Hydrology and Water Quality of Lakes and Streams in Orange County, Florida

By Edward R. German and James C. Adamski

Prepared in cooperation with the

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Conversion Factors, Vertical Datum, Acronyms, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch per year (in/yr)	25.4	millimeter per year

*The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Temperature in degrees Fahrenheit (° F) may be converted to degrees Celsius (° C) as ° C = (° F-32)/1.8.

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Horizontal coordinate information (latitude-longitude) is referenced to the North American Datum of 1927 (NAD 27).

CV	coefficient of variation
DEET	N,N-diethyl-*meta*-toluamide
ET	evapotranspiration
FDEP	Florida Department of Environmental Protection
FEP	fluorinated ethylene propylene
GIS	geographic information system
LOWESS	locally weighted scatterplot smoothing
MCL	maximum contaminant level
µg/L	micrograms per liter
µm	micrometer
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
mL	milliliter
NOAA	National Oceanographic and Atmospheric Administration
NWIS	National Water Information System
n	number
PTFE	polytetrafluoroethylene
RIBs	rapid infiltration basins
R^2	coefficient of determination
SWIM	Surface Water Improvement and Management
TN/TP	total nitrogen to total phosphorus
TSI	tropic state indexes
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Hydrology and Water Quality of Lakes and Streams in Orange County, Florida

By Edward R. German and James C. Adamski

Abstract

Orange County, Florida, is continuing to experience a large growth in population. In 1920, the population of Orange County was less than 20,000; in 2000, the population was about 896,000. The amount of urban area around Orlando has increased considerably, especially in the northwest part of the County. The eastern one-third of the County, however, had relatively little increase in urbanization from 1977-97. The increase of population, tourism, and industry in Orange County and nearby areas changed land use; land that was once agricultural has become urban, industrial, and major recreation areas. These changes could impact surface-water resources that are important for wildlife habitat, for esthetic reasons, and potentially for public supply. Streamflow characteristics and water quality could be affected in various ways.

As a result of changing land use, changes in the hydrology and water quality of Orange County's lakes and streams could occur. Median runoff in 10 selected Orange County streams ranges from about 20 inches per year (in/yr) in the Wekiva River to about 1.1 in/yr in Cypress Creek. The runoff for the Wekiva River is significantly higher than other river basins because of the relatively constant spring discharge that sustains streamflow, even during drought conditions. The low runoff for the Cypress Creek basin results from a lack of sustained inflow from ground water and a relatively large area of lakes within the drainage basin.

Streamflow characteristics for 13 stations were computed on an annual basis and examined for temporal trends. Results of the trend testing indicate changes in annual mean streamflow, 1-day high streamflow, or 7-day low streamflow at 8 of the 13 stations. However, changes in 7-day low streamflow are more common than changes in annual mean or 1-day high streamflow.

There is probably no single reason for the changes in 7-day low streamflows, and for most streams, it is difficult to determine definite reasons for the flow increases. Low flows in the Econlockhatchee River at Chuluota have increased because of discharge of treated wastewater since 1982. However, trends in increasing 7-day low streamflow are evident before 1982, which cannot be attributed to wastewater discharge.

Some of the increases in 7-day low flows may be related to drainage changes resulting from increased development in Orange County. Development for most purposes, including those as diverse as cattle grazing and residential construction, may involve modification of surface drainage through stream channelization and construction of canals. These changes in land drainage can lower the water table, resulting in reductions of regional evapotranspiration rates and increased streamflow. Another possible cause of increasing low flows in streams is use of water from the Floridan aquifer system for irrigation. Runoff of irrigation water or increased seepage from irrigated areas to streams could increase base streamflow compared to natural conditions.

Water-level data were analyzed to determine temporal trends from 83 lakes that had more than 15 years of record. There were significant temporal trends in 33 of the 83 lakes (40 percent) over the entire period of record. Of these 33 lakes, 14 had increasing water levels and 19 lakes had decreasing water levels. The downward trends in long-term lake levels could in part be due to high rainfall accumulation in 1960-1961, which included precipitation from Hurricane Donna (September 1960). The high rainfall resulted in historical high-water levels in many lakes in 1960 or 1961.

A large range of water-quality conditions exists in lakes and streams of Orange County (2000-01). Specific conductance in lake samples ranged from 57 to 1,185

microsiemens per centimeter. Values of pH ranged from 3.2 to 8.7 in stream samples and 4.6 to 9.6 in lake samples. Total nitrogen concentrations ranged from less than 0.2 to 7.1 milligrams per liter (mg/L) as nitrogen in stream samples, and from less than 0.2 to 6.0 mg/L as nitrogen in lake samples. Concentrations of total nitrogen less than 1.0 mg/L as nitrogen are considered background levels. Concentrations of total nitrogen greater than about 1.6 to 2.0 mg/L as nitrogen probably are considered elevated and could indicate contamination from surface runoff. The most commonly detected trace elements in streams were aluminum, barium, boron, iron, manganese, and strontium.

Water-quality data from four sites (Econlockhatchee River, Boggy Creek, Bonnet Creek, and Whittenhorse Creek) had significant temporal trends in at least two of the seven constituents. Values of specific conductance and concentrations of chloride increased at the Boggy Creek, Bonnet Creek, and Whittenhorse Creek sites. Bicarbonate concentrations increased at the Econlockhatchee River, Boggy Creek, and Bonnet Creek sites. Sulfate concentrations increased at the Boggy Creek site. Concentrations of nitrite plus nitrate and ammonia plus organic nitrogen decreased at the Econlockhatchee River site. Phosphorus concentrations significantly decreased at the Econlockhatchee River and Boggy Creek sites. Many of these changes probably are related to changes in land use. However, decreased nitrogen and phosphorus concentrations in the Econlockhatchee River site near Chuluota are the result of constructing a waste-water treatment facility in 1982, providing secondary treatment of wastewater discharged into the river. This facility was upgraded to include nitrogen and phosphorus removal on the Little Econlockhatchee River, a tributary of the Econlockhatchee River.

Multiple sources probably contribute to the occurrence of pesticides that were detected in surface water. The most commonly detected pesticides were atrazine, prometon, simazine, tebuthiuron, and diazinon. Atrazine had the highest concentration (0.716 microgram/liter). Because the surface-water samples were collected during baseflow, runoff probably did not contribute to pesticide concentrations in streams. However, runoff to lakes during wet periods could have contributed pesticides, which can persist during dry conditions. Pesticide detections in samples from relatively pristine sites, such as the pond at Tosohatchee State Reserve, indicate that airborne sources could contribute pesticides to surface water in Orange County.

Introduction

Surface-water resources are important for wildlife habitat, for esthetic reasons, and potentially for potable supply. Over approximately the past 30 years, Orange County and surrounding counties have become a major tourist destination for people from all over the world, beginning with the opening of Walt Disney World in 1971. The increase of population, tourism, and industry in Orange County and nearby areas has altered land use, that is, land that was agricultural has become urban, industrial, and major recreation areas. These changes have the potential to affect streamflow characteristics and water quality in various ways.

There have been major changes in wastewater treatment methods over approximately the past 30 years that have a bearing on water quality. Beginning in 1972, Federal Water Pollution Control Act Amendments, commonly referred to as the Clean Water Act, has provided federal funding to local governments for upgrading wastewater treatment systems. The overall pattern of change has been for numerous small treatment plants to consolidate into large regional treatment centers that provide a greater degree of wastewater treatment than the smaller plants that were replaced. Also, there has been a reduction or complete removal of wastewater discharge to streams (including Reedy Creek, Shingle Creek, Little Econlockhatchee River, and Little Wekiva River) since the late 1980s.

The last comprehensive hydrologic investigation of Orange County was conducted by Lichtler and others (1968) of the U.S. Geological Survey (USGS). Since that time, the USGS and other State and local agencies have collected more hydrologic information about the surface- and ground-water resources of Orange County and surrounding areas. To provide a compilation and interpretation of the additional data, the USGS in cooperation with the City of Orlando, the Orange County Public Utilities, the Orlando Utilities Commission, the Reedy Creek Improvement District, the South Florida Water Management District, and the St. Johns River Water Management District began a 4-year study in 1998. The principal objective of this study is to provide an assessment of surface-water conditions in Orange County including basin hydrology, streamflow statistics, lake levels, and water quality. The data and findings of the study will be useful to the public and to officials who are responsible for planning, developing, and managing the water resources of Orange County and the east-central Florida region.

Purpose and Scope

This report documents hydrologic and water-quality conditions in selected streams and lakes of Orange County, Florida. This report summarizes rainfall data from 1932-2000 at nine stations operated by the National Oceanographic and Atmospheric Administration (NOAA). Daily records for 13 USGS streamflow stations were reviewed to summarize low, mean, and high streamflow conditions during 1934-2000. Low- and high-frequency statistics and duration curves were computed. Periodic lake-level measurements by the USGS and Orange County at 83 lakes during 1933-1998, historical water-quality data collected by the USGS and the Orange County Environmental Protection Division during 1960-2000, and water quality data from 24 lakes and 11 stream sites collected by the USGS and Orange County during 1999-2001 are presented. Trends in lakes levels, streamflow, and water quality are identified and discussed. Areal patterns in water quality are examined; the effect of land use on selected hydrologic characteristics is discussed. This report is one of two reports summarizing the water resources of Orange County. Ground-water data and interpretations are presented in Adamski and German (2003).

Previous Investigations

The USGS has conducted surface-water resource studies in Orange County for more than 30 years. Anderson and Joyner (1966) described the availability and quality of surface water. Lichtler and others (1968) reported on both ground- and surface-water conditions in Orange County. Lichtler and others (1976) investigated the hydrologic connection between ground water and three lakes in the Orlando area. Phelps and German (1995), Smoot and Schiffer (1985), German (1983), Gaggiani and Lamonds (1977), and Pfischner (1968) described the hydrology and quality of water in selected Orange County lakes. Schiffer (1989) described the effects of urban runoff on the water quality of wetlands in the metropolitan Orlando area. Rumenik and Grubbs (1996) reported statistics on low-flow characteristics of streams using data from the beginning of record through September 1987.

State and local government agencies, consultants, and universities also have completed numerous studies and reports. The following list is not comprehensive, but includes studies with information or data related to surface water in Orange County. Water quality and nonpoint loading in the Little Econlockhatchee Drainage basin are discussed in Harper and Herr (1966). Water quality, quantity, and suggested restoration measures for the Little Econlockhatchee River are discussed in Miller & Miller (1984). O'Dell (1994) discussed water quality in the Shingle Creek Basin before and after wastewater diversion. McCann and others (1998) described water quality of lakes in and around Orlando. The Little Wekiva River basin history is described in Woodward-Clyde Consultants (1998). Lake chemistry and water quality in Florida and Orange County were studied by Brezonik (1984), who developed a tropic-state classification system for Florida lakes. Other lake water-quality reports are available on the web page of the City of Orlando (2004).

Acknowledgments

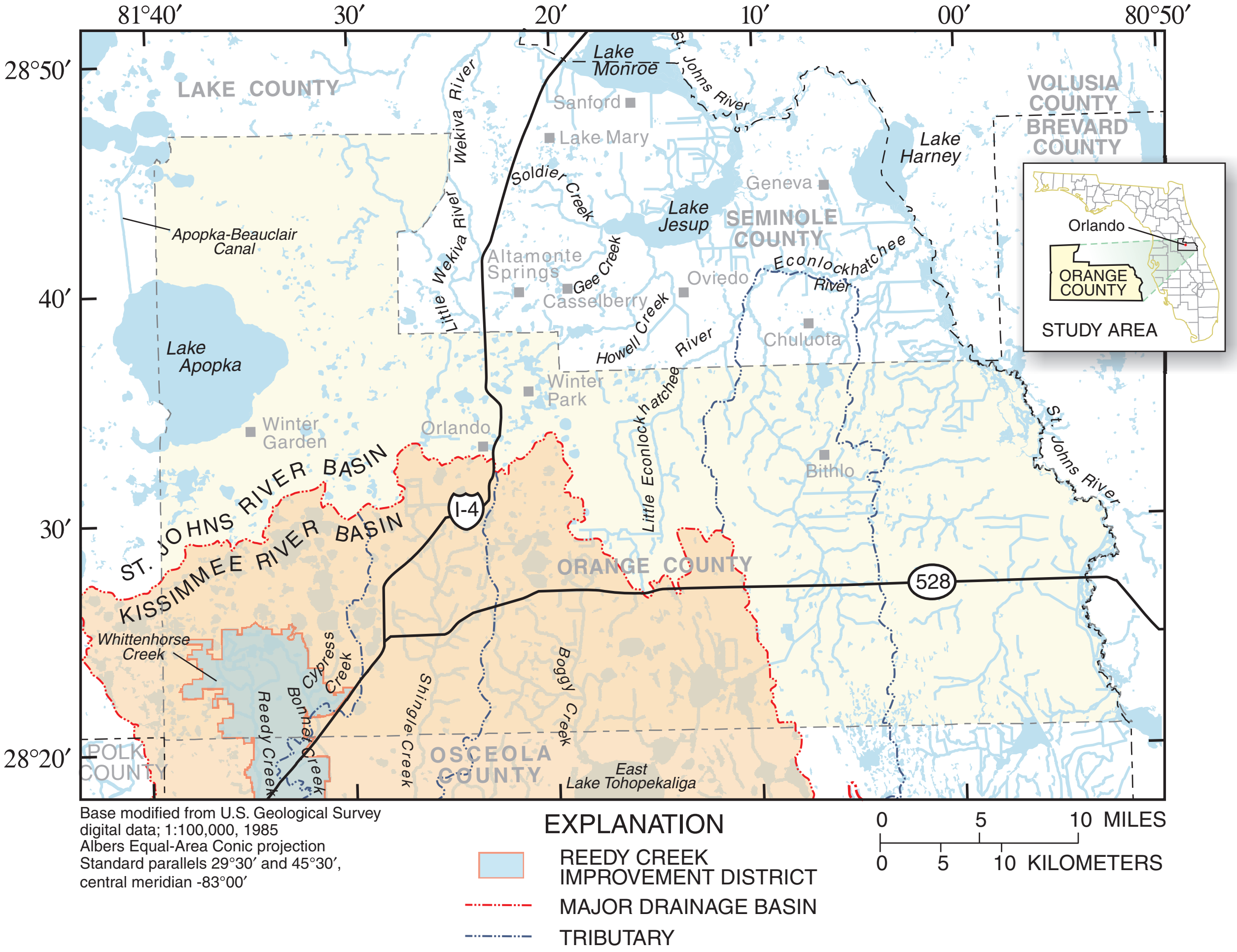
The authors express their appreciation to public officials of Orange County, the City of Orlando, and the Orlando Utilities Commission, whose cooperation and knowledge greatly aided this investigation. The authors are particularly grateful for land-use, lake-level, and water-quality data provided by the City of Orlando Stormwater Utility Bureau, Orange County Environmental Protection Division, Orange County Planning Division, and Reedy Creek Improvement District. The authors also are grateful for access to land owned by the City of Orlando, Orange County, the State of Florida, and private land owners.

Description of the Study Area

Orange County, in the east-central part of the Florida peninsula (fig. 1), encompasses about 1,003 square miles (mi^2); 916 mi^2 are land and the remainder is surface-water bodies. Orlando and surrounding communities (including Winter Park, Altamonte Springs, and others) are the major population centers in the County. Since 1971, the south-central part of Orange County has become a major recreational area with several large theme parks, hotel complexes, and golf courses that attract hundreds of thousands of tourists each year.

Environmental Setting

Orange County has a humid subtropical climate with relatively short, mild winters, and long, hot summers. The normal average annual temperature at Orlando is 72.3 degrees Fahrenheit (°F) and the normal average annual rainfall is about 49.9 inches (National Oceanic and Atmospheric Administration, 2001). More than one-half of the annual rainfall total generally occurs during June through September, commonly referred to as the wet season.

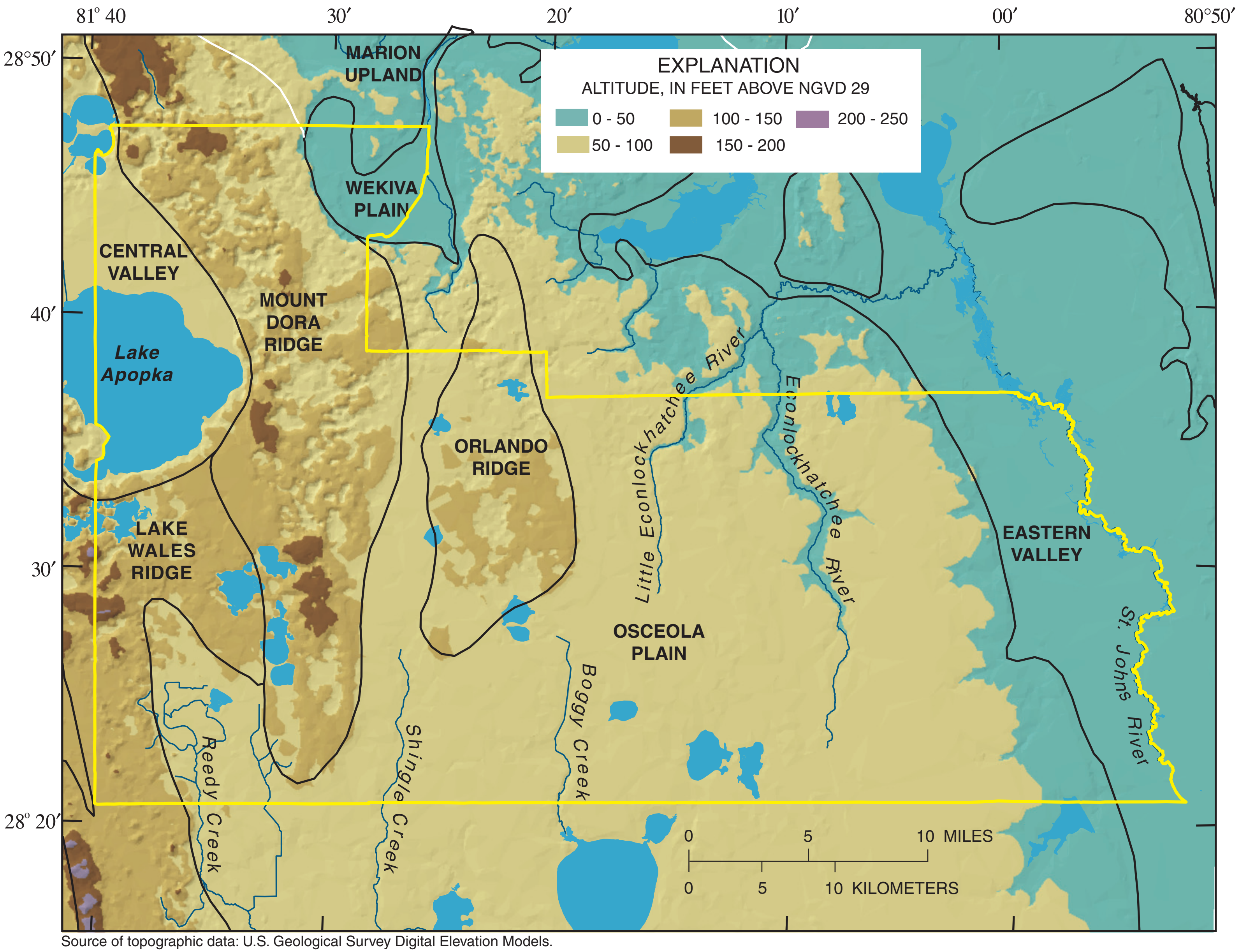


Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 1. Major cities and drainage basins in Orange County, Florida.

Three major hydrogeologic units are present in Orange County: the surficial aquifer, the intermediate confining unit, and the Upper Floridan aquifer. The uppermost surficial sediments consist mostly of quartz sand with varying amounts of clay and shell. The thickness of these sediments generally is about 40 feet (ft) but is greater in highland areas. These surficial sediments comprise the surficial aquifer system. Beneath the surficial sediments are sediments of Miocene to post-Miocene age that include the Hawthorn Group. The Hawthorn Group sediments include noncontinuous clayey sands and clay layers that in some areas retard the downward seepage of water from the surficial aquifer system. The thickness of this intermediate confining unit is variable; the unit is absent at some locations and as thick as 200 ft at other locations. Underlying the intermediate confining unit are the limestones of the Upper Floridan aquifer. The surface of the Upper Floridan aquifer has been modified by erosion; consequently the altitude of the top of the aquifer varies widely. Sinkholes, caused by dissolution of limestone combined with the gradual subsurface movement of unconsolidated sediments into these solution cavities, are common—particularly in higher, well-drained parts of the County. Most of the lakes in Orange County are of sinkhole origin.

Orange County lies in the Atlantic Coastal Plain described by Meinzer (1923, pl. 28). The County contains three topographic regions: (1) low-land regions where altitudes generally are less than 35 ft; (2) intermediate regions where altitudes are between 35 and 105 ft; and (3) highland regions where altitudes generally are above 105 ft. There are eight physiographic provinces within Orange County: the Central Valley, the Eastern Valley, the Lake Wales Ridge, the Marion Upland, the Mount Dora Ridge, the Orlando Ridge, the Osceola Plain, and the Wekiva Plain (White, 1958) (fig. 2). More detailed topographic descriptions of Orange County are given in Puri and Vernon (1964) and in Lichtler and others (1968).

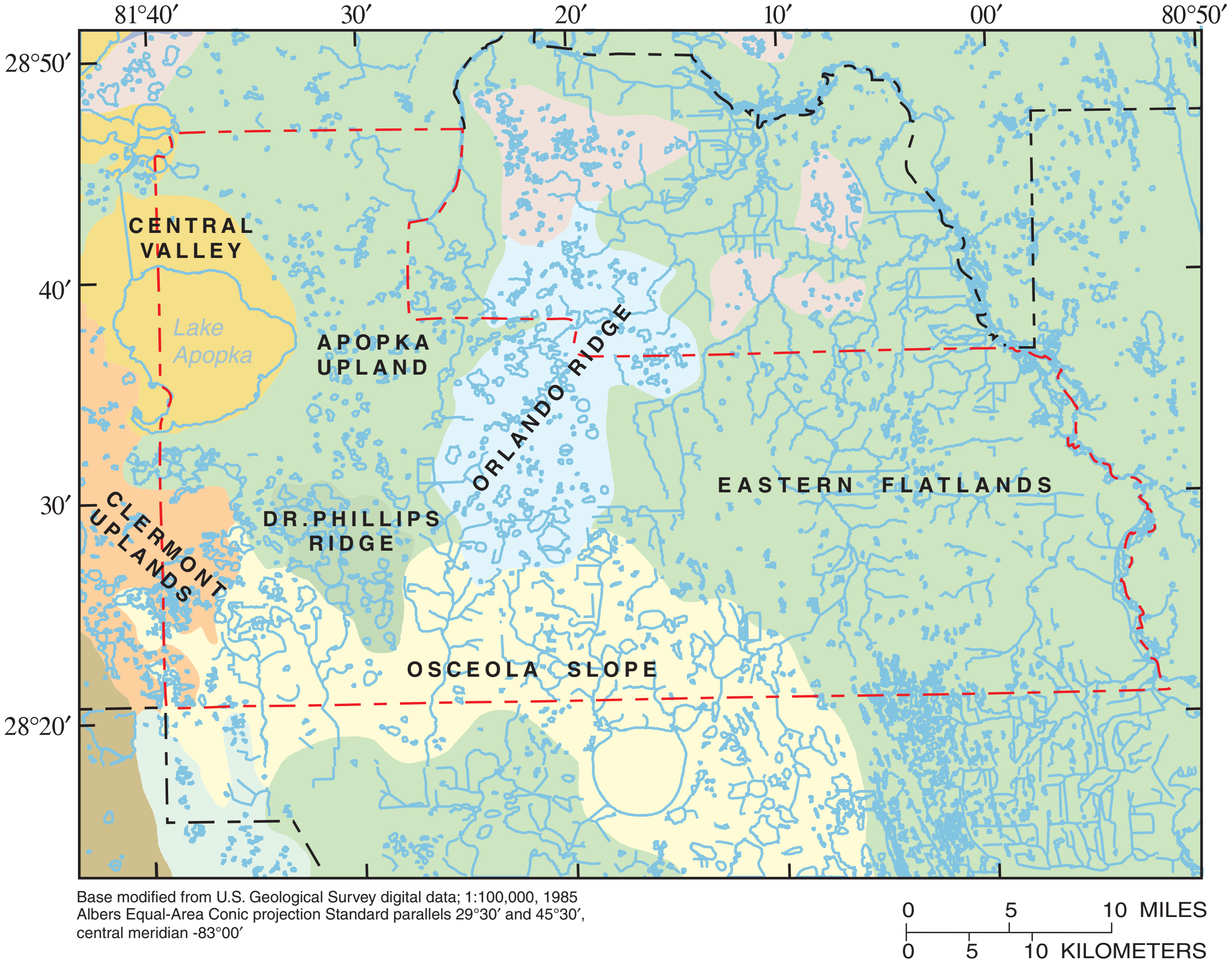


Source of topographic data: U.S. Geological Survey Digital Elevation Models.

Figure 2. Physiography of study area (modified from White, 1970).

The three topographic regions have different characteristics and extent of development. The lowland region includes the St. Johns River marsh, the northern part of the Econlockhatchee River basin, and areas in the northeast part of the County. These lowlands are within the Eastern Valley, the Wekiva Plain, and the Osceola Plain physiographic provinces (fig. 2). Most of the lakes (but not all) in the lowlands are part of the St. Johns River system. The lowlands are relatively unsuited for development because of a perennially high-water table that can be above the land-surface elevation during wet periods. Extensive drainage generally is required for any sort of development. The intermediate region occupies most of the middle part of the County between the lowlands to the east and the highlands to the west, and generally coincides with the Osceola Plain and the Central Valley provinces. This intermediate area is extensively developed in some places, and includes parts of the Orlando metropolitan area. The highlands lie within parts of the Orlando Ridge, the Mount Dora Ridge, and the Lake Wales Ridge in central and west Orange County (fig. 2). These highlands, which contain numerous internally drained lakes and depressions, are areas of effective recharge to the Floridan aquifer system and, thus, are important to Orange County's water supply. The highlands also are excellent for citrus cultivation and urban development. Prior to the severe freezes of 1983, 1985, and 1989, much of the highland areas were used for citrus cultivation. After the freezes, much of the land used to grow citrus trees was converted to urban and residential areas.

Lakes in Orange County can be classified using the lake region classification system of the U.S. Environmental Protection Agency. This system is useful in summarizing and comparing lake water-quality data, and is based primarily on physiography, soils, geology, natural vegetation, and land use and cover. In defining the lake regions, the goal was to "define a reasonable number of lake regions that appear to have some meaningful differences between them" (Griffith and others, 1997, p. 7). For Florida, 47 lake regions have been defined. Orange County includes all or parts of seven lake regions (fig. 3).



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 3. Lake regions of Orange County (modified from Griffith and others, 1997).

Surface Drainage

The source of most surface water in Orange County is rainfall, although some water flows into the County from adjacent areas of higher altitude. It is estimated that about 70 percent of the rain that falls on Orange County returns to the atmosphere by evaporation and transpiration, about 20 percent flows out of the County in streams, and about 10 percent is ground water outflow (Lichtler and others, 1968). Drainage wells drilled into the Upper Floridan aquifer dispose of an estimated 33 million gallons per day (Mgal/d) of excess surface drainage in the Orlando area (Tibbals, 1990).

Orange County contains parts of two major watersheds: the Kissimmee River basin and the St. Johns River basin (table 1). The Kissimmee River basin drains to the south and includes the headwaters of the Everglades system. Surface drainage from southwest and south-central Orange County is into the Kissimmee River basin. Streams within that basin discussed in this report include Bonnet Creek, Boggy Creek, Shingle Creek, Cypress Creek, Whittenhorse Creek, and Reedy Creek (fig. 1). The remaining part of the County (eastern and northern parts) lies within the St. Johns River basin. The St. Johns River defines the eastern boundary of Orange County; the river flows north and discharges into the Atlantic Ocean at Jacksonville. Other streams in the St. Johns River basin include the Little Econlockhatchee River, the Econlockhatchee River, the Apopka-Beauclair Canal, and Wekiva River (fig. 1).

Population, Land Use, and Water Use

Orange County is continuing to experience a large growth in population. In 1920, the population of Orange County was less than 20,000. In 1963, when Lichtler and others (1968) described the water resources of Orange County, the population had increased to about 290,000. In 2000, the population was about 896,000 (Marella, 2004). The increase in population has resulted in land-use changes. A comparison of land use in 1977 with land use in 1997 (fig. 4) shows that the amount of urban area increased around Orlando—from about 140 mi^2 (14 percent) in 1977 to about 220 mi^2 (22 percent) in 1997. Relatively little increase in urbanization between 1977-97 occurred in the eastern most one-third of the County.

Total water use in Orange County in 2000 was about 302 Mgal/d (fig. 5), about 95 percent of which was pumped from the Floridan aquifer system. Most of the usage of surface water is for agricultural irrigation, and until the early 1980s, was for power generation (Marella, 2004). Virtually all water used for public supply is ground water, and usage has increased from 77 Mgal/d in 1965 to 290 Mgal/d in 2000, or about a 280 percent increase (Marella, 2004). Some of the water pumped for public supply is transferred to Brevard County (about 26 Mgal/d, or 9 percent of the total public supply use in 2000). This relatively large increase in public-supply usage has been partially offset by a decline in agricultural usage from 1985 to 2000, so that total water use, inclusive of surface water, has increased from 186 Mgal/d in 1965 to 302 Mgal/d in 2000, or about a 62 percent increase (fig. 5). The decline in agricultural water use after 1985 probably was accelerated by the severely cold winters in the 1980s that badly damaged the citrus industry.

Data Collection and Analysis

Data described in this report include water quality, water level, rainfall, and rate of streamflow. Data-collection sites include streams and lakes. Data from past investigations of water resources by the USGS and other State and local agencies were compiled and analyzed, along with new data collected during this study.

Precipitation, Streamflow, and Lake Levels

Daily rainfall data are from nine meteorological stations operated by the NOAA. The rainfall records used to characterize climate of the study area and to develop simple rainfall-streamflow models for trend analyses are from stations shown in figure 6. Appendix A summarizes annual rainfall for the stations. The daily record at some stations begins in 1931.

The streamflow data for 13 stations described in this report are from the streamflow network operated by the USGS. These data consist of daily means of streamflow, from 1934 to 2000. Station locations are shown in figure 7.

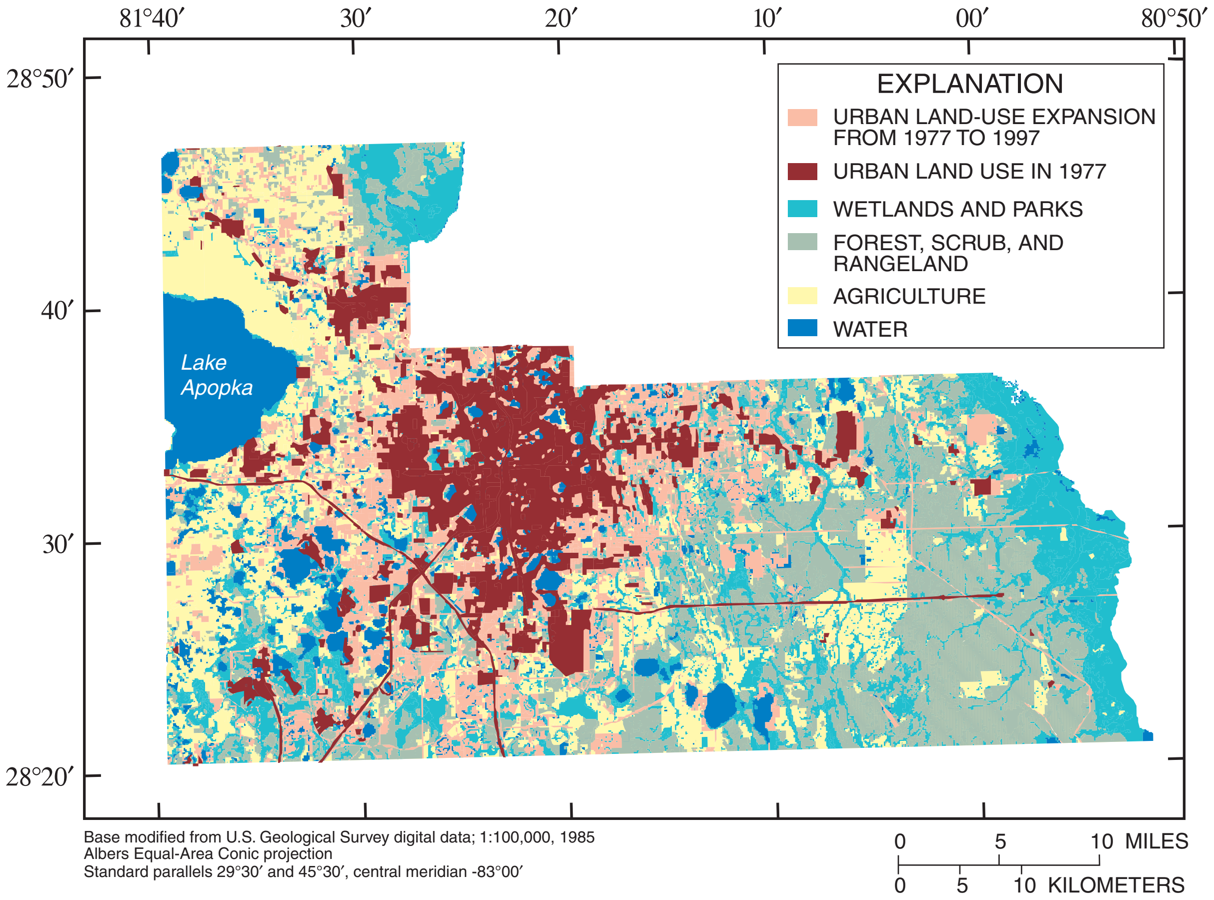
The lake water-level data were collected by the USGS or the Orange County Stormwater Management Division. For some lakes, both the USGS and Orange County maintained records of water levels, but generally not for the same time period. Data collected by USGS and Orange County were combined and analyzed to determine range in lake-level fluctuations and to look for long-term changes in water level. Records of water levels for one lake (Lake Butler) begin in 1933. Figure 8 provides the locations of lakes with more than 15 years of water-level record, each with at least four measurements per year. Appendix B summarizes water levels for these lakes.

Table 1. Characteristics of major drainage basins in Orange County, Florida.

[Basin locations are shown in figure 1]

Basin	Drainage area within Orange County (square miles)	Drains into	Basin relief (altitude, in feet)	Basin description and comments
Kissimmee River Basin				
Kissimmee River	350	Kissimmee River basin	Wide floodplain, low slope	Extensive wetlands in floodplain. Much of the floodplain is used for agriculture and cattle grazing.
Boggy Creek	86	Kissimmee River basin	60-125	Lower basin contains many swampy areas but few lakes. Upper basin has hills and numerous lakes.
Bonnet Creek	55	Kissimmee River basin	75-195	Flat, swampy terrain with several lakes and islands of low relief. Drainage extensively modified and controlled within the Reedy Creek Improvement District (RCID).
Cypress Creek	32	Kissimmee River basin	90-195	Swampy terrain is common along channel. Rolling hills characterize the eastern part of basin, with lakes in the headwaters. A relatively large part of the basin is lakes.
Reedy Creek	49	Kissimmee River basin	75-210	The eastern basin is generally flat, swampy terrain with islands of low relief. The western basin is generally rolling hills with lakes and swamps. Drainage extensively modified and controlled within the RCID. Received treated wastewater from RCID from 1972-1991.
Shingle Creek	83	Kissimmee River basin	70-175	Relatively flat except for hills on western edge. Received up to 22 million gallons per day treated wastewater from 1972 until 1991 when wastewater was diverted to the Conserv II project.
Whittenhorse Creek	12[a]	Reedy Creek	100-150	Swampy terrain is common along channel. Basin contains Bear Bay, a large swampy area. Hills with numerous sinks are adjacent to the swampy areas. The upland areas are used for citrus cultivation and urban developments.
St. Johns River Basin				
St. Johns River	664	Atlantic Ocean	Wide floodplain, low slope	Extensive wetlands in floodplain. Much of the floodplain is used for agriculture and cattle grazing.
Apopka-Beauclair Canal	120	Lake Dora	65-225	Mucklands near Lake Apopka. The canal conveys water from Lake Apopka to Lake Dora. Flow regulated by control structure.
Econlockhatchee River	117	St. Johns River	20-90	Basin contains areas of wetland forest and a few lakes. Area of rapid residential development.
Little Econlockhatchee River	71	Econlockhatchee River	35-127	Basin contains areas of wetland forest and a few lakes. Area of rapid residential development.
Wekiva River	130	St. Johns River	15-195	Wetlands near stream channels, changing to rolling hills with numerous sinks. Streamflow comprised mostly of spring discharge. Parts of river were designated wild and scenic.

[a] Includes drainage area from adjacent county.

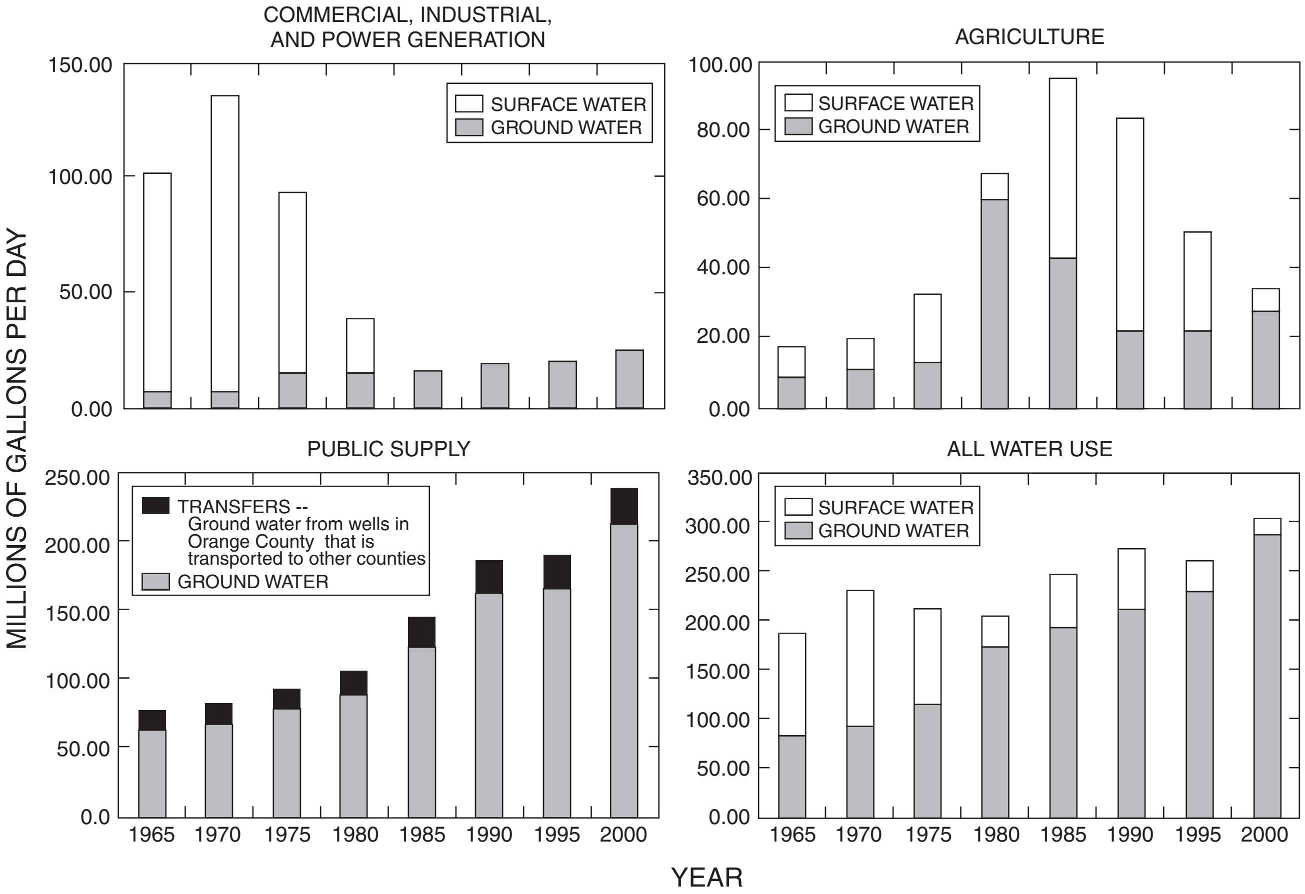


Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 4. Generalized land use in Orange County in 1997 (source: Orange County Growth Management Department), showing expansion of urban land use since 1977 (based on land-use classifications described in Anderson and others, 1976).

A nonparametric statistical procedure, the Kendall Tau test, was used to quantify temporal trends in rainfall, streamflow, and lake levels, and relations between constituent concentrations and streamflow. A trend is an overall increase or decrease in annual rainfall, lake level, or some annual streamflow characteristic—such as 7-day low flow during a selected period of time. The test was used to determine if changes are evidence of real trends, rather than just random sequences of variation that could be observed in a set of data with no real change with time. The test is nonparametric and is not affected by outlying values.

The Kendall Tau test is described in many textbooks and articles on statistical analysis, such as Conover (1980) and Helsel and Hirsch (1992). The test compares the magnitude of a quantity for each year of record with the magnitudes for all other years, and counts the number of concordant and discordant comparisons. A concordant result is one in which the tested quantity increased from one year to a later year; a discordant result is one in which the test quantity decreased from one year to a later year. The greater the number of concordant comparisons relative to the number of discordant results, the greater the probability of a trend for increasing values with time. Conversely, a greater number of discordant comparisons indicate a trend for decreasing values with time. The probability computed using the Kendall test procedure is that the relative abundance of concordant and discordant comparisons could be due to chance alone, based on the initial assumption (the null hypothesis) that there is no change in magnitude with time. Small probabilities indicate that there is little chance that a trend indicated by the test could have resulted from a random (and trendless) data set. In this study, a probability of 5 percent or less was the criterion for statistical significance. The Kendall Tau test does not guarantee the detection of trends in all situations. For example, if a tested quantity increased in value for part of the tested period of record and decreased in value for the rest of the period, statistical trend tests would likely indicate no significant trend for the entire period.



Note. Transfers refer to ground water from wells from Orange County that is transported to other counties for public supply. Totals for the chart showing all water use include recreational and domestic supply usage, as well as the other categories as shown above. Data from U.S. Geological Survey, 2004b.

Figure 5. Summary of water use in Orange County, 1965-2000.

Water Quality

Water-quality samples were collected from 11 streams during this study. In addition, water-quality data were available for four streams (Cypress Creek, Bonnet Creek, Whittenhorse Creek and Reedy Creek), as part of the USGS data-collection network. The numbers and types of water-quality samples are given in table 2. Locations of the water-quality stations are shown in figure 7.

During this study, 24 lakes were sampled (table 3). Five lakes were sampled seasonally (in the summer and fall of 2000 and in the spring of 2001); three lakes were sampled twice (table 3). The remaining 16 lakes were sampled once, generally coinciding with the final seasonal sample collections. Water-quality data from lakes were supplemented with data collected during 2000 and 2001 by the City of Orlando Stormwater Utility Bureau (230 samples from 73 lakes) and by the Orange County Environmental Protection Division (183 samples from 71 lakes). A number of lakes were sampled by more than one agency. Data from 140 lakes were compiled (appendix C). Locations of the lakes with water-quality data are shown in figure 9.

Field measurements (air and water temperatures, specific conductance, dissolved oxygen, and pH) were made and water-quality samples were collected at equal depth increments at each lake. At selected large lakes, field measurements were made at more than one location to assess the spatial variation of water quality in the lake. Field measurements were made and samples collected at equal width increments across the channel at each stream site. The field measurements were made in accordance with USGS protocols (U.S. Geological Survey, variously dated).

Samples were collected from lakes and streams using a 350-milliliter (mL) bailer constructed of fluorinated ethylene propylene (FEP) and polytetrafluoroethylene (PTFE). The bailer had ball-check valves at the top and bottom for collection and isolation of samples from specific depths.

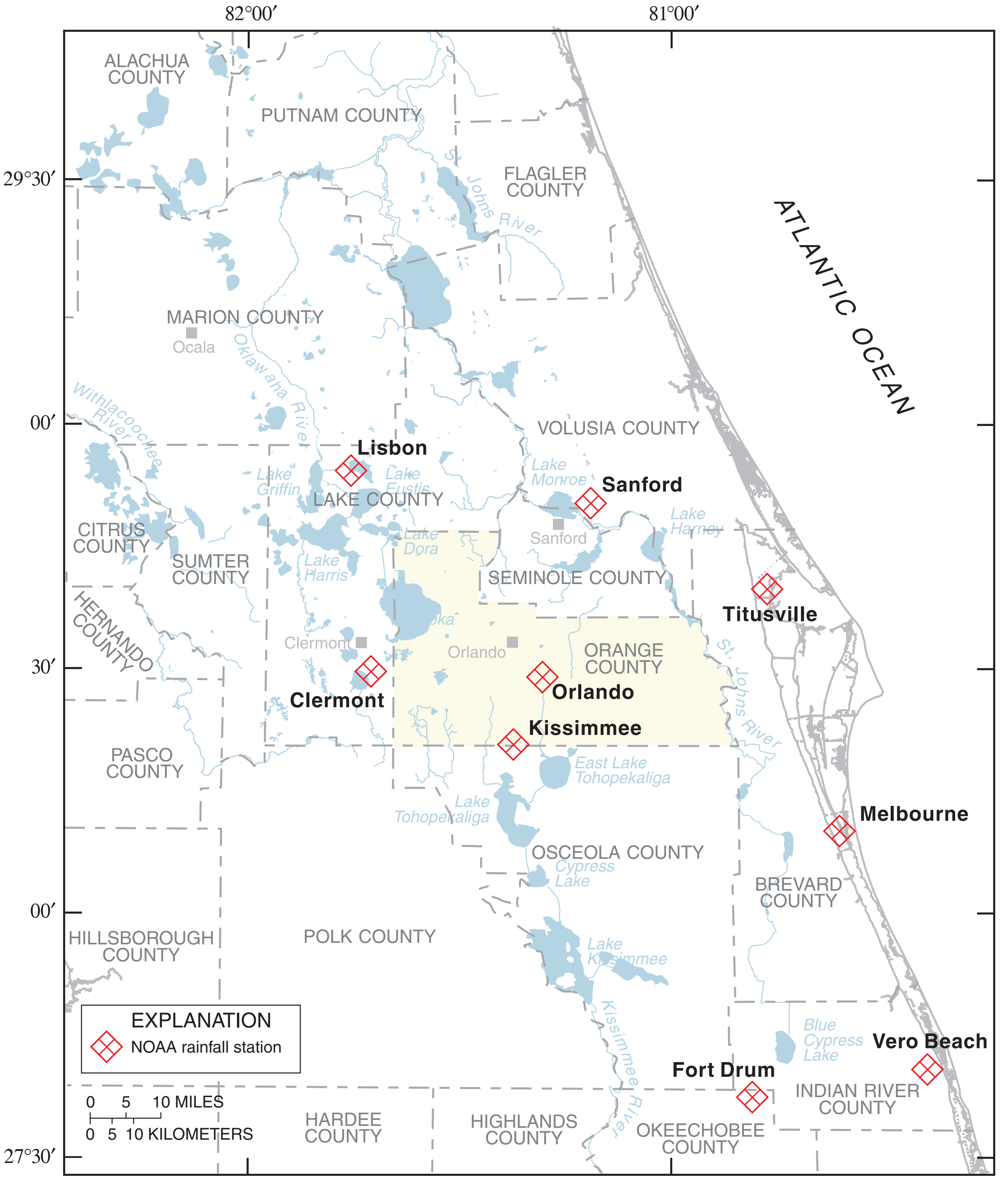


Figure 6. Location of selected National Oceanic Atmospheric Administration rainfall stations in central Florida.

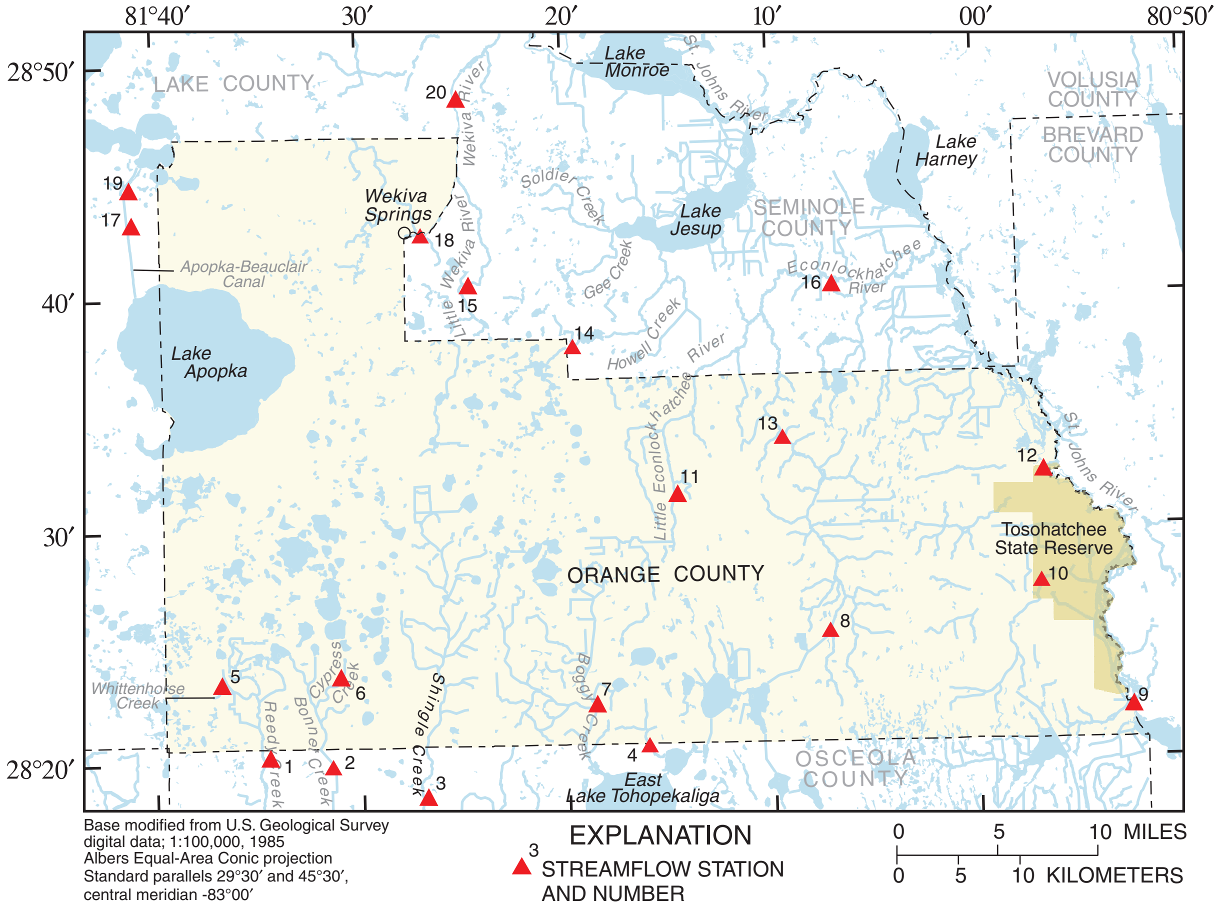
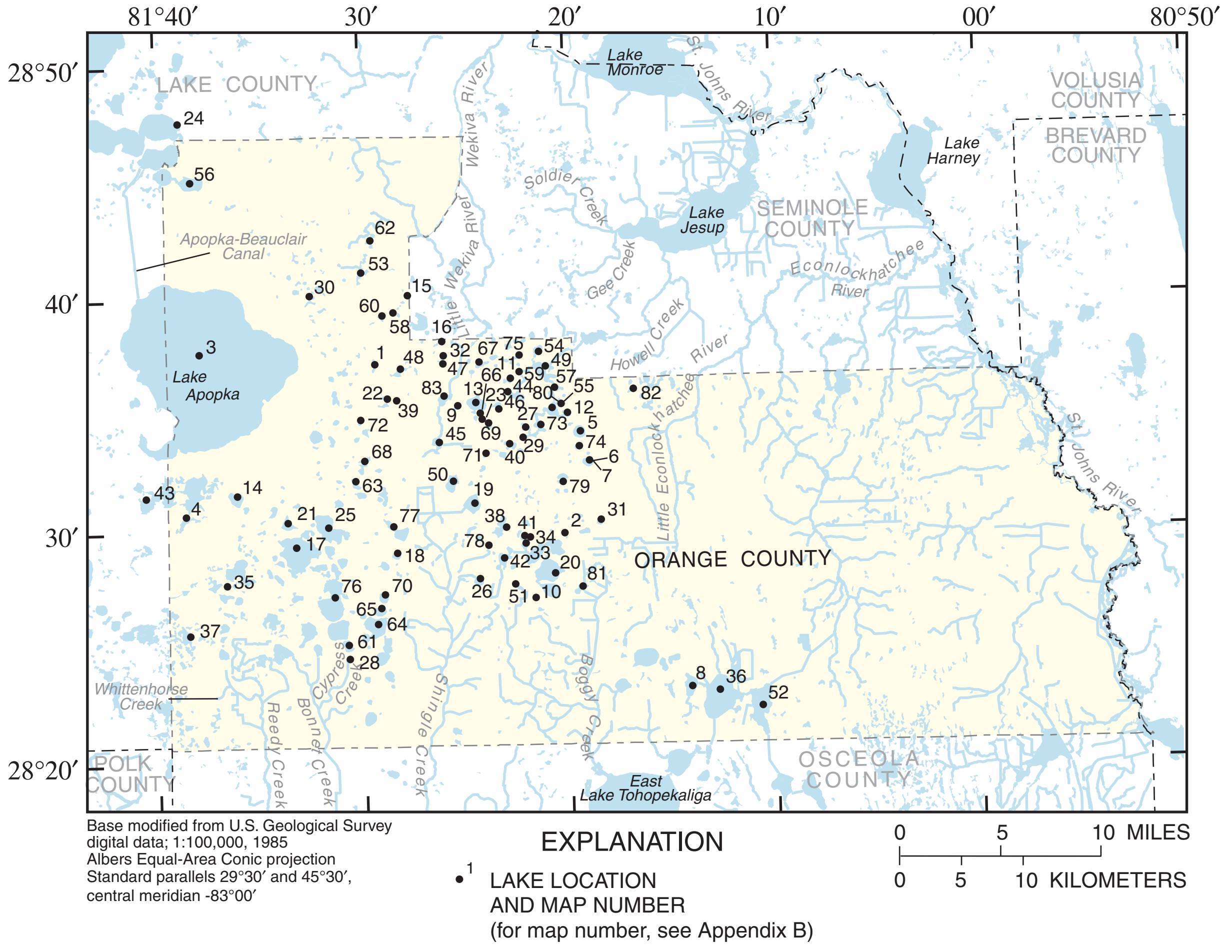


Figure 7. Location of U.S. Geological Survey streamflow and water-quality stations in and near Orange County (map numbers refer to table 2).

Samples were collected for laboratory analysis of alkalinity, major ions, nutrients, silica, selected trace elements, total organic carbon, and chlorophyll-*a* and *b*. Major ions included calcium, magnesium, sodium, potassium, sulfate, chloride, and fluoride. The nutrient analyses included nitrite (filtered), nitrite plus nitrate (filtered), ammonia (filtered), ammonia plus organic nitrogen (filtered and whole water), phosphorus (filtered and whole water), and phosphate (filtered). The trace element analyses included aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, iron, lead, lithium, manganese, selenium, strontium, and vanadium. Samples from selected sites were collected for analysis of 47 pesticides and pesticide metabolites (table 4). Samples from four lakes (Adair, Ellenore, Fairview, and Hope) and four streams (Econlockhatchee River, Little Econlockhatchee River, Little Wekiva River, and Shingle Creek) were analyzed for compounds indicative of household and industrial wastes (table 5).

Samples for inorganic analyses were composited in a plastic churn splitter; samples for organic analyses were composited in a 4-liter amber-glass bottle. Samples were processed with a portable pump equipped with a PTFE diaphragm head and FEP tubing. Samples for major-ion, nutrient, and trace-element analyses were filtered with a 0.45-micrometer (µm) pore-size disposable encapsulated filter. Samples for pesticide analysis were filtered with a 0.7 µm pore-size baked-glass fiber filter in an aluminum filter plate. Whole-water samples were used for analysis of household and industrial waste compounds. Samples for chlorophyll analyses were collected by filtering 100 mL of sample water with 0.7 µm pore-size glass-fiber filters in a polysulfone filter holder. The filter was inserted in a glass vial and chilled. Samples for major-cation and trace-element analyses were acidified with 2-mL nitric acid to adjust sample pH to less than 2. Whole-water samples for nutrient analysis were preserved with 1-mL sulfuric acid. All samples were chilled to less than 4 degrees Celsius (°C) and shipped overnight to USGS laboratories in Ocala, Florida, and Denver, Colorado.



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 8. Location of lakes with four or more water-level measurements each year for more than 15 years.

Before moving from one site to another site to collect samples, equipment was washed with a nonphosphatic detergent and rinsed with deionized water to prevent cross contamination. Equipment used for the collection and processing of trace-elements samples also was rinsed with a 5-percent solution of hydrochloric acid and rinsed with deionized water. Equipment used for the collection and processing of pesticide samples was rinsed with pesticide-grade methanol and rinsed with pesticide-free water. Six field blanks and seven replicate samples were collected for quality assurance. Field-blank samples were analyzed for nutrients, trace elements, and pesticides. In general, concentrations of constituents were less than method detection limits in all field-blank samples. In one field-blank sample, the concentration of total organic carbon was 0.6 milligrams per liter (mg/L). However, total organic carbon also was present in the associated source-solution blank, indicating that the source was not cross contamination or sample-collection techniques.

Duplicate samples were split from the same churn of water as the environmental sample and analyzed for major ions, nutrients, trace elements, and pesticides. In general, results of the environmental and duplicate samples were in good agreement. For example, in both environmental and duplicate samples collected from Jim Creek near Christmas on September 7, 2000, concentrations of barium were 35 micrograms per liter (µg/L), concentrations of beryllium were less than 1.0 µg/L, concentrations of boron were 27 µg/L, concentrations of lithium were 1.2 µg/L, and concentrations of strontium were 410 µg/L. In both environmental and duplicate samples collected from Turkey Lake, on October 31, 2000, concentrations of prometon were 0.005 µg/L, concentrations of atrazine were 0.017 µg/L, and concentrations of diazinon were 0.004 µg/L.

Water-quality data collected from 11 streams for the purposes of this study were supplemented with data collected from 4 additional streams (Cypress Creek, Bonnet Creek, Whittenhorse Creek, and Reedy Creek) as part of

Table 2. Stream sites with streamflow and water-quality data collected by the U.S. Geological Survey, 2000-01.

[Drainage area is in square miles. Data for Cypress Creek, Bonnet Creek, Whittenhorse Creek, and Reedy Creek are from the USGS data-collection network; samples for the other sites were collected as part of this study. Type of data: F, field-measured parameters including specific conductance, dissolved oxygen, pH, and water temperature; I, household and industrial waste compounds; M, major cations and anions; N, nutrients (nitrogen and phosphorus compounds); P, pesticides; S, streamflow; T$_d$, trace elements in a filtered water sample; T$_t$, trace elements in a whole-water sample; H, historical data also available for some constituents. Stream locations are shown in fig. 7]

Map No.	Station name	USGS identifier	Total drainage area	Type of data	No. of samples
9	St. Johns River near Cocoa	02232400	1,330	SFMNH	52
10	Jim Creek at Fish Hole Road near Christmas	02232460	47	FMNT$_d$	2
12	St. Johns River near Christmas	02232500	1,540	SFMNH	52
8	Econlockhatchee River at Magnolia Ranch near Bithlo	02233001	32.9	SH	0
13	Econlockhatchee River near Bithlo	02233100	119	SFMNT$_d$	1
11	Little Econlockhatchee River near Union Park	02233200	27.1	SFMNT$_d$PIH	3
16	Econlockhatchee River near Chuluota	02233500	241	SFMNT$_d$PIH	3
14	Howell Creek near Altamonte Springs	02234308	20.6	FMNT$_d$	1
18	Wekiva River near Apopka	02234635	58.3	SFMNT$_d$P	3
15	Little Wekiva River near Altamonte Springs	02234990	90.7	FMNT$_d$PI	3
20	Wekiva River near Sanford	02235000	189	SFMNH	9
17	Apopka-Beauclair Canal near Astatula	02237700	184	SH	0
19	Apopka-Beauclair Canal below dam near Astatula	02237701	184	FMNT$_d$H	1
7	Boggy Creek near Taft	02262900	83.6	SFMNT$_d$PH	3
3	Shingle Creek at airport near Kissimmee	02263800	89.2	SFMNT$_d$PIH	3
6	Cypress Creek at Vineland	02264000	29.3	SFMNT$_t$H	7
2	Bonnet Creek near Vineland	02264100	44.7	FMNT$_t$H	17
5	Whittenhorse Creek near Vineland	02266200	12.4	SFMNT$_t$H	5
1	Reedy Creek near Vineland	02266300	84.6	SFMNT$_t$H	16
4	Jim Branch near Narcoossee	282043081155900	5.8	FMNT$_d$	1

the USGS long-term data-collection network. Sample-collection methods differed slightly. For example, whole-water samples were collected at each stream site for trace-element analyses.

Florida trophic state indexes (TSI) were calculated for all lakes with sufficient data using the following set of equations (Brezonik, 1984):

TSI = 1/3[chla + SD + 0.5(TP^1) +TN^1)], for nutrient-balanced lakes;

TSI = 1/3[chla + SD + TN^2], for nitrogen-limited lakes; and

TSI = 1/3[chla + SD + TP^2], for phosphorus-limited lakes.

Nutrient-balanced lakes are considered to be those with a ratio of total nitrogen to total phosphorus (TN/TP) between 10 and 30. A TN/TP ratio of less than 10 indicates a nitrogen-limited lakes, and a TN/TP ratio greater than 30 indicates a phosphorus-limited lake.

The independent variables in the TSI equations are calculated as follows:

chla = 16.8 + 14.4 ln(chlorophyll-*a* concentration, in µg/L);

SD = 60 - 30 ln(secchi disk reading, in meters);

TN^1 = 56 + 19.8 ln(total nitrogen concentration, in mg/L as nitrogen);

TN^2 = 59.6 + 21.5 ln(total nitrogen concentration, in mg/L as nitrogen);

TP^1 = 18.6 ln(total phosphorus concentration, in µg/L as phosphorus) - 18.4; and

TP^2 = 23.6 ln(total phosphorus concentration, in µg/L as phosphorus) - 23.8.

Data were analyzed spatially and statistically to illustrate the occurrence and distribution of water-quality constituents and assess factors affecting water quality. Factors qualitatively and quantitatively assessed include size of lake (perimeter), land use, lake region, and geology of the basin. The analyses were done with geographical information systems (GIS) and nonparametric statistical methods. Similar analyses were performed for water-quality data collected from the streams.

Table 3. Lakes sampled by the U.S. Geological Survey, 2000-01.

[Type of data: F, field-measured parameters including specific conductance, dissolved oxygen, pH, and water temperature; M, major cations and anions; N, nutrients (nitrogen and phosphorus compounds); T_d, trace elements in a filtered water sample; P, pesticides; I, household and industrial waste compounds. Map numbers refer to fig. 9 and appendix C]

Map No.	Lake name	Station identifier	Latitude	Longitude	Type of data	No. of samples
1	Johns Lake at Oakland	02237540	283230	0813828	FMNTd	1
2	Lake Adair at Orlando	02234205	283329	0812320	FMNT_dPI	1
3	Lake Beuclair (eastern shore) near Mt. Dora	284617081390200	284617	0813902	FMNT_d	1
4	Lake Fairview at Orlando	02234812	283522	0812420	FMNT_dPI	3
5	Lake Hart near Narcoossee	02262200	282246	0811327	FMNT_dP	3
6	Hickorynut Lake near Oakland	02266275	282540	0813840	FMNT_dP	2
7	Lake Hope at Maitland	02234297	283824	0812215	FMNT_dPI	2
8	Lake Ivanhoe at Orlando	02234225	283326	0812234	FMNT_d	1
9	Lake Jackson near Apopka	284000081275000	284000	0812750	FMNT_dP	1
10	Lake Lotta near Ocoee	283305081304200	283304	0813048	FMNT_d	1
11	Lake Louise near Bithlo	283528081055300	283528	0810553	FMNT_dP	3
12	Lake Maitland at Winter Park	02234300	283649	0812035	FMNT_d	1
13	Lake Mary Jane near Narcoosee	02261900	282246	0811115	FMNT_d	1
14	Lake Ola at Tangerine	02237745	284510	0813800	FMNT_dP	3
15	Lake Oliver near Vineland	282210081385100	282210	0813851	FMNT_d	1
16	Lake Underhill	283219081201302	283219	0812013	FMNT_d	1
17	Marshall Lake near Apopka	284034081315700	284034	0813157	FMNT_dP	1
18	Lake Ellenore near Pine Castle	282927081235000	282927	0812350	FMNT_dPI	1
19	Pond at Tosohatchee State Park near Christmas	282657080561900	282657	0805619	FMNT_dP	2
20	Pond No. 2 at Tosohatchee near Christmas	282702080554200	282702	0805542	FMNT_d	1
21	Raccoon Lake near Windermere	282102081374600	282102	0813746	FMNT_dP	1
22	Reedy Lake near Vineland	282452081370200	282452	0813702	FMNT_d	1
23	Sink on Hartzog Road near Vineland	282450081375100	282450	0813751	FMNT_d	1
24	Turkey Lake at Orlando	283019081283100	283019	0812831	FMNT_dP	3

Historical water-quality data for eight stream sites in and around Orange County (table 2) were retrieved from the USGS National Water Information System (NWIS) database for long-term (1960 to 2001) trend analysis. Data were retrieved for field measurements (water temperature, dissolved oxygen, pH, and alkalinity), major cations (calcium, magnesium, sodium, and potassium), anions (sulfate, chloride, and fluoride), and nutrients (nitrate, ammonia plus organic nitrogen, and phosphorus). However, a nearly complete record was available for only two of the eight sites: Reedy Creek near Vineland and Bonnet Creek near Vineland. USGS data from three of the eight sites (Boggy Creek near Taft, Econlockhatchee River near Chuluota, and Shingle Creek at airport near Kissimmee) were supplemented with data collected by Orange County (Orange County Environmental Protection Division, 2002). Long-term data for the other three sites (Little Econlockhatchee River near Union Park, Cypress Creek at Vineland, and Whittenhorse Creek near Vineland) are not available.

After the data were compiled, data from duplicate samples (collected at the same date and time for quality assurance) were removed. In addition, data from samples collected during times of no flow (zero discharge) were not used.

Interpretation of data from long-term sites is complicated by the fact that sample collection and analysis methods have changed. For example, major-ion data included collection and analysis of both whole water (also referred to as total) and filtered (also referred to as dissolved) samples. Also, the manner of reporting some constituents has changed. In records prior to the 1970s, nitrate concentrations were given as mg/L as nitrate. After the mid-1970s, nitrate concentrations were given as mg/L as nitrogen.

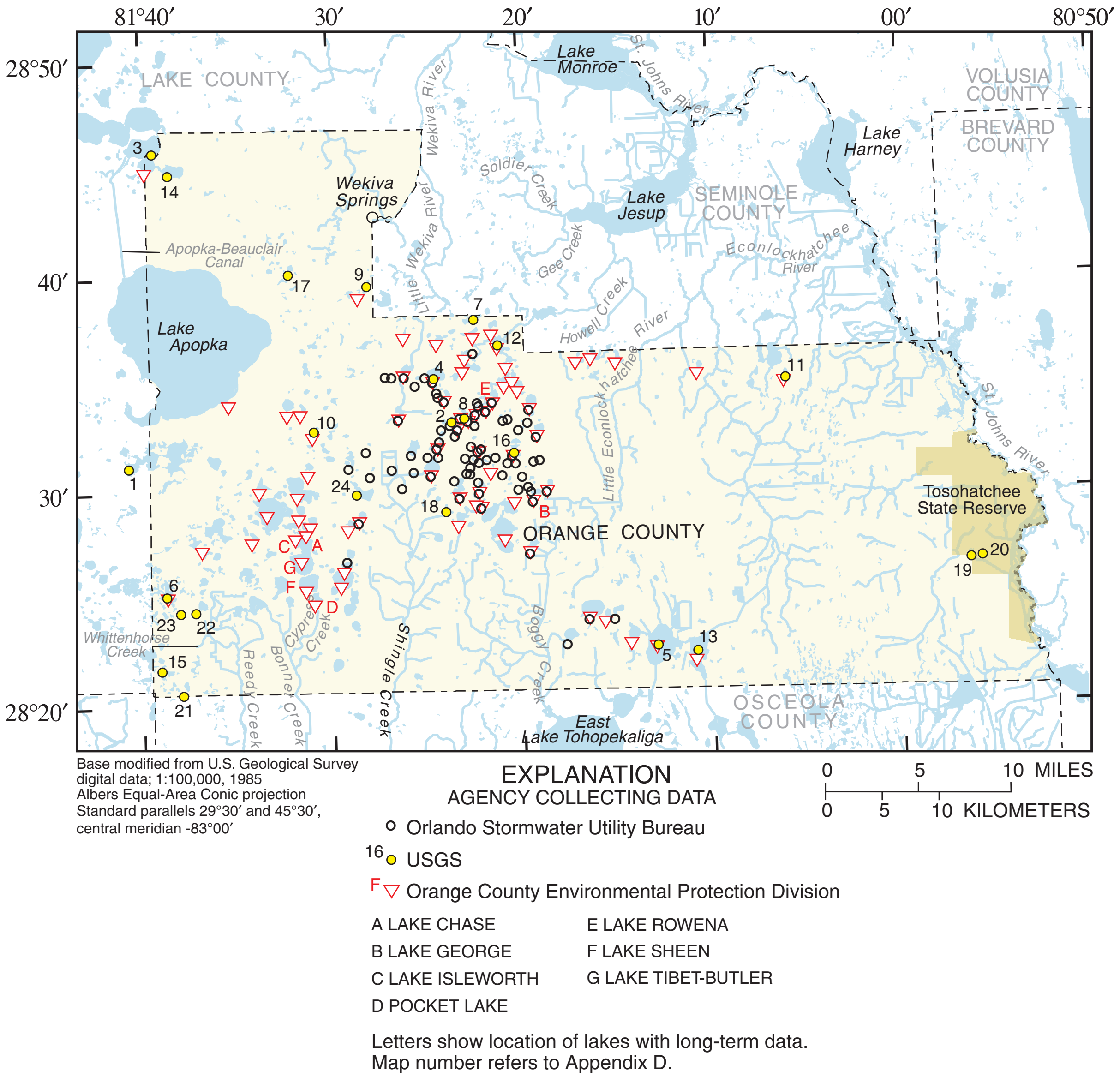


Figure 9. Location of lakes with water-quality data in and around Orange County.

Hence, to obtain consistent, long-term records of each constituent, data were merged or converted. Concentrations of major ions analyzed in whole-water samples were used to supplement concentrations of major ions analyzed in filtered water samples. Field and laboratory alkalinity data were merged. Alkalinity concentrations were converted to bicarbonate concentrations, which were used in the trend analysis.

Nitrate concentrations reported as mg/L as nitrate were converted to mg/L as nitrogen. Nitrate concentrations analyzed on whole-water samples were used to supplement nitrate concentrations analyzed on filtered water samples. Similarly, all available nitrite data were combined. Finally, nitrite concentrations were added to nitrate concentrations to obtain nitrite plus nitrate, in mg/L as nitrogen.

Whole-water organic nitrogen concentrations generally were greater than filtered water organic nitrogen concentrations; hence, data from filtered and whole-water samples could not be merged. Whole-water organic nitrogen data were more numerous, and consequently, were used for data analysis. Both filtered and whole-water ammonia data (which were comparable), in mg/L as nitrogen, were added to the whole-water organic nitrogen concentrations to obtain ammonia plus organic nitrogen, in mg/L as nitrogen.

Table 4. Pesticide and pesticide metabolite compounds sampled, 2000-01.

[Parameter code refers to number used to identify compounds in data base]

Compound	Parameter code	Minimum reporting unit	Compound	Parameter code	Minimum reporting level
Acetochlor	49260	0.006	Methyl Parathion	82667	0.015
Alachlor	46342	.005	Metolachlor	39415	.013
alpha-HCH	34253	.005	Metribuzin	82630	.006
Atrazine	39632	.007	Molinate	82671	.003
Azinphos-methyl	82686	.050	Napropamide	82684	.007
Benfluralin	82673	.010	p,p'-DDE	34653	.003
Butylate	04028	.004	Parathion	39542	.010
Carbaryl	82680	.041	Pebulate	82669	.004
Carbofuran	82674	.020	Pendimethalin	82683	.022
2-Chloro-4-isopropylamino-6-amino-s-triazine (CIAT)	04040	.006	cis-Permethrin	82687	.006
Chlorpyrifos	38933	.005	Phorate	82664	.011
Cyanazine	04041	.018	Prometon	04037	.005
Dacthal (DCPA)	82682	.003	Propachlor	04024	.025
Diazinon	39572	.005	Propanil	82679	.011
Dieldrin	39381	.009	Propargite	82685	.023
2,6-Diethylaniline	82660	.006	Propyzamide (Pronamide)	82676	.004
Disulfoton	82677	.021	Simazine	04035	.005
EPTC	82668	.004	Tebuthiuron	82670	.016
Ethalfluralin	82663	.009	Terbacil	82665	.034
Ethoprophos	82672	.005	Terbufos	82675	.017
Fonofos	04095	.003	Thiobencarb	82681	.010
Lindane	39341	.004	Tri-allate	82678	.002
Linuron	82666	.035	Trifluralin	82661	.009
Malathion	39532	.027			

Phosphorus data included both filtered and whole-water samples, analyzed as total phosphorus and (or) phosphate, and reported in mg/L as phosphorus or phosphate. Only total phosphorus data from whole-water samples, in mg/L as phosphorus, were sufficiently numerous for trend analysis. These data were supplemented with total phosphorus data from whole-water samples reported in mg/L as phosphate after converting to mg/L as phosphorus.

Furthermore, because analytical methods have changed, detection and reporting limits have changed during the period of record; hence, many constituents had more than one reporting limit. In general, where more than one reporting limit existed, all data for the constituent that were less than the highest reporting limit were censored and assigned a value of one-half the reporting limit for statistical testing purposes (Helsel and Hirsch, 1992).

Data from Boggy Creek (map no. 7), Bonnet Creek (map no. 2), Econlockhatchee River (map no. 16), and Whittenhorse Creek (map no. 5) (fig. 7) were analyzed quantitatively for temporal trends. The procedure for temporal trend testing differed according to whether or not the constituent values were significantly related to discharge. If a significant discharge relation exists, the effects of varying discharge must be removed from the constituent values before proceeding with trend testing. If this is not done, the trend testing may reflect changes in water quality that are related to changes in discharge, rather than time. Or, the variability in concentration due to changes in discharge may mask underlying temporal trends in water quality. Therefore, prior to trend testing, the relations of constituent values to discharge were determined using Spearman's rank correlation coefficient (rho). The relations were considered significant if the probability that rho was not equal to zero (no relation) was less than 5 percent.

Table 5. Compounds associated with wastewater sampled, 2000-01.

[µg/L, micrograms per liter. S, suspected; K, known. F, fungicide; H, herbicide; I, insecticide; GUP, general use pesticide; FR, flame retardant; manuf, manufacturing. Parameter code refers to number used to identify compounds in data base]

Compound names	Endocrine disrupting potential	Parameter code	Common use, application, or occurrence	Minimum reporting level (µg/L)
1,4-Dichlorobenzene	S	34572	moth repellent, fumigant, deodorant	0.5
1-Methylnaphthalene		62054	nearly equal concentrations (2-5%) in gasoline/diesel/crude	.5
2,6-Dimethylnaphthalene		62055	indicator of diesel, kerosene (not much in gasoline)	.5
2-Methylnaphthalene		62056	nearly equal concentrations (2-5%) in gasoline/diesel/crude	.5
3-beta-coprostanol		62057	usually a carnivore fecal indicator	2.0
3-Methyl-1(H)-indole (skatol)		62058	fragrance: odor in feces and coal tar	1.0
3-tert-Butyl-4-hydroxy anisole (BHA)	K	62059	antioxidant, preservative	5.0
4-Cumylphenol	K	62060	nonionic detergent metabolite	1.0
4-n-Octylphenol	K	62061	nonionic detergent metabolite	1.0
4-tert-Octylphenol	K	62062	nonionic detergent metabolite	1.0
5-Methyl-1H-benzotriazole		62063	antioxidant in antifreeze, deicers	2.0
Acetophenone		62064	fragrance: soap, detergent, tobacco; flavor: beverages	.5
Acetyl hexamethyl tetrahydronaphthalene (AHTN)		62065	fragrance: musk, widespread usage, persistent in ground-water	.5
Anthracene		34221	wood preservative, in tar/diesel/crude (not gasoline)	.5
Anthraquinone		62066	manuf dye/textiles; seed treatment, bird repellent	.5
Benzo(a)pyrene	K	34248	regulated polychlorinated aromatic hydrocarbon, used in cancer research	.5
Benzophenone	S	62067	fixative for perfumes and soaps	.5
beta-Sitosterol		62068	generally a plant sterol	2.0
beta-Stigmastanol		62086	generally a plant sterol	2.0
Bisphenol A	K	62069	manuf polycarbonate resins; antioxidant, FR	1.0
Bromacil		04029	H, GUP; >80% noncrop grass/brush control	.5
Bromoform		34288	byproduct of wastewater ozination, military uses/explosives	.5
Caffeine		50305	medical: diuretic; highly mobile/biodegradable	.5
Camphor		62070	flavor, odorant, in ointments	.5
Carbaryl	K	82680	I, crop and garden uses, low environmental persistence	1.0
Carbazole		62071	manuf dyes, explosives, and lubricants, I	.5
Chlorpyrifos	K	38933	domestic pest/termite control; highly restricted (2000)	.5
Cholesterol		62072	often a fecal indicator, also a plant sterol	2.0
Cotinine		62005	primary nicotine metabolite	1.0
Diazinon	K	39572	I, > 40% nonagricultural uses, ants, flies, etc.	.5
Dichlorvos	S	38775	I, pet collars, fly spray; breakdown of naled and trichlofon	1.0
d-Limonene		62073	F, antimicrobial, antiviral; fragrance in aerosols	.5
Fluoranthene		34377	common in coal tar/asphalt (not gasoline/diesel)	.5
Hexahydrohexamethyl Cyclopentabenzopyran (HHCB)		62075	fragrance: musk; widespread usage, persistent in ground-water	.5

Table 5. Compounds associated with wastewater sampled, 2000-01. (Continued)

[µg/L, micrograms per liter. S, suspected; K, known. F, fungicide; H, herbicide; I, insecticide; GUP, general use pesticide; FR, flame retardant; manuf, manufacturing. Parameter code refers to number used to identify compounds in data base]

Compound names	Endocrine disrupting potential	Parameter code	Common use, application, or occurrence	Minimum reporting level (µg/L)
Indole		62076	pesticide inert, fragrance: coffee	0.5
Isoborneol		62077	fragrance: perfumery, disinfectants	.5
Isophorone		34409	solvent for lacquers, plastics, oils, silicon, resins	.5
Isopropylbenzene (cumene)		62078	manuf phenol/acetone; component of fuels/paint thinner	.5
Isoquinoline		62079	flavors and fragrances	.5
Menthol		62080	cigarettes, cough drops, liniment, mouthwash	.5
Metalaxyl		50359	H, F, GUP, soil pathogens, mildew, blight, golf turf	.5
Methyl salicylate		62081	liniment, food, beverage, UV-adsorbing lotions	.5
Metolachlor		39415	H, GUP, indicator of agricultural drainage	.5
N,N'-diethyl-methyl-toluamide (DEET)		62082	I, urban uses, mosquito control	.5
Naphthalene		34443	fumigant, moth repellent, about 10% of gasoline	.5
Nonylphenol, diethoxy- total (NPEO2)	K	62083	nonionic detergent metabolite	5.0
Octylphenol, diethoxy- (OPEO2)	K	61705	nonionic detergent metabolite	1.0
Octylphenol, monoethoxy- (OPEO1)	K	61706	nonionic detergent metabolite	1.0
para-Cresol	S	62084	wood preservative	1.0
para-nonylphenol (total)	K	62085	nonionic detergent metabolite	5.0
Pentachlorophenol	S	34459	H, F, wood preservative, termite control	2.0
Phenanthrene		34462	manuf explosives; in tar/diesel/crude (not gasoline)	.5
Phenol		34466	disinfectant, manuf of several products, leachate	.5
Prometon		04037	H, only noncrop areas, applied prior to blacktop	.5
Pyrene		34470	common in coal tar/asphalt (not gasoline/diesel)	.5
Tetrachloroethylene		34476	solvent, degreaser; veterinary: anthelminic	.5
tri(2-Chloroethyl) phosphate	S	62087	plasticizer, FR	.5
tri(Dichlorisopropyl) phosphate	S	62088	FR	.5
Tributylphosphate		62089	antifoaming agent, FR	.5
Triclosan	S	62090	disinfectant, antimicrobial (concern: induced resistance)	1.0
Triethyl citrate (ethyl citrate)		62091	cosmetics, pharmaceuticals, widely used	.50
Triphenyl phosphate		62092	plasticizer, resins, waxes, finishes, roofing paper, FR	.5
tris(2-Butoxyethyl) phosphate		62093	FR	.5

Values of constituents that were not related significantly to discharge were tested for temporal trends using Kendall's tau test to relate constituent value to sample date. The null hypothesis—that no trend in the data exists—was rejected if the p-value was less than 5 percent ($p<0.05$) (Helsel and Hirsch, 1992).

Constituents that were significantly related to discharge were further analyzed to determine if the distribution of the constituent values and the associated discharges were normally distributed and had constant variance over the range of values. Data that were not normally distributed or did not have a constant variance were transformed using either the square root or logarithm (Helsel and Hirsch, 1992).

Regression analysis was used to determine the relation between constituent value and discharge, using either raw data or transformed data, as appropriate. The residual, or the difference between the constituent value and the regression-predicted constituent value for the associated discharge, was computed for each sample. These residuals, referred to as flow-adjusted values, generally are free of the effects of varying discharge and are suitable for trend testing using Kendall's tau.

Data from Reedy Creek could not be analyzed with the methods described above because of the contribution of treated wastewater to the stream from about 1972 to about 1992 (Hampson, 1993; Sumner and Bradner, 1996). The data set was divided into three time periods (pre-1972, 1972-91, and 1992-2001) based on the input of the treated wastewater. Data from these periods were statistically analyzed for differences in rank sums using the nonparametric Kruskal-Wallis test. The Kruskal-Wallis test is similar to the Wilcoxon test that was used in the analysis of trends in streamflow and rainfall, except that more than two time periods are used. Both tests are based on comparison of summed ranks of constituent values for the specified time periods, rather than the actual constituent values.

Data from Shingle Creek and the Little Econlockhatchee River had large temporal gaps and were insufficient for quantitative trend analysis. Data from Cypress Creek also were not quantitatively analyzed because Cypress Creek is a tributary of Bonnet Creek. However, the data from these three streams are summarized in this report.

HYDROLOGY

Precipitation, streamflow, and lake-level data were summarized to determine annual and seasonal variation. The data also were examined for the presence of temporal trends. Trends in streamflow and lake levels have occurred in the Orange County area. It was not always possible to determine precisely the reasons for these temporal trends; however, generalized reasons for trends are suggested when possible.

Annual, Seasonal, and Daily Variation

Daily values of rainfall and streamflow were compiled to provide monthly, seasonal, and annual totals or means. For lake levels, however, generally only periodic observations (four or less per year) were available. For a few lakes, daily values of lake levels were available.

Precipitation

Records of annual precipitation were compiled for nine NOAA rainfall stations in or adjacent to Orange County (fig. 6). At some stations, data were available from 1931-2000 (appendix A). Not all stations had record for the entire 70-year period, but the period of record at all sites (at least 42 years) is adequate to define rainfall patterns that occurred during the period of surface-water data collection. Mean-annual rainfall totals (1931-2000) vary in the vicinity of Orange County from 48.46 inches at Lisbon to 55.15 inches at Titusville. The mean-annual rainfall total for Orlando is 49.92 inches (1931-2000). The highest annual rainfall total measured in Orlando was 68.67 inches in 1960 and the lowest was 30.38 inches in 2000.

Most of the rainfall in Orange County generally occurs during June through September (fig. 10); this 4-month period is commonly referred to as the wet season.

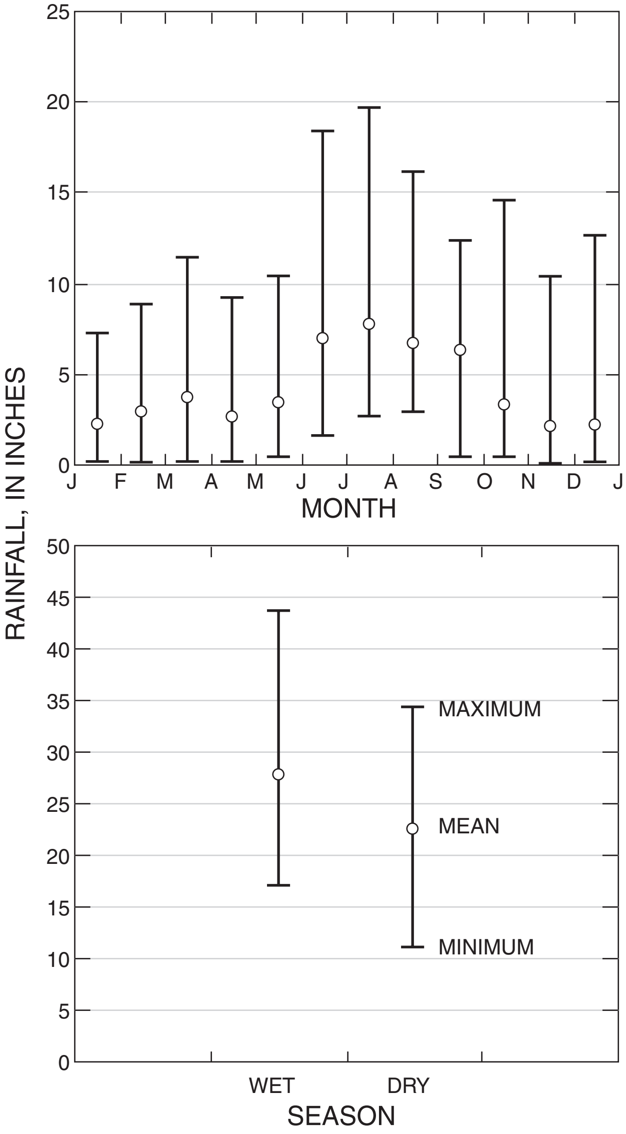


Figure 10. Monthly and seasonal variation in rainfall at Orlando, 1931-2000.

The remaining 8 months (October through May) commonly are referred to as the dry season. During the wet season, average monthly rainfall totals exceed 6 inches at Orlando (1931-2000). In comparison, average monthly rainfall totals during the dry season at Orlando are less than 4 inches. The wettest month in Orange County typically is July, with an average monthly rainfall total of nearly 8 inches (1931-2000). More than one-half of the annual total rainfall in Orange County typically falls during the wet season. The average wet-season rainfall at Orlando was 28.13 inches (1931-2000); the average dry-season rainfall was 21.84 inches. However, there are periods when the most annual rainfall occurred during the dry season in Orange County. For example, 34.22 inches of rainfall occurred during the dry season of 1997 at Orlando—compared to only 30.29 inches during the wet season. In December 1997, a substantial amount of rainfall occurred (12.63 inches); December is normally a dry month, with an average rainfall of 2.09 inches (1931-2000).

Days with relatively low rainfall occurred frequently in Orange County, yet account for little of the annual accumulation. For example, 50 percent of the days with measurable rainfall at Orlando had 0.2 inch or less total rainfall (fig. 11). These relatively low rainfall days accounted for only about 8 percent of the total rainfall accumulation from 1949-1998. Conversely, days with higher daily rainfall totals, though relatively infrequent, account for a large portion of the total rainfall accumulation. For example, rainfall days with totals greater than 1 inch occurred on about 12 percent of the days with measurable rainfall, yet accounted for more than 50 percent of the total rainfall accumulation.

Streamflow

Records of daily streamflow were compiled for 13 stations in or adjacent to Orange County (table 6). Measurement of daily streamflow began in the 1930s for three stations. Measurement of streamflow at two stations did not begin until 1973. The streamflow characteristics, including magnitudes and seasonal patterns of streamflow, vary widely among the 13 stations depending on the drainage basin sizes and characteristics.

The variability in historic streamflow data recorded at the 13 stations in Orange County is indicated by the streamflow statistics presented in table 6. The maximum 1-day streamflow (maximum daily mean streamflow for 1 day), 11,600 cubic feet per second (ft^3/s), for these 13 stations was at the St. Johns River near Christmas (table 6)

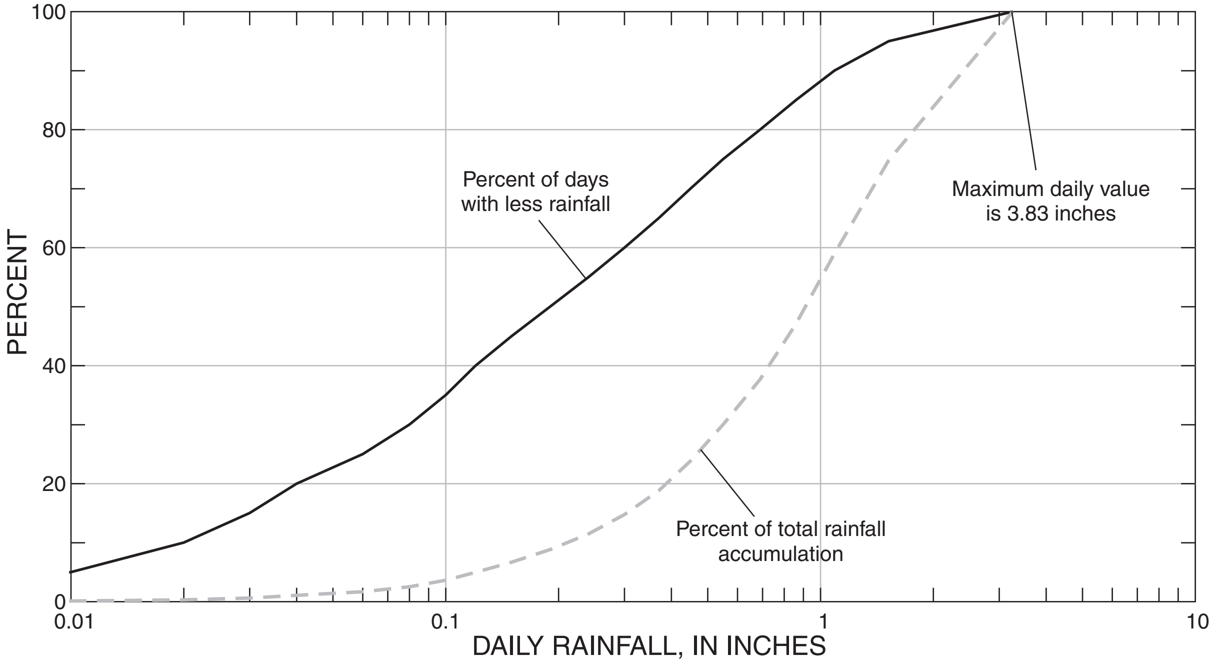


Figure 11. Distribution of daily rainfall at Orlando according to percent of total accumulation and to percent of days with less rainfall, 1949-98. (Days with no rainfall are not included in plot showing percent of days with less rainfall.)

Table 6. Period of record and annual streamflow statistics for stations in Orange County and adjacent counties.

[Statistics are based on daily mean discharge; drainage area is in square miles; flow is in cubic feet per second; median runoff is in inches per year]

Station name	USGS identifier	Period of record	Total drainage area	Annual 1-day high flow			Annual 7-day low flow			Annual daily flow			Annual median runoff
				Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	
St. Johns River near Cocoa	02232400	1954-2000	1,330	174	3,120	9,820	-18	88	570	68	944	2,800	9.6
St. Johns River near Christmas	02232500	1934-2000	1,540	522	4,380	11,600	-82	131	803	104	1,190	3,430	10.5
Econlockhatchee River at Magnolia Ranch near Bithlo	02233001	1973-2000	32.9	17	202	471	0	0	.77	.9	27	51	11.1
Little Econlockhatchee River near Union Park	02233200	1960-2000	27.1	43	386	1,570	.2	3.7	12	6.4	29	62	14.5
Econlockhatchee River near Chuluota	02233500	1936-2000	241	273	2,290	10,100	6.7	31	74	85	259	726	14.9
Little Wekiva River near Altamonte Springs	02234990	1973-2000	90.7	69	257	638	.6	7.3	15.7	8.2	38	68	5.6
Wekiva River near Sanford	02235000	1936-2000	189	260	792	2,060	105	191	257	197	279	500	20
Apopka-Beauclair Canal near Astatula	02237700	1959-1999	184	25	428	754	0	10	92	10	57	263	4.4
Boggy Creek near Taft	02262900	1960-2000	83.6	60	470	3,400	.1	2.6	12	14	52	139	8.4
Shingle Creek at airport near Kissimmee	02263800	1959-2000	89.2	82	499	3,160	0	7.0	31	13	74	163	12.0
Cypress Creek at Vineland	02264000	1946-2000	29.3	0	31	276	0	0	5.3	0	3.4	13	1.1
Whittenhorse Creek near Vineland	02266200	1967-2000	12.4	0	22	96	0	0	1.4	0	3.4	13	3.7
Reedy Creek near Vineland	02266300	1967-2000	84.6	54	288	1,110	0	6.8	18	11	36	107	5.9

in 1953. In contrast, no streamflow was recorded for an entire year at Cypress Creek and Whittenhorse Creek (table 6). The minimum 7-day low flows (minimum daily mean for 7 consecutive days) generally were less than 7 ft^3/s at all stations, even in the St. Johns River. The exception is Wekiva River near Sanford, where the 7-day low flow varied between 105 and 257 ft^3/s during the 1936-2000 period. This relatively high 7-day low flow is because of discharge from Wekiva Spring, Rock Springs, and other springs that provide much of the flow in the river. Spring discharge is relatively stable in comparison to surface runoff, and is less affected by drought. Six of the 13 streams had 7-day low flow of 0 ft^3/s some years. Both St. Johns River stations had a reversal of flow direction. The 7-day low flow at St. Johns River near Christmas was -3 ft^3/s in 1997, -82 ft^3/s in 1999, and -48 ft^3/s in 2000. Near Cocoa, the 7-day low flow in the St. Johns River was -18 ft^3/s in 2000. These reverse flows probably are caused by prevailing winds from a northerly direction during a drought period with little surface runoff. Because of the small slope of the St. Johns River channel, wind can cause significant effects on streamflow. The determination of flow reversals are more reliable because of the advance in acoustic technology equipment, which quantifies negative discharges more accurately than equipment used prior to the late 1980s.

Some differences in basin characteristics can be observed by comparing differences in runoff. Runoff is the median-annual streamflow expressed as an equivalent depth of water over the entire drainage area that results from the median flow for 1 year. Median values of annual mean runoff are given in table 6. Although these runoff quantities are based on different periods of record for each stream, comparisons of general streamflow characteristics among the 13 streams probably are valid because the length of concurrent record exceeds 25 years in all cases.

Median runoff ranges from about 20 inches per year (in/yr) in the Wekiva River to about 1.1 in/yr in Cypress Creek (table 6). The runoff for the Wekiva River is substantially higher than any of the 12 other river basins because of the relatively constant spring discharge that sustains the flow in this stream, even during drought conditions. The low runoff for the Cypress Creek basin results from a lack of sustained inflow from ground water from internally drained areas and a relatively large area of lakes within the drainage basin. About 8 mi^2 of the 32 mi^2 Cypress Creek basin is composed of lakes, from which evaporation probably removes water more rapidly than from other areas. Other streams with relatively low runoff (less than 5 ft^3/s) include the Apopka-Beauclair Canal and Whittenhorse Creek. Most of the flow in Apopka-Beauclair Canal is from Lake Apopka; evaporation from the lake probably results in relatively low runoff into the canal. The Whittenhorse Creek basin contains numerous swampy areas and higher ground that may be internally drained due to the karstic topography. Evaporation from the swampy areas and low runoff from the internally drained areas are factors that probably contribute to the low runoff in Whittenhorse Creek, even though the creek may receive some seepage from rapid infiltration basins (RIBs). The RIBs, located on hills north of Whittenhorse Creek, are operated by the Reedy Creek Improvement District and began receiving reclaimed water in 1991. The RIBs received about 6.7 Mgal/d of reclaimed water in 1995 (O'Reilly, 1998). O'Reilly estimated that about 67 percent of the water applied to the RIBs recharged the Floridan aquifer system, and the remaining 33 percent discharged through the surficial aquifer system to surface-water bodies.

The seasonal pattern of streamflow in Orange County is shown by daily duration hydrographs for selected streams (fig. 12). These hydrographs show the maximum, median, and minimum streamflow for each day of the year for the period of record. Although streamflow varies widely among the six streams for which flows are plotted, there are, nevertheless, some common characteristics. For example, median daily flows tend to reach maximum values August through November, corresponding to the end of the wet season. Minimum daily streamflow generally is lowest in June, after the dry season has ended and before the onset of the wet season has become effective in increasing runoff to streams. Reedy Creek was dry in April, May, and June of some years. Whittenhorse Creek and Cypress Creek were dry each day of the year in some years. There is less of a pattern in maximum annual streamflows. The occurrence of relatively high streamflows during most seasons demonstrates the effects of an extreme rainfall event, which can occur in any season (although it generally occurs during the summer wet season). This direct runoff is more applicable to smaller drainage area streams than to larger drainage basins, which tend to have peak flows caused by an accumulation of several rainfall events.

Lake Levels

Water levels in any lake are a function of the balance between components of the lake water budget. Inputs to a lake are from direct rainfall, surface runoff, and ground-water seepage. Water losses are from evaporation and in many lakes can include ground-water seepage and surface outflow through streams. Water levels in many lakes in the Orlando metropolitan area are controlled by drainage

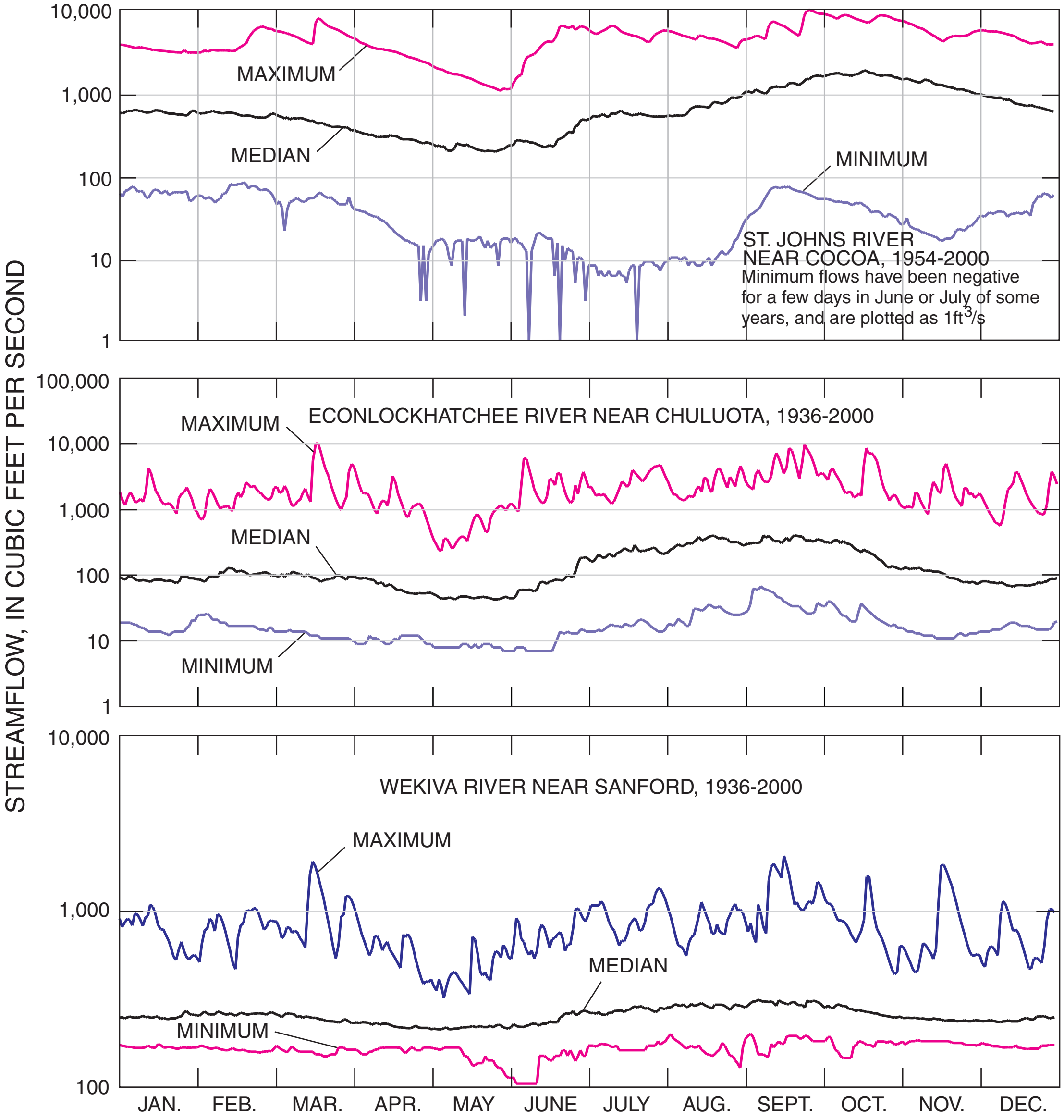


Figure 12. Duration of daily streamflow for selected streams in central Florida.

wells, which direct lake overflow into the Floridan aquifer system. Because rainfall and evaporation are about the same for all lakes over a time period of many years, the large differences in water-level fluctuations among area lakes are due to differences in other components of the water budget. Schiffer (1998) provided a more detailed discussion of lake types and water-level fluctuations.

Eighty-three lakes in or near Orange County have more than 15 years of water-level measurements. For some of the lakes, the record begins in the 1930s (appendix B).

Stage-duration curves for 12 lakes are presented in figure 13. The periods of records are not the same for all the lakes; however, the period of record is probably long enough (at least 35 years) to represent long-term conditions at all 12 lakes. Figure 13 shows the large range in lake variability that occurs in Orange County; the range in lake stage was about 13 ft at Lake Francis and Johns Lake, and about 3 ft at Lake Baldwin, Lake Maitland, and Lake Silver.

The variation and seasonal pattern in lake water levels is illustrated by water-level graphs for Lake Silver and Lake Sherwood (fig. 14). Lake Silver (map no. 69 in figure 8) is a small urban lake in Orlando that is connected through canals and other lakes to Lake Fairview. The water level in Lake Silver is relatively stable compared to other lakes in Orange County, with a maximum and minimum water level that differs by less than 3 ft during 1960-97. The median monthly water levels vary from about 91.8 ft

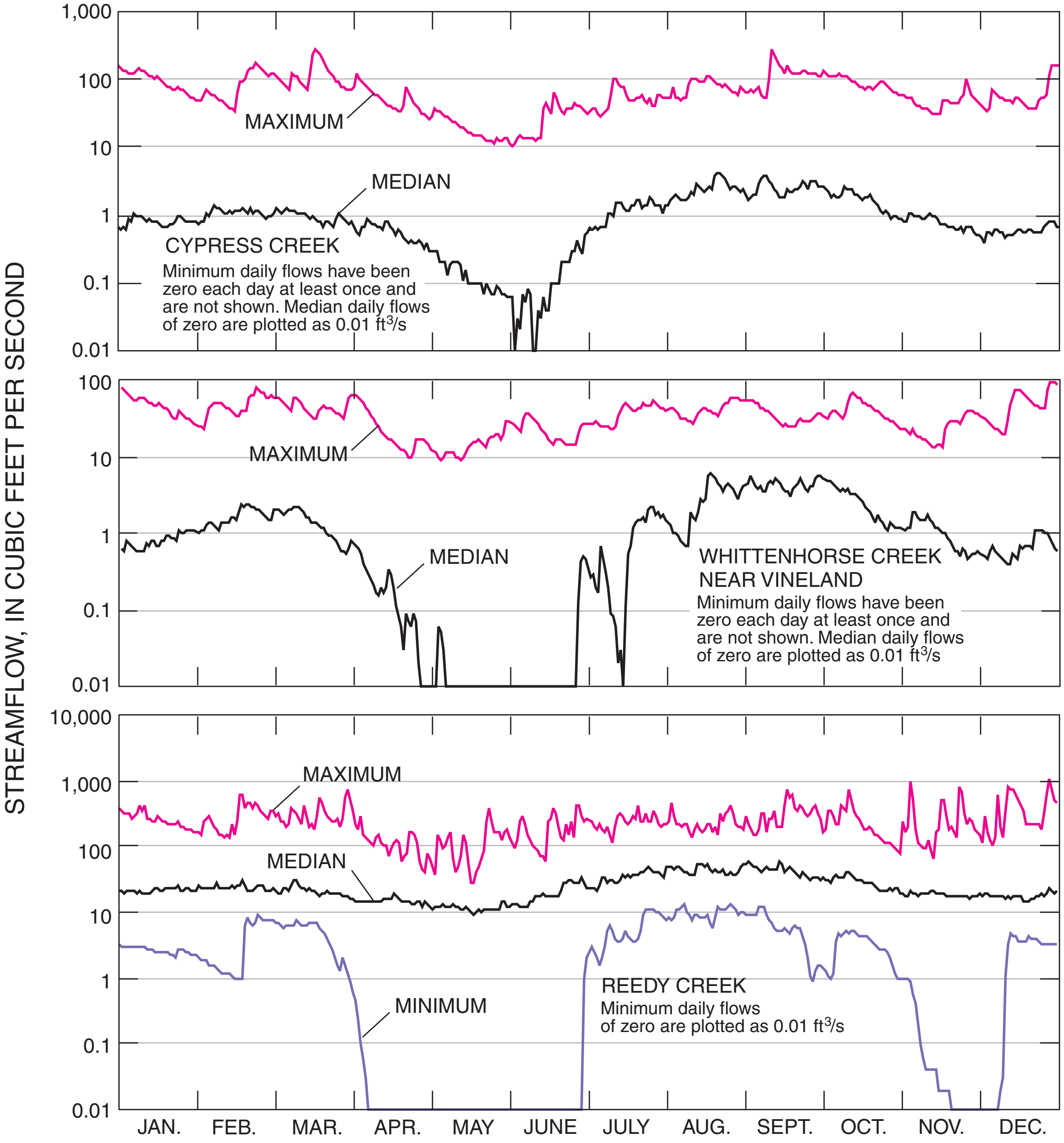


Figure 12. Duration of daily streamflow for selected streams in central Florida. (Continued)

in December to 92.1 ft in July, indicating a small seasonal fluctuation in water level. By contrast, water levels in Lake Sherwood (map no. 68 in figure 8) have a larger range (more than 30 ft).

The outflow seepage rate from Lake Sherwood is dependent on the head difference between the lake and potentiometric surface of the Upper Floridan aquifer, and at times becomes so large in relation to inflow that the lake goes dry. The water-level record summarized for Lake Sherwood (1960-97) indicates that water level has ranged from about 55 ft to nearly 88 ft above NGVD 29 (fig. 14). Despite this large range, monthly water levels indicate only a slight seasonal pattern. Maximum lake levels have been observed in fall (September through December), indicating that the highest water levels generally follow the summer wet period. Median monthly water levels range from 64.3 ft for June and 66.4 ft for November, a range that is low in comparison to the range in water levels that has occurred during the period of record. This lack of a pronounced seasonal variation in water level is due to the storage capacity of Lake Sherwood. Once filled to a high-water level during a relatively wet period, lake water levels may drop slowly during several months of low rainfall. A period of several months of low rainfall may be required for lake water levels to return to more typical levels. Conversely, after a period of extended drought, many months of normal or above-normal rainfall are needed to restore the lake to a more typical level.

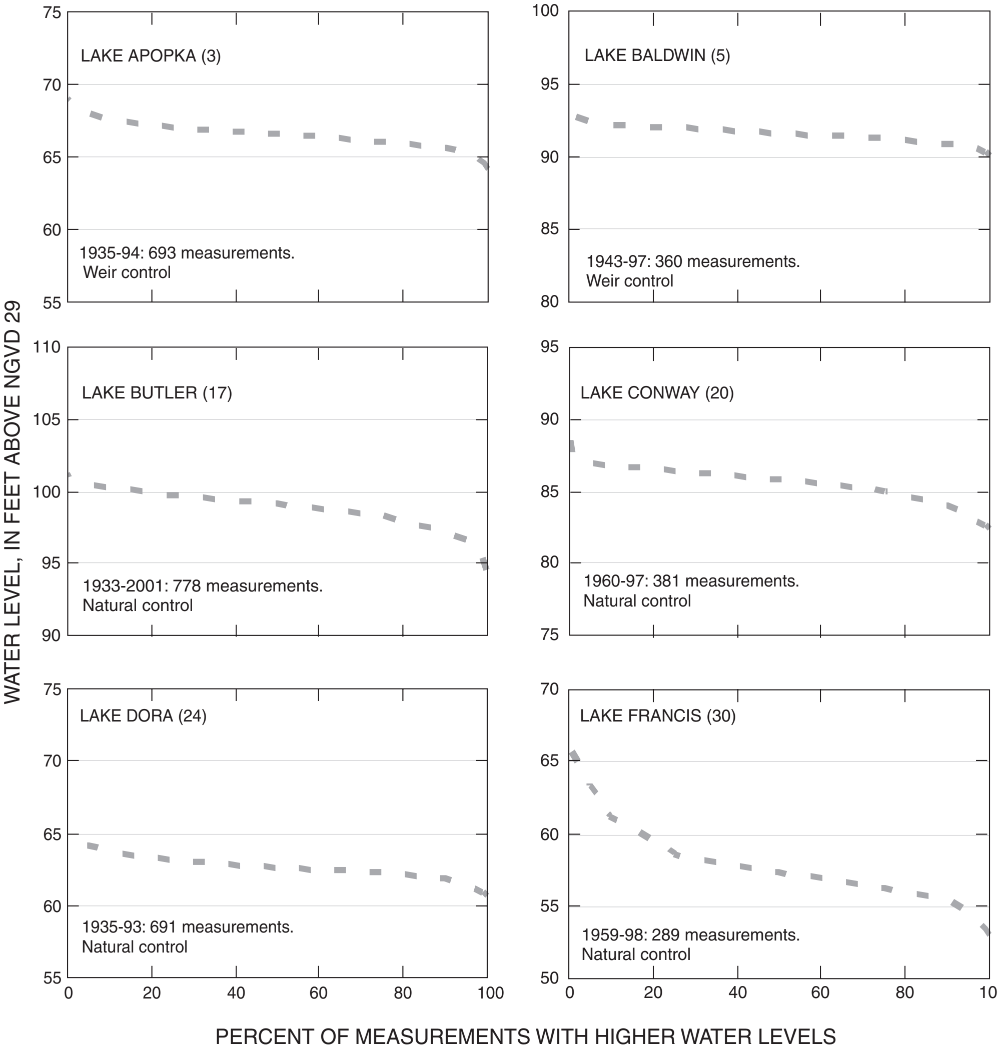


Figure 13. Stage-duration for selected lakes in and around Orange County. (Lake identification number in parentheses after lake name refers to figure 8 and appendix B).

Temporal Trends and Changes

Precipitation

The Kendall-Tau test was used to determine if significant temporal trends in annual rainfall at nine stations (fig. 6) occurred. Trend tests were performed for long-term rainfall record (beginning 1931 at some stations) and also for 1970-2000. Discharge records are available for most streamflow stations for 1970-2000 (record at two stations began in 1973, table 6). Significant long-term trends (5-percent significance level) for increasing annual rainfall are indicated at Fort Drum (table 7). The Melbourne station has a significant trend of increasing annual rainfall totals for 1970-2000. These stations are in the upper part of the St. Johns River basin, and are not located in or adjacent to Orange County.

Total annual rainfall at Orlando has a slight cyclical pattern as depicted by the locally weighted scatterplot smoothing (LOWESS) curve fitted to the data (fig. 15). The LOWESS curve indicates a tendency for slightly higher than average rainfall during 1940-65, and lower than average rainfall from about 1966-85. After about 1985, rainfall totals increased to levels characteristic of the 1940-50 period. The plot of 5-year moving average rainfall and the LOWESS fit show this pattern of rainfall variation more clearly (fig. 15). Although the cyclic variation in rainfall is small compared with year-to-year variation, these cyclic variations could have subtle effects on streamflow or lake levels. The effects may be more notable for lakes, which probably have a longer “memory” of anecedent rainfall than for streams. Thus, lake water levels may tend to follow a temporal pattern similar to the pattern indicated by the 5-year moving average rainfall if other factors affecting lake water levels have relatively small impacts.

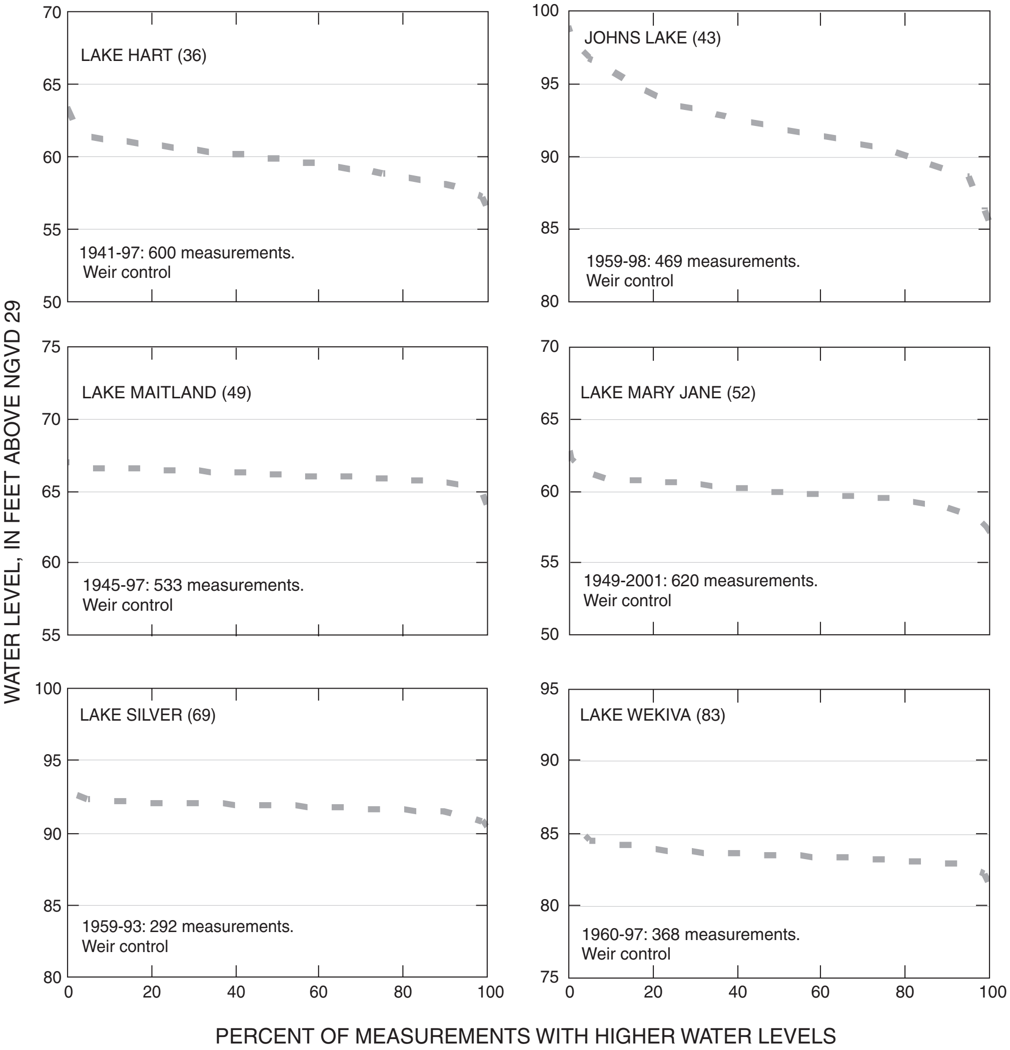


Figure 13. Stage-duration for selected lakes in and around Orange County. (Lake identification number in parentheses after lake name refers to figure 8 and appendix B). (Continued)

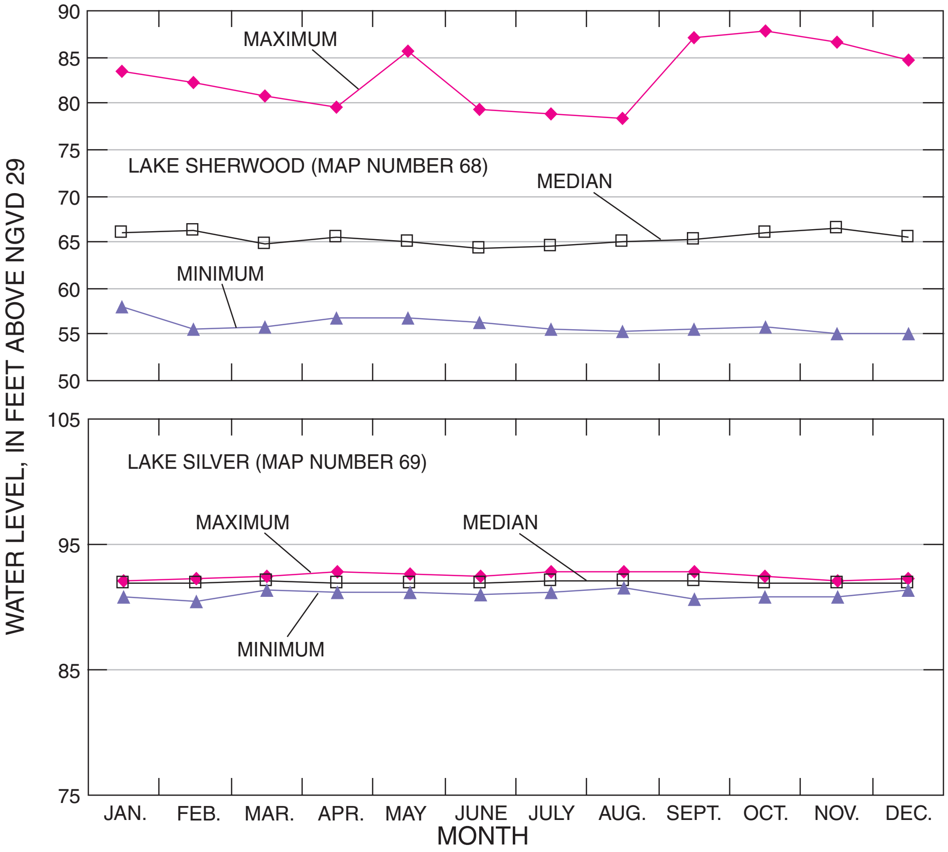
Streamflow

Selected streamflow characteristics computed on an annual basis for 13 stations were examined statistically for temporal trends using the Kendall Tau test. Results of the trend testing indicate changes in annual mean streamflow, 1-day high streamflow, or 7-day low streamflow at 9 of the 13 stations. However, changes in 7-day low streamflow are more common than changes in annual mean or 1-day high streamflow. Changes in low-streamflow characteristics are related to changes in factors controlling streamflow during dry periods, such as spring inflow, ground-water seepage, and wastewater discharge. Changes in mean and high streamflow characteristics are related to factors affecting larger sources of inflow, such as storm runoff or changes in quantities of wastewater discharge that are large in comparison to the mean streamflow. Basin changes may affect magnitudes of some streamflow characteristics and not affect others.

Low-Flow Characteristics

There were significant temporal trends in 7-day low streamflow at 7 of the 13 streamflow stations: Little Econlockhatchee River, Econlockhatchee River near Chuluota, Little Wekiva River, Wekiva River, Boggy Creek, Whittenhorse Creek, and Reedy Creek (table 8). In most of these streams, 7-day low streamflows have significantly increased with time.

The 7-day low flow in Shingle Creek does not have a monotonic temporal trend that is detectable by the Kendall Tau test, but the low flows at this site have changed significantly with time (fig. 16). The 7-day low flows



(Period of record is January 1960 through December 1997. Frequency of measurement is monthly or less. Map number refers to figure 8 and Appendix B).

Figure 14. Maximum, median, and minimum water levels by month for Lake Sherwood and Lake Silver.

generally were less than 5 ft^3/s until 1972, when there was a marked increase to about 11 ft^3/s because of treated wastewater discharged into the creek. As the population served by the wastewater plant discharging into Shingle Creek increased, the wastewater discharge, and consequently, the low flows in Shingle Creek, generally increased each year to a maximum of about 31 ft^3/s in 1984. Redirection of the wastewater from Shingle Creek to RIBs and irrigation areas in west Orange County and Lake County resulted in a pattern of decreasing flow from 1984-89, when redirection of the wastewater discharge was complete. After 1989, the 7-day low flows generally were less than 10 ft^3/s. Nonetheless, the graph of 7-day low flows for Shingle Creek (fig. 16) suggests that low flows since 1989 have tended to be greater than low flows before 1972, although near-zero flows have occurred in both periods.

There was a significant decrease in 7-day low streamflows in the Little Wekiva River near Altamonte Springs (table 8). However, this downward trend in 7-day low streamflow is apparent only since about 1986 (fig. 16).

Table 7. Temporal trends in annual rainfall totals at sites in the vicinity of Orange County.

[The Kendall's Tau is a test statistic based on the relation of annual rainfall total with year. A positive tau indicates an increase in rainfall with time, and a negative tau indicates a decrease in rainfall with time. The p-value is the probability that a pattern of increasing or decreasing rainfall could result from a trendless set of data. A p-value of 0.05 or less is taken as evidence of a significant trend in rainfall and is in bold type]

Location	Period of record	Period of record		1970-2000	
		Kendall's Tau	p-value	Kendall's Tau	p-value
Clermont	1931-2000	-0.02	0.80	-0.06	0.65
Fort Drum	1943-2000	.18	**.04**	.23	.06
Kissimmee	1931-2000	-.03	.69	.23	.06
Melbourne	1931-2000	-.02	.84	.33	**<.01**
Orlando	1931-2000	-.01	.89	.16	.21
Sanford	1931-2000	-.04	.66	.00	.99
Titusville	1931-2000	-.03	.73	.04	.80
Vero Beach	1931-2000	.13	.16	.10	.44
Lisbon	1959-2000	.10	.37	.21	.10

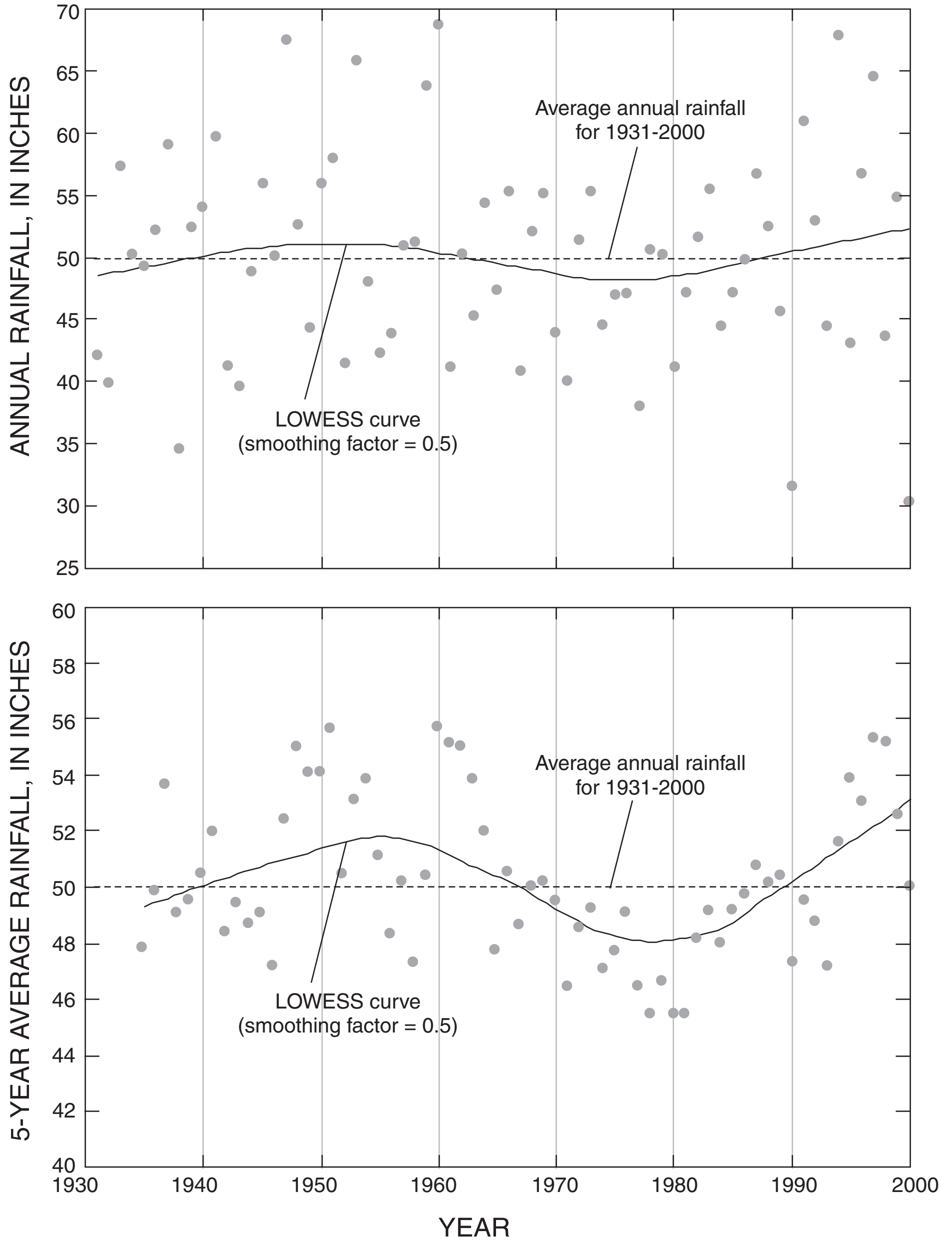


Figure 15. Annual rainfall and 5-year moving average of annual rainfall at Orlando, 1931-2000. (LOWESS: locally weighted scatterplot smoothing)

From beginning of record in 1971 to about 1986, the 7-day low streamflow in the Little Wekiva River appeared to increase. The temporal pattern in low flow in the Little Wekiva River probably is related to discharge of treated wastewater into the stream. As many as seven wastewater treatment plants and a citrus processing plant have discharged into the stream. Currently, however, the Altamonte Springs Wastewater Treatment Plant is the only remaining plant (CDM, 2003); discharge from this plant enters the Little Wekiva River upstream from the gaging station.

The plant began discharging into the river in the mid-1970s, and the amount of treated wastewater discharged to the river probably increased with population growth until about the late 1980s when Project Apricot was instituted by the City of Altamonte Springs. Project Apricot is a water re-use plan in which treated wastewater is distributed throughout urban communities in Altamonte Springs for irrigation purposes. As a result of Project Apricot, the quantity of treated wastewater discharged to the Little Wekiva River (not used in Project Apricot) has decreased from an annual average of about 9.6 ft^3/s in 1989 to about

Table 8. Temporal trends in annual streamflow characteristics at selected sites in the vicinity of Orange County.

[The Kendall Tau is a test statistic based on relation of the annual flow characteristics to time. A positive Kendall Tau value indicates an increase in streamflow with time, and a negative value indicates a decrease in streamflow with time. The p-value, given in parentheses, is the probability that a pattern of increasing or decreasing streamflow could result from a trendless set of data due to chance. A probability of 0.05 or less is taken as evidence of a significant trend and is in bold type. See table 6 for period of record]

Station name	USGS identifier	Years	Kendall's Tau and p-value for selected annual streamflow characteristic		
			Mean	1-day high	7-day low
St. Johns River near Cocoa	02232400	47	0.00 (1.00)	0.015 (0.88)	-0.12 (0.24)
St. Johns River near Christmas	02232500	67	-.04 (.61)	-.08 (.36)	-.04 (.65)
Econlockhatchee River at Magnolia Ranch near Bithlo	02233001	28	**.26 (.05)**	.29 (.13)	-.07 (.65)
Little Econlockhatchee River near Union Park	02233200	41	**.27 (.01)**	.03 (.80)	**.56 (<.01)**
Econlockhatchee River near Chuluota	02233500	65	.09 (.31)	-.07 (.41)	**.61 (<.01)**
Little Wekiva River near Altamonte Springs	02234990	24	.12 (.41)	.27 (.070	**-.46 (<.01)**
Wekiva River near Sanford	02235000	65	.13 (.13)	-.04 (.67)	**.27 (<.01)**
Apopka-Beauclair Canal near Astatula	02237700	41	-.09 (.41)	-.01 (.93)	.09 (.40)
Boggy Creek near Taft	02262900	41	**.23 (.03)**	.09 (.41)	**.25 (.02)**
Shingle Creek near Kissimmee	02263800	42	**.23 (.03)**	.03 (.80)	.17 (.12)
Cypress Creek at Vineland	02264000	55	-.08 (.41)	-.11 (.22)	.03 (.77)
Whittenhorse Creek near Vineland	02266200	34	**.31 (.01)**	**.26 (.03)**	**.30 (.03)**
Reedy Creek near Vineland	02266300	34	**.30 (<.01)**	**.26 (.03)**	**.44 (<.01)**

0.25 ft^3/s in 2000 (Larry Dolamore, City of Altamonte Springs, written commun., 2004). This decline in discharge of treated wastewater generally corresponds with, and is probably the reason for, the pattern of declining low streamflow in the Little Wekiva River (fig. 16).

Increases in 7-day low-flow are indicated by the Kendall Tau test (table 8) and by plots (fig. 16) of annual 7-day low streamflow for the Little Econlockhatchee River, Econlockhatchee River near Chuluota, Wekiva River, Boggy Creek, Whittenhorse Creek, and Reedy Creek. There is probably no single reason for the increases in 7-day low flows, and for most streams it is difficult to determine definite reasons for the flow increases.

The 7-day low flows in the Little Econlockhatchee River near Union Park (fig. 16) have a pattern of increasing flow since 1960 (beginning of record). The increase was fairly uniform until the mid-1980s; since then, the increase has slowed or stopped altogether, although the year-to-year variation in the low flow apparently has increased. The increases in low streamflow prior to about 1982 may be the result of substantial residential development in the basin. This development included construction and operation of as many as 12 local wastewater treatment facilities that discharged wastewater into the Little Econlockhatchee River in 1982 (Kroening, 2004). The local treatment plants were closed in 1982-84 when the regional Iron Bridge wastewater treatment plant took over wastewater treatment for the areas that had been served by the local plants. Treated wastewater discharge from Iron Bridge is discharged into the Little Econlockhatchee River downstream from the gaging station, and thus, has no effect on streamflow at the gaging station near Union Park. Also, discharges from the local wastewater treatment plants, some of which may have been located upstream of the gaging station, probably did not have a significant effect on streamflow at the Little Econlockhatchee gaging station before 1982. There is no indication that 7-day low streamflow decreased from 1984 on, after all of the local wastewater treatment plants were closed.

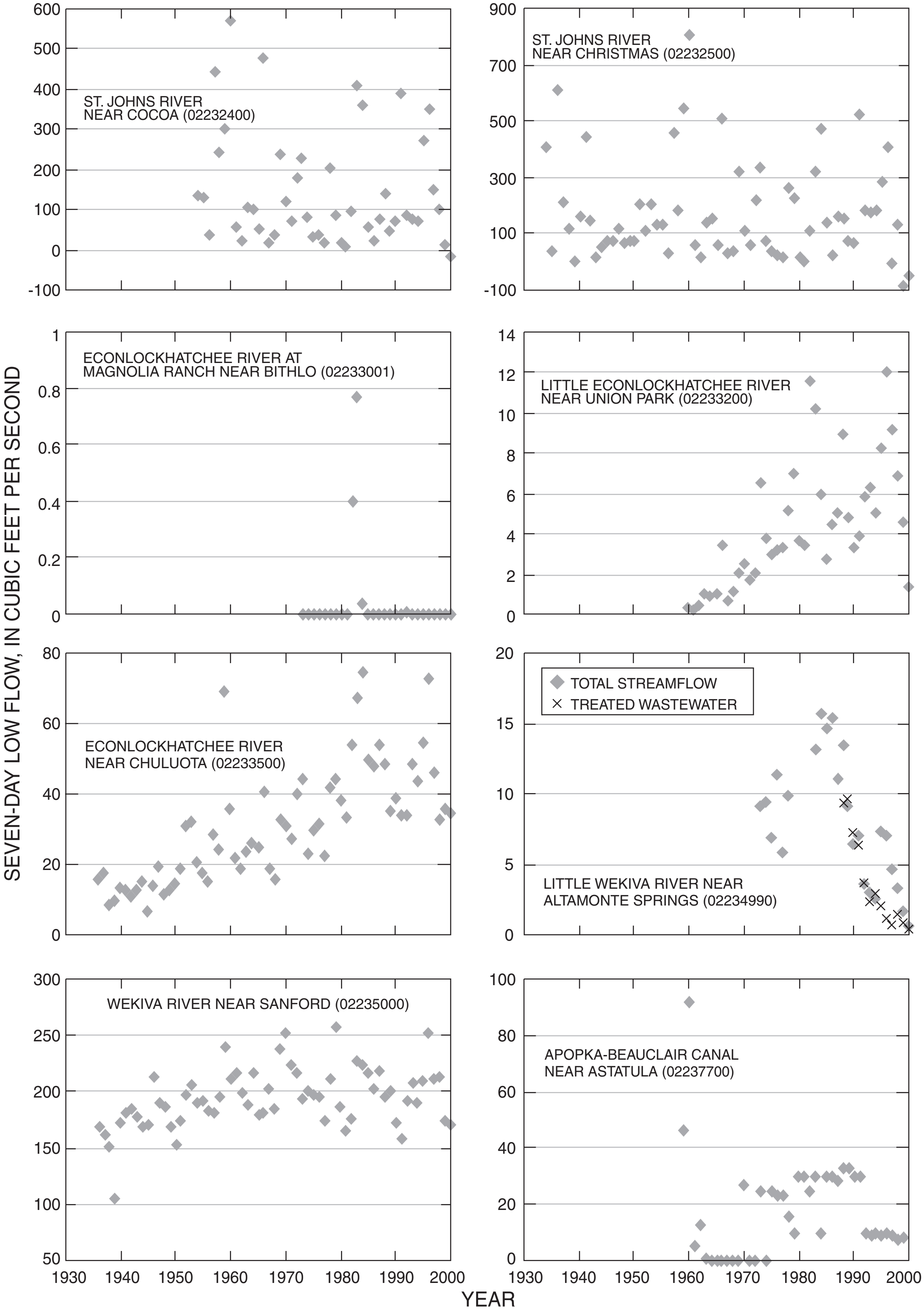


Figure 16. Seven-day low flow for selected streams in or near Orange County, Florida.

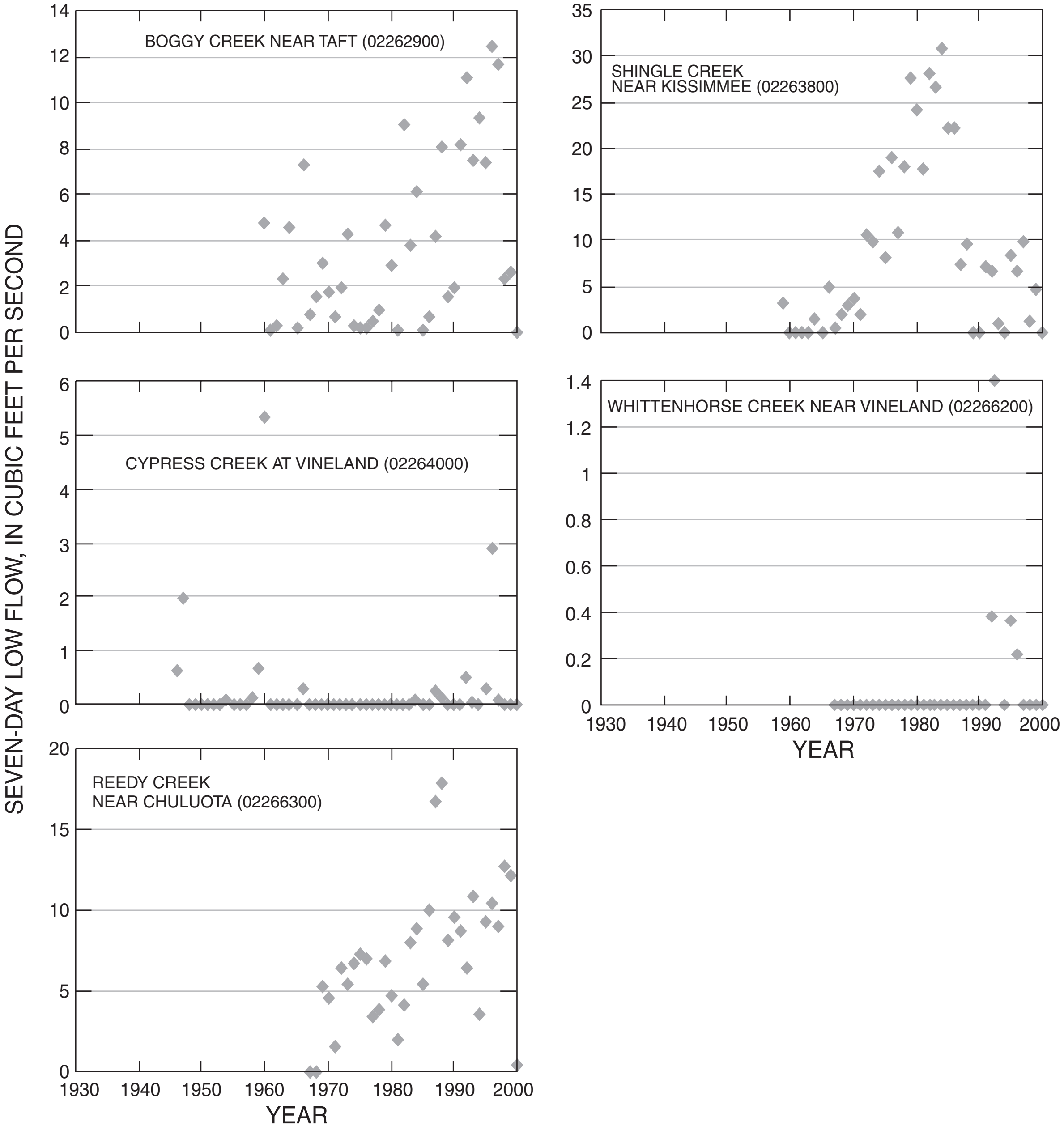


Figure 16. Seven-day low flow for selected streams in or near Orange County, Florida. (Continued)

Major land-use and drainage changes have occurred in the Little Econlockhatchee River basin since the 1960s (Kroening, 2004). These have included channel improvements to the Little Econlockhatchee River and development of a network of drainage ditches to lower the water table and make the land more suitable for residential development. Lowering the water table could result in regional reductions in rates of evapotranspiration (ET). Reducing the ET component of the water budget increases the amount of water available for the other outflow components of the water budget, including seepage and ground-water discharge to streams, which are important in maintaining streamflow during dry periods. Using water from the Floridan aquifer system for irrigation may be another cause of increasing low flows. Runoff of irrigation water, or increased seepage from irrigated areas to streams, could increase base streamflow compared to natural conditions.

The 7-day low flows in the Econlockhatchee River near Chuluota (fig. 16) have a pattern of increasing flow since 1936 (beginning of record). As in the Little Econlockhatchee River, the increase of low flow in the Econlockhatchee River was fairly uniform until the early or mid-1980s; since then the increase has slowed or stopped altogether, although the year-to-year variation in the low flow apparently has increased. This increased low streamflow is probably the result of increasing wastewater discharge and land drainage associated with residential development. Wastewater discharged into the Little Econlockhatchee River from the local wastewater treatment plants (prior to 1984) and from the regional Iron Bridge wastewater treatment plant (after 1982) enter the Econlockhatchee River upstream from the Chuluota gage.

Wastewater discharge contributes a significant part of the low flow at the Econlockhatchee gaging station near Chuluota. The wastewater discharge was about 30 ft^3/s from 1982-88, and the 7-day low flow at the Econlockhatchee site averaged about 57 ft^3/s for that period (fig. 16). Thus, the wastewater could account for more than one-half of the 7-day low flow during the period 1982-88. In 1989, more than one-half of the wastewater was diverted to an overland wastewater treatment facility that discharges into the St. Johns River. The remaining treated wastewater enters the Econlockhatchee River through the Little Econlockhatchee River. In 2000, wastewater discharge was about 16 ft^3/s, or about 46 percent of the 7-day low flow at the Econlockhatchee River near Chuluota (fig. 16).

Low flows in the Wekiva River near Sanford (fig. 16) tended to increase until about 1960, and from then on show no trend. This increase in low flow may be related to basin modifications that began around 1926 (Kroening, 2004) and possible increases in discharge from Wekiva Springs and Rock Springs since about 1960 (Tibbals, 1990). The basin modifications were mostly in the Little Wekiva River basin, and involved construction of drainage ditches for lowering the water table, and extension of the basin by installing water-level control structures on several closed-basin lakes. A possible explanation for increased discharge from the springs since about 1960 is that the springs' vents were flushed of silt and debris during a period of record high discharge in 1960. This flushing could improve the conveyance of the spring vents, and therefore, increase the discharge (Tibbals, 1990).

A pattern of increasing low flow in Boggy Creek near Taft (fig. 16) since 1960 is indicated by the Kendall Tau test. The rate of increase has not been as uniform in Boggy Creek as in the Econlockhatchee River and the Little Econlockhatchee River, although the hydrographs tend to confirm results of the Kendall Tau test.

The Kendall Tau test indicates a trend of increasing low streamflow in Whittenhorse Creek. However, the plot of annual 7-day low streamflow for Whittenhorse Creek shows only 4 years during the period of record during which the 7-day low streamflow exceeded zero (fig. 16). These nonzero 7-day low streamflows occurred in 1992, 1993, 1995, and 1996. Although these four nonzero low flows may be evidence of an increasing tendency towards nonzero 7-day low flows in Whittenhorse, since 1996 there have been no nonzero 7-day low streamflow, so it seems uncertain that a trend in 7-day low flow exists or is continuing.

Some of the increase in low flow in Reedy Creek (fig. 16) during 1970-90 may be due to the discharge of increasing volumes of treated wastewater to the creek. By 1990, wastewater discharge to Reedy Creek was stopped and was redirected to land-application sites. However, low streamflows in Reedy Creek do not seem to have a downward trend since elimination of the wastewater discharge. The apparent increases in 7-day low flows in Little Econlockhatchee River, Boggy Creek, Reedy Creek since 1990, Shingle Creek since 1989, and the nonwastewater component of the 7-day low flow in the Econlockhatchee River may be related to drainage changes resulting from increased development in Orange County. Development for most purposes, including those as diverse as cattle grazing and residential construction, may involve improvement of surface drainage through stream channelization and construction of canals. These changes in land drainage may lower the water table, resulting in regional reductions in rates of ET. Reducing the ET component of the water budget leaves more water for the other outflow components of the water budget, including seepage and ground-water discharge to streams that is important in maintaining streamflow during dry periods. Using water from the Floridan aquifer system for irrigation may be another cause of increasing low flows in streams. Runoff of irrigation water, or increased seepage from irrigated areas to streams, could increase base streamflow compared to natural conditions.

Annual Mean Flow

Annual mean streamflow is the arithmetic mean of individual daily mean discharges during a year. Mean-annual streamflow is the arithmetic mean of annual mean discharges during a specific period. There were increasing temporal trends in annual mean streamflow at 6 of the 13 streamflow stations: Econlockhatchee River at Magnolia Ranch near Bithlo, Little Econlockhatchee River, Boggy Creek, Shingle Creek, Whittenhorse Creek, and Reedy Creek (table 8, fig. 17). There are no indications of decreases in annual mean streamflow among the 13 stations.

The plot of annual mean streamflow for the Econlockhatchee River at Magnolia Ranch near Bithlo (fig. 17) does not indicate that a uniform trend in mean streamflow occurred, although the Kendall Tau test indicates a significant temporal trend. The mean-annual streamflow was low in the 1970s and early 1980s compared to mean-annual streamflow in the 1990s. However, the data do not clearly indicate if a pattern of increasing mean-annual streamflow is occurring.

The annual mean streamflow in Shingle Creek (fig. 17) seems to have increased during 1960-80, with no apparent trend after about 1980. This pattern in annual means does not resemble the pattern in 7-day low streamflows, which were observed to decrease after 1986 in response to redirection of treated wastewater from the creek (fig. 16). This difference in pattern between the low-flow and mean flow in Shingle Creek probably occurs because the average 7-day low streamflows (about 22 ft^3/s since 1986) are substantially less than the average annual mean streamflow (about 100 ft^3/s since 1986). Thus, changes in wastewater inflow are significant compared to low-flow magnitudes, but are relatively insignificant compared to the annual mean streamflow.

The annual mean streamflow in Boggy Creek, Cypress Creek, and Whittenhorse Creek generally increased with time (table 8, fig. 17). However, for these streams there have been years with relatively high streamflow in early as well as later parts of the record.

Double-mass analysis was used to observe possible changes in the rainfall-streamflow relations that might be due to basin development. In this approach, any effects of varying rainfall on streamflow patterns are minimized to some extent, although these effects might be included if the rainfall-runoff relation is not linear. The analysis was performed by first developing linear regression models for each stream, relating annual mean streamflow to annual rainfall for the period of record. Stepwise regression was used to select the three rainfall stations for which the greatest correlation between annual rainfall and streamflow occurred. Cumulative sums of streamflow estimated from rainfall by the regression models (Q_p) were plotted as a function of cumulative sums of actual streamflow (Q) for each year. Changes in the relation between streamflow and rainfall were indicated by a change in slope of the line defined by the plot of Q_p as a function of Q. An increase in the amount of streamflow relative to the amount estimated from the streamflow-rainfall model resulted in a decreasing slope of the line, or a downturn of the line toward a more horizontal position. Conversely, a decrease in the amount of streamflow relative to the amount estimated from the streamflow-runoff model resulted in an upturn of the line toward a more vertical position.

The regression models are summarized in table 9. The best model relating annual mean streamflow to annual rainfall was for Econlockhatchee River near Bithlo, with a coefficient of determination (R^2) of 0.73. This coefficient of determination indicates that 73 percent of the variation in annual mean streamflow was accounted for by variation in annual rainfall. In contrast, the poorest model of annual mean streamflow was for the Apopka-Beauclair Canal ($R^2 = 0.29$), indicating that most of the variation in streamflow was due to factors other than rainfall, including flow control at the gated structure. The coefficients of variation (CV) are an indication of the precision of the models in estimating streamflow, and are expressed as the standard deviation of the residuals (difference between model-predicted streamflow and actual streamflow), in percent of the mean streamflow. The CV's ranged from 15 percent in the Wekiva River to more than 100 percent at Cypress Creek.

The double-mass plots indicate that the streamflow-rainfall relations may have changed with time for Little Econlockhatchee River, Wekiva River, Apopka-Beauclair Canal, Boggy Creek, Shingle Creek, Whittenhorse Creek, and Reedy Creek. Streamflow increased for a selected rainfall amount at all stations except Apopka-Beauclair Canal (fig. 18). The double-mass analysis supports the Kendall Tau test and plots of annual mean streamflow, indicating that annual mean streamflow has increased in Little Econlockhatchee River, Boggy Creek, Shingle Creek, Whittenhorse Creek, and Reedy Creek. However, for the Apopka-Beauclair Canal, the double-mass plots indicate a decrease in annual mean streamflow relative to rainfall beginning about 1977. This possible decrease in streamflow in Apopka-Beauclair Canal after 1977 also is indicated by the plot of annual mean streamflow (fig. 17), but is not indicated by the Kendall Tau test.

Although no temporal trend was indicated in annual mean streamflows in the Wekiva River by the Kendall Tau test (table 8), the double-mass plot indicates a change toward greater streamflow in relation to rainfall beginning

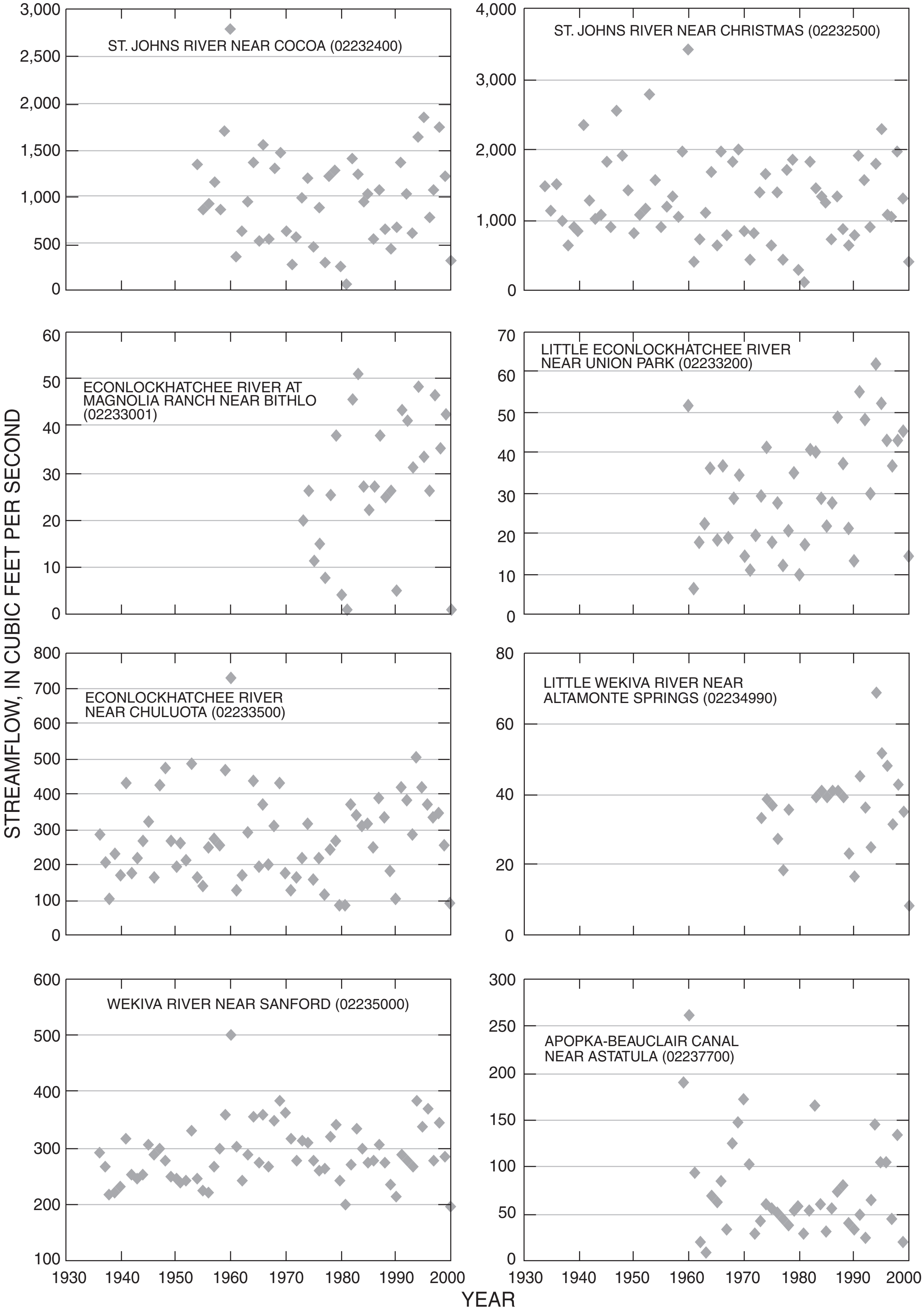


Figure 17. Annual mean streamflow for selected streams in or near Orange County.

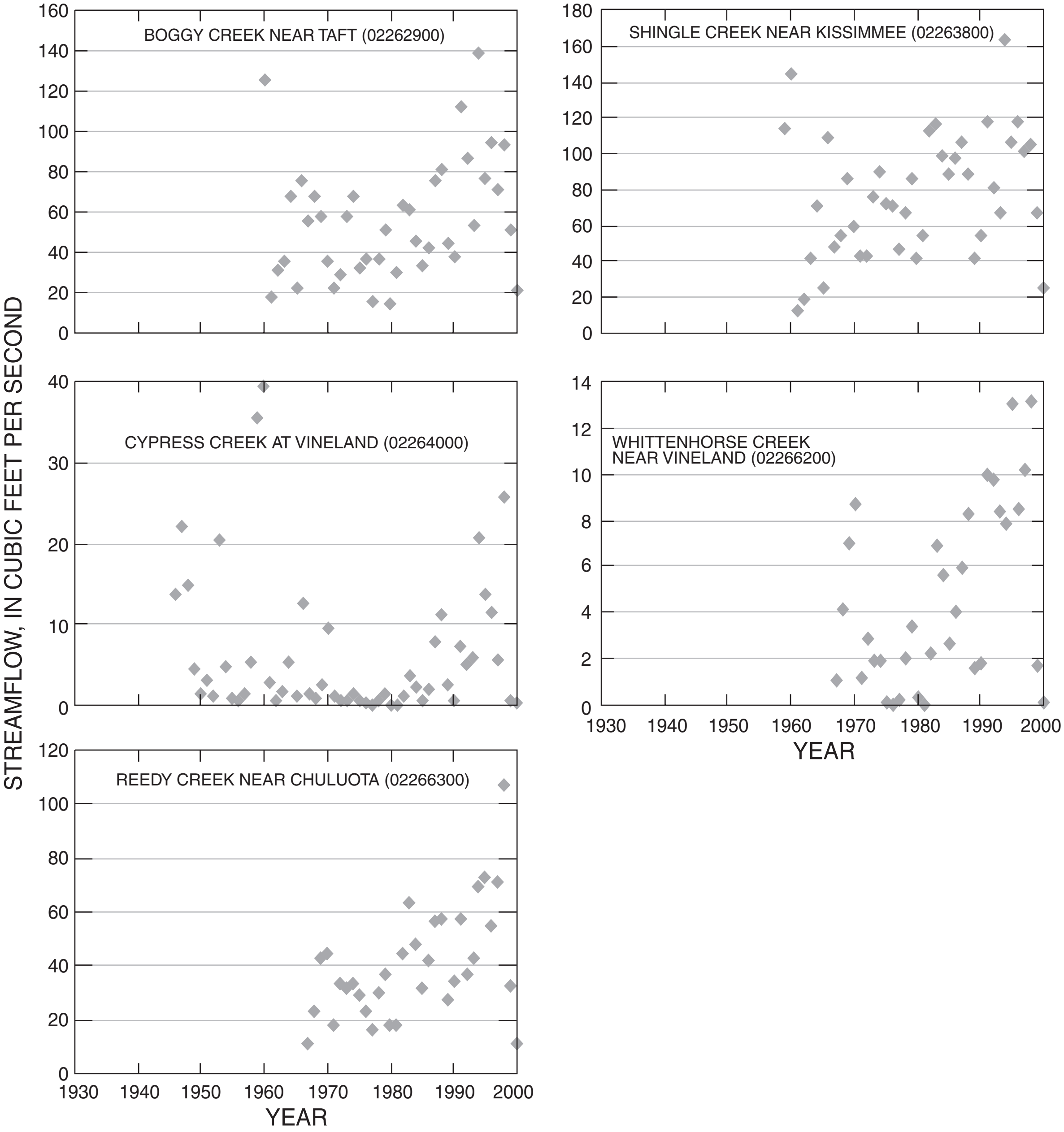


Figure 17. Annual mean streamflow for selected streams in or near Orange County. (Continued)

about 1959 (fig. 18). This increase is not as noticeable from the plot of annual mean streamflow by year, but the plot does indicate a pattern of greater annual mean streamflow after 1959 in the Wekiva River (fig. 17). A comparison of mean-annual streamflow for 1934-1958 (262 ft^3/s) with the mean-annual streamflow for 1959-2000 (302 ft^3/s) also indicates an increase in annual mean streamflow since about 1959. A possible explanation for increased discharge from the springs since about 1960 is that the springs' vents were flushed of silt and debris during a period of record high discharge in 1960. This flushing could improve the conveyance of the spring vents, and therefore, increase the discharge (Tibbals, 1990).

The double-mass plots for Cypress Creek and Whittenhorse Creek (fig. 18) indicate that relatively abrupt changes in magnitude and direction of slope occurred, but do not indicate clearly whether or not there were persistent changes in streamflow over periods of several years. The large slope changes that occur within a few years may be characteristic of intermittent streams. Both streams

Table 9. Summary of regression models for estimating annual mean streamflow from annual rainfall.

[Regression model is Q = Intercept + Term$_1$ + Term$_2$ + Term$_3$, where Q is the estimated annual mean streamflow in cubic feet per second, and Term$_{1,2,3}$ are the products of the coefficients listed below and the annual rainfall in inches for the indicated location: mel, Melbourne; orl, Orlando; ver,Vero Beach; san, Sanford; drm, Fort Drum; clr, Clermont; kis, Kissimmee; tvl, Titusville. R^2 is the coefficient of determination; CV is the coefficient of variation]

Station name	USGS identifier	Intercept	Term$_1$	Term$_2$	Term$_3$	R^2	CV
St. Johns River near Cocoa	02232400	-1,482	26.62 *mel	10.89 *orl	9.67 *ver	0.65	33
St. Johns River near Christmas	02232500	-1,797	32.76 *mel	13.78 *orl	14.47 *ver	.64	32
Econlockhatchee River at Magnolia Ranch near Bithlo	02233001	-54.84	.4041 *mel	.642 *orl	.550 *ver	.73	
Little Econlockhatchee River near Union Park	02233200	-41.22	.384 *mel	.64 *orl	.378 *ver	.65	27
Econlockhatchee River near Chuluota	02233500	-378.5	3.62 *mel	6.23 *orl	3.11 *ver	.67	28
Little Wekiva River near Altamonte Springs	02234990	62.59	1.958 *clr	1.578 *mel	.958 *ver	.42	
Wekiva River near Sanford	02235000	62.59	1.96 *clr	1.58 *mel	.958 *ver	.42	15
Apopka-Beauclair Canal near Astatula	02237700	-58.61	2.57 *kis	1.014 *san	-.792 *tvl	.29	62
Boggy Creek near Taft	02262900	-85.27	.5596 *drm	1.320 *kis	.933 *san	.65	32
Shingle Creek near Kissimmee	02263800	-85.04	.910 *kis	.930 *san	1.27 *ver	.69	25
Cypress Creek at Vineland	02264000	-20.84	.503 *kis	.273 *mel	-.210 *tvl	.49	105
Whittenhorse Creek near Vineland	02266200	-9.818	.099 *drm	.079 *mel	.104 *san	.46	65
Reedy Creek near Vineland	02266300	-26.23	-.546 *clr	.971 *drm	.874 *kis	.50	38

became dry or nearly dry for 2 to 3 years during periods of low rainfall. Once the basins have dried out, it may take several months of relatively high rainfall to restore flow to the streams. Thus, the streamflow-rainfall relation may change rapidly from periods of no flow to periods of sustained flow.

High-Flow Characteristics

There were significant increases in 1-day high streamflows in Whittenhorse Creek and Reedy Creek (table 8). Higher flows in these streams generally occurred during 1985-2000 (fig. 19). The reasons for increasing high flows are unclear, but may be related to development and changes in the basins of these streams. Whittenhorse Creek and Reedy Creek are the only streams with temporal trends indicated for each of the flow conditions tested: 7-day low, annual mean, and 1-day high streamflow.

The trend testing (table 8) and data plots (fig 19) do not indicate evidence for changes in 1-day high streamflows in the Little Wekiva River. However, problems associated with stormwater runoff into the river have been documented (Woodward-Clyde Consultants, 1998). These problems are related to decreased stormwater runoff time and increased river flows and velocities, probably as a result of urbanization. The increased flows have caused erosion problems in Orange County and sedimentation problems in Seminole County. Buildup of sediments has contributed to flooding and has degraded water quality in both the Little Wekiva River and the Wekiva River.

Lake Water Levels

Trends in lake water levels were evaluated from estimated annual mean water levels. The annual mean water levels were determined from periodic water-level measurements by averaging all water level measurements for each year. Years with less than four water-level measurements were not included in the analysis. Temporal trends were only determined for lakes with more than 15 years of record. Two sets of tests were performed. One set of trend tests was completed using the entire period of record at each lake. Because the periods of water-level record varied widely among the lakes, another set of tests was performed for 1970-97. This test included only lakes with record of water level during the entire 1970-97 period, and was used to compare effects of lake type and location on water-level changes during a period common to all lakes included in the analysis.

Interpretation of the statistical trend testing is limited because of the characteristics of the data base, and also because the tests do not consider multiple trends that may occur within the test period. The data base of lake levels is not ideal for comparison of trend-test results among the

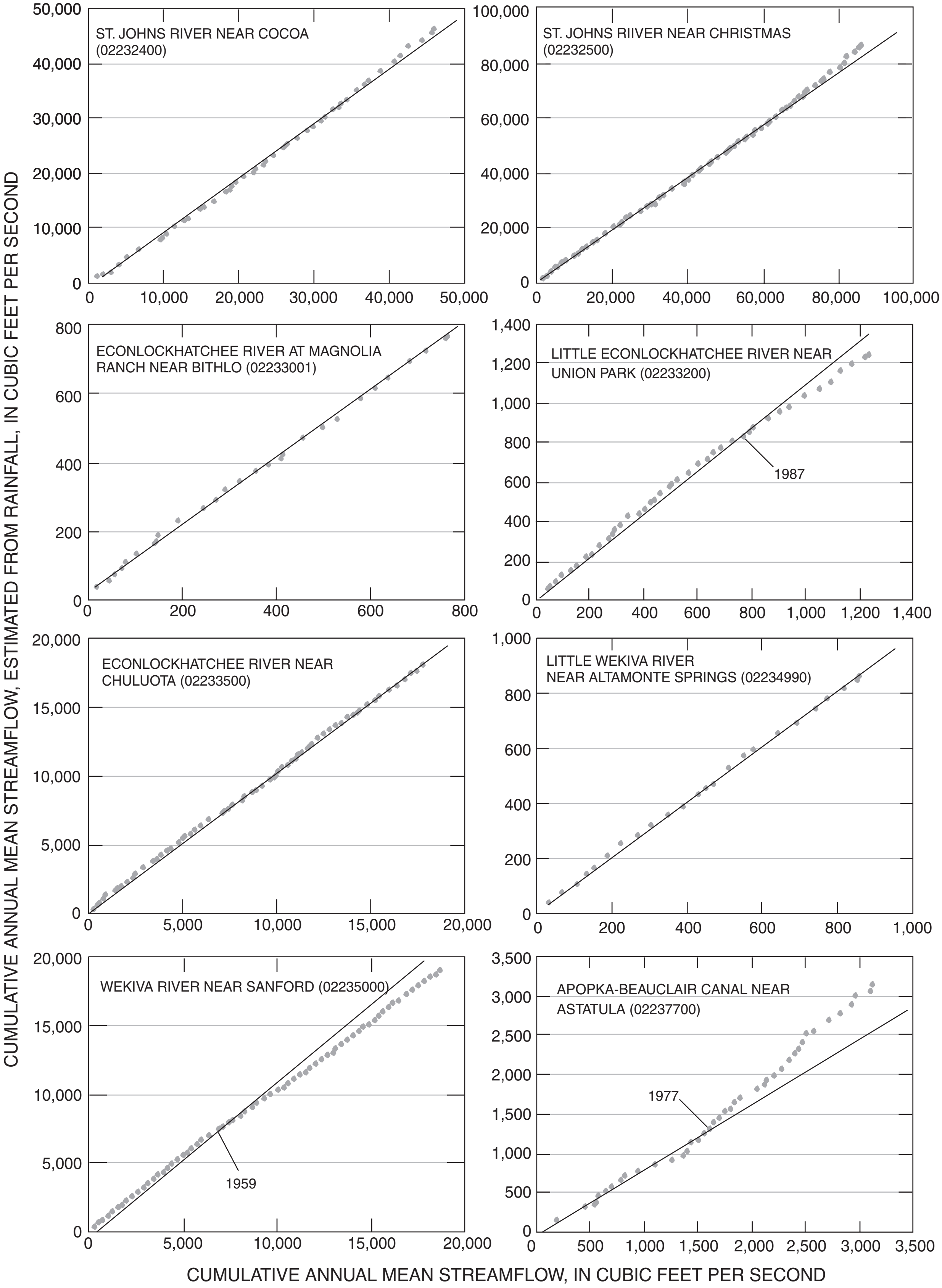


Figure 18. Streamflow for selected streams in or near Orange County. (Points are cumulative annual mean and cumulative annual mean estimated from rainfall. The solid line is hand-fitted to show year when slope of cumulative plot changed.)

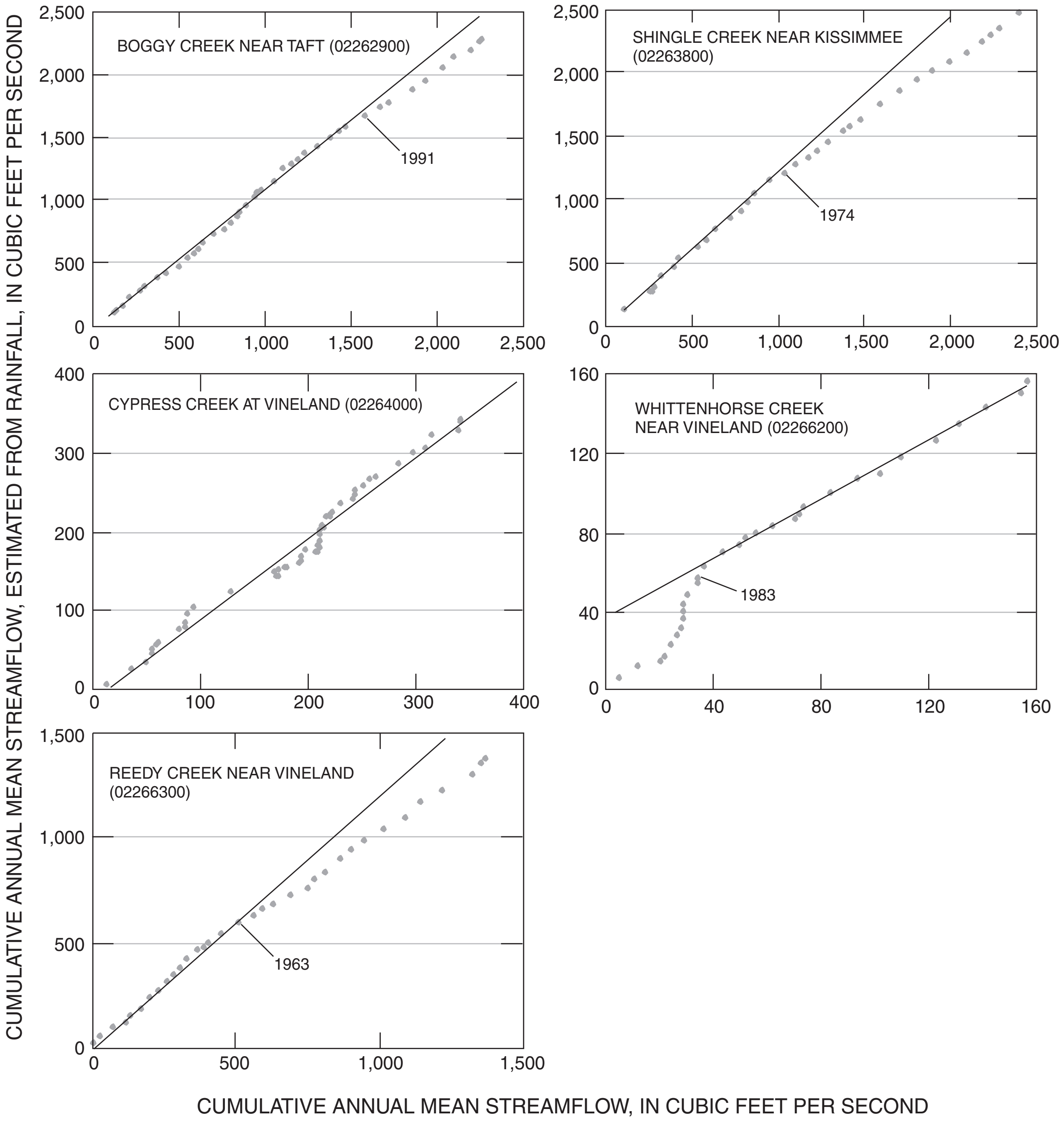


Figure 18. Streamflow for selected streams in or near Orange County. (Points are cumulative annual mean and cumulative annual mean estimated from rainfall. The solid line is hand-fitted to show year when slope of cumulative plot changed.) (Continued)

lakes because of the nonuniformity of period of record and frequency of water-level measurement. Some lakes were measured monthly or more often, and other lakes had quarterly or fewer measurements some years. In some lakes, there were downward trends in water level for several years, followed by upward trends. In these cases of multiple trends within a period of lake data, the statistical test result will apply only to the overall tendency for water-level change over the entire test period and provides no insight regarding short-term trends. In spite of these limitations in trend-test application, some general conclusions can be made regarding trends of lakes water level.

A total of 83 lakes had more than 15 years of record; in some cases the record began in the 1930s. There were significant temporal trends in 33 of the 83 lakes (40 percent) tested using the entire period of record (table 10). Of these 33 lakes, 14 had increasing water levels and 19 lakes had decreasing water levels.

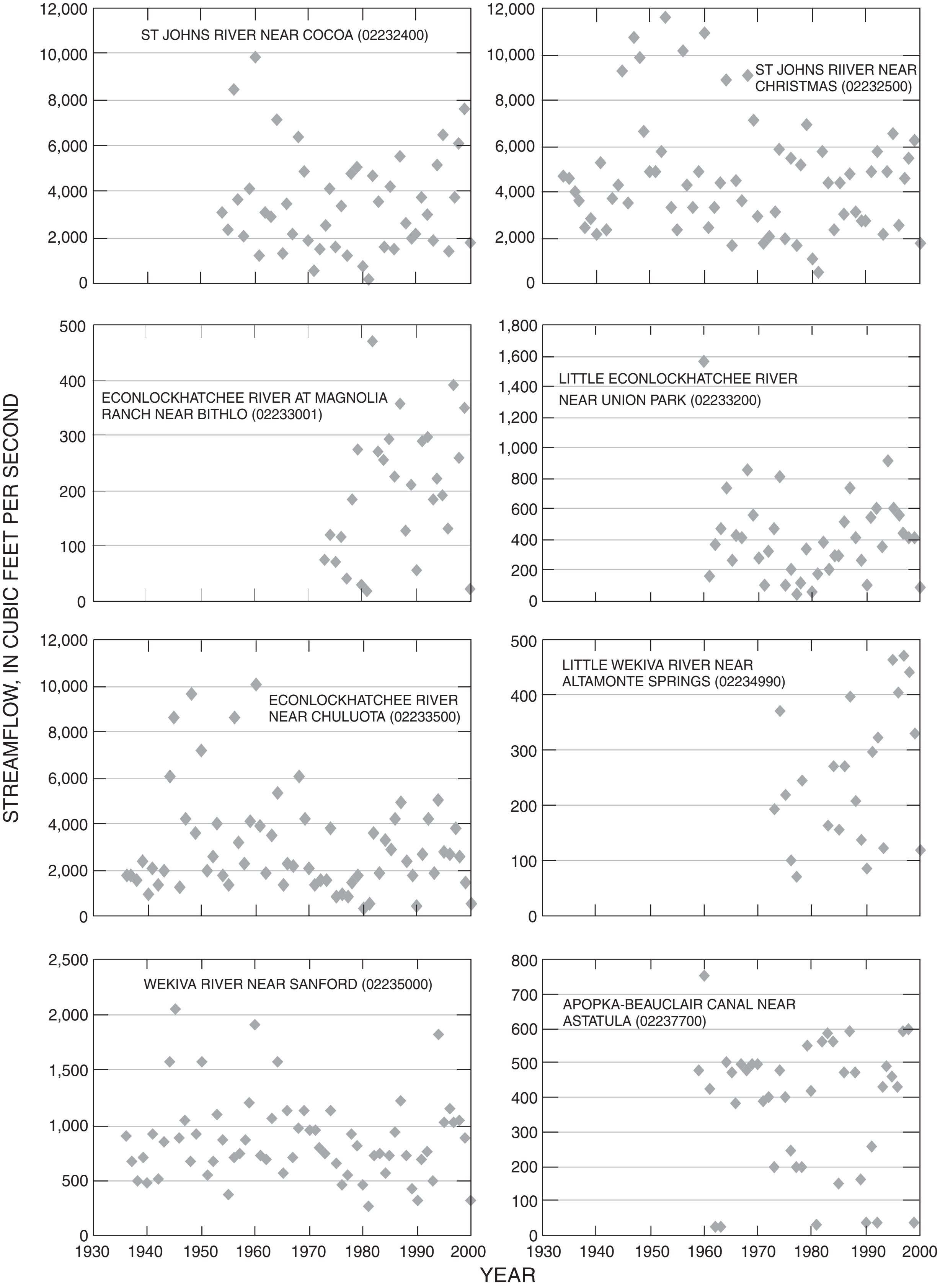


Figure 19. One-day high flow for selected streams in or near Orange County.

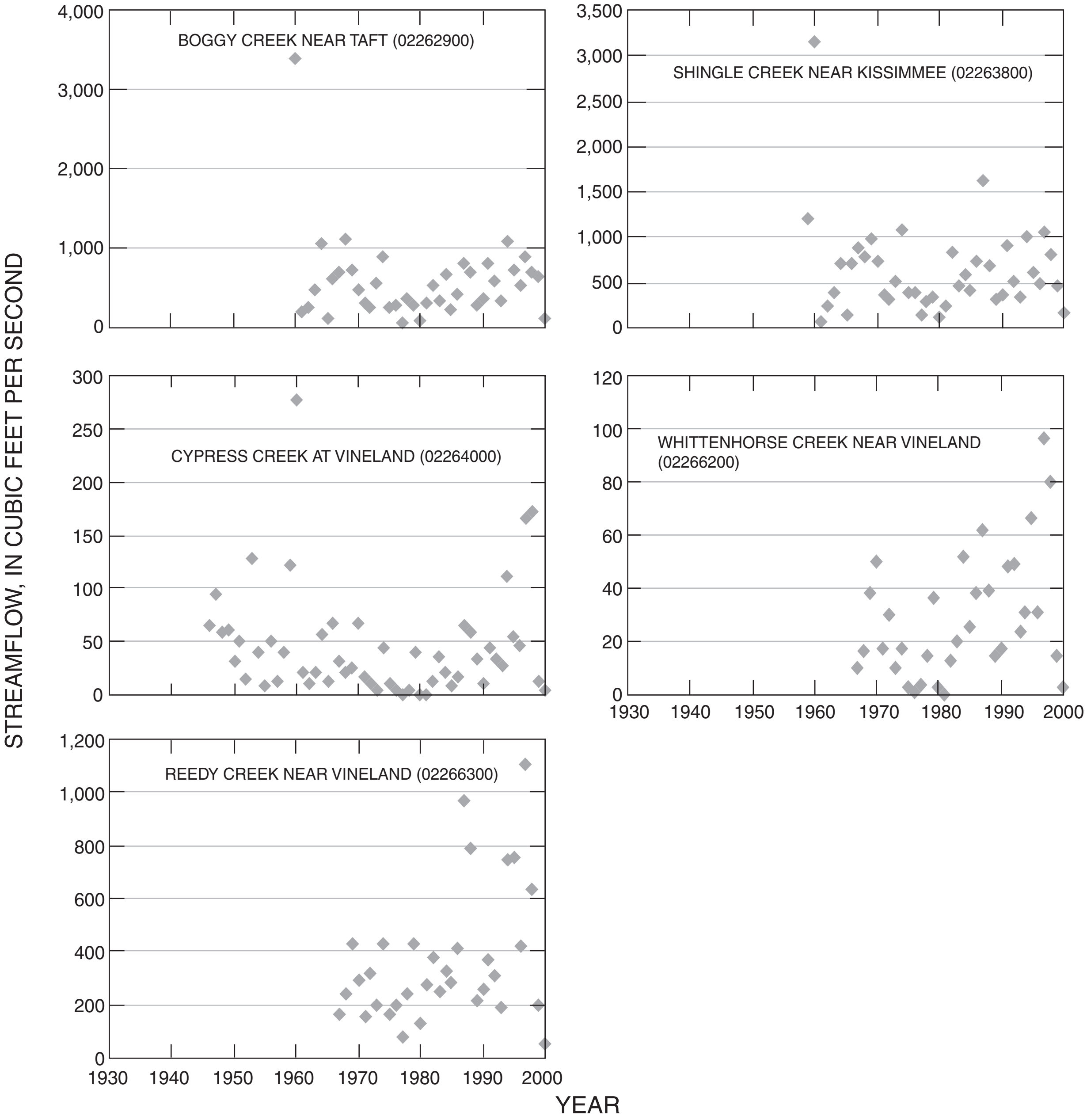


Figure 19. One-day high flow for selected streams in or near Orange County. (Continued)

More than one-half of the lakes with significant trends for the entire period of water-level record had declining water levels. The reason for this predominance of downward trends in long-term record may be that extreme high-water conditions existed for many lakes in 1960 after 2 years of relatively high rainfall—culminated by rains from Hurricane Donna in September 1960. For Orlando, rainfall totals were 63.9 inches in 1959 and 68.7 inches in 1960. At Kissimmee, rainfall totals were 76.7 inches in 1959 and 80.4 inches in 1960. As a result of the high rainfall during these 2 years, historical high-water levels occurred in many lakes in 1960 or 1961 (fig. 20). These high-water levels persisted at least into 1961 at many lakes and likely had an effect on trend testing of the entire period of record for many lakes, especially those in which record-keeping began in or around 1960. Examples of the significance of the 1959-60 high-rainfall totals on historical high-water levels is especially notable for Lake Alpharetta,

Table 10. Results of statistical testing for trends in lake water levels.

[Only lakes with at least 15 years of record are included; annual mean water levels were tested. Type: S, seepage lake; D, lake is part of surface-drainage feature. Control: pump, lake stage can be controlled by pumping; weir, weir control; well, drainage well control; cvt, culvert control, None, no manmade control of water level; <, less than; --, insufficient data for analysis. The Kendall T is a test statistic based on the relation of annual mean lake level with time. A positive T indicates an increase in lake level with time; a negative T indicates a decrease in lake level with time. The p-value is the probability that a pattern of increasing or decreasing water level could result from a trendless set of data. A p-value of 0.05 or less is taken as evidence of a significant trend in water level and is in bold type]

Lake	Map No.	Type	Con-trol	Township (South)	Range (East)	1970 - 1997			Period of record		
						Years	Kendall T	Probability	Years	Kendall T	Probability
Alpharetta	1	S	none	21	28	21	-0.32	**0.04**	31	-0.5	**<0.01**
Anderson	2	S	pump	23	30	23	.15	.32	26	-.08	.55
Apopka	3	D	weir	22	27	--	--	--	58	-.12	.19
Avalon	4	S	none	23	27	16	-.20	.28	19	-.38	**.02**
Baldwin	5	D	weir	22	30	22	.19	.23	34	.04	.77
Barton (Big)	6	S	weir	22	30	26	-.13	.34	36	-.34	**<.01**
Barton (Little)	7	S	well	22	30	17	.07	.71	20	.21	.21
Barton Lake	8	D	weir	24	31	26	.47	**<.01**	36	.38	**<.01**
Bay	9	S	none	22	29	22	.39	**.01**	24	.4	**<.01**
Bearhead	10	S	well	23	29	--	--	--	17	-.09	.62
Bell	11	S	cvt	22	29	23	.31	**.04**	24	.31	**.03**
Berry	12	D	none	22	30	17	.19	.28	17	.19	.28
Big Fairview	13	S	well	22	29	26	.13	.32	36	-.05	.66
Black	14	U	weir	22	27	--	--	--	18	-.22	.21
Border	15	S	none	21	28	--	--	--	17	-.34	.06
Bosse	16	S	weir	21	29	25	.41	**<.01**	33	-.16	.18
Butler	17	D	none	23	28	28	.35	**<.01**	66	-.26	**<.01**
Cane	18	S	none	23	28	--	--	--	18	-.08	.62
Clear	19	D	weir	23	29	26	-.03	.82	35	.18	.13
Conway	20	S	well	23	29	26	.16	.26	44	.17	.10
Crescent	21	U	cvt	23	27	18	.53	**<.01**	22	.25	.11
Crooked	22	S	none	22	28	21	-.07	.67	30	.13	.31
Daniel	23	S	none	22	29	22	.28	.07	23	.34	**.02**
Dora	24	S	none	L		--	--	--	58	-.15	.09
Down	25	S	none	23	28	22	.50	**<.01**	26	.22	.12
Ellenore	26	D	weir	23	29	23	.64	**<.01**	23	.66	**<.01**
Estelle	27	D	well	22	29	--	--	--	17	-.69	**<.01**
Fish	28	U	none	24	28	18	.56	**<.01**	22	.26	.09
Formosa	29	D	well	22	29	--	--	--	17	-.69	**<.01**
Francis	30	S	none	L		28	-.15	.24	40	-.17	.12
Fredrica	31	S	cvt	23	30	--	--	--	18	-.1	.57
Gandy	32	S	cvt	21	29	25	.33	**.02**	34	-.13	.28
Gatlin	33	U	weir	23	29	--	--	--	22	.45	**<.01**
Gem Mary	34	S	none	23	29	19	.19	.25	22	.07	.63
Hancock	35	U	none	23	27	19	.30	.07	22	.19	.20
Hart	36	D	weir	24	31	26	.67	**<.01**	54	.46	**<.01**
Hickory Nut	37	S	none	24	27	--	--	--	17	.43	**.02**
Holden	38	S	well	23	29	--	--	--	22	.22	.15
Horseshoe	39	S	cvt	22	28	--	--	--	17	-.29	.10
Ivanhoe	40	S	weir	22	29	--	--	--	31	.62	**<.01**
Jennie Jewel	41	S	well	23	29	--	--	--	22	.33	**.03**
Jessamine	42	U	well	23	29	26	-.37	**<.01**	36	-.42	**<.01**

Table 10. Results of statistical testing for trends in lake water levels. (Continued)

[Only lakes with at least 15 years of record are included; annual mean water levels were tested. Type: S, seepage lake; D, lake is part of surface-drainage feature. Control: pump, lake stage can be controlled by pumping; weir, weir control; well, drainage well control; cvt, culvert control, None, no manmade control of water level; <, less than; --, insufficient data for analysis. The Kendall T is a test statistic based on the relation of annual mean lake level with time. A positive T indicates an increase in lake level with time; a negative T indicates a decrease in lake level with time. The p-value is the probability that a pattern of increasing or decreasing water level could result from a trendless set of data. A p-value of 0.05 or less is taken as evidence of a significant trend in water level and is in bold type]

Lake	Map No.	Type	Con-trol	Township (South)	Range (East)	1970 - 1997			Period of record		
						Years	Kendall T	Probability	Years	Kendall T	Probability
Johns	43	S	weir	22	27	28	.21	0.10	40	-0.15	0.18
Killarney	44	D	well	22	29	27	.34	**.01**	36	.45	**<.01**
Lawne	45	D	weir	22	29	26	.57	**<.01**	36	.18	.12
Little Fairview	46	S	well	22	29	25	-.05	.74	44	-.03	.78
Lockhart	47	S	cvt	21	29	19	.53	**<.01**	22	.26	.10
Long	48	S	pump	21	28	--	--	--	22	-.36	**.02**
Maitland	49	D	weir	21	30	26	-.27	.06	50	.12	.2
Mann	50	S	well	22	29	26	-.07	.61	36	-.15	.2
Mary	51	s	weir			22	.22	.17	24	.30	**.04**
Mary Jane	52	D	weir	24	31	28	.45	**<.01**	52	-.06	.56
Mccoy	53	U	cvt	21	28	22	-.01	.94	23	.06	.69
Minnehaha	54	D	weir	21	30	21	.05	.76	22	.07	.63
Mizell	55	D	weir	22	30	--	--	--	19	.16	.33
Ola	56	D	cvt	20	27	16	.45	**.02**	18	.55	**<.01**
Osceola	57	D	weir	22	30	--	--	--	19	.14	.4
Page	58	S	well	21	28	--	--	--	17	-.4	**.03**
Park & Gem	59	D	none	21	29	25	-.61	**<.01**	24	-.67	**<.01**
Pleasant	60	S	well	21	28	--	--	--	17	-.6	**<.01**
Pocket	61	U	none	24	28	--	--	--	17	.53	**<.01**
Prevatt	62	U	none	20	28	19	.23	.17	20	.18	.27
Rose	63	U	none	22	28	26	.26	.06	36	.03	.76
Sand Lake (Big)	64	S	cvt	24	28	26	.12	.39	35	-.34	**<.01**
Sand Lake (Little)	65	S	none	23	28	17	.53	**<.01**	20	.13	.44
Sarah	66	S	weir	22	29	20	.19	.24	21	.24	.13
Shadow	67	S	cvt	21	29	--	--	--	16	.17	.37
Sherwood	68	S	well	22	28	26	.21	.13	34	-.13	.29
Silver	69	S	weir	22	29	22	.04	.80	28	.17	.21
Spring	70	S	well	23	28	22	.24	.14	25	-.13	.37
Spring, No. Orange Blossom Trail	71	S	none	22	29	18	.03	.85	39	-.23	**.04**
Stanley	72	S	well	22	28	--	--	--	17	-.41	**.02**
Sue	73	D	none	22	30	25	-.69	**<.01**	44	-.82	**<.01**
Susannah	74	S	weir	22	30	19	-.25	.13	26	-.46	**<.01**
Sybelia	75	S	well	21	29	20	-.08	.60	20	-.08	.6
Tibet Butler	76	D	none	23	28	26	.36	**<.01**	35	.12	.3
Turkey	77	S	none	23	28	--	--	--	19	-.64	**<.01**
Tyler	78	U	weir	23	29	--	--	--	23	.28	.06
Underhill	79	S	well	22	30	21	-.58	**<.01**	36	-.03	.8
Virginia	80	D	weir	22	30	--	--	--	19	.15	.36
Warren	81	D	none	23	30	25	-.31	**.03**	34	-.48	**<.01**
Waunatta	82	U	weir	22	30	16	.03	.86	20	.11	.52
Wekiva (Orlando)	83	D	weir	22	29	27	-.24	.08	29	-.38	**<.01**

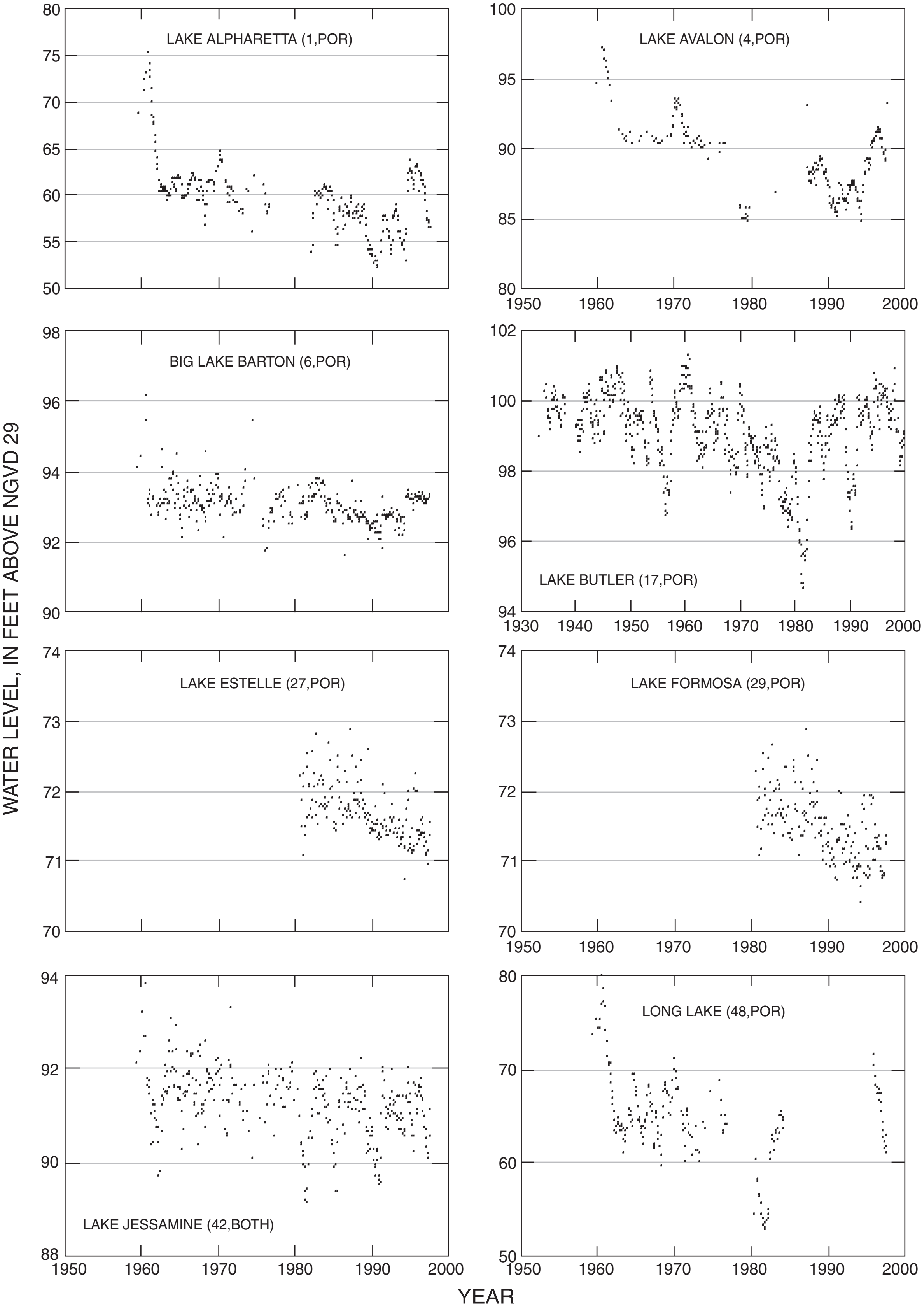


Figure 20. Lakes with a significant downward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.)

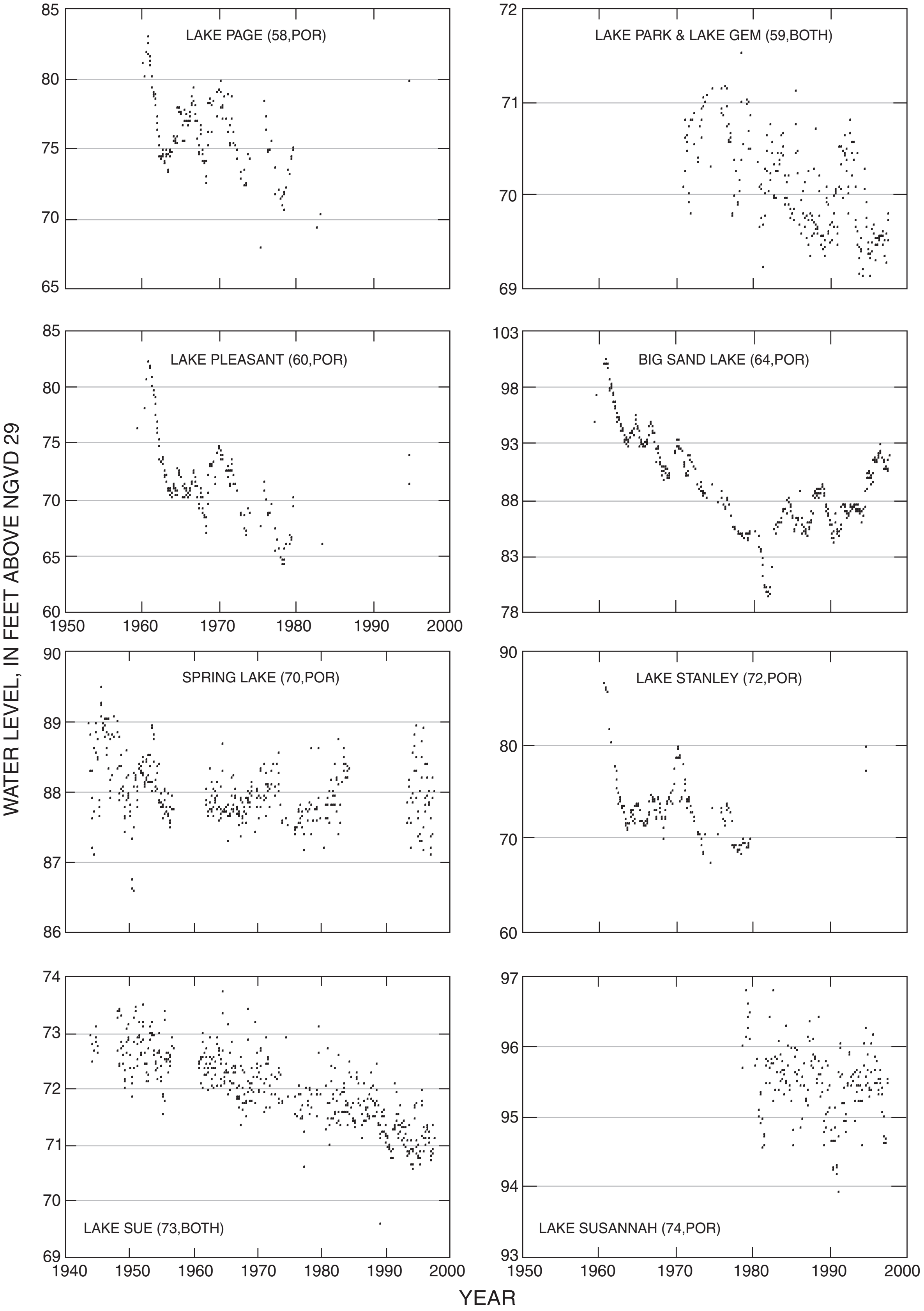


Figure 20. Lakes with a significant downward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.) (Continued)

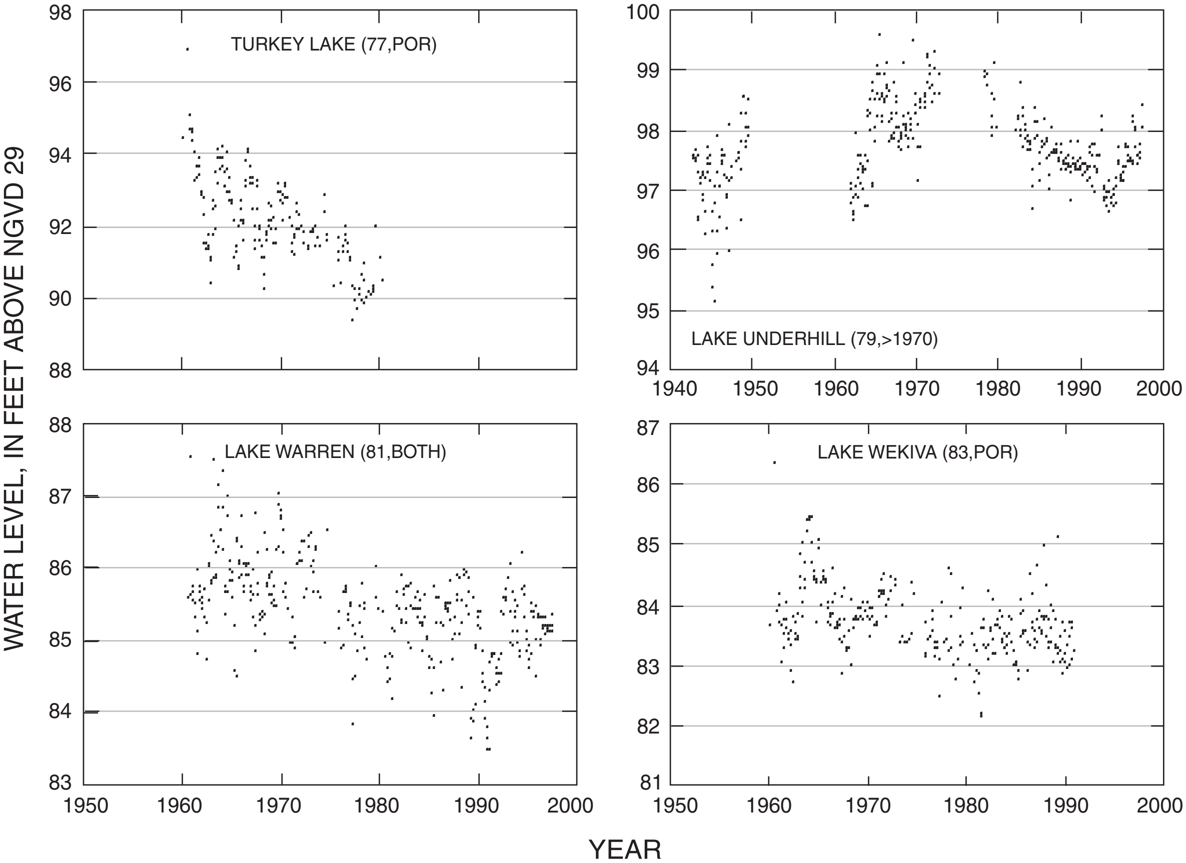


Figure 20. Lakes with a significant downward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.) (Continued)

Lake Avalon, Lake Jessamine, Long Lake, Lake Page, Lake Pleasant, Big Sand Lake, Lake Stanley, Turkey Lake, and Lake Warren (fig. 20). All of these lakes had high-water levels during 1960-61 that exceeded water levels throughout the period of record.

The high-water levels of 1959-60 likely will never be repeated in many lakes. Since the early 1900s, drainage wells were constructed to augment surface drainage in Orange County, when incompatibility between expanding urban land use and variable lake stages was noted (Kimrey, 1978). Flooding in 1959-60 resulted in the construction of about 35 additional drainage wells in Orange County (Lichtler and others, 1968). Most of the drainage wells are operational and are an effective flood-control measure. Drainage wells on the perimeter of many lakes probably limit the highest lake levels to the approximate elevation of the well intake. Other drainage wells intercept street runoff that otherwise would reach lakes, thereby reducing the effective drainage area (and maximum water levels) of the lakes.

For many or even most lakes, there has not been a uniform pattern of declining or increasing water level over the period of record. Instead, periods of decreasing water levels and periods of increasing water levels have occurred. Lake Butler (fig. 20) and Hickory Nut Lake (fig. 21) are two examples of lakes that had a pattern of declining water levels from 1959-60 to the early 1980s, probably indicating a change from the high-water levels resulting from heavy rainfall during 1959-60 to low water levels that occurred in the early 1980s as a result of relatively low rainfall. Following this period of decline, there was an upward water-level trend in many lakes. This pattern of lake-level fluctuations is similar to the pattern of rainfall, especially the 5-year moving average of rainfall (fig. 15).

From 1970-97, trends were indicated in 24 of the 57 lakes (42 percent) tested (table 10). Nineteen lakes had increasing water levels and five lakes had decreasing water levels. The number of lakes with trends in water levels during 1970-97 were tabulated according to lake type and to presence or absence of a manmade water-level control.

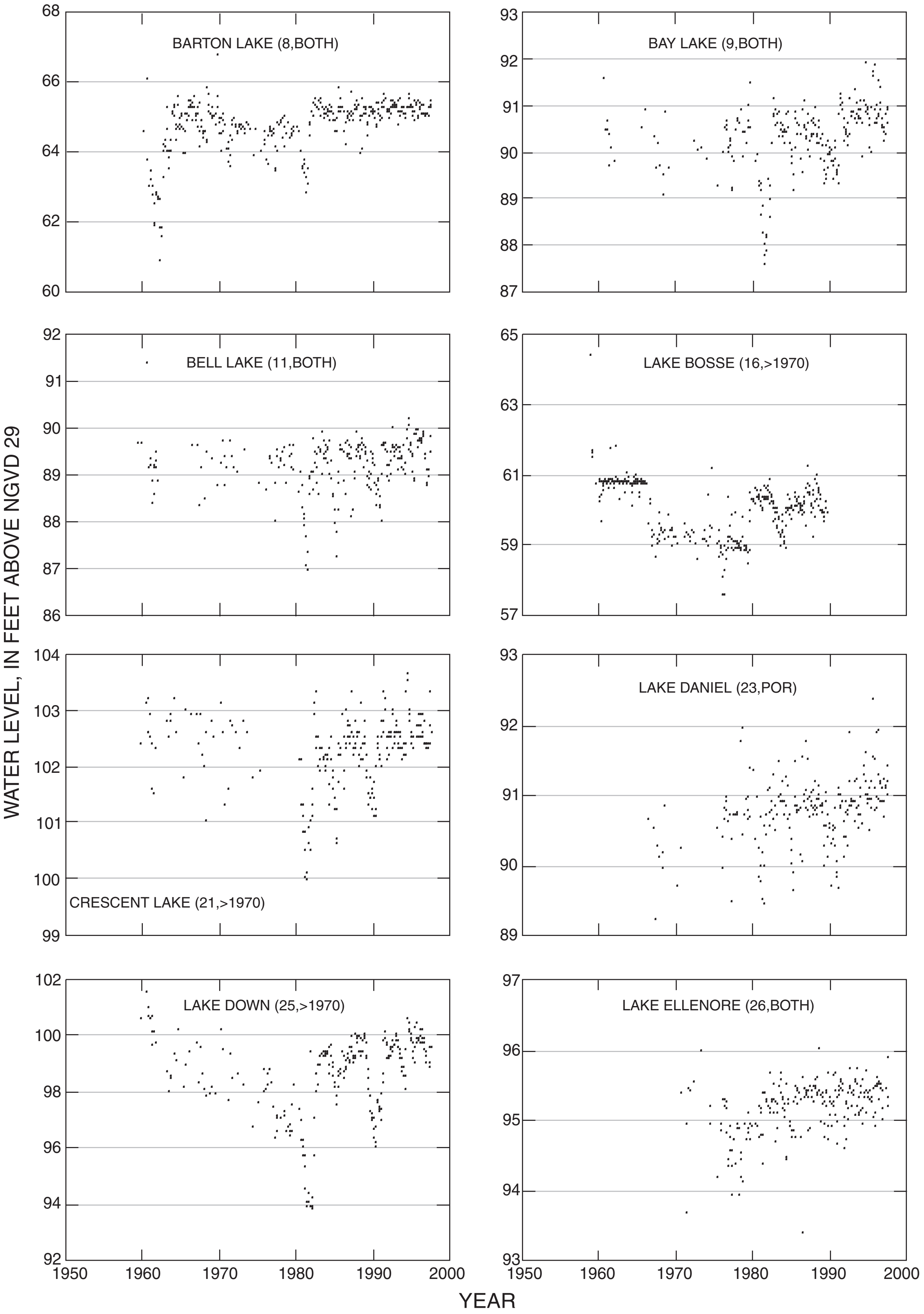


Figure 21. Lakes with a significant upward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.)

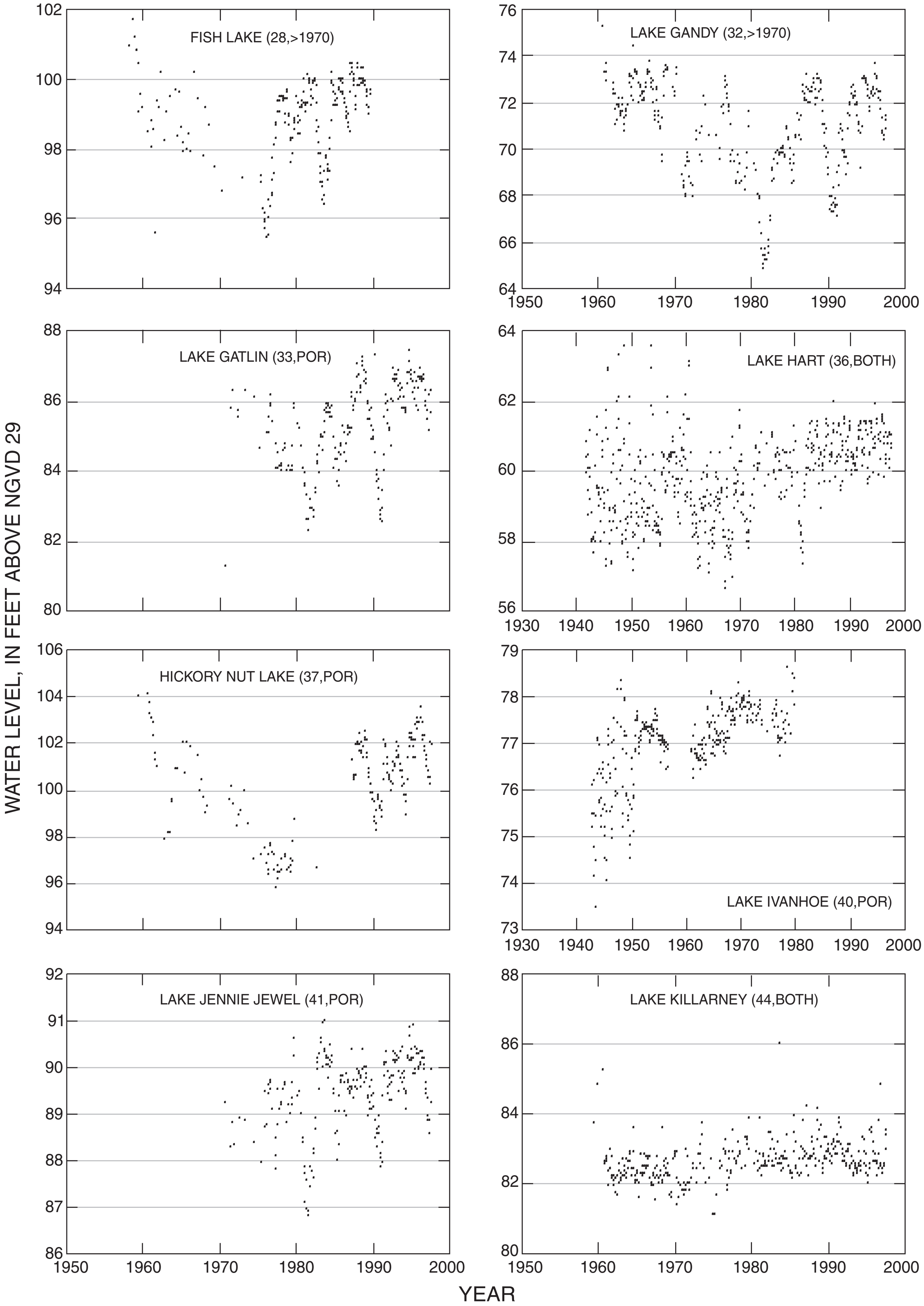


Figure 21. Lakes with a significant upward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.) (Continued)

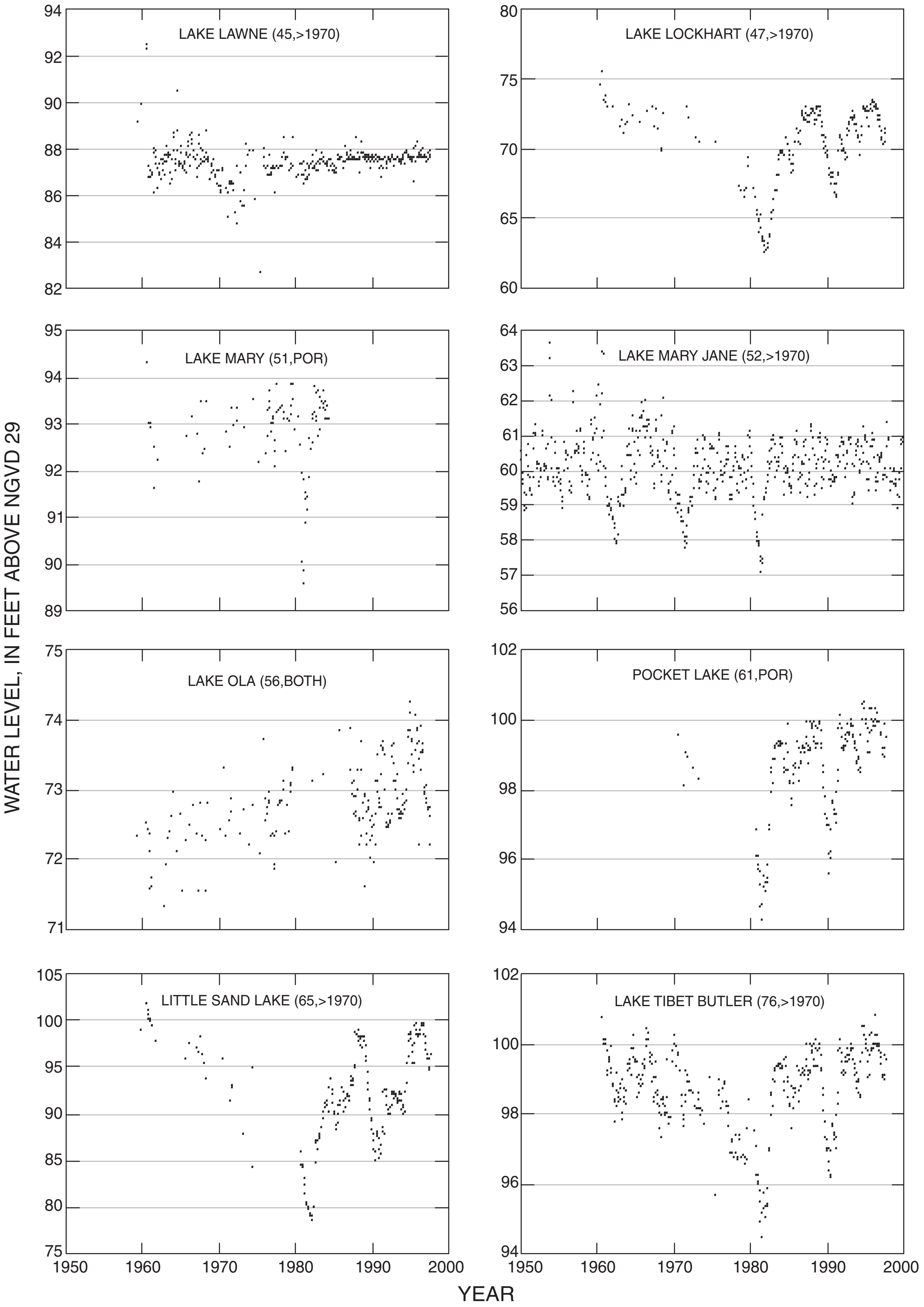


Figure 21. Lakes with a significant upward trend in water level. (Data are from USGS and Orange County Stormwater Management Division. Number in parentheses refers to location in figure 8 and appendix B. Por, trend is for entire period of record; >1970, trend is for 1970-97 only; both, trend is for period of record and also for 1970-97.) (Continued)

The lake types considered were drainage lakes and seepage lakes. Drainage lakes lose water primarily through a surface-water outlet; seepage lakes have no surface-water outflow, losing water primarily to the ground-water system or through evaporation. Some lakes were not classified because surface-drainage features are not well defined or are likely to affect lake drainage only at relatively high-water levels.

Several types of water-level control are used. Some lakes have weirs or culverts, which direct water from the lake into streams, canals, or other lakes when the lake level reaches the elevation of the weir top or culvert floor. Drainage wells, present on some lakes, function similar to weirs or culverts, by removing water from the lakes when lake levels reach the elevation of the well intake. Pumping stations are used intermittently at a few lakes to mitigate flooding during wet periods.

The number of lakes in each group with apparent downward trends in water levels during 1970-97 are summarized in the following table:

Lake type	Manmade water-level control	
	Yes	No
Drainage	0	3
Seepage	1	1
Unknown	0	0
Total	1	4

Lakes with no manmade water-level controls account for four of the five lakes with downward trends in water levels. Of these four lakes, three are drainage lakes. However, no definite conclusions regarding relations between lake type and presence of water-level controls can be made, because of the small number of lakes with downward trends.

A similar comparison for lakes with apparent upward trends in water level during 1970-97 is as follows:

Lake type	Manmade water-level control	
	Yes	No
Drainage	7	2
Seepage	4	3
Unknown	2	1
Total	13	6

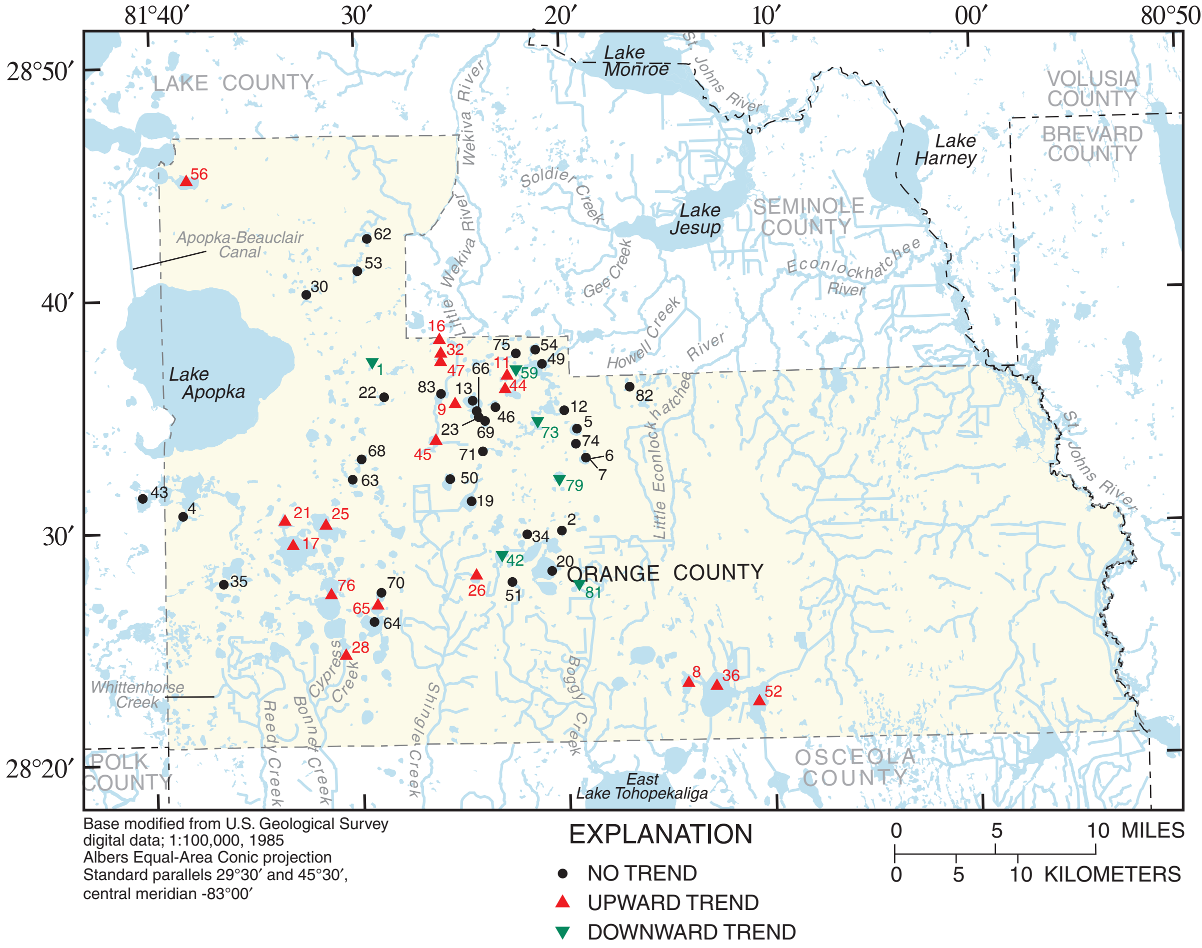
Lakes with manmade water-level controls account for 13 of the 19 lakes with upward trends in water levels. However, lakes with manmade water-level controls also are the most numerous among the lakes that were tested for trends, and accounted for 37 of the 57 lakes (65 percent) that were tested. Therefore, this comparison probably does not indicate that the presence of manmade water-level controls is related to upward trends in water level.

The locations of lakes with sufficient water-level record for statistical trend testing for 1970-97 were plotted to determine if there were areal patterns in lakes with trends (fig. 22). The lakes are identified by number on figure 22; the map numbers are listed in appendix B. Lakes with no apparent water-level trend are widely scattered throughout Orange County. A group of six lakes with increasing water level is located in southwest Orange County. Many of these lakes are connected and are part of the Lake Butler chain: Lake Crescent (21), Lake Down (25), Lake Butler (17), and Lake Tibet-Butler (76). Increasing water levels in these lakes may be related to urban development replacing orange groves that previously occupied most of the area. Some citrus groves may have used lake water for irrigation, contributing to the water loss from lakes. However, other lakes in areas where there has been less development also have shown an increase in water level. These lakes include Barton Lake (8), Lake Hart (36), and Lake Mary Jane (52) in southeast Orange County. Several lakes in the north-central area also have shown upward water-level trends during 1970-97. These include Bay Lake (9), Bell Lake (11), Lake Bosse (16), Lake Gandy (32), Lake Killarney (44), Lawne Lake (45), and Lake Lockhart (47). The most apparent change in Lawne Lake (fig. 21), however, is a series of relatively low lake levels in the early 1970s, compared to water levels before and after this period. Lake Ola (56), in northwest Orange County, has shown a relatively consistent upward water-level trend.

Lakes with significant decreasing trends in water levels during 1970-97 are scattered throughout Orange County. For example, Lake Sue (73) had a consistent downward water-level trend from an average of about 72.5 ft in 1950 to about 71 ft in the late 1990s (fig. 20). Possible causes could include increased outflow from Lake Sue through the stream channel connecting Lake Sue to Lake Virginia, or increased leakage from the lake to the Upper Floridan aquifer.

Streamflow Duration and Recurrence Intervals

The computation and interpretation of streamflow duration statistics is discussed in Searcy (1959), who pointed out that, in a strict sense, flow-duration statistics are applicable only for the period of streamflow data used to compute them. Because temporal trends were identified in both high and low streamflow in many areas in Orange County, the duration statistics presented in this report



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 22. Lakes with trends in mean-annual water level for 1970-97. (Only lakes with at least 15 years of record are included. Number refers to appendix B.)

should not be interpreted rigorously as probability statistics, but rather as descriptive indicators of streamflow characteristics. The statistics may be useful for water-supply studies, waste-load allocation studies, and other types of studies where streamflow characteristics are necessary. The approximate nature of the duration statistics (table 11) is especially true for the smaller streams in rapidly urbanizing areas, such as the Little Econlockhatchee River, the Econlockhatchee River, Boggy Creek, Shingle Creek, Cypress Creek, Whittenhorse Creek, and Reedy Creek.

Streamflow duration statistics were computed from daily mean streamflow (table 11). For streams with no apparent temporal trends in streamflow, daily streamflow for the entire period of record was used in the duration analysis. However, for some streams, data from early periods were not used because of temporal trends in streamflow that resulted in historical data being nonrepresentative of current conditions. These streams, and the periods of record used in calculation of flow duration, are:

Site ID	Stream	Period of record
02233200	Little Econlockhatchee River	1980-2000
02233500	Econlockhatchee River	1980-2000
02235000	Wekiva River	1960-2000
02262900	Boggy Creek	1985-2000
02263800	Shingle Creek	1959-1970 1991-2000
02266300	Reedy Creek	1980-2000

There were no significant temporal trends in annual mean streamflow during any of the periods listed above. For Shingle Creek, data from 1971-90 were excluded from flow-duration calculations because of the discharge of substantial amounts of treated wastewater (as much as 20 ft^3/s) into the creek.

The flow-durations computed by Lichtler and others (1968) are given in table 11 for comparison with those computed in this study. While not greatly different in most cases, the streamflow durations calculated in this study for

Table 11. Flow-duration characteristics for selected streams in Orange County and adjacent counties.
[Streamflows in cubic foot per second]

USGS identifier	Name	Period of record	Streamflows for selected percentiles (Percent of time streamflow exceeds indicated discharge)						
			99	90	75	50	25	10	1
02232400	St Johns River near Cocoa	1954-2000	18	94	226	593	1,350	2,390	5,410
		1954-1962[a]	29	100	250	750	1,800	2,900	6,800
02232500	St Johns River near Christmas	1935-2000	24	110	300	810	1,800	3,200	7,000
		1935-1962[a]	29	110	300	900	1,800	3,500	8,000
02233200	Little Econlockhatchee River near Union Park	1960-2000	.9	3.7	7.4	16	33	69	270
		1960-1962[a]	<.1	.5	1.8	5	15	42	210
02233500	Econlockhatchee River near Chuluota	1936-2000	14	32	55	110	300	700	2,300
		1936-1962[a]	11	22	40	90	290	680	2,700
02235000	Wekiva River near Sanford	1936-2000	160	200	230	260	330	440	910
		1936-1962[a]	170	190	210	240	300	400	850
02237700	Apopka-Beauclair Canal	1959-1999	.02	7.1	18	29	38	268	529
02262900	Boggy Creek near Taft	1960-2000	.4	4.9	11	25	62	140	490
		1960-1962[a]	<.1	.5	5	18	65	120	460
02263800	Shingle Creek near Kissimmee	1959-2000	.06	7.8	19	41	92	194	540
		1959-1962[a]	<.1	<.1	.9	12	55	150	520
02264000	Cypress Creek near Vineland	1946-2000	0	.04	.1	.9	4.7	19	81
		1946-1962[a]	<.1	<.1	.4	2.1	11	32	95
02266200	Whittenhorse Creek near Vineland	1967-2000	0	.03	.06	.82	6.2	15	44
02266300	Reedy Creek near Vineland	1967-2000	.09	6.7	12	23	48	94	290

[a] From plots of Lichtler and others (1968).

streams other than the St. Johns River tend to be greater than those given by Lichtler and others (1968), especially for streamflows that were exceeded 25 percent of the time or more. Differences in streamflow duration calculated by Lichtler and others (1968) and the present study may be related to changes in basin land use, as discussed previously, or by differences in the period of record available for the computations. Lichtler and others (1968) had 10 years of daily streamflow data for the St. John River near Cocoa, 4 or 5 years of record for Boggy Creek, Shingle Creek, and Little Econlockhatchee River, and only periodic measurements of discharge for Reedy Creek.

Low-flow frequency statistics typically are computed for the 7-day average annual minimum flow, although any number (n) of consecutive days could be considered. The determination of n-day low-flow recurrence intervals is a two-step process. First, the lowest (or highest) streamflow average for an n-day period is determined for each year. Then, recurrence intervals for these n-day low or high flows are computed using log-Pearson analysis (Riggs, 1968).

A similar procedure is used for high-flow frequency statistics. Guidelines and procedures of the Interagency Advisory Committee on Water Data (1982) were used when completing the log-Pearson analysis.

Ideally, the streamflow data series should contain no temporal trends; otherwise, the recurrence intervals calculated from the series will not be representative of current conditions. Two approaches may be used to more accurately estimate flow recurrence in streams that have a temporal trend in streamflow. One approach is to limit the data series to a trendless period that represents present conditions, if such a period exists. Another approach is to “detrend” the data by determining the relation between the annual streamflow characteristic and time, and by using this relation to “correct” data in the annual data series for all previous years to estimate the flow that would have occurred each year in the past if the temporal trend had been absent. Although this detrending procedure probably provides a more accurate estimate of recurrence intervals than the use of unadjusted data would provide, the accuracy of recurrence intervals computed from detrended data is difficult to assess. The function used to detrend the data is an approximation that may introduce error into the data series used in the recurrence-interval calculation. Also, any future change in a streamflow trend will make recurrence intervals calculated using data prior to the trend change inaccurate. The fact that a trend exists in a streamflow characteristic is an indication that the stream may be sensitive to factors such as land-use or water-use changes and that recurrence intervals are likely to change in response to many types of basin development.

The 7-day low-flow data series for some streams were adjusted to remove effects of temporal trends when the plotted data indicated that a relatively uniform trend in the data was present (fig. 16). Adjustments were made using the median of all ratios $(Q_i - Q_j) / (Y_i - Y_j)$, where Q_i and Q_j are the magnitudes of the 7-day low flows and Yi and Yj are the corresponding years. In this notation, i ranges from B to E-1, and j ranges from B+1 to E, where B is the first year of record and E is the last year of record. The USGS computer program SWSTAT (Alan Lumb, Wilbert O. Thomas, Jr., and Kathleen Flynn, U.S. Geological Survey, written commun., 1994) was used to compute the median ratio, commonly referred to as the slope estimator. Detrended values of 7-day low flow are given by:

$$D_i = S\ (E\text{-}i) + Q_i\ ,$$

where

D_i = the detrended flow for year i;
S = the slope estimator for the period of record being detrended, in cubic feet per second per year;
E = the ending year for the trend, determined by examining plotted data (fig. 16); and
Q_i = the 7-day low flow for year i.

The slope estimator and ending year for detrending are given in the following table.

Site ID	Stream	Slope estimator	Years detrended
02233200	Little Econlockhatchee River	0.18	1960-1990
02233500	Econlockhatchee River	.60	1936-1980
02262900	Boggy Creek	.11	1960-2000
02266300	Reedy Creek	.24	1967-2000

For Shingle Creek, data from 1971-1990 were excluded from recurrence-interval calculations because of the discharge of treated wastewater (as much as 20 ft3/s) into the creek. For the Wekiva River, the trendless period 1960-2000 was used for calculation of the recurrence intervals.

The 7-day low flows which occur, on average, every 2 and 10 years generally are higher than those computed by Lichtler and others (1968) (table 12). The differences are greatest for 7-day low flows in the Econlockhatchee River, where the 2-year and 10-year low flow values computed in the present study are more than 70 percent greater than those computed by Lichtler and others (1968). Differences between the 365-day low flows in the Econlockhatchee River are much smaller (less than 20 percent). Recurrence intervals computed for the St. Johns River and Wekiva River in the present study are within about 30 percent of the values given by Lichtler and others (1968), and generally are within about 10 percent.

These differences between low-flow frequency statistics computed by Lichtler and others (1968) and in the present study probably reflect differences in period of record as well as changes in land use. The period of record used by Lichtler and others (1968) was 27 to 29 years, whereas the present study used 41 years of record beginning in 1960 for the Wekiva River and more than 60 years of record for the Econlockhatchee River and the St. Johns River. The relatively large differences in recurrence intervals for the Econlockhatchee River may reflect land-use changes that relate to the trend for increasing 7-day low flows during 1936 to the mid-1980s.

Water Quality

Water-quality data for 15 stream sites and 140 lakes are summarized in the following sections. Areal patterns of water quality and temporal trends in stream quality are discussed. Types of water-quality data include major ions and nutrients, trace elements, pesticides, and household and industrial waste compounds.

Rainfall, streamflow, and lake levels during 2000-2001 were relatively low. Therefore the sampling that was performed during this study may not be representative of wetter conditions. The effects of varying streamflow are described for some constituents with sufficient historical record.

Major Ions and Nutrients in Streams

A large range of water-quality conditions exists in streams of Orange County (table 13). For example, specific conductance in samples from streams ranged from 84 microsiemens per centimeter (µS/cm) to 617 µS/cm, with a median value of 269 µS/cm. Other water-quality indicators and constituents also had wide ranges of values and concentrations in samples. Values of pH ranged from 3.2

Table 12. Low and high-flow frequency statistics for selected streams in and near Orange County.

[--, no data available. Streamflows are for recurrence intervals determined in present study; recurrence intervals taken from plots in Lichtler and others (1968). In the present study, the entire period of record was used except for Shingle Creek, where data from 1971-90 were excluded because of discharge of treated wastewater into the creek. The 7-day low-flow recurrence intervals were computed using de-trended annual flows as follows: Little Econlockhatchee River, 0.18 ft^3/s-yr; Econlockhatchee River, 0.60 ft^3/s-yr; Boggy Creek, 0.11 ft^3/s-yr; Reedy Creek, 0.24 ft^3/s-yr. The 1-day high-flow statistics were computed using Bulletin 17B guidelines (Interagency Advisory Committee on Water Data, 1982) and include upper and lower 95-percent confidence limits for the estimated 1-day high streamflow, in parentheses]

USGS identifier	Name	Period of record	1-day high flow			7-day low flow			365-day low flow		
			2-year	10-year	50-year	2-year	10-year	50-year	2-year	10-year	50-year
02232400	St. Johns River near Cocoa	1954 - 2000	3,000 (2,500 - 3,500)	6,500 (5,400 - 8,200)	10,000 (7,900 - 14,000)	97	22	8.2	950	340	140
02232500	St. Johns River near Christmas	1935 - 2000	4,000 (3,600 - 4,500)	7,800 (6,900 - 9,300)	12,000 (9,900 - 15,000)	140	20	3.8	1,300	520	240
		1935 - 1962[a]	--	--	--	130	22	--	1,200	420	--
02233200	Little Econlockhatchee River near Union Park	1960 - 2000	340 (280 - 420)	840 (660 - 1,100)	1,300 (990 - 1,900)	6.4	3.6	2.3	28	13	7.6
02233500	Econlockhatchee River near Chuluota	1936 - 2000	2,400 (2,100 - 2,800)	5,800 (4,900 - 7,400)	9,500 (7,500 - 13,000)	38	29	26	250	130	84
		1936 - 1962[a]	--	--	--	22	12	--	220	110	--
02235000	Wekiva River near Sanford	1936 - 2000	800 (740 - 880)	1,400 (1,200 - 1,500)	1,800 (1,600 - 2,200)	200	170	161	280	230	210
		1936 - 1962[a]	--	--	--	180	130	--	260	210	--
02237700	Apopka-Beauclair Canal	1959 - 1999	310 (240 - 410)	910 (670 - 1,300)	1,500 (1,000 - 2,300)	22	3.3	0.4	62	25	14
02262900	Boogy Creek near Taft	1960 - 2000	450 (370 - 550)	1,100 (890 - 1,500)	1,900 (1,400 - 2,800)	5.1	2.0	0	49	23	14
02263800	Shingle Creek near Kissimmee	1959 - 1970, 1991 - 2000	510 (420 - 610)	1,200 (990 - 1,700)	2,000 (1,600 - 3,000)	0	0	0	75	33	17
02264000	Cypress Creek near Vineland	1946 - 2000	28 (21 - 37)	110 (80 - 170)	215 (150 - 350)	0	0	0	2.5	0.3	.08
02266200	Whittenhorse Creek near Vineland	1967 - 2000	21 (16 - 29)	69 (48 - 110)	120 (80 - 210)	0	0	0	3	.2	0
02266300	Reedy Creek near Vineland	1967 - 2000	300 (250 - 360)	690 (550 - 930)	1,100 (830 - 1,600)	7	0	0	36	18	11

[a] From Lichtler and others (1968).

Table 13. Summary statistics of water-quality indicators and chemical constituents in samples from 15 streams, 1997-2002.

[Data source: Orange County Environmental Protection Division and U.S. Geological Survey. ° C, degrees Celsius; all units are in milligrams per liter unless otherwise noted; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than]

Constituent	No. of samples	Minimum	25th percentile	Median	75th percentile	Maximum
Water temperature, ° C	62	12.8	21	24.5	26.4	29.7
Specific conductance, µS/cm	62	84	205	269	305	617
Dissolved oxygen	62	.2	2.9	4.6	6.2	9.5
pH, standard units	62	3.2	6.2	6.7	7.2	8.7
Calcium	40	2	13	23	32	47
Magnesium	40	1.6	2.9	4	5.4	25
Sodium	40	6.2	11	15	23	57
Potassium	40	.8	2.2	3.2	4.1	15
Bicarbonate	40	<1.0	29	51	96	194
Sulfate	40	.8	9.9	16	22	110
Chloride	40	11	20	27	39	120
Fluoride	40	<.1	<.1	.08	.14	.59
Nitrite plus nitrate as nitrogen	62	<.02	.02	.06	.18	1.2
Nitrite as nitrogen	51	<.01	<.01	<.01	<.01	.03
Ammonia as nitrogen, total	16	.02	.03	.04	.11	1.8
Ammonia as nitrogen, dissolved	46	<.01	<.01	.02	.06	.77
Ammonia plus organic nitrogen as nitrogen, total	62	<.2	.59	.77	1.5	7.1
Nitrogen, total	62	.3	.74	.97	1.6	7.1
Phosphorus, total	62	<.02	.03	.07	.11	.3
Orthophosphate as phosphorus	46	<.01	.01	.05	.08	.23
Organic carbon, total	62	.8	9.8	16	30	68
Chlorophyll-*a,* µg/L	45	<.1	<.1	<.1	5.3	41

to 8.7 (table 13). The low pH values that occur in some streams probably are the result of leaching of organic acids such as tannic acid in situations where water stands in contact with plant debris for extended periods of time. These low pH values may be accompanied by high-water color, also leached from the plant debris (German, 1986).

Nutrients and chlorophyll-*a* also had large ranges of concentrations. Total nitrogen concentrations ranged from 0.3 to 7.1 mg/L as nitrogen in samples from streams (table 13). The U.S. Environmental Protection Agency (USEPA) has recommended that total nitrogen concentrations in central Florida streams not exceed 0.9 mg/L (U.S. Environmental Protection Agency, 2000a). This criteria was exceeded in more than one-half of the samples taken of water from streams during this study. The Florida Department of Environmental Protection (FDEP) is developing new nutrient criteria for streams that will apply to specific regions within Florida, based on water-quality data. These new criteria probably will provide a better means for assessing water quality than the more general USEPA criteria.

Comparison of concentrations of various forms of nitrogen indicates that most of the nitrogen is in the form of organic nitrogen. Total ammonia plus organic nitrogen ranged from less than 0.2 to 7.1 mg/L as nitrogen in samples from streams; however, concentrations of total ammonia were less than or equal to 0.04 mg/L as nitrogen in about 50 percent of the samples (table 13).

Few pristine streams exist in Orange County; assessing natural or background concentrations of nitrogen is difficult. Jim Creek, which flows through the Tosohatchee State Reserve, probably is the most pristine stream in Orange County, and was sampled twice during this study. The two samples from Jim Creek had ammonia plus organic nitrogen concentrations in whole-water samples (unfiltered) of 1.5 and 1.6 mg/L as nitrogen. The nitrite plus nitrate concentrations in Jim Creek were less than 0.1 mg/L in both samples. Hence, concentrations of total nitrogen (sum of nitrite, nitrate, ammonia, and organic nitrogen) may be considerably greater than the USEPA recommended criteria of 0.9 mg/L, even in apparently pristine streams.

Concentrations of total nitrogen that exceeded 2.0 mg/L as nitrogen were present in samples from the Apopka-Beauclair Canal, Bonnet Creek, Cypress Creek, Reedy Creek, and Whittenhorse Creek. Land use in these stream basins historically has been agricultural, but is changing to urban and residential; hence, determining the source of nitrogen in these samples is difficult.

Concentrations of total phosphorus ranged from less than 0.02 to 0.30 mg/L as phosphorus in samples from streams. Most, but not all, of the phosphorus present was as orthophosphate (table 13). The USEPA recommended that total phosphorus concentrations in streams not exceed 0.04 mg/L (U.S. Environmental Protection Agency, 2000a). This criterion was exceeded in more than one-half of the samples of water from streams taken during this study (table 13).

Chlorophyll-*a* ranged from less than 0.1 to 41 μg/L in samples from streams (table 13). Chlorophyll-*a* is indicative of phytoplankton (algae and cyanobacteria) in the water. Certain species of cyanobacteria, such as those of the genera *Microcystis* and *Cylindrospermopsis,* can produce toxins (mycrocystin and cylindrospermopsin, respectively) that can be released into the water (Van Dolah, 2002). Currently, no drinking water or other health related regulations are associated with these toxins (U.S. Environmental Protection Agency, 2002). However, the World Health Organization (2002) has a drinking-water guideline for mycrocystin of 1 μg/L.

A number of streams in and around Orange County are listed as impaired in the State of Florida's 303(d) list for 1998 (Florida Department of Environmental Protection, 2002). Sites on the 303(d) list have quality of water that does not support designated uses. These streams include the Econlockhatchee River, Little Econlockhatchee River, Little Wekiva River, Reedy Creek, and Shingle Creek.

Specific conductance of water from streams draining Orange County has considerable spatial variation and ranged from 84 to 617 μS/cm with a median of 269 μS/cm (table 13). Low values of specific conductance were in samples from Jim Branch (84 μS/cm) in south-central Orange County and Whittenhorse Creek (85 μS/cm) (U.S. Geological Survey, 2004a) in southwestern Orange County. High values of specific conductance were in samples from Jim Creek (617 μS/cm) in eastern Orange County and the Econlockhatchee River (529 μS/cm) near Chuluota in south-central Seminole County.

The relatively high specific conductance in samples from Jim Creek may be related to seepage of water from the Upper Floridan aquifer into the surficial aquifer system, which provides baseflow to Jim Creek. Data from two lakes in Tosohatchee State Reserve indicate discharge of ground water from the Upper Floridan aquifer in the area. Jim Creek can go dry during drought conditions, which indicates that Jim Creek does not receive discharge directly from the Upper Floridan aquifer. However, the water quality of the surficial aquifer system, which contributes water to Jim Creek during baseflow conditions, is affected by discharge from the Upper Florida aquifer. Specific conductance in samples from four wells in the Jim Creek basin that tap the surficial aquifer system were 508, 1,140, 1,180, and 3,990 μS/cm. The relatively high specific conductance in samples from the Econlockhatchee River is probably related to treated wastewater discharge to the river, and to seepage of water from the Upper Floridan aquifer into the stream.

In general, the relative concentrations of the ionic constituents in streams appear to be related to geology and land use. The Wekiva River contains calcium-bicarbonate water because a large percentage of its discharge is from Wekiva Springs, which issues from the Upper Floridan aquifer. Ground water in the Upper Floridan aquifer generally is calcium or calcium-magnesium bicarbonate type as a result of dissolution of the carbonate rocks of the aquifer (Adamski and Knowles, 2001). Other streams—such as Cypress Creek, Jim Branch, and Whittenhorse Creek—generally have relatively low specific conductance and a sulfate or chloride type water because they do not receive substantial quantities of wastewater or seepage from the Upper Floridan aquifer.

Other streams, such as Boggy Creek, the Econlockhatchee River, and Shingle Creek, have bicarbonate or mixed anion type water, which could result from the effects of land use as much as from geology. Water used for lawn irrigation generally is from the Upper Floridan aquifer. Calcium and bicarbonate concentrations in stream water could be affected by runoff from lawn irrigation. In addition, the Little Econlockhatchee River receives reclaimed water from a wastewater treatment facility. Specific conductance was greater in samples from the Econlockhatchee River near Chuluota (384, 434, and 529 μS/cm), downstream from the treatment facility, than in samples from the Little Econlockhatchee River near Union Park (165, 205, and 257 μS/cm), upstream from the treatment facility. The treatment plant discharges about 15 ft^3/s of reclaimed water to the river (Alan Oyler, City of Orlando, oral commun., 2002). Discharge of the Econlockhatchee River during sample collection ranged from 42 to 61 ft^3/s. At times of low flow, reclaimed water can account for nearly one-third of the discharge of the Econlockhatchee River, which probably affects major-ion concentrations in the river.

Eight stream sites in and around Orange County had water-quality data beginning in the 1960s (table 14). The ranges of selected constituents at the sites are shown in figures 23 and 24. A number of constituents had a large range of values at several of the stream sites during the periods of record. For example, specific conductance ranged from 33 to 720 µS/cm at the Econlockhatchee River near Chuluota, and from 43 to 395 µS/cm at Reedy Creek near Vineland (U.S. Geological Survey, 2004a). Bicarbonate concentrations ranged from 11 to 112 mg/L at the Econlockhatchee River near Chuluota and from less than 1 to 91 mg/L a Reedy Creek near Vineland (U.S. Geological Survey, 2004a). Nutrient concentrations also had large variations in concentrations at a number of sites. Nitrite plus nitrate ranged from less than 0.5 to 6.1 mg/L at the Econlockhatchee River and from 0.5 to 3.2 mg/L as nitrogen at Reedy Creek. Phosphorus ranged from 0.03 to 4.9 mg/L at the Econlockhatchee River and from 0.03 to 2.5 mg/L at Reedy Creek (U.S. Geological Survey, 2004a).

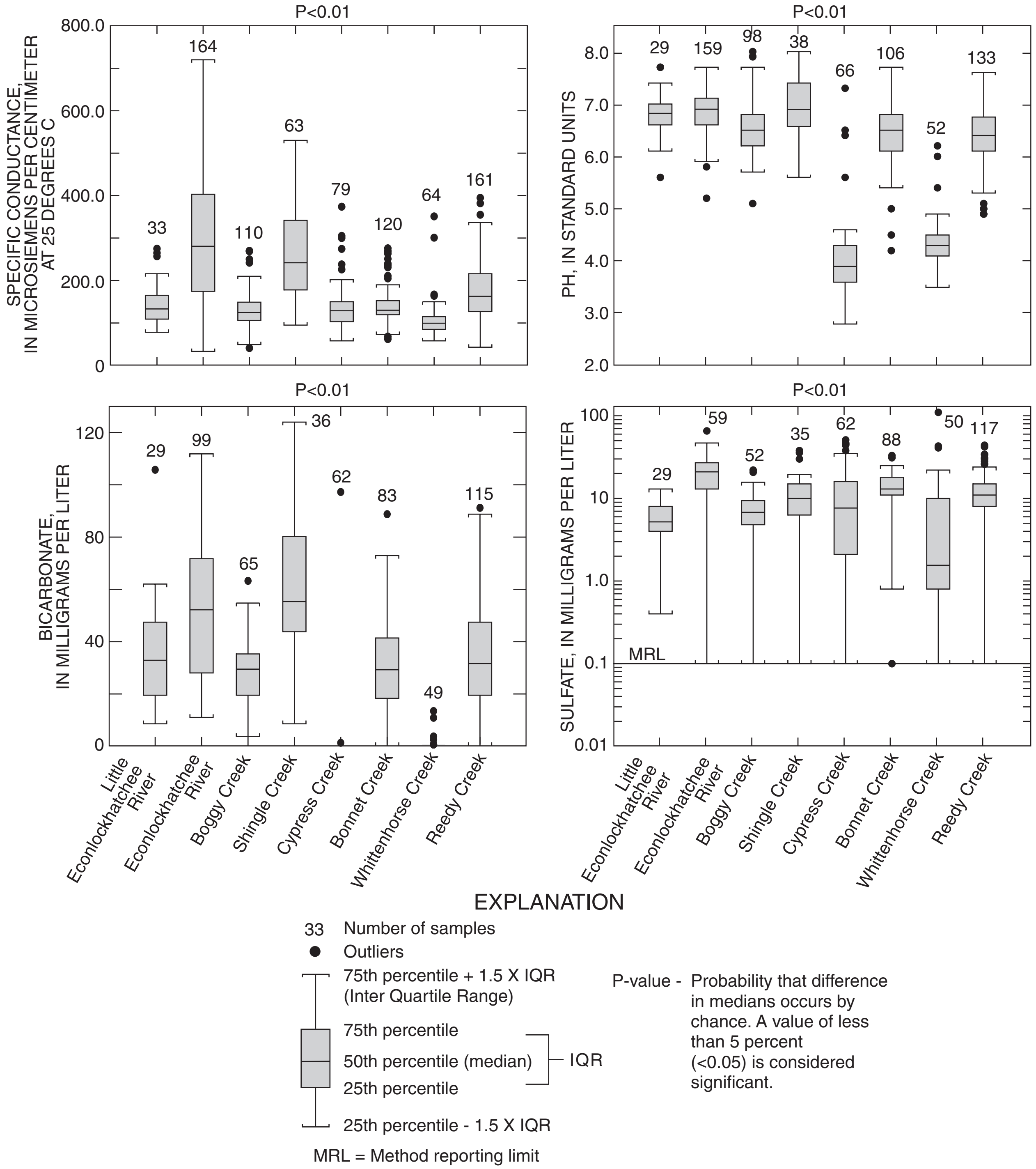
Values of specific conductance, and concentrations of bicarbonate, sulfate, chloride, nitrite plus nitrate, ammonia plus organic nitrogen, and phosphorus were statistically tested for correlations with mean-daily discharge values at the eight sites using Spearman's rho correlation coefficient (table 15). The correlation was considered significant if the probability of no correlation (rho = 0) was less than 5 percent ($p<0.05$). All sites had at least two properties or constituents that correlated with discharge, and for Econlockhatchee River, five of seven properties or constituents correlated with discharge. Most properties or constituents correlated negatively with discharge. Constituents that increased in concentration with increasing discharge include sulfate (Little Econlockhatchee River), ammonia plus organic nitrogen (Boggy Creek, Bonnet Creek, and Reedy Creek), and phosphorus (Bonnet Creek). Specific conductance was strongly correlated to discharge at the Econlockhatchee River, but was not significantly correlated to discharge at Boggy Creek (fig. 25), the Little Econlockhatchee River, or Cypress Creek. The correlations between specific conductance and discharge were relatively weak (absolute value of rho less than 0.50) at Bonnet Creek, Whittenhorse Creek, and Reedy Creek (table 15). Major-ion concentrations, and hence, specific conductance, typically are diluted by rain events (Helsel and Hirsch, 1992), and therefore, would be expected to have strong negative correlations with discharge. The reason for weak or no correlations at seven of the stream sites is unclear.

Data from four sites (Econlockhatchee River, Boggy Creek, Bonnet Creek, and Whittenhorse Creek) were analyzed for temporal trends in water quality. Quantitative trend analysis was limited to specific conductance, bicarbonate, sulfate, chloride, nitrite plus nitrate nitrogen, ammonia plus organic nitrogen, and phosphorus. Flow-adjusted values were used for the water-quality variables that were significantly correlated with discharge. The effect of flow adjustment on specific conductance at the Econlockhatchee River is shown in figure 26. For presentation in figure 26, residuals were added to the median value of specific conductance.

Table 14. Stream sites with historical water-quality data, periods of record, basin sizes, and number of samples.

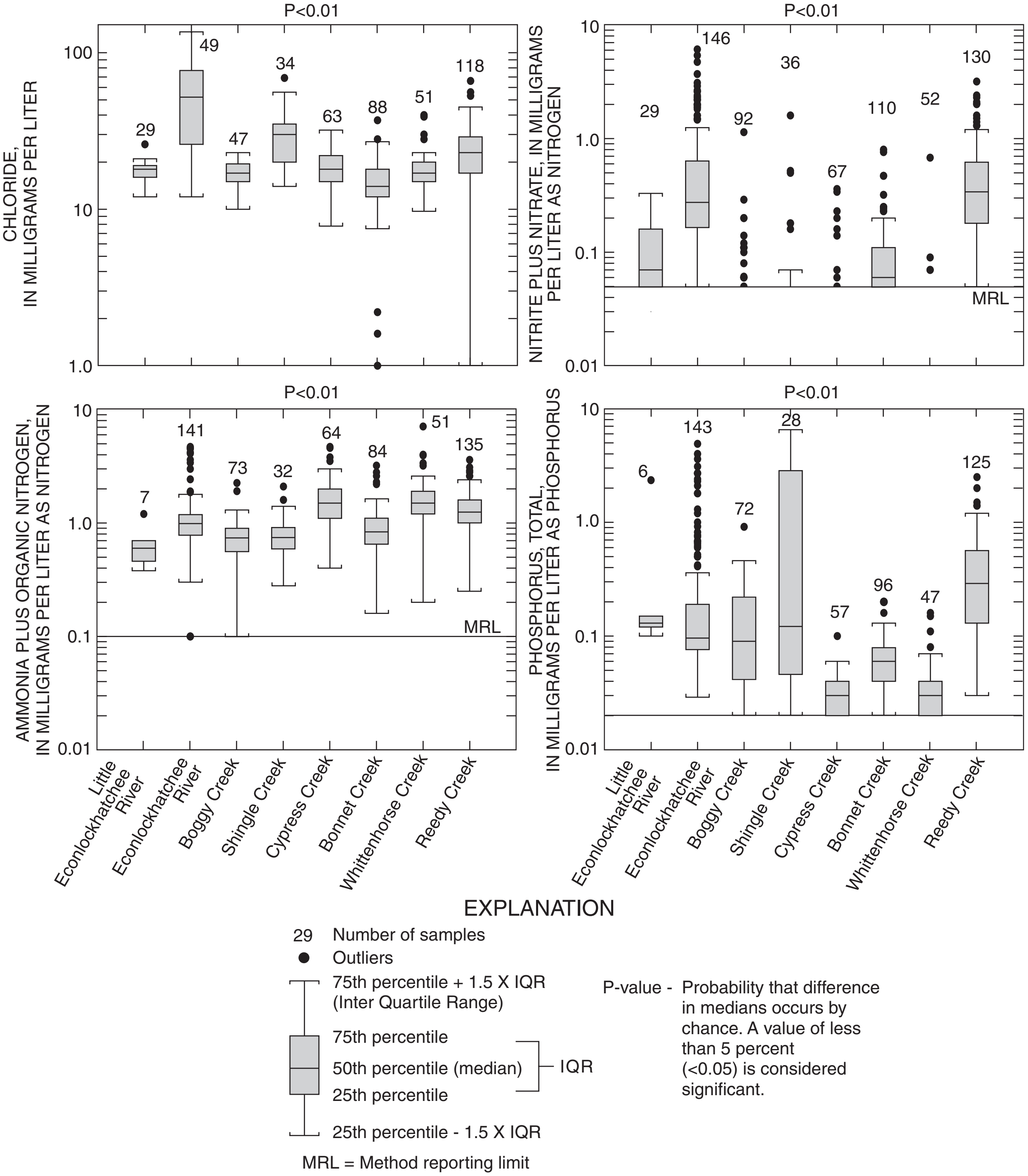
[Source of basin size, U.S. Geological Survey; source of water-quality data, U.S. Geological Survey and Orange County Environmental Protection Division]

Station name	Station identifier	Period of record	Basin size, square miles	No. of samples
Boggy Creek near Taft	02262900	10/27/1960 - 2/22/2001	83.6	111
Bonnett Creek near Vineland	02264100	5/23/1961 - 9/19/2001	44.7	120
Cypress Creek near Vineland	02264000	7/24/1963 - 9/17/2001	29.3	82
Econlockhatchee River near Chuluota	02233500	5/9/1966 - 2/6/2001	241	166
Little Econlockhatchee River near Union Park	02233200	11/3/1960 - 2/8/2001	27.1	33
Reedy Creek near Vineland	02266300	5/23/1961 - 9/18/2001	84.6	161
Shingle Creek near Kissimmee Airport	02263800	8/21/1962 - 2/28/2001	89.2	63
Whittenhorse Creek near Vineland	02266200	10/23/1968 - 9/17/2001	12.4	64



Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

Figure 23. Distribution of specific conductance, pH, and concentrations of bicarbonate and sulfate in historical samples for selected streams, 1960-2001.



Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

Figure 24. Distribution of chloride, nitrite plus nitrate, ammonia plus organic nitrogen, and total phosphorus in historical samples for selected streams, 1960-2001.

Table 15. Relation between water-quality properties or constituents and streamflow at selected streams in Orange County.

[The sign of the Spearman rho coefficient indicates if the property or constituent value increases with increasing discharge (positive) or decreases with increasing discharge (negative). The p-value, given in parentheses, is the probability of no relation between property or constituent. A probability of 0.05 or less is taken as evidence of a significant relation and is given in bold type. <, less than; *, less than 10 samples]

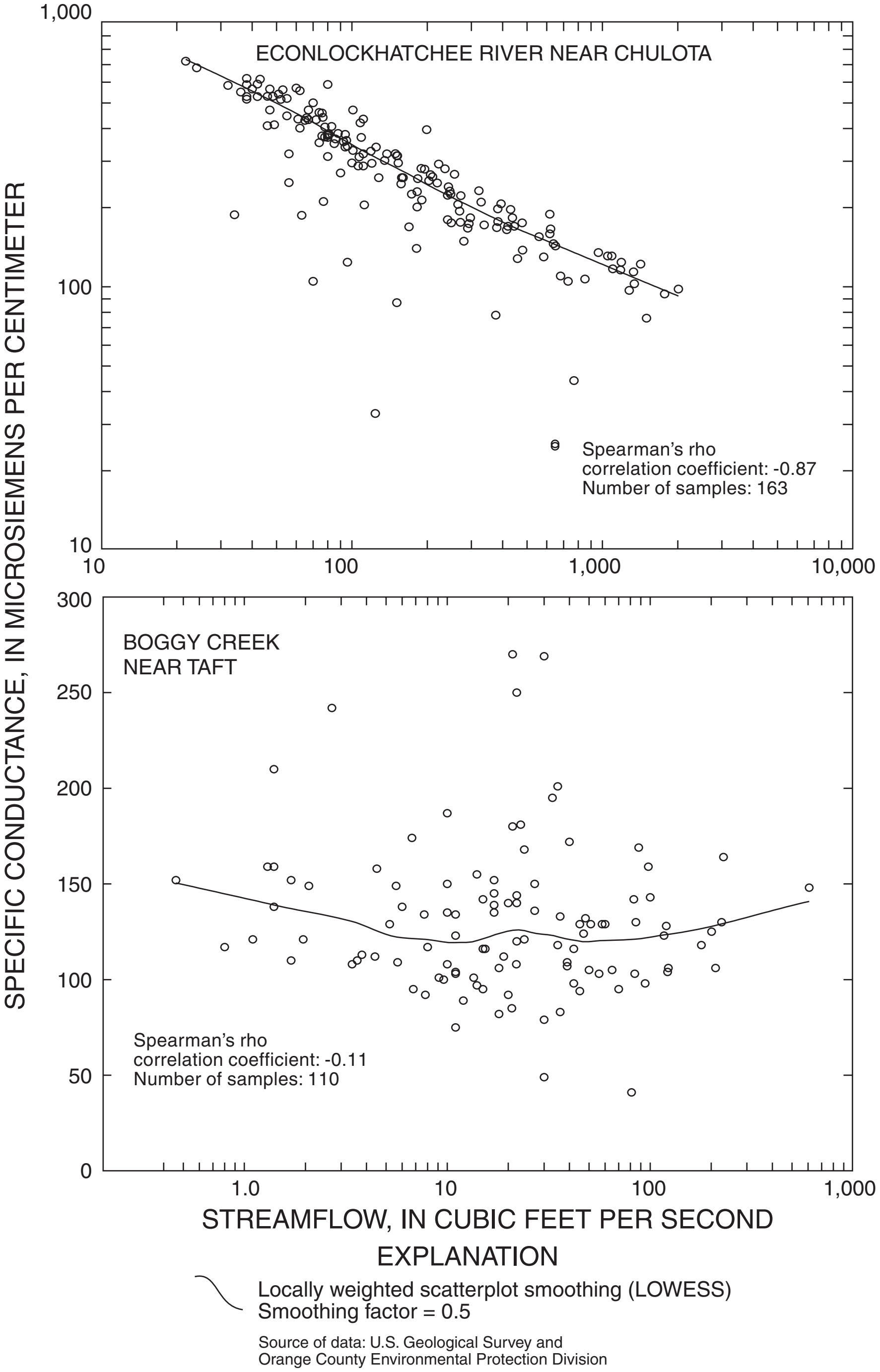
Station name and identifier	Spearman's rho correlation coefficient and p-value						
	Specific conductance	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate	Ammonia plus organic nitrogen	Phosphorus
Boggy Creek (02262900)	-0.11 (p=.26)	0.09 (p=.45)	0.18(p=.19)	-0.26 (p=.08)	0.15 (p=.14)	**0.35** (p<.01)	**-0.19** (p=.02)
Bonnett Creek (02264100)	**-.33** (p<.01)	**-.33** (p<.01)	.18 (p=.10)	.08 (p=.46)	.17 (p=.07)	**.48** (p<.01)	**.32** (p<.01)
Cypress Creek (02264000)	-.18 (p=.11)	**-.38** (p<.01)	.17 (p=.19)	-.04 (p=.77)	-.02 (p=.89)	-.15 (p=.24)	**-.27** (p=.04)
Econlockhatchee River (02233500)	**-.87** (p<.01)	**-.88** (p<.01)	**-.81** (p<.01)	**-.95** (p<.01)	**-.62** (p<.01)	.12 (p=.16)	-.09 (p=.31)
Little Econlockhatchhee River (02233200)	-.108 (p=.54)	-.33 (p=.08)	**.43** (p=.02)	**-.48** (p=.01)	.2 (p=.29)	*	*
Reedy Creek (02266300)	**-.37** (p<.01)	**-.37** (p<.01)	-.04 (p=.68)	-.17 (p=.06)	-.05 (p=.60)	**.52** (p<.01)	**-.18** (p=.04)
Shingle Creek (02263800)	**-.36** (p<.01)	-.32 (p=.06)	-.28 (p=.10)	**-.51** (p<.01)	-.21 (p=.22)	.07 (p=.70)	.05 (p=.81)
Whittenhorse Creek (02266200)	-.06 (p=.59)	**-.44** (p<.01)	-.01 (p=.95)	**-.32** (p=.02)	.10 (p=.46)	-.11 (p=.39)	-.13 (p=.35)

Concentrations of properties or constituents and values of residuals were analyzed for temporal trends using Kendall's tau. The trend was considered significant if the probability of no correlation (rho = 0) was less than 5 percent ($p<0.05$; table 16). All four sites had significant trends in at least two of the seven properties or constituents. At Boggy Creek, concentrations of five properties or constituents had significant temporal trends (table 16). Values of specific conductance and concentrations of chloride increased at Boggy Creek, Bonnet Creek, and Whittenhorse Creek. Bicarbonate concentrations increased at the Econlockhatchee River, Boggy Creek, and Bonnet Creek (fig. 27). Sulfate concentrations increased at Boggy Creek (fig. 28). Concentrations of nitrite plus nitrate and ammonia plus organic nitrogen decreased at the Econlockhatchee River (fig. 29). Phosphorus concentrations significantly decreased at the Econlockhatchee River and Boggy Creek (table 16; fig. 29).

Decreasing nitrate plus nitrite nitrogen and total phosphorus concentrations in the Econlockhatchee River near Chuluota probably are the result of the construction of a wastewater treatment facility upstream on the Little Econlockhatchee River. The facility, a tertiary treatment facility that removes nitrogen and phosphorus, was constructed in 1982 and updated in 1987. It replaced several older facilities that discharged effluent into the Econlockhatchee River and its tributaries. The effluent discharging from the facility most likely has lower concentrations of nitrogen and phosphorus than the effluent from the preexisting facilities (Alan Oyler, City of Orlando, oral commun., 2002).

The increase in bicarbonate concentrations at the Econlockhatchee River, which occurred primarily in the 1990s (fig. 27), could result from effluent from the facility and (or) runoff of lawn irrigation water obtained from the carbonate Floridan aquifer system. As noted earlier, effluent from the facility can account for nearly one-third of the discharge of the Econlockhatchee River during low flow conditions. Urban land use in the basin, which includes residential land use, increased from 12 percent in 1977 to more than 27 percent in 1997. An increase in the volume of irrigation runoff would be expected with increasing urbanization. Most of the increase in urban land use occurred in the Little Econlockhatchee River basin, but data were insufficient for trend analysis at that site.

Changes with time also occurred at Boggy Creek. Specific conductance (fig. 26), concentrations of bicarbonate (fig. 27), sulfate (fig. 28), and chloride (fig. 28) increased at Boggy Creek probably as a result of increases in urban land use (fig. 4). Urban and transportation land use in the basin increased from about 36 percent in 1977 to almost 51 percent in 1997. Phosphorus concentrations decreased at Boggy Creek. This decrease appears to span the entire period of record (fig. 29), and probably is related to a decrease in agricultural and range land use from 45 percent in 1977 to less than 19 percent in 1997.



Source of data: U.S. Geological Survey and Orange County Environmental Protection Division

Figure 25. Relation of specific conductance to streamflow for historical samples from the Econlockhatchee River and Boggy Creek, 1960-2001.

Specific conductance (fig. 26) and chloride concentrations (fig. 28) increased at Whittenhorse Creek throughout most of the period of record. The trend could be partially related to the construction of RIBs in the creek basin for disposal of treated wastewater. However, full use of the RIBs did not begin until about 1992, and the trends in both specific conductance and chloride appear to begin at the beginning of the period of record (1968). Changes in land use, such as an increase in transportation and urban land use from less than 2 percent in 1977 to 6 percent in 1997, could be affecting specific conductance and chloride concentrations in Whittenhorse Creek.

Data from Reedy Creek were analyzed with a different method because the creek receives effluent from a wastewater treatment facility. The data were grouped into three periods of record: the period prior to wastewater discharge (period 1, pre-1972), the period of wastewater discharge (period 2, 1972-91), and the period after

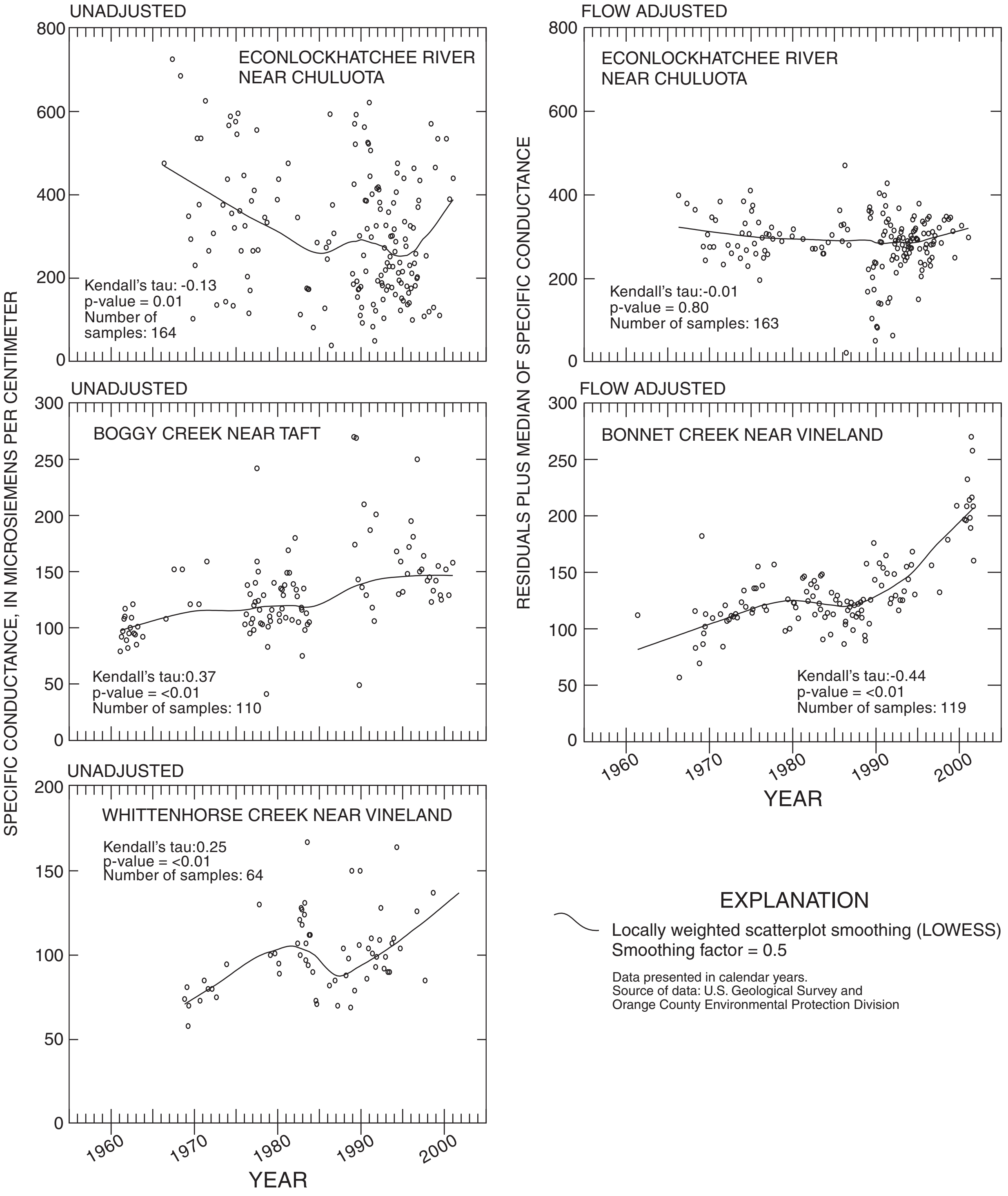


Figure 26. Relation of specific conductance to time in samples for the Econlockhatchee River and Boggy, Bonnet, and Whittenhorse Creeks.

Table 16. Temporal trends in water quality at selected sites in Orange County.

[The Kendall's Tau is a test statistic based on relation of the water-quality constituent or property with time. A positive Kendall Tau value indicates an increase in property or constituent value with time, and a negative value indicates a decrease in property or constituent value with time. The p-value, given in parentheses, is the probability that a pattern of increasing or decreasing property or constituent value could result from a trendless set of data due to chance. A probability of 0.05 or less is taken as evidence of a significant trend and is given in bold type. <, less than, *, more than 75 percent of data were below detection limit]

Station name and identifier	Flow adjustment	Kendall's Tau and p-value						
		Specific conductance	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate	Ammonia plus organic nitrogen	Phosphorus
Boggy Creek (02262900)	Unadjusted	**0.37 (p<.01)**	**0.39 (p<.01)**	**0.28 (p<.01)**	**0.32 (p<.01)**	0.02 (p=.76)	-0.08 (p=.31)	**-0.62 (p<.01)**
	Flow adjusted						-.14 (p=.09)	**-.61 (p<.01)**
Bonnet Creek (02264100)	Unadjusted	**.34 (p<.01)**	.07 (p=.36)	-.08 (p=.29)	**.55 (p<.01)**	-.11 (p=.07)	-.02 (p=.76)	-.11 (p=.12)
	Flow adjusted	**.44 (p<.01)**	**.17 (p=.02)**				.06 (p=.41)	-.10 (p=.16)
Econlockhatchee River (02233500)	Unadjusted	**-.13 (p=.01)**	.04 (p=.55)	-.05 (p=.57)	-.11 (p=.25)	**-.50 (p<.01)**	**-.33 (p<.01)**	**-.60 (p<.01)**
	Flow adjusted	-.01 (p=.80)	**.39 (p<.01)**	.08 (p=.37)	-.11 (p=.25)	**-.45 (p<.01)**		
Whittenhorse Creek (02266200)	Unadjusted	**.25 (p<.01)**	*	-.03 (p=.74)	**.30 (p<.01)**	*	<-.01 (p=.98)	-.09 (p=.35)
	Flow adjusted		*		**.37 (p<.01)**	*		

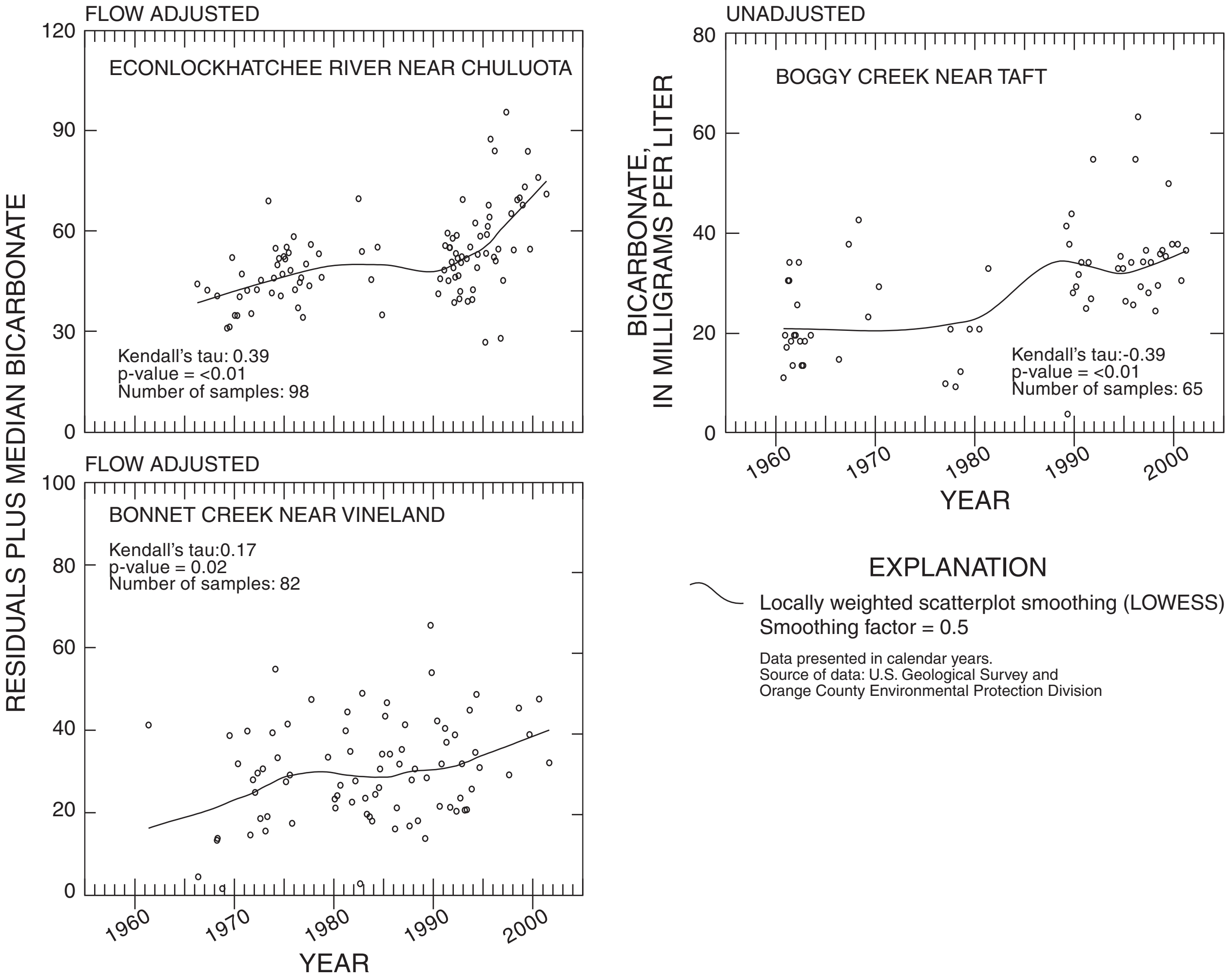
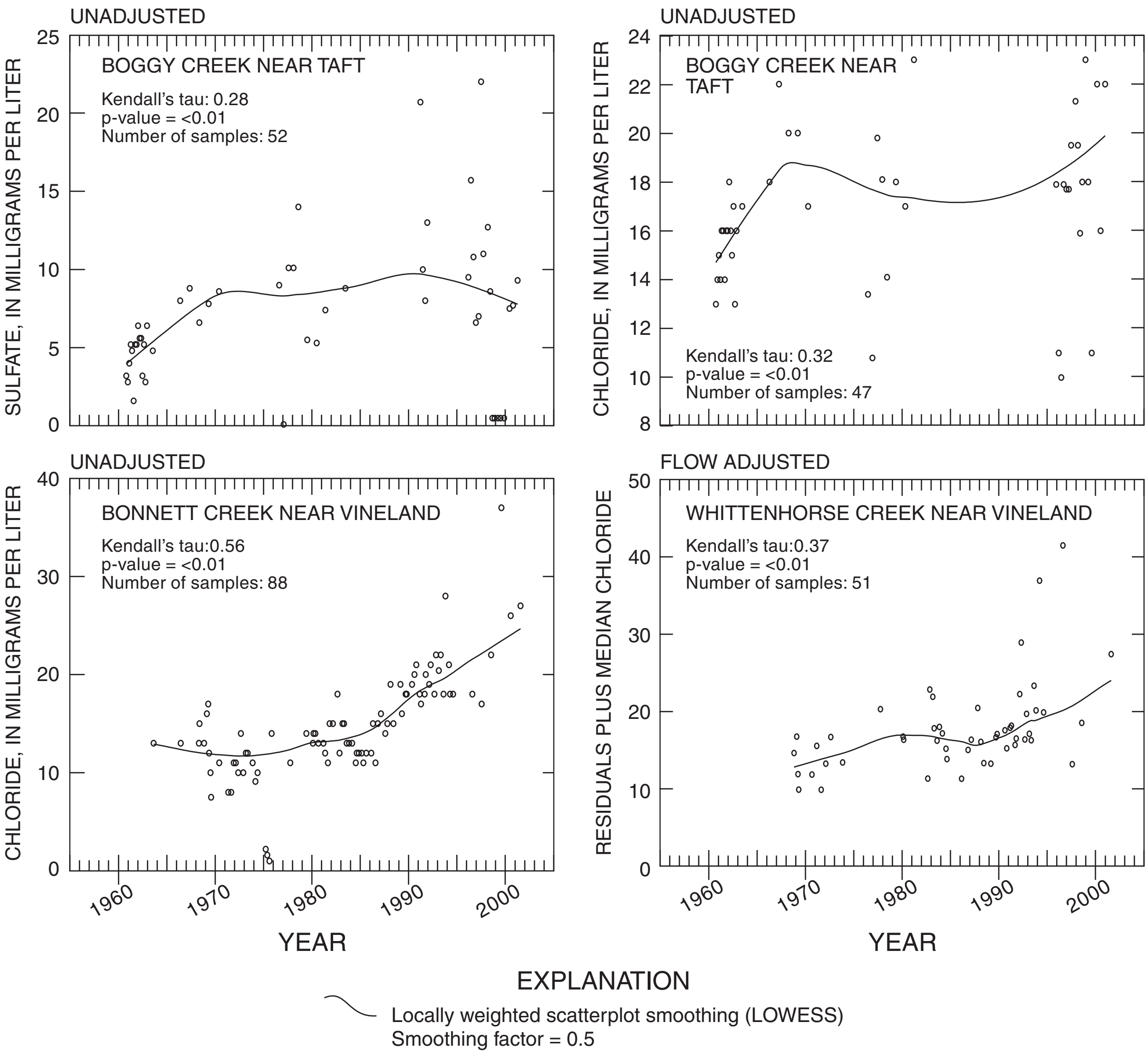


Figure 27. Relation of bicarbonate concentrations to time in samples for the Econlockhatchee River and Boggy and Bonnet Creeks.

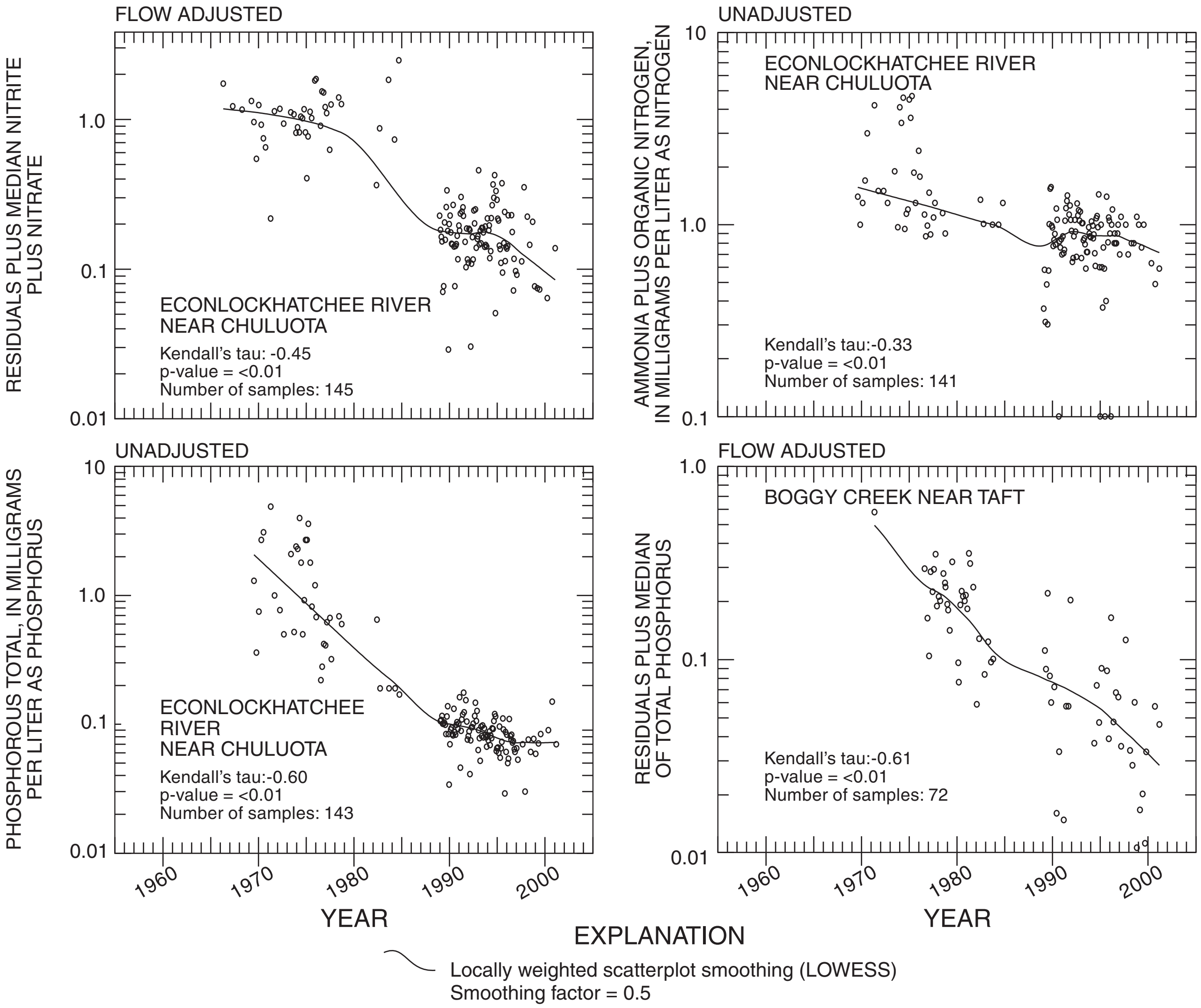


Data presented in calendar years.
Source of data: U.S. Geological Survey and
Orange County Environmental Protection Division

Figure 28. Relation of sulfate concentrations to time in samples for Boggy Creek, and relation of chloride concentrations to time in samples for Boggy, Bonnet, and Whittenhorse Creeks.

wastewater discharge (period 3, 1992-2001). A nonparametric statistical test (Kruskal-Wallis) was used to analyze differences in median concentrations of constituents for the three periods.

The Kruskal-Wallis test indicated that significant differences did exist in median values of specific conductance and concentrations of bicarbonate, sulfate, chloride, nitrite plus nitrate, ammonia plus organic nitrogen, and phosphorus among the three periods. The Kruskal-Wallis test does not identify which periods are significantly higher than the other periods. However, the highest median values and concentrations seemed to occur during period 2 (fig. 30). These relatively high values and concentrations probably are related to the discharge of treated wastewater into Reedy Creek from 1972-91. Median values of specific conductance and concentrations of sulfate, chloride, and nitrite plus nitrate also seem to be greater during period 3 than during period 1, indicating that concentrations of these constituents did not return to predevelopment levels after the discontinuation of treated wastewater discharge into Reedy Creek. This apparent lag time could result from the storage of sulfate, chloride, and nitrite plus nitrate in the sediments of Reedy Creek during period 2. The extensive wetlands in the Reedy Creek basin could be storing the constituents from earlier waste water discharge. These constituents presently (2004) could be slowly leaching back into the water column, thereby preventing the return of their concentrations to predevelopment levels.



Data presented in calendar years.
Source of data: U.S. Geological Survey and
Orange County Environmental Protection Division

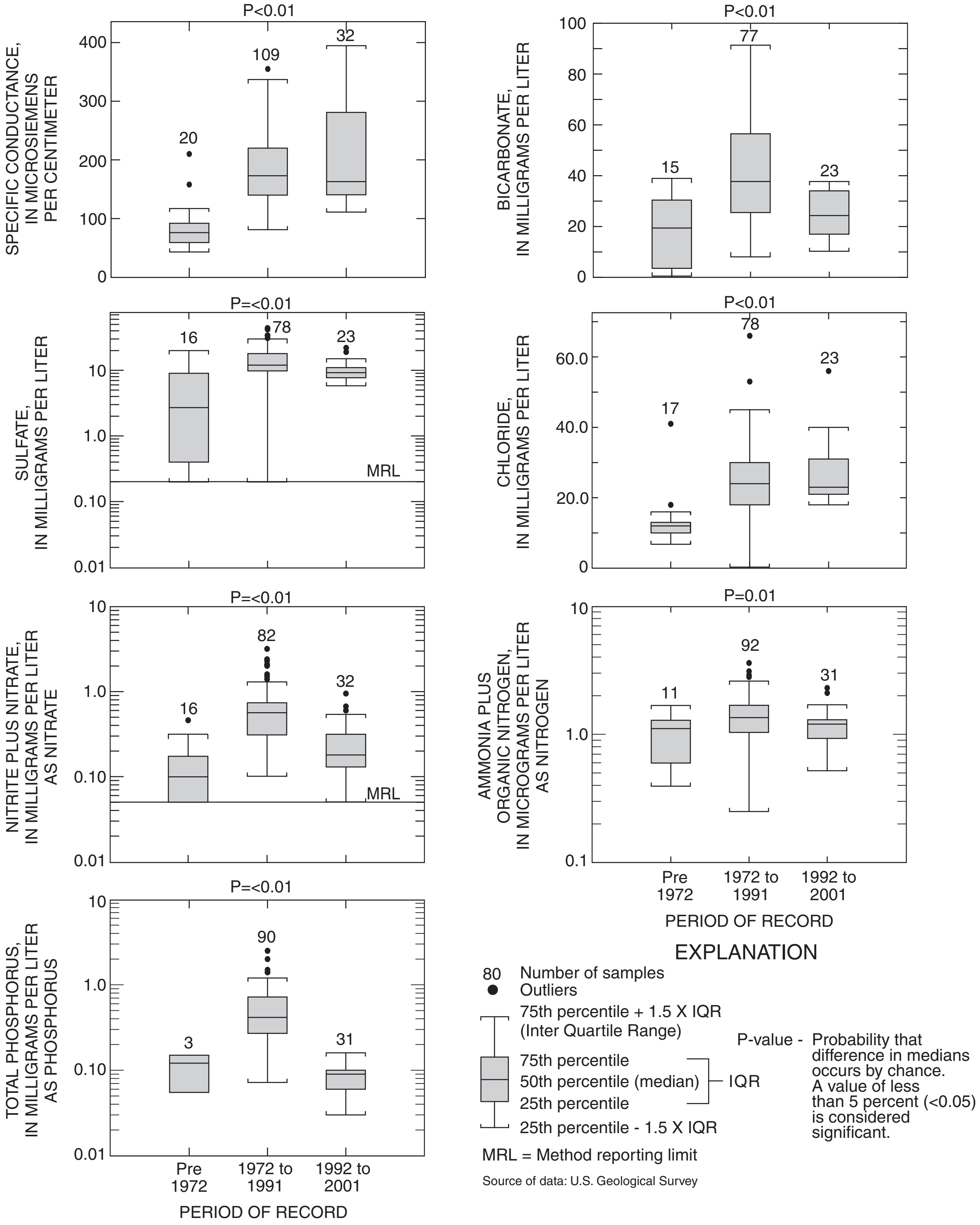
Figure 29. Relation of nitrite plus nitrate and ammonia plus organic nitrogen concentrations to time in samples for the Econlockhatchee River, and relation of total phosphorus concentrations to time in samples for the Econlockhatchee River and Boggy Creek.

The trends in water-quality constituents in Reedy Creek also could be affected by land-use changes. Urban land use in the basin increased from 4.8 percent in 1977 to 8.1 percent in 1997. Urban land use has continued to increase to the present (2004) and probably is greater than 8.1 percent. Furthermore, most of this urban development is tourist attractions, which are equivalent to high-density urban land use. Hence, the impact on water quality could be relatively large in comparison to the size of the urban land-use area.

Water-quality data for Shingle Creek were not analyzed for temporal trends. Previous investigations indicated that there were substantial changes in water quality in Shingle Creek as a result of removal of wastewater discharge into the stream. Phosphorus loads carried by Shingle Creek decreased by 62 percent, and nitrogen loads decreased by 39 percent after removal of the wastewater in 1987 (O'Dell, 1994).

Major Ions and Nutrients in Lakes

A number of surface-water bodies in and around Orange County are listed as impaired in the State of Florida's 303(d) list (Florida Department of Environmental Protection, 2002). Sites in the 303(d) list have quality of water that does not support designated uses. Lake Apopka, Lake Beauclair, Lake Carlton, and Lake Olive are in the 303(d) list.



Source of data: U.S. Geological Survey

Figure 30. Distribution of specific conductance, and concentrations of bicarbonate, sulfate, chloride, nitrite plus nitrate, ammonia plus organic nitrogen, and total phosphorus in historical samples for Reedy Creek.

Lake Apopka is noteworthy because it is considered Florida's most polluted large lake (St. Johns River Water Management District, 2004a). Sources of nutrient-rich contamination have included runoff from about 20,000 acres of farmlands, discharge of treated wastewater from shoreline communities, and discharges from citrus processing plants.This addition of nutrients changed Lake Apopka from a popular recreational lake before the late 1940s to a pea-green lake with a thick layer of bottom muck and little fishing or other recreation potential. Additionally, outflow from Lake Apopka contributes significant phosphorus loads to lakes downstream in the Ocklawaha Chain of Lakes. The sources of nutrient inflow to Lake Apopka no longer exist and the lake is presently (2004) being restored by St. Johns River Water Management District according to the Lake Apopka Restoration Act of 1985 and Florida's Surface Water Improvement and Management (SWIM) Act of 1987. An overview of the restoration project is available on the SJRWMD website (St. Johns River Water Management District, 2004b).

There are some regional patterns in lake water quality in Orange County. These regional patterns probably are due to several factors that are characteristic of the regions, including seepage rates of ground water to or from lakes, quality of ground water seepage, land use, and types of soils and vegetation around the lakes. For example, in areas where the potentiometric surface of the Upper Floridan aquifer exceeds the lakes water-surface elevation, lakes may contain relatively hard water if they receive water from the Upper Floridan aquifer, either from spring flow or from diffuse upward leakage. Conversely, lakes in ridge areas that are isolated from the Upper Floridan aquifer may contain soft water and be vulnerable to acidification by atmospheric deposition (Brezonik and others, 1980). Lakes in agricultural areas may receive runoff or ground-water seepage that is enriched in nutrients and other constituents because of fertilizer application.

A summary of lake water quality by the lake regions defined by the USEPA (fig. 3) is given in Griffith and others (1997), and is based on data from several sources collected from 1979-96. Griffith and others (1997) data indicated the general types of lake water quality that are characteristic of the lake regions, although the water quality may vary widely within each region. One of the most unique water-quality characteristics of the lake regions is the low median pH value and high median water color of Osceola Slope lakes (fig. 31). The low pH and relatively low median specific conductance are indications that the region is isolated from the Upper Floridan aquifer. The high median water color indicates that the low pH values may result from tannins leached from vegetative debris, rather than from atmospheric deposition into unbuffered lake waters. Another notable characteristic of the Osceola Slope lakes is that Secchi-disk clarity tends to be relatively low, probably as a result of the high-water color rather than high chlorophyll-*a* concentrations. Chlorophyll-*a* concentrations in Osceola Slope lakes tend to be relatively low.

The highest median total phosphorus concentrations and chlorophyll-*a* occur in lakes in the Central Valley region and the Orlando Ridge region (fig. 31). Variation in total phosphorus and chlorophyll-*a* concentrations among lakes in these two lake regions also is high, as shown by the relatively large differences between 75th and 25th percentile concentrations. These relatively high concentrations probably are related to land use. The Central Valley (fig. 3) contains relatively large amounts of agricultural lands that may be a source of phosphorus to lakes. Phosphorus enrichment could result in high chlorophyll-*a* levels. The Orlando ridge area contains mostly urban land use. Use of fertilizers on lawns and recreational areas may contribute to phosphorus enrichment of lakes in the area, and subsequent high chlorophyll-*a* levels.

Water quality of lakes in the Dr. Phillips Ridge lake region is unique among the other six lake regions in Orange County because of the low phosphorus and chlorophyll-*a* concentrations, and the high Secchi-disk clarity, all desirable water-quality conditions from an aesthetic and recreational viewpoint. The relatively high pH and specific conductance of the lakes in the Dr. Phillips Ridge region suggest that the lakes could be affected by discharge from the Upper Florida aquifer. However, land-surface altitude in this area is 100-170 ft above NGVD 29 (Griffith and others, 1997); the region is a recharge area for the upper Floridan aquifer.

Data for 2000-01 collected by USGS, Orange County, and the City of Orlando indicate that a large range of water-quality conditions exist in the lakes of Orange County. For example, specific conductance ranged from 57 to 1,185 µS/cm, with a median of 202 µS/cm (table 17). There is no clear areal pattern in specific conductance (fig. 32). For example, lakes with relatively high specific conductance (176-250 µS/cm) and lakes with relatively low specific conductance (57-175 µS/cm) both occur in the urbanized areas of central Orange County. The four lakes with specific conductance greater than 500 µS/cm are scattered, with one in southwest Orange County, another in west-central Orange County, and the other two lakes in southeast Orange County.

Other water-quality indicators and constituents also had wide ranges of values and concentrations in samples from lakes. Values of pH ranged from 4.6 to 9.6 in samples from lakes (table 17). Concentrations of bicarbonate

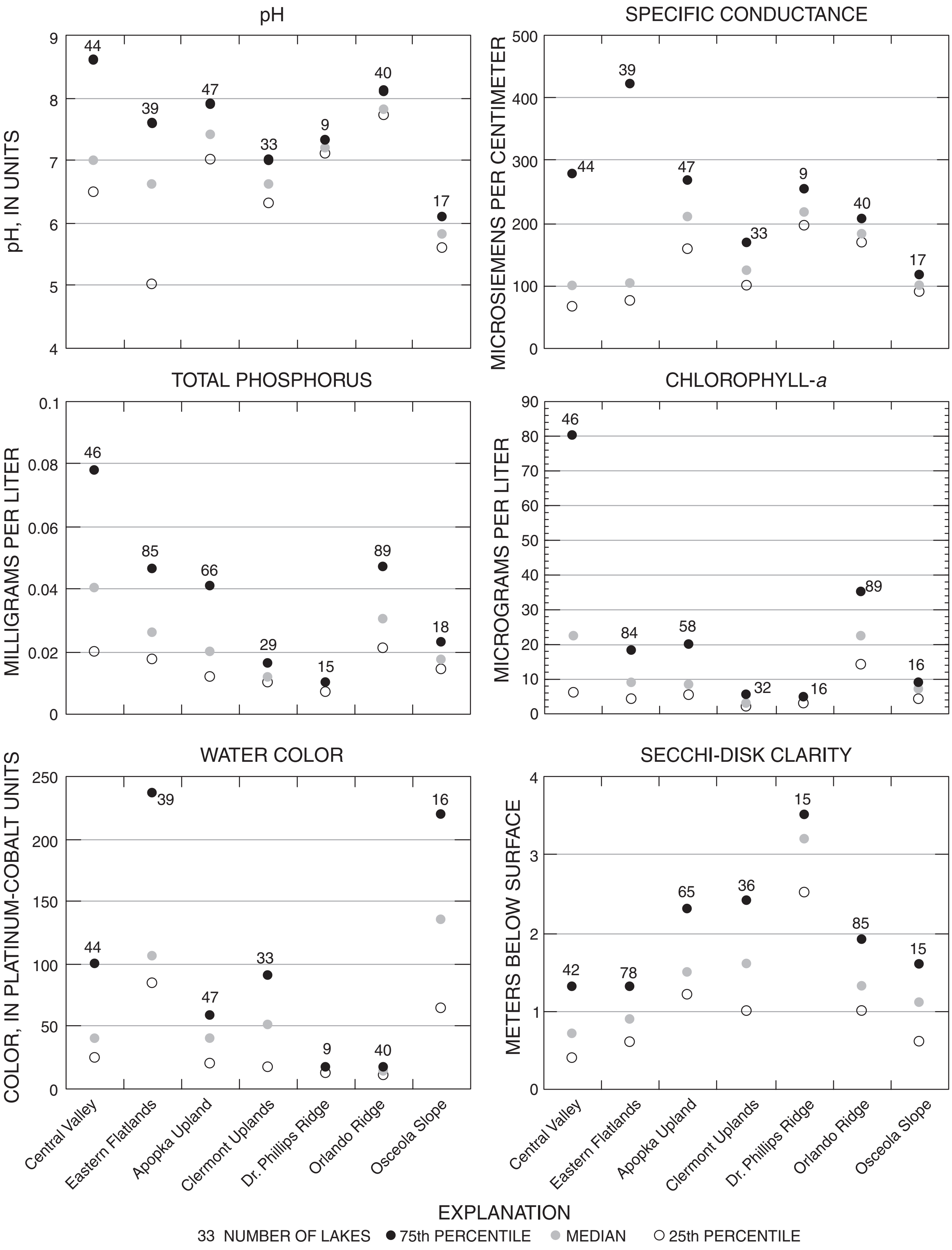


Figure 31. Comparison of lake water quality by lake region. (Data are from Griffith and others, 1997.)

Table 17. Summary statistics of water-quality indicators and chemical constituents in samples from 140 lakes in Orange County, 2000-01.

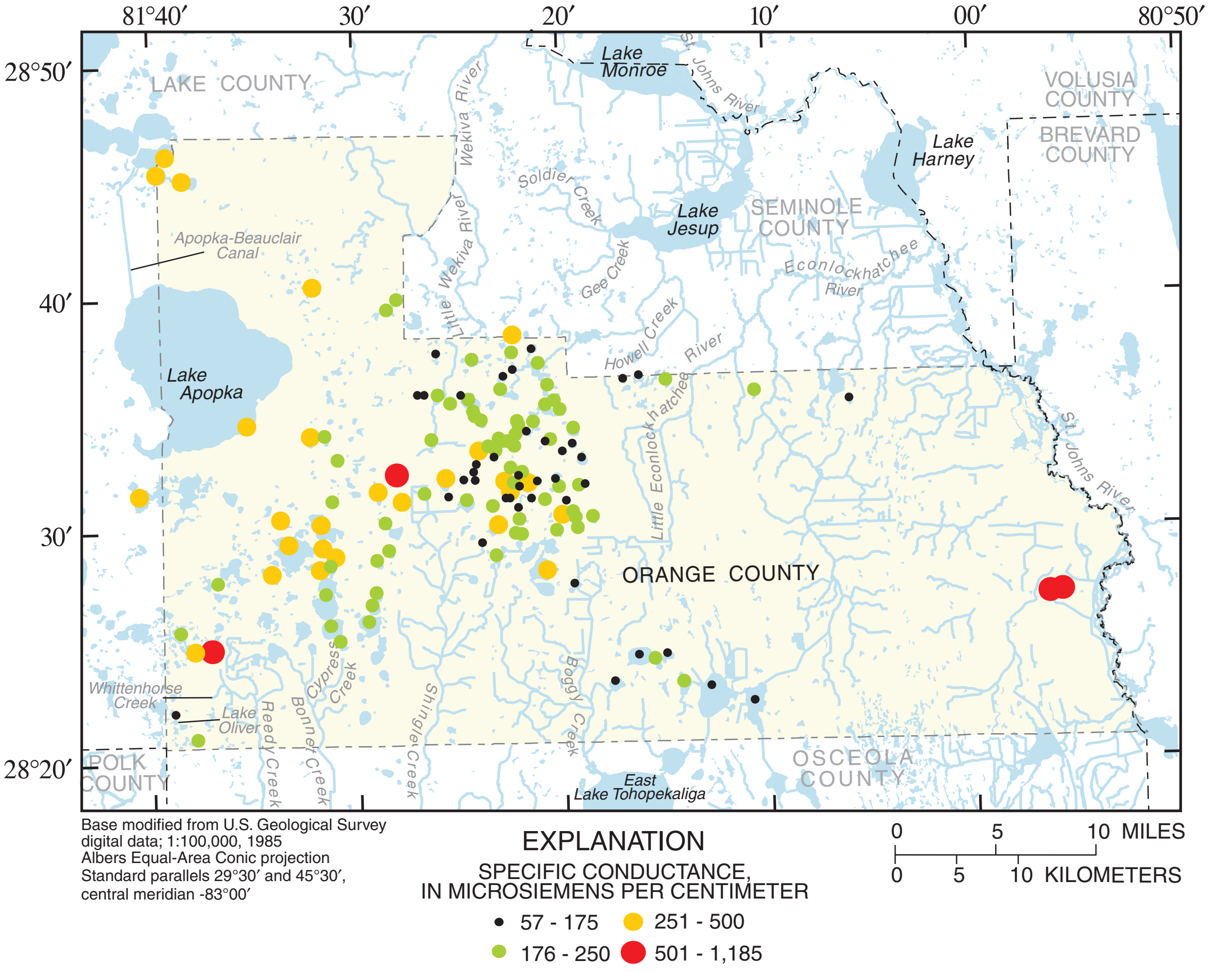
[Data source, City of Orlando Stormwater Utility Bureau, Orange County Environmental Protection Division, U.S. Geological Survey. ° C, degrees Celsius; all units are in milligrams per liter unless otherwise noted; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than]

Constituent	No. of samples	Minimum	25th percentile	Median	75th percentile	Maximum
Temperature, ° C	422	11.7	22.1	28.2	29.9	33.4
Specific conductance, µS/cm	421	57	166	202	240	1,185
pH, standard units	421	4.6	6.9	7.7	8.2	9.6
Calcium	191	1.6	12	16	22	40
Magnesium	192	1.2	3.2	4.2	6.9	20.3
Sodium	192	<1.0	9.2	12	15	160
Potassium	191	<1.0	2.5	4.2	7.8	19
Bicarbonate	431	<1.0	27	47	68	169
Sulfate	218	<1.0	14	27	38	81
Chloride	216	9.7	17	26	32	290
Nitrite plus nitrate as nitrogen	426	<.05	<.05	<.05	<.05	.51
Nitrite as nitrogen	426	<.02	<.02	<.02	<.02	.05
Ammonia as nitrogen	431	<.02	<.02	.02	.03	.53
Ammonia plus organic nitrogen as nitrogen	428	<.2	.58	.79	1.1	6
Nitrogen, total	448	<.2	.58	.8	1.1	6
Phosphorus, total	446	<.02	<.02	<.02	.04	.38
Orthophosphate as phosphorus	427	<.02	<.02	<.02	<.02	.45
Chlorophyll-*a*, µg/L	447	<.5	3.7	13	27	200

ranged from less than 1 to 169 mg/L, sulfate ranged from less than 1 to 81 mg/L, and chloride ranged from 9.7 to 290 mg/L (table 17). National Secondary Drinking Water Regulations for chloride and sulfate specify a maximum concentration of 250 mg/L. Secondary standards are nonenforceable standards set for cosmetic (skin or tooth discoloration) or aesthetic effects (taste, odor, or color) (U.S. Environmental Protection Agency, 2002). The secondary standard for chloride was exceeded in a sample from a pond at Tosohatchee State Reserve (290 mg/L; appendix D).

Water type in lakes, as related to the major dissolved cations and anions, is variable in Orange County (fig. 33). Reedy Lake and Lake Louise are examples of lakes with sodium-chloride type water. The sodium-chloride water type may result from domestic wastewater seepage into a lake, or from upward leakage of relict seawater through the Upper Floridan aquifer in the eastern part of Orange County. Lake Underhill and Lake Ivanhoe have a calcium-bicarbonate water type. This type of water may result from seepage of water from the Upper Floridan aquifer or seepage from the surficial aquifer in areas that were irrigated using water from the Upper Floridan aquifer. Another possible source of calcium-bicarbonate type water may be storm runoff from streets, parking lots, and other concrete features. Other lakes, such as Lake Ola, have a mixed water type, suggesting several different sources of inflow to the lake.

Total nitrogen concentrations ranged from less than 0.2 to 6 mg/L as nitrogen (table 17). Comparison of concentrations of various forms of nitrogen indicates that most of the nitrogen present in the samples from lakes is in the form of organic nitrogen. For example, concentrations of nitrite and nitrite plus nitrate were less than the reporting limits (0.02 and 0.05 mg/L, respectively) in at least 75 percent of the samples from lakes. Ammonia plus organic nitrogen ranged from less than 0.2 to 6.0 mg/L as nitrogen. However, concentrations of ammonia were less than or equal to the reporting limit of 0.02 mg/L as nitrogen (table 17) in about 50 percent of the samples from lakes. There is little areal pattern in total nitrogen occurrence in Orange County lakes. Lakes with total nitrogen



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

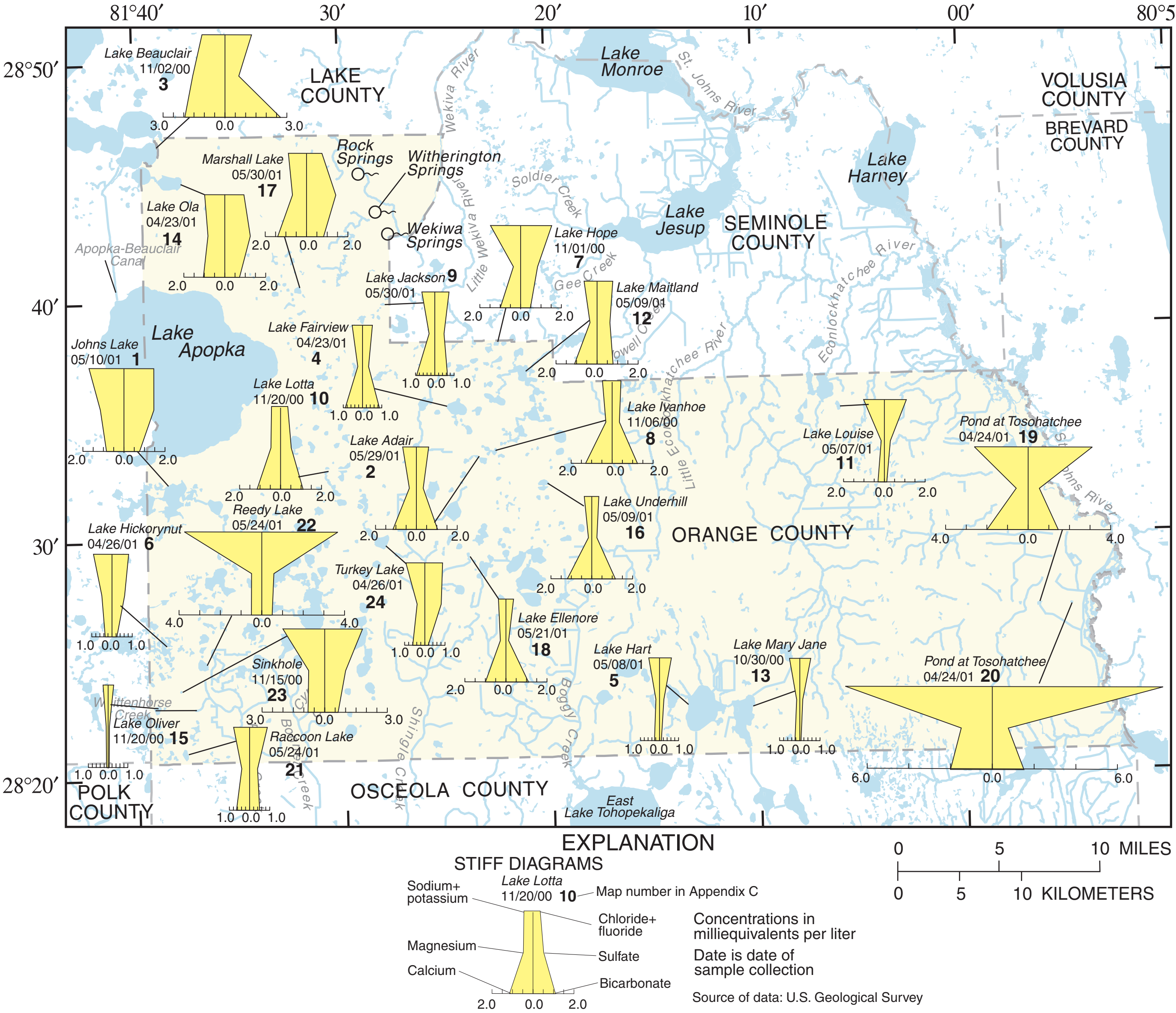
Figure 32. Specific conductance for selected lakes in Orange County, 2000-01.

concentrations in all four ranges plotted in figure 34 are located within urbanized areas of central Orange County. Most lakes in the northwest part of the County have relatively high total nitrogen concentrations, perhaps because of fertilizer usage in the agricultural areas.

The USEPA has recommended that total nitrogen concentrations in central Florida lakes and reservoirs should not exceed 0.52 mg/L (U.S. Environmental Protection Agency, 2000b). This criterion was exceeded in about one-half of the lakes sampled during this study (fig. 34). Presently, the FDEP is developing new nutrient criteria for lakes that will apply to specific regions within Florida, based on existing water-quality data. These new criteria probably will provide a better means for assessing water quality in lakes than the more general existing USEPA criteria.

Few pristine sites are present in Orange County, so assessing natural or background concentrations of nitrogen is difficult. Two ponds in Tosohatchee State Reserve had ammonia plus organic nitrogen concentrations ranging from 0.84 to 1.5 mg/L as nitrogen (appendix D). Concentrations of total nitrogen may exceed the USEPA recommendation even in pristine-appearing lakes.

Concentrations of total nitrogen exceeded 2.0 mg/L as nitrogen in samples from Lake Apopka, Lake Beauclair, Lake Carlton, Lake Cherokee, Lake Holden, John’s Lake, Lake Kasey, Lake Kozart, Lake Lawsona, Lake Mann, Marshall Lake, and Lake Walker, and the Apopka-Beauclair Canal. Land use in many of these lake basins historically has been agricultural, but is changing to urban and residential. Hence, determining the source of nitrogen in these samples is difficult.

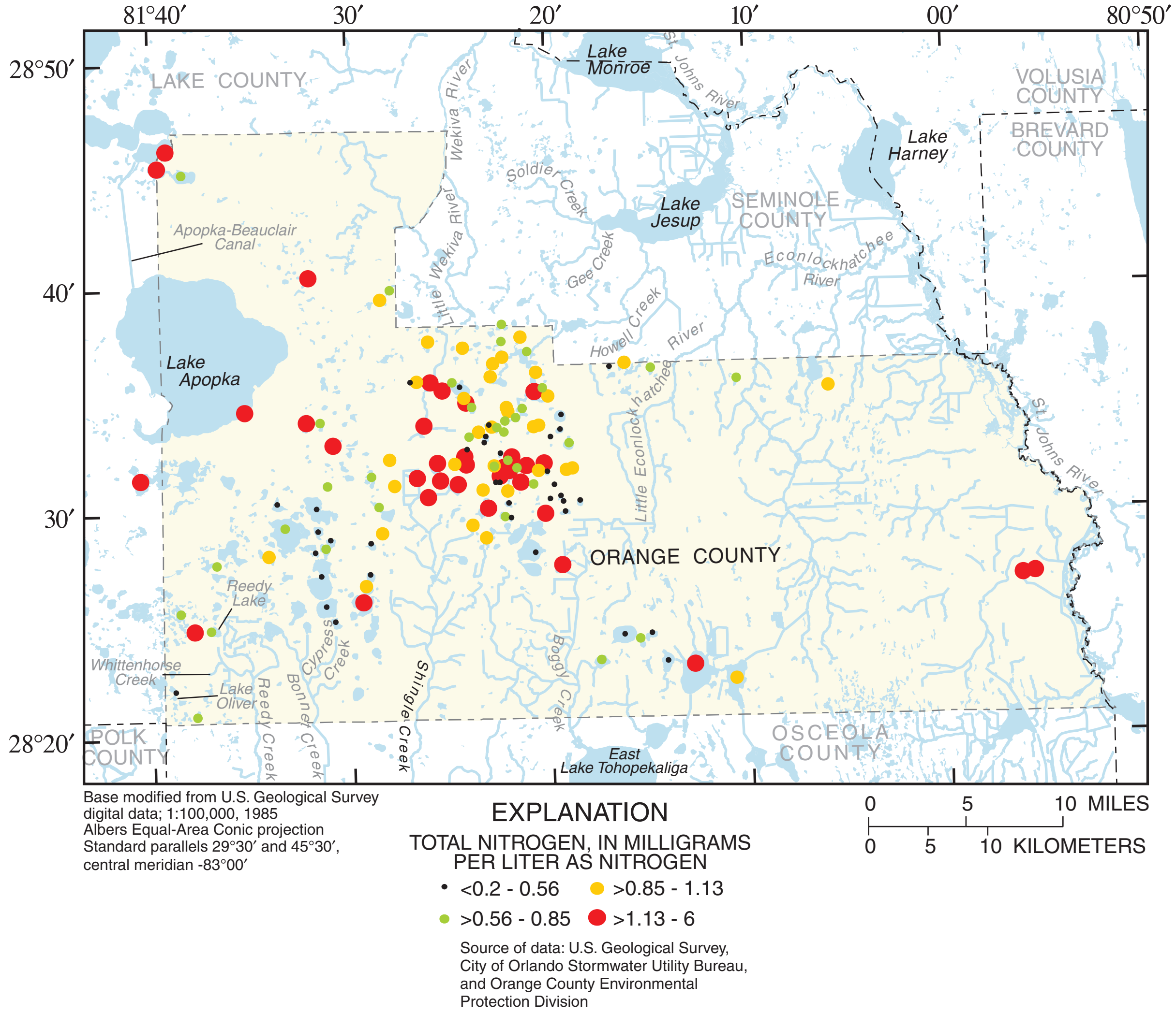


Source of data: U.S. Geological Survey

Figure 33. Concentrations of major cations and anions for selected lakes in Orange County, 2000-01. (Lake names and map numbers refer to appendix C.)

Concentrations of total phosphorus ranged from less than 0.02 to 0.38 mg/L as phosphorus. Most of the phosphorus present was as orthophosphate (table 17). The USEPA recommended criteria for phosphorus in central Florida lakes is 0.010 mg/L (U.S. Environmental Protection Agency, 2000b), which is lower than the detection limit for the samples taken during this study. About 25 percent of the samples had a phosphorus content of 0.04 mg/L or greater.

The source of phosphorus probably is not naturally occurring sediments. The Orlando Ridge lake region, in the central part of Orange County, is described as having phosphatic sand and clay at shallow depths (Griffith and others, 1997). However, analysis of well logs in and around the Orlando Ridge region indicates that depth to the top of phosphatic sediments ranges from about 10 to 200 ft, with a median of about 50 ft. Many lakes with total phosphorus concentrations greater than the median of 0.02 mg/L (such as Lake Concord, Lake Eola, Lake Lawsona, Lake Mann, and Lake Rowena) are in areas where phosphatic sediments are 40 to 80 ft below land surface, according to well logs. In addition, the altitude of the Upper Floridan aquifer potentiometric surface in the vicinity of Orlando ranges from about 40 to 50 ft above NGVD 29 (Knowles, 2001). The surface



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

EXPLANATION

TOTAL NITROGEN, IN MILLIGRAMS PER LITER AS NITROGEN

- • <0.2 - 0.56
- ● >0.85 - 1.13
- ● >0.56 - 0.85
- ● >1.13 - 6

Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

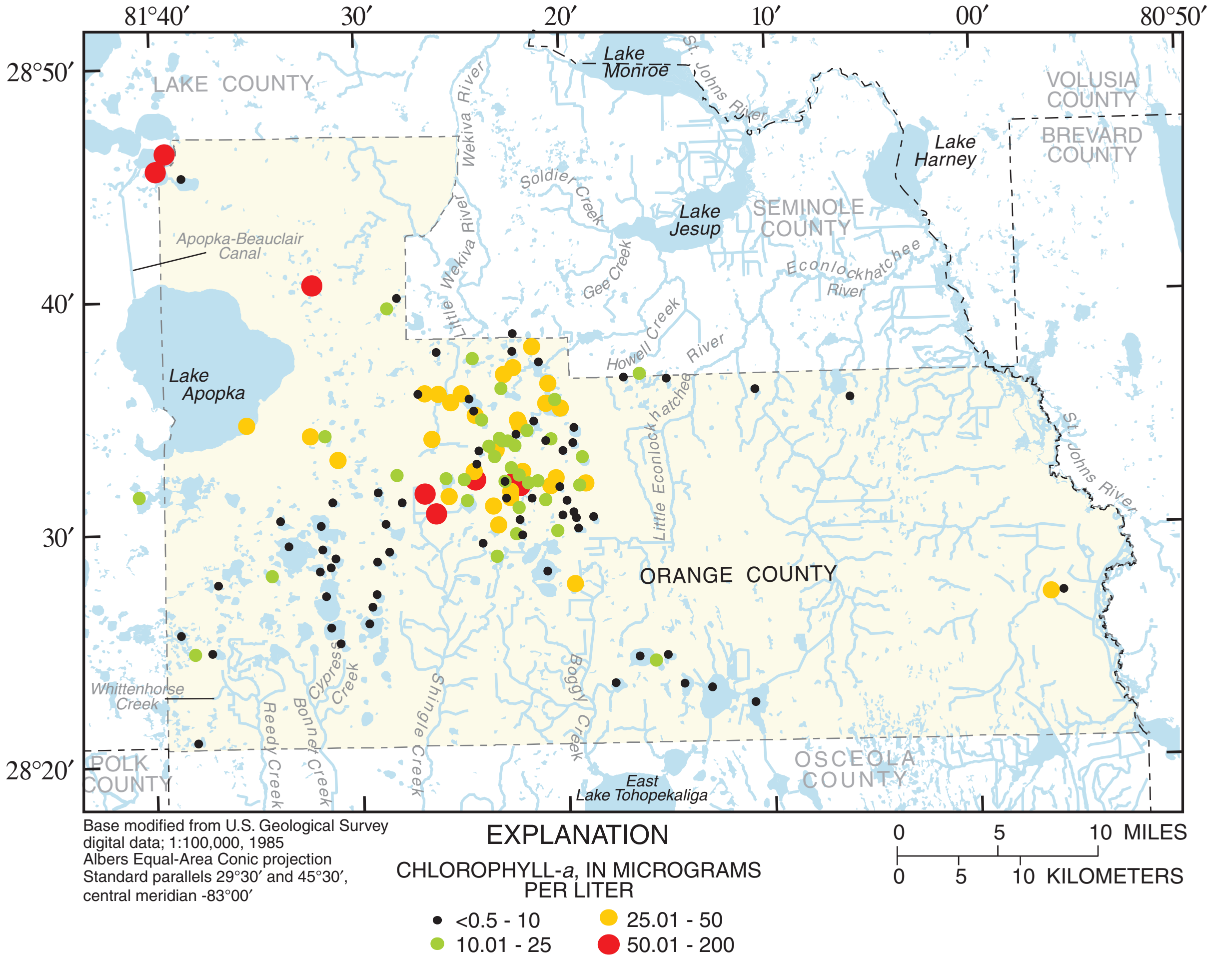
Figure 34. Total nitrogen concentrations for selected lakes in Orange County, 2000-01.

altitude of lakes in the area ranges from about 70 to 110 ft above NGVD 29, indicating that the vertical flow of water generally would be downward.

Chlorophyll-*a* ranged from less than 0.5 to 200 µg/L in samples from lakes (table 17; fig. 35). The USEPA recommended criterion for chlorophyll-*a* in central Florida lakes is 2.6 µg/L (U.S. Environmental Protection Agency, 2000b). This criterion was exceeded in more than one-half of the lakes sampled in 2000-2001. Chlorophyll-*a* concentrations exceeding 10 µg/L generally occurred in the urbanized central part of the County. However, not all lakes in central Orange County had water with chlorophyll-*a* concentrations greater than 10 µg/L

The TSI values for Orange County lakes ranged from 18 to 110 units (fig. 36). The highest TSI values (greater than 70) generally occurred in the urbanized central part of the County and in the northwest (agricultural) areas. However, not all lakes in the central part of the County had high TSI values—several had TSI values of 35 or less.

Lakes surrounded by relatively pristine land cover can have relatively high TSI values as a result of low water clarity, even if other water-quality constituents indicate a low trophic state. For example, Lake Hart and Lake Louise had relatively low concentrations of chlorophyll-*a* (5.9 and 6.3 µg/L, respectively; appendix C), but low water clarity of the lakes resulted in maximum TSI values of 54 and 55, respectively. Low water clarity, therefore, is not always related to high concentrations of chlorophyll-*a,* though the TSI values, which are a function of water clarity, would generally always be relatively high in colored lakes. This effect of water color may make interpretation of the TSI values difficult for lakes with high organic color. Brezonik



Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

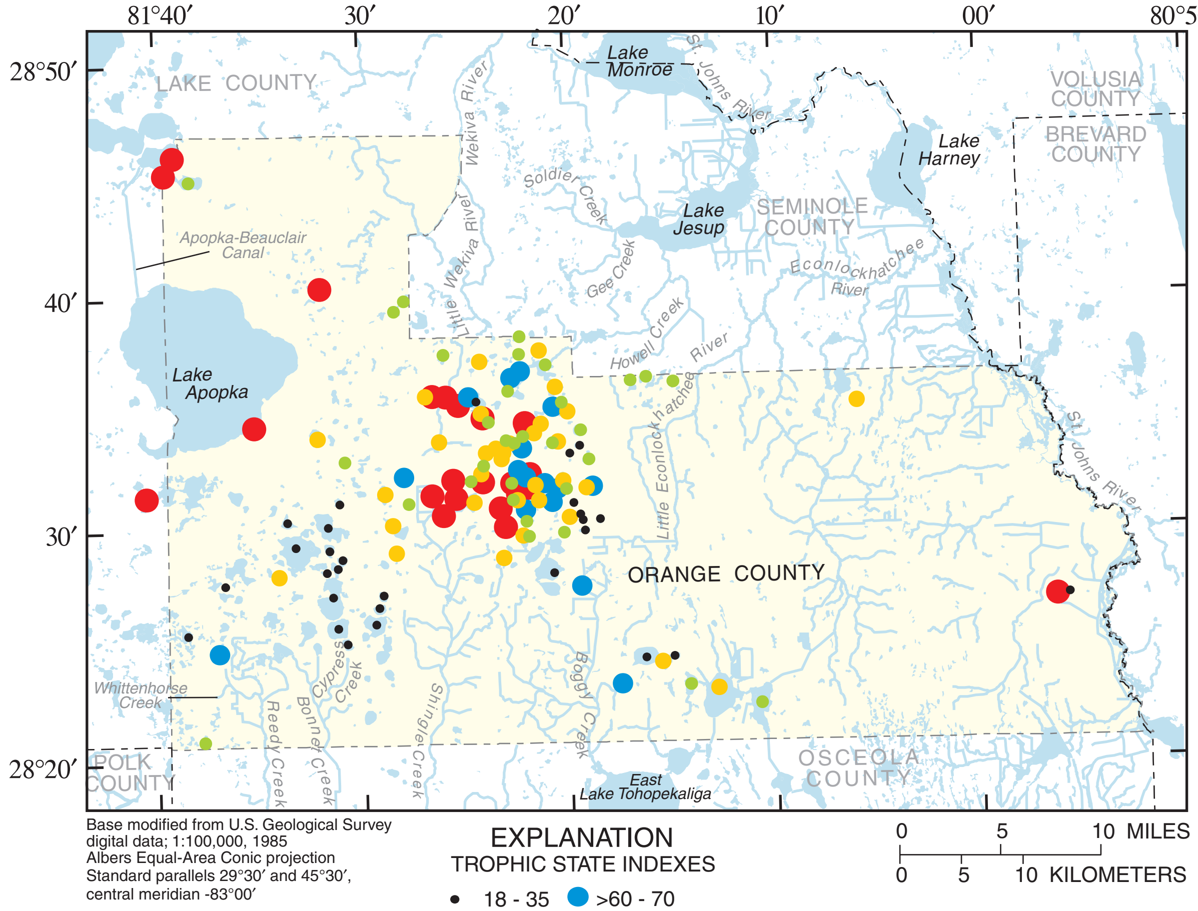
Figure 35. Chlorophyll-*a* concentrations for selected lakes in Orange County, 2000-01.

and Pollman (1999) reported that high levels of organic (humic) color apparently effect the way a lake responds to phosphorus enrichment, and recommended further studies to better define trophic response-nutrient loading relations in colored lakes.

Although chlorophyll-*a* concentrations are related to phosphorus concentrations in lakes, the absence of phosphorus does not necessarily limit algal growth. Concentrations of chlorophyll-*a* ranged from less than 0.5 to 139 µg/L in 240 samples from lakes with total phosphorus concentrations less than 0.02 mg/L (fig. 37).

The presence of relatively high concentrations of total phosphorus in samples from lakes, however, is almost always associated with high chlorophyll-a concentrations. Samples from 23 lakes with total phosphorus concentrations greater than or equal to 0.10 mg/L as phosphorus had relatively high chlorophyll-*a* concentrations, ranging from 5.6 to 200 µg/L, with a median of about 36 µg/L, and relatively high TSI values, ranging from 53 to 110, with a median of 80. Hence, determining the source of phosphorus in lakes is important in understanding eutrophication.

Lakes with levels of chlorophyll-*a* exceeding 10 µg/L generally have water clarity of less than 2 m (fig. 37). These lakes also are likely to have a green or brown turbid appearance because of the suspended algae that is the source of the chlorophyll-*a*. However, lakes with chlorophyll-*a* concentrations less than 1 µg/L may have either low or high secchi-disk clarity, with clarity ranging from less than 1 m to more than 5 m. The low clarity in



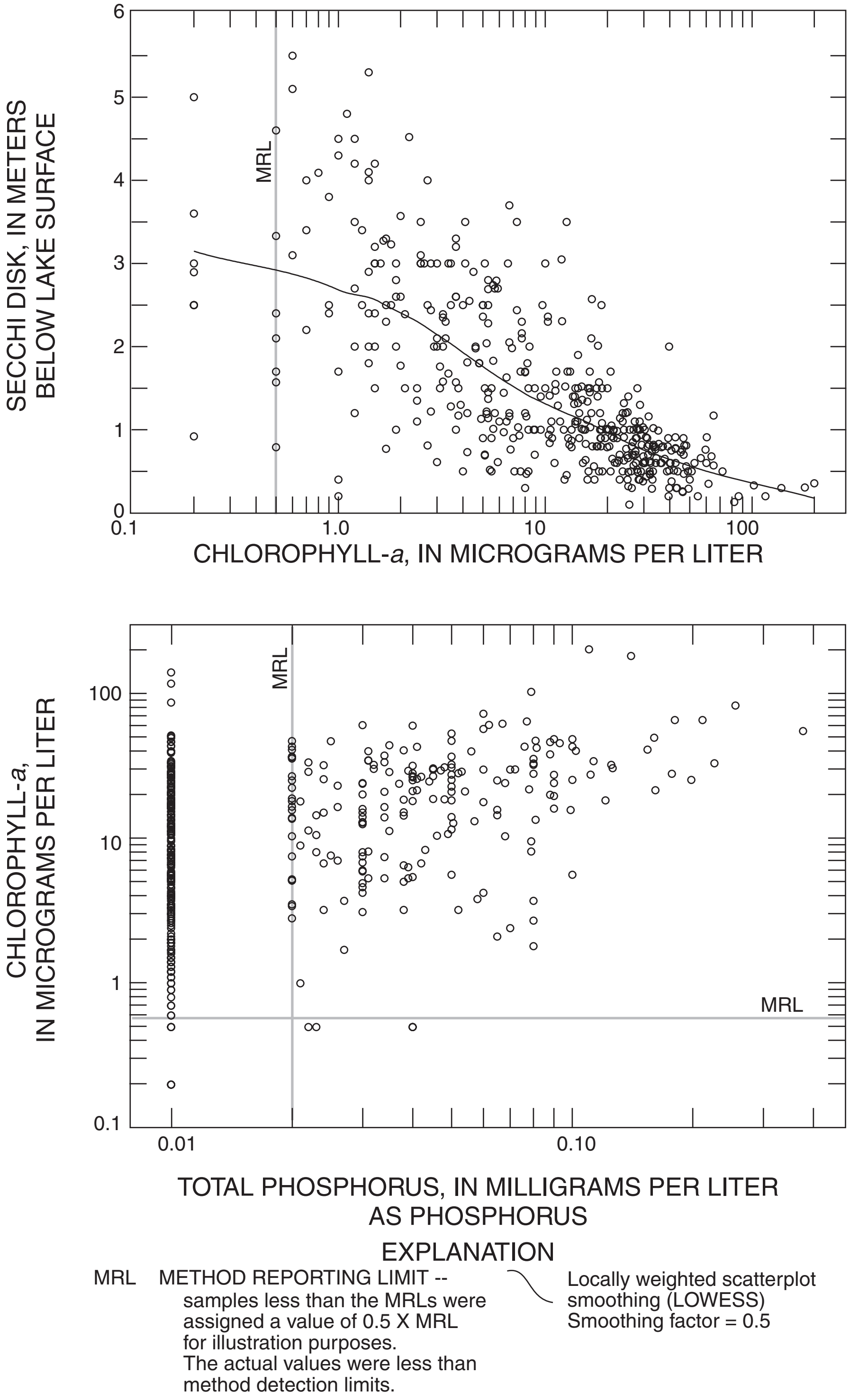
Base modified from U.S. Geological Survey digital data; 1:100,000, 1985
Albers Equal-Area Conic projection
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

Figure 36. Trophic state indexes for selected lakes in Orange County, 2000-01.

lakes with low chlorophyll-*a* concentrations is probably the result of humic compounds leached from leaves and other vegetative debris that are in contact with the water for extended time periods. The leached compounds give water a characteristic dark tea color, although the water itself generally contains little suspended material. Thus, lakes with low chlorophyll-*a* concentrations may either contain clear, uncolored water with a high secchi disk reading, or clear (nonturbid) water with a high color and a low secchi-disk reading.

Water quality can vary significantly among lakes within a relatively small area. For example, samples from Lake Oliver (map no. 15 in figure 9) and nearby Reedy Lake (map no. 22 in figure 9) in southwestern Orange County had the lowest and one of highest values of specific conductance (57 and 543 µS/cm, respectively; appendix D). The sample from Lake Oliver also had a lower pH (5.1) than the sample from Reedy Lake (7.3, appendix D). Water from Raccoon Lake (map no. 21 in figure 9), also in southwest Orange County, had specific conductance of 206 µS/cm (appendix D). Water type of Lake Oliver and Reedy Lake is sodium chloride. Water type of Raccoon Lake is mixed cation and anion (fig. 33). Total nitrogen concentrations in samples from Lake Oliver, Raccoon Lake, and Reedy Lake were 0.47, 0.84, and 0.83 mg/L as nitrogen, respectively (appendix C).



Source of data: U.S. Geological Survey, City of Orlando Stormwater Utility Bureau, and Orange County Environmental Protection Division

Figure 37. Relation of water clarity (secchi disk readings) with chlorophyll-*a* concentrations, and relation of chlorophyll-*a* concentrations to total phosphorus concentrations.

The source of differences in water quality between Lake Oliver and Reedy Lake is difficult to determine. The shores of both lakes presently (2004) are surrounded by forests and wetlands; however, RIBs that receive treated wastewater (reclaimed water) are located upgradient (southwest) of Reedy Lake. Reclaimed water also is used to irrigate citrus groves south-southwest of Reedy Lake. The chemistry of water from Reedy Lake generally is within the chemical range of reclaimed water (table 18). In May 1991, measured specific conductance was 114 µS/cm and chloride concentration was 19 mg/L for Reedy Lake (Rebecca Gubert, Reedy Creek Improvement District, written commun., 2002). Although historical data for Reedy Lake are sparse, the water quality of Reedy Lake may have changed substantially in the past decade to reflect the influence of infiltrating RIB water.

Table 18. Comparison of water quality of Reedy Lake with range of water quality of reclaimed water.

[Reclaimed-water data from Sumner and Bradner (1996). Units are in milligrams per liter unless otherwise noted; µS/cm, microsiemens per centimeter]

Constituent	Reedy Lake	Reclaimed water
Specific conductance, µS/cm	543	480-550
pH, standard units	7.5	5.9-8.2
Calcium	10	25-35
Magnesium	6	5.0-10
Sodium	79	45-80
Bicarbonate	30	29-125
Chloride	130	60-155

Lake water quality in other parts of Orange County also ranges widely over short distances. In eastern Orange County, samples from two lakes (water-filled borrow pits remaining from road-construction activities) in Tosohatchee State Reserve had the highest specific conductance. Both lakes are located in the Eastern Flatlands region. Two samples from the first lake (map no. 19 in figure 9) had specific conductances of 450 and 558 µS/cm. Specific conductance in the sample from the second lake (map no. 20 in figure 9), about 0.5 mi east of the first lake, was 1,185 µS/cm (fig. 32; appendix D). The water type of the first and second lakes was calcium-sodium bicarbonate-chloride and sodium chloride, respectively (fig. 33). Water clarity also was substantially different between the two sites. Secchi disk readings for the first lake were 0.92 and 0.62 m, and secchi disk reading for the second lake was more than 3.0 m.

The water quality of the two lakes at Tosohatchee State Reserve probably is affected by ground-water discharge from the Upper Floridan aquifer. The potentiometric surface of the Upper Floridan aquifer is above land surface in eastern Orange County, indicating that the area is a place of potential ground-water discharge. The trace element strontium generally is present in relatively high concentrations in water from the Upper Floridan aquifer, compared with water from the surficial aquifer system (Adamski and German, 2003), and thus may be useful as an indicator of ground-water discharge. Specific conductance and strontium concentrations in samples from the lakes are similar to water from the Upper Floridan aquifer. Values of specific conductance from three nearby flowing wells that tap the Upper Floridan aquifer ranged from 2,790 to 4,190 µS/cm. Strontium concentrations in samples from the three wells ranged from 4,200 to 6,500 µg/L. Strontium concentrations in samples from the two lakes range from 450 to 1,600 µg/L. In contrast, the median strontium concentration in 37 samples collected from lakes across Orange County is 57 µg/L. Differences in water quality between the two lakes probably is related to the amount of discharge each lake receives from the Upper Floridan aquifer rather than to differences in land use, which is predominantly forested wetlands.

Water-quality data indicate that most large lakes in Orange County are well mixed. Field measurements were obtained at two to eight locations on selected large lakes (Fairview, Hart, Hickorynut, Louise, Maitland, Ola, Turkey, and Underhill). Results indicated that field measurements generally were consistent spatially and vertically in nearly all lakes. For example, at Lake Hart, a large lake in south-central Orange County, specific conductance at three locations and at depths of 0.15, 0.9, 1.5, and 2.1 m on May 8, 2001, ranged from 114 to 115 µS/cm; pH ranged from 5.9 to 6.1 at the same locations; temperature ranged from about 23.1 to 23.6 °C.

In contrast, water quality in Lake Beauclair was vertically heterogeneous. Specific conductance at depths of 0.15 and 1.8 m was 441 and 514 µS/cm, respectively. Temperature ranged from 25.4 and 22.9 °C, and concentrations of dissolved oxygen ranged from 16 to less than 0.1 mg/L at the same depths. Lake Beauclair had a secchi disk reading of 0.36 m and a chlorophyll-*a* concentration of 200 µg/L.

Seasonal variations in water quality are indicated by data from seven lakes, each of which had ten or more samples collected from June 2000 through October 2001 (fig. 38). However, the variations were not consistent among the lakes. For example, total phosphorus in samples from Lake Rowena ranged from less than 0.02 to 0.05 mg/L, whereas total phosphorus concentrations in samples from the other six lakes were all less than 0.02 mg/L

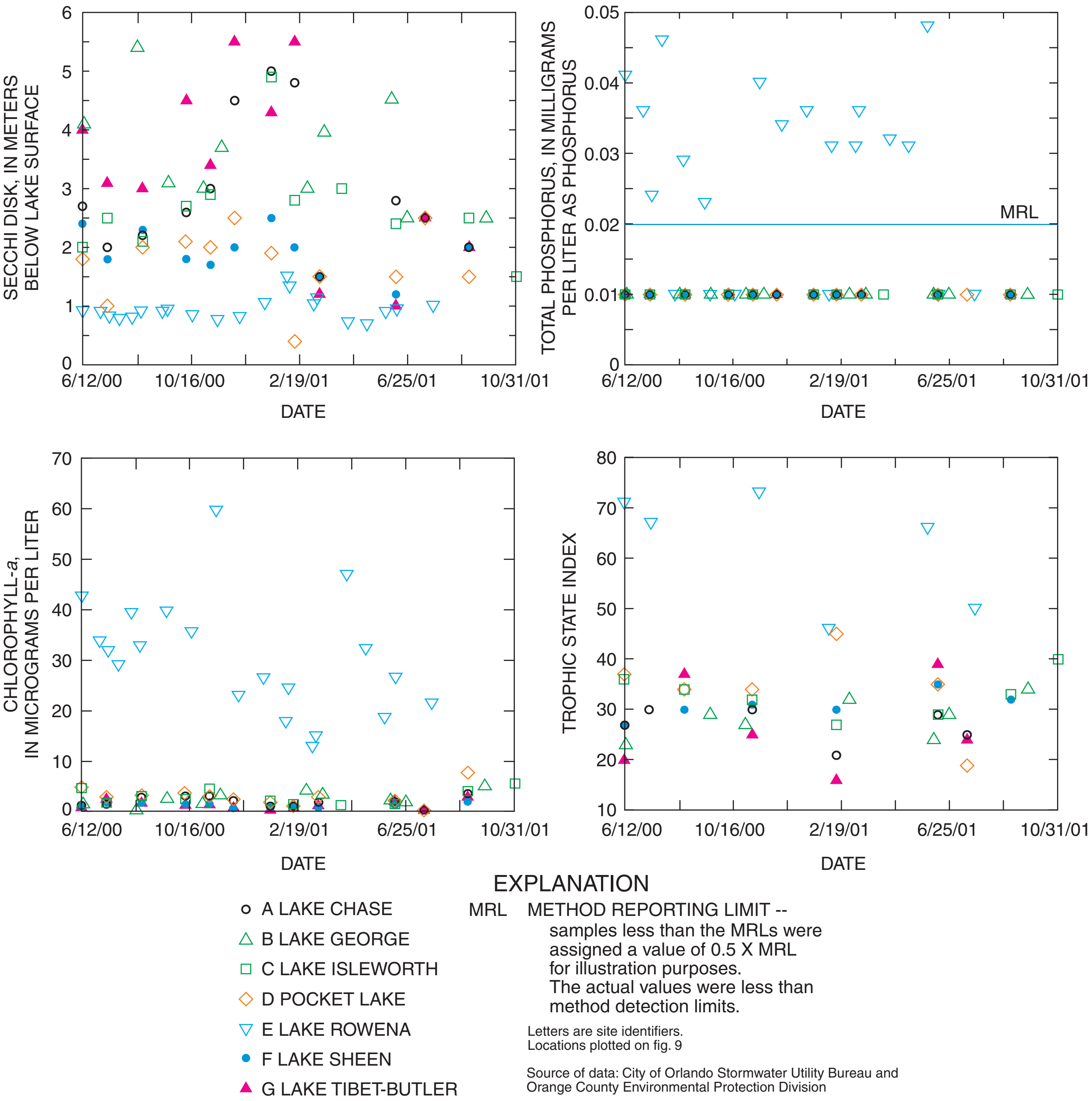


Figure 38. Temporal variations of water clarity (secchi disk readings), total phosphorus and chlorophyll-*a* concentrations, and trophic state indexes for seven lakes in Orange County.

(fig. 38). Chlorophyll-*a* concentrations in Lake Rowena ranged from 13 to 60 µg/L, whereas chlorophyll-*a* concentrations in samples from the other six lakes were all less than 10 µg/L. Conversely, secchi disk readings in Lake Rowena consistently were 1.5 m or less, whereas secchi disk readings in six lakes increased during winter months. Lake Rowena also had the greatest TSI, ranging from 46 to 73. TSI values of the other six lakes all were less than 50 (fig. 38). Seasonal variations in these water-quality indicators probably are related to temperature, rainfall, and amount of sunlight, and subsequently, to algal and (or) cyanobacteria production. Lakes with low concentrations of nutrients and lower algal production, as indicated by chlorophyll-*a* concentrations, have less variation in water quality throughout the year than does a lake with relatively higher concentrations of nutrients and chlorophyll-*a*.

Trace Elements in Streams and Lakes

A total of 37 filtered samples from 24 lakes and 24 filtered samples from 11 streams was analyzed for 15 trace elements. In addition, 17 whole-water samples from 4 streams (Cypress, Bonnet Creek, Whittenhorse Creek, and Reedy Creek) were analyzed for 9 trace elements. The most commonly detected trace elements in lakes (table 19) and streams (table 20) were aluminum, barium, boron, iron, manganese, and strontium. Barium has a maximum contaminant level (MCL) in drinking water of 2,000 µg/L (U.S. Environmental Protection Agency, 2002). The maximum concentration of barium detected was 56 µg/L (table 19, appendix D), which was in a sample from one of the ponds at Tosohatchee State Reserve. Aluminum, iron, and manganese have secondary standards of 200, 300, and 50 µg/L, respectively (U.S. Environmental Protection Agency, 2002). The maximum concentrations of these constituents in samples from streams were: aluminum, 684 µg/L (Bonnet Creek); iron, 1,100 µg/L (Bonnet Creek); and manganese, 550 µg/L (Jim Creek).

Arsenic was detected in 26 of 37 samples from lakes (table 19) and in 21 of 39 samples from streams (table 20). Selenium was detected in 8 of 37 samples from lakes and in 7 of 41 samples from streams. Arsenic and selenium both have an MCL of 50 µg/L for drinking water (U.S. Environmental Protection Agency, 2002). Maximum concentrations of arsenic and selenium were 7.2 and 3.0 µg/L, respectively (table 20). Arsenic concentrations exceeded 4.0 µg/L in samples from the Apopka-Beauclair canal (7.2 µg/L), Lake Beauclair (4.2 µg/L), and Marshall Lake (5.5 µg/L) (U.S. Geological Survey, 2004a). The maximum selenium concentration (3 µg/L) was in a sample from the Little Wekiva River (U.S. Geological Survey, 2004a).

Four trace elements (beryllium, cadmium, chromium, and cobalt) were not detected in any samples. Lead was detected in only three whole-water samples from Cypress Creek and one whole-water sample from Reedy Creek. Lead has an MCL of 15 µg/L in drinking water (U.S. Environmental Protection Agency, 2002). The maximum lead concentration measured (3.0 µg/L) was in a sample from Cypress Creek (U.S. Geological Survey, 2004a).

Table 19. Summary statistics of trace-element concentrations in samples from 24 lakes in Orange County.

[All analyses on filtered samples; all units are in micrograms per liter]

Constituent	No. of samples	No. of detections	Minimum	25th percentile	Median	75th percentile	Maximum
Aluminum	33	33	5.1	29	38	62	300
Arsenic	37	26	.6	.95	1.5	2.4	5.5
Barium	34	32	.5	9	13	16	56
Beryllium	34	0					
Boron	34	34	25	34	49	61	200
Cadmium	34	0					
Chromium	34	0					
Cobalt	34	0					
Iron	37	31	1.2	3.4	9.2	67	835
Lead	34	0					
Lithium	34	6	.6	1	1.1	1.6	3
Manganese	37	24	.3	1.3	3	5.9	15
Selenium	37	8	.5	.5	.75	1.6	1.6
Strontium	37	37	9	36	57	67	1,600
Vanadium	34	22	1	1	2	2	6

Table 20. Summary statistics of trace-element concentrations in samples from 15 streams in Orange County.

[All analyses on filtered samples unless noted; all units are in micrograms per liter; --, not detected]

Constituent	No. of samples	No. of detections	Minimum	25th percentile	Median	75th percentile	Maximum
Aluminum, filtered	21	21	13	22	44	60	170
Aluminum, whole water	17	17	47	143	190	331	684
Arsenic, filtered	24	8	.3	.65	1	2.2	7.2
Arsenic, whole water	15	13	1	1.9	2.2	3.2	3.7
Barium	24	24	9	12	14	17	35
Beryllium, filtered	24	0	--	--	--	--	--
Beryllium, whole water	17	0	--	--	--	--	--
Boron	24	24	10	29	39	53	119
Cadmium, filtered	22	0	--	--	--	--	--
Cadmium, whole water	17	0	--	--	--	--	--
Chromium, filtered	24	0	--	--	--	--	--
Chromium, whole water	17	0	--	--	--	--	--
Cobalt	24	0	--	--	--	--	--
Iron, filtered	24	23	3.3	52	128	210	516
Iron, whole water	17	17	150	281	416	540	1,100
Lead, filtered	24	0	--	--	--	--	--
Lead, whole water	17	4	1	1	1.5	2.3	3
Lithium	24	17	.8	1	1.1	1.4	3
Manganese, filtered	24	23	1.1	5.5	9.4	11	550
Manganese, whole water	17	17	4.8	8.9	9.9	15	63
Selenium, filtered	24	6	.5	1.2	2.4	2.9	3
Selenium, whole water	17	1	1.4	--	--	--	--
Strontium	24	24	22	77	140	175	410
Vanadium	24	13	1	2	2	2	6

Pesticides in Streams and Lakes

Pesticides are synthetic, organic compounds used to control insects (insecticides), plants (herbicides), fungi (fungicides), and other nuisance organisms. For pesticide analysis, 18 samples from 6 stream sites (table 21) and 26 samples from 13 lakes (table 22) were collected (appendix E). The results indicate that low concentrations of pesticides are ubiquitous and persistent in the surface-water resources of Orange County. Pesticides were detected in nearly every sample and at every site (appendix E).

Pesticides were detected in nearly all samples from the six stream sites during all three sampling periods. The maximum number of pesticide compounds detected in a single sample was nine (Little Econlackhatchee River, table 21). The only sample with no detectable concentrations of pesticides was the sample collected from the Wekiva River near Apopka in February 2001 (table 21). Similarly, pesticides were detected in nearly all samples from all 13 lakes during all 3 sampling periods. The maximum number of pesticide compounds detected in a single sample was six. The only sample with no detectable concentrations of pesticides was a sample collected from Lake Hart in July 2000 (table 22).

The most commonly detected compounds were herbicides, including atrazine, prometon, simazine (triazine herbicides for control of broad leaf plants), and tebuthiuron (a nonselective herbicide). The most commonly detected insecticide was diazinon (table 23). Concentrations generally were low, with many results reported as measured but not quantified. The maximum concentration of any pesticide was 0.7 µg/L for atrazine. Atrazine and simazine have MCLs set for drinking water of 3.0 and 4.0 µg/L, respectively (U.S. Environmental Protection Agency, 2002).

In general, the number of compounds and concentrations detected were similar among the periodic samples collected from each site. For example, samples collected

Table 21. Stream sites, date of sample collection, and number of pesticide compounds detected in each sample.

Station name	Station identifier	Date	No. of detections
Boggy Creek	02262900	4/26/2000	4
		9/6/2000	4
		2/22/2001	3
Econlockhatchee River	02233500	4/12/2000	7
		9/5/2000	6
		2/6/2001	3
Little Econlockhatchee River	02233200	4/25/2000	5
		8/31/2000	9
		2/8/2001	6
Little Wekiva River	02234990	4/11/2000	8
		8/29/2000	6
		2/14/2001	7
Shingle Creek	02263800	4/24/2000	6
		9/13/2000	4
		2/28/2001	3
Wekiva River	02234635	4/12/2000	4
		9/6/2000	5
		2/5/2001	0

from Lake Fairview in July 2000, November 2000, and April 2001 each had four pesticides detected (atrazine, diazinon, prometon, and tebuthiuron) at concentrations ranging from about 0.005 to 0.155 µg/L (appendix E). The number of detections was slightly more variable for periodic samples from streams. The number of detections from the Wekiva River ranged from none (February 2001) to five (September 2000), and the number of detections in the Little Econlockhatchee River ranged from five (April 2000) to nine (August 2000; table 21).

Multiple sources probably contribute to the occurrence of pesticides in surface water. Pesticides were detected in 10 of 34 ground-water samples (16 surficial aquifer system wells, 14 Upper Floridan aquifer wells, and 4 Lower Floridan aquifer wells) collected from April 1999 through February 2000 (Adamski and German, 2003). The surface-water samples collected for this study were collected during baseflow conditions when ground water contributes most of the flow to streams. However, the number and concentrations of pesticides detected in ground-water samples were less than in surface-water samples. Ten pesticides were detected in all the ground-water samples, with a maximum number of compounds detected in any one sample being three. The maximum concentration detected was 0.42 µg/L for simazine (Adamski and German, 2003). Hence, ground water probably is not the only source of pesticides to lakes and streams.

Because the surface-water samples were collected during baseflow, runoff probably did not contribute to pesticide concentrations in streams. However, runoff to lakes during wet periods could have contributed pesticides, which may persist during dry conditions.

Pesticide detections in samples from relatively pristine sites, such as the pond at Tosohatchee State Reserve (table 22), indicate that airborne sources could contribute some pesticides to surface-water resources. Pesticides have been detected in both rain and dry-deposition samples across the United States (Majewski and Capel, 1995). However, the number of pesticides detected and the concentrations (atrazine at 0.007 and 0.003 µg/L; appendix E) in the two samples from the pond at Tosohatchee were much less than at other sites with nearby agricultural or urban land use such as Lake Ola or Turkey Lake (table 22).

Table 22. Lake site, date of sample collection, and number of pesticide compounds detected in each sample.

Station name	Station identifier	Date	No. of detections
Lake Adair	02234205	5/29/2001	6
Lake Ellenore	282927081235000	5/21/2001	6
Lake Fairview	02234812	7/12/2000	5
		11/6/2000	5
		4/23/2001	5
Lake Hart	02262200	7/20/2000	0
		10/30/2000	3
		5/8/2001	4
Lake Hickorynut	02266275	7/18/2000	2
		4/26/2001	5
Lake Hope	02234297	7/19/2000	4
		11/1/2000	5
Lake Jackson	284000081275000	5/30/2001	2
Lake Louise	283528081055300	7/19/2000	3
		11/1/2000	4
		5/7/2001	1
Lake Ola	02237745	7/18/2000	6
		11/2/2000	4
		4/23/2001	4
Lake Marshall	284034081315700	5/30/2001	3
Pond at Tosohatchee	282657080561900	11/8/2000	1
		4/24/2001	2
Raccoon Lake	282102081374600	5/24/2001	6
Turkey Lake	283019081283100	7/13/2000	5
		10/31/2000	4
		4/26/2001	6

Table 23. Pesticide compounds, number of detections, and range of concentrations in samples from lakes and streams in Orange County, 2000-01.

[All units are in micrograms per liter; E, estimated concentrations]

Pesticide compound	Lake samples (26 samples)		Stream samples (18 samples)		Total No. of detections	Total range of concentrations
	No. of detections	Range of concentrations	No. of detections	Range of concentrations		
Atrazine	25	E0.003 - 0.375	17	E0.002 - 0.716	42	E0.002 - 0.716
Carbaryl	3	E.004 - E.023	6	E.004 - E.022	9	E.004 - E.023
Chlorpyrifos	1	E.003	2	E.002 - .005	3	E.002 - .005
Deethyl Atrazine	16	E.002 - E.038	15	E.006 - .078	31	E.002 - E.078
Diazinon	14	E.003 - .026	10	E.004 - .087	24	E.002 - .087
Malathion	0		1	.025	1	.025
Metolachlor	8	E.001 - E.004	2	E.002 - .009	10	E.001 - .009
Pendimethalin	1	E.008	1	.004	2	.004 - E.008
Prometon	17	E.003 - .04	16	E.003 - E.012	33	E.003 - .04
Simazine	8	E.002 - .016	8	E.004 - .009	16	E.003 - .016
Tebuthiuron	7	E.005 - E.02	10	E.004 - .02	17	E.004 - .02
Trifluralin	0		1	E.003	1	E.003

These results indicate that no single source or process contributes to the occurrence and distribution of pesticides in surface-water resources of Orange County. Although atmospheric deposition is important, local land use and ground-water discharge also contribute pesticides to surface water. Additional study is needed to better quantify the contribution of each source. Furthermore, these data were collected under baseflow conditions. Data-collection under different hydrologic conditions, such as flooding, is needed to understand the effects of discharge and overland runoff on concentrations and loads at the sites.

Household and Industrial Waste Compounds in Streams and Lakes

Samples from four lakes (Adair, Ellenore, Fairview, and Hope) and four streams (Econlockhatchee River, Little Econlockhatchee River, Little Wekiva River, and Shingle Creek) were collected for analysis of compounds indicative of household and industrial wastes using a method described by Zaugg and others (2002). A duplicate sample also was collected from Lake Hope for quality assurance purposes. These sites were selected because their basins have a large percentage of urban and residential land use.

Results indicate that many of the compounds were detected at low concentrations in every sample. The number of compounds per sample ranged from 3 compounds in the samples from Lake Ellenore to 12 compounds in the sample from the Little Econlockhatchee River. Concentrations of most compounds were less than 1 µg/L. The maximum concentrations (estimated) of detected compounds were 1.4 µg/L for *para*-nonylphenol in the sample from Little Econlockhatchee River, and 1.4 µg/L of NPEO1-total in a sample from Lake Hope (table 24). In general, the concentrations and the number of compounds detected in the two samples from Lake Hope were in good agreement (table 24), indicating good reproducibility of results. In addition, concentrations of diazinon detected with this method in samples from Lake Adair, Lake Hope, Little Econlockhatchee River, and the Little Wekiva River were in good agreement with the results of the pesticide analyses discussed in the previous section. For example, diazinon concentrations in the samples from Lake Adair were 0.04 and 0.03 µg/L for the household waste method and the pesticide analysis, respectively.

The source of many of these compounds is wastewater or septic-tank effluent. For example, 3*beta*-coprostanol (table 24) is a carnivore fecal indicator, generally indicating human waste. Caffeine is consumed in coffee, tea, and other popular beverages and may be introduced into wastewater systems. The mosquito repellent N,N-diethyl-*meta*-toluamide (DEET) may also be introduced into wastewater systems through bathing or laundry wastewater, or may enter water bodies directly through recreational activities such as fishing and swimming. Other compounds, such as pyrene, are additives in asphalt and could result from runoff of paved surfaces (Zaugg and others, 2002).

Table 24. Selected results of analysis of surface-water samples for household and industrial wastes compounds.

[All units are in micrograms per liter; E, estimated concentrations; NA, not analyzed; <, less than]

Constituent	Use or source[a]	Little Econlockhatchee River	Econlockhatchee River	Lake Hope	Lake Hope (duplicate)
3*beta*-coprostanol	carnivore fecal indicator	<0.600	E.542	<0.600	<0.600
5-Methyl-1H-benzotriazle	antioxidant in antifreeze	<.100	E.138	<.100	<.100
Caffeine	beverages; plants	E.074	E.068	<.080	<.080
Cotinine	nicotine metabolite	.051	<.080	<.040	<.040
Diazinon	insecticide	.139	<.030	<.030	E.023
Fluoranthene	component of asphalt	E.024	<.030	E.011	E.007
N,N-diethyl-*meta*-toluamide (DEET)	mosquito repellent	E.089	E.078	E.023	E.029
NPEO1-total	detergent metabolite	<1.00	E1.140	E1.400	E1.370
OPEO1	detergent metabolite	E.074	E.140	E.070	E.056
para-Cresol	wood preservative	E.046	<.060	<.040	<.040
para-nonylphenol, total	detergent metabolite	E1.4	E.528	E.390	<.500
Pyrene	component of asphalt	E.018	<.030	E.011	E.006
Tri(2-chloroethyl)phosphate	plasticizer; flame retardant	.117	.075	.04	E.037
Triclosan	disinfectant	NA	E.034	NA	NA

[a] Zaugg and others (2002).

A few of the compounds detected in these samples have known or suspected environmental effects. For example, the nonylphenol compounds (NPEO1, OPEO1, and *para*-nonylphenol) are detergent metabolites with endocrine-disrupting potential (Zaugg and others, 2002). Triclosan, an antimicrobial ingredient in household soaps and cleaners, could cause the growth of resistant strains of bacteria (Zaugg and others, 2002). Hence, more study is needed to assess the occurrence and distribution of these compounds in lakes and streams.

Summary and Conclusions

The increase of population, tourism, and industry in Orange County, Florida, and nearby areas has changed land use. These changes could impact surface-water resources that are important for wildlife habitat, for esthetic reasons, and potentially for potable supply. Streamflow characteristics and water quality could be affected in various ways. Rainfall data for 1930-2000 and streamflow data from 1934-2000 were compiled and analyzed to determine if changes in streamflow occurred. Water-quality data from lakes and streams for 1960-2000 were analyzed. During 2000-01, additional samples were collected.

Selected streamflow characteristics computed on an annual basis for 13 stations were examined statistically for temporal trends using the Kendall Tau test. Results of the trend testing indicate changes in annual mean streamflow, 1-day high streamflow, or 7-day low streamflow at 9 of the 13 stations. However, changes in 7-day low streamflow are more common than changes in annual mean or 1-day high streamflow.

Statistical tests and graphical analyses indicate temporal changes in 7-day low streamflow at 7 of the 13 streamflow stations: Little Econlockhatchee River, Econlockhatchee River near Chuluota, Little Wekiva River, Wekiva River, Boggy Creek, Whittenhorse Creek, and Reedy Creek. Streamflow increased with time in all of these streams except the Little Wekiva River. Low flow in Shingle Creek increased from 1972 until 1984 in response to treated wastewater discharge and decreased after 1984 when the treated wastewater was redirected from Shingle Creek to other means of disposal. However, 7-day low flows in Shingle Creek generally have been greater after 1989 than before 1984.

There is probably no single reason for the increases in 7-day low streamflows, and for most streams it is difficult to determine definite reasons for the flow increases. Low-flows in the Econlockhatchee River at Chuluota increased because of discharge of treated wastewater. Reasons for the apparent increases in 7-day low flows in Little

Econlockhatchee River, Boggy Creek, Reedy Creek since 1990, Shingle Creek since 1989, and the nonwastewater component of the 7-day low flow in the Econlockhatchee River may be related to drainage changes related to the increased development in Orange County. These changes in land drainage can lower the water table, resulting in reductions of regional evapotranspiration rates and increased streamflow. Another possible cause of increasing low flows in streams is use of water from the Floridan aquifer system for irrigation. Runoff of irrigation water, or increased seepage from irrigated areas to streams, could increase base streamflow compared to natural conditions.

Double-mass plots indicate that streamflow-rainfall relations may have changed with time for Little Econlockhatchee River, Wekiva River, Apopka-Beauclair Canal, Boggy Creek, Shingle Creek, Whittenhorse Creek, and Reedy Creek. Streamflow increased for a selected rainfall amount at all stations except Apopka-Beauclair Canal. The double-mass analysis supports the Kendall Tau test and plots of annual mean streamflow, indicating that annual mean streamflow has increased in Little Ecohlockhachee River, Boggy Creek, Shingle Creek, Whittenhorse Creek, and Reedy Creek. However, for the Apopka-Beauclair Canal, the double-mass plots indicate a decrease in annual mean streamflow relative to rainfall beginning about 1977.

Water levels in 83 lakes that had more than 15 years of water-level record were examined statistically and graphically for trends. Using the entire period of record for each lake, there were significant temporal trends in 33 (40 percent) of the 83 lakes. Of these 33 lakes, 14 had increasing water levels and 19 lakes had decreasing water levels. The reason for the predominance of downwards trends in long-term record may be the extreme high-water conditions that existed for many lakes in 1960 and following years as the result of 2 years of relatively high rainfall culminated by rains from Hurricane Donna in September 1960. Historical high-water levels occurred in many lakes in 1960 or 1961. In many lakes, there is little likelihood that the high-water levels of 1959-60 will be repeated, because drainage wells were constructed to provide lake drainage or intercept storm runoff. For many or even most lakes, there has not been a uniform pattern of declining or increasing water level over the period of record. Instead, periods of declining water levels and periods of increasing water levels have occurred. This pattern of lake-level fluctuations is similar to patterns in rainfall.

Data indicate that a large range of water-quality conditions exists in lakes and streams of Orange County (2000-01). Specific conductance in samples from lakes ranged from 57 to 1,185 microsiemens per centimeter (μS/cm), with a median of 202 μS/cm. Values of pH ranged from 3.2 to 8.7 in samples from streams and 4.6 to 9.6 in samples from lakes. Specific conductance in samples from streams draining Orange County ranged from 84 to 617 μS/cm, with a median of 269 μS/cm.

A total of 37 filtered samples from 24 lakes and 24 filtered samples from 11 streams was analyzed for 15 trace elements. In addition, 17 whole-water samples from Cypress Creek, Bonnet Creek, Whittenhorse Creek, and Reedy Creek were analyzed for 9 trace elements. The most commonly detected trace elements were aluminum, barium, boron, iron, manganese, and strontium.

Data for 1960-2001 from four sites (Boggy Creek, Bonnet Creek, Econlockhatchee River, and Whittenhorse Creek) were analyzed for trends in specific conductance, bicarbonate, sulfate, chloride, nitrite plus nitrate nitrogen, ammonia plus organic nitrogen, and phosphorus. All four sites had significant trends in at least two of the seven constituents. Values of specific conductance and concentrations of chloride increased at the Boggy Creek, Bonnet Creek, and Whittenhorse Creek sites. Bicarbonate concentrations increased at the Econlockhatchee River, Boggy Creek, and Bonnet Creek sites. Sulfate concentrations increased at the Boggy Creek site. Concentrations of nitrite plus nitrate and ammonia plus organic nitrogen decreased at the Econlockhatchee River site. Phosphorus concentrations significantly decreased at the Econlockhatchee River and Boggy Creek sites. Many of these changes probably are related to changes in land use. However, the Econlockhatchee River near Chuluota has been affected by wastewater discharges.

A total of 18 samples from 6 stream sites and 26 samples from 13 lakes was collected for pesticide analysis. The results indicate that low concentrations of pesticides are ubiquitous and persistent in the surface-water resources of Orange County. Pesticides were detected in nearly every sample.

The most commonly detected compounds were herbicides, including atrazine, prometon, simazine (triazine herbicides for control of broadleaf plants), and tebuthiuron (a nonselective herbicide). The most commonly detected insecticide was diazinon. Concentrations generally were low, with many results reported as estimated values. The highest concentration was 0.716 microgram per liter (μg/L) for atrazine. In general, the number of compounds and concentrations detected were similar among the periodic samples collected from each site.

Samples from four lakes and four streams in Orange County were collected and analyzed for compounds indicative of household and industrial wastes. The number of compounds detected in each samples ranged from 3 to 12.

Concentrations were less than 1 µg/L for most compounds. The source of many of the compounds is related to wastewater or urban runoff. Several of the compounds have known or suspected environmental effects. Nonylphenol compounds, which are detergent metabolites, are known to have endocrine disrupting potential. Triclosan, an antimicrobial ingredient in many household soaps and detergents, could cause the growth of resistant strains of bacteria. Further study is needed to assess the occurrence and distribution of these compounds in lakes and streams of central Florida.

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Appendixes A-E

Appendix A. Annual rainfall totals for selected National Oceanographic and Atmospheric Administration stations.

[Rainfall totals are in inches per year]

Year	Clermont	Fort Drum	Kissimmee	Melbourne	Orlando	Sanford	Titusville	Vero Beach	Lisbon
1931	44.26		38.11		42.12	42.45	37.11		
1932	38.16		47.11		39.9	39.41	47.19		
1933	65.12		65.44		57.42	52.86	58.67		
1934	54.43		58.5		50.3	58.48	47.79		
1935	54.89		40.44		49.27	48.65	66.36		
1936	48.88		45.59		52.18	47.34	53.91		
1937	53.34		54.88		59.1	49.87	49.31		
1938	37.06		33.03	26.39	34.55	35.54	35.18		
1939	51.3		54.85	55.08	52.42	51.81	48.42		
1940	47.83		49.58	42.15	54.02	48.51	55.68		
1941	52.66		63.1	58.78	59.65	70.73	66.38		
1942	47.11		45.5	44.5	41.29	40.61	49.76		
1943	49.2	48.06	41.5	44.87	39.61	51.24	47.57	45.68	
1944	56.11	41.5	43.34	50.01	48.85	64.91	65.57	50.72	
1945	53.70	47.81	50.13	56.76	55.95	57.19	60.55	47.12	
1946	48.47	43.53	48.75	50.73	50.13	54.2	51.21	44.05	
1947	54.15	59.4	64.55	74.16	67.47	67.38	62.22	65.57	
1948	46.51	50.05	50.16	56.05	52.59	52.69	58.45	63.15	
1949	45.62	54.95	64.38	46.71	44.28	53.66	65.06	54.72	
1950	54.79	38.31	50.55	40.9	55.96	55.78	44.06	35.23	
1951	52.1	53.15	54.8	47.47	57.92	54.91	66.03	53.37	
1952	42.01	53.28	44.85	46.04	41.45	47.62	59.4	44.13	
1953	66.87	64.4	76.27	64.02	65.85	74.06	81.74	60.97	
1954	35.63	56.63	41.6	46.51	48.02	45.57	48.14	55.95	
1955	40.24	43.75	40.38	38.69	42.26	53.05	55.09	37.55	
1956	49.22	43.8	52.41	41.13	43.91	42.48	43.62	39.43	
1957	52.04	60.45	60.02	57.76	50.93	55.13	66.89	63.51	
1958	62.35	45.96	49.18	57.94	51.2	59.53	52.15	43.97	
1959	68.09	63.89	76.36	54.84	63.77	62.28	65.63	65.78	67.58
1960	66.27	53.96	80.38	68.9	68.67	62.88	67.18	64.71	59.93
1961	32.28	35.38	28.07	41.58	41.78	37.41	41.88	32.7	33.11
1962	40.33	56.28	42.53	45.23	50.35	35.04	61.87	33.81	38.66
1963	50.04	55.43	54.88	57.25	45.28	51.72	75.73	61.53	45.08
1964	55.15	46.3	49.04	50.39	54.39	57.89	62.37	45.29	51.03
1965	47.81	43.74	41.09	32.52	47.4	48.8	47.27	51.2	49.67
1966	56.62	48.66	51.12	63.62	55.29	53.14	70.54	65.58	50.59
1967	53.53	42.63	43.07	40.67	40.91	41.97	48.96	37.88	40.65
1968	53.39	48.98	48.92	51.17	52.1	50.56	64.37	67.01	51.7
1969	63.71	57.01	56.05	59.88	55.18	51.19	71.72	62.79	53.07
1970	48.21	35.92	41.88	38.71	43.96	45.88	53.9	45.96	36.3
1971	49.77	52.08	39.46	36.55	40.09	48.72	47.99	51.93	42.5
1972	46.67	48.09	40.04	46.83	51.35	63.82	54.67	50.7	46.16
1973	54.94	62.4	54.11	47.96	55.37	51.15	51.69	68.31	52
1974	45.39	53.94	36.71	36.5	44.55	45.31	51.99	50.68	44.14
1975	49.81	55.13	50.07	43.03	47.04	50.93	45.09	45.55	45.43

Appendix A. Annual rainfall totals for selected National Oceanographic and Atmospheric Administration stations. (Continued)

[Rainfall totals are in inches per year]

Year	Clermont	Fort Drum	Kissimmee	Melbourne	Orlando	Sanford	Titusville	Vero Beach	Lisbon
1976	55.96	54.26	40.08	46.85	47.08	45.68	49.42	47.48	48.59
1977	40.41	45.08	48.35	45.96	38.12	45.6	42.35	47.86	40.04
1978	50.79	57.2	43.48	55.2	50.59	51.07	48.66	46.26	46.63
1979	67.36	61.23	52.56	50.79	50.23	53.13	64.12	60.81	57.49
1980	40.1	37.53	30.96	35.95	41.21	48.41	40.15	39.7	42.58
1981	52.19	32.74	45.36	31.97	47.1	41.67	40.83	44.73	34.43
1982	53.87	61.26	45.12	45.17	51.61	59.91	70.5	81.74	62.67
1983	57.7	64.29	63.27	57.67	55.52	62.85	65.94	67.14	53.21
1984	48.75	48.6	42.37	38.53	44.44	47.71	50.59	61.81	45.01
1985	50.64	42.81	44.44	51.52	47.19	49.48	56.64	54.23	39.66
1986	48.58	48.48	39.95	39.9	49.83	43.9	40.37	62.83	43.82
1987	52.85	48.79	55.83	50.38	56.79	46.23	50.32	53.23	47.19
1988	58.89	39.15	59.15	36.11	52.49	60.05	59.8	44.49	51.57
1989	49.89	50.9	50.69	42.99	45.66	40.65	45.62	45.85	47.5
1990	44.58	48.14	45.36	48.02	31.68	36.38	47.24	49.13	41.94
1991	43.34	62.77	53.39	58.58	60.9	69.28	73.2	72.91	66.29
1992	53.78	60.39	54.06	49.36	52.96	59.88	58.84	60.05	55.87
1993	37.92	51.74	38.87	39.29	44.53	37.21	40.18	58.2	44.31
1994	65.48	60.19	73.01	69.85	67.85	71.09	78.33	77.06	66.88
1995	52.27	64.25	48.73	70.11	43.05	59.32	49.95	51.78	52.12
1996	51.64	79.21	55.80	49.52	56.66	62.82	64.29	61.66	57.9
1997	63.1	70.83	63.53	64.62	64.51	54.28	64.66	59.28	56.06
1998	34.47	79.09	43.26	55.18	43.75	48.83	43.33	62.93	42.69
1999	42.66	58.59	51.98	61.51	54.8	47.04	57.49	47.28	54.13
2000	28.92	32.52	38.15	43.21	30.38	32.83	32.73	42.45	29.26

Appendix B. Summary of water-level measurements for selected lakes.

[USGS ID is the station identifier used for storage in the U.S. Geological Survey data files. Source of data: 1, U.S. Geological Survey; 2, Orange County Stormwater Management Division]

Lake	USGS ID	Source of data	Map No. (fig. 8)	No. of measure-ments	First measurement	Last measurement	Water level (in feet)				
							Minimum	P5	Median	P95	Maximum
Alpharetta		2	1	312	9/15/1959	9/15/1997	52.11	54.06	59.87	65.69	75.12
Anderson		2	2	262	1/15/1960	9/15/1997	75.02	76.36	80.33	85.27	88.66
Apopka	02237600	1	3	693	12/15/1935	11/15/1994	64.18	65.37	66.62	68.05	69
Avalon		2	4	205	1/15/1960	9/15/1997	84.77	85.47	89.18	93.43	97.22
Baldwin	02233450	1, 2	5	360	3/15/1943	9/15/1997	90.01	90.73	91.7	92.46	93.26
Barton (Barton Lake)		2	8	376	1/15/1960	9/15/1997	60.86	63.08	64.98	65.46	66.73
Barton (Big Lake Barton)		2	6	362	7/15/1959	9/15/1997	91.61	92.29	93.04	93.79	96.13
Barton (Little Lake Barton)		2	7	236	8/15/1960	9/15/1997	90.97	91.42	91.86	92.78	95.38
Bay		2	9	244	8/15/1960	9/15/1997	87.6	89.14	90.4	91.15	91.9
Bearhead		2	10	184	8/15/1960	9/15/1997	89.1	89.55	89.89	90.57	92.5
Bell		2	11	247	7/15/1959	9/15/1997	86.93	88.11	89.32	89.84	91.39
Berry		2	12	192	9/15/1980	9/15/1997	65.33	65.87	69.37	70.79	71.58
Big Fairview		2	13	372	7/15/1959	9/15/1997	85.69	86.84	87.76	88.54	90.22
Black		2	14	187	1/15/1960	9/15/1997	90.25	91.58	93.66	97.14	98.28
Border		2	15	161	7/15/1959	10/15/1979	66.56	67.93	72.06	76.89	80.34
Bosse		2	16	336	8/15/1960	9/15/1997	57.58	58.85	60.12	60.86	64.35
Butler	02263900	1, 2	17	778	4/15/1933	8/15/2001	94.63	96.7	99.28	100.51	101.28
Cain		2	18	186	7/15/1959	9/15/1997	96.67	97.64	98.75	99.25	99.81
Clear		2	19	368	1/15/1961	9/15/1997	92.51	93.4	94.28	94.9	97.05
Conway	02234215	1, 2	20	471	11/15/1942	9/15/1997	74.38	76.03	85.66	87.04	89.04
Crescent		2	21	228	1/15/1960	9/15/1997	99.95	101	102.4	103.1	103.65
Crooked		2	22	301	12/15/1960	9/15/1997	55.97	59.97	64.8	71.61	81.9
Daniel		2	23	228	6/15/1966	9/15/1997	89.23	89.88	90.82	91.5	92.35
Dora	02237800	1	24	691	11/15/1935	9/15/1993	60.74	61.51	62.72	64.16	65
Down		2	25	252	1/15/1960	9/15/1997	93.82	95.71	99.1	100.2	101.5
Ellenore (Rattlesnake)		2	26	234	9/15/1970	9/15/1997	93.37	94.43	95.25	95.61	96.02
Estelle		2	27	190	9/15/1980	9/15/1997	70.72	71.14	71.6	72.42	72.87
Fish		2	28	229	1/15/1960	9/15/1997	95.42	96.33	99.23	100.3	101.7
Formosa		2	29	190	9/15/1980	9/15/1997	70.4	70.8	71.44	72.33	72.88
Francis	02237660	1	30	289	9/15/1959	8/15/1998	53.09	54.7	57.42	63.44	66.18

Appendix B. Summary of water-level measurements for selected lakes. (Continued)

[USGS ID is the station identifier used for storage in the U.S. Geological Survey data files. Source of data: 1, U.S. Geological Survey; 2, Orange County Stormwater Management Division]

Lake	USGS ID	Source of data	Map No. (fig. 8)	No. of measurements	First measurement	Last measurement	Water level (in feet)				
							Minimum	P5	Median	P95	Maximum
Fredrica		2	31	186	7/15/1959	11/15/1994	95.79	96.29	97.36	98.07	99.26
Gandy		2	32	348	8/15/1960	9/15/1997	64.89	67.26	71.45	73.29	75.26
Gatlin		2	33	226	10/15/1970	9/15/1997	81.29	82.9	85.59	86.84	87.45
Gem Mary		2	34	226	1/15/1960	9/15/1997	86.11	87.36	89.25	90.21	92.38
Hancock		2	35	233	7/15/1959	9/15/1997	91.01	91.58	95.69	98.2	99.4
Hart	02262200	1, 2	36	600	11/15/1941	9/15/1997	56.63	57.81	59.93	61.46	63.55
Hickory Nut		2	37	190	7/15/1959	9/15/1997	95.79	96.59	100.7	103.1	104.1
Holden		2	38	234	7/15/1959	9/15/1997	87.81	88.97	90.3	91.37	92.15
Horseshoe		2	39	179	9/15/1980	9/15/1997	58.87	63.72	71.64	73.1	76.64
Ivanhoe	02234225	1, 2	40	338	11/15/1942	10/15/1979	73.49	75.2	77.14	77.97	78.6
Jennie Jewel		2	41	228	9/15/1970	9/15/1997	86.83	87.85	89.62	90.39	90.98
Jessamine		2	42	367	7/15/1959	9/15/1997	89.15	89.94	91.32	92.27	93.82
Johns	02237540	1, 2	43	469	7/15/1959	10/15/1998	85.67	88.63	92.06	96.85	99.04
Killarney		2	44	371	7/15/1959	9/15/1997	81.11	81.9	82.58	83.57	86.03
Lawne		2	45	373	7/15/1959	9/15/1997	82.7	86.28	87.49	88.27	92.49
Little Fairview		2	46	463	2/15/1948	9/15/1997	86.79	87.93	88.96	89.95	91.33
Lockhart		2	47	228	4/15/1960	9/15/1997	62.57	63.83	70.74	72.99	75.46
Long		2	48	212	7/15/1959	9/15/1997	52.85	54.57	64.54	74.11	80.47
Maitland	02234300	1, 2	49	533	5/15/1945	9/15/1997	64.15	65.32	66.23	66.63	66.96
Mann		2	50	373	7/15/1959	9/15/1997	86.82	89.66	90.78	91.68	96.7
Mary		2	51	247	8/15/1960	9/15/1997	89.57	91.76	93.14	93.79	94.32
Mary Jane	02261900	1, 2	52	620	11/15/1949	7/15/2001	57.07	58.43	60.06	61.26	63.64
Mccoy		2	53	216	3/15/1967	9/15/1997	52.43	55.81	60.26	61.66	62.01
Minnehaha		2	54	231	1/15/1962	9/15/1997	64.11	65.17	66.21	66.57	67.11
Mizell		2	55	200	9/15/1978	9/15/1997	64.05	65.2	66.25	66.75	67.26
Ola		2	56	195	7/15/1959	9/15/1997	71.33	71.9	72.77	73.82	74.24
Osceola		2	57	198	9/15/1978	9/15/1997	64.11	65.04	66.24	66.7	67.26
Page		2	58	167	1/15/1960	10/15/1994	67.85	71.74	75.87	80.14	82.86
Park & Gem		2	59	367	11/15/1960	9/15/1997	69.13	69.4	70.1	70.95	71.51
Pleasant		2	60	165	7/15/1959	11/15/1994	64.07	65.87	71.18	79.6	82.21

Appendix B. Summary of water-level measurements for selected lakes. (Continued)

[USGS ID is the station identifier used for storage in the U.S. Geological Survey data files. Source of data: 1, U.S. Geological Survey; 2, Orange County Stormwater Management Division]

Lake	USGS ID	Source of data	Map No. (fig. 8)	No. of measure-ments	First measurement	Last measurement	Water level (in feet)				
							Minimum	P5	Median	P95	Maximum
Pocket		2	61	193	9/15/1970	9/15/1997	94.23	95.5	99.15	100	100.5
Prevatt		2	62	205	1/15/1960	9/15/1997	47.45	50.06	54.14	57.31	57.91
Rose		2	63	363	1/15/1960	9/15/1997	67.78	71.93	80.07	82.48	87.03
Sand Lake (Big)		2	64	356	7/15/1959	9/15/1997	79.43	83.73	88.75	96.33	100.4
Sand Lake (Little)		2	65	216	1/15/1960	9/15/1997	78.59	81.35	91.97	99.44	101.8
Sarah		2	66	221	3/15/1967	9/15/1997	85.95	86.82	87.7	88.33	88.97
Shadow		2	67	157	8/15/1960	11/15/1978	80.14	80.61	81.19	81.58	84.25
Sherwood		2	68	343	5/15/1960	9/15/1997	54.97	58.43	65.18	79.1	87.91
Silver	02234800	1,2	69	292	10/15/1959	9/15/1997	90.4	91.23	91.97	92.39	92.88
Spring		2	70	241	1/15/1960	9/15/1997	92.87	94.32	98.1	104.9	111.7
Spring (North Orange Blossom Trail)	02234200	1, 2	71	400	10/15/1943	8/15/1997	86.58	87.4	87.9	88.85	89.48
Stanley		2	72	165	8/15/1960	11/15/1994	67.3	68.96	72.97	79.67	86.42
Sue	02234261	1, 2	73	478	11/15/1943	9/15/1997	69.6	70.87	72	73.1	73.72
Susannah	02233445	1, 2	74	270	3/15/1943	9/15/1997	93.91	94.63	95.57	96.35	96.79
Sybelia		2	75	201	12/15/1975	9/15/1997	66.47	67.85	70.92	72.05	73.2
Tibet Butler		2	76	365	10/15/1960	9/15/1997	94.46	96.25	98.94	100.1	100.8
Turkey		2	77	183	1/15/1960	6/15/1980	89.34	90.16	91.96	94.12	96.85
Tyler		2	78	228	9/15/1970	9/15/1997	90.5	91.34	93.35	93.53	94.98
Underhill	02262550	1, 2	79	379	11/15/1942	9/15/1997	95.12	96.64	97.58	98.87	99.6
Virginia		2	80	201	9/15/1978	9/15/1997	64.05	65.09	66.24	66.69	67.26
Warren		2	81	364	8/15/1960	9/15/1997	83.45	84.33	85.45	86.52	87.53
Waunatta		2	82	211	1/15/1960	9/15/1997	59.13	61.41	62.33	62.87	63.28
Wekiva (Orlando)		2	83	368	1/15/1960	9/15/1997	81.73	82.86	83.6	84.6	86.35

Appendix C. Summary of lake water-quality data.

[Source of data: 1, City of Orlando and U.S. Geological Survey; 2, Orange County; 3, City of Orlando; 4, City of Orlando and Orange County; 5, U.S. Geological Survey; 6, U.S. Geological Survey, City of Orlando, and Orange County; 7, U.S. Geological Survey and Orange County; mg/L, milligrams per liter, µg/L, micrograms per liter; --, no data]

Lake	Latitude degrees	Longitude degrees	Source of data	No. of samples	Average		
					Total phosphorus (mg/L)	Total nitrogen (mg/L)	Chlorophyll-*a* (µg/L)
Adair	28.560	81.391	1	4	0.04	1.06	39.2
Anderson	28.499	81.337	2	4	.01	1.16	20.2
Angel	28.517	81.388	3	2	.14	.90	38.0
Apopka	28.577	81.587	2	1	.02	4.70	25.5
Arnold	28.531	81.341	3	5	.02	.71	22.9
Baldwin	28.572	81.322	4	5	.01	.65	11.2
Barton	28.551	81.316	4	3	.01	.79	15.8
Bay	28.591	81.422	3	6	.04	1.39	31.8
Beardall	28.536	81.402	1	3	.13	1.32	24.8
Beauclair	28.771	81.651	5	1	.11	5.10	200.0
Beauty	28.523	81.378	3	2	.06	.55	2.5
Bell	28.611	81.379	2	4	.01	.93	18.6
Berry	28.586	81.333	2	1	.01	.95	39.3
Bessie	28.488	81.527	2	4	.01	.54	1.6
Big Sand (middle/north)	28.434	81.490	2	2	.01	.92	3.4
Blanche	28.481	81.516	2	2	.01	.58	1.5
Buck	28.409	81.249	3	4	.01	.55	2.1
Burkett	28.610	81.268	2	4	.01	1.24	22.7
Butler	28.490	81.554	2	2	.01	.65	1.1
C	28.531	81.318	3	4	.06	.81	35.7
Cane	28.485	81.473	4	2	.01	.78	8.4
Carlton	28.759	81.658	2	3	.01	4.90	113.6
Cay Dee (south)	28.563	81.345	3	3	.01	.83	7.9
Chase	28.475	81.520	2	6	.01	.52	1.5
Cherokee	28.533	81.371	3	3	.06	1.24	38.6
Clear	28.521	81.409	4	3	.02	1.26	36.0
Como	28.535	81.352	3	4	.12	1.34	23.3
Concord	28.557	81.385	4	5	.01	.75	27.3
Conway	28.470	81.345	2	6	.01	.45	3.8
Copeland	28.527	81.374	3	4	.06	.93	24.5
Crescent	28.508	81.561	2	5	.01	.61	1.8
Daniel	28.582	81.402	3	3	.03	.98	17.7
Davis	28.531	81.366	3	1	.38	1.15	54.7
Dot	28.552	81.387	3	4	.04	.67	17.5
Down	28.504	81.528	2	5	.01	.35	.8
Ellenore	28.491	81.397	5	1	.03	1.00	7.5
Eola	28.544	81.373	3	3	.05	.82	28.7
Estelle (west)	28.575	81.366	3	3	.04	.83	21.0
Fairview	28.594	81.407	6	4	.01	.66	5.5
Farrar	28.508	81.321	3	5	.01	.43	4.0
Formosa	28.568	81.369	4	4	.02	.87	19.0
Fredrica	28.508	81.307	4	5	.01	.46	3.0
Gandy	28.628	81.433	2	1	.01	.95	2.4
Gear	28.556	81.331	3	2	.01	.58	3.8
Gem Mary	28.496	81.365	4	3	.02	.68	17.6
George	28.501	81.320	4	7	.01	.40	2.6

Appendix C. Summary of lake water-quality data. (Continued)

[Source of data: 1, City of Orlando and U.S. Geological Survey; 2, Orange County; 3, City of Orlando; 4, City of Orlando and Orange County; 5, U.S. Geological Survey; 6, U.S. Geological Survey, City of Orlando, and Orange County; 7, U.S. Geological Survey and Orange County; mg/L, milligrams per liter, µg/L, micrograms per liter; --, no data]

Lake	Latitude degrees	Longitude degrees	Source of data	No. of samples	Average		
					Total phosphorus (mg/L)	Total nitrogen (mg/L)	Chlorophyll-*a* (µg/L)
Georgia	28.606	81.246	4	1	0.01	0.60	3.7
Giles	28.530	81.334	3	4	.03	.66	16.0
Greenwood	28.533	81.360	3	3	.07	.57	12.3
Hancock	28.463	81.612	2	1	.01	.83	1.2
Hart	28.385	81.214	7	4	.02	1.28	5.9
Hiawassee	28.528	81.481	3	2	.02	.79	4.3
Hickorynut (middle)	28.427	81.642	7	5	.01	.76	.9
Highland	28.560	81.370	3	4	.03	.81	19.0
Holden	28.503	81.384	4	5	.03	1.85	38.3
Hope	28.640	81.371	5	2	.03	.82	4.4
Hourglass	28.522	81.357	2	2	.01	1.75	26.0
Isleworth	28.472	81.529	2	7	.01	.58	3.5
Ivanhoe (east)	28.563	81.376	4	5	.01	.99	19.7
Ivanhoe (middle)	28.563	81.380	6	4	.02	.72	11.9
Ivanhoe (west)	28.565	81.383	4	5	.02	.78	18.4
Jackson	28.667	81.464	5	1	.01	.72	5.6
Jennie Jewel (west)	28.497	81.370	2	3	.01	.93	25.0
Jessamine (middle)	28.481	81.386	2	1	.01	1.10	16.2
John's	28.526	81.675	5	1	.09	2.33	16.0
Kasey	28.598	81.443	3	4	.08	1.36	47.1
Kelly	28.598	81.448	3	1	.03	.34	4.9
Killarney	28.601	81.381	2	3	.01	.85	15.0
Kozart	28.526	81.443	3	3	.19	3.26	57.4
Kristy	28.598	81.413	3	3	.05	.81	15.9
Lawne	28.565	81.437	3	5	.09	1.35	27.6
Lawne (middle)	28.565	81.437	2	4	.01	1.25	29.2
Lawsona	28.541	81.364	3	3	.10	1.41	39.1
Little Sand Lake	28.446	81.487	2	3	.01	.62	2.9
Lorna Doone	28.542	81.403	4	5	.04	.89	19.1
Lotta (north)	28.551	81.513	2	2	.01	1.15	25.1
Louise	28.591	81.098	7	4	.02	.88	6.3
Lucerne (east)	28.534	81.379	3	4	.04	.72	15.6
Lucerne (west)	28.534	81.379	3	4	.03	.65	25.4
Lurna	28.523	81.374	3	3	.08	.69	29.7
Maitland	28.620	81.350	7	4	.01	.91	14.5
Mann	28.537	81.426	3	5	.05	1.65	36.1
Marsha	28.478	81.483	2	1	.01	.45	1.4
Marshall	28.676	81.533	5	1	.14	5.50	180.0
Mary Jane	28.374	81.179	7	3	.02	1.30	6.2
Minnehaha	28.630	81.355	2	1	.01	1.10	31.1
Mizell	28.593	81.338	2	1	.01	.57	14.4
Monterey	28.532	81.313	3	2	.08	.87	32.8
Mud	28.389	81.292	3	3	.04	.83	5.0
Nan	28.608	81.281	2	4	0.01	.63	8.3
Nona	28.408	81.272	4	5	.01	.43	1.6
Ola	28.754	81.637	5	3	.01	.78	9.3
Olive	28.539	81.367	6	4	0.04	1.02	20.8
Oliver	28.369	81.648	6	1	.01	.47	--

Appendix C. Summary of lake water-quality data. (Continued)

[Source of data: 1, City of Orlando and U.S. Geological Survey; 2, Orange County; 3, City of Orlando; 4, City of Orlando and Orange County; 5, U.S. Geological Survey; 6, U.S. Geological Survey, City of Orlando, and Orange County; 7, U.S. Geological Survey and Orange County; mg/L, milligrams per liter, µg/L, micrograms per liter; --, no data]

Lake	Latitude degrees	Longitude degrees	Source of data	No. of samples	Average		
					Total phosphorus (mg/L)	Total nitrogen (mg/L)	Chlorophyll-*a* (µg/L)
Olivia	28.521	81.518	2	1	.01	.63	5.3
Olympia	28.569	81.524	2	1	.01	.78	11.5
Osceola	28.604	81.343	2	2	.01	.98	31.8
Page	28.659	81.472	2	1	.01	.97	11.8
Pamela	28.521	81.462	3	4	.03	1.41	10.8
Park	28.616	81.371	3	3	.05	1.09	23.1
Pineloch	28.507	81.367	4	6	.02	.63	9.5
Pocket	28.421	81.513	2	6	.01	.58	2.4
Pond at Tosohatchee State Park near Christmas	28.449	80.939	5	2	.05	1.17	16.1
Pond No. 2 at Tosahatchee near Christmas	28.451	80.928	5	1	.01	1.20	6.6
Porter	28.512	81.323	3	4	.01	.45	5.6
Price	28.598	81.175	2	1	.01	.64	1.1
Rabama	28.520	81.329	3	4	.05	.62	7.0
Raccoon	28.351	81.629	5	1	.02	.84	5.2
Red	28.405	81.259	2	1	.01	.73	21.4
Reedy	28.414	81.617	5	1	.03	.83	6.8
Richmond	28.512	81.434	3	3	.06	1.87	51.5
Rock	28.547	81.401	3	5	.03	.66	12.3
Rowena	28.571	81.360	4	6	.03	.84	31.9
Sandy	28.540	81.466	3	3	.08	.82	8.8
Sarah	28.585	81.403	3	4	.02	.92	19.8
Sawyer	28.469	81.568	2	1	.01	1.10	12.4
Shadow	28.623	81.403	2	2	.01	.81	11.7
Shannon	28.564	81.341	3	5	.01	.61	7.2
Sheen	28.432	81.521	2	6	.01	.60	1.4
Silver	28.579	81.397	4	3	.02	.72	14.0
Sink on Hartzog Road near Vineland	28.414	81.631	5	1	.04	1.50	18.0
Spring NW	28.557	81.399	3	4	.03	.92	20.2
Spring SW	28.455	81.484	3	1	.01	.37	1.7
Starke	28.568	81.536	2	3	.01	1.17	22.4
Sue	28.577	81.354	4	2	.02	.66	15.5
Sunset	28.536	81.412	3	4	.02	1.08	9.7
Susannah	28.562	81.323	3	4	.02	.79	16.5
Sybellia	28.628	81.371	2	3	.01	.83	9.4
Tennessee	28.510	81.332	3	4	.04	.65	11.2
Terrace	28.521	81.346	3	4	.04	1.28	17.5
Tibet-Butler	28.454	81.524	2	6	.01	.48	1.1
Turkey	28.505	81.475	5	3	.03	.78	10.2
Underhill	28.536	81.337	6	4	.01	1.19	34.0
Virginia	28.589	81.345	2	3	.01	1.20	32.3
Wade	28.516	81.368	3	3	.11	1.23	32.4
Walker	28.524	81.424	3	2	.16	1.78	30.1
Warren	28.460	81.323	4	4	.06	1.56	30.4
Wekiva (Orlando)	28.598	81.432	4	3	.06	1.36	35.6
Whippoorwill (also known as Barton Lake)	28.388	81.236	2	2	.01	.51	5.2
Winyah	28.578	81.368	3	4	.06	.90	35.1

Appendix D. Field measurements and concentrations of major ions, nutrients, and trace elements in samples collected from lakes during this study, 2000-2001.

[All concentrations dissolved, except where noted; DMS, degrees, minutes, seconds; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; SO_4, sulfate; SiO_2, silicon dioxide; N, nitrogen, P, phosphorus]

Site identifier	Site name	Map No. (fig. 9)	Latitude (DMS)	Longitude (DMS)	Date	Specific conductance, field (µS/cm)	Specific conductance, lab (µS/cm)	pH, field (standard units)	pH, lab (standard units)	Water temperature (°C)
02237540	Johns Lake at Oakland[1]	1	283230	0813828	5/10/2001	406	410	7.5	7.4	22.8
02234205	Lake Adair at Orlando[1]	2	283329	0812320	5/29/2001	211	214	7.7	7.5	28.5
284617081390200	Lake Beauclair (eastern shore) near Mt. Dora[1]	3	284617	0813902	11/2/2000	478	484	9.0	7.4	24.2
02234812	Lake Fairview at Orlando[1]	4	283522	0812420	7/12/2000	187	178	7.7	7.9	30.0
02234812	Lake Fairview at Orlando		283522	0812420	11/6/2000	167	167	6.7	7.6	23.4
02234812	Lake Fairview at Orlando		283522	0812420	4/23/2001	178	178	7.2	7.7	23.9
02262200	Lake Hart near Narcoossee[1]	5	282246	0811327	7/20/2000	91	92	5.6	5.9	30.0
02262200	Lake Hart near Narcoossee		282246	0811327	10/30/2000	98	97	6.2	5.9	22.8
02262200	Lake Hart near Narcoossee		282246	0811327	5/8/2001	115	117	5.9	6.0	23.3
02266275	Hickorynut Lake near Oakland[1]	6	282540	0813840	7/18/2000	177	177	6.0	7.1	30.4
02266275	Hickorynut Lake near Oakland		282540	0813840	4/26/2001	206	207	7.2	7.0	24.5
02234297	Lake Hope at Maitland[1]	7	283824	0812215	7/19/2000	317	317	6.4	7.2	33.4
02234297	Lake Hope at Maitland		283824	0812215	11/1/2000	328	326	7.1	7.0	22.8
02234225	Lake Ivanhoe at Orlando[1]	8	283326	0812234	11/6/2000	211	212	8.0	7.4	24.0
284000081275000	Lake Jackson near Apopka[1]	9	284000	0812750	5/30/2001	212	214	7.2	7.3	28.3
283305081304200	Lake Lotta near Ocoee	10	283304	0813048	11/20/2000	213	209	6.5	7.4	20.8
283528081055300	Lake Louise near Bithlo[1]	11	283528	0810553	7/19/2000	151	151	6.1	6.5	30.2
283528081055300	Lake Louise near Bithlo		283528	0810553	11/1/2000	150	153	6.9	6.6	23.5
283528081055300	Lake Louise near Bithlo		283528	0810553	5/7/2001	174	176	6.4	6.4	24.2
02234300	Lake Maitland at Winter Park[1]	12	283649	0812035	5/9/2001	231	232	8.1	7.7	
02261900	Lake Mary Jane near Narcoossee[1]	13	282246	0811115	10/30/2000	100	105	6.2	6.0	22.9
02237745	Lake Ola at Tangerine[1]	14	284510	0813800	7/18/2000	303	302	6.6	7.8	29.7
02237745	Lake Ola at Tangerine		284510	0813800	11/2/2000	308	304	6.5	7.4	23.0
02237745	Lake Ola at Tangerine		284510	0813800	4/23/2001	325	325	7.2	7.6	23.2
282210081385100	Lake Oliver near Vineland	15	282210	0813851	11/20/2000	57	55		5.1	20.4
283219081201302	Lake Underhill[1]	16	283219	0812013	5/9/2001	175	178	8.1	7.5	23.8
284034081315700	Marshall Lake near Apopka	17	284034	0813157	5/30/2001	322	339	8.3	7.0	28.2
282927081235000	Lake Ellenore near Pine Castle[1]	18	282927	0812350	5/21/2001	169	175	7.1	7.3	26.4
282657080561900	Pond at Tosohatchee State Park near Christmas[1]	19	282657	0805619	11/8/2000	450	444	6.2	7.2	21.5
282657080561900	Pond at Tosohatchee State Park near Christmas		282657	0805619	4/24/2001	558	560	6.9	7.3	22.5
282702080554200	Pond No. 2 at Tosohatchee near Christmas[1]	20	282702	0805542	4/24/2001	1,185	1,190	7.7	8.6	25.3
282102081374600	Raccoon Lake near Windermere	21	282102	0813746	5/24/2001	206	208		7.1	28.6
282452081370200	Reedy Lake near Vineland[1]	22	282452	0813702	5/24/2001	543	548	7.5	7.3	25.7
282450081375100	Sink on Hartzog Road near Vineland	23	282450	0813751	11/15/2000	397	390	6.3	7.0	21.5
283019081283100	Turkey Lake at Orlando[1]	24	283019	0812831	7/13/2000	200	188	7.1	7.3	31.0
283019081283100	Turkey Lake at Orlando		283019	0812831	10/31/2000	197	196	6.8	7.1	23.4
283019081283100	Turkey Lake at Orlando		283019	0812831	4/26/2001	226	226	6.8	6.6	23.5

[1] Field measurements were obtained at various depths.

Appendix D. Field measurements and concentrations of major ions, nutrients, and trace elements in samples collected from lakes during this study, 2000-2001. (Continued)

[All concentrations dissolved, except where noted; DMS, degrees, minutes, seconds; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; SO_4, sulfate; SiO_2, silicon dioxide; N, nitrogen, P, phosphorus]

Site identifier	Transparency (inches)	Oxygen, dissolved (mg/L)	Calcium (mg/L)	Magneium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Acid neutralizing capacity (mg/L as $CaCO_3$)	Chloride (mg/L)	Sulfate (mg/L as SO_4)	Fluoride (mg/L)	Bromide (mg/L)	Silica (mg/L as SiO_2)	Residue on evaporation (mg/L at 180°C)
02237540	14	6.5	17	14	28	19	38	51	70	0.31	0.25	1.3	262
02234205	48	7.5	23	4.2	13	4.2	52	21	16	.18	.06	.24	132
284617081390200	14		39	19	18	13	139	45	32	.41	.2	4.3	329
02234812		8.9	20	2.7	10	2.2	51	15	13	.1	<.05	.2	109
02234812	96	8.1	17	2.9	10	2.4	41	16	14	.1	.07	.3	101
02234812	96	8.1	18	3	11	2.4	44	18	15	.11	<5	.17	107
02262200	28		4.6	1.9	8.6	1.3	6.6	16	7.3	<.1	<.05	1.3	99
02262200	29	8.0	4.5	2	9.5	1.5	4.8	17	8	<.1	.11	1.2	86
02262200	24	8.2	5.3	2.3	12	1.7	4.8	22	11	<.1	.08	.96	101
02266275	114	7.0	5.7	5.6	13	7.8	12	25	25	<.1	.07	.2	121
02266275		8.0	6.7	6.1	16	8.6	12	29	30	<.1	1.2	.07	131
02234297	48		19	4.3	30	4.7	27	53	37	<.1	<.05	.5	193
02234297		3.3	20	4.3	31	5.1	26	54	40	<.1	.1	.5	190
02234225	42	7.7	26	3.7	9.3	2.7	62	15	17	.13	<.05	.5	128
284000081275000	72	5.4	19	3.6	13	4.2	33	26	23	<.1	.06	.59	134
283305081304200		7.3	23	5.7	7.3	4.8	55	12	25	.21	<.05	3.6	143
283528081055300	20		5.7	1.7	18	2.2	8.8	30	9.9	<.1	<.05	2.2	111
283528081055300	50	7.3	5.3	1.8	19	2.4	7.1	31	11	<.1	<.05	2.2	106
283528081055300	<12	7.0	6.3	1.9	22	2.4	6	38	14	<.1	.07	.92	111
02234300	78	8.5	22	4.2	13	2.6	39	27	30	.1	.08	.14	143
02261900	24	7.1	4.8	1.9	11	1.3	5.5	19	6.9	<.1	<.05	1.5	101
02237745	120	7.4	20	9.9	14	12	42	31	51	.11	.06	.7	192
02237745	110	7.7	20	9.9	14	12	39	31	54	.1	<.05	.7	193
02237745		8.2	21	10	15	13	36	33	60	.1	<5	.3	194
282210081385100		7.7	1.6	1.2	5.7	0.3	3	9.8	3.3	<.1	<.05	4.6	51
283219081201302	30	8.8	24	2	7.4	1.8	58	12	12	.1	<.05	.19	108
284034081315700	12	7.9	28	8.3	12	14	41	26	68	.19	.16	1.4	228
282927081235000		4.7	20	3.3	7.1	2.2	55	13	6.4	<.1	.08	.15	116
282657080561900	36	1.3	32	5.7	9.3	2.7	52	86	25	<.1	.3	2.9	292
282657080561900	24	6.3	40	7	58	3.3	73	110	26	<.1	<5	1.3	354
282702080554200		9.3	40	18	160	3.5	76	290	37	<.1	<5	.24	681
282102081374600	48	7.2	13	4.7	15	5.4	25	31	19	<.1	.08	1.1	135
282452081370200	30	4.5	10	6	79	12	25	130	28	.12	.3	5.1	311
282450081375100		8.1	16	9.3	39	12	32	64	48	.12	.13	.6	243
283019081283100	52	4.6	11	3.9	16	5.3	18	28	27	.11	.07	.4	126
283019081283100	66	6.7	10	4.2	16	5.7	11	28	30	.11	.07	.3	124
283019081283100		6.8	12	4.6	18	6.1	8.3	31	39	.11	<5	.26	148

Appendix D. Field measurements and concentrations of major ions, nutrients, and trace elements in samples collected from lakes during this study, 2000-2001. (Continued)

[All concentrations dissolved, except where noted; DMS, degrees, minutes, seconds; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; SO_4, sulfate; SiO_2, silicon dioxide; N, nitrogen, P, phosphorus]

Site identifier	Dissolved solids, calculated sum (mg/L)	Nitrite (mg/L as N)	Nitrite plus nitrate (mg/L as N)	Ammonia (mg/L as N)	Organic plus ammonia nitrogen, whole water (mg/L as N)	Organic plus ammonia nitrogen (mg/L as N)	Phos-phorus, whole water (mg/L as P)	Phos-phorus (mg/L as P)	Phos-phorus, ortho (mg/L as P)	Carbon, organic, whole water (mg/L)	Chloro-phyll-*a* (µg/L)	Alumium (µg/L)	Arsenic (µg/L)
02237540	225	<0.01	0.23	0.012	2.1	1.6	0.09	<0.02	0.02	23	16	110	3.7
02234205	113	<.01	<.02	<.01	.93	.61	.02	<.02	<.01	7.7	25		1.5
284617081390200	252	<.01	<.02	.02	5.1	2.2	.11	.03	<.01	35	200	35	4.2
02234812	93	<.01	<.02	.02	.48	.28	.02	<.02	<.01	7		44	2.3
02234812	86	<.01	<.02	.05	.8	.56	<.02	<.02	.01	20	7.3	29	2.4
02234812	94	<.01	<.02	<.01	.56	.47	<.02	<.02	<.01	7.2	2.8	42	2.2
02262200	44	<.01	.12	<.01	1.1	.81	.02	<.02	.01	22	5.1	280	<2
02262200	47	<.01	.09	.029	1.3	1.4	.03	<.02	<.01	22	4.2	300	.7
02262200	60	<.01	.12	<.01	1.2	.95	<.02	<.02	.01	17	3	190	.6
02266275	87	<.01	<.02	<.01	.77	.59	<.02	<.02	<.01	11	<.1	26	<2
02266275	105	<.01	<.02	<.01	.62	.56	<.02	<.02	<.01	11	1.7	36	1.1
02234297	162	<.01	<.02	<.01	.62	.52	.02	<.02	<.01	8.5	2.8	32	< 2
02234297	170	<.01	.05	.06	.97	.54	.03	<.02	<.01	13	6	42	<1
02234225	112	<.01	<.02	.05	.97	.6	.03	<.02	.02	7.3	14	26	<1
284000081275000	109	<.01	<.02	.021	.72	.55	<.02	<.02	<.01	8.5	5.6		1.8
283305081304200	115	<.01	<.02	.02	1.1	.64	.05	<.02	<.01	14		5.1	1.2
283528081055300	73	<.01	<.02	<.01	.81	.51	.04	<.02	.01	15	5.4	96	<2
283528081055300	76	<.01	<.02	.04	.82	.7	.02	<.02	<.01	17	3.5	65	<1
283528081055300	90	<.01	<.02	<.01	.91	.59	<.02	<.02	.01	12	8	62	.8
02234300	123	<.01	<.02	<.01	.63	.44	<.02	<.02	.01	6.4	6.9	32	2.6
02261900	49	<.01	<.02	.027	1.5	1.3	.03	<.02	<.01	25	5.9	290	.9
02237745	159	<.01	<.02	.01	.74	.64	<.02	<.02	<.01	7.8	12	19	<2
02237745	164	<.01	<.02	.04	.93	.79	<.02	<.02	<.01	12	5.8	11	1.8
02237745	174	<.01	<.02	<.01	.68	.58	<.02	<.02	<.01	6.8	10	19	1.7
282210081385100	29	<.01	.02	.04	.45	.35	<.02	<.02	<.01	12		58	<1
283219081201302	94	<.01	<.02	<.01	1.3	.57	<.02	<.02	.01	8.3	34	42	.6
284034081315700	183	<.01	<.02	<.01	5.5	1.4	.14	<.02	<.01	22	180		5.5
282927081235000	85	<.01	<.02	<.01	1	.84	.03	<.02	<.01	.9	7.5	59	1.5
282657080561900	194	<.01	<.02	.07	.84	.78	<.02	<.02	.03	20	<.1	31	<1
282657080561900	290	<.01	<.02	<.01	1.5	1	.08	.02	.02	19	32	<3	.9
282702080554200	596	<.01	<.02	<.01	1.2	1.1	<.02	<.02	<.01	14	6.6	10	1.3
282102081374600	104	<.01	<.02	<.01	.84	.62	.02	<.02	<.01	9	5.2	100	3
282452081370200	286	<.01	<.02	<.01	.83	.62	.03	<.02	<.01	11	6.8	32	3.6
282450081375100	209	<.01	<.02	.044	1.5	.98	.04	<.02	<.01	21	18	12	.7
283019081283100	98	<.01	<.02	.02	.64	.47	.03	<.02	<.01	11	24	41	<2
283019081283100	100	<.01	<.02	.04	1	.83	.02	<.02	<.01	12	3.4	38	1.1
283019081283100	116	<.01	<.02	<.01	.7	.6	.03	<.02	<.01	11	3.1	32	1.2

Appendix D. Field measurements and concentrations of major ions, nutrients, and trace elements in samples collected from lakes during this study, 2000-2001. (Continued)

[All concentrations dissolved, except where noted; DMS, degrees, minutes, seconds; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; SO_4, sulfate; SiO_2, silicon dioxide; N, nitrogen, P, phosphorus]

Site identifier	Barium (µg/L)	Beryllium (µg/L)	Boron (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Cobalt (µg/L)	Iron (µg/L)	Lead (µg/L)	Lithium (µg/L)	Manganese (µg/L)	Selenium (µg/L)	Strontium (µg/L)	Vanadium (µg/L)
02237540	20	<1	86	<0.5	<1	<1	34	<2	<1	6.4	1.6	65	2
02234205							<2			<1	<.5	64	
284617081390200	<.5	<1	41	<.5	<1	<1	<2	<2	1.8	1.3	<1	170	2
02234812	3	<.5	49	<.5	<1	<1	1.2	<1	<.5	.3	<2	61	2
02234812	3	<1	52	<.5	<1	<1	<2	<2	<1	<1	<4	57	1
02234812	5	<1	50	<.5	<1	<1	2.2	<2	<1	<1	<.5	60	1
02262200	15	<.5	30	<.5	<1	<1	405	<1	.6	7.8	<2	31	<1
02262200	14	<1	30	<.5	<1	<1	540	<2	<1	7.2	.5	31	<1
02262200	16	<1	40	<.5	<1	<1	417	<2	<1	5.7	<.5	36	<1
02266275	10	<.5	49	<.5	<1	<1	2.2	<1	<.5	<.2	<2	25	1
02266275	10	<1	60	<.5	<1	<1	2.3	<2	<1	<1	<.5	28	<1
02234297	9	<.5	110	<.5	<1	<1	3.6	<1	<.5	3.2	<2	44	2
02234297	9	<1	110	<.5	<1	<1	3.5	<2	<1	7.5	<4	43	3
02234225	.5	<1	33	<.5	<1	<1	<2	<2	1.1	<1	<4	67	2
284000081275000							2.3			2.1	<.5	58	
283305081304200	17	<1	40	<.5	<1	<1	10	<2	<1	1.1	<4	59	<1
283528081055300	13	<.5	38	<.5	<1	<1	154	<1	<.5	3.5	<2	35	1
283528081055300	12	<1	40	<.5	<1	<1	42	<2	<1	2.1	<4	33	1
283528081055300	14	<1	50	<.5	<1	<1	67	<2	<1	3.6	<.5	37	2
02234300	9	<1	40	<.5	<1	<1	2	<2	<1	<1	<.5	52	2
02261900	15	<1	30	<.5	<1	<1	835	<2	<1	6.6	<.5	32	<1
02237745	40	<.5	61	<.5	<1	<1	2.7	<1	<.5	.7	<2	76	1
02237745	43	<1	62	<.5	<1	<1	3.6	<2	<1	<1	<4	75	1
02237745	43	<1	60	<.5	<1	<1	3.4	<2	<1	<1	<.5	81	<1
282210081385100	3	<1	25	<.5	<1	<1	150	<2	<1	15	<4	9	<1
283219081201302	<.5	<1	30	<.5	<1	<1	<2	<2	<1	<1	<.5	56	2
284034081315700							<2			<1	.7	110	
282927081235000	2	<1	27	<.5	<1	<1	3.3	<2	<1	1.6	.5	55	1
282657080561900	21	<1	25	<.5	<1	<1	95	<2	1.1	2.5	<4	450	<1
282657080561900	20	<1	30	<.5	<1	<1	38	<2	1	5.7	.8	550	<1
282702080554200	56	<1	40	<.5	<1	<1	8	<2	3	<1	1.6	1,600	<1
282102081374600	3	<1	55	<.5	<1	<1	4.7	<2	<1	<1	.5	33	6
282452081370200	11	<1	200	<.5	<1	<1	66	<2	<1	1.2	1.6	40	1
282450081375100	15	<1	120	<.5	<1	<1	8.2	<2	<1	2.8	<.5	82	<1
283019081283100	13	<.5	61	<.5	<1	<1	11	<1	<.5	1.1	<2	60	2
283019081283100	12	<1	60	<.5	<1	<1	9.2	<2	<1	1.2	<.5	57	1
283019081283100	16	<1	70	<.5	<1	<1	12	<2	<1	3.3	<.5	64	2

Appendix E. Concentrations of pesticides in samples collected from lakes and streams during this study, 2000-2001.

[All concentrations dissolved; µg/L, micrograms per liter; <, less than; E, estimated concentration; M, presence verified, not quantified]

Site identifier	Site name	Map No.	Date	2,6-Diethylaniline (µg/L)	Actochlor (µg/L)	Alachlor (µg/L)	alpha HCH	Atrazine (µg/L)	Benfluralin (µg/L)	Butylate (µg/L)	Carbaryl (µg/L)
Lakes											
02234205	Lake Adair at Orlando	2	5/29/2001	<0.002	<0.004	<0.002	<0.005	0.375	<0.010	<0.002	<0.041
02234812	Lake Fairview at Orlando	4	7/12/2000	<.003	<.002	<.002	<.002	.155	<.002	<.002	<.003
02234812	Lake Fairview at Orlando		11/6/2000	<.002	<.004	<.002	<.005	.116	<.010	<.002	<.041
02234812	Lake Fairview at Orlando		4/23/2001	<.002	<.004	<.002	<.005	.11	<.010	<.002	<.041
02262200	Lake Hart near Narcoossee	5	7/20/2000	<.003	<.002	<.002	<.002	<.001	<.002	<.002	<.003
02262200	Lake Hart near Narcoossee		10/30/2000	<.002	<.004	<.002	<.005	.01	<.010	<.002	<.041
02262200	Lake Hart near Narcoossee		5/8/2001	<.002	<.004	<.002	<.005	.013	<.010	<.002	<.041
02266275	Hickorynut Lake near Oakland	6	7/18/2000	<.003	<.002	<.002	<.002	.008	<.002	<.002	<.003
02266275	Hickorynut Lake near Oakland		4/26/2001	<.002	<.004	<.002	<.005	.009	<.010	<.002	<.041
02234297	Lake Hope at Maitland	7	7/19/2000	<.003	<.002	<.002	<.002	.039	<.002	<.002	<.003
02234297	Lake Hope at Maitland		11/1/2000	<.002	<.004	<.002	<.005	.037	<.010	<.002	<.041
284000081275000	Lake Jackson near Apopka	9	5/30/2001	<.002	<.004	<.002	<.005	.013	<.010	<.002	<.041
283528081055300	Lake Louise near Bithlo	11	7/19/2000	<.003	<.002	<.002	<.002	.005	<.002	<.002	E.014
283528081055300	Lake Louise near Bithlo		11/1/2000	<.002	<.004	<.002	<.005	E.003	<.010	<.002	E.023
283528081055300	Lake Louise near Bithlo		5/7/2001	<.002	<.004	<.002	<.005	E.006	<.010	<.002	<.041
02237745	Lake Ola at Tangerine	14	7/18/2000	<.003	<.002	<.002	<.002	.03	<.002	<.002	<.003
02237745	Lake Ola at Tangerine		11/2/2000	<.002	<.004	<.002	<.005	.016	<.010	<.002	<.041
02237745	Lake Ola at Tangerine		4/23/2001	<.002	<.004	<.002	<.005	.02	<.010	<.002	<.041
284034081315700	Marshall Lake near Apopka	17	5/30/2001	<.002	<.004	<.002	<.005	E.007	<.010	<.002	<.041
282927081235000	Lake Ellenore near Pine Castle	18	5/21/2001	<.002	<.004	<.002	<.005	.051	<.010	<.002	<.041
282657080561900	Pond at Tosohatchee State Reserve	19	11/8/2000	<.002	<.004	<.002	<.005	E.003	<.010	<.002	<.041
282657080561900	Pond at Tosohatchee State Reserve		4/24/2001	<.002	<.004	<.002	<.005	E.007	<.010	<.002	<.041
282102081374600	Raccoon Lake near Windermere	21	5/24/2001	<.002	<.004	<.002	<.005	.011	<.010	<.002	<.041
283019081283100	Turkey Lake at Orlando	24	7/13/2000	<.003	<.002	<.002	<.002	.023	<.002	<.002	<.003
283019081283100	Turkey Lake at Orlando		10/31/2000	<.002	<.004	<.002	<.005	.017	<.010	<.002	<.041
283019081283100	Turkey Lake at Orlando		4/26/2001	<.002	<.004	<.002	<.005	.044	<.010	<.002	E.004
Streams											
02262900	Boggy Creek near Taft		4/26/2000	<.003	<.002	<.002	<.002	.044	<.002	<.002	< .003
02262900	Boggy Creek near Taft		9/6/2000	<.003	<.002	<.002	<.002	E.003	<.002	<.002	E.004
02262900	Boggy Creek near Taft		2/22/2001	<.002	<.004	<.002	<.005	E.002	<.010	<.002	<.041
02233500	Econlockhatchee River		4/12/2000	<.003	<.002	<.002	<.002	.366	<.002	<.002	E.011
02233500	Econlockhatchee River		9/5/2000	<.003	<.002	<.002	<.002	.078	<.002	<.002	E.008
02233500	Econlockhatchee River		2/6/2001	<.002	<.004	<.002	<.005	.195	<.010	<.002	<.041
02233200	Little Econlockhatchee River		4/25/2000	<.003	<.002	<.002	<.002	.124	<.002	<.002	<.003
02233200	Little Econlockhatchee River		8/31/2000	<.003	<.002	<.002	<.002	.106	<.002	<.002	E.007
02233200	Little Econlockhatchee River		2/8/2001	<.002	<.004	<.002	<.005	.168	<.010	<.002	<.041
02234990	Little Wekiva River near Altamonte Springs		4/11/2000	<.003	<.002	<.002	<.002	.716	<.002	<.002	E.022
02234990	Little Wekiva River near Altamonte Springs		8/29/2000	<.003	<.002	<.002	<.002	.048	<.002	<.002	E.014
02234990	Little Wekiva River near Altamonte Springs		2/14/2001	<.002	<.004	<.002	<.005	.373	<.010	<.002	E<.041
02263800	Shingle Creek at airport near Kissimmee		4/24/2000	<.003	<.002	<.002	<.002	.373	<.002	<.002	<.003
02263800	Shingle Creek at airport near Kissimmee		9/13/2000	<.003	<.002	<.002	<.002	.04	<.002	<.002	<.003
02263800	Shingle Creek at airport near Kissimmee		2/28/2001	<.002	<.004	<.002	<.005	.179	<.010	<.002	<.041
02234635	Wekiva River near Apopka		4/12/2000	<.003	<.002	<.002	<.002	.008	<.002	<.002	<.003
02234635	Wekiva River near Apopka		9/6/2000	<.003	<.002	<.002	<.002	.005	<.002	E<.002	<.003
02234635	Wekiva River near Apopka		2/5/2001	<.002	<.004	<.002	<.005	<.007	<.010	<.002	<.041

Appendix E. Concentrations of pesticides in samples collected from lakes and streams during this study, 2000-2001. (Continued)

[All concentrations dissolved; µg/L, micrograms per liter; <, less than; E, estimated concentration; M, presence verified, not quantified]

Site identifier	Carbofran (µg/L)	Chlorpyrifos (µg/L)	CIAT (µg/L)	Cyanaine (µg/L)	DCPA (µg/L)	Diazinon (µg/L)	Dieldrin (µg/L)	Disulfoton (µg/L)	EPTC (µg/L)	Ethal-fluralin (µg/L)	Etho-prophos (µg/L)	Fonofos (µg/L)	Lindane (µg/L)
Lakes													
02234205	<0.020	<0.005	E0.032	<0.018	<0.003	0.026	<0.005	<0.02	<0.002	<0.009	<0.005	<0.003	<0.004
02234812	<.003	<.004	E.038	<.004	<.002	.008	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234812	<.020	<.005	E.031	<.018	<.003	.008	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02234812	<.020	<.005	E.024	<.018	<.003	E.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02262200	<.003	<.004	<.002	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02262200	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02262200	<.020	<.005	E.003	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02266275	<.003	<.004	<.002	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02266275	<.020	<.005	E.003	<.018	<.003	E.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02234297	<.003	<.004	E.005	<.004	<.002	.012	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234297	<.020	<.005	E.005	<.018	<.003	E.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
284000081275000	<.020	<.005	<.006	<.018	<.003	.011	<.005	<.02	<.002	<.009	<.005	<.003	<.004
283528081055300	<.003	<.004	<.002	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
283528081055300	<.020	<.005	E.004	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
283528081055300	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02237745	<.003	<.004	E.009	<.004	<.002	E.003	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02237745	<.020	<.005	E.008	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02237745	<.020	<.005	E.005	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
284034081315700	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
282927081235000	<.020	<.005	E.008	<.018	<.003	.01	<.005	<.02	<.002	<.009	<.005	<.003	<.004
282657080561900	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
282657080561900	<.020	<.005	E.002	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
282102081374600	<.020	E.003	<.006	<.018	<.003	.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
283019081283100	<.003	<.004	E.004	<.004	<.002	E.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
283019081283100	<.020	<.005	E.005	<.018	<.003	E.004	<.005	<.02	<.002	<.009	<.005	<.003	<.004
283019081283100	<.020	<.005	E.006	<.018	<.003	.008	<.005	<.02	<.002	<.009	<.005	<.003	<.004
Streams													
02262900	<.003	<.004	E.007	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02262900	<.003	<.004	<.002	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02262900	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02233500	<.003	<.004	E.024	<.004	<.002	.007	<.001	<.02	<.002	<.004	<.003	<.003	<.009
02233500	<.003	<.004	E.011	<.004	<.002	.01	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02233500	<.020	<.005	E.018	<.018	<.003	E.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02233200	<.003	<.004	E.018	<.004	<.002	.009	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02233200	<.003	E.002	E.015	<.004	<.002	.04	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02233200	<.020	<.005	E.016	<.018	<.003	.009	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02234990	<.003	.005	E.033	<.004	<.002	.087	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234990	<.003	<.004	E.007	<.004	<.002	.033	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234990	<.020	<.005	E.015	<.018	<.003	.008	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02263800	<.003	<.004	E.078	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02263800	<.003	<.004	E.009	<.004	<.002	.004	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02263800	<.020	<.005	E.02	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004
02234635	<.003	<.004	E.006	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234635	<.003	<.004	E.004	<.004	<.002	<.002	<.001	<.02	<.002	<.004	<.003	<.003	<.004
02234635	<.020	<.005	<.006	<.018	<.003	<.005	<.005	<.02	<.002	<.009	<.005	<.003	<.004

Appendix E. Concentrations of pesticides in samples collected from lakes and streams during this study, 2000-2001. (Continued)

[All concentrations dissolved; µg/L, micrograms per liter; <, less than; E, estimated concentration; M, presence verified, not quantified]

Site identifier	Linuron (µg/L)	Malathion (µg/L)	Azinphos-Methyl (µg/L)	Methyl parathion (µg/L)	Metolachlor (µg/L)	Metribuzin (µg/L)	Molinate (µg/L)	Napropamide (µg/L)	p,p' DDE (µg/L)	Parathion (µg/L)	Pebulate (µg/L)	Pendimethalin (µg/L)	*cis*-Perethrin (µg/L)
Lakes													
02234205	<0.035	<0.027	<0.050	<0.006	<0.013	<0.006	<0.002	<0.007	<0.003	<0.007	<0.002	<0.010	<0.006
02234812	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02234812	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02234812	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02262200	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02262200	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02262200	<.035	<.027	<.050	<.006	E.002	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02266275	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02266275	<.035	<.027	<.050	<.006	E.001	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02234297	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02234297	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
284000081275000	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
283528081055300	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
283528081055300	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
283528081055300	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02237745	<.002	<.005	<.001	<.006	E.003	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02237745	<.035	<.027	<.050	<.006	E.001	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02237745	<.035	<.027	<.050	<.006	E.004	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
284034081315700	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
282927081235000	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
282657080561900	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
282657080561900	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
282102081374600	<.035	<.027	<.050	<.006	E.001	<.006	<.002	<.007	<.003	<.007	<.002	E.008	<.006
283019081283100	<.002	<.005	<.001	<.006	E.004	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
283019081283100	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
283019081283100	<.035	<.027	<.050	<.006	E.001	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
Streams													
02262900	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02262900	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02262900	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02233500	<.002	<.005	<.001	<.006	<.005	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02233500	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02233500	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02233200	<.002	.025	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02233200	<.002	<.005	<.001	<.006	E.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02233200	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02234990	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02234990	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02234990	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02263800	<.002	<.005	<.001	<.006	.009	<.004	<.004	<.050	<.006	<.004	<.004	<.004	<.005
02263800	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02263800	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006
02234635	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	<.004	<.005
02234635	<.002	<.005	<.001	<.006	<.002	<.004	<.004	<.003	<.006	<.004	<.004	.004	<.005
02234635	<.035	<.027	<.050	<.006	<.013	<.006	<.002	<.007	<.003	<.007	<.002	<.010	<.006

Appendix E. Concentrations of pesticides in samples collected from lakes and streams during this study, 2000-2001.

[All concentrations dissolved; µg/L, micrograms per liter; <, less than; E, estimated concentration; M, presence verified, not quantified]

Site identifier	Phorate (µg/L)	Prometon (µg/L)	Pronamide (µg/L)	Propachlor (µg/L)	Propanil (µg/L)	Propargite (µg/L)	Simazine (µg/L)	Tebuthiuron (µg/L)	Terbacil (µg/L)	Terbufos (µg/L)	Thiobencarb (µg/L)	Triallate (µg/L)	Trifluralin (µg/L)
Lakes													
02234205	<.011	E.01	<.004	<.010	<.011	<.02	E.005	E.01	<.034	<.02	<.005	<.002	<.009
02234812	<.002	.04	<.003	<.007	<.004	<.01	<.005	E.02	<.007	<.01	<.002	<.001	<.002
02234812	<.011	.02	<.004	<.010	<.011	<.02	<.011	E.01	<.034	<.02	<.005	<.002	<.009
02234812	<.011	.03	<.004	<.010	<.011	<.02	<.011	E.01	<.034	<.02	<.005	<.002	<.009
02262200	<.002	<.02	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	<.002
02262200	<.011	M	<.004	<.010	<.011	<.02	E.003	<.02	<.034	<.02	<.005	<.002	<.009
02262200	<.011	M	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
02266275	<.002	<.02	<.003	<.007	<.004	<.01	E.004	<.01	<.007	<.01	<.002	<.001	<.002
02266275	<.011	<.01	<.004	<.010	<.011	<.02	E.003	<.02	<.034	<.02	<.005	<.002	<.009
02234297	<.002	E.01	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	<.002
02234297	<.011	E.01	<.004	<.010	<.011	<.02	<.011	E.01	<.034	<.02	<.005	<.002	<.009
284000081275000	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
283528081055300	<.002	<.02	<.003	<.007	<.004	<.01	.012	<.01	<.007	<.01	<.002	<.001	<.002
283528081055300	<.011	<.01	<.004	<.010	<.011	<.02	E.006	<.02	<.034	<.02	<.005	<.002	<.009
283528081055300	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
02237745	<.002	E.01	<.003	<.007	<.004	<.01	E.002	<.01	<.007	<.01	<.002	<.001	<.002
02237745	<.011	E.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
02237745	<.011	E.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
284034081315700	<.011	E.01	<.004	<.010	<.011	<.02	<.011	E.01	<.034	<.02	<.005	<.002	<.009
282927081235000	<.011	E.01	<.004	<.010	<.011	<.02	E.005	E.01	<.034	<.02	<.005	<.002	<.009
282657080561900	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
282657080561900	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
282102081374600	<.011	E.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
283019081283100	<.002	E.01	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	<.002
283019081283100	<.011	E.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
283019081283100	<.011	M	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
Streams													
02262900	<.002	E.01	<.003	<.007	<.004	<.01	<.005	.02	<.007	<.01	<.002	<.001	<.002
02262900	<.002	E.01	<.003	<.007	<.004	<.01	<.005	E.01	<.007	<.01	<.002	<.001	<.002
02262900	<.011	E.01	<.004	<.010	<.011	<.02	<.011	E.01	<.034	<.02	<.005	<.002	<.009
02233500	<.002	E.01	<.003	<.007	<.004	<.01	.009	E.01	<.007	<.01	<.002	<.001	<.002
02233500	<.002	E.01	<.003	<.007	<.004	<.01	<.005	.01	<.040	<.01	<.002	<.001	<.002
02233500	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
02233200	<.002	M	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	<.002
02233200	<.002	E.01	<.008	<.007	<.004	<.01	E.004	M	<.007	<.01	<.002	<.001	<.002
02233200	<.011	E.01	<.004	<.010	<.011	<.02	.016	M	<.034	<.02	<.005	<.002	<.009
02234990	<.002	E.01	<.003	<.007	<.004	<.01	E.004	.02	<.007	<.01	<.002	<.001	<.002
02234990	<.002	E.01	<.003	<.007	<.004	<.01	.008	<.01	<.007	<.01	<.002	<.001	<.002
02234990	<.011	E.01	E.001	<.010	<.011	<.02	E.005	E.01	<.034	<.02	<.005	<.002	<.009
02263800	<.002	E.01	<.003	<.007	<.004	<.01	.005	.01	<.007	<.01	<.002	<.001	<.002
02263800	<.002	E.01	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	<.002
02263800	<.011	E.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009
02234635	<.002	E.01	<.003	<.007	<.004	<.01	.006	<.01	<.007	<.01	<.002	<.001	<.002
02234635	<.002	M	<.003	<.007	<.004	<.01	<.005	<.01	<.007	<.01	<.002	<.001	E.003
02234635	<.011	<.01	<.004	<.010	<.011	<.02	<.011	<.02	<.034	<.02	<.005	<.002	<.009