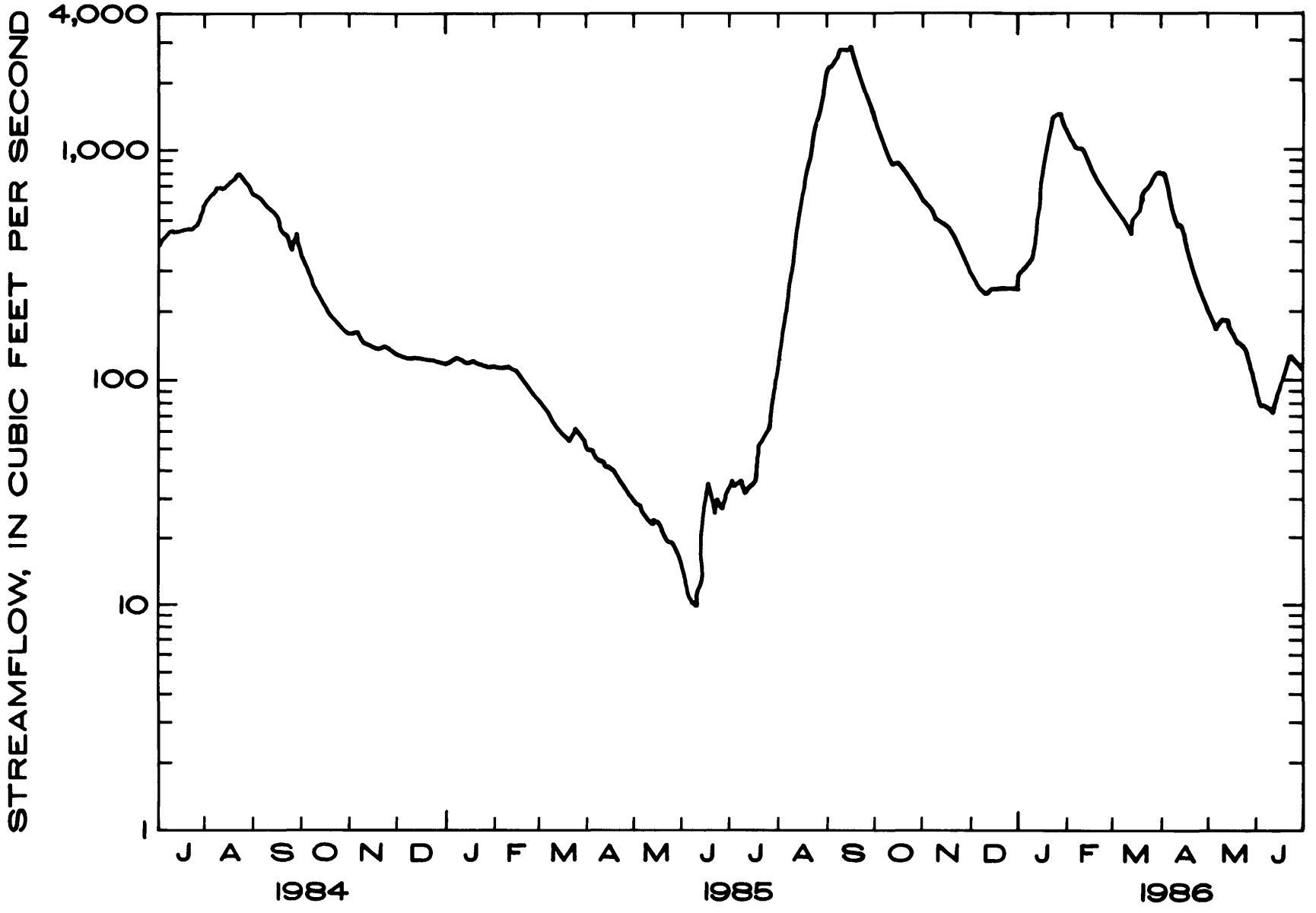

Figure 6.--Streamflow in the Withlacoochee River near Floral City, July 1984 through June 1986.

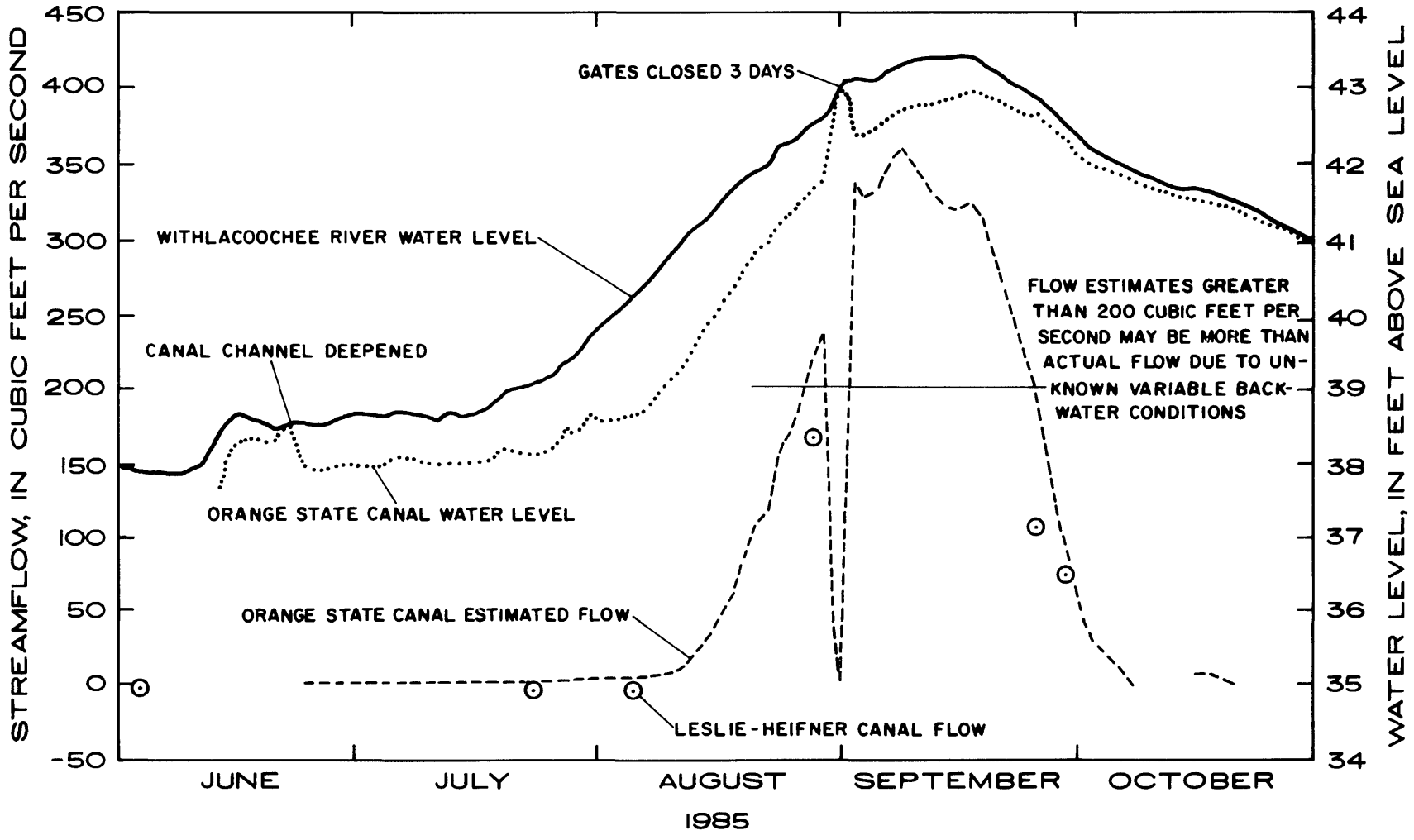

Figure 7.--Streamflow in Orange State and Leslie-Heifner Canals, with comparison to water levels of the Orange State Canal and the Withlacoochee River near Floral City.

Figure 7 shows the effects of gate closure in the Orange State Canal during periods of high flow. Water-level data for Leslie-Heifner Canal were not plotted because the water levels are very similar to the Orange State Canal.

Flow in Leslie-Heifner Canal is less than in Orange State Canal most of the time, a result of a generally higher bed elevation in Leslie-Heifner Canal creating backwater. However, extreme high water levels on the Withlacoochee River have resulted in higher flows at the structure in Leslie-Heifner Canal than Orange State Canal due to the shorter distance of the control from the river and differences in conveyance properties of the two canals. In September 1985, the gate at the Leslie-Heifner Canal structure was closed to a partial gate opening, thus reducing the flow through the canal.

Variable backwater conditions in the Orange State Canal, rapidly changing canal water levels, and constriction at the structure may result in flows as much as 25 percent less than the estimated values when streamflows rise above 200 ft^3/s.

Ground Water

Upper Floridan Aquifer

The configuration of the potentiometric surface of the Upper Floridan aquifer for May and September 1985 are shown in figures 8 and 9. The potentiometric surface is highest in the southeast and declines toward the west, with a depression that occurs along the river near State Road 44. Fluctuations of the potentiometric surface between the wet and dry seasons vary no more than 5 feet during most years. By drawing flow lines perpendicular to the contours, it is evident that the direction of flow is from the southeast and toward the northwest and the downstream part of the Withlacoochee River, following surface-water flow lines in the eastern half of the study area. Surface-water and ground-water systems probably act as one unconfined system in the eastern half of the basin, as indicated by water levels that are similar and few or no confining layers between the two aquifers.

The water-level data seem to confirm that the Inverness Fault described by Vernon (1951) is present near the Floral City Pool. The potentiometric surface is high to the east of Floral City but then drops quickly to the west. The change in flow lines, as indicated by the potentiometric surface in the western half of the study area, probably is caused by changes in permeabilities or changes in the thickness of the confining beds.

Water levels in the well at Floral City from 1977-86 are shown in figure 10. This well is affected by pumping, but the generalized variations of the record are evident. For comparison purposes, a continuous water-level hydrograph was recorded for a well on Duval Island, which is between two of the main bodies of the Floral City Pool. The water levels in the Duval Island well (fig. 11) are closer to the pool levels than the well at Floral City and indicate higher Upper Floridan aquifer water levels in the pool area than have been previously indicated (Schiner and Hayes, 1984).

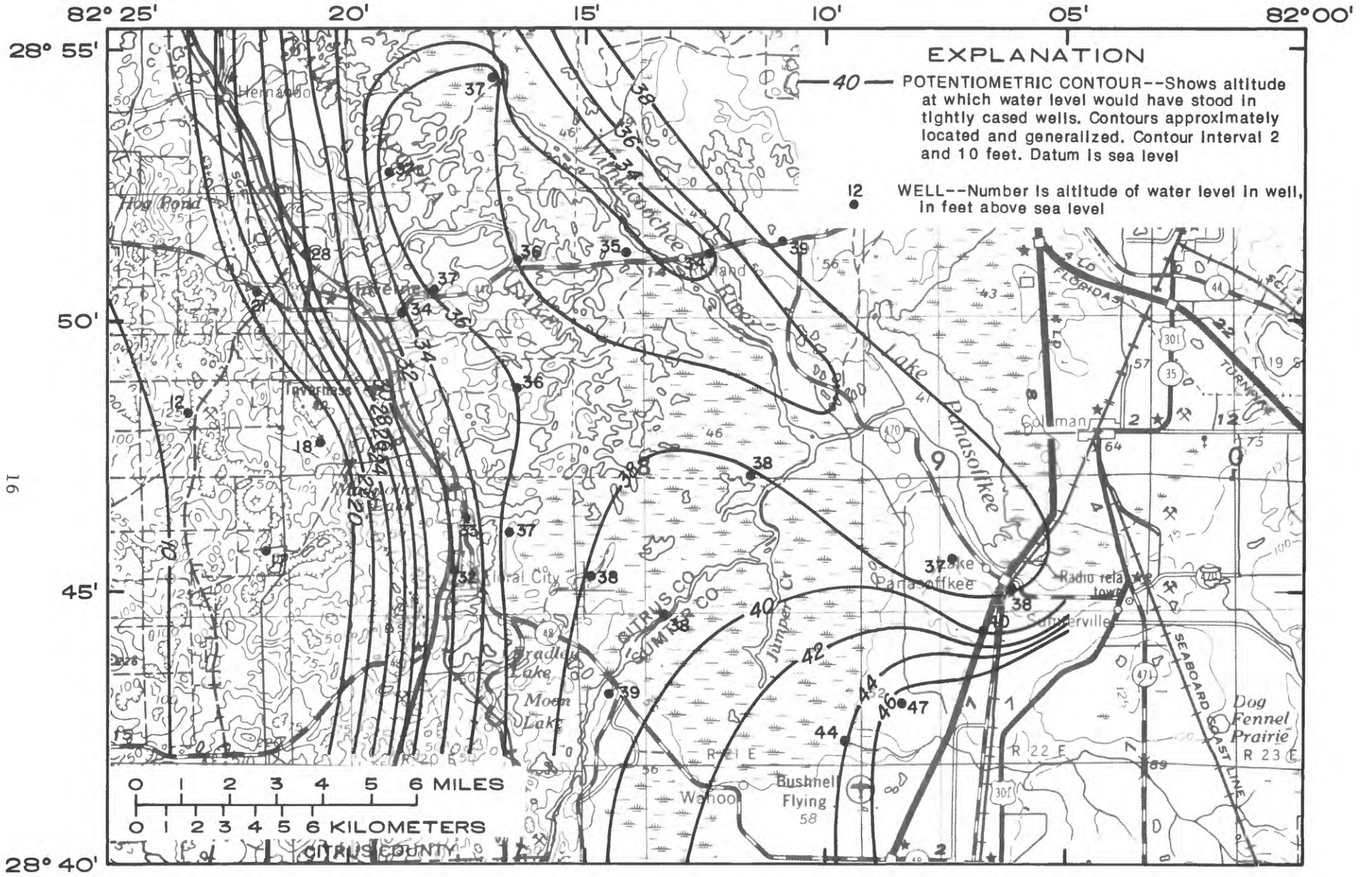

Figure 8.--Potentiometric surface of the Upper Floridan aquifer in the Tsala Apopka Lake area, May 1985.

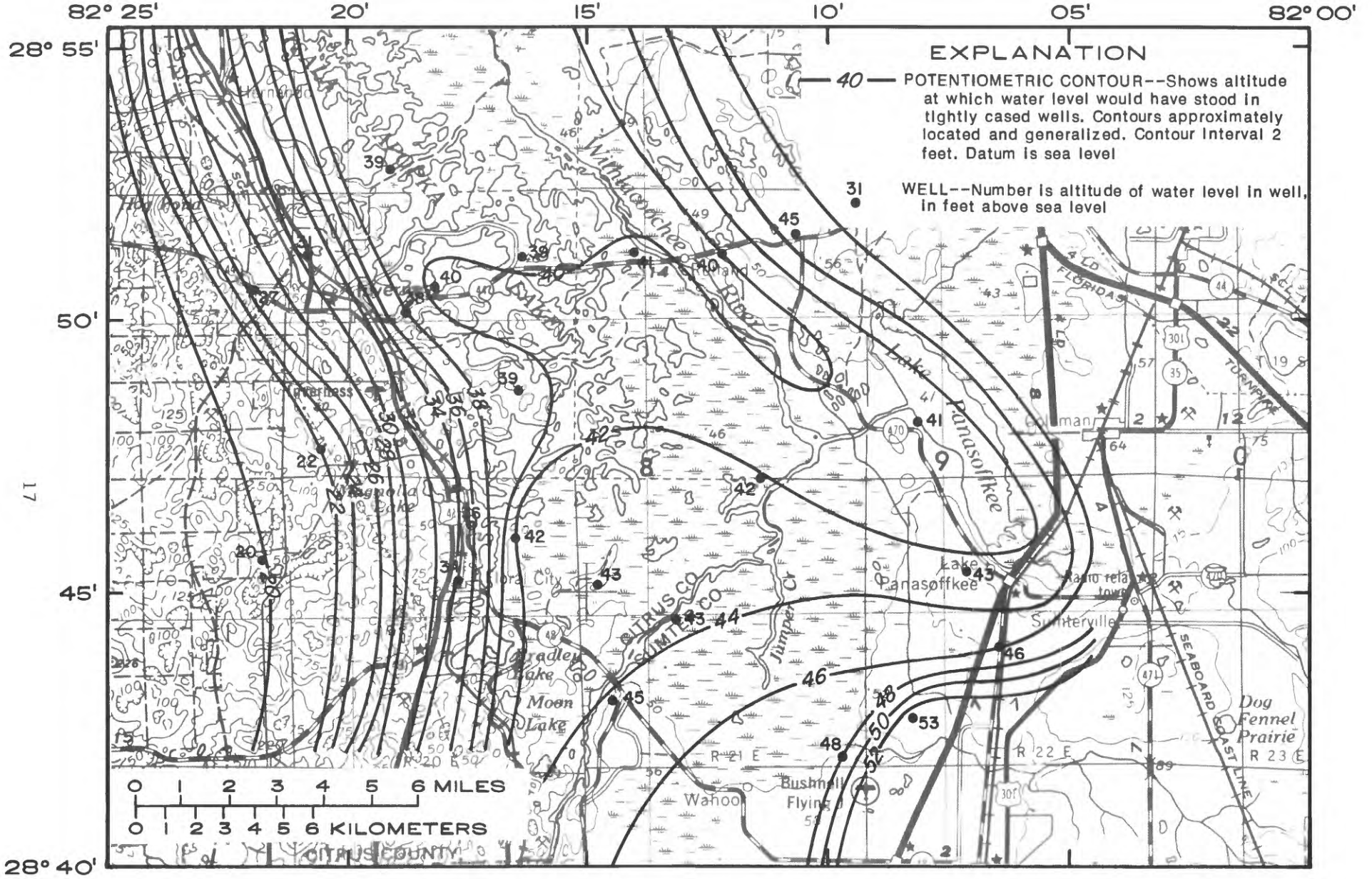

Figure 9.--Potentiometric surface of the Upper Floridan aquifer in the Tsala Apopka Lake area, September 1985.

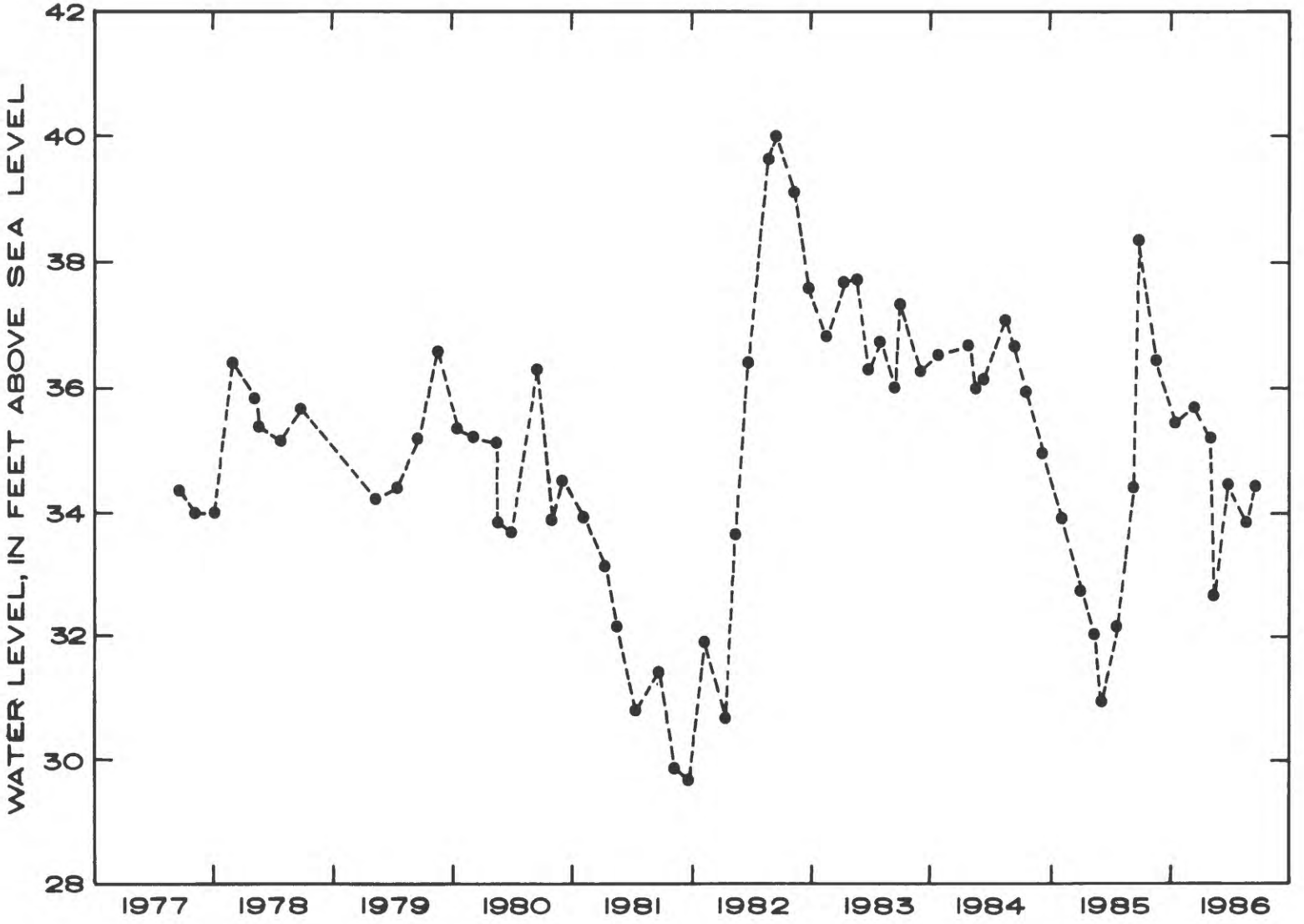

Figure 10.--Water levels of the Floral City well, 1977-86.

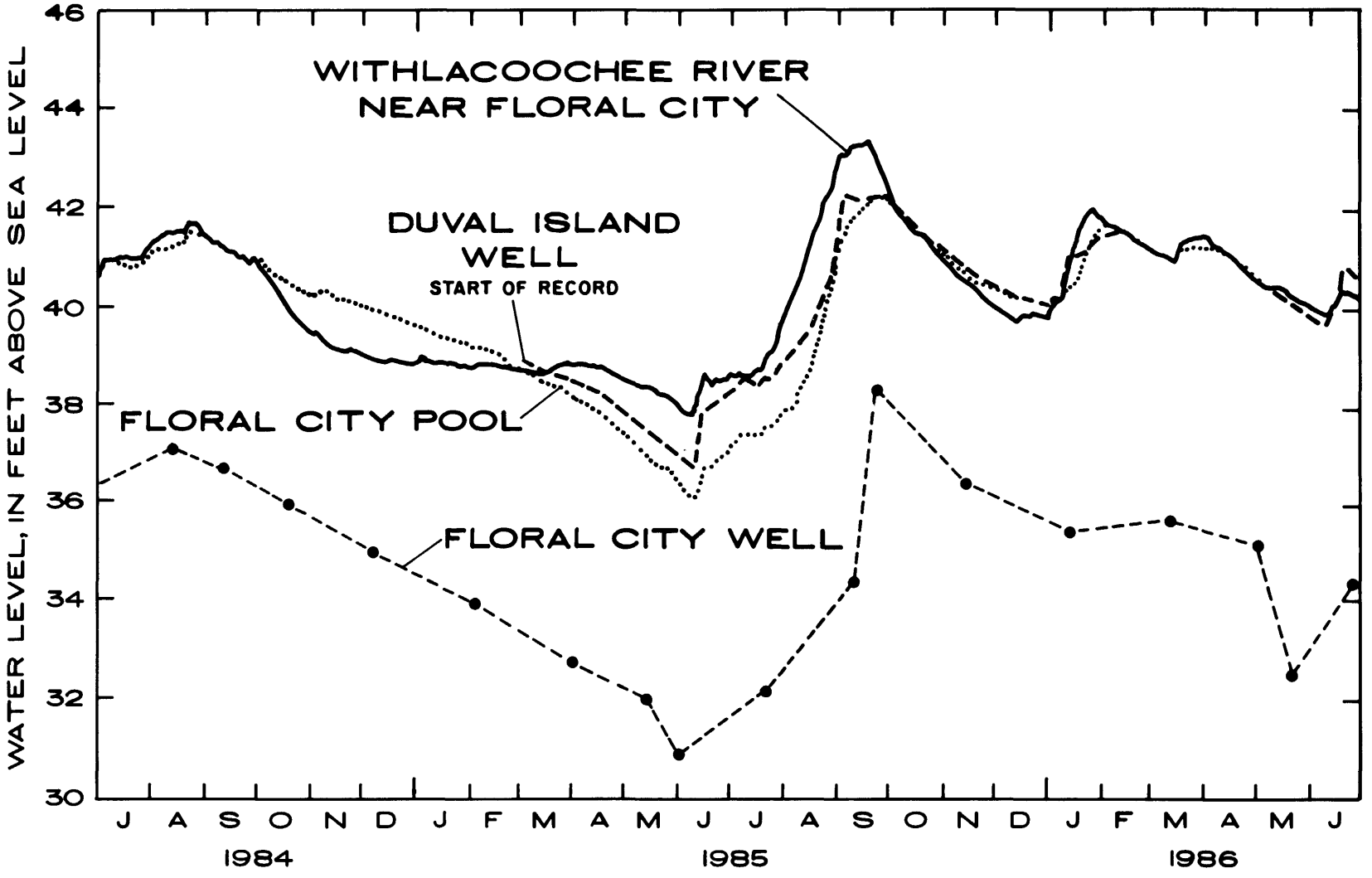

Figure 11.--Water levels of the Withlacoochee River near Floral City, the Floral City Pool of Tsala Apopka Lake, the Duval Island well, and the Floral City well, July 1984 through June 1986.

Surficial Aquifer System

The surficial aquifer system is not generally used for domestic water supply in the area because the Upper Floridan aquifer offers higher yields and better quality. Because the water level of the surficial aquifer system generally follows the fluctuations of the potentiometric surface of the Floridan aquifer system, it has not been continuously monitored over a long term.

HYDROLOGIC RELATIONS AMONG THE WITHLACOOCHEE RIVER, THE FLORAL CITY POOL, AND THE UPPER FLORIDAN AQUIFER

Most of this report deals with seasonal variation of water levels, extending from extremely dry conditions to extremely wet conditions. For the purpose of comparing hydrologic changes, three ranges of pool and river water levels were chosen as best representing hydrologic conditions. Low-range water levels, below 39.0 feet elevation, represent extended dry periods with little or no rainfall in the area. Middle-range water levels encompass water levels between 39.0 and 41.0 feet elevation and occur approximately 50 percent of the time. High-range water levels, occurring during wet seasons, extend above 41.0 feet elevation.

Withlacoochee River

The Wysong Dam (inflatable fabridam) was constructed below the confluence of the Outlet River and the Withlacoochee River (fig. 2) so that the water levels of Lake Panasoffkee could be maintained during dry seasons. At the time of construction, it was thought that the river could be maintained at a minimum of 39 feet elevation during the dry season. However, since construction, there have been several extended dry periods that indicate the dam cannot maintain the desired level of 39 feet elevation unless all flow through it is eliminated.

A comparison of water levels in the reach between Croom and Holder (see fig. 1 for location) on the Withlacoochee River (fig. 12) shows that the river at the Floral City gage has been maintained approximately 0.75 foot higher in the middle and low ranges of stage of the river after the installation of the dam. A report by Mann (1984) on Lake Panasoffkee and the Wysong Dam indicates that levels at the Floral City gage remain an average of 0.31 foot higher than preconstruction time.

During high-range and low-range periods, the dam has little influence on the streamflow in the Orange State and Leslie-Heifner Canals. During the high-range period, the dam is usually deflated to transmit large flows in the river to prevent reverse flow into Lake Panasoffkee. During the low-range period, the river cannot be maintained at a level that will cause water to flow through the canals. Two effects of the dam during the low range of river stage are the recharge of ground water in the reach between the Floral City gage and the dam, and slightly higher water levels in the shallow areas in the river where the streambed may be dry in prolonged dry periods (Kimrey and Anderson, 1987).

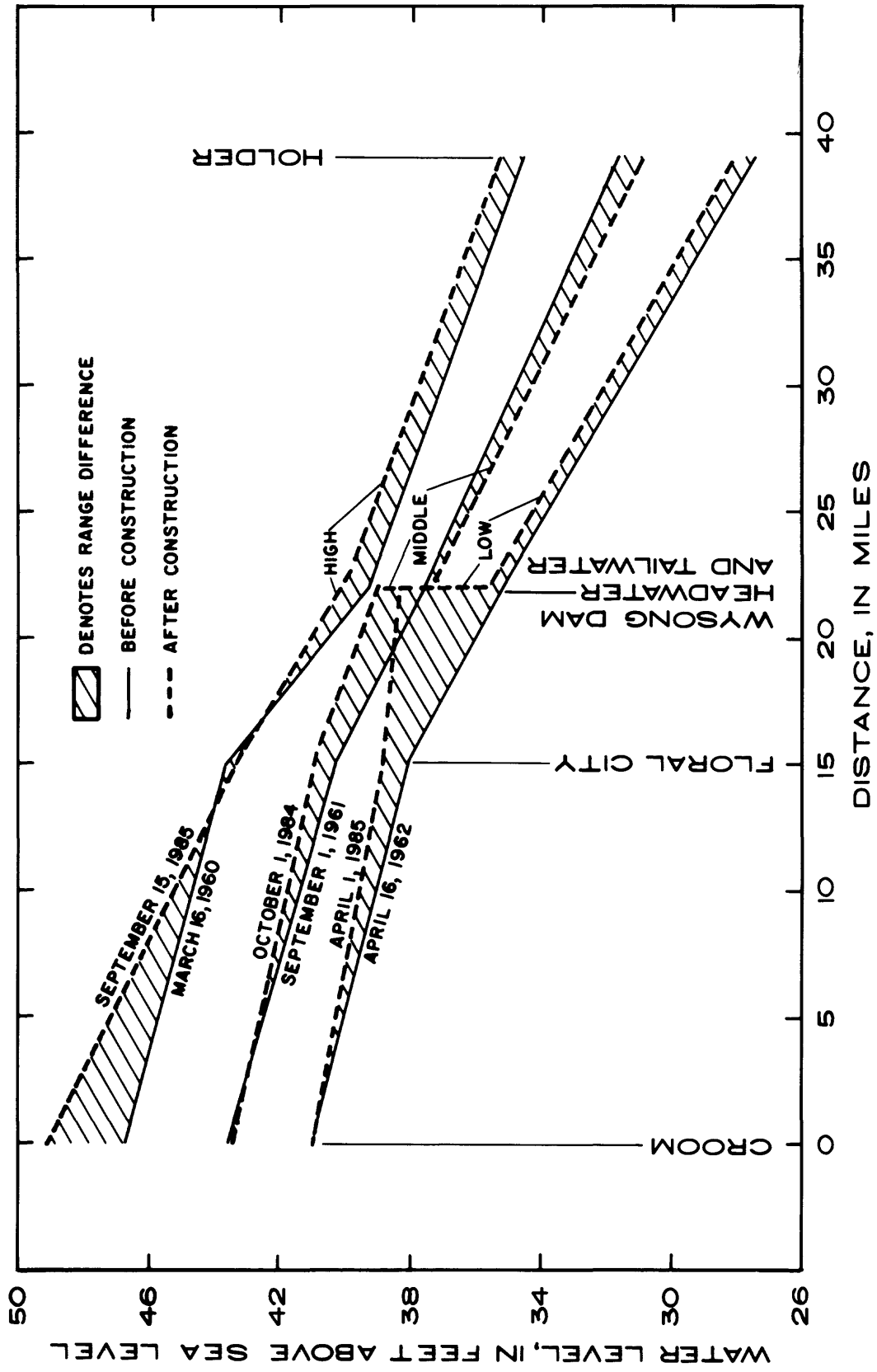

Figure 12.--Comparison of high-, middle-, and low-range stages of the Withlacoochee River before and after construction of the Wysong Dam at Carlson.

During the middle range of stage, the river does not have sufficient streamflow (ranging from approximately 200-400 ft^3/s) to significantly increase water levels in the Floral City Pool. However, there is a small amount of flow going to the lake that partially counteracts the loss of lake water to evapotranspiration, ground-water recharge, and outflow.

The water levels shown in figure 12 before construction of Wysong Dam were selected as best typifying the high, middle, and low stages at Croom. The high-water levels in 1960 were selected as the best preconstruction data set having record at all four stations and where discharge at the Holder station was equal to the September 1985 flow. September 1, 1961, was chosen as representing antecedent conditions of an extended dry period. Levels for 1984 and 1985 were used to compare these different conditions.

Changes at Floral City for the high-, middle-, and low-range water levels are a 0.34-foot drop, a 0.63-foot rise, and 0.71-foot rise, respectively. Changes at Wysong Dam (upper gage) for the high-, middle-, and low-range are a 0.85-foot rise, a 1.40-foot rise, and a 3.14-foot rise, respectively.

Floral City Pool

Water levels in the chain of pools in Lake Tsala Apopka are influenced by the inflow from the Withlacoochee River. Before the construction of canals, the response of pool levels to changing river levels was probably very slow. After the Orange State Canal was dug, the water moved more quickly into the lake, causing more dynamic variations in water levels. If the Withlacoochee River did not supply inflow to the lake, high-range pool levels would probably be much lower in elevation than what occur today. Without river inflow, the pool levels would reflect ground-water levels, with much less dynamic movement and probably less gradient among pools.

A stage-duration curve of the Withlacoochee River near Floral City (fig. 13) indicates that the Withlacoochee River does not exceed 40.31 feet elevation more than 40 percent of the time, and the Floral City Pool does not exceed 40.25 feet elevation more than 40 percent of the time. These curves are based on the same period of record, from 1957 to 1985, and indicate that the river remains slightly higher than the lake for about 95 percent of the time. A similar duration curve based on record from 1965 to 1986 (after construction of Wysong Dam) shows little difference except a slightly flatter curve due to fewer high-range water levels.

Figure 13 also indicates some differences between the Withlacoochee River, which is continually flowing all year, and the pool, which has periods of no inflow. When the pool level drops to an elevation of 38.2 feet and there is little or no inflow, the Floral City Lake and Lake Hampton water levels will drop quickly to as low as 35.2 feet elevation. This condition exists about 5 percent of the time. At the high-flow end of the curve, the pool remains higher longer than the river, mainly because the conveyance for outflow from the pool is more restrictive than the river channel.

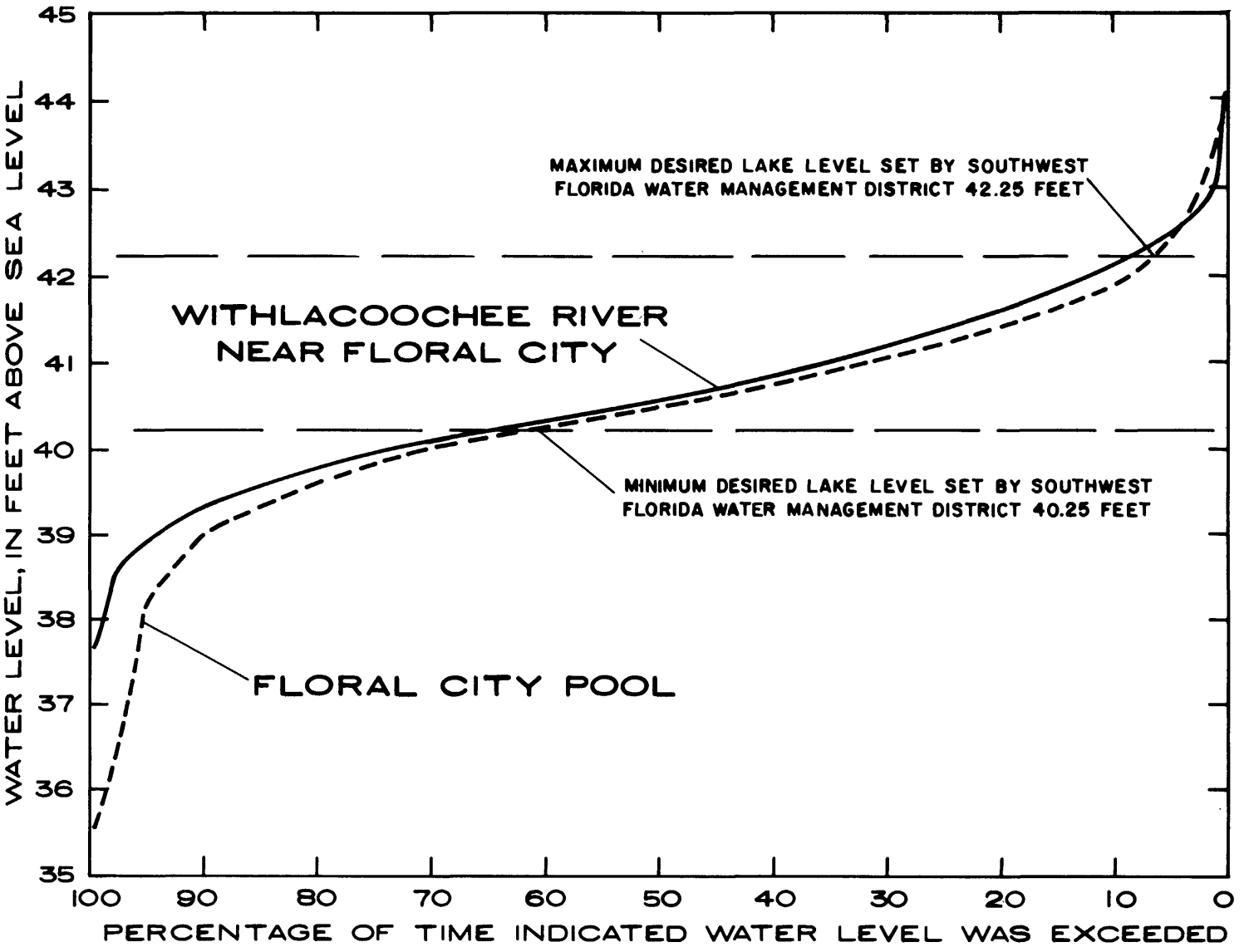

Figure 13.--Stage-duration curves of the Withlacoochee River near Floral City and the Floral City Pool, 1957-85.

Upper Floridan Aquifer

The river has eroded or has been dredged into the Upper Floridan aquifer in many sections of the study area. When the potentiometric surface of the Upper Floridan aquifer falls below river levels during extended dry periods, the river recharges the aquifer and is a "losing" stream. This may happen all along the river reach, but it is only noticeable when the difference of water levels between the river and the aquifer is appreciable, as in the area upstream of Wysong Dam known as the "narrows" (fig. 2). After a wet season and streamflow has declined, the river is a "gaining" stream, that is, the aquifer feeds the river because the river level is below the potentiometric surface. Water levels of the surficial aquifer system and the potentiometric surface of the Upper Floridan aquifer are nearly the same in the study area.

A straight-line interpolation of water-level profiles from the well at Floral City across the lake to the Duval Island well during May and September 1985 is shown in figure 14. These profiles indicate that there is potential for recharge to the Upper Floridan aquifer from the pool.

The amount of recharge to the aquifer from the river and lake has not been quantified in this report because the physical characteristics of the Upper Floridan aquifer change rapidly in this area. In figure 11, the hydrographs of the Withlacoochee River, the Floral City Pool, the Duval Island well and the well at Floral City are similar, except that the levels are lower by approximately 3 to 7 feet at the well at Floral City.

SURFACE-WATER MOVEMENT IN THE VICINITY OF THE FLORAL CITY POOL

The Orange State Canal is the main conveyance for transporting water from the Withlacoochee River to the Floral City Pool, and the Leslie-Heifner and Golf Course Canals are the main conveyances from the Floral City Pool to the Inverness Pool (fig. 2). During times of middle-range water levels, the Leslie-Heifner Canal does provide some inflow to the Floral City Pool, but most of the water goes into storage in the wetlands adjacent to the canal. During low-range water levels, the water stored in the wetlands around the canals and Floral City Pool drains into the canal and lake, depending on hydraulic gradient. Other canals that carry flow into and out of the lake include five uncontrolled channels, at sites 1, 2, 3, 4, and 7 (fig. 2). Culverts controlled by lift gates or board controls include those at site 5, Lake Bradley structure, and Little Lake Canal which allow water to move in or out of the Orange State Canal. Indirectly, Moccasin Slough also allows uncontrolled flow during the wet season to move out of the drainage area of the Floral City Pool. Bryant Slough and the Henderson Lake Canal receive uncontrolled flow from Moccasin Slough. During extreme high water, Shinn Ditch facilitates movement of water in the extreme eastern section of the study area along the Withlacoochee River. Shinn Ditch was not gaged during the current study because the main pool and the eastern part of the area were not connected during that time.

Orange State Canal

The Orange State Canal is generally straight, with a few bends that do not significantly diminish the volume and velocity of the water received from the Withlacoochee River. The channel is quite shallow and overflows into

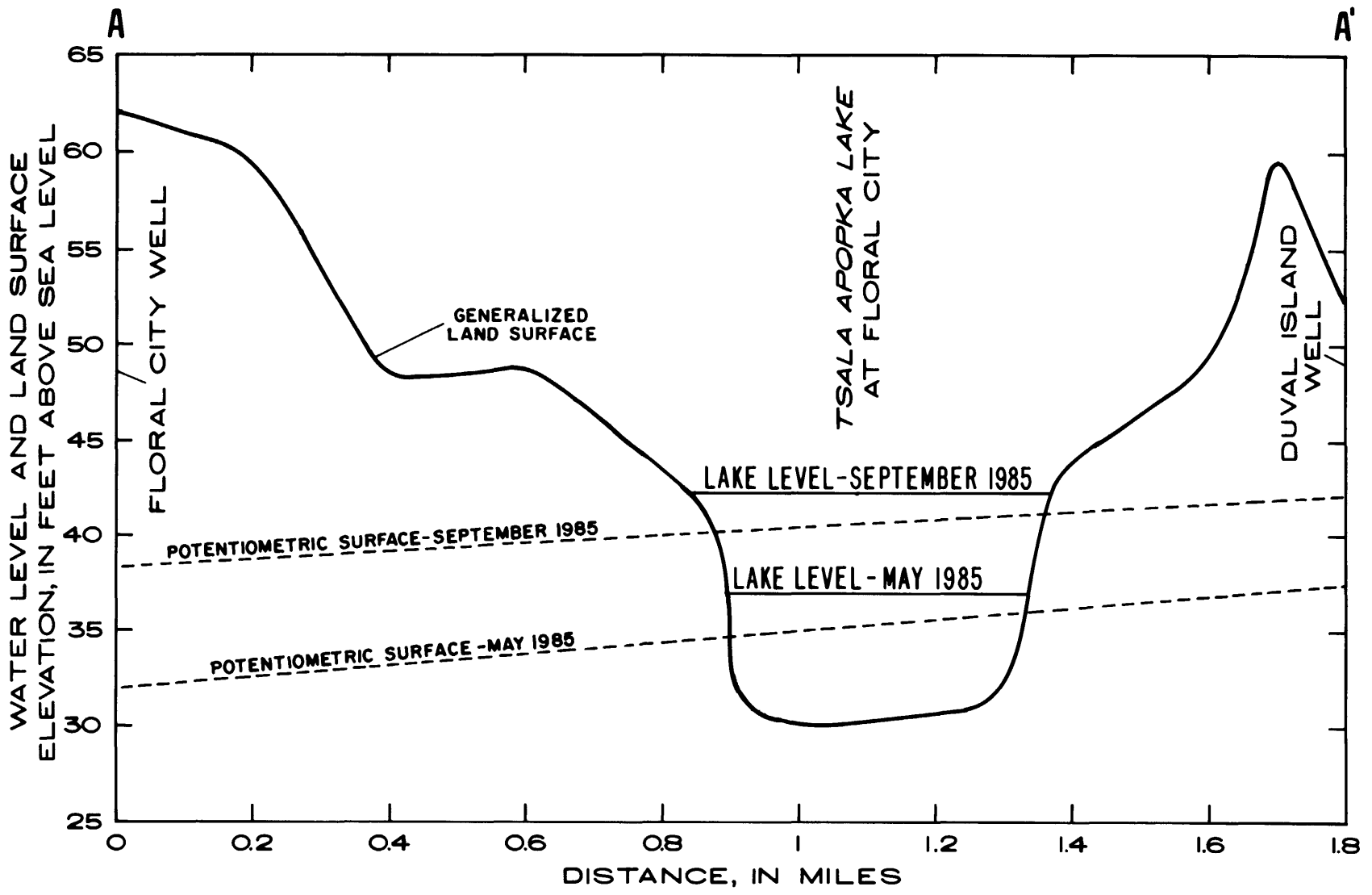

Figure 14.--Gradient of the potentiometric surface of the Upper Floridan aquifer across the Floral City Pool (line of section shown in fig. 2 and plate 1).

swamp areas when an elevation of 39.5 to 40.0 feet is reached. Overflow moving through the swamp adjacent to the canal is restricted by vegetation and trees, but the extent of restriction is not known. The canal was the major source of high flows to Lake Tsala Apopka in 1934 and 1960, the two highest flood years on record. Low flow from the river is controlled by the elevation of the bottom of the canal. No flow from the river can be detected below 39.0 feet elevation, but seepage through the thick layers of organic matter on the bottom of the canal occurs if there is a hydraulic gradient in the canal. Flow can be measured at the structure in the canal until the water level drops to 37.85 feet elevation, but flow under this condition may be seepage from the storage in the bed sediments of the canal rather than flow from the river.

Although the canal water level was not recorded daily until 1983, it can be estimated that the water level in the canal is between those of the river and the pool, and probably less than 0.05 foot different from either river or pool about 60 percent of the time (fig. 13). Inflow to the pool is large when the river rises above 41.0 feet elevation and the water level of the pool is much lower than that of the river, but this condition is not normal. Instead, backwater conditions are normal, and the flow is determined by the fall between the river and the Floral City Pool as well as water level at the Orange State Canal structure. A different set of backwater conditions occurs when the Golf Course Canal structure is open. Flow is then determined by the fall between the Withlacoochee River, the Floral City Pool, and the Inverness Pool. This usually results in higher flow because of the greater fall and more opportunity for water movement through channelized areas that have high conveyance capacities.

There are four factors that define flow conditions for the Orange State Canal. These are explained as follows:

1. A low- to middle-range canal stage and free-fall condition happens rarely, but occurs when the canal and the Floral City Pool levels are below 39.5 feet and the Withlacoochee River is rising quickly. Under this condition, the water level in the canal upstream of the control is used to determine the discharge. This condition occurred in the beginning of the rainy season in summer 1985 after the lake had been extremely low because of an extended dry period.

2. High-range water levels and a positive flow condition occurs when (a) the Withlacoochee River rises above 41.0 feet elevation and has a high-streamflow, and (b) the fall between the river and the pool is greater than 0.75 foot. During this time, the river levels are used to compute streamflow, because the high stage and velocity of the river flow is forcing the water through the canal at a rate greater than the typical backwater condition. This condition occurred in August 1985 after heavy rains occurred upstream.

3. High-range water levels and backwater conditions occur rarely, but may result in the highest discharge in the canal because of the high water levels. These conditions are (a) the Withlacoochee River rises above 42.0 feet, (b) there is fall through the structure in Orange State Canal, (c) the canal water level is above 41.0 feet, (d) fall between the river and the Floral City Pool is between 0.75 foot and 0.20 foot, and (e) the Golf Course Canal structure is open and there is flow

through that structure toward the Inverness Pool. By opening the Golf Course Canal structure, the fall is between the Withlacoochee River and the Inverness Pool, but the level of the Floral City Pool plays a significant role in flow conditions. The water level of the canal upstream of the structure is used to compute streamflow for these short occurrences.

This high-flow condition does not last long, but can contribute more water to the lake in 1 day than will be contributed in 1 month during a dry season, such as spring 1985. The duration curve in figure 13 shows that the Withlacoochee River rose above 42.0 feet only 12 percent of the time for the period of record. This condition lasted less than 30 days during August and September 1985 but probably contributed more than 90 percent of the total inflow to the Floral City Pool for the year. Floods of long duration, such as in 1960, could have considerable effect on the water levels of the area if prolonged inflow occurs.

4. The middle-range water levels and variable backwater condition occurs at least 50 percent of the time. The fall between the Withlacoochee River and the Floral City Pool is used to calculate the flow through the canal. The flow is usually sluggish (less than 0.4 foot per second and depends on (a) less than 0.30 foot of fall between the river and the Floral City Pool, (b) the river water level is less than 41.0 feet, and (c) the Golf Course Canal structure is closed. The river-to-lake fall was determined to provide the best statistical correlation to compute streamflow. Included in the data set were the streamflow measurements made when there was reverse flow from the lake to the river. Reverse flow occurs periodically in Orange State Canal, particularly when the river and lake equilibrate after a wet season and then the river water level drops due to reduction of streamflow. Negative flow was measured in October 1984 and 1985 and again in April 1986, but the duration of the reverse flow was short because of gate closure by SWFWMD. Although flow through the canal is sluggish most of the time, any inflow for maintenance of lake levels is important. Backwater conditions continue to occur as water levels reach the low range, but control gates on the structures are usually closed at that time to prevent negative flow.

Leslie-Heifner Canal

The Leslie-Heifner Canal has many bends that cause channel friction and loss in conveyance. Because of the adjacent small coves and wetlands, the flow volume is lost to storage and recharge as it travels along the canal. The canal flows for longer periods at middle stages than does the Orange State Canal because its water-surface gradient is toward Moccasin Slough and the Inverness Pool, which is steeper than the gradient to the Floral City Pool. The Leslie-Heifner Canal contributes water to the Floral City Pool during dry season, but amounts are quite variable and depend on the water-surface gradient that occurs in the vicinity of sites 3 and 4 and Tussock Lake.

During dry season, flow through Moccasin Slough is minimal; thus, the Leslie-Heifner Canal becomes a drain for the surrounding wetlands that are in the northeast part of the Floral City basin and will convey water downgradient, whichever direction that may be. During an extremely wet season,

flow is usually directed through the Leslie-Heifner Canal to Tussock Lake and Moccassin Slough, with flow coming out of the Floral City Lake at sites 3 and 4 to join the downgradient flow toward the Inverness Pool. Flow enters the Floral City Lake at sites 3 and 4 at initial stages of high inflow from the Leslie-Heifner Canal, but as the lake rises, water then flows out of the lake.

The control structure on the canal can be manipulated to allow less flow during extreme high water, but water levels in the downstream part of the canal will probably rise to the same level as the Floral City Pool due to the uncontrolled flow at sites 3 and 4 from the Floral City Lake.

In 1985, flow through the canal did not begin until water levels rose above an estimated 39.0 feet elevation. Flow through the structure is nearly always in a backwater condition and too variable to determine daily flow. Flow in the canal does not increase significantly until the water levels in the river rise above 41.0 feet elevation. In August and September 1985, measurements indicated that flow through the structure peaked at approximately 200 ft^3/s, but then decreased considerably as the Floral City Pool water levels rose and created higher backwater conditions. Also, during part of September, the gate at the structure was partially closed, thus reducing the flow.

Golf Course Canal

The Golf Course Canal structure is usually opened during high flow periods to move more water into the Inverness Pool. During this time, it is an important part of the flow system of the Orange State Canal. During low-water periods, the structure restricts flow from the Inverness Pool toward the Floral City Pool, which could lower all the lakes in the area. Reverse flow may occur at approximately 38.0 feet elevation if the structure is open, but flow to the Floral City Lake would not continue for long periods of time because of the bed elevation of the canal from Lake Hampton to Tussock Lake (site 7).

Site 1

Site 1 (fig. 2) is in a canal on the northern side of the Floral City Lake connecting to Lake Hampton. The canal is 30 feet wide and approximately 2 to 5 feet deep at most lake level elevations. Bed elevation of the canal is approximately 35.0 feet. The canal is capable of conveying large volumes of water from the Floral City Lake into Lake Hampton during high flows. No reverse flow was observed or measured during the study period, indicating that Floral City Lake and Lake Hampton are probably the same lake system, reacting the same hydrologically. Flow is not controlled through this canal.

Site 2

Site 2 is in an uncontrolled canal connecting the northeastern part of Floral City Lake with Tussock Lake. Flow has been toward Tussock Lake for water levels above 40.0 feet elevation. Below that level, sandbars form and surface-water movement ceases between the two lakes. Streamflow volumes are generally less than 2 ft^3/s because there is no defined channel from site 2 to Tussock Lake.

Site 3

Site 3 is in the main boat canal which connects the northeastern part of Floral City Lake with the Leslie-Heifner Canal. The canal is used for boat access from parts of a residential subdivision and is kept fairly free of weeds by county maintenance.

The bed elevation at site 3 was approximately 38.0 feet during the study period, but new bridge construction in 1986 may change the point of zero flow. Direction of flow at site 3 depends on hydraulic gradient between the two water bodies. Negative (outflow from Floral City Lake) and positive (inflow from Leslie-Heifner Canal) flows have been measured at this site. Flow at this site is usually toward the lake below water levels of 41.5 feet elevation and toward Leslie-Heifner Canal above 41.5 feet elevation.

Site 3 will flow for an extended time after the gates in the Leslie-Heifner Canal have been closed. This extension of streamflow over time is mainly due to drainage of the wetlands adjacent to the canal, with small amounts of water being released over time.

Site 4

Site 4 is in a canal approximately one-third mile south of site 3. The canal is a dredged channel in the northeastern corner of Floral City Lake. It is located mostly in an extremely shallow part of the lake, with large amounts of emergent vegetation adjacent to the canal. The canal appears to be connected to the free-water surface of the lake after lake levels rise above an elevation of 41.0 to 41.5 feet. This canal connects the lake to the Leslie-Heifner Canal at high-water levels.

The direction of flow at this site is not the same as site 3 during certain periods of time. During a period of low-water levels, with no rainfall and stable conditions, the flow direction is toward Leslie-Heifner Canal at site 4. At site 3, flow direction is toward the Floral City Lake. The canal on the lake side is an isolated surface-water body that has a higher water level than the main body of Floral City Lake.

The point of zero flow was approximately 38.7 feet elevation during the study. Bridge construction in 1986 may change that elevation to allow more water movement through the canal. Between water levels of 40.5 to 41.5 feet elevation, the entire flow system becomes dynamic. Direction of flow then follows the direction of the slope between levels in the Leslie-Heifner Canal and the canal in the Floral City Lake. For water levels above 41.5 feet elevation, flow is generally moving out of the Floral City Lake into the Leslie-Heifner Canal.

Site 5

The canal at site 5 is an overflow channel from the Orange State Canal and inflow is through a culvert controlled by boards. Considerable amounts of flow can enter the wetlands within the Floral City basin at high water, and reverse flow toward the Orange State Canal has been recorded during times when the water levels in the wetlands are higher than the river. This canal does

not have the same conveyance capacity as the larger canals, but can make a difference in the overall inflow or outflow to the Floral City Pool. When the Orange State Canal gate is closed due to extreme high water, high volumes of water may enter the Floral City Lake through this culvert unless the structure is also closed.

Site 6

Site 6 is in the Leslie-Heifner Canal at a private bridge, approximately halfway between the canal structure and sites 3 and 4. This site was used to estimate loss of flow through the Leslie-Heifner Canal during high-flow periods when adjacent wetlands along the canal fill up with the inflow. Reverse flow toward the Withlacoochee River was not observed at this site.

Site 7

Site 7 is in the main boat canal between Lake Hampton and Tussock Lake under a private bridge. During middle- and high-range water levels, flow direction is from Lake Hampton to Tussock Lake. Highest flows were measured during times when the Golf Course Canal structure was open.

Because Tussock Lake receives inflow from the Leslie-Heifner Canal, its water level is higher than those of Hampton Lake and the Floral City Pool for extended periods of low water levels. Low flows of less than 5 ft^3/s from Tussock Lake toward Lake Hampton have been observed and measured when water levels were between 37.5 and 40.0 feet elevation.

Lake Bradley Canal

The Lake Bradley site is located in a canal that extends from Orange State Canal to Lake Bradley. The control structure is a small lift gate that is opened by SWFWMD for inflow to the lake at times. Reverse flow has not been observed due to closure of the gates. Lake Bradley maintains higher lake levels than the Orange State Canal for longer periods of time without inflow; therefore, reverse flow is possible if the structure were opened.

Little Lake Canal

The Little Lake Canal is an extension off the canal from Orange State Canal to Lake Bradley. The canal is shallow and is dry part of the time. Flow to Little Lake is controlled by SWFWMD by use of a culvert and board control. Time of inflow to Little Lake is short because the lake is small and does not require large volumes of water to maintain lake levels. Reverse flow has not been observed in the canal.

Ferris Canal

Ferris Canal, not a separate water body, creates a navigable area around the east side of Duval Island. Water flows from the Orange State Canal through the Ferris Canal and the wetlands part of the Floral City Lake and

reaches the northeastern body of lake during periods of high flow. Most of this flow to the northeastern body of the lake is probably being routed out of the lake at sites 2, 3, and 4 during times of peak flow. An estimated 20 to 30 percent of the flow at the Orange State Canal structure is possibly being routed by the Ferris Canal into the lake during high flow. This estimation is based on a discharge measurement at the Duval Island bridge. Ferris Canal could not be directly measured because of the wetlands adjacent to the canal.

Moccasin Slough

Moccasin Slough is mainly a wetland area with small, natural water channels through swampy areas. The streamflow measurement site is in a small, dredged area at a private bridge. Flow does move through the area until water levels in the slough drop to approximately 40.0 feet elevation. No flow is measurable or discernible at levels below 40.0 feet elevation, but seepage may move downgradient. High flows occur for short periods of time in wet seasons, with inflow from the Leslie-Heifner Canal, the Floral City Pool, and possibly from Tussock Lake. Water flows through the slough, with most of the flow probably moving into the Inverness Pool and small amounts (unknown) moving toward the Bryant Slough area.

Bryant Slough is controlled by a structure beneath State Road 44 that allows water to spill over a lift gate above 40.0 feet elevation. This structure may be controlling part of the flow through Moccasin Slough, creating a backwater effect for a part of the area. During extreme flood conditions, the Bryant Slough structure can be opened to allow large amounts of flow to pass and return to the Withlacoochee River. This may change the flow pattern produced by large volumes of uncontrolled flow through Moccasin Slough.

A large percentage of the uncontrolled flow through Moccasin Slough fills the canals to the East Cove area and Spivey Lake, and moves downgradient through the chain of lakes in the Inverness Pool. The best site for measurement of the excess streamflow from Moccasin Slough is in the canal from Spivey Lake to Henderson Lake. At this site, flow from Moccasin Slough and the Golf Course Canal are combined. During high-flow measurements, flow at this site indicated a loss of streamflow volume compared to the addition of the streamflow at the Golf Course Canal structure and Moccasin Slough. This was probably due to water going into storage in the upstream lakes, wetlands, and Bryant Slough and not reaching equilibrium with the upstream water levels until much later.

STREAMFLOW PATTERNS

Three water-level periods were chosen as best typifying the high-, middle-, and low-flow conditions that occurred during the 1985-86 water years. Data that represent a high-range period were collected in late September and early October 1985 when most of the structures were open. Several sets of data were collected during the study period with several sites having closed structures, a condition that is typical during most years. Because the gates at Orange State Canal and Leslie-Heifner Canal were closed during a large part of 1985, data collected in June 1986 were used as an example of middle-range conditions with inflow through the canals. Low-range conditions are

represented by data collected in March 1985 when water levels in the pool were approaching 38.4 feet elevation, close to the point-of-zero flow at site 3, the longest flowing site. All three sets of data for each site are presented in table 1.

Table 1.--Streamflow data for selected water-level periods at data-collection sites in the Floral City Pool area, Tsala Apopka Lake, 1985-86

[Data in cubic feet per second. Negative signs indicate outflow from the main lake body of the Floral City Pool]

Streamflow site	Low range (<39.0 feet elevation) 03-25-85	Middle range (39.0-41.0 feet elevation) 06-04-86	High range (>41.0 feet elevation) [1]09-25-85 to 10-01-85
Orange State Canal	0	7.5	192 (09-25)
Leslie-Heifner Canal	0	4.7	109 (09-26)
Canal from Orange State Canal to Little Lake	0	0	0 (09-25)
Canal from Orange State Canal to Lake Bradley	0	0	0 (09-25)
Site 1	0	0	-135 (09-25)
Site 2	0	-.2 estimated	-25 (09-26)
Site 3	2.2	1.7	-53 (09-26)
Site 4	0	1 estimated	-30 (09-26)
Site 5	0	0	39 (09-25)
Site 6	No data	No data	85 (10-01)
Canal from Lake Hampton to Tussock Lake	No data	1 estimated	-122 (09-25)
Golf Course Canal	0	0	-173 (09-25)
Moccasin Slough	No data	No data	-165 (10-01)
Bryant Slough	0	0	-30 (09-25)
Canal from Spivey Lake to Henderson Lake	0	0	-253 (09-25)

[1]Date of measurement in parentheses.

High-Range Water Levels

The streamflow data for September 1985 (fig. 15) are representative of flow-through patterns of the Floral City Pool at high water (above 41.0 feet elevation). Water from the Withlacoochee River entered both the Orange State and Leslie-Heifner Canals. Water from the Orange State Canal entered the Floral City Lake. Water from Leslie-Heifner Canal moved both north through Moccasin Slough and west through Tussock Lake, toward the Inverness Pool. Some flow in the Orange State Canal, less than 5 percent, was diverted through

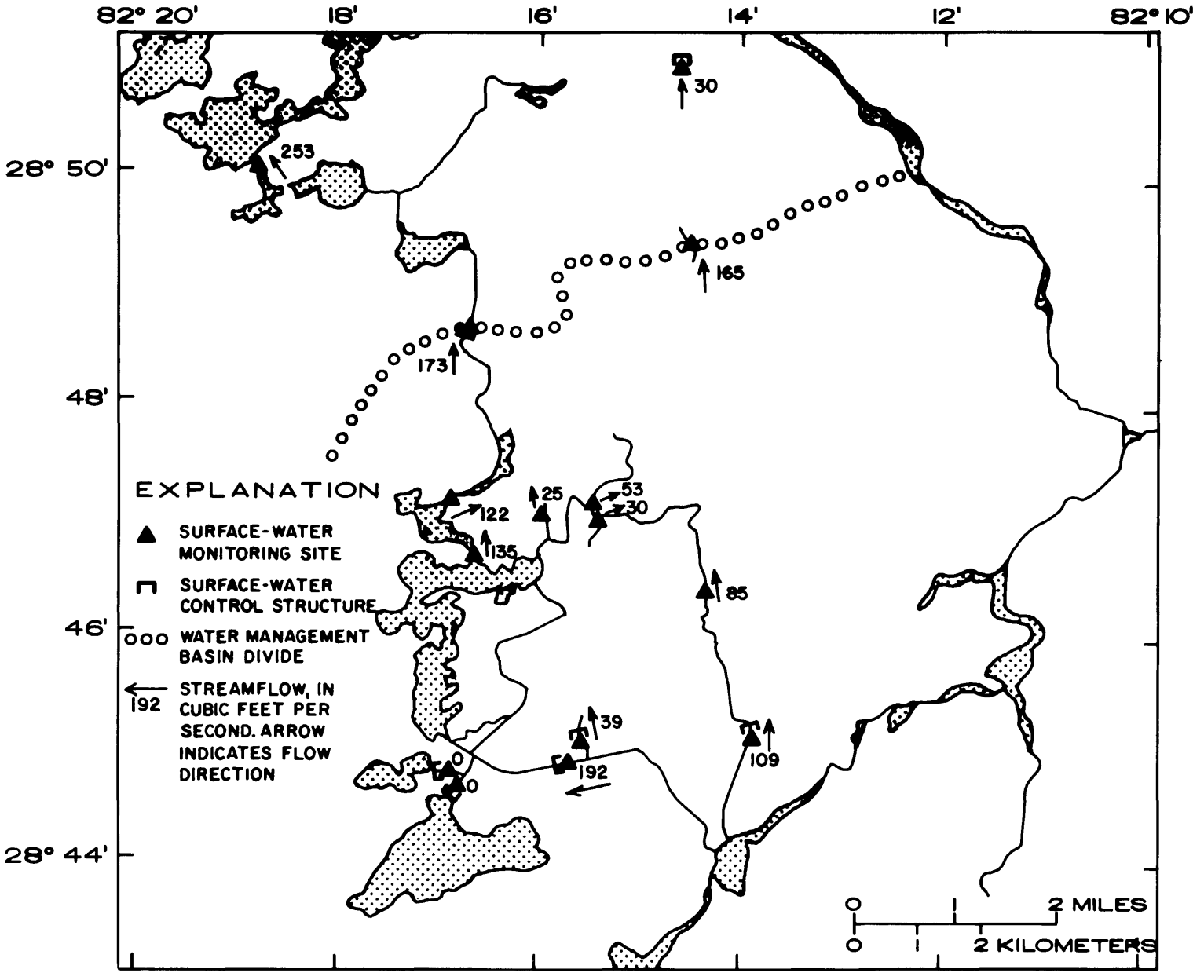

Figure 15.--Streamflow during high-range water levels (above 41.0 feet elevation) of the Floral City Pool, September 25 through October 1, 1985.

the canals to Lake Bradley and Little Lake near Floral City. Of a total of 194 ft^3/s at the Orange State Canal structure, the flow on August 29, 1985, was 10.9 ft^3/s to Lake Bradley and 0.5 ft^3/s to Little Lake. The structures in the canals to Lake Bradley and Little Lake were closed in September after the two lakes had reached fairly high levels. After the closure, the flow in Orange State Canal entered the Floral City Lake through the Ferris Canal and wetlands adjoining the canal (approximately 25-30 percent) and through the main channel (70 percent). The water in the Floral City Lake then moved out of sites 1, 2, 3, and 4 on the north and northeast end of the lake. Flow from sites 1 and 2 moved eventually into Tussock Lake and from there through the Golf Course Canal to the Inverness Pool. Flow exiting through sites 3 and 4 joined that from the Leslie-Heifner Canal. The combined flow then moved through the wetlands into Tussock Lake, Golf Course Canal, and Moccassin Slough. The flow through Moccassin Slough was then routed through wetlands to the Bryant Slough and the East Cove Lake area. The East Cove Lake area is part of the chain of connected lakes of the Inverness Pool. Flow from this area combined with the flow from the Golf Course Canal and moved eventually through the canal from Spivey Lake to Henderson Lake. The flow in the Spivey-Henderson Canal was considerably higher than at the Golf Course Canal structure, indicating additional inflow from Moccasin Slough. Flow through Bryant Slough returned water to the Withlacoochee River.

In high-water conditions, such as in September 1985, the directions of flow throughout the system are constantly changing due to changes in water-surface gradient. Measurements were made in August 1985, but the Floral City Pool was rising after a long dry period and had not stabilized sufficiently to represent high-water conditions. But, by the end of September, the outflow combined from Golf Course Canal and Moccasin Slough (338 ft^3/s) generally equaled the inflow combined from Leslie-Heifner Canal, Orange State Canal, and site 5 (340 ft^3/s) for the Floral City Pool.

Middle-Range Water Levels

A middle-range period (39.0-41.0 feet elevation) was chosen that typified steady-state flow conditions with inflow structures open (fig. 16). On June 4, 1986, the Floral City Pool was approximately 40.0 feet elevation, which is 0.25 foot below the minimum desired level set by SWFWMD. This lake level is important because at this level there is little or no flow through Moccasin Slough and most of the inflow is retained in the Floral City Pool (fig. 2). The northern limits of the Floral City Pool are the closed structure in the Golf Course Canal and the Moccasin Slough gaging site.

A total of 12.2 ft^3/s entered the lake system through the Orange State Canal (7.5 ft^3/s) and Leslie-Heifner (4.7 ft^3/s) Canal on June 4. Only 2.7 ft^3/s entered Floral City Lake from Leslie-Heifner Canal, with the rest going into the wetlands adjoining the canal. Approximately 1.0 ft^3/s was flowing from Tussock Lake back into Lake Hampton, indicating that the flow was either moving from the Leslie-Heifner Canal or draining from the wetlands in Moccasin Slough and Tussock Lake. A total of 11.0 ft^3/s was entering the main lake body of the Floral City Pool for that day. This situation is a common middle-range occurrence when the lake is slightly lower than the river and the controls on the two major canals are open.

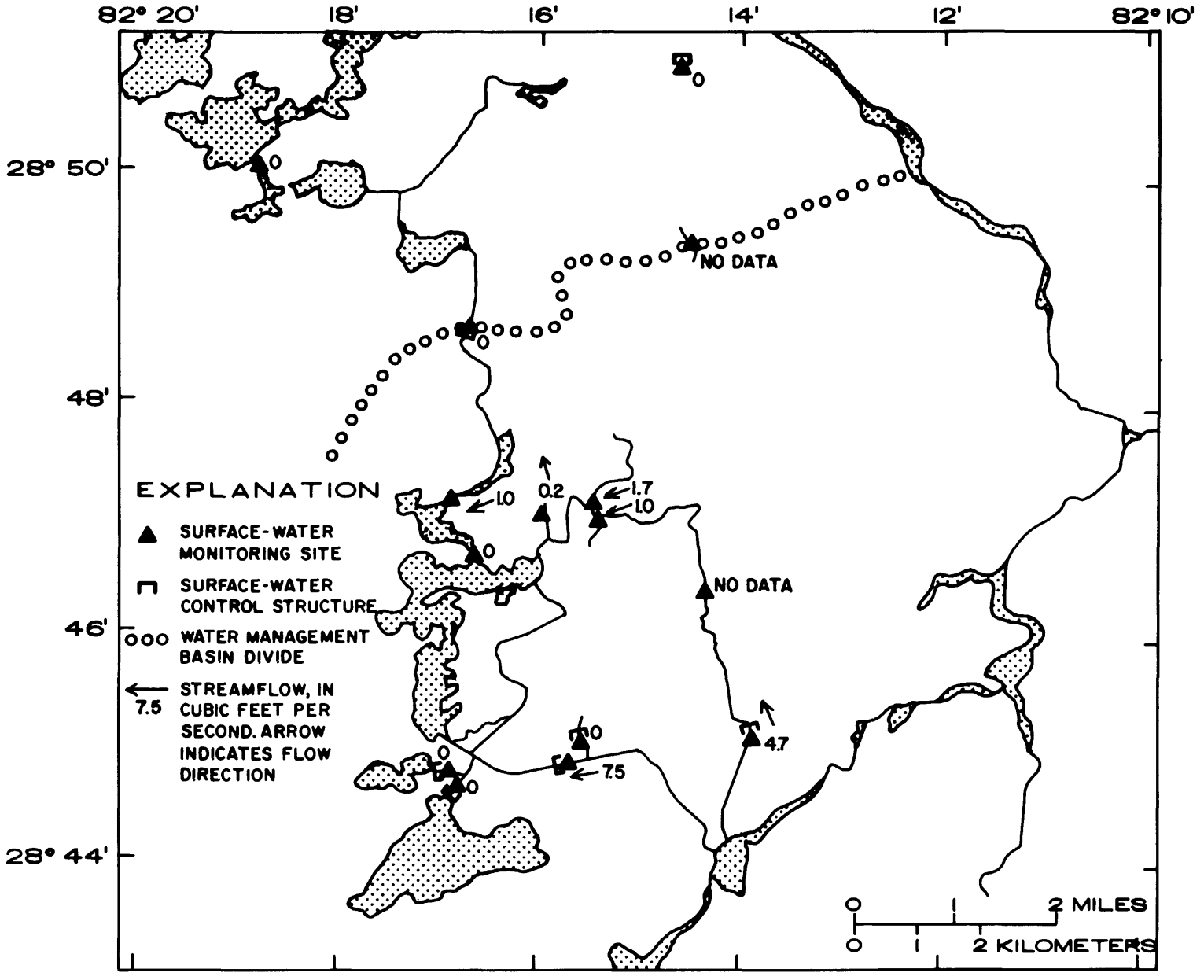

Figure 16.--Streamflow during middle-range water levels (39 to 41 feet elevation) of the Floral City Pool, June 4, 1986.

When the Leslie-Heifner and Orange State Canals are closed to prevent reverse flow to the river, there is still flow from the wetlands through site 3 and site 7 into Lake Hampton and Floral City Lake. This flow indicates that the lakes are more dynamic than the wetlands. Whether the flow comes from surface water or ground water is not known, but drainage from the wetlands continues as long as the pool level drops and until the water level at site 3 drops to 38.0 feet elevation, which is the elevation of the bottom of the canal.

Low-Range Water Levels

It is the usual practice of SWFWMD to close structures during low-range water levels (below 39.0 feet elevation). On March 25, 1985, the Floral City Pool water levels had dropped to an elevation of 38.39 feet, with no inflow entering the Floral City Lake except at site 3 (2.2 ft^3/s) (fig. 17). At approximately 38.5 feet elevation, the inflow from the Withlacoochee River to the Orange State and Leslie-Heifner Canals ceases because of the emergence of the canal bed. Water levels of the river and the Floral City Pool begin diverging at this point. By the time the Floral City Lake drops to 38.0 feet elevation, it is virtually isolated from any inflow point other than seepage from adjoining wetlands.

1985--A YEAR OF EXTREMES

The 1985 water year (October 1, 1984, through September 30, 1985) was not a typical hydrologic year in the Withlacoochee River basin. A prolonged dry period was prevalent from October 1984 through June 1985, followed by an extremely wet period, of greater than normal rainfall. In a typical year, water levels rise in the river at least twice, once in late summer and once in winter. From October until January or February, the river is fed by ground-water inflow and the river remains between 40.0 and 41.0 feet elevation (see duration curve in fig. 13). In January or February, there is a shorter wet season with less rainfall, but the river rises enough during that time to recharge the ground-water system in the vicinity. From March until mid-June, there is another period of steady flow, indicated by duration curves for most sites in the area, that gradually decreases as the length of time between rains increases. The summer rains that begin in mid-June and end in late September cause both surface runoff and ground-water recharge. The surface runoff from mid-June through September can amount to large volumes of flow, but the river usually drops to a somewhat steady state by October.

By October 1, 1984, the summer rainy season had ended and the Withlacoochee River started to drop quickly below 41.0 feet elevation. Reverse flow was measured in the Orange State Canal on October 7 and the structure gates were closed October 9, 1984, to prevent any additional loss of water from the Floral City Pool. No significant rains occurred in January and February 1985; therefore, the beginning of the dry season started with much lower water levels than in previous years. The gates on all the structures remained closed from October 9, 1984, through March 25, 1985. Until the beginning of March, the Floral City Lake remained higher than the river, thereby creating a reverse flow potential through the Orange State Canal and possibly through the Leslie-Heifner Canal. When the structure in the Orange State Canal was

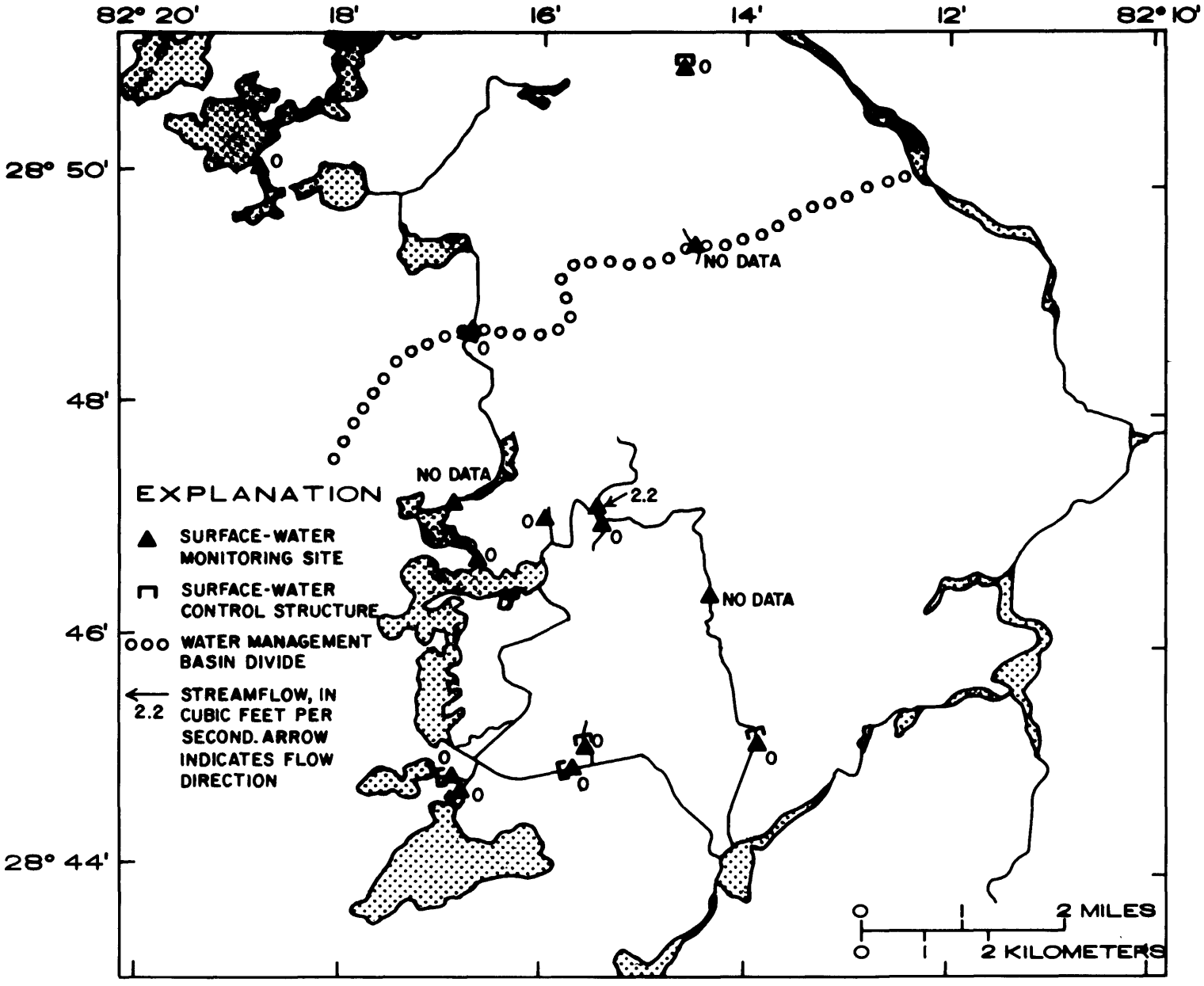

Figure 17.--Streamflow during low-range water levels (below 39 feet elevation) of the Floral City Pool, March 25, 1985.

opened, there was an initial flush of water through the canal for approximately a week, but afterwards the flow dropped to zero. Flow through the Leslie-Heifner Canal was negligible because the point of zero flow in the canal was higher than the Withlacoochee River.

The extended dry period continued through June 12, 1985, and nearly equaled the dry period of 1981-82. If rains had not been sufficient through August and September to fill the lake to desired levels set by SWFWMD, the low lake levels would have continued. The 1981 dry period extended through July, dropping water levels to an elevation of 35.79 feet at the Floral City Lake gage. Minimum level for 1985 was 36.08 feet on June 12, 1985, at the lake gage.

Flow to the lake virtually ceases after water levels in the area drop below 38.0 feet elevation. The only inflow to the Floral City Lake and Lake Hampton is reverse flow from Tussock Lake into Lake Hampton, but the flow is very small in the overall water budget. This flow is not measurable at site 1 on the canal between Lake Hampton and Floral City Lake. With cessation of flow and the increasing evapotranspiration due to the high temperatures during May, the lake level began dropping as much as 0.04 ft/d (0.48 in/d). To counteract the drop of 0.04 ft/d in Floral City Lake and Lake Hampton, an estimated surface-water inflow of 28 acre-ft/d, or 14.1 ft^3/s would be needed for a 700-acre surface-area lake if rainfall for that day was deficient.

After June 12, 1985, the levels began rising in the Orange State and Leslie-Heifner Canals, but flow did not rise above 5 ft^3/s until August. The bottom elevation at the Orange State Canal structure is approximately 37.85 feet elevation, but a sandbar under the bridge near the Floral City Lake gage was restricting flow at water levels up to approximately 38.4 feet elevation. Thus, the canal was slowly flowing into the lake by the Ferris Canal, which is on the east side of Duval Island. The reach of the Orange State Canal under the main channel bridge was deepened on June 25, and flow began entering the lake through the canal. By mid-September, the Withlacoochee River had reached a fairly high elevation of nearly 43.5 feet. Measured flow through the Orange State Canal was 192 ft^3/s on September 26. Flows are not normally this high because the river does not usually rise above 43.0 feet elevation.

WATER QUALITY

Floral City Pool

The quality of the water in the Floral City Pool is quite variable due to inflow from the Withlacoochee River. During times of heavy rains, the inflow is mostly runoff from swamps and has a low mineral content and low pH. During periods of medium or low flow from the river, the water contains constituents dissolved from the particulate phase while the water was in the river, and from dissolved constituents inherent to water from the Upper Floridan aquifer. When the lake has no inflow at all, the water has a higher algal content which raises the pH, and, during the day, accounts for a higher dissolved oxygen concentration, but the dissolved constituent concentration remains stable. At times, the lake water appears very brown and turbid. Analyses indicate that this condition occurs because of the presence of blue-green algae and because the water is high in color and organic carbon (swamp water in most cases).

The mineralization of water samples from a survey of 29 different sites in Floral City Lake, Lake Hampton, and Tussock Lake indicates that very little change occurs through the flow system of the Floral City Pool. Variation between each site may be influenced by lake depth and inflow from the shoreline as well as mixed water from inflow. An intense sampling series in April 1986, indicated that specific conductance ranged from 151 μS/cm in the southern part of Floral City Lake to 132 μS/cm in Tussock Lake, the most northern lake of the flow system. Seasonally, specific conductance ranges from approximately 100 to 300 μS/cm.

Dissolved oxygen, pH, and other parameters may be affected by residence time of surface-water flow, high algal content during warm seasons, and depth of water and water movement over the nutrient-rich bed sediments in the wetlands. In April 1986, dissolved oxygen ranged from 3.9 mg/L in Tussock Lake to 7.3 mg/L in the southern part of Floral City Lake. Most of Floral City Lake sites ranged from 5.7 to 7.3 mg/L dissolved oxygen.

Canals and River

Because of flow from the river, the water quality of the canals is basically the same as the river. Only during periods of little or no flow in the canals can ground water seepage affect water quality in the canals. Historically, water quality of the river shows a low level of dissolved constituents (Kimrey and Anderson, 1987). The periods of higher flow show lower pH, specific conductance, and nutrients, indicating the effect of rainfall and runoff from swamps. During periods of low flow, pH, specific conductance, and dissolved constituents, such as calcium and magnesium, indicate that inflow is from the Upper Floridan aquifer. Specific conductance of water samples from the Withlacoochee River near Floral City has ranged from 69 to 332 μS/cm during the period of record.

Ground Water

Water from the Upper Floridan aquifer is generally of good quality and does not vary significantly. Water quality is variable in the surficial aquifer system and insufficient data exist to accurately define its constituent concentration. Color and iron concentration, the only problems for public supply in the area, are easily reduced by treatment.

HYDROLOGIC CONSIDERATIONS FOR WATER MANAGEMENT

The purpose of the study was to determine the hydrologic conditions that most affect the dynamic change in water levels in the Floral City Pool. Various hydraulic practices on the major hydrologic components in the system, inflow and outflow, may influence these prevailing conditions.

Inflow to the pool is affected by water level of the Withlacoochee River, water-level gradient between the river and the Floral City Pool, and prevailing conditions in the canals. Outflow is affected by water-level gradient between the Floral City Pool and the Inverness Pool and by the condition of the canals. Listed in the following sections are some possible methods for future hydraulic manipulations that may assist in maintaining desired, stable lake levels.

Inflow to the Lake System

Withlacoochee River

Water levels for the Withlacoochee River near Floral City are controlled by SWFWMD through manipulation of the inflatable part of the Wysong Dam at Carlson, approximately 7 miles downstream of the Floral City gage. Comparison of water-level profiles on the river before and after construction of the dam (fig. 12) shows that dam manipulation can result in higher levels of the river reach between Wysong Dam and Floral City for low- and middle-range water levels. The dam is deflated during high-range water levels because the velocity of the river would damage the dam. Water levels high enough (greater than 39.0 feet elevation) to induce flow down the Orange State and Leslie-Heifner Canals cannot be maintained by the Wysong Dam during an extended dry period.

Raising middle-range water levels of the river cause higher flows through Orange State and Leslie-Heifner Canals. In most times of potential reverse flow through the canals, the fall from the river to the pool is less than -0.10 foot. If the fall from the river to the pool changed from -0.05 to +0.05, the flow in Orange State Canal would change from approximately -6 ft^3/s (if controls were open) to approximately +12 ft^3/s, a total change of 18 ft^3/s to the lake. This change would be 12 ft^3/s if controls were always closed during periods of potential reverse flow. This change in flow would probably counteract about 0.01 ft/d of decline in water levels in the main body of the Floral City Pool. In most periods when middle-range water levels occur, the Floral City Pool declines approximately 0.01 to 0.02 ft/d. This additional inflow may maintain stable water levels in the Floral City Pool for extended periods, and for reduced periods when the pool drops to low-range water levels.

The effects of raising water levels at the dam as much as 1.0 foot higher, at low- to middle-range levels could have detrimental effects. The higher levels at the dam could influence the levels of Outlet River and Lake Panasoffkee, perhaps causing problems such as high water levels, lower streamflow, and deteriorating biological conditions. Although there would still be a gradient in water levels for downstream flow, increased recharge to the Upper Floridan aquifer would be occurring through the bed of the river. The estimated rise of 0.10 foot at the Floral City gage to 1.0 foot rise at the dam may not occur due to increased ground-water recharge.

Canals

Reverse flow can occur when lake levels are higher than river levels and the gates are open. The streamflow in the canals is closely monitored by the SWFWMD during critical times, such as October and March, when the river levels drop quickly after seasonal rainfall ends.

The conveyance capacities of the canals are probably lower at present than in 1962 when the canals were cleaned and dredged so that navigation was possible. Since that time, the bottom of the channels have accumulated debris and very little water flows through the canals when the water level is below 39.0 feet elevation. This situation may have compounded the low-flow or no-flow condition for several months in 1985, even with the structure gates open.

The Orange State Canal structure has a bottom elevation of 37.85 feet, and Leslie-Heifner Canal structure has a bottom elevation of approximately 35.0 feet. High-velocity streamflow may remove the top layers of debris and partially clean the canals, but this action would result in moving the debris into the lake.

Sites 1-7 in the lake system can be considered as both input and output locations. Most of the canals are kept free of weeds by boat traffic and by county maintenance, but mucky debris on the canal beds restricts some of the conveyance capacity of each canal.

Outflow from the Lake System

Canals

The total outflow of the Floral City Pool is through two main channels, the Golf Course Canal and Moccasin Slough. Moccasin Slough carries considerable uncontrolled flow during extreme high water, thereby affecting water-management practices in the downstream Inverness Pool and Hernando Pool.

If flow through Moccasin Slough were controlled, the flow of surface water to the Inverness Pool could be maintained by flow through the Golf Course Canal structure. The main benefit of controlled flow through Moccasin Slough would be a rise in water levels in the wetland areas of the Floral City Pool. Water levels in the wetland areas would depend on the amount of seepage to the Upper Floridan aquifer and surficial aquifer system in the area, as well as evaporation and transpiration. If higher water levels in the wetlands can be maintained, they could continue feeding the main lake body of Floral City Pool for a longer period of time.

The structure in Leslie-Heifner Canal can restrict water until river-water levels reach 44.0 feet elevation. Above 44.0 feet, Leslie-Heifner Canal gates are overtopped, and Dead Lake adjacent to the Withlacoochee River overflows into the Leslie-Heifner Canal below the structure (fig. 2). At these high levels, uncontrolled flow will travel to the Floral City Pool and to the Inverness Pool through Moccasin Slough with the present surface-water flow system.

The Bryant Slough control structure is also an integral part of the flow system in the area. Although the location is in the designated Inverness Pool, the maintenance of surface-water levels at a minimum of 40.0 feet elevation is helpful in maintaining both ground-water and surface-water levels in Moccasin Slough. This restriction of surface-water levels will cause less flow to move through the Moccasin Slough area from the wetlands adjacent to the Floral City Pool. This also reduces the loss of surface water to recharge of the Upper Floridan aquifer by keeping the vertical gradient low along the river (fig. 8).

SUMMARY

The lake chain in west-central Florida known as Tsala Apopka Lake has a surface area of approximately 19,000 acres. It is divided into three water-management pools, the Floral City Pool, the Inverness Pool, and the Hernando

Pool, in downgradient order. The Floral City Pool is an extensive combination of open-water bodies of lakes with wetlands and connecting canals, covering an area of approximately 4,750 acres when lake levels rise to above 41.0 feet elevation. Floral City Lake and Lake Hampton, the largest lakes of the Floral City Pool, total about 700 acres during extended dry periods when water levels decline below 37.0 feet elevation. These two lakes are connected until levels decline below 35.0 feet elevation. Pool depths are generally shallow, with no depressions deeper than 14 feet in Floral City Lake when the lake level is at an elevation of 40.25 feet. The eastern part of the pool is less than 5 feet deep and contains dense, emergent vegetation.

Less than normal rainfall occurred in 1984 and early 1985, resulting in a cumulative deficit of 19.4 inches of rainfall from August 1984 through May 1985. As the dry period continued, the Floral City Pool began receding due to lack of inflow. The Inverness Pool of Tsala Apopka Lake did not recede as low as the Floral City Pool because it received inflow from the wetlands of Moccasin Slough. During the time when the Floral City Pool was without surface-water inflow in May and June 1985, the Floral City Lake level declined about 0.04 ft/d (0.48 in/d). Floral City Lake and Lake Hampton, at a surface area of approximately 700 acres, would have had to receive 28 acre-ft/d (14.1 ft^3/s) of surface-water inflow, or 0.48 in/d of rainfall, during this time to have maintained the same water level. Actual surface-water inflow during this time is estimated to have been less than 1 acre-ft/d (0.5 ft^3/s).

Although the water levels of the Floral City Pool are affected by rainfall, rapid rises in water levels in the rainy season primarily are due to inflow from the Withlacoochee River. This inflow enters through the structures in Orange State and Leslie-Heifner Canals and through a small overflow canal located on the Orange State Canal above the main water-control structure. Outflow from the Floral City Pool is through the Golf Course Canal and the wetland area of Moccasin Slough. There is a water-control structure on the Golf Course Canal but flow through the Moccasin Slough area is uncontrolled.

Above-normal rainfall in August and September 1985 and normal rainfall conditions through 1986 brought lake levels back to desired management levels. High-range water levels (above 41.0 feet) on the Withlacoochee River influenced flow in the Orange State and Leslie-Heifner Canals by pushing large volumes of water through the canals into the Floral City Pool and downgradient areas. The water level of the Floral City Pool rose 6.2 feet between June 10 and September 27, 1985. During that time, rainfall at Inverness was recorded at 3.3 feet.

Inflow from the Withlacoochee River was also allowed to travel through the Floral City Pool downgradient to the Inverness Pool when water levels began rising in the Floral City Pool. The Golf Course Canal water-control structure was opened in August and September 1985 to allow water to flow downgradient to the Inverness Pool. At the same time, uncontrolled flow was also moving through Moccasin Slough downgradient into the Inverness Pool. Streamflow through the Golf Course Canal structure and Moccasin Slough were almost equal near the end of September 1985. By the end of September and beginning of October 1985, inflow to the Floral City Pool (340 ft^3/s) nearly equaled the outflow from the pool (338 ft^3/s).

At middle-range water levels from 39.0-41.0 feet elevation, backwater conditions are present about 50 percent of the time in the canals that extend between the Withlacoochee River and the Floral City Pool. The variable fall between the two water bodies can become negative; that is, the elevation of the Floral City Pool is higher than that of normally upgradient Withlacoochee River, creating a potential for reverse flow. Structures placed on the canals are usually closed during these periods of potential reverse flow.

Ground-water recharge and discharge play important roles in the hydrologic cycle in the area. The bottom of the Withlacoochee River is possibly connected to the Upper Floridan aquifer in some areas between State Road 48 and the Wysong Dam. The river gains water from the Upper Floridan when the potentiometric surface of the aquifer is higher than the river water level, and loses water when the potentiometric surface is lower than the river water level. A comparison of ground-water and surface-water levels near the Floral City Lake indicates that the Upper Floridan aquifer appears to be receiving recharge from the lake. The Inverness Fault is thought to inhibit the flow of ground water from the eastern section of the study area. The potentiometric surface dips steeply westward from the Floral City Pool.

Streamflow volumes to the Floral City Pool are affected by the water level of the Withlacoochee River. Backwater effects from the Wysong Dam during water levels below 41.0 feet elevation have helped raise levels upstream past the entrance of the canals at Bonnet Lake. The dam is effective in maintaining water levels as high as 0.75 foot higher than preconstruction data indicate.

Analysis of streamflow patterns of the various canals that are connected to the Floral City Pool indicates that Orange State Canal is the main conveyance for volume of water into the pool, but Leslie-Heifner Canal continues feeding the pool for a longer period of time as water levels decline. Outflow is through several canals, eventually exiting through the Golf Course Canal and Moccasin Slough.

Streamflow input from the Withlacoochee River and Floral City Pool ranged from 340 to as much as 600 ft^3/s in September 1985, to zero flow. Middle-range flow (water levels between 39-41 feet) ranges from approximately 10 to 30 ft^3/s. The middle-range flow from the Withlacoochee River usually is dependent on backwater.

Water quality of the pool is variable, mainly due to the characteristics of the inflow water. Most of this inflow and lake water is dark colored and contains low amounts of dissolved constituents. Quality of ground water from the Upper Floridan aquifer is also similar in constituents because of abundant recharge capacities of the area, but usually the ground water has less color than lake or river water.

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